



Appendix P

Deep-slope and Pelagic Fish Characterisation

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This Environmental Impact Statement, including the Executive Summary, and all chapters of and attachments and appendices to it and all drawings, plans, models, designs, specifications, reports, photographs, surveys, calculations and other data and information in any format contained and/or referenced in it, is together with this disclaimer referred to as the "**EIS**".

Purpose of EIS

The EIS has been prepared by, for and on behalf of Wafi Mining Limited and Newcrest PNG 2 Limited (together the "**WGJV Participants**"), being the participants in the Wafi-Golpu Joint Venture ("**WGJV**") and the registered holders of exploration licences EL 440 and EL1105, for the sole purpose of an application (the "**Permit Application**") by them for environmental approval under the Environment Act 2000 (the "**Act**") for the proposed construction, operation and (ultimately) closure of an underground copper-gold mine and associated ore processing, concentrate transport and handling, power generation, water and tailings management, and related support facilities and services (the "**Project**") in Morobe Province, Independent State of Papua New Guinea. The EIS was prepared with input from consultants engaged by the WGJV Participants and/or their related bodies corporate ("**Consultants**").

The Permit Application is to be lodged with the Conservation and Environment Protection Authority ("**CEPA**"), Independent State of Papua New Guinea.

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Any future development of the Project is subject to further studies, completion of statutory processes, receipt of all necessary or desirable Papua New Guinea Government and WGJV Participant approvals, and market and operating conditions.

Engineering design and other studies are continuing and aspects of the proposed Project design and timetable may change.

NEWCREST MINING LIMITED DISCLAIMER

Newcrest Mining Limited ("**Newcrest**") is the ultimate holding company of Newcrest PNG 2 Limited and any reference below to "Newcrest" or the "Company" includes both Newcrest Mining Limited and Newcrest PNG 2 Limited.

Forward Looking Statements

The EIS includes forward looking statements. Forward looking statements can generally be identified by the use of words such as "may", "will", "expect", "intend", "plan", "estimate", "anticipate", "continue", "outlook" and "guidance", or other similar words and may include, without limitation, statements regarding plans, strategies and objectives of management, anticipated production or construction commencement dates and expected costs or production outputs. The Company continues to distinguish between outlook and guidance. Guidance statements relate to the current financial year. Outlook statements relate to years subsequent to the current financial year.

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Forward looking statements are based on the Company's good faith assumptions as to the financial, market, regulatory and other relevant environments that will exist and affect the Company's business and operations in the future.

The Company does not give any assurance that the assumptions will prove to be correct. There may be other factors that could cause actual results or events not to be as anticipated, and many events are beyond the reasonable control of the Company. Readers are cautioned not to place undue reliance on forward looking statements. Forward looking statements in the EIS speak only at the date of issue. Except as required by applicable laws or regulations, the Company does not undertake any obligation to publicly update or revise any of the forward looking statements or to advise of any change in assumptions on which any such statement is based.

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Newcrest results are reported under International Financial Reporting Standards (IFRS) including EBIT and EBITDA. The EIS also includes non-IFRS information including Underlying profit (profit after tax before significant items attributable to owners of the parent company), All-In Sustaining Cost (determined in accordance with the World Gold Council Guidance Note on Non-GAAP Metrics released June 2013), AISC Margin (realised gold price less AISC per ounce sold (where expressed as USD), or realised gold price less AISC per ounce sold divided by realised gold price (where expressed as a %), Interest Coverage Ratio (EBITDA/Interest payable for the relevant period), Free cash flow (cash flow from operating activities less cash flow related to investing activities), EBITDA margin (EBITDA expressed as a percentage of revenue) and EBIT margin (EBIT expressed as a percentage of revenue). These measures are used internally by Management to assess the performance of the business and make decisions on the allocation of resources and are included in the EIS to provide greater understanding of the underlying performance of Newcrest's operations. The non-IFRS information has not been subject to audit or review by Newcrest's external auditor and should be used in addition to IFRS information.

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As an Australian Company with securities listed on the Australian Securities Exchange (ASX), Newcrest is subject to Australian disclosure requirements and standards, including the requirements of the Corporations Act 2001 and the ASX. Investors should note that it is a requirement of the ASX listing rules that the reporting of Ore Reserves and Mineral Resources in Australia comply with the 2012 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (the JORC Code) and that Newcrest's Ore Reserve and Mineral Resource estimates comply with the JORC Code.

Competent Person's Statement

The information in the EIS that relates to Golpu Ore Reserves is based on information compiled by the Competent Person, Mr Pasqualino Manca, who is a member of The Australasian Institute of Mining and Metallurgy. Mr Pasqualino Manca, is a full-time employee of Newcrest Mining Limited or its relevant subsidiaries, holds options and/or shares in Newcrest Mining Limited and is entitled to participate in Newcrest's executive equity long term incentive plan, details of which are included in Newcrest's 2017 Remuneration Report. Ore Reserve growth is one of the performance measures under recent long term incentive plans. Mr Pasqualino Manca has sufficient experience which is relevant to the styles of mineralisation and type of deposit under consideration and to the activity which he is undertaking to qualify as a Competent Person as defined in the JORC Code 2012. Mr Pasqualino Manca consents to the inclusion of material of the matters based on his information in the form and context in which it appears.

HARMONY GOLD MINING COMPANY LIMITED DISCLAIMER

Harmony Gold Mining Company Limited ("**Harmony**") is the ultimate holding company of Wafi Mining Limited and any reference below to "Harmony" or the "Company" includes both Harmony Gold Mining Company Limited and Wafi Mining Limited.

Forward Looking Statements

These materials contain forward-looking statements within the meaning of the safe harbor provided by Section 21E of the Securities Exchange Act of 1934, as amended, and Section 27A of the Securities Act of 1933, as amended, with respect to our financial condition, results of operations, business strategies, operating efficiencies, competitive positions, growth opportunities for existing services, plans and objectives of management, markets for stock and other matters. These include all statements other than statements of historical fact, including, without limitation, any statements preceded by, followed by, or that include the words "targets", "believes", "expects", "aims", "intends", "will", "may", "anticipates", "would", "should", "could", "estimates", "forecast", "predict", "continue" or similar expressions or the negative thereof.

These forward-looking statements, including, among others, those relating to our future business prospects, revenues and income, wherever they may occur in this EIS and the exhibits to this EIS, are essentially estimates reflecting the best judgment of our senior management and involve a number of risks and uncertainties that could cause actual results to differ materially from those suggested by the forward-looking statements. As a consequence, these forward-looking statements should be considered in light of various important factors, including those set forth in these materials. Important factors that could cause actual results to differ materially from estimates or projections contained in the forward-looking statements include, without limitation: overall economic and business conditions in South Africa, Papua New Guinea, Australia and elsewhere, estimates of future earnings, and the sensitivity of earnings to the gold and other metals prices, estimates of future gold and other metals production and sales, estimates of future cash costs, estimates of future cash flows, and the sensitivity of cash flows to the gold and other metals prices, statements regarding future debt repayments, estimates of future capital expenditures, the success of our business strategy, development activities and other initiatives, estimates of reserves statements regarding future exploration results and the replacement of reserves, the ability to achieve anticipated efficiencies and other cost savings in connection with past and future acquisitions, fluctuations in the market price of gold, the occurrence of hazards associated with underground and surface gold mining, the occurrence of labour disruptions, power cost increases as well as power stoppages, fluctuations and usage constraints, supply chain shortages and increases in the prices of production imports, availability, terms and deployment of capital, changes in government regulation, particularly mining rights and environmental regulation, fluctuations in exchange rates, the adequacy of the Group's insurance coverage and socio-economic or political instability in South Africa and Papua New Guinea and other countries in which we operate.

For a more detailed discussion of such risks and other factors (such as availability of credit or other sources of financing), see the Company's latest Integrated Annual Report and Form 20-F which is on file with the Securities and Exchange Commission, as well as the Company's other Securities and Exchange Commission filings. The Company undertakes no obligation to update publicly or release any revisions to these forward-looking statements to reflect events or circumstances after the date of this EIS or to reflect the occurrence of unanticipated events, except as required by law.

Competent Person's Statement

The Wafi-Golpu Joint Venture is an unincorporated joint venture between a wholly-owned subsidiary of Harmony Gold Mining Company Limited and a wholly-owned subsidiary of Newcrest Mining Limited.

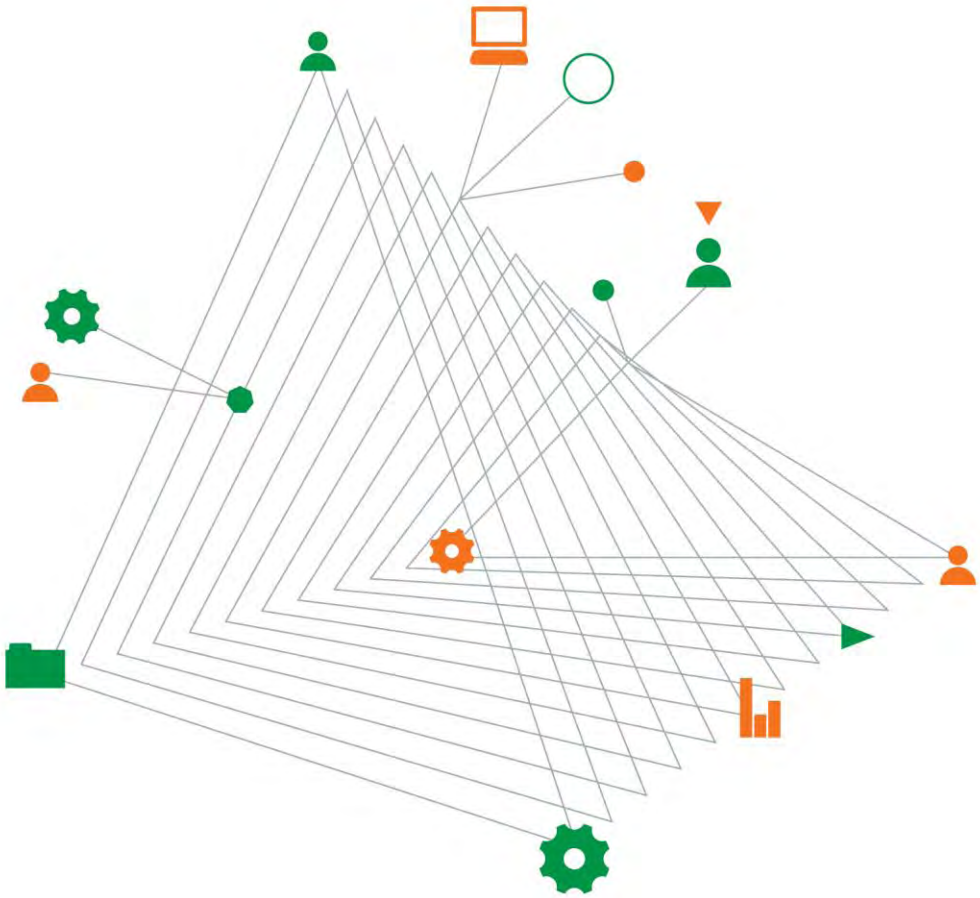
The information in the EIS that relates to Golpu Ore Reserves is based on information compiled by the Competent Person, Mr Pasqualino Manca, who is a member of The Australasian Institute of Mining and Metallurgy. Mr Pasqualino Manca, is a full-time employee of Newcrest Mining Limited or its relevant subsidiaries, holds options and/ or shares in Newcrest Mining Limited and is entitled to participate in Newcrest's executive equity long term incentive plan, details of which are included in Newcrest's 2017 Remuneration Report. Ore Reserve growth is one of the performance measures under recent long term incentive plans. Mr Pasqualino Manca has sufficient experience which is relevant to the styles of mineralisation and type of deposit under consideration and to the activity which he is undertaking to qualify as a Competent Person as defined in the JORC Code 2012. Mr Pasqualino Manca consents to the inclusion of material of the matters based on his information in the form and context in which it appears.

Wafi-Golpu Joint Venture

Wafi-Golpu Project

Deep-slope and pelagic fish characterisation

25 June 2018



Wafi-Golpu Project

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Rev B	Final	25 June 2018	Francisco J. Neira (Marscco) Travis Wood (Coffey)	Daniel Moriarty	Daniel Moriarty

Executive summary

Background

Wafi Mining Limited and Newcrest PNG 2 Limited (WGJV Participants) are equal participants in the Wafi-Golpu Joint Venture (the WGJV). The WGJV is investigating the feasibility of constructing, operating and (ultimately) closing an underground copper-gold mine and associated ore processing, concentrate transport and handling, power generation, water and tailings management and related support facilities and services (Hereafter the “Wafi-Golpu Project” orthe “Project”), located beneath Mt Golpu, approximately 300 kilometres (km) north-northwest of Port Moresby and 65 km south-west of Lae in the Morobe Province of the Independent State of Papua New Guinea (PNG). The Project includes ore processing, concentrate transport and handling, power generation, water management, a deep sea tailings placement (DSTP) system for tailings management, access roads to the mine and related support facilities.

The WGJV has commissioned a range of studies to inform the Project’s Feasibility Study Update and to prepare an Environmental Impact Statement (EIS).

This report describes findings of two separate deep-slope and pelagic fish characterisation surveys undertaken in the upper Huon Gulf in November 2016 and May 2017.

Objectives

The objectives of the deep-slope and pelagic fish surveys were to:

- Describe the species composition and prevalence of the deep-slope and pelagic fish fauna of the Study Area within the Huon Gulf, as identified through baited dropline and trawl sampling.
- Record key biological characteristics of all species of fish sampled, including length and weight frequencies, sex and reproductive condition.
- Determine concentrations of trace metals in tissue samples (muscle and liver) taken from fishes captured in proximity to the Outfall Area, at one or more reference sites and at locations more broadly within the Huon Gulf sourced from other fisheries where practicable.
- Provide data that can be compared with data gathered in connection with other instances where DSTP is utilised as a tailings management solution, as well as initiating a baseline dataset against which future monitoring results can be compared.
- Inform an assessment of potential impacts to fisheries and fish species due to proposed DSTP discharge by the Wafi-Golpu Project.

Study area and survey timing

The surveyed area covered shelf to slope waters of the upper Huon Gulf including: (a) the Markham Canyon, up to approximately 9 nautical miles (nmi) to the southeast of Lae; (b) shelf waters off Labu Lakes, about 6 nmi south of Lae; and (c) a shallow area known as Benalla Banks, approximately 18 nmi south of Lae. In this study, the term “shelf waters” refers to waters of the continental shelf, i.e., the shallow gradually sloping seabed (0.5° to 1° slope) around a continental margin, not usually deeper than 200 m. The term “slope waters” refers to waters of the continental slope, i.e., the steeply sloping seabed (average slope angle 4° to 20°) leading from the outer edge of the shelf to the continental rise, and which in the case of the present Study Area starts at around 100 m depth.

The Markham Canyon deepens in a south-easterly direction, and is characterised by a very steep bathymetric profile with almost no continental shelf followed by a particularly ridged slope that drops sharply to depths greater than 1,000 m. The base of the canyon is relatively flat, with a gradient of around 2° continuing eastwards into the New Britain Trench. Several rivers with high suspended-sediment loads discharge into the Huon Gulf, including the large Markham River adjacent to Lae, along with the Busu, Bupu, Bunga and Buiem rivers to the east.

Sampling design included a survey area of approximately 46 km^2 to the southeast of the Markham River, which encompassed the area identified for the proposed Outfall Area (herein referred to as "DSTP Study Area"), and a second area directly south of the Markham River mouth adjacent to the Labu Lakes and ending further south at Benalla Banks (herein referred to as "Reference Study Area"). The Reference Study Area was investigated in order to see if the fish catch differed in terms of diversity and abundance in the shallow shelf areas outside of the Markham Canyon.

Fishing surveys were completed in the DSTP Study Area and the Reference Study Area by Marscco and Coffey staff from 3 to 13 November 2016, and by Marscco and WGJV staff from 4 to 10 May 2017. The second survey in May 2017 was included so as to allow investigation of whether the results from the initial November sampling were unusual or whether the trends seen were consistent year-round.

Fishing in the two areas was carried out using baited droplines to capture deep-slope species and surface trolling with artificial lures to catch pelagic species.

Key findings

The key findings from the deep-slope and pelagic fish characterisation study are summarised as follows.

Fish abundance and diversity

- Sixty-one individuals of eight species from five families were caught over the DSTP Study Area and the Reference Study Area during baseline fishing surveys undertaken during an 11-day period in November 2016 (90 fishing hours) and a subsequent 7-day period in May 2017 (56 fishing hours).
- Families identified comprised two elasmobranch families, namely Centrophoridae (gulper sharks, three species) and Squalidae (dogfishes, one species), and three bony fish families, namely Lutjanidae (snappers, two species), Sciaenidae (drummers, one species) and Muraenesocidae (pike eels, one species).
- Results of the study indicate that the overall diversity of fish species in the upper western Huon Gulf off Lae is low both in terms of species of elasmobranchs and bony fishes, with the diversity being much lower than that recorded in similar baseline DSTP-associated studies conducted elsewhere in PNG, such as Woodlark, Misima, Ramu and Lihir.
- Except for one saddletail snapper (Lutjanus malabaricus; family Lutjanidae), no other deep slope snappers or individuals from the other two most prevalent fish families recorded in comparable baseline studies elsewhere in PNG, namely Serranidae (sea basses and groupers) and Lethrinidae (emperors), were captured in the DSTP Study Area in November 2016 or May 2017. This saddletail snapper was captured at a site between the Bunga and Buiem rivers in May 2017, at a depth of 100 m.
- Specimens of only two lutjanid species were captured during the November 2016 survey, a mangrove jack (Lutjanus argentimaculatus) and a saddletail snapper, both of which originated from sites in the Reference Study Area outside the Markham Canyon, at depths of less than 110 m. Saddletail snappers were frequently observed for sale at the local fish market at DCA Point, in Lae.
- The most abundant species collected during the study was the dwarf gulper shark, Centrophorus atromarginatus (family Centrophoridae), accounting for 80% and 55% of all individuals caught in November 2016 (n = 33) and May 2017 (n = 11), respectively. All dwarf gulper sharks were captured around the upper reaches and northern walls of the Markham Canyon at depths between 100 m and 540 m, with just over 93% recorded at depths between 100 m and 400 m. None were

caught at sites shallower than 100 m outside the canyon, such as sites LABU1 and LABU4 outside Labu Lakes.

- Locals at Wagang village indicated that they have inadvertently captured dwarf gulper shark in the past, but stated that this deep-slope species is not commonly caught nor targeted to be sold or for consumption.
- Longfin gulper shark, another species of the Centrophoridae and closely-related to dwarf gulper sharks, were also caught during the November 2016 and May 2017 surveys but in very small numbers. The five longfin gulper sharks recorded during this study were captured exclusively in the DSTP Study Area over the Markham Canyon, at depths between 330 m and 460 m, and were identified as Centrophorus longipinnis, a gulper shark species only recently described by elasmobranch taxonomists based at CSIRO (Hobart) using standard morphology and molecular analyses.
- A single large specimen of gulper shark (Centrophorus granulosus) was captured in the Markham Canyon in November 2016 at a depth of 550 m. The specimen was a 1.6 m total length (TL), 30 kg female in early stages of pregnancy. The capture of this and the two other gulper shark species during this study appears to be the first record of representatives of the bathy-demersal shark family Centrophoridae in baseline studies in PNG, but the Centrophorus genus has been recorded in Indonesia and the Philippines (White et al.., 2017).
- Combined overall fishing effort over the DSTP and Reference Study Areas across the two surveys totalled 146 hours, 90 hours in November 2016 and 56 hours in May 2017 of systematic dropline fishing regime at 41 sites over 18 days.
- The fishing effort during this study was greater than that reported for fish surveys undertaken during similar DSTP-associated EIS characterisation studies in PNG, such as those in Woodlark (approximately 32 hours), Misima (approximately 54 hours) and Ramu Nickel (approximately 121 hours) projects, but was similar to that reported during the 1994 deep-sea fishing for the Lihir baseline study (141 hours).
- Fish catch per unit of effort (CPUE) across all depth strata over the DSTP and Reference Study Areas averaged 0.09 kg/hook h-1 during the November 2016 survey, and 0.11 kg/hook h-1 during the May 2017 survey. Even considering the 30-kg female gulper shark captured during the November 2016 survey, this CPUE is considerably lower than the average 4.0 kg/hook h-1 recorded during the deep-slope fish survey off the south coast of Misima Island, lower than the average 0.5 kg/hook h-1 recorded at Woodlark Island and lower than the 0.19 kg/hook h-1 recorded at Niolam Island (Lihir Group) based on catches from selected locations. The average CPUE across all sites in the current study were also lower than that reported for the Rai Coast for the Ramu Nickel Project (NSR, 1998), i.e., 0.43 kg/hook h-1 to 3.08 kg/hook h-1, but within the range of CPUE obtained from Astrolabe Bay and islands offshore of Madang fished during the same study, i.e., 0.02 kg/hook h-1 to 0.29 kg/hook h-1.
- The low CPUE by weight is likely to be directly associated to the lower number of deep-slope fishes captured during the surveys in November 2016 (n = 41) and May 2017 (n = 20) compared to those reported from Misima (n = 84), Lihir (n = 411), Ramu (n = 54) and Woodlark (n = 121). The overall low abundances of sharks (aside from dwarf gulper sharks) and bony fish species in the areas fished during the study could be attributed to a number of factors including: (a) lack of suitable habitats such as clean coastal reefs as well as offshore reefs and seamounts, which normally sustain a great variety of fish communities; (b) likely reduced incidence of available prey, as indicated by the very few stomachs with prey remains in all sharks dissected; and (c) heavy sediment deposition over the seafloor from daily loadings transported downstream by the Markham River as well as the Busu and Bupu (and other) rivers. In terms of the latter, findings from other EIS investigations show that sediments from these rivers cover much of the seafloor in the DSTP Study Area, and extend as far south as the local fishing grounds to the east of the southern end of the Labu Lakes.
- No pelagic fish species were captured over the DSTP or Reference Study Areas after 23 trolling sessions totalling 16.5 hours of fishing during the November 2016 and May 2017 surveys. The absence of pelagic fishes was unexpected, even after the substantial effort using three rods and a

suite of standard lures. Factors which may have contributed to the zero catches include trolling mostly through areas of high turbidity, i.e., high concentrations of suspended solids from the river plumes, time of year, and/or species normally caught further south simply not venturing close to Lae due to absence of potential prey, i.e., schooling fishes.

- Fourteen specimens of bony fishes were sourced by the survey team from the local fish market at DCA Point in Lae during the November 2016 survey. These comprised five species from two families, Lutjanidae (snappers, mangrove jacks) and Carangidae (trevallies, mackerels). In terms of numbers, 9 of the 14 specimens were lutjanids normally found in coastal areas with offshore reefs (e.g., Pristipomoides typus and L. malabaricus), or areas associated with coastal lagoon/lake environments (L. argentimaculatus).
- All species observed at the DCA Point fish market were reportedly captured within the upper 100 m, and in coastal areas south of Lae, typically outside the influence of noticeable sediment plumes derived from Markham River. These fishing depths and locations were confirmed during discussions with local fishers.
- Given the numbers and persistent catches of dwarf gulper sharks in the Markham Canyon, this small bathy-demersal shark can be regarded as a good indicator species representative of the canyon’s continental slope and, as such, it could be regularly sampled to monitor fluctuations in abundance as well as potential changes in tissue metals concentrations over time.
- The finding of three pregnant dwarf gulper shark females suggests the presence of a resident population capable of surviving a seemingly harsh environment with likely scarce food resources. The capture of longfin gulper sharks, one also comprising a female in a late stage of pregnancy, also suggests the presence of a well-established population that could also be regarded as a good indicator species for future baseline and monitoring studies.

Metals in fish tissue

- Metals concentrations in muscle and liver tissues taken from 44 dwarf gulper sharks generally showed no clear trends as function of length or weight. Notable exceptions were as follows:
  - Mercury concentrations in muscle increased with increasing shark length and weight both in November 2016 and May 2017.
  - Cadmium concentrations in liver increased with increasing shark length and weight.
  - Selenium concentrations in liver decreased with increasing shark length and weight.
  - Zinc concentrations in liver increased with increasing shark length and weight.
- Most metals concentrations in muscle and liver tissues of dwarf gulper sharks showed little variation over specimens caught from different depth ranges. The exceptions were copper in muscle, which increased by an order of magnitude in dwarf gulper shark specimens caught between 400 m to 500 m in November 2016, and mercury in muscle samples from November 2016, which gradually increased with increasing depth. The reason for these trends is not clear given that there is no correlation with dwarf gulper shark sizes over the depth ranges.
- Metals concentrations in muscle from dwarf gulper sharks showed little variation between individuals caught in November 2016 and May 2017. This reflects the similar range in lengths and weights of dwarf gulper sharks caught over the two surveys.
- Metals concentrations in muscle and liver of numerous bony fish and sharks examined in this study exceeded the FSANZ food standards and generally expected levels (GELs) for contaminants. Metals that exceeded the FSANZ standards and GELS were arsenic, copper, mercury, selenium and zinc.
- Exceedances of the FSANZ standards and GELS for these metals were also recorded in other DSTP-associated deep-slope fishing surveys in PNG (Woodlark, Misima and Lihir).
- Maximum metal concentrations (silver, arsenic, cadmium, copper, lead, selenium and zinc) in liver of two species of the family Lutjanidae in the current study were mostly lower than those reported

for lutjanid species in other DSTP-associated studies in PNG – Woodlark, Misima and Lihir. The exceptions were chromium concentrations, which were similar to those reported for Woodlark; nickel concentrations, which were similar to those reported for Lihir; and mercury concentrations, which were higher than those reported for Woodlark, Misima and Lihir.

- Maximum metal concentrations (arsenic, chromium, copper, mercury and selenium) in muscle of two species of the family Lutjanidae in the current study were mostly lower than those reported for lutjanid species in other DSTP-associated studies in PNG – Woodlark, Misima and Lihir. The exceptions were silver, cadmium, nickel, selenium and zinc which were at concentrations similar to those studies.

Existing fishing practices

- The most common fishing methods observed were generally performed by regular fishers from Labu and included handlining using 'drop-stone' techniques, vertical long-lining and trolling. Discussions with locals indicated that handline methods targeted both demersal and pelagic fishes in depths usually between 50 m and 100 m, while trolling targeted fishes in shallower areas to depths of 10 m. Fishing depths were estimated from discussions with locals at the DCA Point fish market based on the number of rolls of fishing line that they noted as being dispensed from the reel, with each roll comprising 10 m of fishing line.
- Spearfishing, netting, hand collection and trap fishing practices are also used.
- Most regular fishers from Labu or those spoken to at the DCA Point fish market indicated that fishing takes place six days a week, with no fishing conducted on Sundays.
- Most of the fish caught by villagers from Wagang are taken for personal or village consumption, while fish caught by villagers from Labu are also sold at the DCA Point fish market and to a lesser extent the main street market in Lae. Discussions with local fishers and officials from Morobe Provincial Fisheries indicated that a number of factors including difficulty accessing ice and cold storage facilities, and rising fuel costs, resulted in direct market sale currently being the most economically viable option for fishers (as opposed to supplying to commercial markets).
- Fishers were typically observed sailing south from Labu or Lae at around 8 am to fishing grounds located over an area just south of Lae in the upper Huon Gulf, usually just beyond the Lae Port Exclusion Zone limits, though sometimes further offshore. Fishers would generally return to Labu or the DCA Point fish market between 2 pm and 4 pm, taking advantage of the prevailing south-easterly afternoon winds. No fishing activity was observed in the DSTP Study Area either in November 2016 or May 2017, except for a few fishers dispersed along the coast near Wagang, where fishing takes place almost exclusively from the shore. Handline fishing was occasionally observed from the shore near Lae, and in the vicinity of the Busu, Bumbu and Markham river entrances.
- Species caught by local fishers and sold at the DCA Point fish market were identified as being seasonally variable and include mackerel (often used as bait), saddletail snapper, sharptooth jobfish, emperors and various reef fishes. Captured pelagic species include rainbow runner, bigeye trevally and tuna. Several other species were also observed for sale at the street market including grouper, triggerfish, snake eel, whitecheek sharks and barracuda.

A fish trap net system is located adjacent to Labu Miti. This was established as an economic development project in association with the PNG National Fisheries Authority (NFA) and Japanese Trust Fund. These trap nets target a variety of fish including mackerel, rainbow runner and mahi-mahi (dolphinfish).

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Abbreviations

Ag	silver
ANOVA	Analysis of Variance
As	arsenic
Cd	cadmium
Cr	chromium
CVAAS	Cold Vapour Atomic Absorption Spectrometry
CPUE	catch per unit of effort
Cu	copper
DCA Point	Department of Civil Aviation Point
DSTP	deep sea tailings placement
EIS	environmental impact statement
Fe	iron
FSANZ	Food Standards Australia New Zealand
GEL	generally expected level
Hg	mercury
ICP-OES	inductively coupled plasma optical emission spectrometry
kg/hook h^{-1}	kilogram per hook per hour
km^2	square kilometres
m	metres
min	minutes
mm	millimetres
mg kg^{-1}	milligram per kilogram
Mn	manganese
n	number of samples
Ni	nickel
nmi	nautical mile
Pb	lead
PQL	practical quantification limit
%	percent
PNG	Independent State of Papua New Guinea
Se	selenium
TL	total length
Zn	zinc

Terms

bathy-demersal	Term used to describe animals associated with and/or living above the seafloor in the bathypelagic zone, i.e., at depths between 1,000 m to 4,000m.
Coastal Area	The Coastal Area includes the proposed Port Facilities Area and the proposed Outfall Area.
deep-slope	Term used to describe animals associated with or living on the continental slope.
DSTP Study Area	An area of approximately 46 km^2 to the southeast of the Markham River, opposite the Outfall Area. This comprises five fishing transects between Wagang and Singaua, that range in length from about 1.0 nmi to 2.5 nmi.
Lutjanid	Common name given to tropical snappers, i.e., bony fishes classified in the family Lutjanidae.
Outfall Area	The area encompassing the Outfall System, pipeline laydown area, choke station, access track and parking turnaround area.
Outfall System	Includes mix/de-aeration tank seawater intake pipelines and DSTP outfall pipelines. Located in the Outfall Area.
pelagic	Term used to describe animals living throughout water column from surface to seafloor between the coastal zone and open ocean; used predominantly to describe fast swimming and/or schooling fishes found in the uppermost 200 m, i.e., epipelagic zone.
Reference Study Area	An area commencing about 2 nmi south of the Markham River mouth adjacent to the Labu Lakes and ending further south at Benalla Banks to the northeast of Salamaua Island.
Study Area	The area comprising the DSTP Study Area and the Reference Study Area.
Wafi-Golpu Joint Venture	Wafi-Golpu Joint Venture (acronym: WGJV) being an unincorporated joint venture between the WGJV Participants

1. Introduction

1.1. Background

Wafi Mining Limited and Newcrest PNG 2 Limited (WGJV Participants) are equal participants in the Wafi-Golpu Joint Venture (the WGJV). The WGJV is investigating the feasibility of constructing, operating and (ultimately) closing an underground copper-gold mine and associated ore processing, concentrate transport and handling, power generation, water and tailings management and related support facilities and services (g hereafter the "Wafi-Golpu Project" or the "Project"), located beneath Mt Golpu, approximately 300 kilometres (km) north-northwest of Port Moresby and 65 km southwest of Lae in the Morobe Province of the Independent State of Papua New Guinea (PNG). The Project includes ore processing, concentrate transport and handling, power generation, water management, a deep sea tailings placement (DSTP) system for tailings management, access roads to the mine and related support facilities.

Geographically, the Project occupies a mine to port footprint that extends from the Mine Area to the Coastal Area with an Infrastructure Corridor that links the two areas. Together these discrete areas make up the proposed Project Area:

- **Mine Area**. The area encompassing the proposed block cave mine, underground access declines and nearby infrastructure, including a portal terrace and waste rock dump supporting each of the Watut and Nambonga declines, the Watut Process Plant, power generation facilities, laydown areas, water treatment facilities, quarries, wastewater discharge and raw water make-up pipelines, raw water dam, sediment control structures, roads and accommodation facilities for the construction and operations workforces.
- **Infrastructure Corridor**. The area encompassing the proposed Project infrastructure linking the Mine Area and the Coastal Area, being corridors for pipelines and roads and associated laydown areas. The proposed concentrate pipeline, terrestrial tailings pipeline and fuel pipeline will connect the Mine Area to the Coastal Area. A proposed Mine Access Road and Northern Access Road will connect the Mine Area to the Highlands Highway. New single-lane bridges are proposed over the Markham, Watut and Bavaga rivers. Laydown areas will be located at key staging areas.
- **Coastal Area**. The Coastal Area includes the proposed Port Facilities Area and the proposed Outfall Area:
  - Port Facilities Area. Located at, or in proximity to, the Port of Lae, with a site adjacent to Berth 6 (also known as Tanker Berth) nominated as the preferred option. The proposed facilities will include the concentrate filtration plant and materials handling, storage, ship loading facilities and filtrate discharge pipeline.
  - Outfall Area. Located approximately six kilometres east of the port. The proposed facilities will include the Outfall System comprising the mix/de-aeration tank and associated facilities, seawater intake pipelines and DSTP outfall pipelines, pipeline laydown area, choke station, access track and parking turnaround area.

The WGJV has commissioned a range of studies to inform the Project's Feasibility Study Update and to prepare an Environmental Impact Statement (EIS).

This report describes the findings of the deep-slope and pelagic fish characterisation study. The Study Area for this report addresses the Coastal Area includes:

- An area of approximately 46 km^2 to the southeast of the Markham River, opposite the Outfall Area. This comprises five fishing transects between Wagang and Singaua, that range in length from about 1.0 nmi to 2.5 nmi. This area is referred to as the 'DSTP Study Area'.

- An area commencing about 2 nmi south of the Markham River mouth adjacent to the Labu Lakes and ending further south at Benalla Banks to the northeast of Salamaua Island. This area is referred to as the 'Reference Study Area'.

Future development of the Project remains subject to ongoing deep orebody drilling and definition (after underground access has been achieved), technical studies, completion of statutory permitting processes and securing Government and WGJV Participants' approvals.

Engineering design and other studies, including environmental studies, are continuing and there is potential that aspects of the proposed Project design, layout and timetable may change.

1.2. Objectives

The objectives of the deep-slope and pelagic fish study were to:

- Describe the species composition and prevalence of pelagic and deep-slope fish fauna of the Study Area within the upper Huon Gulf.
- Record key biological characteristics of all species of fish sampled, including length and weight frequencies, sex and reproductive condition.
- Determine concentrations of trace metals in tissue samples (muscle and liver) taken from fishes captured in proximity to the Outfall Area, at one or more reference sites and at locations more broadly within the upper Huon Gulf sourced from other fisheries, where practicable.
- Provide data that can be compared with data gathered in connection with other instances where DSTP is utilised as a tailings management solution, as well as initiating a baseline dataset against which future monitoring results can be compared.
- Make an assessment of potential impacts to fisheries and fish species due to proposed DSTP discharge by the Wafi-Golpu Project.

2. Methods

2.1. Study areas and timing

The deep-slope and surface pelagic fishing surveys covered an area of approximately 46 km^2 to the southeast of the Markham River, opposite the Outfall Area (herein referred to as “DSTP Study Area”), and an area directly south of the Markham River mouth adjacent to the Labu Lakes and ending further south at Benalla Banks to the northeast of Salamaua Island (herein referred to as “reference study Area”). The locations of the deep-slope fishing sites and surface trolling trajectories completed during November 2016 are shown in Figure 2.1 and Figure 2.2, respectively, while locations of the deep-slope fishing sites and surface trolling trajectories completed during May 2017 are shown in Figure 2.3 and Figure 2.4, respectively.

The Reference Study Area was investigated in order to see if the fish catch differed in terms of diversity and abundance in the shallow shelf areas outside of the Markham Canyon.

The overall area surveyed included shelf and slope waters of upper Huon Gulf including the Markham Canyon, approximately 9 nautical miles (nmi) to the east of Lae, shelf waters off Labu Lakes, about 6 nmi south of Lae, and a shallow area known as Benalla Banks, approximately 18 nmi south of Lae (Figure 2.1).

The Markham Canyon deepens in a southeasterly direction, and is characterised by a very steep bathymetric profile with almost no shelf followed by a particularly ridged slope that drops sharply to depths of more than 1,000 m, ending in a relatively flat seafloor, with a gradient of around 2º continuing eastwards into the New Britain Trench. Several rivers with high sediment loads discharge into the Huon Gulf, including the large Markham River adjacent to Lae, along with the Busu, Bupu, Bunga and Buiem rivers to the east (Figure 2.1).

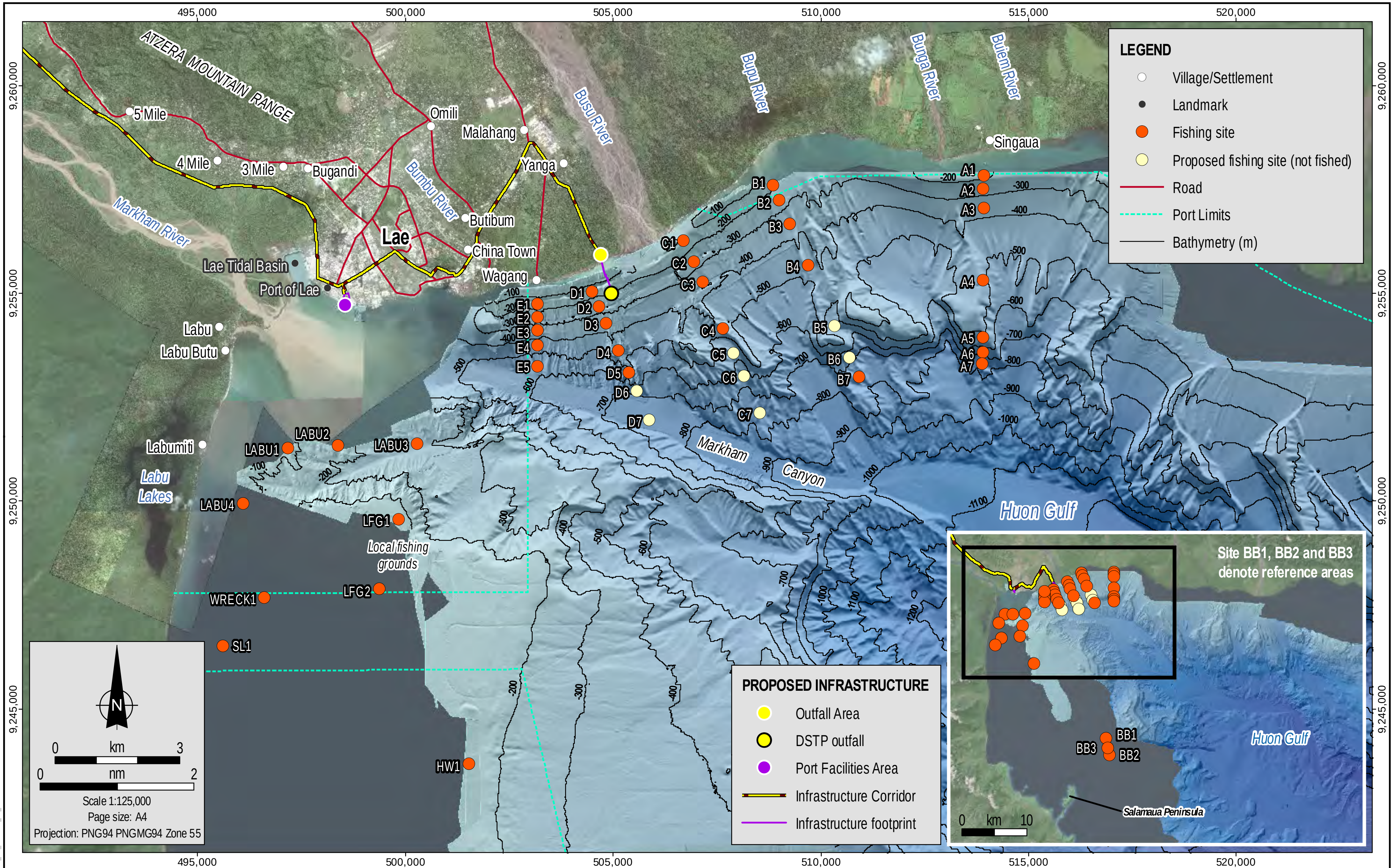
Deep-slope and surface pelagic fishing surveys were undertaken by Marscco and Coffey staff during 3 to 13 November 2016, and by Marscco and WGJV staff during 4 to 10 May 2017.

2.2. Sampling design and fishing effort

2.2.1. DSTP Study Area

Prior to the field campaign, 33 deep-slope fishing sites were chosen in the DSTP Study Area, being distributed along five nearly north-south oriented transects over the Markham Canyon. Transects were labelled A (eastern-most) to E (closest to Lae), and each comprised seven sites except transect E which comprised five sites. Each site was selected to represent a discrete 100 m depth range, and followed previously bathymetric contours identified from high-resolution 3D-bathymetry data collected with multibeam sonar within the Markham Canyon area (IHA, 2017). Fished depth ranges comprised: (1) 100 to 200 m; (2) 200 to 300 m; (3) 300 to 400 m; (4) 400 to 500 m; (5) 500 to 600 m; (6) 600 to 700 m; and (7) 700 to 800 m.

For convenience, each fishing site was labelled according to transect and depth stratum, e.g., A1 (transect A; 100 to 200 m), B2 (transect B, 200 to 300 m), C3 (transect C, 300 to 400 m). The rationale behind sampling depth strata rather than discrete depths reflects the difficulty to maintain a precise position above an exact depth as a result of tidal currents and winds, coupled with seabed steepness and short horizontal distances between sites on a steeply-sloping seafloor.



MXD Reference: 0520CC_11_GIS004_v0_4

Source:
Fishing sites, roads and Port Limits from Coffey (Port Limits indicative only).
Villages/Settlements, landmarks and infrastructure from WGJV and Coffey.
Bathymetry from WGJV survey.
Imagery from WGJV (capture date 2016) and ArcGIS Online (capture date unknown).

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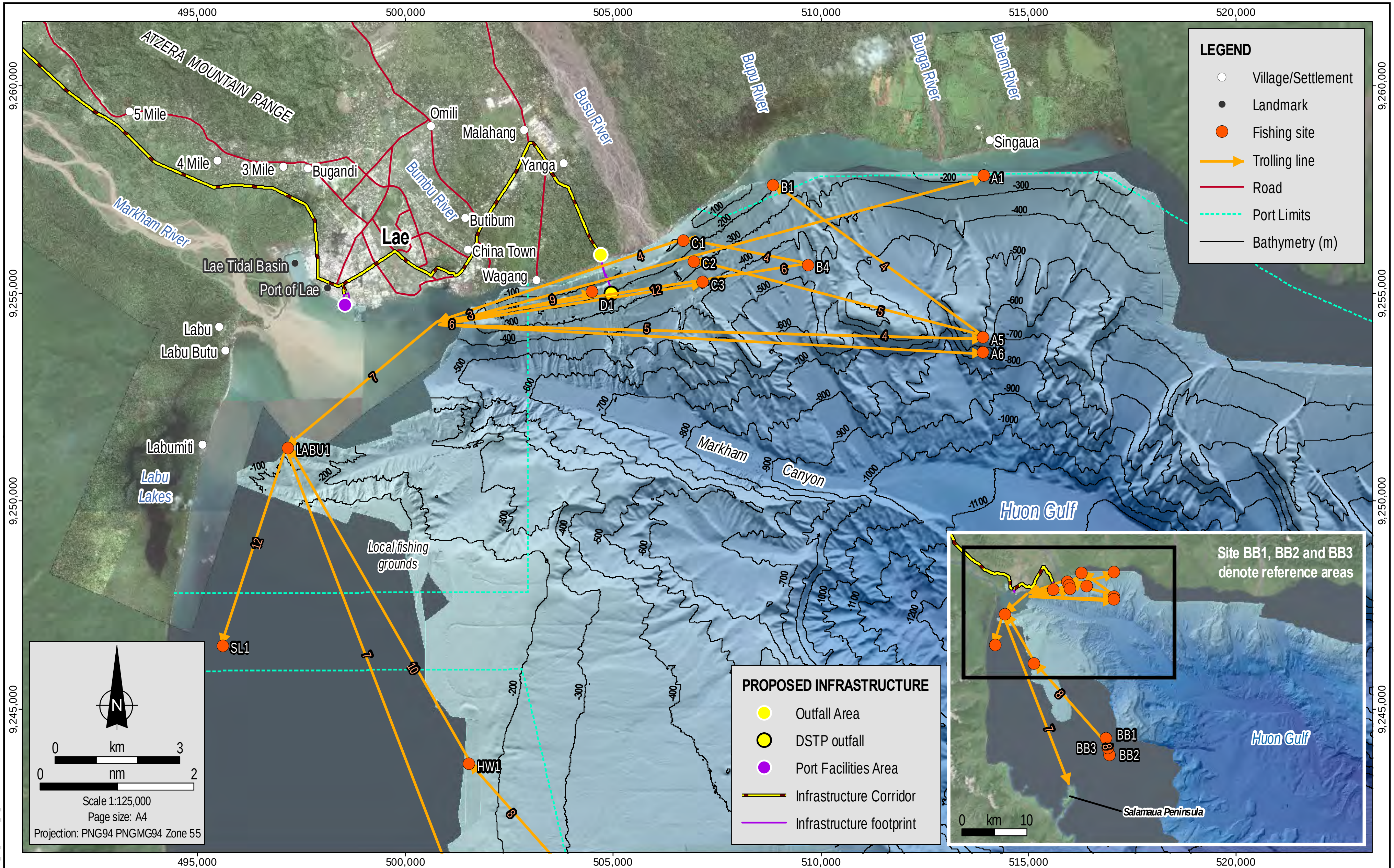
Date: 23.03.2018
Project: 754-ENAUABTF100520DD
File Name: 0520DD_11_F02.01_GIS

WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Deep-slope fishing sites in the upper Huon Gulf – November 2016

Figure No: 2.1



Source:
Fishing and trolling sites, roads and Port Limits from Coffey (Port Limits indicative only).
Villages/Settlements, landmarks and infrastructure from WGJV and Coffey.
Bathymetry from WGJV survey.
Imagery from WGJV (capture date 2016) and ArcGIS Online (capture date unknown).

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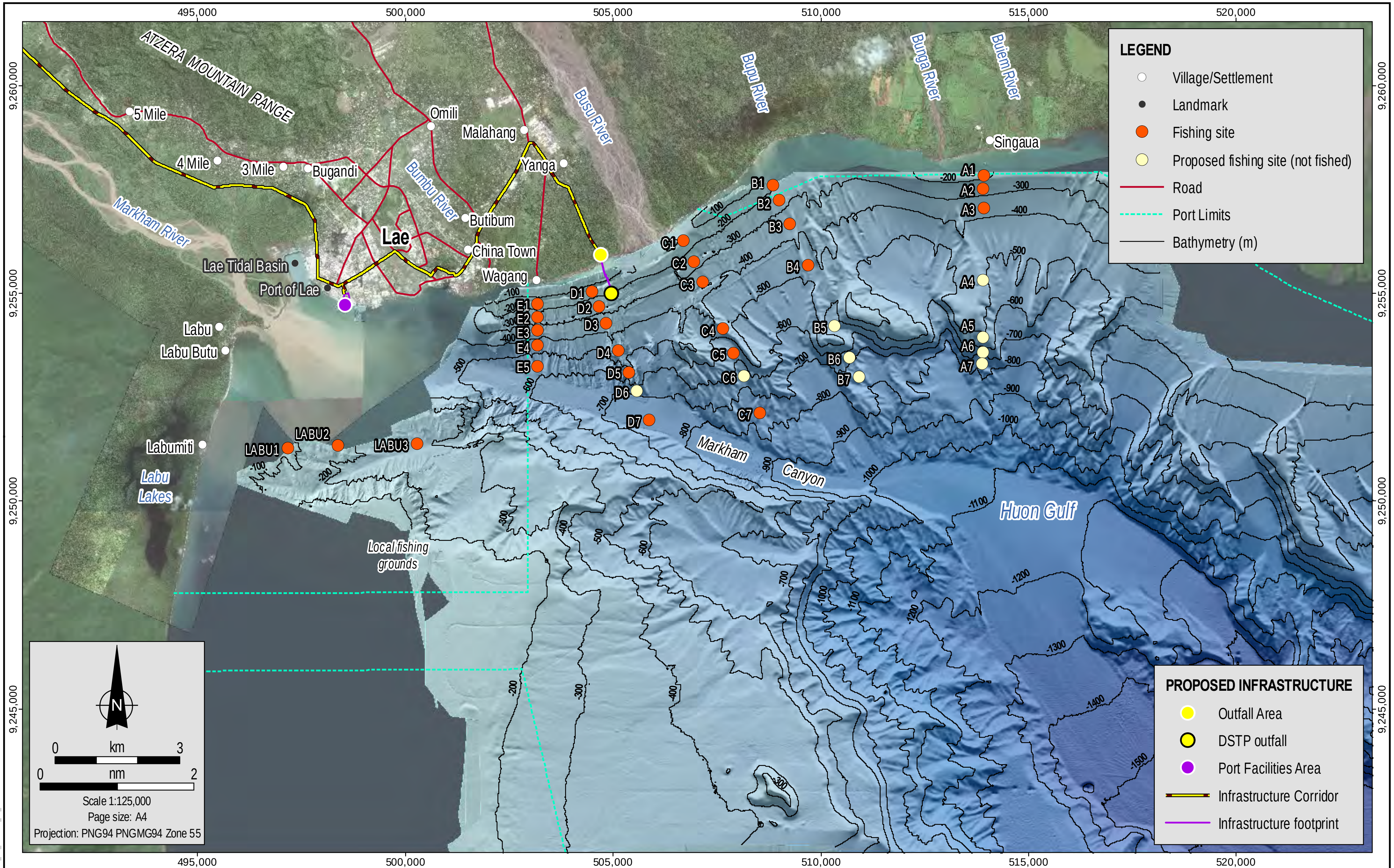
File Name: 0520DD_11_F02.02_GIS

WAFI-GOLPU JOINT VENTURE
Wafi-Golpu Project

Surface trolling trajectories in the upper Huon Gulf – November 2016

Figure No: 2.2

MXD Reference: 0520CC_11_GIS003_v0_4



Source:
Fishing sites, roads and Port Limits from Coffey (Port Limits indicative only).
Villages/Settlements, landmarks and infrastructure from WGJV and Coffey.
Bathymetry from WGJV survey.
Imagery from WGJV (capture date 2016) and ArcGIS Online (capture date unknown).

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File Name: 0520DD_11_F02.03_GIS

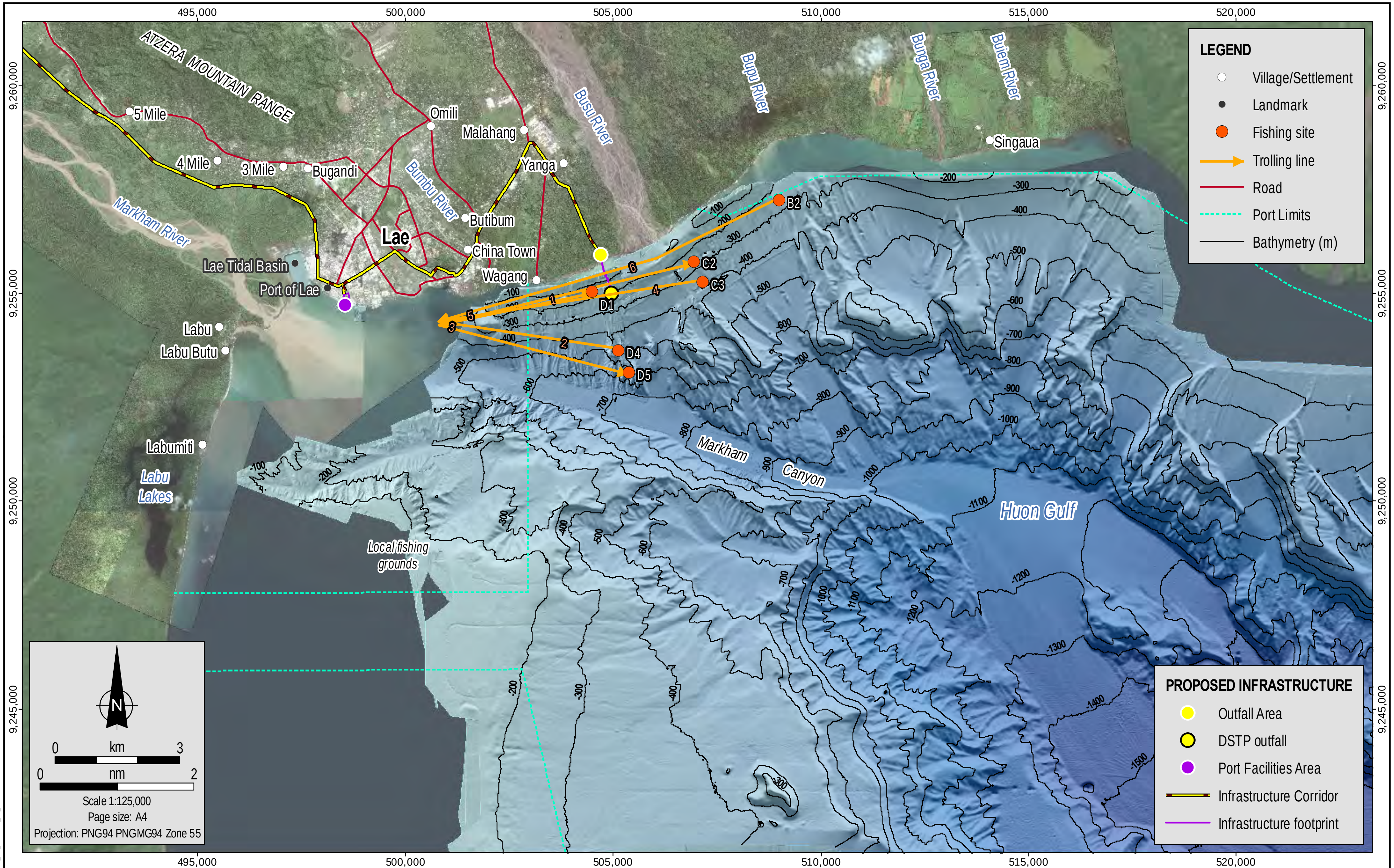
WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Deep-slope fishing sites in the upper Huon Gulf – May 2017

Figure No: 2.3

MXD Reference: 0520CC_11_GIS002_v0_4



MXD Reference: 0520CC_11_GIS001_v0_4

Source:
Fishing and trolling sites, roads and Port Limits from Coffey (Port Limits indicative only).
Villages/Settlements, landmarks and infrastructure from WGJV and Coffey.
Bathymetry from WGJV survey.
Imagery from WGJV (capture date 2016) and ArcGIS Online (capture date unknown).

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Date: 23.03.2018
Project: 754-ENAUABTF100520DD
File Name: 0520DD_11_F02.04_GIS

WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Surface trolling trajectories in the upper Huon Gulf – May 2017

Figure No: 2.4

Deep-slope fishing in the DSTP Study Area during 3 to 13 November 2016 was completed at 26 of the 33 pre-selected sites (Figure 2.1). Information on each site in the DSTP Study Area, including depth range (m) and total bottom fishing effort per site (minutes), is provided in Table 2.1. Geographical positions of each site are provided in Appendix A. The omission of seven sites followed a decision mid-survey to re-allocate more fishing effort to the reference sites south of Lae where most local people fish (see Section 2.3). The re-design in sampling strategy was also prompted by earlier findings of catches mostly dominated by dwarf gulper sharks suggesting little or no species diversity within the DSTP Study Area.

Deep-slope fishing in the DSTP Study Area during 4 to 10 May 2017 was completed at 24 of the 33 pre-selected sites (Figure 2.3; Table 2.1). Three sites fished during this survey were sites not fished during the November 2016 survey, i.e., sites C5, C7 and D7.

Surface trolling for pelagic fishes in the DSTP Study Area was carried out on 17 occasions in November 2016 and on six occasions in May 2017 (Figure 2.3 and Figure 2.4; Table 2.2). Most trolling sessions were conducted during trips to and from selected fishing sites within the DSTP Study Area, and either starting or stopping just outside Lae Yacht Club.

Table 2.1: Summary of fishing locations and total fishing effort by fishing event at sites in the DSTP Study Area during the November 2016 and May 2017 surveys

Transect	Site	Depth stratum (m)	November 2016			May 2017		
			Rods used	Total fishing effort (min)	Fish caught	Rods used	Total fishing effort (min)	Fish caught
A	A1	100-200	3	147	0	2	120	1
	A2	200-300	2	113	0	2	120	3
	A3	300-400	2	120	0	2	120	0
	A4	400-500	2	120	1	N/F	N/F	N/F
	A5	500-600	3	174	1	N/F	N/F	N/F
	A6	600-700	3	178	0	N/F	N/F	N/F
	A7	700-800	3	135	0	N/F	N/F	N/F
B	B1	100-200	3	165	3	2	120	0
	B2	200-300	3	156	5	2	120	0
	B3	300-400	3	155	0	2	120	1
	B4	400-500	3	90	0	2	120	0
	B5	500-600	N/F	N/F	N/F	N/F	N/F	N/F
	B6	600-700	N/F	N/F	N/F	N/F	N/F	N/F
	B7	700-800	2	122	0	N/F	N/F	N/F
C	C1	100-200	3	169	3	2	120	0
	C2	200-300	3	145	4	2	120	0
	C3	300-400	2	87	3	2	120	1
	C4	400-500	2	120	0	2	120	0
	C5	500-600	N/F	N/F	N/F	2	120	0
	C6	600-700	N/F	N/F	N/F	N/F	N/F	N/F
	C7	700-800	N/F	N/F	N/F	2	120	0
D	D1	100-200	2	111	1	2	120	3
	D2	200-300	2	120	0	2	240	2
	D3	300-400	2	105	2	2	120	1

Transect	Site	Depth stratum (m)	November 2016			May 2017		
			Rods used	Total fishing effort (min)	Fish caught	Rods used	Total fishing effort (min)	Fish caught
	D4	400-500	2	120	1	2	120	1
	D5	500-600	2	90	0	2	120	0
	D6	600-700	N/F	N/F	N/F	N/F	N/F	N/F
	D7	700-800	N/F	N/F	N/F	2	60	0
E	E1	100-200	2	77	0	2	240	2
	E2	200-300	3	174	1	2	120	3
	E3	300-400	2	110	4	2	120	0
	E4	400-500	2	120	0	2	120	0
	E5	500-600	2	90	1	2	120	0
TOTAL				**3,313 min (55.2 hours)**	**30**		**3,060 min (51.0 hours)**	**18**

N/F = not fished.

Table 2.2: Summary of 23 trolling sessions completed during the November 2016 and May 2017 fishing surveys; "from Lae" refers to starting from just outside Lae Yacht Club

Trolling session	Study area	Date	From (site/ location)	To (site/ location)	Start	Finish	Duration (min)	Fish
1	DSTP	3-Nov-16	Lae	A1	7:40	8:40	60	0
2		4-Nov-16	Lae	A5	7:40	8:40	60	0
3		4-Nov-16	A5	B1	9:00	9:50	50	0
4		4-Nov-16	B4	C1	14:20	14:50	30	0
5		4-Nov-16	C1	Lae	16:00	17:00	60	0
6		5-Nov-16	Lae	A5	8:50	9:50	60	0
7		5-Nov-16	A5	C2	11:30	13:10	100	0
8		6-Nov-16	Lae	A6	7:50	8:50	60	0
9		6-Nov-16	B4	Lae	15:45	16:25	40	0
10		7-Nov-16	Lae	LABU1	8:30	9:00	30	0
11	Reference	7-Nov-16	LABU1	Salamaua Island	14:30	15:30	60	0
12		8-Nov-16	Benalla Banks (BB1)	Benalla Banks (BB2)	10:35	10:55	20	0
13		8-Nov-16	Benalla Banks (BB3)	Halfway Reef (HW)	14:00	14:30	30	0
14	DSTP	9-Nov-16	Lae	D1	8:30	9:00	30	0
15	Reference	10-Nov-16	Halfway Reef (HW)	LABU1	12:45	13:30	45	0
16	DSTP	12-Nov-16	Lae	C3	7:40	8:15	35	0

17	Reference	12-Nov-16	LABU1	Sugarloaf area (SL1)	11:35	12:00	25	0
Total trolling time – November 2016							**795 min (13.3 hours)**	**0**
18	DSTP	4-May-17	Lae	D1	08:35	08:55	20	0
19		4-May-17	D4	Lae	15:45	16:10	25	0
20		5-May-17	Lae	D5	07:55	08:20	25	0
21		5-May-17	C3	Lae	15:45	16:35	50	0
22		6-May-17	Lae	C2	08:00	08:40	40	0
23		6-May-17	B2	Lae	15:22	16:10	48	0
Total trolling time – May 2017							**208 min (3.5 hours)**	**0**

2.2.2. Reference Study Area

Fishing locations in the Reference Study Area comprised 12 sites south of Lae, which were initially selected at random during the November 2016 survey to expand the overall spatial coverage (Figure 2.1).

Eight of the 12 sites were located opposite to Labu Lakes some 2.2 nmi south of Lae, including four at depths between 20 m and 225 m (LABU1, LABU2, LABU3 and LABU4), while the remaining four were located further south. Two of the sites, LFG1 (78 m to 101 m depth) and LFG2 (76 m to 93 m depth), were within "Local Fishing Grounds" and were selected following frequent sightings of fishing by locals on outrigger canoes during the survey period. Sites labelled as SL1 (Sugarloaf 1) and WRECK1 (Imperial Japanese Navy shipwreck (*Kongo Maru*) near Sugarloaf) comprised the shallowest sites fished during the study, i.e., 22 m to 28 m and 18 m to 25 m, respectively, while depths at the three southern-most additional sites over Benalla Banks ranged from 37 m to 260 m. Information on each site in the Reference Study Area, including depth range (m) and total bottom fishing effort per site (minutes), is provided in Table 2.3. Geographical positions of each site are provided in Appendix B.

Bottom fishing in the Reference Study Area was completed at all 12 sites during the November 2016 survey, and at three of the 12 sites (LABU1, LABU2 and LABU3) during the May 2017 survey (Table 2.3). Greater fishing effort was placed in the DSTP Study Area than the Reference Study Area in May 2017 to better understand fish diversity and abundance in the vicinity of the Outfall Area in the Markham Canyon.

Surface trolling for pelagic fishes in the Reference Study Area was carried out on six occasions in November 2016 (Table 2.2; Figure 2.2).

Table 2.3: Summary of fishing locations and total fishing effort by fishing event in the Reference Study Area south of Lae during the November 2016 and May 2017 surveys

Transect / area	Site	Depth range (m)	November 2016			May 2017		
			Rods used	Total fishing effort (min)	Fish caught	Rods used	Total fishing effort (min)	Fish caught
Labu	LABU1	42-108	3	427	1	2	60	0
	LABU2	100-139	3	184	3	2	120	1
	LABU3	210-225	3	100	5	2	120	1
	LABU4	22-110	2	120	0	N/F	N/F	N/F
Local Fishing Grounds	LFG1	78-101	3	162	0	N/F	N/F	N/F
	LFG2	76-93	3	180	0	N/F	N/F	N/F
Sugarloaf Wreck	WRECK1	18-25	2	240	2	N/F	N/F	N/F
Sugarloaf	SL1	22-28	2	120	0	N/F	N/F	N/F
Halfway Reef	HW1	77-120	3	183	0	N/F	N/F	N/F
Benalla Banks	BB1	50-165	2	114	0	N/F	N/F	N/F
	BB2	46-195	2	125	0	N/F	N/F	N/F
	BB3	37-260	2	135	0	N/F	N/F	N/F
TOTAL				**2,090**	**11**		**300**	**2**

N/F = not fished.

2.3. Fishing procedures

2.3.1. Deep-slope fishing

All deep-slope fishing was conducted from "*Fast Track*", a twin-engine, 10.6-m-long Carolina Classic game fishing vessel sourced from the PNG-registered company Collins Shipping Lt (Plate 2.1). Fishing was carried out using three 12V Daiwa Marine Power 3000 electric reels each attached to a heavy-duty, overhead Daiwa Tanacom Bull Dendoh game rod. Each reel was spooled with 1,200-m-long, 60 lb braided line, and each was powered by an independent 12V, 100Ah deep-cycle battery (Plate 2.2 and Plate 2.3). Leaders for each rod consisted of a 100 lb Icon Super monofilament line fitted with three Hosaku 8/0 circle hooks spaced 0.7 m apart, or two Gamakatsu Octopus 7/0 or 6/0 circle hooks spaced 0.5 m apart, and joined to the terminal main line with heavy-duty swivels. Larger hooks were used at depths between 100 and 800 m, whereas smaller hooks were used at sites with depths less than 100 m. Sinkers consisted of 2 kg to 3 kg downrigger bombs (Plate 2.4), and bait comprised pieces of "long tom" (Family Belonidae), "croaker" (Family Sciaenidae) and "halibut" (Family Pleuronectidae) sourced from the local supermarket in Lae.

Daily deep-slope bait fishing during the November 2016 and May 2017 surveys was confined to daylight hours between 08:00 am and 17:00 pm. Data recorded at each site included date, transect/site, time at initial fishing depth following deployment, i.e., as soon as the downrigger bombs reached the seabed, time at line retrieval from seafloor (whether with fish or not), and number of fish

Photo credit: Coffey/Marscco

Plate 2.1
Fast Track vessel used for fishing survey

Photo credit: Coffey/Marscco

Plate 2.2
Electric reels connected to 12V deep-cycle batteries

Photo credit: Coffey/Marscco

Plate 2.3
12V Daiwa Marine 3000 electric reel

caught. Most sites during the November 2016 survey were fished using three rods with three baited circle hooks each (Plate 2.4), while all sites during the May 2017 survey were fished with two rods and either two or three baited hooks.

Fishing events at each site were designed to last at least 60 minutes of bottom fishing time. However, time at each site, including non-fishing time, was invariably greater than 60 minutes to allow for deployment and retrieval of lines (with or without catch), as well as vessel relocation back to site when drifting out of the designated depth stratum. Positioning and maintenance of the vessel directly above each depth stratum was monitored using the on-board GPS-coupled Simrad NSS12 plotter (Plate 2.5) and Furuno NAVnet single-beam echosounder (Plate 2.6), along with a mobile geographic information system (GIS) unit consisting of an Apple iPad with Avenza software pre-loaded with site positions. Drift rate at each site during each fishing event was reduced as much as possible using a sea anchor (Plate 2.7) deployed from the stern. Positions of sites randomly selected within the Reference Study Area were recorded both in the on-board Simrad plotter and mobile GIS unit.

Bottom fishing time recorded by each rod operator during each fishing event at each site was summed to obtain effort, i.e., total bottom time (minutes), and this value subsequently used to calculate catch per unit of effort (CPUE) by site. Results of CPUE per site calculated for the November 2016 and May 2017 surveys are presented in Section 3.3. In all, fishing effort during the November 2016 survey over the DSTP Study Area and Reference Study Area totalled 90 hours of bottom fishing in 42 fishing events across 38 sites, whereas effort in both areas during the May 2017 survey totalled 56 hours of bottom fishing in 29 fishing events across 27 sites (Table 2.4).

2.3.2. Surface trolling

All surface trolling for pelagic fishes during the November 2016 and May 2017 surveys was carried out from the stern of the game fishing vessel *Fast Track* using three game rods and various artificial lures commonly used to catch tuna and Spanish mackerel, including Lively Lures (e.g., Mack bait) and Halcos. Lures were trolled 0.5 to 1.5 m below the surface, at speeds of 6 to 9 knots. Each trolling session lasted 20 to 100 minutes, and totalled 13.2 hours and 3.5 hours during the November 2016 and May 2017 surveys, respectively (Table 2.2). Trolling in the DSTP Study Area was discontinued after 6 May 2017 (session 23) due to the zero catches of pelagic fishes, and to increase effort in deep-slope fishing during the remaining days of the May 2017 survey.

Table 2.4: Summary of sampled sites, fishing events and total fishing effort (hours) in the DSTP and Reference Study Areas during the 3 to 13 November 2016 and 4 to 10 May 2017 surveys

Surveyed area	November 2016			May 2017		
	Sampled sites	Fishing events	Total fishing effort (hours)	Sampled sites	Fishing events	Total fishing effort (hours)
DSTP Study Area	26	26	55.2	24	26	51.0
Reference Study Area	12	16	34.8	3	3	5.0
Total	**38**	**42**	**90.0**	**27**	**29**	**56.0**

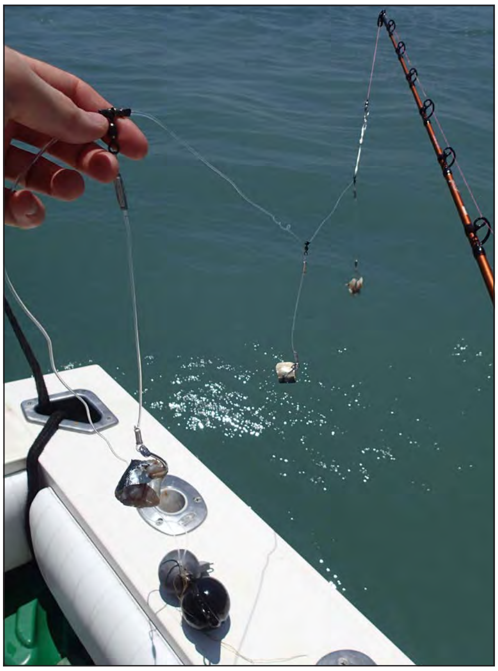


Photo credit: Coffey/Marscco

Plate 2.4
Leader set-up with three baited circle hooks and down rigger bombs

Photo credit: Coffey/Marscco

Plate 2.5
GPS-coupled Simrad NSS12 plotter

Photo credit: Coffey/Marscco

Plate 2.6
Furuno NavNet echosounder

2.3.3. On-board handling of captured fishes

Every shark and bony fish caught was humanely euthanised as soon as they landed on board the vessel, and a record made of the date, transect, site, depth and time of day when caught. Digital photographs of fresh specimens of each species were taken for future records, and to facilitate subsequent identifications to family, genus and/or species levels. Landed fishes were kept on ice for the duration of the fishing day before being taken back for biological examination, which included further identification and dissection to collect muscle tissue and livers for subsequent metals analysis (Section 3.4).

2.4. Fish market species

Fourteen bony fishes were sourced from the DCA Point fish market in Lae during November 2016 to complement species diversity recorded in the DSTP and Reference Study Areas (Plate 2.8). Each individual was identified to species level, examined for biological information, e.g., total length and weight, sex and reproductive condition, and dissected to obtain muscle and liver tissue samples for subsequent metal analysis. Discussions were held with local fishers at the market to determine the locations and approximate depths of where the purchased fish were caught.

No fish were sourced from the DCA Point fish market in May 2017. However, three visits were made to the market to ascertain species diversity on those particular occasions.

2.5. Fish identifications

Every shark and bony fish examined during this characterisation study was identified to family and species level using a combination of fish atlases and specific published information on respective groups, including the widely-used website Fish Base (www.fishbase.org). Sharks of the families Centrophoridae and Squalidae, along with bony fishes of the family Lutjanidae and Muraenesocidae were identified using Last and Stevens (2009) and Allen (1985, 2009), respectively. Visual identification of shark species was conducted by Dr Will White (Senior Curator – Australian National Fish Collection). Further DNA 'fingerprinting' of the shark species are currently underway. Species of the families Sciaenidae and Carangidae were identified using Allen (2009) and Smith-Vaniz (1984).

Confirmation of identifications of these and other fish species were also carried out using atlases for specific areas encompassing waters of Papua New Guinea (Gloerfelt-Tarp and Kailola, 1984; Randall *et al*., 1990), accessing Fishes of Australia website (fishesofaustralia.net.au; Gomon and Bray, 2017), and personal communications with specialists on specific groups, namely Dr Will White (CSIRO Hobart – families Centrophoridae, Squalidae), and Dr Gerry Allen (Cairns – family Lutjanidae). A short descriptive summary of each species captured during the November 2016 and May 2017 surveys is provided by family in Section 3.1, along with photographs obtained of fresh specimens. Short summaries are also provided for each of the bony fishes sourced from the DCA Point fish market. Common names employed in descriptions correspond to main English names adopted by the Food and Agriculture Organisation.

Photo credit: Coffey/Marscco

Plate 2.7
Sea anchor deployed to reduce drift speed

Photo credit: Coffey/Marscco

Plate 2.8
Local street fish market at DCA Point in Lae

2.6. Morphological and biological data

All sharks and bony fishes examined during this study were weighed whole to the nearest gram (g) and measured to the nearest millimetre (mm). Lengths measured correspond to total length (TL), i.e., anterior margin of head to end of tail. In the case of most bony fish species, all spines and soft rays of the dorsal (D) and anal (A) fins were counted to aid taxonomic identifications. Counts are provided in the descriptive accounts of each species using standard fish taxonomy nomenclature (see Section 3.1), 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 denotes a continuous dorsal fin with 10 spines and 11 soft rays).

Sharks were sexed by determining presence (males) or absence (females) of claspers, i.e., posterior extensions of paired pelvic fins in males which serve as intromittent organs[1] to channel semen during mating, as well as subsequent examination of gonads inside the body cavity following dissection. Numbers of pregnant females were recorded and the number of pups counted. Bony fishes were sexed by dissecting gut cavity and visually identifying ovaries in females and testes in males. The reproductive condition of each male and female bony fish processed was identified using the standard I to V scale of gonadal maturity, where I, II, III, IV and V correspond to immature, developing or resting, maturing, spawning (running ripe) and spent, respectively. This gonadal maturity scale does not apply to sharks.

Morphological and biological data obtained of all specimens of each species, along with fishing event, date and time, transect and depth stratum, are provided in Appendix A.

2.7. Catch data analysis

Statistical analysis performed on catch data assumed that all fishes were randomly distributed and equally vulnerable to fishing gear at all depth strata, and that one unit of fishing effort would capture a constant proportion of a total homogeneous stock. The method assumes that each fishing rod was operated by experienced fishers having the same amount of bait handling and fishing experience. Under these conditions, catch per unit of effort (CPUE) by site and fishing event was estimated as the total number of fishes caught by all rods combined per hour of bottom fishing time (dependent variable). Fishing gear, including electric reels, rods and circle hooks, as well as bait and fishing time (morning and afternoon) were considered as fixed factors. Additional CPUE estimation was carried out for comparative reasons by combining all depth strata per site across the DSTP and Reference Study Areas, by summing weights of fish captured per hook and fishing hour, i.e., average of kilograms of fish per hook h^{-1}. Presenting CPUE in this way allowed comparison with results from other DSTP fish studies.

Analysis of Variance (ANOVA) using type III sums of squares was employed to test for significant differences in CPUE across depth strata for the most abundant species, i.e., dwarf gulper shark (Table 2.4). Data were log-transformed (log10 [n + 1]) to account for heterogeneity of variance following Cochran's test. All descriptive summaries and statistical analyses were carried out in MS Excel.

2.8. Fish tissue samples

Muscle and liver tissue samples were obtained from 40 individuals representing all six species that were captured during the November 2016 survey in the DSTP and Reference Study Areas, as well as all 14 fishes sourced from the local street market during the survey period. Muscle and liver tissues were also obtained from all 20 individuals of the five species which were captured during the May

[1] An intromittent organ is a general term for an external organ of a male organism that delivers sperm during copulation.

2017 survey in the two Study Areas. However, liver samples from all these 20 individuals could not be analysed for metals due to a problem encountered during the digestion process at the analytical laboratory, which rendered all samples unusable.

Fish external examinations and subsequent dissections were performed at premises facilitated by WGJV at their 9-Mile and 11-Mile camps during November 2016 and May 2017 respectively, in rooms equipped with freezer facilities, running water and air conditioning. Dissections of muscle and liver tissue sampled were carried out maintaining the best possible hygienic conditions and thus avoiding contamination. Measures of quality assurance for sterile environment included: (a) using powder-free latex gloves when handling specimens and equipment (e.g., analytical balance); (b) performing dissections on clean plastic sheets; (c) discarding scalpel blades immediately after use in one individual, i.e., single-use only; and (d) using 98% ethanol to sterilize forceps between dissections.

2.8.1. Collection and storage procedures

Sharks were opened along the entire ventral cavity, and samples of muscle and liver tissue removed with a scalpel blade (#23) and forceps; a new scalpel blade was used on each specimen to avoid contamination, and forceps diligently cleaned with 98% ethanol after dissection. Muscle samples from sharks were obtained from the inside the body cavity by dissecting tissue along the anterior upper portion of exposed muscle. Muscle tissue samples from bony fishes were obtained from the top left side of the anterior trunk region of each specimen, whereas liver was removed whole. Every muscle tissue and liver was weighed to the nearest 0.01 g in a high-precision analytical balance, and immediately stored in a freezer in zip-lock plastic bags labelled with information such as specimen number, date, transect/site and tissue weight.

Tissue samples removed from sharks and bony fishes captured during the November 2016 survey, as well as those from fishes sourced from the street market, were transported frozen by air from Lae to Port Moresby upon completion of the survey, and presented to quarantine authorities in Port Moresby with the appropriate documentation on 14 November 2016. Samples were flown the same day directly to Brisbane International Airport where they were declared and handed to the quarantine office with all permits and Chain of Custody forms. All samples were collected by a representative from Advanced Analytical Australia Pty Ltd (AAA) and taken to a laboratory in NSW for analysis on 17 November 2016. Tissue samples from sharks and bony fishes captured during the May 2017 survey were transported frozen directly from Lae to the AAA laboratory in NSW via TNT international shipping service. These samples were shipped on 11 May 2017 and arrived at the laboratory on 15 May 2017.

Total amounts of muscle and liver tissue samples removed from each specimen dissected during November 2016 (n = 54) and May 2017 (n = 20) are provided in Section 3.2, along with codes employed in the Chain of Custody forms provided to AAA (see also appendices D and E).

2.8.2. Metals analysis

Muscle and liver tissue samples were analysed by AAA (NSW) for total trace concentrations (mg kg^{-1}) (wet weight concentrations) of the following metals and metalloids: arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), manganese (Mn), nickel (Ni), selenium (Se), silver (Ag) and zinc (Zn). For simplicity, this group of metals and metalloids is referred to as 'metals' throughout this report. Metals analysis was conducted using inductively coupled plasma optical emission spectrometry (ICP-OES). Mercury analysis was conducted using AAA method 04-006 by cold vapour atomic absorption spectrometry (CVAAS). The method involves a hot digestion of the tissue in the presence of nitric acid and hydrogen peroxide, prior to CVAAS analysis.

Wet weight analysis was performed in order to allow comparison to food standards and other DSTP deep-slope and pelagic fish studies.

Data obtained for each metal is summarised for each fish species examined, as listed in Table 3.11 to Table 3.22 (Section 3.5), with each table providing minimum, maximum and average values, total numbers of fishes tested, standard deviations and practical quantification limits (PQL) for each metal.

Liver and muscle concentrations of As, Cu, Fe, Hg, Se and Zn (mg kg^{-1}) were plotted by depth stratum (m) for the most abundant species caught during the study, namely dwarf gulper shark (*Centrophorus atromarginatus*). A paired two sample t-Test (for mean differences) was used to compare trace concentrations of each As, Cu, Fe, Hg, Se and Zn between muscle and liver tissue samples of same individuals of this species (n = 33). In addition, Pearson correlations and linear regressions were performed on trace concentrations of Cu and Zn in liver and Hg in muscle against total lengths (mm) to examine potential bioaccumulation with increasing length (proxy for age) in dwarf gulper shark. The R-square statistic, which is a measure of how close the data are to the fitted regression line, was used to determine the 'goodness of fit' (how well data fit to a regression curve) of the regression models.

Concentrations of selected metals in muscle tissue were checked against recommended standards developed by Food Standards Australia New Zealand (FSANZ). The standards comprise the Australia New Zealand Food Standards Code - Standard 1.4.1 - Contaminants and Natural Toxicants (FSANZ, 2016), and the Food Standards Australia New Zealand - Generally Expected Levels (GELs) for Metal Contaminants (FSANZ, 2001). The Standard 1.4.1 (Contaminants and Natural Toxicants) specifies the maximum levels of contaminants and natural toxicants that are permitted in the foods listed in the standard. The FSANZ GELs provide recommended levels that if exceeded in foods, should be further investigated. Table 2.5 below outlines these standards and GELs.

For simplicity, the FSANZ Food Standards Code Standard 1.4.1 is referred to in this report as 'FSANZ standard'. The FSANZ GELs are referred to as 'FSANZ GEL'.

Table 2.5: Summary of food standards and guidelines; all values correspond to mg/kg

Metal	FSANZ Standard 1.4.1[a] (mg/kg)	FSANZ GEL (median)[b] (mg kg)	FSANZ GEL (90th percentile)[b] (mg/kg)
Arsenic	2	-	-
Cadmium	-	-	-
Chromium	-	-	-
Copper	-	0.5	2
Iron	-	-	-
Lead	0.5	-	-
Mercury[c]	1 (mean value; applies to dwarf gulper shark) 1.5 (maximum value; applies to dwarf gulper shark) 1 (maximum value; applies to gulper shark) 0.5 (mean; applies to bony fish) 1 (maximum; applies to bony fish)	0.5	2
Manganese	-	-	-
Nickel	-	-	-
Selenium	-	0.5	2
Silver	-	-	-
Zinc	-	5	15

- denotes no applicable standard or guideline
a Source: Australia New Zealand Food Standards Code - Standard 1.4.1 - Contaminants and Natural Toxicants. Canberra: Commonwealth of Australia. Standards are maximum permitted values unless otherwise noted.

b Source: Food Standards Australia New Zealand 2001. Generally Expected Levels (GELS) for Metal Contaminants - Additional guidelines to Max levels in Standard 1.4.1 - Contaminants and Natural Toxicants. The 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 source of the concentration.
c These criteria were calculated based on the criteria in S19-7 of the Australia New Zealand Food Standards Code - Standard 1.4.1 - Contaminants and Natural Toxicants. Limits are given for both mean concentrations in a group of sample units and maximum concentrations in any sample unit.

3. Results

3.1. Fished species

Fishes captured during the November 2016 and May 2017 surveys over the DSTP Study Area and the Reference Study Area comprised four species of sharks from two families, and four species of bony fishes from three families. Individuals from these eight species were fished from depths between 18 m and 540 m (Table 3.1 and Table 3.2).

Sharks identified during the November 2016 survey included three species from the deep-water Family Centrophoridae, namely dwarf gulper shark (*Centrophorus atromarginatus*); longfin gulper shark (*C. longipinnis*); and gulper shark (*C. granulosus*) (Plate 3.1 and Plate 3.2). Both the dwarf and long-finned gulper sharks were also captured during the May 2017 survey, along with five individuals of the deep-water shark Family Squalidae, namely fatspine spurdog (*Squalus crassispinus*) (Plate 3.2).

Bony fishes identified during the November 2016 survey included blackspotted croaker (*Protonibea diacanthus*) from the Family Sciaenidae; and mangrove jack (*Lutjanus argentimaculatus*) and saddletail snapper (*L. malabaricus*), both from the Family Lutjanidae (Plate 3.3). One saddletail snapper was also captured during the May 2017 survey, along with one individual of common pike eel (*Muraenesox bagio*) from the Family Muraenesocidae (Plate 3.4).

Species summaries are provided below for the sharks and bony fishes captured during the November 2016 and May 2017 surveys, and include a short descriptive account of their morphology, total dorsal- and anal-fin counts (spines and rays in case of bony fishes only), and additional literature information. A summary of total numbers caught is provided in Table 3.1 (November 2016) and Table 3.2 (May 2017), together with range of lengths (mm) and weights (g), and depth stratum where caught (m). Biological information of each of the 40 specimens belonging to each of the six species recorded in November 2016 and 20 specimens of the five species recorded in May 2017 is provided in Table 3.3 and Table 3.4, respectively, including date caught, length and weight, as well as sex and reproductive condition.

Table 3.1: Summary of species caught in the DSTP and Reference Study Areas during the 3 to 13 November survey

Surveyed area	Species caught	Common name	Total caught	Biological data and tissue samples	Length range (mm)	Weight range (g)	Depth range (m)
DSTP Study Area	*Centrophorus atromarginatus*	Dwarf gulper shark	25	25	410-770	348-2,500	100-540
	Centrophorus longipinnis	Longfin gulper shark	3	3	720-762	2,200-2,350	330-360
	Centrophorus granulosus	Gulper shark	1	1	1,600	30,000	550
	Protonibea diacanthus	Blackspotted croaker	1	1	950	6,800	250
Subtotal			*30*	*30*			
Reference Study Area	*Centrophorus atromarginatus*	Dwarf gulper shark	8	8	410-720	360-2,350	100-225
	Lutjanus malabaricus	Saddletail snapper	2	1	340	570	18-25

	Lutjanus argentimaculatus	Mangrove jack	1	1	635	3,700	100
Subtotal			*11*	*10*			
Total			**41**	**40**			

Table 3.2: Summary of species caught in the DSTP and Reference Study Areas during the 4 to 10 May survey

Surveyed area	Species caught	Common name	Total caught	Biological data and tissue samples	Length range (mm)	Weight range (g)	Depth range (m)
DSTP Study Area	*Centrophorus atromarginatus*	Dwarf gulper shark	9	9	450-707	517-4,100	120-386
	Squalus crassispinus	Fatspine spurdog	5	5	405-652	331-1,500	180-300
	Centrophorus longipinnis	Longfin gulper shark	2	2	725-890	2,000-9,800	370-460
	Lutjanus malabaricus	Saddletail snapper	1	1	420	1,300	100
	Muraenesox baggio	Common pike eel	1	1	1,050	3,800	124
Subtotal			*18*	*18*			
Reference Study Area	*Centrophorus atromarginatus*	Dwarf gulper shark	2	2	420-458	437-591	120-230
Subtotal			*2*	*2*			
Total			**20**	**20**			

Table 3.3: Biological data of species caught in DSTP and Reference Study Areas during the November 2016 survey

Fish No.	Date	Transect / Site	Depth stratum (m)	Actual depth (m)	Family	Species	Common name	TL (mm)	Weight (g)	Sex	Reproductive stage / condition
1	3-Nov-16	A4	400-500	430	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	710	2,170	F	N/A
2	4-Nov-16	B2	200-300	245	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	532	776	F	N/A
3	4-Nov-16	B1	100-200	120	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	500	698	F	N/A
4	4-Nov-16	B1	100-200	105	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	520	720	M	N/A
5	4-Nov-16	B1	100-200	170	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	420	403	F	N/A
6	4-Nov-16	B2	200-300	245	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	490	683	M	N/A
7	4-Nov-16	B2	200-300	250	Sciaenidae	*P. diacanthus*	Blackspotted croaker	950	6,800	M	III
8	4-Nov-16	B2	200-300	290	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	535	500	M	N/A
9	4-Nov-16	B2	200-300	298	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	675	1,950	F	N/A
10	4-Nov-16	C1	100-200	208	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	620	1,500	F	N/A
11	4-Nov-16	C1	100-200	200	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	550	1,100	F	N/A
12	5-Nov-16	A5	500-600	550	Centrophoridae	*C. granulosus*	Gulper shark	1600	30,000	F	Early stage pregnancy
13	5-Nov-16	C2	200-300	295	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	705	2,250	F	N/A

Fish No.	Date	Transect / Site	Depth stratum (m)	Actual depth (m)	Family	Species	Common name	TL (mm)	Weight (g)	Sex	Reproductive stage / condition
14	5-Nov-16	C2	200-300	295	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	410	348	M	N/A
15	5-Nov-16	C2	200-300	290	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	655	1,600	F	N/A
16	5-Nov-16	C2	200-300	300	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	605	1,350	M	N/A
17	7-Nov-16	LABU1	100-200	105	Lutjanidae	*L. argentimaculatus*	Mangrove jack	635	3,700	F	II
18	7-Nov-16	LABU3	200-300	218	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	700	2,350	F	Pregnant – 1 pup
19	7-Nov-16	LABU3	200-300	226	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	720	2,200	F	N/A
20	7-Nov-16	LABU3	200-300	226	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	410	360	F	N/A
21	7-Nov-16	LABU3	200-300	220	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	690	2,100	F	Early stage pregnancy
22	7-Nov-16	LABU3	200-300	220	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	460	517	F	N/A
23	7-Nov-16	LABU2	100-200	137	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	465	514	M	N/A
24	7-Nov-16	LABU2	100-200	122	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	510	613	M	N/A
25	7-Nov-16	LABU2	100-200	122	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	450	440	F	N/A
26	9-Nov-16	D4	400-600	460	Centrophoridae	C. atromarginatus	Dwarf gulper shark	750	2,200	M	N/A
27	9-Nov-16	D1	100-200	187	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	430	406	F	N/A

Fish No.	Date	Transect / Site	Depth stratum (m)	Actual depth (m)	Family	Species	Common name	TL (mm)	Weight (g)	Sex	Reproductive stage / condition
28	12-Nov-16	C3	300-400	360	Centrophoridae	*C. longipinnis*	Longfin gulper shark	720	2,350	M	N/A
29	12-Nov-16	C3	300-400	360	Centrophoridae	*C. longipinnis*	Longfin gulper shark	762	2,220	M	N/A
30	12-Nov-16	D3	300-400	308	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	580	1,200	M	N/A
31	12-Nov-16	D3	300-400	300	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	770	2,150	M	N/A
32	12-Nov-16	C3	300-400	367	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	760	2,500	M	N/A
33	12-Nov-16	E3	300-400	343	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	580	1,250	M	N/A
34	11-Nov-16	E3	300-400	330	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	580	1,250	M	N/A
35	11-Nov-16	E2	200-300	260	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	560	1,150	M	N/A
36	11-Nov-16	E3	300-400	330	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	580	1,250	M	N/A
37	11-Nov-16	E3	300-400	330	Centrophoridae	*C. longipinnis*	Longfin gulper shark	740	2,300	M	N/A
38	12-Nov-16	SW1	0-100	24	Lutjanidae	*L. malabaricus*	Saddletail snapper	340	570	F	I
39	13-Nov-16	E5	500-600	540	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	660	2,400	F	Pregnant – 1 pup
40	04-Nov-16	C1	100-200	184	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	680	2,100	F	Early stage pregnancy

N/A denotes that reproductive stage cannot be determined. The scale used to determine reproductive condition in bony fishes does not apply to sharks.

Table 3.4: Biological data of species caught in DSTP and Reference Study Areas during the May 2017 survey

Fish No.	Date	Transect / Site	Depth stratum (m)	Actual depth (m)	Family	Species	Common name	TL (mm)	Weight (g)	Sex	Reproductive stage / condition
1	4-May-17	D1	100-200	180	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	509	691	F	N/A
2	4-May-17	D1	100-200	180	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	450	517	M	N/A
3	4-May-17	D1	100-200	180	Squalidae	*S. crassispinus*	Fatspine spurdog	405	331	F	N/A
4	4-May-17	D2	200-300	250	Squalidae	*S. crassispinus*	Fatspine spurdog	415	343	M	N/A
5	4-May-17	D3	300-400	346	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	478	2300	M	N/A
6	4-May-17	D4	400-500	460	Centrophoridae	*C. longipinnis*	Longfin gulper shark	890	9800	F	Pregnant – 1 pup
7	7-May-17	A2	200-300	300	Squalidae	*S. crassispinus*	Fatspine spurdog	652	1500	F	N/A
8	7-May-17	B3	300-400	386	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	561	947	M	N/A
9	7-May-17	A2	200-300	270	Squalidae	*S. crassispinus*	Fatspine spurdog	500	525	M	N/A
10	7-May-17	A2	200-300	290	Squalidae	*S. crassispinus*	Fatspine spurdog	495	509	M	N/A
11	5-May-17	C3	300-400	370	Centrophoridae	*C. longipinnis*	Longfin gulper shark	725	2000	M	N/A
12	7-May-17	A1	100-200	100	Lutjanidae	*L. malabaricus*	Saddletail snapper	420	1300	M	II
13	9-May-17	LABU2	120	120	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	420	591	M	N/A
14	9-May-17	LABU3	230	230	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	458	437	M	N/A
15	8-May-17	E2	200-300	300	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	609	1200	M	N/A
16	8-May-17	E2	200-300	300	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	580	1100	M	N/A
17	8-May-17	E2	200-300	300	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	607	1200	M	N/A
18	10-May-17	AS2	200-300	215	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	707	4100	F	N/A
19	10-May-17	AS1	100-200	120	Centrophoridae	*C. atromarginatus*	Dwarf gulper shark	515	672	F	N/A
20	10-May-17	AS1	100-200	124	Muraenesocidae	*M. bagio*	Common pike eel	1050	3800	F	II

N/A denotes that reproductive stage cannot be determined. The scale used to determine reproductive condition in bony fishes does not apply to sharks.

3.1.1. Family Centrophoridae

Centrophorus atromarginatus – Dwarf gulper shark

Dwarf gulper shark was the most abundant species caught during the November 2016 and May 2017 surveys. Total captured dwarf gulper sharks comprised 33 individuals at depths between 100 m and 540 m in November 2016 (410-770 mm total length (TL); 348-2,500 g), and 11 individuals at depths between 120 m and 386 m in May 2017 (420-707 mm TL; 437-4,100 g) (Plate 3.1A-D). Diagnostic characters include two dorsal fins preceded by short, stout grooved spines, the first dorsal fin slightly larger than the second; free pectoral-fin rear tip greatly elongate; dorsal and caudal fins with dark margins; sub-terminal notch in caudal fin; and no anal fin. Dwarf gulper sharks are viviparous and give birth to a single 280–360 mm long pup, which depends solely on yolk during embryonic stage. This marine bathy-demersal species is found on the upper continental slope throughout Indo-West Pacific region, including northern PNG. It is fished in some areas by demersal long-liners and processed for its meat, fins (low value) and liver oil (very high value). Its reported depth range is from 183 m to 405 m (White *et al*., 2006); the shallowest and deepest individuals recorded during this study were captured at 100 m and 540 m, respectively, and the maximum recorded length is 870 mm TL (White *et al*., 2006).

Centrophorus granulosus – Gulper shark

A single large female was caught in November 2016 at a depth of 550 m (1,600 mm TL; 30 kg) (Plate 3.1E). This gulper shark species is currently the largest existing *Centrophorus* species recorded, with maximum recorded total length to 1,700 mm and at least 30 kg (White *et al*., 2006, 2013). Gulper sharks are viviparous, and give birth to new-born individuals between 350 mm and 420 mm TL; up to 11 near-term pups have been observed in a litter from a pregnant female measuring 1,650 mm TL (White *et al*., 2013). Diagnostic characters include two dorsal fins preceded by short grooved spines, first dorsal fin slightly larger than second and with long base; pectoral-fin free rear tip slightly elongate; and no anal fin. Gulper shark are a solitary species found on outer continental shelves and upper continental slopes in all ocean basins except the Eastern Pacific, at depths of 98 m to 1,700 m, but usually between 200 m and 600 m. Its distribution across the western Pacific includes Japan, PNG and Australia (White *et al*., 2006, 2013).

Centrophorus longipinnis – Longfin gulper shark

Three longfin gulper sharks were captured in November 2016 at depths of 330 m to 360 m, with two others captured in May 2017 at depths of 370 m to 460 m (720-890 mm TL; 2,000-9,800 g) (Plate 3.2). As with other gulper sharks, longfin gulpers are also viviparous, and give birth to new-born individuals between 330 mm and 360 mm TL (Will White – personal communication); large female caught in May 2017 was pregnant with a single late-term pup measuring 350 mm TL (Plate 3.2). Diagnostic characters include two dorsal fins preceded by short grooved spines, a long but low first dorsal fin with a comparably long base; and no anal fin. The capture of the five longfin gulper sharks in the Markham Canyon comprises the first record of this species in PNG waters. Elsewhere, longfin gulper sharks have been reported in Taiwan (type specimen), Indonesia (off southwest Java and eastern Lombok), and the Philippines (Compagno, et al., 2005; White et al., 2017).

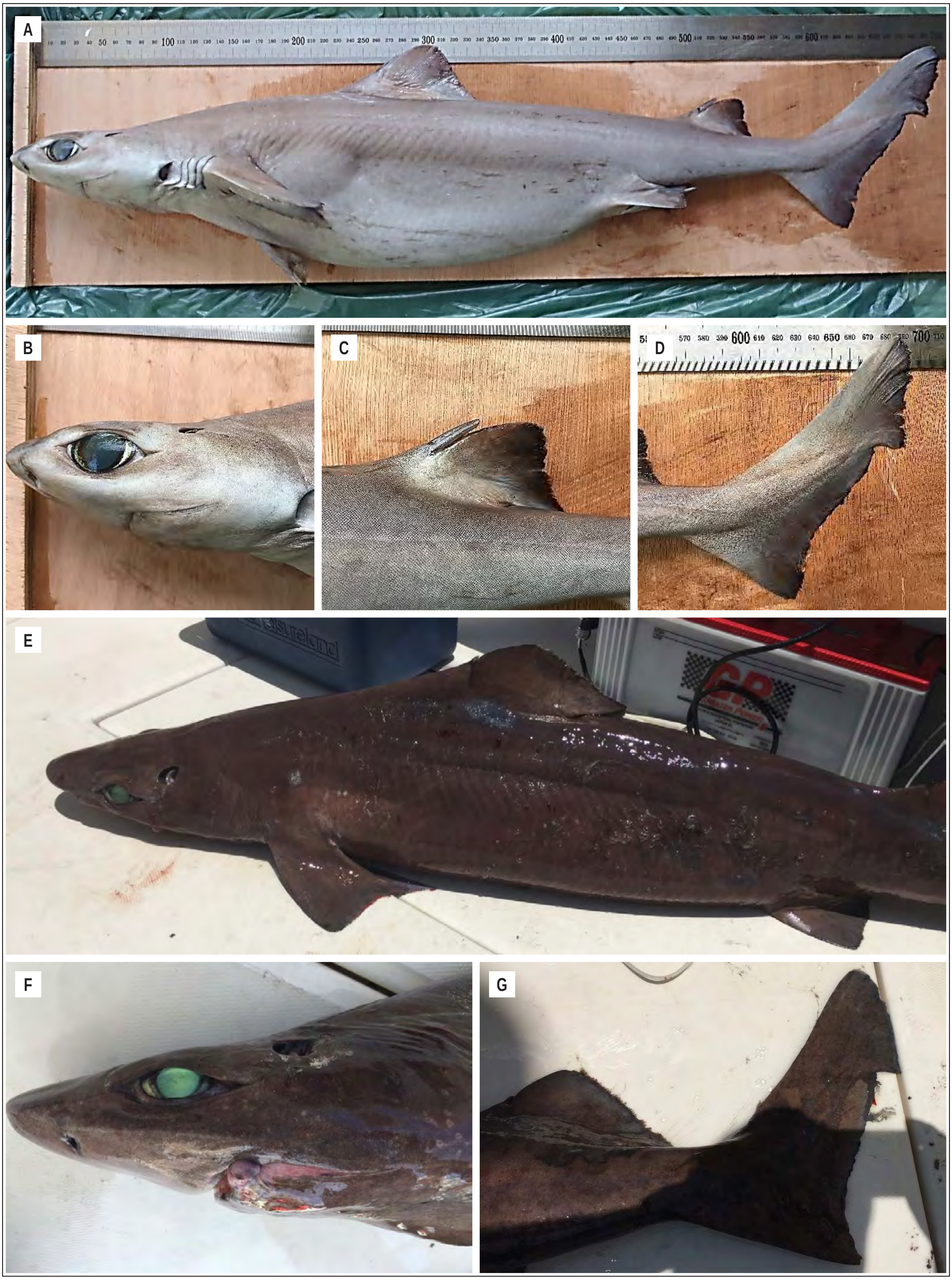


Photo credit: Coffey/Marscco

Plate 3.1

A. Dwarf gulper shark, *Centrophorus atromarginatus* – female caught at 430 m from site A4 (710 mm TL and 2,170 g).
B, **C**, **D**. Close-ups of head, stout, serrated spine in front of second dorsal fin, and tail, respectively.
E. Gulper shark, *Centrophorus granulosus* – female caught at 550 m at site A5; note short, stout serrated spines in front of first and second dorsal fins (1,600 mm TL and 30,000 g).
F, **G**. Close-ups of head and tail, respectively.

Photo credit: Coffey/Marscco

Plate 3.2

A. Long-finned gulper shark, *Centrophorus cf. longipinnis* – pregnant female caught at 460 m from site D4 in May 2017 (890 mm TL; 9,800 g).
B. Close-up of head and trunk region of pregnant female shortly after capture – note long-based first dorsal fin.
C. Near full-term single pup removed from pregnant female (35 mm TL; 200 g).
D. Recently captured male long-finned gulper shark, *C. longipinnis* – caught at 370 m from site C3 in May 2017 (725 mm TL; 2,000 g).
E. Fatspine spurdog, *Squalus crassispinus* – male caught at 290 m from site A2 in May 2017; note stout spines in front of first and second dorsal fins, slender caudal peduncle and elongated upper caudal-fin lobe (500 mm TL; 525 g).

3.1.2. Family Squalidae

Squalus crassispinus – Fatspine spurdog

Five fatspine spurdogs were captured in May 2017 at depths of 180 m to 300 m (405-652 mm TL; 331-1,500 g) (Plate 3.2E). This species of spurdog shark belongs to the Order Squaliformes (Suborder Squaloidea), which was recently described based on specimens from the continental slope of northern Western Australia (Last *et al*., 2007). Diagnostic characters include the fusiform body with a short, pointy snout, low dorsal fins preceded by robust, sharp spines, and a white posterior margin of the caudal fin. Maximum lengths of male and females captured during May 2017 survey were 500 mm and 652 mm TL, respectively. Fatspine spurdog sharks have been described as endemic to the lower shelf and upper slope off northwestern Australia, and have been recorded at depths of 187 m to 262 m (Last *et al*., 2007). The capture of this species in the Markham Canyon supports the suggestion that it probably occurs more widely in the eastern Indian Ocean (Last *et al*., 2007).

3.1.3. Family Lutjanidae

Lutjanus argentimaculatus – Mangrove jack

One mangrove jack was caught at a depth of 100 m (635 mm TL, 3,700 g) (Plate 3.3A). Diagnostic characters include greenish-brown to reddish body, slightly concave caudal fin, and scale rows on back roughly parallel to the lateral line. Counts: D X, 13-14; A III, 8. This species is well known from estuaries and inshore waters, as well as offshore reefs to depths of 120 m; young and sub-adults occur in mangrove estuaries. Maximum recorded length to 1,500 mm and at least 12,000 g (Allen, 1985, 2009; Fish Base; Gomon and Bray, 2017a).

Lutjanus malabaricus – Saddletail snapper

Two saddletail snappers were caught at depths of 18 m to 25 m (340 mm TL, 570 g) (Plate 3.3B). Diagnostic characters include red to orange body, truncate caudal fin, and scale rows on back rising obliquely above the lateral line. Counts: D XI, 12-14; A III, 8. This species is widespread in the tropical Indo-West-Pacific, and from Shark Bay (WA) around the north to Sydney (NSW), to a depth of 100 m; juveniles usually in shallow inshore waters while adults inhabit coastal and offshore reefs. Maximum recorded length to 1,000 mm and at least 7,000 g (Allen, 1985, 2009; Bray, 2017a).

3.1.4. Family Sciaenidae

Protonibea diacanthus – Blackspotted croaker

One blackspotted croaker was caught at a depth of 250 m (950 mm TL, 6,800 g) (Plate 3.3C). Diagnostic characters include dark colouration, and relatively narrow tail peduncle. This species is found throughout Indo-west Pacific region from Persian Gulf and India, north to Japan, and south to Papua New Guinea and northern Australia, predominantly in estuaries and coastal waters over muddy bottoms, rocky reefs and other structures to 100 m. Counts: D X-XI, 22-25; A II, 7. Also known as black jew or jewfish. Maximum recorded length to 1,600 mm and at least 16,000 g (Allen, 2009; Bray, 2017b).

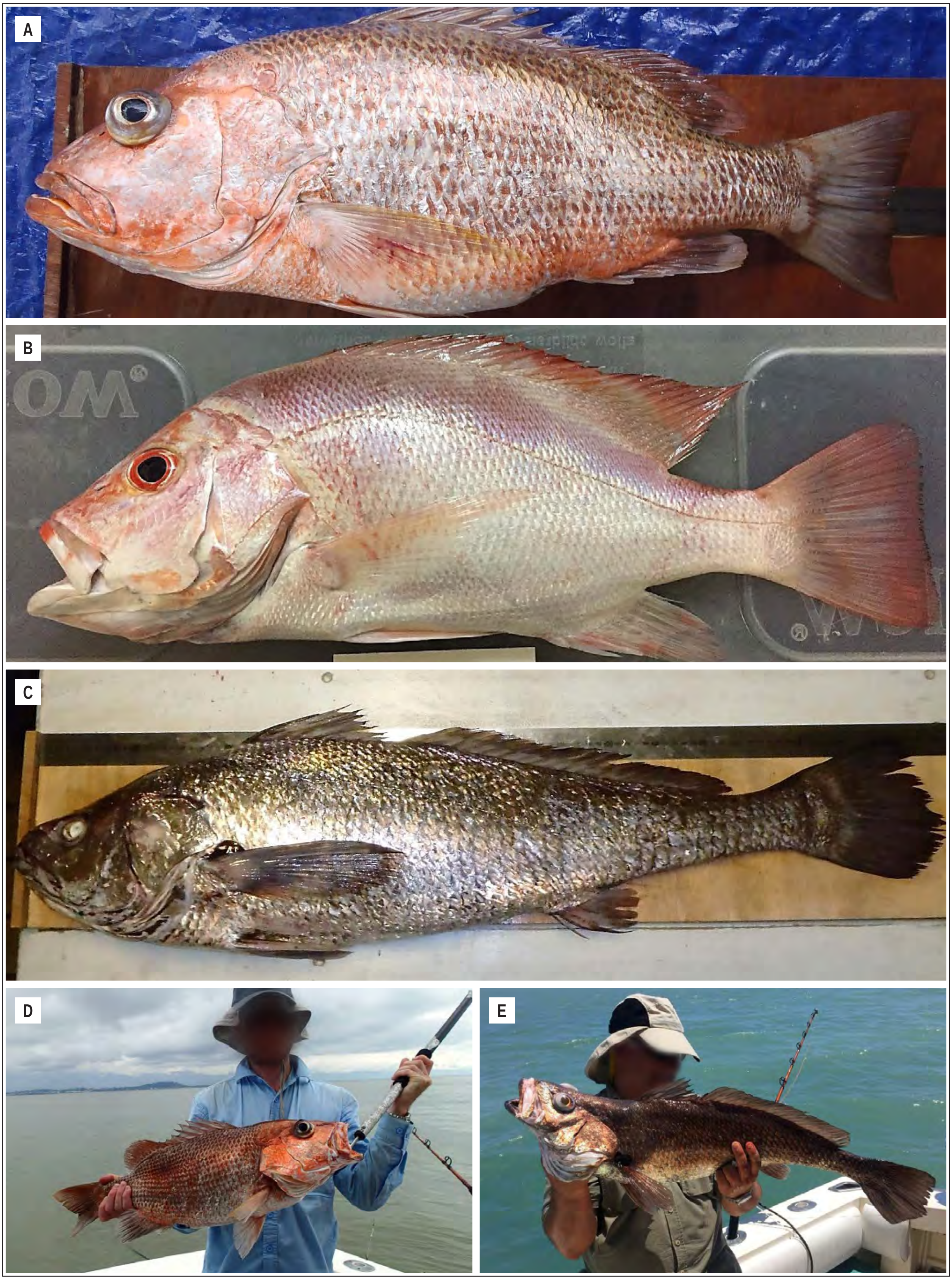


Photo credit: Coffey/Marscco

Plate 3.3

A. Mangrove jack, *Lutjanus argentimaculatus* – female caught at 105 m from site LABU1 (635 mm TL and 3,700 g).
B. Saddletail snapper, *Lutjanus malabaricus* – female caught at 24 m from site Sugarloaf WRECK1 (340 mm TL and 570 g).
C. Blackspotted croaker, *Protonibea diacanthus* – male caught at 250 m at site B2 (950 mm TL and 6,800 g).
D. Mangrove jack and **E**. blackspotted croaker shortly after capture.

3.1.5. Family Muraenesocidae

Muraenesox bagio – Common pike eel

One common pike eel was caught at a depth of 124 m (1,050 mm TL; 3,800 g) (Plate 3.4). Common pike eels are a predatory, carnivorous species reported to occur across the northern half of Australia and throughout and the Indo-West Pacific region, including PNG, where it is normally found in soft bottoms in estuaries and coastal waters to depths of 100 m. Diagnostic characters include robust, eel-shaped body with long snout, large mouth with conspicuous, sharp lower jaw and palate (vomerine) teeth, and posterior nostrils only slightly nearer to eye than to anterior nostrils (Plate 3.4D). Maximum reported length to 2,000 mm (Bray, 2017c).

3.2. Local market species

Representatives of five species from two families were obtained from the local fish market and examined for this report. These comprised sharptooth jobfish (*Pristipomoides typus*), mangrove jack (*L. argentimaculatus*) and saddletail snapper (*L. malabaricus*) from the Family Lutjanidae; and bigeye trevally (*Caranx sexfasciatus*) and pennantfish (*Alectis ciliaris*) from the Family Carangidae. Biological information of each of the 14 specimens of all five species is provided in Table 3.5, including date caught, lengths and weights, as well as sex and reproductive condition. Species summaries below pertain to three of the five bony fish species sourced at the Lae street market in November 2016; notes on the lutjanids *L. argentimaculatus* (Plate 3.5B) and *L. malabaricus* (Plate 3.5C) are provided in Section 3.1.3 above.

3.2.1. Family Lutjanidae

Pristipomoides typus – Sharptooth jobfish

Sharptooth jobfish are commonly found in rocky bottoms at depths between 40 m and 100 m. Diagnostic characters include elongate, rosy red body, last soft rays of dorsal and anal fins extended into short filaments, no scales along the dorsal or anal fin bases, and a forked caudal fin with a white margin along the lower lobe (Plate 3.5A). Recorded throughout the tropical western Pacific, including south-east Asia. Counts: D X, 11-12; A III, 8. Also known as sharptooth snapper. Maximum reported size to 700 mm (Allen, 1985, 2009).

3.2.2. Family Carangidae

Caranx sexfasciatus – Bigeye trevally

Bigeye trevally are pelagic schooling species often found in large schools associated with costal and offshore reefs, to depths of around 100 m. Diagnostic characters include the deep, silver body, large eye with a well-developed gelatinous membrane, white tips of soft dorsal fin and anal fin, and dark, deeply forked caudal fin (Plate 3.5D). Widespread distribution in the tropical Indo-Pacific region, including PNG. Counts: D VII-VIII, 19-21; A III, 16-18. Maximum reported size of bigeye trevally is 780 mm and 8,000 g (Allen, 2009; Gomon and Bray, 2017b).

Alectis ciliaris - Pennantfish

Pennantfish are a pelagic species found worldwide in tropical coastal reefs to depths of 100 m, and occur throughout the tropical Indo-West Pacific region including PNG. Diagnostic characters include the deep silver body with mostly tiny embedded scales, rounded head profile, scutes (sharp scales) only along posterior straight section of lateral line, and extremely long, filamentous anterior dorsal and anal-fin rays in juveniles. It is also known as African pompano and threadfin trevally. Maximum reported sizes of pennantfish is 1,300 mm and 13,000 g (Allen, 2009; Bray 2017d).

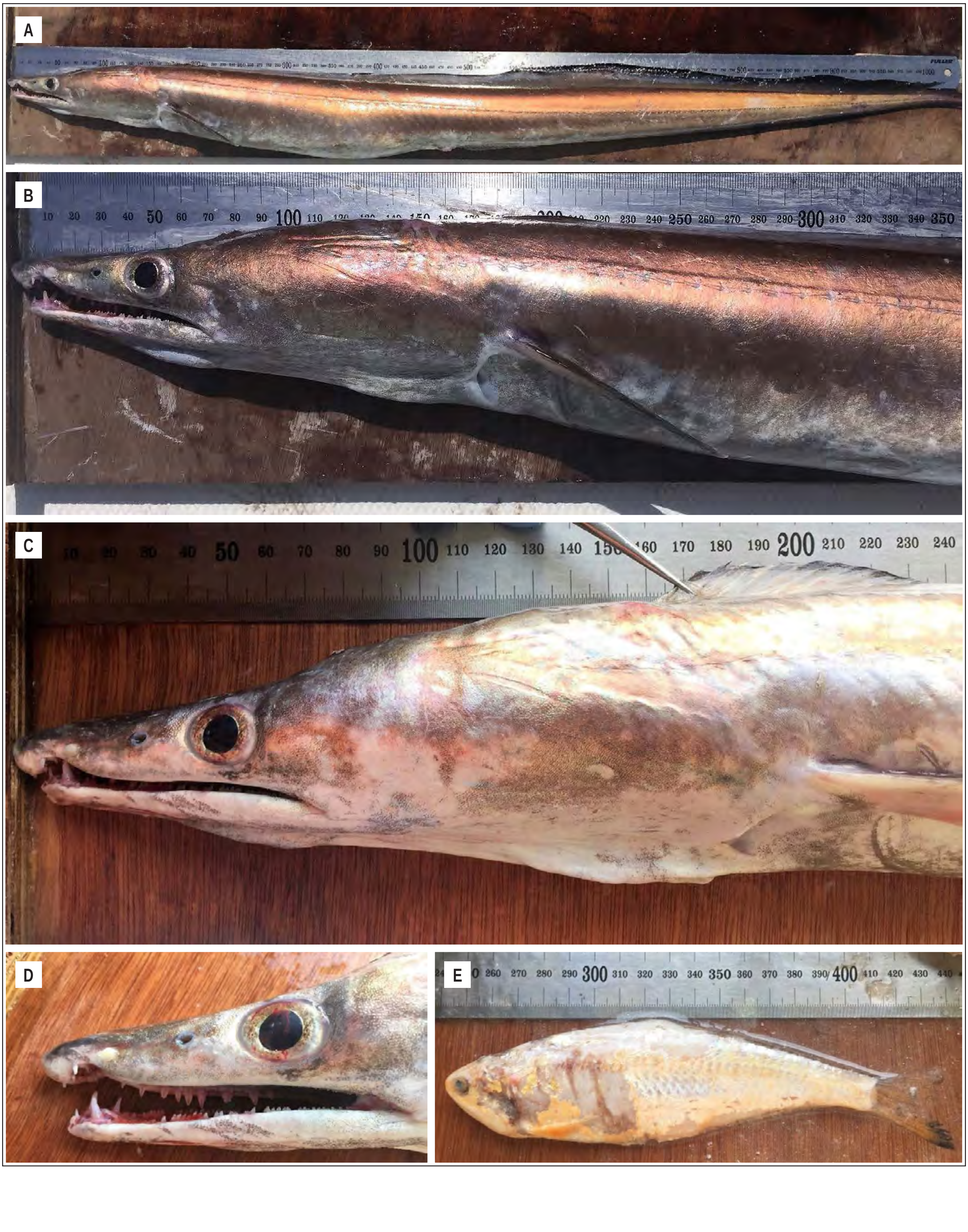


Photo credit: Coffey/Marscco

Plate 3.4
A. Common pike conger eel, *Muraenesox bagio* shortly after capture – female caught at 124 m between sites D1 and E1 in May 2017 (1,050 mm TL; 3,800 g).
B, C. Close-ups of head and anterior trunk – note origin of long-based dorsal fin in **C**.
D. Close-up of elongate snout showing sharp multi-cusped teeth along lower jaw and single row of sharp vertical vomerine teeth along palate (upper jaw).
E. Whole adult hairpin anchovy, *Setipinna tenuifilis* (Family Engraulidae) removed from stomach of eel.

Table 3.5: Biological data of fish species sourced from the local market in November 2016

Fish No.	Date	Location	Depth (m)	Family	Species	Common name	TL (mm)	Weight (g)	Sex	Reproductive stage
1	05-Nov-16	South of Lae, offshore from Labu Lakes	100-200	Lutjanidae	*Pristipomoides typus*	Sharptooth jobfish	590	2,000	F	II
2	05-Nov-16	South of Lae, offshore from Labu Lakes	100-200	Lutjanidae	*Lutjanus malabaricus*	Saddletail snapper	470	1,500	M	II
3	05-Nov-16	South of Lae, offshore from Labu Lakes	100-200	Carangidae	*Caranx sexfasciatus*	Bigeye trevally	610	2,400	F	III
4	05-Nov-16	South of Lae, offshore from Labu Lakes	Max 70	Lutjanidae	*Lutjanus argentimaculatus*	Mangrove jack	340	635	F	I
5	05-Nov-16	South of Lae, offshore from Labu Lakes	Max 70	Lutjanidae	*Lutjanus argentimaculatus*	Mangrove jack	530	2,350	M	II
6	09-Nov-16	South of Lae, offshore from Labu Lakes	30-40	Lutjanidae	*Lutjanus malabaricus*	Saddletail snapper	415	1,050	F	I
7	09-Nov-16	South of Lae, offshore from Labu Lakes	30-40	Lutjanidae	*Pristipomoides typus*	Sharptooth jobfish	655	2,800	M	II
8	09-Nov-16	South of Lae, offshore from Labu Lakes	30-40	Lutjanidae	*Lutjanus malabaricus*	Saddletail snapper	430	1,200	F	I
9	10-Nov-16	South of Lae, offshore from Labu Lakes	30-40	Lutjanidae	*Lutjanus malabaricus*	Saddletail snapper	470	1,700	F	I
10	10-Nov-16	South of Lae, offshore from Labu Lakes	30-40	Carangidae	*Alectis ciliaris*	Pennantfish	420	1,200	M	II
11	10-Nov-16	South of Lae, offshore from Labu Lakes	30-40	Carangidae	*Caranx sexfasciatus*	Bigeye trevally	500	1,450	M	II
12	12-Nov-16	Off Salamaua Is	<100	Lutjanidae	*Lutjanus malabaricus*	Saddletail snapper	510	2,100	F	III
13	12-Nov-16	Off Salamaua Is	<100	Carangidae	*Caranx sexfasciatus*	Bigeye trevally	650	3,050	M	II
14	11-Nov-16	Labu fishing area	<50	Carangidae	*Caranx sexfasciatus*	Bigeye trevally	680	3,550	M	II

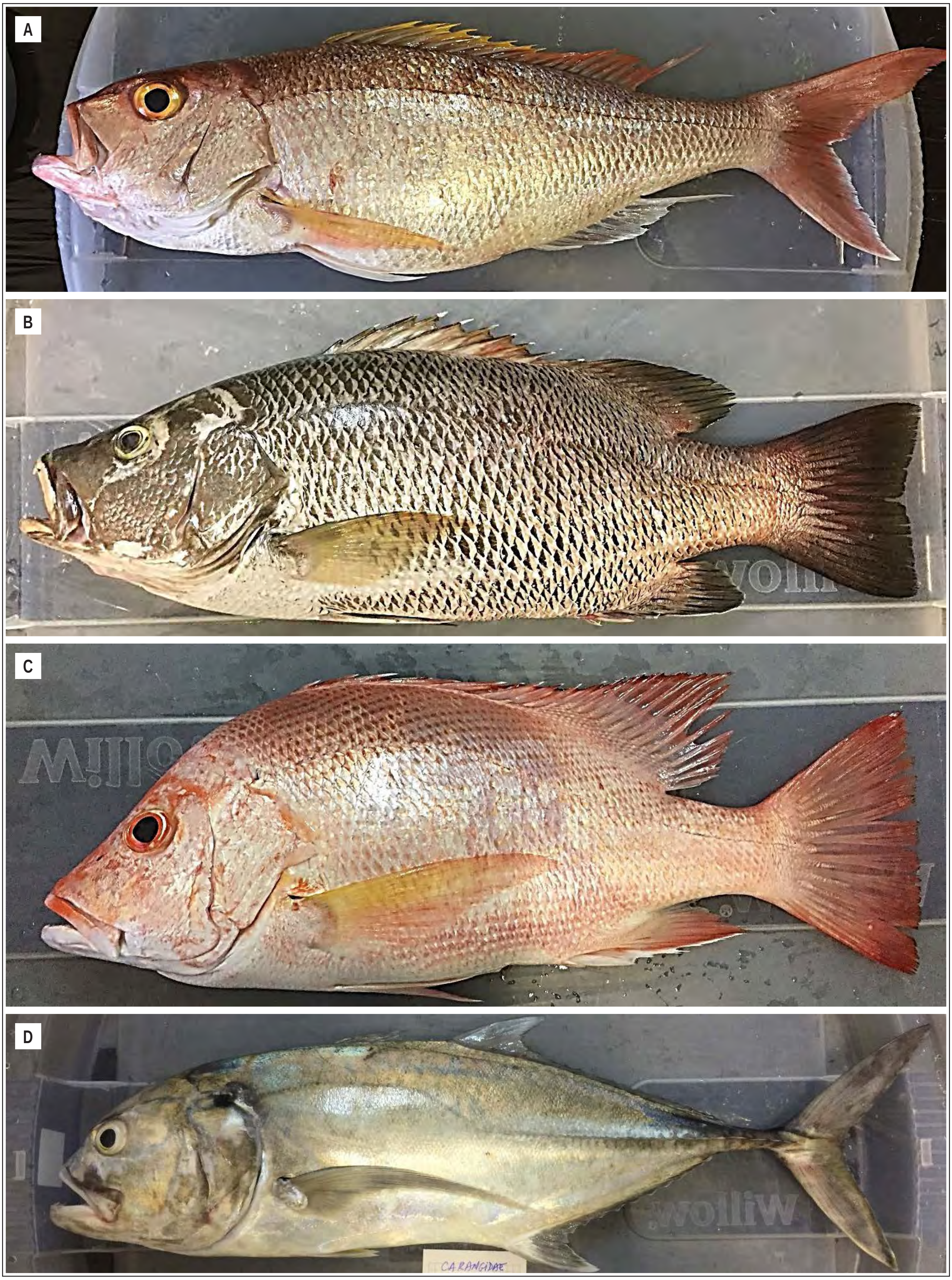


Photo credit: Coffey/Marscco

Plate 3.5

Species obtained from local fish market in Lae in November 2016.

A. Sharptooth jobfish, *Pristipomoides typus* (male, 655 mm TL, 2,800 g);
B. Sub-adult mangrove jack, *Lutjanus argentimaculatus* (male, 530 mm TL, 2,350 g);
C. Saddletail snapper, *Lutjanus malabaricus* (female, 470 mm TL, 1,700 g);
D. Bigeye trevally, *Caranx sexfasciatus* (male, 650 mm TL, 3,050 g).

3.3. Biological observations

The female/male sex ratio of the 33 dwarf gulper sharks (*C. atromarginatus*) caught in November 2016 was 1.2 (Table 3.3), whereas the ratio was close to 0.4 in the case of the 11 dwarf gulper sharks caught in May 2017 (Table 3.4). Internal examination of the reproductive condition of each female dwarf gulper shark caught in November 2016 revealed two specimens in early stages pregnancy and two pregnant specimens each carrying one near-term pup still feeding on yolk sac reserves (Table 3.3). In contrast, none of the three female dwarf gulper sharks captured in May 2017 was showing signs of pregnancy. The single 1,600 mm TL, 30 kg female gulper shark (*C. granulosus*) landed from the DSTP Study Area in November 2016 had yolked eggs in the uterus, i.e., in early stages of pregnancy, while the only female longfin gulper shark (*C. longipinnis*) caught in May 2017 was in the late stages of pregnancy with an unborn, nearly full-term single pup (Table 3.4; Plate 3.2C).

Examination of stomach contents of each of the 33 dwarf gulper sharks caught in November 2016 showed only three specimens with remains of crustaceans that were visually identified as prawns. These three dwarf gulpers were captured in the Reference Study Area south of Lae, and comprised two females (690 mm and 720 mm TL) from site LABU3 and a male (465 mm TL) from site LABU2. In each case, remains were single units and comprised either the rostrum (anterior carapace) or the tail section. In addition to prawns, examination of stomach contents of the 700 mm TL pregnant female from site LABU3 revealed a circle hook that was identified as one of those used during this study, with the whole bait still attached. No prey remains were found in the stomachs of any of the 25 dwarf gulper sharks fished from the DSTP Study Area in the Markham Canyon in November 2016.

Examination of stomach contents of each of the 11 dwarf gulper sharks caught in May 2017 showed remains of a single slipper lobster (decapod crustacean of the Family Scyllaridae) in a 478 mm TL male dwarf gulper shark caught at a depth of 346 m. Prey remains identified inside stomachs of other species captured in May 2017 included a prawn in a 500 mm TL male fatspine spurdog (*S. crassispinus*) caught at 270 m, a large, relatively fresh squid in a 725 mm TL male longfin gulper shark (C. *longipinnis*) from 370 m, and a whole fish in the 1,050 mm TL female common pike eel (*M. bagio*) caught at 124 m, which was subsequently identified as an adult hairpin anchovy (*Setipinna tenuifilis*) from the Family Engraulidae (Plate 3.4E).

Internal examination of each of the 14 bony fishes sourced from the local market showed all to be at reproductive stages ranging from immature (stage I) to maturing (stage III), with none in spawning conditions, i.e., running ripe, stage IV (Table 3.5).

3.4. Catch results

3.4.1. Fishing effort

Shelf and slope fishing effort during the November 2016 survey totalled 90 hours of combined fishing by 2 to 3 operators (one rod each) during 42 fishing events over 38 sites across the DSTP and Reference Study Areas. Fishing effort by area comprised 55.2 hours over 26 fishing events within the DSTP Study Area, and 34.8 hours over 16 events in the Reference Study Area (Table 2.4).

Fishing effort during the May 2017 survey totalled 58 hours of combined fishing by 2 operators (one rod each) during 29 fishing events over 27 sites across the DSTP and Reference Study Areas. Fishing effort by area comprised 52 hours over 26 fishing events within the DSTP Study Area, and 6.0 hours in three events in the Reference Study Area (Table 2.4).

In terms of effort by depth stratum, most slope fishing in the DSTP Study Area took place between the 100 and 500 m depth contours, both in November 2016 (77%) and May 2017 (79%) (Table 2.1).

Surface fishing effort during the November 2016 survey resulted in 17 trolling sessions lasting a combined total of 13.2 hours, with greatest effort (11 sessions) concentrated on the DSTP Study Area. Only six trolling sessions totalling 3.5 hours over the DSTP Study Area were undertaken in May 2017 before a decision was made to discontinue trolling due to nil catches (Table 2.2).

3.4.2. Total numbers

Forty-one individuals comprising 37 sharks (Family Centrophoridae; 90.2% of total catch) and four bony fish species were caught using baited droplines within the DSTP and Reference Study Areas during the November 2016 survey (Table 3.1). All 41 individuals originated from 17 of the 38 sites sampled across the two study areas (Table 2.1 and Table 2.3). Combining all species, the maximum number of individuals caught in a single fishing event was five at the 200 m to 300 m depth stratum at B2 (site 2 of transect B) on 4 November 2016 (Table 2.1), and five at depths of 210 m to 225 m at site LABU3 on 7 November 2016 (Table 2.3); single individuals were caught during seven fishing events while no fish was captured during 21 events (Table 2.1).

Twenty individuals comprising 18 sharks (Families Centrophoridae and Squalidae; 90.0% of total catch) and two bony fish species were caught within the DSTP and Reference Study Areas during the May 2017 survey (Table 3.2). All 20 individuals originated from 12 of the 27 sites sampled across the two study areas (Table 2.1 and Table 2.3). The maximum number of individuals caught in a single fishing event was three at depths between 100 m and 300 m at sites A2, D1 and E2; single individuals were caught during five fishing events while none was captured during 14 events (Table 2.1).

No pelagic fish were caught during surface trolling sessions conducted over the DSTP or Reference Study Areas during the November 2016 or the May 2017 surveys (Table 2.2).

3.4.3. Catch per unit of effort (CPUE)

Combining all species caught during the November 2016 survey, the greatest CPUEs within the DSTP Study Area were 2.18 fish/hour at site E3 (300 m to 352 m), 2.07 fish/hour at site C3 (324 m to 370 m) and 1.92 fish/hour at site B2 (200 m to 290 m). The greatest CPUE across the Reference Study Area was 3.0 fish/hour at site LABU3 (210 m to 225 m) (Table 3.6). Highest CPUEs within the DSTP Study Area during the May 2017 survey were 1.50 fish/hour at sites A2, D1 and E1 (Table 3.7).

Average CPUE combining all catches from all depth strata over the DSTP and Reference Study Areas was 0.09 kg/hook h^{-1} in November 2016 and 0.11 kg/hook h^{-1} in May 2017. Split by study area, the estimated CPUEs in the DSTP and Reference Study Areas averaged 0.11 kg/hook h^{-1} and 0.02 kg/hook h^{-1} in November 2016, respectively; and 0.12 kg/hook h^{-1} and 0.03 kg/hook h^{-1} in May 2017, respectively.

Table 3.6: Summary CPUE in DSTP Study Area during the November 2016 survey – number of fish caught per fishing hour per site; total fishing effort is the sum of minutes spent bottom fishing with 2 or 3 baited droplines used during that specific fishing event

Date	Transect	Site	No. Rods	Time (EST)	Total fishing effort (min)	Actual drift depth (m)	Fish caught	Species	CPUE (fish/hour)
3-Nov-16	A	A1	3	8:50-10:00	147	125-200	0		0
		A2	2	10:19-11:15	113	217-245	0		0
		A3	2	11:40-12:43	120	282-350	0		0
		A4	2	13:00-14:08	120	400-500	1	*C.a*	0.50
4-Nov-16	B	B1	3	10:05-11:29	165	105-200	3	*C.a*	1.09
		B2	3	11:32-12:59	156	200-290	5	*C.a* (4); *P.d* (1)	1.92
		B3	3	13:15-14:30	155	300-400	0		0
	C	C1	3	14:50-16:00	169	100-208	3	*C.a*	1.06
5-Nov-16	A	A5	3	9:57-11:25	174	500-536	1	*C.g*	0.34
	C	C2	3	13:20-14:40	145	200-295	4	*C.a*	1.66
6-Nov-16	A	A6	3	9:00-10:55	178	600-750	0		0
		A7	3	11:30-12:34	135	700-799	0		0
	B	B7	2	13:33-14:35	122	700-781	0		0
		B4	3	15:00-15:36	90	409-530	0		0
9-Nov-16	D	D1	2	9:11-10:33	111	58-190	1	*C.a*	0.54
		D2	2	10:44-12:16	120	190-311	0		0
		D4	2	12:32-13:35	120	390-460	1	*C.a*	0.50
	C	C4	2	13:58-15:20	120	400-470	0		0
	E	E1	2	15:55-16:45	77	100-200	0		0
11-Nov-16	E	E2	3	8:26-9:54	174	200-300	1	*C.a*	0.34
		E4	2	10:15-11:40	120	394-500	0		0
		E3	2	11:51-13:19	110	300-352	4	*C.a* (3); *C.l* (1)	2.18

Date	Transect	Site	No. Rods	Time (EST)	Total fishing effort (min)	Actual drift depth (m)	Fish caught	Species	CPUE (fish/hour)
12-Nov-16	C	C3	2	8:25-9:22	87	324-370	3	*C.a* (1); *C.l* (2)	2.07
	D	D3	2	9:51-11:13	105	300-380	2	*C.a*	1.14
13-Nov-16	D	D5	2	8:06-9:06	90	520-570	0		0
	E	E5	2	9:37-10:38	90	511-540	1	*C.a*	0.67

Depth stratum is next to site label, e.g., A1 = site A, 100 to 200 m.
Species: *C.a* = *Centrophorus atromarginatus*; *C.g* = *Centrophorus granulosus*; *C.l* = *Centrophorus longipinnis*; *P.d* = *Protonibea diacanthus*.

Table 3.7: Summary CPUE in DSTP and Reference Study Areas during the May 2017 survey – number of fish caught per fishing hour per site; total fishing effort is the sum of minutes spent bottom fishing with 1 to 2 baited droplines used during that specific fishing event

Date	Transect	Site	No. Rods	Time EST	Total fishing effort (min)	Actual drift depth	Fish caught	Species	CPUE (fish/hour)
4-May-17	D	D1	2	09:05- 10:20	120	180-200	3	*C.a* (2); *S.c*	1.50
		D2	2	10:30-11:40	120	220-250	1	*S.c*	0.50
		D3	2	12:10-13:30	120	346-400	1	*C.a*	0.50
		D4	2	13:40-15:45	120	450-500	1	*C.l*	0.50
05-May-17	D	D5	2	08:48-10:38	120	570-590	0		0.00
	C	C5	2	11:10-12:10	120	530-550	0		0.00
		C4	2	12:46-14:07	120	440-480	0		0.00
		C3	2	14:40-15:40	120	360-380	1	*C.l*	0.50
06-May-17	C	C2	2	08:55-10:15	120	210-220	0		0.00
		C1	2	10:34-12:02	120	114-170	0		0.00
	B	B1	2	12:22-13:36	120	160-170	0		0.00
		B2	2	13:52-15:15	120	270-298	0		0.00

Date	Transect	Site	No. Rods	Time EST	Total fishing effort (min)	Actual drift depth	Fish caught	Species	CPUE (fish/hour)
07-May-17	B	B3	2	08:00-09:00	120	300-390	1	*C.a*	0.50
	A	A1	2	09:16-10:28	120	100-130	1	*L.m*	0.50
		A2	2	10:40-12:11	120	260-300	3	*S.c*	1.50
		A3	2	12:35-14:02	120	370-400	0		0.00
	B	B4	2	15:45-16:45	120	480-490	0		0.00
08-May-17	E	E1	2	08:40-09:49	120	130-150	0		0.00
		E2	2	10:06-11:36	120	280-300	3	*C.a*	1.50
	C	C7	2	13:05-14:05	120	720-750	0		0.00
	D	D7	1	14:20-15:20	60	750-780	0		0.00
09-May-17	E	E3	2	08:06-09:16	120	360-390	0		0.00
		E4	2	09:34-10:34	120	460-500	0		0.00
		E5	2	11:00-12:00	120	550-590	0		0.00
	LABU	LABU3	2	12:35-13:35	120	200-240	1	*C.a*	0.50
		LABU2	2	14:00-15:26	120	100-130	1	*C.a*	0.50
		LABU1	2	15:43-16:13	60	62-100	0		0.00
10-May-17	D	D2	2	08:21-09:21	120	215-230	1	*C.a*	0.50
	E	E1	2	09:52-10:40	120	120-150	2	*M.b; C.a*	1.00

Depth stratum is next to site label, e.g., A1 = site A, 100 to 200 m.
Species: *C.a = Centrophorus atromarginatus*; *C.l = Centrophorus longipinnis*; *L.m = Lutjanus malabaricus*; *M.b = Muraenesox bagio*; *S.c = Squalus crassispinus*

3.4.4. Vertical distribution

Examination of vertical distribution of the 44 dwarf gulper sharks caught during the November 2016 and May 2017 surveys in the DSTP and Reference Study Areas indicates that just over 93% were caught at depths between 100 m and 400 m (n = 41), with 41% of the total captured in the 200 m to 300 m depth stratum (n = 18; Figure 3.1). The shallowest depth range of 0-100 m is not included in Figure 3.1 as no sharks were caught at such depth range, nor is this classified as 'deep slope'.

3.5. Metals concentrations

Descriptions of the muscle and liver tissue samples tested from 40 specimens captured in November 2016 (six species) and the 14 specimens obtained at the DCA Point fish market in November 2016 (five species) are provided in Table 3.8 and Table 3.9, respectively. Data on muscle weights (wet weight) tested from the 20 specimens captured in May 2017 (five species) are provided in Table 3.10. Liver tissue from the May 2017 specimens could not be tested due to laboratory malfunction during the digestion process.

For simplicity, the metalloids arsenic (As) and selenium (Se) are referred to as ‘metals’ throughout this report.

Table 3.8: Details of muscle and liver tissue samples collected for metal analyses from sharks and bony fishes captured during November 2016

Fish No.	Date	Transect / Site	Depth stratum (m)	Common name	Sample label	Muscle (g)*	Sample label	Liver (g)*
1	3-Nov-16	A4	400-500	Dwarf gulper shark	M1	31.74	L1	36.64
2	4-Nov-16	B2	200-300	Dwarf gulper shark	M2	18.16	L2	18.55
3	4-Nov-16	B1	100-200	Dwarf gulper shark	M3	14.52	L3	21.40
4	4-Nov-16	B1	100-200	Dwarf gulper shark	M4	14.50	L4	23.10
5	4-Nov-16	B1	100-200	Dwarf gulper shark	M5	10.92	L5	11.88
6	4-Nov-16	B2	200-300	Dwarf gulper shark	M6	20.6	L6	23.0
7	4-Nov-16	B2	200-300	Blackspotted croaker	M7	61.0	L7	51.45
8	4-Nov-16	B2	200-300	Dwarf gulper shark	M8	14.97	L8	31.53
9	4-Nov-16	B2	200-300	Dwarf gulper shark	M9	37.55	L9	57.17
10	4-Nov-16	C1	100-200	Dwarf gulper shark	M10	29.20	L10	47.08
11	4-Nov-16	C1	100-200	Dwarf gulper shark	M11	20.41	L11	29.0
12	5-Nov-16	A5	500-600	Gulper shark	M12	39.67	L12	29.53
13	5-Nov-16	C2	200-300	Dwarf gulper shark	M13	26.80	L13	34.90
14	5-Nov-16	C2	200-300	Dwarf gulper shark	M14	8.50	L14	13.96
15	5-Nov-16	C2	200-300	Dwarf gulper shark	M15	19.28	L15	33.33
16	5-Nov-16	C2	200-300	Dwarf gulper shark	M16	22.80	L16	33.27
17	7-Nov-16	LABU1	100-200	Mangrove jack	M17	46.36	L17	18.27
18	7-Nov-16	LABU3	200-300	Dwarf gulper shark	M18	17.16	L18	39.57
19	7-Nov-16	LABU3	200-300	Dwarf gulper shark	M19	37.83	L19	68.50
20	7-Nov-16	LABU3	200-300	Dwarf gulper shark	M20	6.30	L20	11.44

Fish No.	Date	Transect / Site	Depth stratum (m)	Common name	Sample label	Muscle (g)*	Sample label	Liver (g)*
21	7-Nov-16	LABU3	200-300	Dwarf gulper shark	M21	30.64	L21	42.35
22	7-Nov-16	LABU3	200-300	Dwarf gulper shark	M22	12.04	L22	16.37
23	7-Nov-16	LABU2	100-200	Dwarf gulper shark	M23	11.86	L23	16.17
24	7-Nov-16	LABU2	100-200	Dwarf gulper shark	M24	7.32	L24	25.0
25	7-Nov-16	LABU2	100-200	Dwarf gulper shark	M25	7.64	L25	11.80
26	9-Nov-16	D4	400-600	Dwarf gulper shark	M26	54.24	L26	45.75
27	9-Nov-16	D1	100-200	Dwarf gulper shark	M27	12.34	L27	15.42
28	12-Nov-16	C3	300-400	Longfin gulper shark	M28	23.58	L28	84.19
29	12-Nov-16	C3	300-400	Longfin gulper shark	M29	31.09	L29	67.39
30	12-Nov-16	D3	300-400	Dwarf gulper shark	M30	18.25	L30	28.93
31	12-Nov-16	D3	300-400	Dwarf gulper shark	M31	36.0	L31	38.51
32	12-Nov-16	C3	300-400	Dwarf gulper shark	M32	44.98	L32	53.22
33	12-Nov-16	E3	300-400	Dwarf gulper shark	M33	15.76	L33	25.05
34	11-Nov-16	E3	300-400	Dwarf gulper shark	M34	23.81	L34	28.71
35	11-Nov-16	E2	200-300	Dwarf gulper shark	M35	21.30	L35	30.36
36	11-Nov-16	E3	300-400	Dwarf gulper shark	M36	33.0	L36	30.35
37	11-Nov-16	E3	300-400	Longfin gulper shark	M37	39.16	L37	54.12
38	12-Nov-16	SW1	0-100	Saddletail snapper	M38	18.67	L38	2.14
39	13-Nov-16	E5	500-600	Dwarf gulper shark	M39	29.89	L39	34.39
40	4-Nov-16	C1	100-200	Dwarf gulper shark	M40	17.80	L40	47.90

* Weights are given as wet weight.

Table 3.9: Details of muscle and liver tissue samples collected for metal analyses from bony fishes sourced from local street market during November 2016

Fish No.	Date	Approximate location	Depth (m)	Common name	Sample label	Muscle (g)*	Sample label	Liver (g)*
1	5-Nov-16	South of Lae, offshore from Labu Lakes	100-200	Sharptooth jobfish	MM1	19.77	ML1	13.23
2	5-Nov-16	South of Lae, offshore from Labu Lakes	100-200	Saddletail snapper	MM2	27.14	ML2	9.16
3	5-Nov-16	South of Lae, offshore from Labu Lakes	100-200	Bigeye trevally	MM3	32.53	ML3	11.36
4	5-Nov-16	South of Lae, offshore from Labu Lakes	Max. 70	Mangrove jack	MM4	32.31	ML4	5.36
5	5-Nov-16	South of Lae, offshore from Labu Lakes	Max. 70	Mangrove jack	MM5	27.13	ML5	13.84
6	9-Nov-16	South of Lae, offshore from Labu Lakes	30-40	Saddletail snapper	MM6	30.18	ML6	3.78
7	9-Nov-16	South of Lae, offshore from Labu Lakes	30-40	Sharptooth jobfish	MM7	46.03	ML7	16.34
8	9-Nov-16	South of Lae, offshore from Labu Lakes	30-40	Saddletail snapper	MM8	31.0	ML8	5.09
9	10-Nov-16	South of Lae, offshore from Labu Lakes	30-40	Saddletail snapper	MM9	49.94	ML9	14.88
10	10-Nov-16	South of Lae, offshore from Labu Lakes	30-40	Pennantfish	MM10	34.80	ML10	11.60
11	10-Nov-16	South of Lae, offshore from Labu Lakes	30-40	Bigeye trevally	MM11	41.31	ML11	12.85
12	12-Nov-16	Off Salamaua Is	<100	Saddletail snapper	MM12	29.14	ML12	16.09
13	12-Nov-16	Off Salamaua Is	<100	Bigeye trevally	MM13	50.15	ML13	15.50
14	11-Nov-16	Labu fishing area	<50	Bigeye trevally	MM14	55.66	ML14	20.90

* Weights are given as wet weight.

Table 3.10: Details of muscle and liver tissue samples collected for metal analyses from sharks and bony fishes captured during May 2017

Fish No.	Date	Transect / Site	Depth stratum (m)	Common name	Sample label	Muscle (g)*	Sample label	Liver (g)*
1	4-May-17	D1	100-200	Dwarf gulper shark	MD1-1	13.20	LD1-1	11.40
2	4-May-17	D1	100-200	Dwarf gulper shark	MD1-2	12.15	LD1-2	10.94
3	4-May-17	D1	100-200	Fatspine spurdog	MD1-3	14.83	LD1-3	13.70
4	4-May-17	D2	200-300	Fatspine spurdog	MD2-4	7.96	LD2-4	7.92
5	4-May-17	D3	300-400	Dwarf gulper shark	MD3-5	13.39	LD3-5	35.27
6	4-May-17	D4	400-500	Longfin gulper shark	MD4-6	15.02	LD4-6	24.09
7	7-May-17	A2	200-300	Fatspine spurdog	MA2-7	19.86	LA2-7	22.36
8	7-May-17	B3	300-400	Dwarf gulper shark	MB3-8	10.77	LB3-8	23.46
9	7-May-17	A2	200-300	Fatspine spurdog	MA2-9	17.30	LA2-9	9.65
10	7-May-17	A2	200-300	Fatspine spurdog	MA2-10	14.88	LA2-10	10.37
11	5-May-17	C3	300-400	Longfin gulper shark	MC3-11	27.08	LC3-11	20.94
12	7-May-17	A1	100-200	Saddletail snapper	MA1-12	19.72	LA1-12	6.17
13	9-May-17	LABU2	120	Dwarf gulper shark	MLABU2-13	11.40	LLABU2-13	18.13
14	9-May-17	LABU3	230	Dwarf gulper shark	MLABU3-14	14.85	LLABU3-14	10.28
15	8-May-17	E2	200-300	Dwarf gulper shark	ME2-15	16.08	LE2-15	12.33
16	8-May-17	E2	200-300	Dwarf gulper shark	ME2-16	13.41	LE2-16	15.30
17	8-May-17	E2	200-300	Dwarf gulper shark	ME2-17	17.23	LE2-17	13.42
18	10-May-17	AS2	200-300	Dwarf gulper shark	MAS2-18	27.28	LAS2-18	24.72
19	10-May-17	AS1	100-200	Dwarf gulper shark	MAS1-19	14.88	LAS1-19	11.03
20	10-May-17	AS1	100-200	Common pike eel	MAS1-20	13.83	LAS1-20	15.92

* Weights are given as wet weight.

A selection of the metals presented in this section are shown graphically below. Plotting was restricted to those metals with analytical results largely above the PQLs and to those metals that have applicable food standards and GELs.

All metals concentrations given in this section are in mg kg^{-1}, wet weight.

Averaged liver and muscle concentrations from individual dwarf gulper sharks and grouped into their respective depth ranges are presented in Figure 3.2; the error bars represent 95% confidence intervals. Metal concentrations in dwarf gulper sharks were consistent over the depth strata, with concentrations in liver generally higher than in muscle (Figure 3.2) except in the case of As and Hg which were higher in muscle.

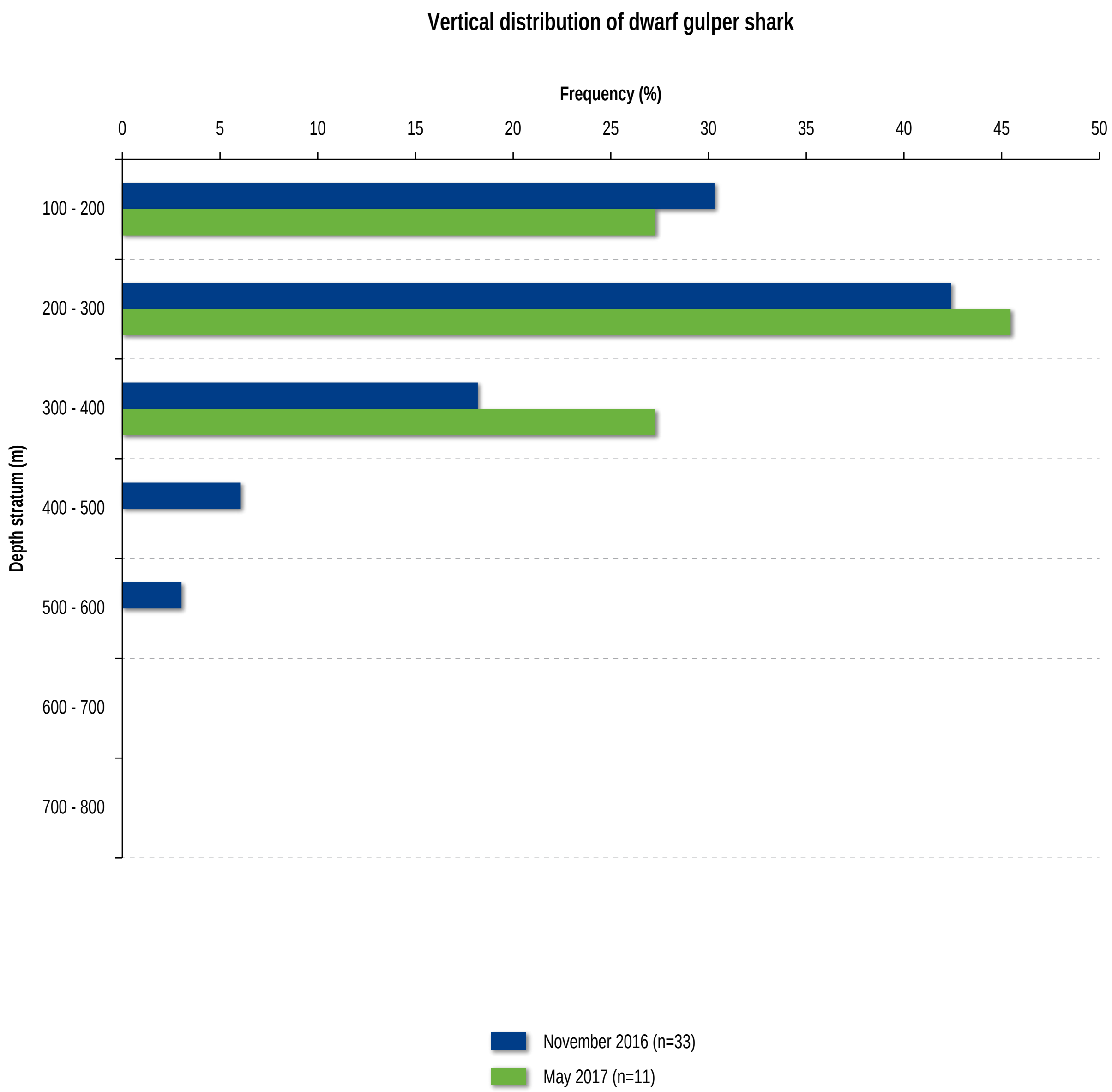
Mean concentrations of metals in liver and muscle tissue samples from caught fishes and market bought fishes are presented in Figure 3.3 and Figure 3.4, respectively.

Metal concentrations in liver and muscle samples of dwarf gulper shark by weight and total length are presented in Figure 3.5, Figure 3.6 and Figure 3.7.

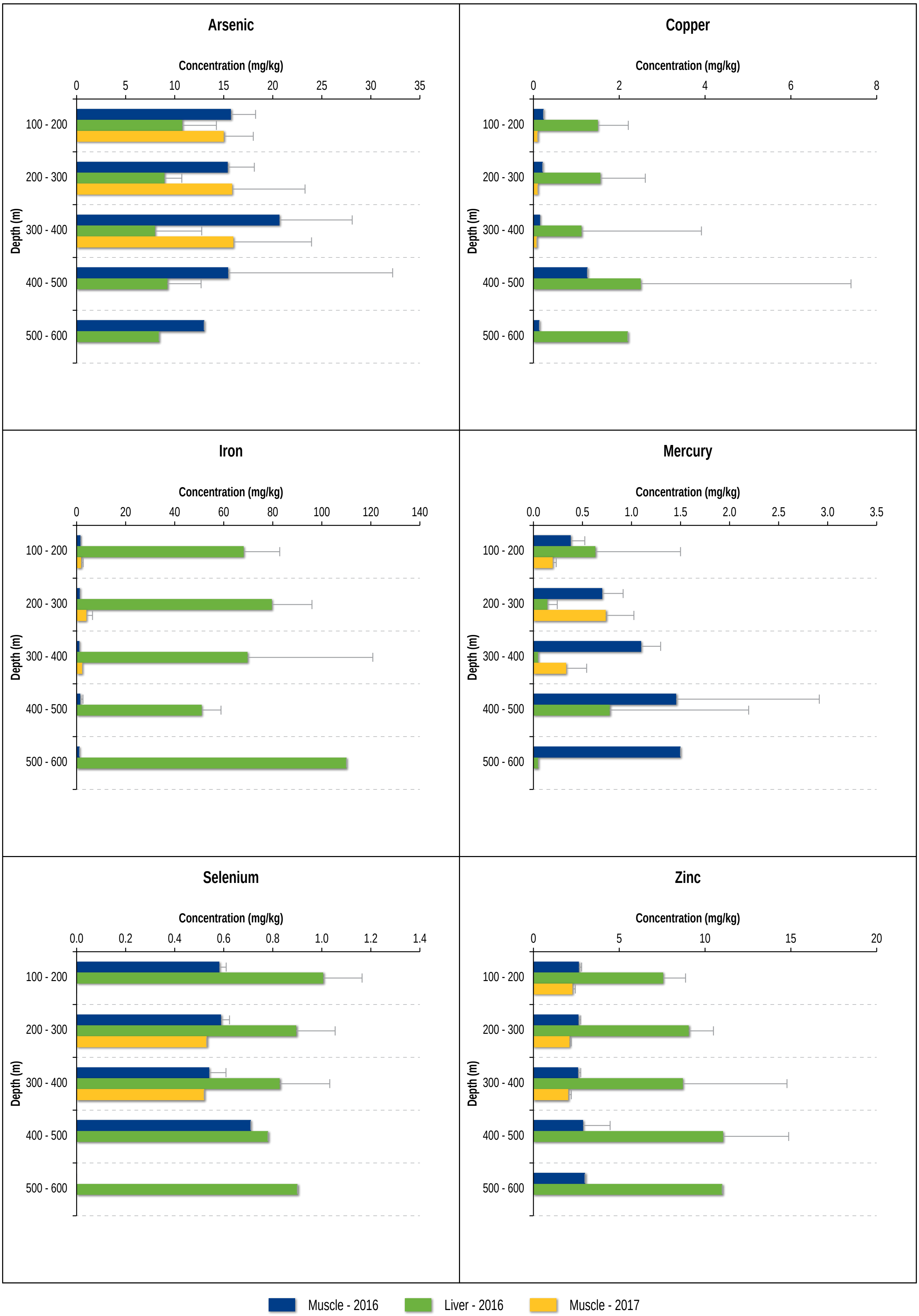
Table 3.11 through to Table 3.22 present the concentration data (mg kg^{-1}) of each of the 12 metals and metalloids analysed during this study (As, Cd, Cr, Cu, Fe, Pb, Hg, Mn, Ni, Se, Ag and Zn).

Each table provides data for the sharks and bony fish species caught during the November 2016 survey (n = 40), bony fishes purchased at the Lae street market in November 2016 (n = 14), and the sharks and bony fish species captured during the May 2017 survey (n = 20). For each metal, the minimum, maximum and mean concentrations are presented. The number of samples and standard deviations are also included. The practical quantification limits (PQLs) are also provided for each metal as well as the FSANZ Standard or GEL where applicable. Additionally, for copper, mercury, selenium and zinc the median and 90th percentile values are also provided as to allow comparison to the FSANZ GEL. Results for muscle are compared to the FSANZ Standard and FSANZ GEL as it is expected that this portion of the fish would be consumed as food. For comparative purposes, results for liver are also compared to the FSANZ Standard and FSANZ GEL; although these portions of the fish are less likely to be eaten.

The raw metal and metalloid concentration data for all fish muscle and liver tissue are presented in Appendix C.



coffey A TETRA TECH COMPANY	Date: 04.07.2017 Project: 754-ENAUABTF100520CC File Name: 0520CC_11_F03.01_GRA	WAFI-GOLPU JOINT VENTURE Wafi-Golpu Project	Vertical distribution of dwarf gulper sharks	Figure No: 3.1



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Date: 04.07.2017
Project: 754-ENAUABTF100520CC
File Name: 0520CC_11_F03.02_GRA

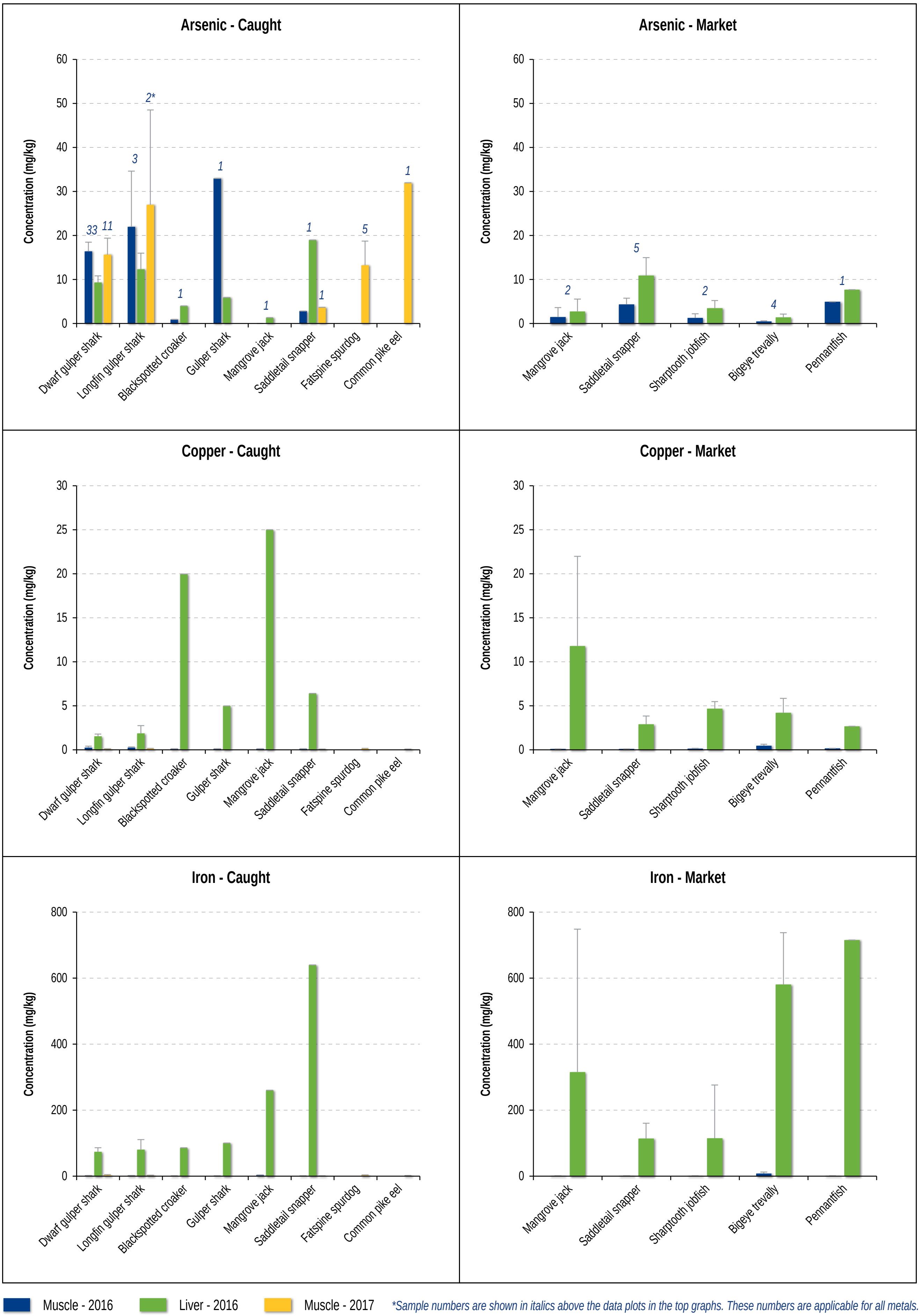
WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Mean metals concentrations in liver and muscle of dwarf gulper sharks by depth

Figure No: 3.2

AI Reference:0520_11_GRA002.ai 3



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Date: 04.08.2017
Project: 754-ENAUABTF100520CC
File Name: 0520CC_11_F03.03_GRA

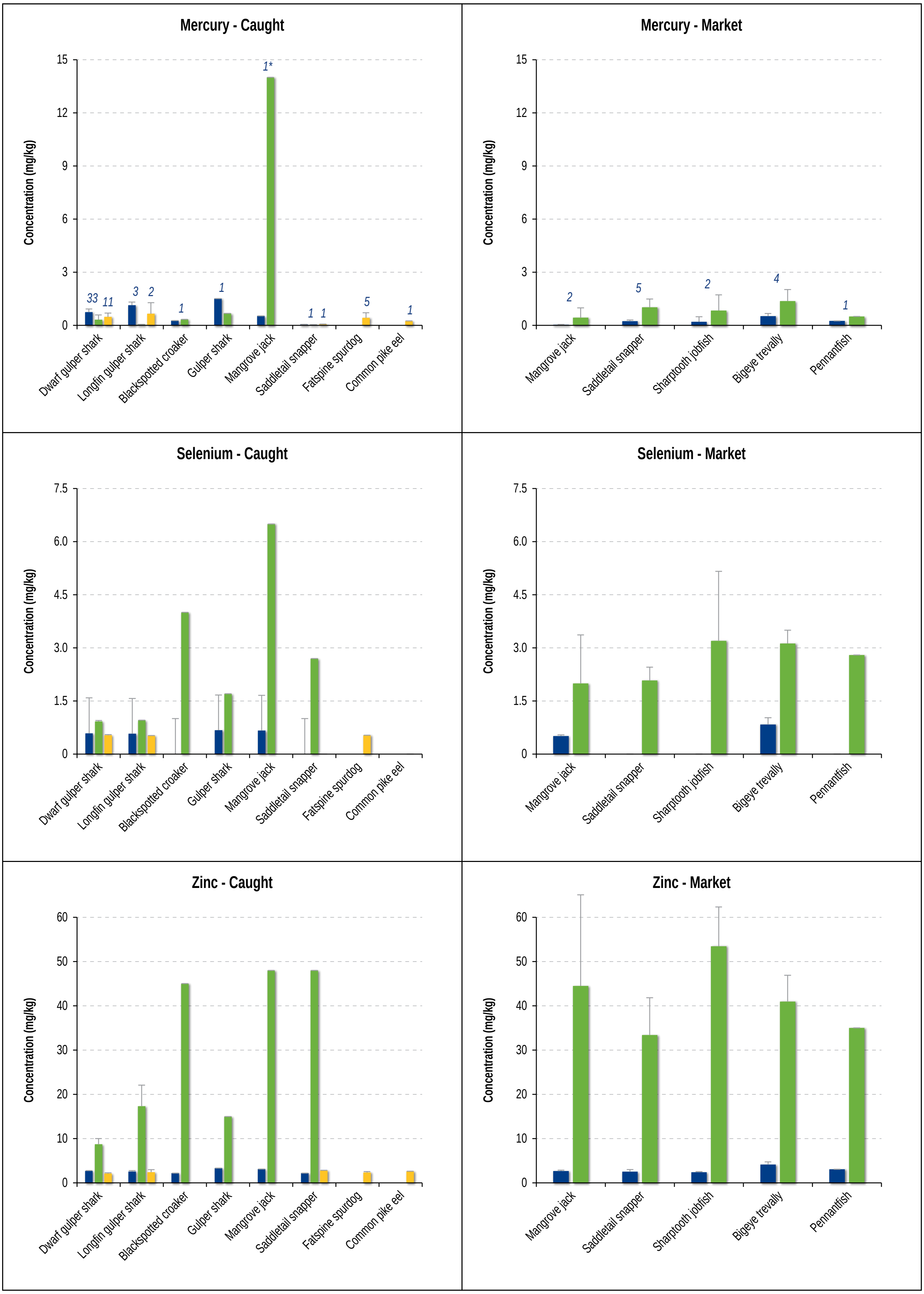
WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Mean metals concentrations (As, Cu, Fe) in liver and muscle of fishes caught (Nov 2016; May 2017) and sourced from DCA Point fish market (Nov 2016)

Figure No: 3.3

AI Reference:0520_11_GRA003.ai 4



Muscle - 2016 | Liver - 2016 | Muscle - 2017

**Sample numbers are shown in italics above the data plots in the top graphs. These numbers are applicable for all metals.*

AI Reference:0520_11_GRA004.ai 4

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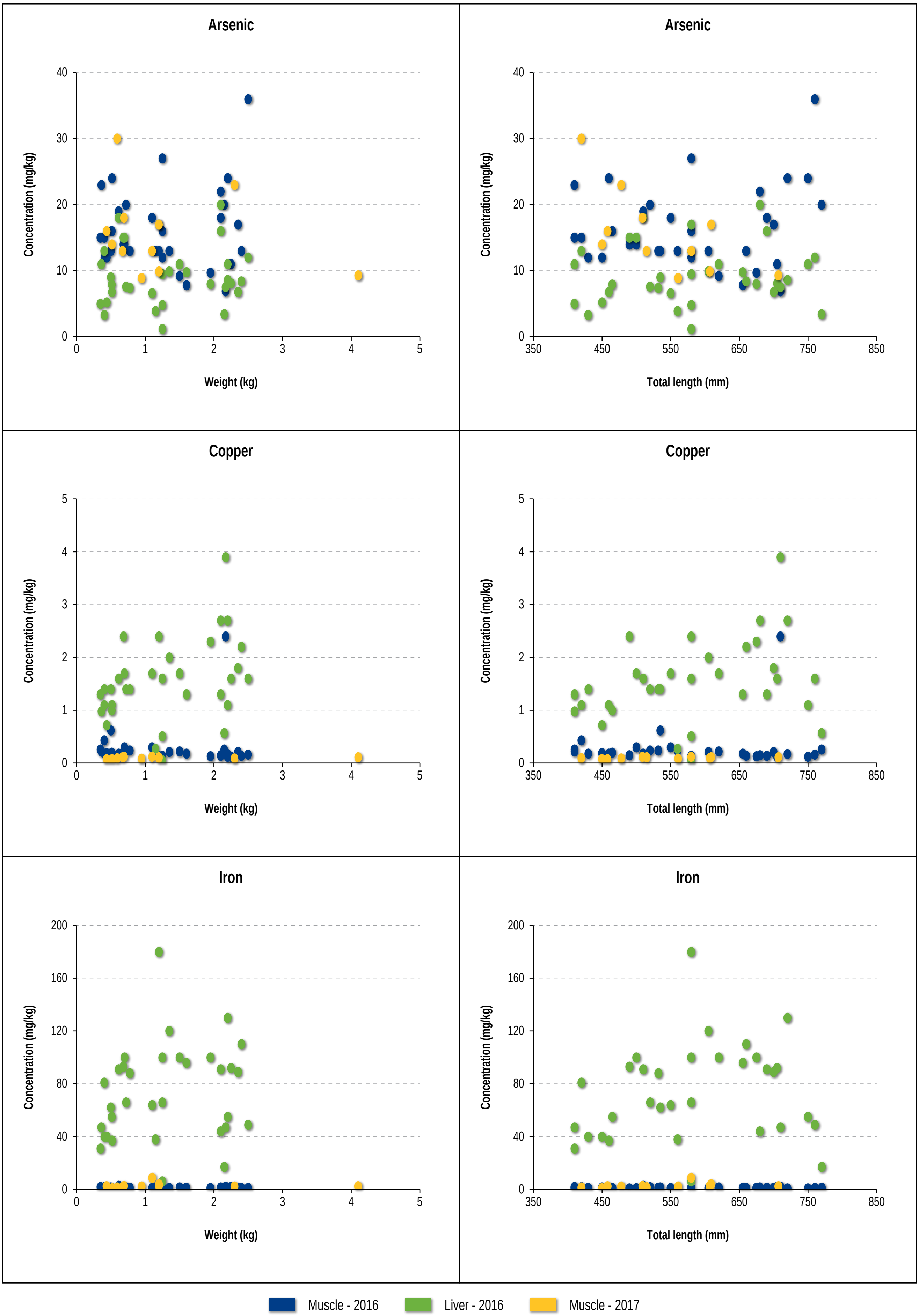
Date: 04.08.2017	WAFI-GOLPU JOINT VENTURE	Mean metals concentrations (Hg, Se, Zn) in liver and muscle of fishes caught (Nov 2016; May 2017) and sourced from DCA Point fish market (Nov 2016)	Figure No: 3.4
Project: 754-ENAUABTF100520CC	Wafi-Golpu Project		
File Name: 0520CC_11_F03.04_GRA			



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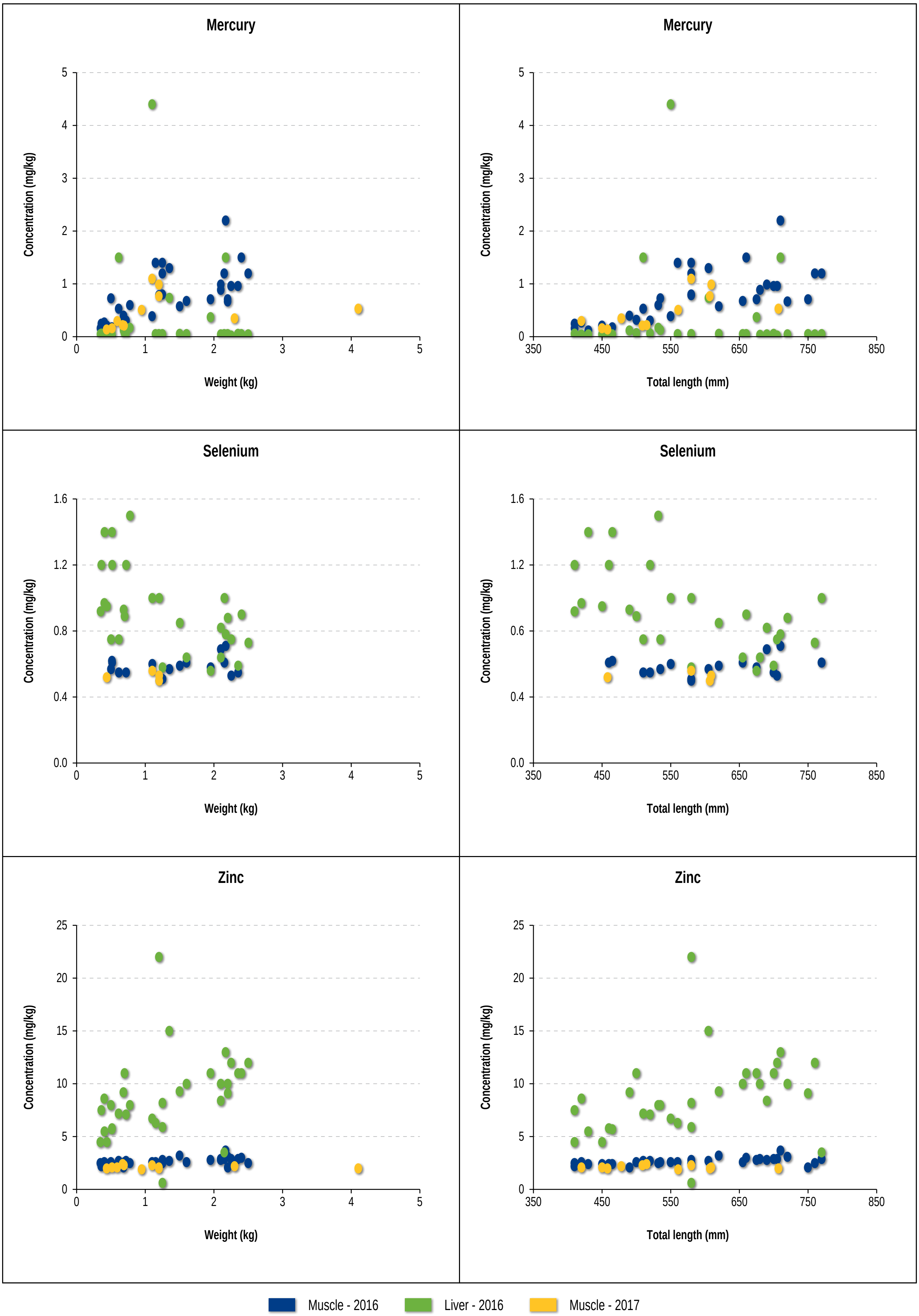
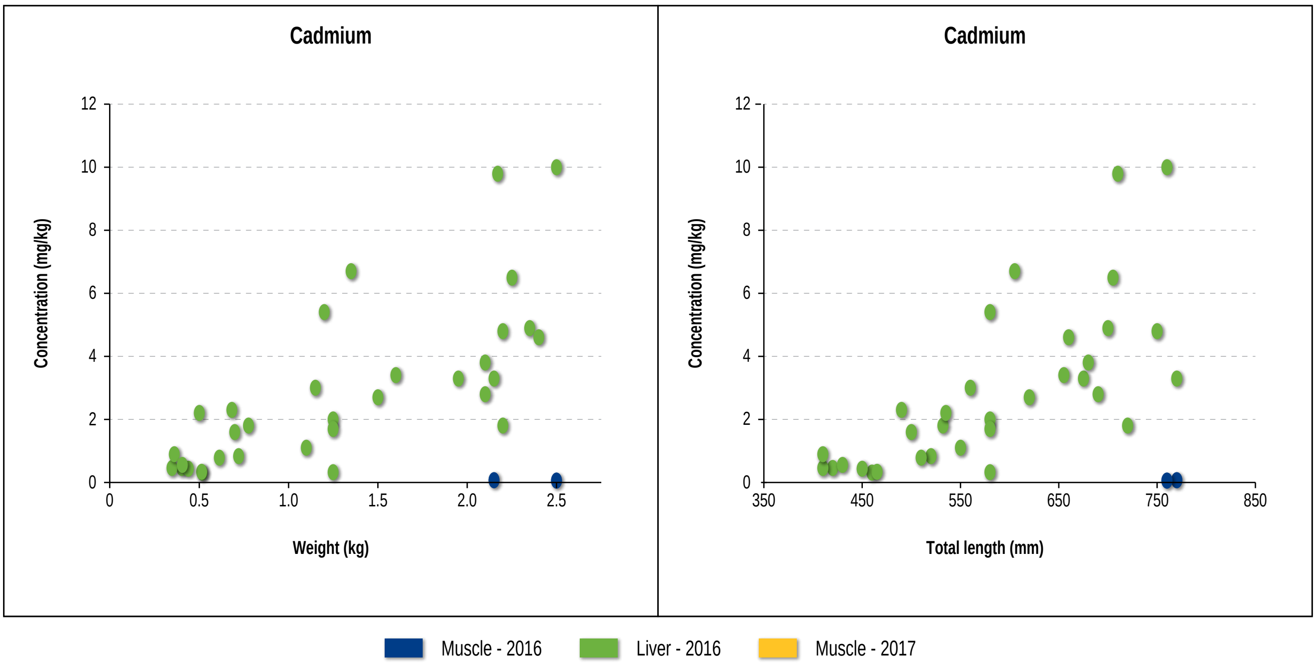
AI Reference:0520_11_GRA005.ai_3



coffey A TETRA TECH COMPANY	Date: 04.07.2017 Project: 754-ENAUABTF100520CC File Name: 0520CC_11_F03.06_GRA	WAFI-GOLPU JOINT VENTURE Wafi-Golpu Project	Metals concentrations (Hg, Se, Zn) in liver and muscle of dwarf gulper sharks by total weight and length	Figure No: 3.6

AI Reference:0520_11_GRA006.ai 3



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Date: 06.07.2017
Project: 754-ENAUABTF100520CC
File Name: 0520CC_11_F03.07_GRA

WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Metals concentrations (Cd) in liver and muscle of dwarf gulper sharks by total weight and length

Figure No: 3.7

3.5.1. Arsenic (As)

The ranges of concentrations of As across all caught specimens were 1.2 to 20 mg kg^{-1} in liver and less than 0.4 to 36 mg kg^{-1} in muscle. The highest As concentration in liver (20 mg kg^{-1}) was recorded in a dwarf gulper shark caught in November 2016 survey, while the highest concentration in muscle (38 mg kg^{-1}) was recorded in a longfin gulper shark caught in May 2017 (Table 3.11).

The ranges of concentrations across all market specimens were 0.71 to 16 mg kg^{-1} in liver and less than 0.4 mg kg^{-1} to 6.2 mg kg^{-1} in muscle. The highest As concentrations in liver and muscle were recorded in saddletail snapper specimens.

Table 3.11: Concentrations of arsenic (mg kg^{-1}) in liver and muscle samples of specimens caught in the upper Huon Gulf (n = 40) and sourced from the Lae street market (n = 14) in November 2016, and in muscle samples from specimens fished the same area in May 2017 (n = 20)

Arsenic (PQL = 0.4)		**Muscle**					**Liver**				
FSANZ Standard (maximum of 2 mg kg^{-1})											
	Caught species	**Min**	**Max**	**Mean**	**n**	**StdDev**	**Min**	**Max**	**Mean**	**n**	**StdDev**
Nov 2016	Dwarf gulper shark	**6.9**	**36**	**16.4**	33	6.2	1.2	**20**	**9.3**	33	4.5
	Longfin gulper shark	**12**	**34**	**22**	3	11.1	**10**	**16**	**12.3**	3	3.2
	Blackspotted croaker	0.96	0.96	0.96	1	0	4	**4**	**4**	1	0
	Gulper shark	**33**	**33**	**33**	1	0	**5.9**	**5.9**	**5.9**	1	0
	Mangrove jack	<0.4	<0.4	<0.4	1	0	1.3	1.3	1.3	1	0
	Saddletail snapper	**2.8**	**2.8**	**2.8**	1	0	**19**	**19**	**19**	1	0
	Market species										
	Mangrove jack	0.41	**2.6**	1.5	2	1.6	1.3	**4.2**	**2.8**	2	2.1
	Saddletail snapper	**2.3**	**6.2**	**4.3**	5	1.6	**3.5**	**16**	**10.9**	5	4.7
	Sharptooth jobfish	0.83	1.8	1.32	2	0.69	**2.6**	**4.4**	**3.5**	2	1.3
	Bigeye trevally	<0.4	0.60	0.52	4	0.10	0.71	**2.4**	1.5	4	0.7
	Pennantfish	**5**	**5**	**5**	1	0	**7.7**	**7.7**	**7.7**	1	0
May 2017	**Caught species**										
	Dwarf gulper shark	**8.9**	**30**	**15.7**	11	6.4	-	-	-	-	-
	Longfin gulper shark	**16**	**38**	**27**	2	15.6	-	-	-	-	-
	Fatspine spurdog	**5.5**	**21**	**13.3**	5	6.2	-	-	-	-	-
	Saddletail snapper	**3.7**	**3.7**	**3.7**	1	0	-	-	-	-	-
	Common pike eel	**32**	**32**	**32**	1	0	-	-	-	-	-

Bold indicates exceedance of the FSANZ standard.
- denotes no data

3.5.2. Cadmium (Cd)

The ranges of Cd concentrations recorded across all caught specimens were 0.31 to 23 mg kg^{-1} in liver and less than 0.05 to 0.15 mg kg^{-1} in muscle, with most samples (37 of 40 of the November 2016 specimens and all May 2017 specimens) having less than 0.05 mg kg^{-1} in muscle (Table 3.12). The highest Cd concentrations in liver (23 mg kg^{-1}) and muscle (0.15 mg kg^{-1}) were recorded in longfin gulper shark specimens caught in November 2016.

The ranges of concentrations across all market specimens were 0.16 to 6.30 mg kg^{-1} in liver, whereas all concentrations in muscle were below the PQL of 0.05 mg kg^{-1}. The highest Cd concentration (6.3 mg kg^{-1}) was recorded in the liver of a sharptooth jobfish.

Table 3.12: Concentrations of cadmium (mg kg^{-1}) in liver and muscle samples of specimens caught in the upper Huon Gulf (n = 40) and sourced from the Lae street market (n = 14) in November 2016, and in muscle samples from specimens fished the same area in May 2017 (n = 20)

Cadmium (PQL = 0.05)		Muscle					Liver				
	Caught species	**Min**	**Max**	**Mean**	**n**	**StdDev**	**Min**	**Max**	**Mean**	**n**	**StdDev**
Nov 2016	Dwarf gulper shark	<0.05	0.07	0.07	33	0.01	0.31	10	2.88	33	2.56
	Longfin gulper shark	<0.05	0.15	0.15	3	0	14	23	19	3	4.58
	Blackspotted croaker	<0.05	<0.05	<0.05	1	0	4.5	4.5	4.5	1	0
	Gulper shark	<0.05	<0.05	<0.05	1	0	12	12	12	1	0
	Mangrove jack	<0.05	<0.05	<0.05	1	0	7.8	7.8	7.8	1	0
	Saddletail snapper	<0.05	<0.05	<0.05	1	0	2.3	2.3	2.3	1	0
	Market species										
	Mangrove jack	<0.05	<0.05	<0.05	2	0	0.16	0.36	0.26	2	0.14
	Saddletail snapper	<0.05	<0.05	<0.05	5	0	1.4	2.8	2.0	5	0.52
	Sharptooth jobfish	<0.05	<0.05	<0.05	2	0	5.5	6.3	5.9	2	0.57
	Bigeye trevally	<0.05	<0.05	<0.05	4	0	0.74	2.80	1.99	4	0.94
	Pennantfish	<0.05	<0.05	<0.05	1	0	1.30	1.30	1.30	1	0
May 2017	**Caught species**										
	Dwarf gulper shark	<0.05	<0.05	<0.05	11	0	-	-	-	-	-
	Longfin gulper shark	<0.05	<0.05	<0.05	2	0	-	-	-	-	-
	Fatspine spurdog	<0.05	<0.05	<0.05	5	0	-	-	-	-	-
	Saddletail snapper	<0.05	<0.05	<0.05	1	0	-	-	-	-	-
	Common pike eel	<0.05	<0.05	<0.05	1	0	-	-	-	-	-

No FSANZ standard or FSANZ GEL for cadmium.
- denotes no data

3.5.3. Chromium (Cr)

The ranges of Cr concentrations recorded across all caught specimens were less than 0.1 to 0.23 mg kg^{-1} in liver and less than 0.1 to 0.19 mg kg^{-1} in muscle. Most samples (37 of 40 liver samples and 39 of 40 muscle samples from November 2016; and 16 of 20 muscle samples from May 2017 specimens) had Cr concentrations below the PQL of 0.1 mg kg^{-1} (Table 3.13). The highest Cr concentrations in liver (0.23 mg kg^{-1}) and muscle (0.19 mg kg^{-1}) were recorded in dwarf gulper sharks.

The Cr concentrations across all market specimens were below the PQL of 0.1 mg kg^{-1} both in liver and muscle tissues.

Table 3.13: Concentrations of chromium (mg kg^{-1}) in liver and muscle samples of specimens caught in the upper Huon Gulf (n = 40) and sourced from the Lae street market (n = 14) in November 2016, and in muscle samples from specimens fished the same area in May 2017 (n = 20)

Chromium (PQL = 0.1)		Muscle					Liver				
	Caught species	**Min**	**Max**	**Mean**	**n**	**StdDev**	**Min**	**Max**	**Mean**	**n**	**StdDev**
Nov 2016	Dwarf gulper shark	<0.1	0.19	0.19	33	0	<0.1	0.23	0.15	33	0.07
	Longfin gulper shark	<0.1	<0.1	<0.1	3	0	<0.1	<0.1	<0.1	3	0
	Blackspotted croaker	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Gulper shark	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Mangrove jack	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Saddletail snapper	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Market species										
	Mangrove jack	<0.1	<0.1	<0.1	2	0	<0.1	<0.1	<0.1	2	0
	Saddletail snapper	<0.1	<0.1	<0.1	5	0	<0.1	<0.1	<0.1	5	0
	Sharptooth jobfish	<0.1	<0.1	<0.1	2	0	<0.1	<0.1	<0.1	2	0
	Bigeye trevally	<0.1	<0.1	<0.1	4	0	<0.1	<0.1	<0.1	4	0
	Pennantfish	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
May 2017	**Caught species**										
	Dwarf gulper shark	<0.1	0.19	0.15	11	0.03	-	-	-	-	-
	Longfin gulper shark	<0.1	<0.1	<0.1	2	0	-	-	-	-	-
	Fatspine spurdog	<0.1	<0.1	<0.1	5	0	-	-	-	-	-
	Saddletail snapper	<0.1	<0.1	<0.1	1	0	-	-	-	-	-
	Common pike eel	<0.1	<0.1	<0.1	1	0	-	-	-	-	-

No FSANZ standard or FSANZ GEL for chromium.
- denotes no data

3.5.4. Copper (Cu)

The ranges of Cu concentrations across all caught specimens were 0.06 to 25 mg kg^{-1} in liver and 0.11 to 2.4 mg kg^{-1} in muscle. The highest concentrations were recorded in the liver of the mangrove jack (20 mg kg^{-1}) and muscle of a dwarf gulper shark (2.4 mg kg^{-1}) caught in November 2016 (Table 3.14).

The ranges of concentrations across all market specimens were 1.8 to 17 mg kg^{-1} in liver and 0.08 to 0.66 mg kg^{-1} in muscle, with the highest concentrations recorded in the liver of a mangrove jack (11.8 mg kg^{-1}) and muscle of a bigeye trevally (0.66 mg kg^{-1}).

Table 3.14: Concentrations of copper (mg kg^{-1}) in liver and muscle samples of specimens caught in the upper Huon Gulf (n = 40) and sourced from the Lae street market (n = 14) in November 2016, and in muscle samples from specimens fished the same area in May 2017 (n = 20)

Copper (PQL = 0.05)		**Muscle**							**Liver**						
FSANZ GEL (mg kg^{-1}) (median = 0.5, 90th percentile = 2)															
	Caught species	**Min**	**Median**	**Max**	**Mean**	**n**	**StdDev**	**90th Perc.**	**Min**	**Median**	**Max**	**Mean**	**n**	**StdDev**	**90th Perc.**
Nov 2016	Dwarf gulper shark	0.12	0.18	2.4	0.27	33	0.39	0	0.06	**1.4**	3.9	1.54	33	0.77	**2.40**
	Longfin gulper shark	0.16	0.25	0.31	0.24	3	0.08	0.30	1.2	**1.7**	2.7	1.87	3	0.76	**2.50**
	Blackspotted croaker	0.13	0.13	0.13	0.13	1	0	0.13	20	**20**	20	20	1	0	**20**
	Gulper shark	0.11	0.11	0.11	0.11	1	0	0.11	5	**5**	5	5	1	0	**5**
	Mangrove jack	0.13	0.13	0.13	0.13	1	0	0.13	25	**25**	25	25	1	0	**25**
	Saddletail snapper	0.11	0.11	0.11	0.11	1	0	0.11	6.4	**6.4**	6.40	6.40	1	0	**6.4**
	Market species														
	Mangrove jack	0.11	0.12	0.12	0.12	2	0.01	0.12	6.6	**11.8**	17	11.8	2	7.35	**15.96**
	Saddletail snapper	0.08	0.10	0.14	0.10	5	0.02	0.12	1.8	**2.7**	4.7	2.92	5	1.07	**3.94**
	Sharptooth jobfish	0.11	0.14	0.16	0.14	2	0.04	0.16	4.3	**4.7**	5.1	4.70	2	0.57	**5.02**
	Bigeye trevally	0.29	0.50	0.66	0.49	4	0.17	0.64	2.6	**4.3**	5.7	4.23	4	1.65	**5.67**
	Pennantfish	0.19	0.19	0.19	0.19	1	0	0.19	2.7	**2.7**	2.7	2.70	1	0	**2.70**
May 2017	**Caught species**														
	Dwarf gulper shark	0.07	0.10	0.12	0.10	11	0.02	0.12	-	-	-	-	-	-	-
	Longfin gulper shark	0.09	0.11	0.14	0.11	2	0.04	0.13	-	-	-	-	-	-	-
	Fatspine spurdog	0.11	0.16	0.17	0.15	5	0.03	0.17	-	-	-	-	-	-	-
	Saddletail snapper	0.09	0.09	0.09	0.09	1	0	0.09	-	-	-	-	-	-	-
	Common pike eel	0.10	0.10	0.10	0.10	1	0	0.10	-	-	-	-	-	-	-

Bold indicates exceedance of the FSANZ GEL.
- denotes no data

3.5.5. Iron (Fe)

The ranges of Fe concentrations across all caught specimens were 6.1 to 640 mg kg^{-1} in liver and 0.64 to 8.8 mg kg^{-1} in muscle, with the highest concentrations recorded in the liver of a saddletail snapper (640 mg kg^{-1}) and muscle of a dwarf gulper shark (8.8 mg kg^{-1}) caught in May 2017 (Table 3.15).

The ranges of concentrations across all market specimens were 35 to 820 mg kg^{-1} in liver and 0.56 to 16 mg kg^{-1} in muscle, with the highest liver and muscle concentrations recorded in bigeye trevally specimens.

Table 3.15: Concentrations of iron (mg kg^{-1}) in liver and muscle samples of specimens caught in the upper Huon Gulf (n = 40) and sourced from the Lae street market (n = 14) in November 2016, and in muscle samples from specimens fished the same area in May 2017 (n = 20)

Iron (PQL = 0.5)		Muscle					Liver				
	Caught species	**Min**	**Max**	**Mean**	**n**	**StdDev**	**Min**	**Max**	**Mean**	**n**	**StdDev**
Nov 2016	Dwarf gulper shark	0.81	2.90	1.34	33	0.42	6.1	180	73.5	33	36.0
	Longfin gulper shark	1.40	2.0	1.63	3	0.32	58	110	80.3	3	26.8
	Blackspotted croaker	0.78	0.78	0.78	1	0	86	86	86	1	0
	Gulper shark	0.64	0.64	0.64	1	0	100	100	100	1	0
	Mangrove jack	3.4	3.4	3.4	1	0	260	260	260	1	0
	Saddletail snapper	0.71	0.71	0.71	1	0	640	640	640	1	0
	Market species										
	Mangrove jack	0.56	1.10	0.83	2	0.38	100	570	335	2	332
	Saddletail snapper	0.74	1.30	0.92	5	0.23	48	190	121	5	55.9
	Sharptooth jobfish	0.89	1.30	1.10	2	0.29	35	210	122	2	124
	Bigeye trevally	4.20	16	8.90	4	5.0	430	820	617	4	169
	Pennantfish	1.50	1.50	1.50	1	0	760	760	760	1	0
May 2017	**Caught species**										
	Dwarf gulper shark	0.93	8.80	2.88	11	2.12	-	-	-	-	-
	Longfin gulper shark	2.2	2.4	2.3	2	0.1	-	-	-	-	-
	Fatspine spurdog	1.2	4.0	2.5	5	1.1	-	-	-	-	-
	Saddletail snapper	1.1	1.1	1.1	1	0	-	-	-	-	-
	Common pike eel	1.4	1.4	1.4	1	0	-	-	-	-	-

No FSANZ standard or FSANZ GEL for iron.
- denotes no data

3.5.6. Lead (Pb)

A Pb concentration above the PQL of 0.1 mg kg^{-1} was recorded in muscle from a single dwarf gulper shark caught in May 2017. Liver and muscle Pb concentrations in all other specimens from the two surveys were below the PQLs of 0.1 mg kg^{-1} (Table 3.16).

Table 3.16: Concentrations of lead (mg kg^{-1}) in liver and muscle samples of specimens caught in the upper Huon Gulf (n = 40) and sourced from the Lae street market (n = 14) in November 2016, and in muscle samples from specimens fished the same area in May 2017 (n = 20)

Lead (PQL = 0.1)		Muscle					Liver				
FSANZ Standard (mg kg^{-1}) (max = 0.5)											
	Caught species	**Min**	**Max**	**Mean**	**n**	**StdDev**	**Min**	**Max**	**Mean**	**n**	**StdDev**
Nov 2016	Dwarf gulper shark	<0.1	<0.1	<0.1	33	0	<0.1	<0.1	<0.1	33	0
	Longfin gulper shark	<0.1	<0.1	<0.1	3	0	<0.1	<0.1	<0.1	3	0
	Blackspotted croaker	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Gulper shark	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Mangrove jack	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Saddletail snapper	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Market species										
	Mangrove jack	<0.1	<0.1	<0.1	2	0	<0.1	<0.1	<0.1	2	0
	Saddletail snapper	<0.1	<0.1	<0.1	5	0	<0.1	<0.1	<0.1	5	0
	Sharptooth jobfish	<0.1	<0.1	<0.1	2	0	<0.1	<0.1	<0.1	2	0
	Bigeye trevally	<0.1	<0.1	<0.1	4	0	<0.1	<0.1	<0.1	4	0
	Pennantfish	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
May 2017	**Caught species**										
	Dwarf gulper shark	<0.1	0.10	0.10	11	0	-	-	-	-	-
	Longfin gulper shark	<0.1	<0.1	<0.1	2	0	-	-	-	-	-
	Fatspine spurdog	<0.1	<0.1	<0.1	5	0	-	-	-	-	-
	Saddletail snapper	<0.1	<0.1	<0.1	1	0	-	-	-	-	-
	Common pike eel	<0.1	<0.1	<0.1	1	0	-	-	-	-	-

- denotes no data

3.5.7. Mercury (Hg)

The ranges of Hg concentrations across all caught specimens were 0.02 to 14 mg kg^{-1} in liver and 0.02 to 2.2 mg kg^{-1} in muscle. The highest concentrations were recorded in the liver of the mangrove jack (14 mg kg^{-1}) and muscle of a dwarf gulper shark (2.2 mg kg^{-1}) caught in November 2016 (Table 3.17). The ranges of concentrations across all market specimens were 0.16 to 2 mg kg^{-1} in liver and 0.03 to 0.71 mg kg^{-1} in muscle, with the highest Hg concentrations in liver (2 mg kg^{-1}) and muscle (0.71 mg kg^{-1}) recorded in bigeye trevally specimens.

Table 3.17: Concentrations of mercury (mg kg^{-1}) in liver and muscle samples of specimens caught in the upper Huon Gulf (n = 40) and sourced from the Lae street market (n = 14) in November 2016, and in muscle samples from specimens fished the same area in May 2017 (n = 20)

Mercury (PQL = 0.1)		Muscle							Liver						
FSANZ Standard (mg kg^{-1}) (max values: dwarf gulper sharks = 1.5, other sharks and bony fish = 1) FSANZ Standard (mg kg^{-1}) (mean values: sharks = 1, bony fish = 0.5) FSANZ GEL (mg kg^{-1}) (median = 0.5, 90th percentile = 2)															
Nov 2016	**Caught species**	**Min**	**Median**	**Max**	**Mean**	**n**	**Std Dev**	**90th Perc**	**Min**	**Median**	**Max**	**Mean**	**n**	**Std Dev**	**90th Perc**
	Dwarf gulper shark	0.02	0.71	**2.20**	0.75	33	0.49	1.38	0.02	0.05	**4.40**	0.31	33	0.82	0.67
	Longfin gulper shark	0.99	1.10	**1.30**	**1.13**	3	0.16	1.26	0.03	0.05	0.05	0.04	3	0.01	0.05
	Blackspotted croaker	0.26	0.26	0.26	0.26	1	0	0.26	0.34	0.34	0.34	0.34	1	0	0.34
	Gulper shark	1.50	1.50	**1.50**	**1.50**	1	0	1.50	0.67	0.67	0.67	0.67	1	0	0.67
	Mangrove jack	0.53	0.53	0.53	**0.53**	1	0	0.53	14	14	**14**	**14**	1	0	14
	Saddletail snapper	0.05	0.05	0.05	0.05	1	0	0.05	0.03	0.03	0.03	0.03	1	0	0.03
	Market species														
	Mangrove jack	0.03	0.04	0.05	0.04	2	0.01	0.05	0.16	0.44	0.72	0.44	2	0.40	0.66
	Saddletail snapper	0.19	0.21	0.36	0.24	5	0.07	0.31	0.40	0.93	**1.90**	**1.02**	5	0.54	1.52
	Sharptooth jobfish	0.05	0.20	0.35	0.20	2	0.21	0.32	0.40	0.85	**1.30**	**0.85**	2	0.64	1.21
	Bigeye trevally	0.34	0.51	0.71	**0.52**	4	0.16	0.67	0.73	1.40	**2.0**	**1.38**	4	0.66	1.97
	Pennantfish	0.25	0.25	0.25	0.25	1	0	0.25	0.51	0.51	0.51	**0.51**	1	0	0.51
May 2017	**Caught species**														
	Dwarf gulper shark	0.14	0.35	1.10	0.48	11	0.34	0.99	-	-	-	-	-	-	-
	Longfin gulper shark	0.35	0.66	0.97	0.66	2	0.44	0.91	-	-	-	-	-	-	-
	Fatspine spurdog	0.08	0.38	0.75	0.41	5	0.33	0.75	-	-	-	-	-	-	-
	Saddletail snapper	0.06	0.06	0.06	0.06	1	0	0.06	-	-	-	-	-	-	-
	Common pike eel	0.24	0.24	0.24	0.24	1	0	0.24	-	-	-	-	-	-	-

Bold indicates exceedance of the FSANZ standard. Grey shading indicates exceedance of the FSANZ GEL
- denotes no data

3.5.8. Manganese (Mn)

The ranges of Mn concentrations across all caught specimens were less than 0.1 to 1.56 mg kg^{-1} in liver and less than 0.1 to 0.18 mg kg^{-1} in muscle. Concentrations of a number of muscle samples (19 of 40 in November 2016 specimens and 14 of 20 in May 2017 specimens) were less than 0.1 mg kg^{-1} (Table 3.18). The highest Mn concentrations were recorded in the liver of the saddletail snapper and muscle of a dwarf gulper shark caught in May 2017.

The ranges of concentrations across all market specimens were 0.93 to 2.41 mg kg^{-1} in liver and less than 0.1 to 0.11 mg kg^{-1} in muscle. Manganese concentrations in 12 of 14 muscle samples were below the PQL of 0.1 mg kg^{-1}. The highest Mn concentrations were recorded in the liver of a sharptooth jobfish and muscle of a bigeye trevally.

Table 3.18: Concentrations of manganese (mg kg^{-1}) in liver and muscle samples of specimens caught in the upper Huon Gulf (n = 40) and sourced from the Lae street market (n = 14) in November 2016, and in muscle samples from specimens fished the same area in May 2017 (n = 20)

Manganese (PQL = 0.1)		Muscle					Liver				
	Caught species	**Min**	**Max**	**Mean**	**n**	**StdDev**	**Min**	**Max**	**Mean**	**n**	**StdDev**
Nov 2016	Dwarf gulper shark	<0.1	0.14	0.11	33	0.01	<0.1	0.59	0.38	33	0.14
	Longfin gulper shark	0.10	0.11	0.11	3	0.01	0.11	0.31	0.22	3	0.10
	Blackspotted croaker	<0.1	<0.1	<0.1	1	0	0.57	0.57	0.57	1	0
	Gulper shark	<0.1	<0.1	<0.1	1	0	0.18	0.18	0.18	1	0
	Mangrove jack	<0.1	<0.1	<0.1	1	0	1	1	1	1	0
	Saddletail snapper	<0.1	<0.1	<0.1	1	0	1.56	1.56	1.56	1	0
	Market species										
	Mangrove jack	<0.1	<0.1	<0.1	2	0	1.16	2.21	1.69	2	0.74
	Saddletail snapper	<0.1	0.10	0.10	5	0	0.93	1.31	1.04	5	0.16
	Sharptooth jobfish	<0.1	<0.1	<0.1	2	0	1.74	2.41	2.08	2	0.47
	Bigeye trevally	<0.1	0.11	0.11	4	0	1.29	1.62	1.44	4	0.16
	Pennantfish	<0.1	<0.1	<0.1	1	0	1.32	1.32	1.32	1	0
May 2017	**Caught species**										
	Dwarf gulper shark	<0.1	0.18	0.12	11	0.03	-	-	-	-	-
	Longfin gulper shark	<0.1	<0.1	<0.1	2	0	-	-	-	-	-
	Fatspine spurdog	<0.1	<0.1	<0.1	5	0	-	-	-	-	-
	Saddletail snapper	<0.1	<0.1	<0.1	1	0	-	-	-	-	-
	Common pike eel	0.12	0.12	0.12	1	0	-	-	-	-	-

No FSANZ standard or FSANZ GEL for manganese.
- denotes no data

3.5.9. Nickel (Ni)

The ranges of Ni concentrations across all caught specimens were less than 0.06 to 0.14 mg kg^{-1} in liver and less than 0.06 to 0.07 mg kg^{-1} in muscle, with most samples (34 of 40 liver samples and 39 of 40 muscle samples from November 2016 specimens, and all samples from May 2017 specimens) having concentrations below the limit of detection (PQL) of 0.06 mg kg^{-1} (Table 3.19). The highest concentrations in liver (0.14 mg kg^{-1}) and muscle (0.07 mg kg^{-1}) were recorded in dwarf gulper sharks caught in November 2016.

The ranges of concentrations across all market specimens were less than 0.06 to 0.06 mg kg^{-1} in liver, with 13 of 14 samples below the PQL. Nickel in muscle from all market specimens were below the PQL. The highest concentration was recorded in the liver of a saddletail snapper.

Table 3.19: Concentrations of nickel (mg kg^{-1}) in liver and muscle samples of specimens caught in the upper Huon Gulf (n = 40) and sourced from the Lae street market (n = 14) in November 2016, and in muscle samples from specimens fished the same area in May 2017 (n = 20)

Nickel (PQL = 0.06)		Muscle					Liver				
	Caught species	**Min**	**Max**	**Mean**	**n**	**StdDev**	**Min**	**Max**	**Mean**	**n**	**StdDev**
Nov 2016	Dwarf gulper shark	<0.06	0.07	0.07	33	0	<0.06	0.14	0.09	33	0.03
	Longfin gulper shark	<0.06	<0.06	<0.06	3	0	<0.06	<0.06	<0.06	3	0
	Blackspotted croaker	<0.06	<0.06	<0.06	1	0	<0.06	<0.06	<0.06	1	0
	Gulper shark	<0.06	<0.06	<0.06	1	0	0.07	0.07	0.07	1	0
	Mangrove jack	<0.06	<0.06	<0.06	1	0	<0.06	<0.06	<0.06	1	0
	Saddletail snapper	<0.06	<0.06	<0.06	1	0	<0.06	<0.06	<0.06	1	0
	Market species										
	Mangrove jack	<0.06	<0.06	<0.06	2	0	<0.06	<0.06	<0.06	2	0
	Saddletail snapper	<0.06	<0.06	<0.06	5	0	<0.06	0.06	0.06	5	0
	Sharptooth jobfish	<0.06	<0.06	<0.06	2	0	<0.06	<0.06	<0.06	2	0
	Bigeye trevally	<0.06	<0.06	<0.06	4	0	<0.06	<0.06	<0.06	4	0
	Pennantfish	<0.06	<0.06	<0.06	1	0	<0.06	<0.06	<0.06	1	0
May 2017	**Caught species**										
	Dwarf gulper shark	<0.06	<0.06	<0.06	11	0	-	-	-	-	-
	Longfin gulper shark	<0.06	<0.06	<0.06	2	0	-	-	-	-	-
	Fatspine spurdog	<0.06	<0.06	<0.06	5	0	-	-	-	-	-
	Saddletail snapper	<0.06	<0.06	<0.06	1	0	-	-	-	-	-
	Common pike eel	<0.06	<0.06	<0.06	1	0	-	-	-	-	-

No FSANZ standard or FSANZ GEL for nickel.
- denotes no data

3.5.10. Selenium (Se)

The ranges of Se concentrations across all caught specimens were less than 0.5 mg kg^{-1} to 6.5 mg kg^{-1} in liver and less than 0.5 to 0.71 mg kg^{-1} in muscle. Selenium concentrations in 19 of 40 muscle samples from November 2016 and 14 of 20 muscle samples from May 2017 were below the PQL of 0.5 mg kg^{-1}. Only five liver samples were below the PQL. The highest Se concentrations were recorded in the liver of the mangrove jack (6.5 mg kg^{-1}) and muscle of a dwarf gulper shark (0.71 mg kg^{-1}) caught in November 2016 (Table 3.20).

The ranges of concentrations across all market specimens were 1.3 to 4.2 mg kg^{-1} in liver and less than 0.50 mg kg^{-1} to 1.1 mg kg^{-1} in muscle, with the highest concentrations recorded in the liver of a sharptooth jobfish (4.2 mg kg^{-1}) and muscle of a bigeye trevally (0.8 mg kg^{-1}).

Table 3.20: Concentrations of selenium (mg kg^{-1}) in liver and muscle samples of specimens caught in the upper Huon Gulf (n = 40) and sourced from the Lae street market (n = 14) in November 2016, and in muscle samples from specimens fished the same area in May 2017 (n = 20)

Selenium (PQL = 0.5)		Muscle							Liver						
FSANZ GEL (mg kg^{-1}) (median = 0.5, 90th percentile = 2)															
	Caught species	**Min**	**Median**	**Max**	**Mean**	**n**	**StdDev**	**90th Perc.**	**Min**	**Median**	**Max**	**Mean**	**n**	**StdDev**	**90th Perc.**
Nov 2016	Dwarf gulper shark	<0.5	**0.58**	0.71	0.59	33	0.06	0.65	<0.5	**0.90**	1.50	0.92	33	0.25	1.26
	Longfin gulper shark	<0.5	**0.57**	0.63	0.57	3	0.08	0.62	0.62	**0.65**	1.60	0.96	3	0.56	1.41
	Blackspotted croaker	<0.5	0	<0.5	<0.5	1	0	0	4	**4**	4	4	1	0	**4**
	Gulper shark	0.67	**0.67**	0.67	0.67	1	0	0.67	1.70	**1.70**	1.70	1.70	1	0	1.70
	Mangrove jack	0.66	**0.66**	0.66	0.66	1	0	0.66	6.50	**6.50**	6.50	6.50	1	0	**6.50**
	Saddletail snapper	<0.5	0	<0.5	<0.5	1	0	0	2.70	**2.70**	2.70	2.70	1	0	**2.70**
	Market species														
	Mangrove jack	0.50	**0.52**	0.53	0.52	2	0.02	0.53	1.30	**2**	2.70	2.0	2	0.99	**2.56**
	Saddletail snapper	<0.5	0	<0.5	<0.5	5	0	0	1.70	**2**	2.80	2.08	5	0.43	**2.52**
	Sharptooth jobfish	<0.5	0	<0.5	<0.5	2	0	0	2.20	**3.20**	4.20	3.20	2	1.41	**4**
	Bigeye trevally	0.67	**0.80**	1.10	0.84	4	0.19	1.03	2.90	**2.95**	3.70	3.13	4	0.39	**3.49**
	Pennantfish	<0.5	0	<0.5	<0.5	1	0	0	2.80	**2.80**	2.80	2.80	1	0	**2.80**
May 2017	**Caught species**														
	Dwarf gulper shark	<0.5	**0.53**	0.56	0.53	11	0.03	0.55	-	-	-	-	-	-	-
	Longfin gulper shark	<0.5	**0.52**	0.52	0.52	2	0	0.52	-	-	-	-	-	-	-
	Fatspine spurdog	<0.5	**0.53**	0.53	0.53	5	0	0.53	-	-	-	-	-	-	-
	Saddletail snapper	<0.5	0	<0.5	<0.5	1	0	0	-	-	-	-	-	-	-
	Common pike eel	<0.5	0	<0.5	<0.5	1	0	0	-	-	-	-	-	-	-

Bold indicates exceedance of the FSANZ standard.
- denotes no data

3.5.11. Silver (Ag)

The ranges of Ag concentrations across all caught specimens were less than 0.1 to 0.7 mg kg^{-1} in liver and less than 0.1 mg kg^{-1} in muscle, with Ag concentrations in 27 of 40 liver samples and all muscle samples testing below the PQL of 0.1 mg kg^{-1} (Table 3.21). The highest Ag concentration in liver (0.7 mg kg^{-1}) was recorded in the mangrove jack.

The concentrations of Ag in liver and muscle of all market specimens were below the PQL.

Table 3.21: Concentrations of silver (mg kg^{-1}) in liver and muscle samples of specimens caught in the upper Huon Gulf (n = 40) and sourced from the Lae street market (n = 14) in November 2016, and in muscle samples from specimens fished the same area in May 2017 (n = 20)

Silver (PQL = 0.1)		Muscle					Liver				
	Caught species	**Min**	**Max**	**Mean**	**n**	**StdDev**	**Min**	**Max**	**Mean**	**n**	**StdDev**
Nov 2016	Dwarf gulper shark	<0.1	<0.1	<0.1	33	0	<0.1	0.24	0.17	33	0.06
	Longfin gulper shark	<0.1	<0.1	<0.1	3	0	0.13	0.25	0.19	3	0.06
	Blackspotted croaker	<0.1	<0.1	<0.1	1	0	0.23	0.23	0.23	1	0
	Gulper shark	<0.1	<0.1	<0.1	1	0	0.12	0.12	0.12	1	0
	Mangrove jack	<0.1	<0.1	<0.1	1	0	0.70	0.70	0.70	1	0
	Saddletail snapper	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Market species										
	Mangrove jack	<0.1	<0.1	<0.1	2	0	<0.1	<0.1	<0.1	2	0
	Saddletail snapper	<0.1	<0.1	<0.1	5	0	<0.1	<0.1	<0.1	5	0
	Sharptooth jobfish	<0.1	<0.1	<0.1	2	0	<0.1	<0.1	<0.1	2	0
	Bigeye trevally	<0.1	<0.1	<0.1	4	0	<0.1	<0.1	<0.1	4	0
	Pennantfish	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
May 2017	**Caught species**										
	Dwarf gulper shark	<0.1	<0.1	<0.1	11	0	-	-	-	-	-
	Longfin gulper shark	<0.1	<0.1	<0.1	2	0	-	-	-	-	-
	Fatspine spurdog	<0.1	<0.1	<0.1	5	0	-	-	-	-	-
	Saddletail snapper	<0.1	<0.1	<0.1	1	0	-	-	-	-	-
	Common pike eel	<0.1	<0.1	<0.1	1	0	-	-	-	-	-

No FSANZ standard or FSANZ GEL for silver.
- denotes no data

3.5.12. Zinc (Zn)

The ranges of Zn concentrations across all caught specimens were 0.63 to 48 mg kg^{-1} in liver and 1.9 to 3.7 mg kg^{-1} in muscle. The highest Zn concentrations recorded in liver were from mangrove jack and saddletail snapper (48 mg kg^{-1}), while the highest Zn concentration in muscle (3.7 mg kg^{-1}) was recorded in a dwarf gulper shark caught in November 2016 (Table 3.22). The ranges of concentrations across all market specimens were 22 to 58 mg kg^{-1} in liver and 2.2 to 4.8 mg kg^{-1} in muscle, with the highest concentrations recorded in liver of a sharptooth jobfish (58 mg kg^{-1}) and muscle of a bigeye trevally (4.8 mg kg^{-1}).

Table 3.22: Concentrations of zinc (mg kg^{-1}) in liver and muscle samples of specimens caught in the upper Huon Gulf (n = 40) and sourced from the Lae street market (n = 14) in November 2016, and in muscle samples from specimens fished the same area in May 2017 (n = 20)

Zinc (PQL = 0.2)		Muscle							Liver						
FSANZ GEL (mg kg^{-1}) (median = 5, 90th percentile = 15)															
Nov 2016	**Caught species**	**Min**	**Median**	**Max**	**Mean**	**n**	**Std Dev**	**90th Perc**	**Min**	**Median**	**Max**	**Mean**	**n**	**Std Dev**	**90th Perc**
	Dwarf gulper shark	2.10	2.6	3.70	2.65	33	0.32	2.98	0.63	**8.40**	22	8.72	33	3.81	12
	Longfin gulper shark	2.30	2.6	2.70	2.53	3	0.21	2.68	14	**16**	22	17.33	3	4.16	**20.8**
	Blackspotted croaker	2.20	2.2	2.20	2.20	1	0	2.20	45	**45**	45	45	1	0	**45**
	Gulper shark	3.30	3.3	3.30	3.30	1	0	3.30	15	**15**	15	15	1	0	**15**
	Mangrove jack	3.10	3.1	3.10	3.10	1	0	3.10	48	**48**	48	48	1	0	**48**
	Saddletail snapper	2.20	2.2	2.20	2.20	1	0	2.20	48	**48**	48	48	1	0	**48**
	Market species														
	Mangrove jack	2.60	2.70	2.80	2.70	2	0.14	2.78	34	**44.5**	55	44.5	2	14.85	**52.9**
	Saddletail snapper	2.20	2.50	3.40	2.60	5	0.47	3.08	22	**32.0**	48	33.4	5	9.63	**43.2**
	Sharptooth jobfish	2.40	2.45	2.50	2.45	2	0.07	2.49	49	**53.5**	58	53.5	2	6.36	**57.1**
	Bigeye trevally	3.40	4.30	4.80	4.20	4	0.59	4.68	35	**40**	49	41	4	6.06	**46.9**
	Pennantfish	3.10	3.10	3.10	3.10	1	0	3.10	35	**35**	35	35	1	0	**35.0**
May 2017	**Caught species**														
	Dwarf gulper shark	1.90	2.10	2.40	2.13	11	0.16	2.30	-	-	-	-	-	-	-
	Longfin gulper shark	2.10	2.40	2.70	2.40	2	0.42	2.64	-	-	-	-	-	-	-
	Fatspine spurdog	2.0	2.40	2.50	2.34	5	0.21	2.50	-	-	-	-	-	-	-
	Saddletail snapper	2.80	2.80	2.80	2.80	1	0	2.80	-	-	-	-	-	-	-
	Common pike eel	2.60	2.60	2.60	2.60	1	0	2.60	-	-	-	-	-	-	-

Bold indicates exceedance of the FSANZ standard.
- denotes no data

3.5.13. Statistical results

Only dwarf gulper sharks were available in sufficient numbers to undertake comparative statistical analyses of metal concentration in muscle and liver, and relationships between metals and total lengths and weight of these sharks.

Statistical analyses using paired two sample t-Tests (for overall mean difference) showed that mean arsenic and mercury concentrations (mg kg^{-1}) in dwarf gulper sharks caught in November 2016 (n = 33) were significantly greater in muscle than liver samples ($P<0.0001$), whereas copper, iron and zinc concentrations were greater in liver than muscle samples ($P<0.001$) (Figure 3.5 and Figure 3.6).

Mercury concentrations in muscle collected from these 33 dwarf gulper sharks showed a significant positive correlation with total length (Pearson correlation coefficient R = 0.69), suggesting some degree of bioaccumulation with increasing length (linear regression fit $R^2 = 0.49$; $P<0.001$). Similarly, cadmium concentrations in liver showed a significant linear correlation with total weight (Pearson correlation coefficient R = 0.73; linear fit $R^2 = 0.53$; ANOVA $P<0.0001$), as did with total length (Pearson correlation coefficient R = 0.72; linear fit $R^2 = 0.52$; ANOVA P<0.0001). However, better fits were obtained when exponential (non-linear) models were used to test liver cadmium concentrations against total length ($R^2 = 0.63$; $P<0.0001$) and weight ($R^2 = 0.60$; $P<0.0001$), likewise suggesting some degree of bioaccumulation with increasing length/weight (see Figure 3.7). Additional statistical analyses showed small but significant linear regressions of zinc concentrations in liver of dwarf gulper sharks with both length and weight (Figure 3.6), but no significant linear relationships of copper or arsenic concentrations in liver with either length or weight (Figure 3.5).

3.6. Existing fishing practices offshore of Lae

3.6.1. Existing fishing methods

Locals as well as visitors from surrounding areas were observed during November 2016 and May 2017 undertaking fishing activities in the vicinity of Lae, and nearby villages such as Labu and Wagang, using various methods. The most commonly observed fishing methods used by regular fishers from Labu included handlining, using a variety of drop-stone techniques, vertical long-lining and trolling. Drop-stone fishing techniques vary, but typically involve using a single baited hook or hook fitted with feathers (to act as a lure) attached to a stone or other weight (acting as a sinker) by a self-releasing knot made from palm leaf or monofilament line that is released into the sea. Once the bait reaches the targeted fishing zone, the stone is detached from the line with a pull by the fisher, releasing the baited hook. The line is slowly brought back to the surface using jig-type movements that mimic a small fish. The fishing line is usually wrapped around a piece of timber or empty plastic bottle that serves as a reel. Discussions with locals indicated that handline methods targeted both demersal and pelagic fishes in depths usually between 50 m and 100 m, while trolling targeted fishes in shallower areas to depths of 10 m. Fishing depths were estimated from discussions with locals at the DCA Point roadside fish market and based on the number of rolls of fishing line that they noted as being dispensed from the reel, with each roll holding around 10 m of fishing line.

Fishing was largely observed to be undertaken from custom-built, wooden, non-motorised outriggers and, to a lesser extent, motorised dinghies or ‘banana boats’. Outrigger canoes sit low on the water and are propelled using one short paddle, with sails also fitted for faster travel during favourable wind and sea conditions (Plate 3.6). Regular fishers from Labu who generally gather at the DCA Point fish market indicated that fishing takes place six days a week, and that no fishing takes place on Sundays.

Most fishes caught by Wagang villagers are reportedly taken for personal consumption or sharing in the village, while fishes caught by Labu villagers are also sold at the DCA Point fish market (Plate 2.8 and Plate 3.7) and, to a lesser extent, the main market in Lae. Discussions with local fishers and officials from Morobe Provincial Fisheries indicated that a number of factors including rising fuel costs and difficulty accessing ice and cold storage facilities resulted in direct market sales now being the most economically viable option for fishers (as opposed to supplying to commercial outlets). This was also documented by Kinch (2006).

Other reported fishing methods used in the Huon Gulf include spearfishing, netting, hand collection and trap fishing practices. Although illegal in PNG, the use of dynamite and derris root, *Derris trifoliata* to catch fish is still occasionally practiced in the Huon Gulf; although the locations of these activities were not reported (Kinch, 2006).

3.6.2. Key targeted species and areas

Fishers were typically observed sailing south from Labu or Lae at around 8 am to fishing grounds located over an area just south of Lae in the upper Huon Gulf, usually just beyond the Lae Port Exclusion Zone limits, though sometimes further offshore. Fishers generally return to Labu or the DCA Point fish market between 2 pm and 4 pm, taking advantage of the prevailing southeasterly afternoon winds. No fishing activity was observed in the DSTP Study Area either in November 2016 or May 2017, except for a few fishers dispersed along the coast near Wagang, where fishing is reported to take place almost exclusively from the shore. Handline fishing was occasionally observed from the shore near Lae, and in the vicinity of the Busu, Bumbu and Markham river entrances.

Fish species caught by local fishers and sold at the DCA Point fish market were identified as being seasonally variable and include mackerel (often used as bait; Plate 3.8), saddletail snapper, sharptooth jobfish, emperors and various reef fishes (Plate 2.8). Captured pelagic species include rainbow runner, bigeye trevally (Plate 3.9) and tuna. Several other species were also observed for sale at the street market including grouper (Plate 3.10), triggerfish (Plate 3.11), snake eel (Plate 3.12), whitecheek sharks, *Carcharhinus coatesi* (Plate 3.13), and barracuda (Plate 3.14).

A fish trap net system is located adjacent to Labu Miti. This was established as an economic development project in association with the PNG National Fisheries Authority (NFA) and Japanese Trust Fund. These trap nets target a variety of fish including mackerel, rainbow runner (*Elagatis bipinnulata*) and mahi-mahi (dolphinfish, i.e., *Coryphaena* spp.).

Mangrove jack, black bass, mullet, and bigeye trevally are targeted by local fishers near Labu Lakes, while invertebrates such as crabs, lobsters, shrimps, and snails are also consumed. *Beche-de-mer* (sea cucumber) is known to be harvested though a temporary ban is currently in place due to over-exploitation (Morobe Provincial Fisheries, pers. comm.).

Photo credit: Coffey/Marscco

Plate 3.6
Local fisher on outrigger canoe in offshore waters south of Lae

Photo credit: Coffey/Marscco

Plate 3.7
Outrigger canoe entering access canal to DCA Point

Photo credit: Coffey/Marscco

Plate 3.8
Strings of mackerel for sale at DCA Point

Photo credit: Coffey/Marscco

Plate 3.9
Trevally for sale at DCA Point market

Photo credit: Coffey/Marscco

Plate 3.10
Grouper for sale at DCA Point market

Photo credit: Coffey/Marscco

Plate 3.11
Triggerfish for sale at DCA Point market

Photo credit: Coffey/Marscco

Plate 3.12
Snake eel and baitfish (mackerel) sold at DCA Point market

Photo credit: Coffey/Marscco

Plate 3.13
Whitecheek sharks for sale at DCA Point market

Photo credit: Coffey/Marscco

Plate 3.14
Barracuda (left), bigeye trevally (middle) and saddletail snappers for sale at DCA Point market

4. Discussion

4.1. Species diversity and abundance

4.1.1. Caught species

Deep-slope fishes recorded during the characterisation surveys in November 2016 and May 2017 comprised eight species from five families. Two families corresponded to the elasmobranch families Centrophoridae (gulper sharks) and Squalidae (dogfishes), and the remaining three to bony fishes of the families Lutjanidae (deep-water snappers), Sciaenidae (croakers) and Muraenesocidae (pike eels). Three of the eight species were gulper sharks of the family Centrophoridae, with the dwarf gulper shark *Centrophorus atromarginatus* comprising the most abundant species caught across the two surveys over the DSTP and Reference Study Areas (n = 44), and accounting for 72% of the total caught by numbers. The capture of three gulper shark species during this study appears to be the first record of representatives of the bathy-demersal shark family Centrophoridae in DSTP baseline studies in PNG (Table 4.1).

The number of species recorded during this study was lower than that reported for similar DSTP-associated surveys elsewhere in PNG, i.e., Woodlark, Lihir, Misima and Ramu (Table 4.1). This finding suggests that the overall diversity of deep-slope fishes in the DSTP Study Area and Reference Study Area is remarkably low, at least during the times when surveys were completed. Such low diversity is also reflected in the overall dominance of one gulper shark species, and the fact that catches in November 2016 and May 2017 resulted in almost identical families/species contributions despite the consistent fishing effort during the two surveys, i.e., three families /six species in November 2016 and four families /five species in May 2017. Three of the species caught in the November 2016 survey were also captured during the May 2017 survey: dwarf and longfin gulper sharks, and saddletail snapper from the family Lutjanidae.

Similar studies at various locations in PNG show that the most abundant fish families recorded almost always include Lutjanidae (deep-water snappers), Serranidae (groupers, rock cods) and Lethrinidae (emperors), some of which are represented by up to 10 to 12 species (Table 4.1). However, except for one saddletail snapper (*Lutjanus malabaricus*) caught at site A1 (100 m) during the May 2017 survey, no individuals of either of the other two families was captured in the DSTP Study Area during the November 2016 or May 2017 surveys. The other two individuals of the Lutjanidae captured during the study, namely mangrove jack (*Lutjanus argentimaculatus*) and saddletail snapper, originated from sites in the Reference Study Area outside the Markham Canyon, at depths of less than 105 m. Lutjanids, serranids and lethrinids are generally well represented in offshore reefs and continental slopes of islands of PNG and others islands throughout the Indo-Pacific region (Randall *et al*., 1990; Allen, 2009). Several species of these three well-known families have been recorded during fish surveys over slope waters of Wamunon Bay, off Woodlark Island, as well as Misima Island and Niolam Island, of the Lihir Islands Group (NSR, 1988, 1996; Coffey, 2012; Table 4.1).

It is likely that the main reasons for the overall low diversity and abundance (aside from dwarf gulper sharks) recorded during this study are (a) the lack of clean coastal reefs as well as offshore reefs, which normally sustain a great variety of fish communities, including sharks and rays, and (b) the large daily input of sediment transported downstream by the Markham River as well as the Busu, Bupu and other nearby rivers, which end up covering much of the seafloor in the main survey area, and extend as far south as the area over the local fishing grounds, i.e., at sites LFG1 and LFG2. The bathymetric definition of the deep slope down to around 500 m (IHAconsult, 2017) shows the general smothering by terrestrial silt, sand and gravel and the absence of any deeply incised canyons and rocky canyon wall habitat. Further convincing evidence of such low diversity can be observed by comparing results from this study with those obtained during a survey carried out in January 2012 in Wamunon Bay, on the north coast of Woodlark Island, which features diverse coral and offshore reefs, and no rivers discharging anywhere along the island’s north coast (Coffey, 2012). Both this present study and the Wamunon Bay field survey were led and conducted by the same marine fisheries scientist using similar fishing methodology, i.e., baited droplines. Thus, the deep-slope fish survey in Wamunon Bay: (a) covered an area approximately six times smaller than that surveyed over the DSTP Study Area in the Markham Canyon (7.5 km^2 versus 46 km^2); (b) listed 28 species from five bony fish families (no elasmobranchs) compared to eight species from five families; (c) comprised significantly less fishing effort in terms of bottom time (31.5 hours versus 146 hours); and (d) was limited to a depth of 300 m compared to 800 m.

All dwarf gulper sharks (n = 44) were captured in the Markham Canyon at depths between 105 m and 540 m, and none was caught below 540 m even though fishing was conducted to a maximum depth of 800 m. The observation that dwarf gulper sharks are only found in deep-slope waters below depths of 100 m is supported by the fact that none were caught at shallower sites fished outside the canyon, such as LABU1, LABU4 and LFG1 in the Reference Study Area offshore from Labu Lakes. In addition, local fishers from Wagang stated that they have inadvertently captured gulper sharks in the past, though it is not commonly caught or targeted.

Dwarf gulper sharks were captured along with longfin gulper shark, a closely-related species from the same family but much less abundant than dwarf gulpers. Longfin gulper sharks are remarkably similar to dwarf gulper sharks except for their comparatively longer first dorsal fin and associated first-dorsal fin base. The five longfin gulper sharks recorded during this study were captured exclusively in the DSTP Study Area, at depths between 330 m and 460 m, and were identified as *Centrophorus longipinnis* (White et al., 2017).

The only species of gulper shark (*Centrophorus granulosus*) recorded during this study was captured in the Markham Canyon in November 2016 at a depth of 550 m, and corresponded to a 1,600 mm TL long, 30 kg female in early stages of pregnancy. Members of this species have been misidentified numerous times in past studies with the closely-related albeit much smaller longfin gulper shark (White *et al*., 2013). Since no other individual of this large gulper shark species was caught during either the November 2016 or May 2017 surveys, assumptions regarding habitat depth range in the canyon cannot be made other than it is highly unlikely they occur over areas shallower than 100 m.

Two additional species recorded in the DSTP Study Area during the May 2017 survey were absent in the November 2016 catches. These were the fatspine spurdog (*Squalus crassispinus*), a shark species of the family Squalidae, and the common pike eel (*Muraenesox bagio*), a bony fish belonging to the family Muraenesocidae. Five fatspine spurdogs were captured at depths between 180 m and 300 m, whereas the only common pike eel was caught at a depth of 124 m. While it cannot be determined whether these constitute transient species or represent species with established populations in the area, their capture would suggest that the deep-slope fish fauna composition in the Markham Canyon and associated shallow coastal areas may change seasonally.

A single specimen of blackspotted croaker, *Protonibea diacanthus* (family Sciaenidae), was captured in the DSTP Study Area during the November 2016 survey at a site located between the Busu and Bupu rivers (site B2), from a depth of 250 m. This finding is rather unusual as species of this family are usually associated to shallow coastal waters with muddy bottoms to depths of 100 m or less, as well as estuarine habitats (Allen, 2009). Such a finding implies that a population of this species is likely to inhabit coastal estuarine systems, such as those provided by entrances of the rivers discharging into the Huon Gulf.

No pelagic fish species were captured over the DSTP or Reference Study Areas after 23 trolling sessions totalling 16.5 hours of fishing time during the November 2016 and May 2017 surveys. The absence of pelagic fishes (based on zero trolling catches) was unexpected, even after substantial fishing effort using three rods and a suite of standard lures. Factors which may have contributed to the zero catches include trolling mostly through areas of high turbidity, i.e., high concentrations of suspended solids from the river plumes, time of year, and/or species normally caught further south simply not venturing close to Lae due to absence of potential prey, i.e., schooling fishes.

Table 4.1: Summary of deep-slope fish studies at various DSTP locations in PNG. Studies have been listed by sampling period starting from the current study

Project (type of sampling)	Location(s)	Total No. fish caught	No. families	No. species	Abundant families (No. species) % of total catch	Sampling period(s)	Gear used	Depth strata and/or overall depth range (m)	Reference
Wafi-Golpu (characterisation)	Lae (DSTP and Reference Study Areas)	20	4	5	Centrophoridae (2) = 65%	4-10 May 2017	Heavy-duty rods fitted with 12V electric reels	5 depth strata in DSTP Study Area 18-800 m	This study
Wafi-Golpu (characterisation)	Lae (DSTP and Reference Study Areas)	41	3	6	Centrophoridae (3) = 90.2%	3-13 Nov 2016	Heavy-duty rods fitted with 12V electric reels	5 depth strata in DSTP Study Area 18-800 m	This study
Woodlark (characterisation)	Wamunon Bay (DSTP area)	121	5	28	Lutjanidae (12) = 67.0% Serranidae (9) = 21.0% Lethrinidae (5) = 10.0%	20-29 Jan 2012	Alvey Reels Standard rods & reels Long-lines	5 depth strata 50-300 m	Coffey (2012)
Ramu (characterisation)	Basamuk (DSTP area) Cape Rigny (control)	40	8	10	Lutjanidae (3) = 77.5% Serranidae (3) = 7.5%	19-29 May 1998	Alvey “Reef King” Reels	80-400 m	NSR (1998)
	Astrolabe Bay and offshore islands/reefs at Bil Bil Isl., Bagabag Isl. and Planet Rock (control)	14	4	8	Lujtjaniadae (8) = 57.1% Serranidae (3) = 21.4 % Lethrinidae (2) = 14.3%	Sep 1997	Alvey “Reef King” Reels	80-400 m	NSR (1998)
Lihir (characterisation)	Niolam Island (10 sites)	411	4	16	Lutjanidae (10)[§] = 62.5% Carangidae (3) = 18.8% Serranidae (2) = 12.5% Lethrinidae (1) = 6.3%	19-28 Mar 1994	Samoan-type hand reels	50-1,000 m	NSR (1996)

Project (type of sampling)	Location(s)	Total No. fish caught	No. families	No. species	Abundant families (No. species) % of total catch	Sampling period(s)	Gear used	Depth strata and/or overall depth range (m)	Reference
Lihir (characterisation)	Niolam Island (10 sites)	411	4	16	Lutjanidae (10)[§] = 62.5% Carangidae (3) = 18.8% Serranidae (2) = 12.5% Lethrinidae (1) = 6.3%	19-28 Mar 1994	Samoan-type hand reels	50-1,000 m	NSR (1996)
Lihir	Niolam Island East coast and West coast (control area)	975	-	98	Lutjanidae (10) = 38.6% Serranidae (4) = 9.9% 17 species accounted for 61% of total catch	12-29 Nov 1999 9-15 Feb 2000 14-12 Mar 2000 23 Nov-5 Dec 2000 8-13 Mar 2001 9 Jan-11 Feb 2002	Standard rod & reels	4 depth strata 20-350 m	Brewer *et al*. (2007) - CSIRO
Misima (characterisation)	South coast	84	6*	17	Lutjanidae (9) = 53.6% Serranidae (9) = 33.3% Lethrinidae (2) = 8.3%	29 Jan-10 Mar 1988	Hand-made wooden reels	130-230 m	NSR (1988)
Misima (characterisation)	North coast (control area)	63	5[†]	19	Lutjanidae (9) = 44.4% Serranidae (3) = 30.2% Lethrinidae (2) = 17.4%	30 Jan-9 Mar 1988	Alvey reels	170-230 m	NSR (1988)

* includes family of tiger shark (Carcharhinidae) and pelagic tuna (Scombridae)
[†] includes family of tiger shark, blacktip and whitetip reef sharks (Carcharhinidae)
[§] no information of catch by family; - no information

4.1.2. Fishing effort and CPUE

Average CPUEs in the DSTP Study Area in November 2016 (0.11 kg/hook h^{-1}) and May 2017 (0.12 kg/hook h^{-1}) were markedly greater than average CPUEs estimated for the Reference Study Area in November 2016 (0.02 kg/hook h^{-1}) and May 2017 (0.03 kg/hook h^{-1}). The higher average CPUEs obtained in the DSTP Study Area compared to the Reference Study Area could be at least partially attributed to overall greater spatial coverage and number of fishing hours spent in the former area both in November 2016 and May 2017. It should be noted that limited statistical comparisons between the DSTP and Reference Study Areas can be made, owing to the lower amount of catch data from the Reference Study Area.

Combined overall fishing effort over the DSTP and Reference Study Areas totalled 90 hours in November 2016 and 56 hours in May 2017 (overall total of 146 hours), and followed a thorough, systematic dropline fishing regime at a total of 41 sites over 11 days in November 2016 and 7 days in May 2017. The fishing effort was greater than that reported for fish surveys undertaken during similar DSTP-associated characterisation studies in PNG, such as those in Misima (approximately 54 hours in control and potential impact areas; NSR, 1988) and Ramu Nickel (approximately 121 hours in control and potential impact) projects; NSR, 1998), but was similar to that reported during the 1994 deep-sea fishing survey undertaken for the Lihir baseline study (141 hours) (NSR, 1996).

Fish catch per unit of effort (CPUE) across all depth strata over the DSTP and Reference Study Areas averaged 0.09 kg/hook h^{-1} during the November 2016 survey, and 0.11 kg/hook h^{-1} during the May 2017 survey. Even considering the 30-kg female gulper shark captured during the November 2016 survey, this CPUE is considerably lower than the average 4.0 kg/hook h^{-1} recorded during the deep-slope fish survey off the south coast of Misima Island (average assumes one hook per line; NSR, 1988), lower than the average 0.5 kg/hook h^{-1} recorded at Wamunon Bay (Coffey, 2012) and lower than the 0.19 kg/hook h^{-1} recorded at Niolam Island (Lihir Group) based on catches from selected locations (NSR, 1996). Average CPUE across all sites in the current study were also lower than those reported off the Rai Coast for the Ramu Nickel Project (NSR, 1998), i.e., 0.43 kg/hook h^{-1} to 3.08 kg/hook h^{-1} but similar to the CPUE from Astrolabe Bay and islands offshore of Madang fished during the same study, i.e., 0.025 kg/hook h^{-1} to 0.28 kg/hook h^{-1}. The low CPUE by weight is likely to be directly associated to the lower numbers of fishes captured during the surveys in November 2016 (n = 41) and May 2017 (n = 20), compared to those reported from Ramu (n = 54), Misima (n = 84), Wamunon Bay (n = 121) and Lihir (n = 411) (Table 4.1). In addition, the low numbers of deep-slope fishes caught during the November 2016 and May 2017 surveys off Lae could be attributed to a number of factors, including overall low abundances of sharks (aside from dwarf gulper sharks) and bony fish species in the areas fished, reduced prey availability as well as lack of suitable habitats (e.g., rocky reefs and seamounts) coupled with high rates of sediment deposition over the seafloor.

4.1.3. Market species

Fourteen specimens of bony fishes were sourced by the survey team from the fish market at DCA Point in Lae during the November 2016 survey. These comprised five species from two families, Lutjanidae (snappers, mangrove jack) and Carangidae (trevallies, mackerels). In terms of numbers, 9 of the 14 specimens were lutjanids normally found in coastal areas with offshore reefs (e.g., *Pristipomoides typus* and *L. malabaricus*), or areas associated with coastal lagoon/lake environments (*L. argentimaculatus*). All the species observed at the DCA Point fish market were reportedly captured within the upper 100 m, and in coastal areas south of Lae, well outside the influence of sediment plumes derived from the Markham River. These fishing depths and locations were confirmed during discussions with local fishers.

4.1.4. Ecological and biological observations

A number of observations were made during the field work to inform the study in addition to the sample processing. Most of these observations pertain to the dwarf gulper shark, which comprised the most abundant species caught during the study. Given the frequent catches of this species in the DSTP Study Area, which often included two or three individuals caught per line drop (i.e., double and triple headers), the dwarf gulper shark could be regarded as a suitable indicator species of the canyon's continental slope and be a focus for further baseline and operations monitoring. The finding of three pregnant dwarf gulper shark females suggest the presence of a resident, resilient population capable of surviving a seemingly harsh environment with likely scarce food resources. The capture of longfin gulper sharks, one also comprising a female in a late stage of pregnancy, also suggests the presence of a well-established population which could be regarded as a good indicator species for future baseline and monitoring studies.

4.2. Metals in tissue

This section discusses the fish tissue metal and metalloid concentration results presented in Section 3.5.

Metals concentrations in muscle and liver tissue samples taken from 44 dwarf gulper sharks showed no clear trends as function of length or weight, except for the following cases:

- Mercury concentrations in muscle increased with increasing shark length and weight both in November 2016 and May 2017.
- Cadmium concentrations in liver increased with increasing shark length and weight.
- Selenium concentrations in liver decreased with increasing shark length and weight.
- Zinc concentrations in liver increased with increasing shark length and weight.

While the reason for the decrease in selenium in liver tissue with increasing shark weight and length is unclear, the increase in mercury, cadmium and zinc concentrations in muscle with increasing weight and length suggests bioaccumulation of these metals over time.

Most metals in muscle and liver from dwarf gulper sharks showed little variation across the depth strata except for the following cases:

- Copper concentrations in muscle increased sharply (by about an order of magnitude) in specimens caught between depths of 400 m to 500 m.
- Mercury concentrations in liver and muscle showed the highest variability over different depth ranges, with concentrations in muscle increasing gradually with increasing depth.

It is not clear why copper in muscle was distinctively higher in samples from 400 m to 500 m as there was no marked increase in dwarf gulper shark size in this depth range.

Metals concentrations in muscle from dwarf gulper sharks showed little variation between individuals caught in November 2016 and May 2017. This could be attributed to the similar range in lengths and weights of dwarf gulper sharks caught during the two surveys.

Arsenic and mercury concentrations in dwarf gulper sharks caught in November 2016 were significantly greater in muscle than liver samples. Copper, iron and zinc concentrations were greater in liver than muscle samples. Metals concentrations are typically higher in the liver as a result of the detoxification role of this organ. This suggests that arsenic and mercury favour bioaccumulation in muscle tissue in dwarf gulper shark, while copper, iron and zinc favour bioaccumulation in the liver.

Metal concentrations in muscle and liver of bony fish and sharks examined during this study were compared to the FSANZ food standards and generally expected levels (GELs) for contaminants. The key findings are as follows:

- The FSANZ standard (maximum limit) for arsenic of 2 mg kg-1 was exceeded in muscle from all dwarf gulper sharks in November 2016 and May 2017, as well in liver of 32 of the 33 dwarf gulper sharks (liver was only analysed in November 2016). This standard was also exceeded by muscle from all longfin gulper sharks, the single gulper shark, the fatspine spurdogs, the common pike eel and all saddletail snappers. The arsenic FSANZ standard was also exceeded in the liver of blackspotted croaker. Arsenic concentrations were higher in sharks (gulper, dwarf gulper and longfin gulper) than in bony fishes tested.
- The FSANZ standard (maximum limit) for arsenic of 2 mg kg-1 was also exceeded in muscle and liver of all market-bought saddletail snapper, the pennantfish and one of the two mangrove jacks. The arsenic FSANZ standard was also exceeded in liver of all of the market-bought sharptooth jobfish and one of the four bigeye trevallies.
- The copper FSANZ GELs (median value of 0.5 mg kg-1 and 90th percentile value of 2 mg kg-1) were exceeded in liver of all caught and market-bought specimens in November 2016. There were no copper FSANZ GEL exceedances in muscle of any of the individuals tested in May 2017.
- There were no exceedances of the lead FSANZ standard (maximum limit) of 0.5 mg kg-1 in muscle or liver from the November 2016 survey or in muscle from the May 2017 survey.
- The mercury FSANZ standard (maximum limit) of 1.5 mg kg-1 was exceeded in the muscle of one dwarf gulper shark and the liver from another dwarf gulper shark. The FSANZ standard (maximum limit) of 1 mg kg-1 was exceeded in muscle from two longfin gulper sharks and in the muscle from the single gulper shark. The FSANZ standard varies for dwarf gulper shark and the other sharks because the application of the standard is based on the number of samples caught. The mercury FSANZ standard (maximum limit) of 1 mg kg-1 was exceeded in the liver from the mangrove jack caught in November 2016.
- The mercury FSANZ standard (maximum limit) of 1 mg kg-1 was exceeded in the liver tissue of the following market-bought specimens: one saddletail snapper, one sharptooth jobfish and two bigeye trevallies.
- The selenium FSANZ GEL (median value) of 0.5 mg kg-1 was exceeded in muscle of dwarf gulper sharks, the longfin gulper sharks, gulper shark and mangrove jack from the November 2016 survey. This GEL was also exceeded by the dwarf gulper shark, longfin gulper shark and fatspine spurdog from the May 2017 survey, and the market-bought mangrove jack and bigeye trevally.
- The selenium FSANZ GEL (median value) of 0.5 mg kg-1 was exceeded by all liver samples of both the caught and market-bought specimens from the November 2016 survey. The liver samples of the caught blackspotted croaker, mangrove jack and saddletail snapper exceeded the selenium FSANZ GEL (90th percentile value) of 2 mg kg-1. This GEL was exceeded in the liver tissue of all of the market-bought specimens.
- The zinc FSANZ GEL (median value) of 5 mg kg-1 and the zinc FSANZ GEL (90th percentile value) of 15 mg kg-1 were exceeded by the liver samples of all caught and market-bought specimens, with the exception of the dwarf gulper shark, which did not exceed the FSANZ GEL (90th percentile value).

Metal concentrations in muscle and liver tissue samples from fish caught or market-sourced in this study were compared to those reported in studies conducted for other DSTP-associated projects in PNG, specifically Misima (NSR, 1988), Lihir (NSR, 1996) and Woodlark (Coffey, 2012). No metals concentrations were reported for fish catches from the NSR (1998) Ramu study. Review of the tissue metals concentrations from these studies allows understanding as to whether baseline (i.e., pre-DSTP) exceedance of food standards is common in fish tissue in PNG.

Exceedances of FSANZ standards and GELs were recorded in bony fish species (fish and liver tissue) caught during characterisation surveys at Misima, Lihir and Woodlark. These exceedances included:

- Misima – arsenic, copper, lead, mercury and zinc.
- Lihir – arsenic, copper and mercury.
- Woodlark – arsenic, copper, mercury, selenium and zinc.

The exceedances of food standards for arsenic, copper, mercury, selenium and zinc in fish and tissue in this study are therefore not surprising given this has been reported in fish tissue for other DSTP studies in PNG.

None of the species tested for metals during the current study have been recorded in other DSTP-associated studies in PNG. This fact precludes making any direct comparisons of metals concentrations between the same species. Instead of intraspecific comparison, however, general comparisons across genera of the family Lutjanidae can be made against lutjanids tested for Misima (NSR, 1988), Lihir (NSR, 1996), and Woodlark (Coffey, 2012). This comparison is shown in Table 4.2.

To allow direct comparison with the results of the current study, metals concentrations for the Misima and Lihir studies have been converted from dry weight to wet weight concentrations. This was done by assuming a moisture content of 80% and dividing the results by five, as previously performed in NSR (1996).

Maximum metal concentrations in liver of two species of the family Lutjanidae tested in the current study were mostly lower than those reported for lutjanid species from Woodlark, Misima and Lihir (Table 4.2). Arsenic, copper and mercury in muscle were lower in the current study than lutjanid species from Woodlark, Misima and Lihir. The main differences between lutjanid species can be summarised as follows (in terms of maximum metals concentrations):

- Silver concentrations in liver were slightly lower than those in lutjanids tested from Woodlark, Misima and Lihir.
- Arsenic concentrations in muscle and liver were much lower than those in lutjanids tested from Woodlark, Misima and Lihir.
- Cadmium concentrations in liver were much lower than those in lutjanids tested from Woodlark, Misima and Lihir. However, cadmium concentrations in muscle were similar to those reported for Woodlark, Misima and Lihir.
- Chromium concentrations in muscle and liver were lower than those in lutjanids tested from Lihir but similar to those reported for Woodlark.
- Copper concentrations in muscle and liver were lower than in lutjanids tested from Woodlark, Misima and Lihir.
- Lead concentrations in liver were lower than those in lutjanids tested from Woodlark, Misima and Lihir.
- Mercury concentrations in liver were higher than those in lutjanids tested from Woodlark, Misima and Lihir. Mercury concentrations in muscle were lower than those reported for Woodlark, Misima and Lihir.
- Nickel concentrations in liver were lower than those lutjanids tested from Lihir but similar to those from Woodlark.
- Selenium concentrations in liver were lower than those lutjanids tested from Lihir. Selenium concentrations in muscle were lower than those reported for Woodlark.

- Zinc concentrations in liver were lower than in lutjanids tested from Lihir and Misima but similar to those from Woodlark. Zinc concentrations in muscle were similar to those reported for Woodlark, Misima and Lihir.

Table 4.2: Concentrations of metals (mg kg^{-1}, wet weight) in liver and muscle tissues of bony fish species of the family Lutjanidae caught during the current study and characterisation studies at Woodlark, Misima and Lihir

Silver		**Liver**				**Muscle**			
Species		**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**	**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**
Oblique-banded snapper *Pristipomoides zonatus*	Minimum	<0.10	-	<0.10	-	<0.10	-	<0.10	-
	Maximum	<0.10	-	0.43	-	<0.10	-	<0.10	-
Saddle-back snapper *Paracaesio kusakarii*	Minimum	0.13	<0.8	<0.10	-	<0.10	<0.8	<0.10	-
	Maximum	0.13	<0.8	0.47	-	<0.10	<0.8	<0.10	-
Small-toothed jobfish *Aphareus rutilans*	Minimum	<0.10	<0.8	<0.10	-	<0.10	<0.8	<0.10	-
	Maximum	<0.10	0.24	0.30	-	<0.10	<0.8	<0.10	-
Banded snapper *Pristipomoides* sp.	Minimum	<0.10	<0.8	<0.10	-	<0.10	<0.8	<0.10	-
	Maximum	0.39	0.28	0.26	-	<0.10	<0.8	<0.10	-
Red bass *Lutjanus bohar*	Minimum	<0.10	-	-	-	<0.10	-	-	-
	Maximum	<0.10	-	-	-	<0.10	-	-	-
Yellowlined snapper *Lutjanus rufolineatus*	Minimum	<0.10	-	-	-	<0.10	-	-	-
	Maximum	0.24	-	-	-	<0.10	-	-	-
Saddletail snapper *Lutjanus malabaricus*	Minimum	-	-	-	<0.10	-	-	-	<0.10
	Maximum	-	-	-	<0.10	-	-	-	<0.10
Mangrove jack *Lutjanus argentimaculatus*	Minimum	-	-	-	<0.10	-	-	-	<0.10
	Maximum	-	-	-	0.7	-	-	-	<0.10
Arsenic		**Liver**				**Muscle**			
Species		**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**	**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**
Oblique-banded snapper *Pristipomoides zonatus*	Minimum	4.90	-	2.69	-	5.90	-	2.90	-
	Maximum	19	-	40.53	-	16	-	13.86	-
Saddle-back snapper *Paracaesio kusakarii*	Minimum	11	2.06	3.68	-	3.40	1.16	0.94	-
	Maximum	11	13.74	11.02	-	3.40	4.50	2.83	-

Small-toothed jobfish *Aphareus rutilans*	Minimum	19	1.74	10.38	-	4.40	0.72	3.73	-
	Maximum	20	16.92	18.74	-	7.10	5.18	10.28	-
Banded snapper *Pristipomoides* sp.	Minimum	2.90	1.70	2.34	-	1.10	0.56	0.76	-
	Maximum	11	4.84	7.55	-	4.70	8.94	7.43	-
Red bass *Lutjanus bohar*	Minimum	40	-	-	-	15	-	-	-
	Maximum	40	-	-	-	15	-	-	-
Yellowlined snapper *Lutjanus rufolineatus*	Minimum	7.2	-	-	-	2.3	-	-	-
	Maximum	8.2	-	-	-	2.5	-	-	-
Saddletail snapper *Lutjanus malabaricus*	Minimum	-	-	-	2.8	-	-	-	2.8
	Maximum	-	-	-	3.7	-	-	-	2.8
Mangrove jack *Lutjanus argentimaculatus*	Minimum	-	-	-	1.3	-	-	-	<0.4
	Maximum	-	-	-	4.2	-	-	-	2.6
Cadmium		**Liver**				**Muscle**			
Species		**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**	**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**
Oblique-banded snapper *Pristipomoides zonatus*	Minimum	1.90	-	0.47	-	<0.05	-	<0.05	-
	Maximum	20	-	103.26	-	<0.05	-	<0.05	-
Saddle-back snapper *Paracaesio kusakarii*	Minimum	49	4.20	9.64	-	<0.05	<0.04	<0.05	-
	Maximum	49	74.40	53.25	-	<0.05	0.08	<0.05	-
Small-toothed jobfish *Aphareus rutilans*	Minimum	11	3.50	3.22	-	<0.05	<0.04	<0.05	-
	Maximum	30	17.34	25.87	-	<0.05	<0.05	<0.05	-
Banded snapper *Pristipomoides* sp.	Minimum	2.20	2.42	2.80	-	<0.05	<0.05	<0.05	-
	Maximum	35	45.60	33.12	-	<0.05	0.08	<0.05	-
Red bass *Lutjanus bohar*	Minimum	16	-	-		<0.05	-	-	-
	Maximum	16	-	-		<0.05	-	-	-
Yellowlined snapper *Lutjanus rufolineatus*	Minimum	8.1	-	-		<0.05	-	-	-
	Maximum	56	-	-		<0.05	-	-	-
Saddletail snapper *Lutjanus malabaricus*	Minimum	-	-	-	1.40	-	-	-	<0.05
	Maximum	-	-	-	2.80	-	-	-	<0.05

Mangrove jack *Lutjanus argentimaculatus*	Minimum	-	-	-	0.16	-	-	-	<0.05
	Maximum	-	-	-	7.80	-	-	-	<0.05
Chromium		**Liver**				**Muscle**			
Species		**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**	**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**
Oblique-banded snapper *Pristipomoides zonatus*	Minimum	<0.10	-	<0.10	-	<0.10	-	<0.10	-
	Maximum	<0.10	-	0.26	-	0.23	-	0.31	-
Saddle-back snapper *Paracaesio kusakarii*	Minimum	<0.10	-	<0.10	-	0.12	-	<0.10	-
	Maximum	<0.10	-	0.12	-	0.12	-	0.13	-
Small-toothed jobfish *Aphareus rutilans*	Minimum	<0.10	-	<0.10	-	<0.10	-	<0.10	-
	Maximum	<0.10	-	4.93	-	<0.10	-	0.12	-
Banded snapper *Pristipomoides* sp.	Minimum	<0.10	-	<0.10	-	<0.10	-	1.80	-
	Maximum	0.13	-	0.11	-	0.30	-	<0.10	-
Red bass *Lutjanus bohar*	Minimum	<0.10	-	-	-	<0.10	-	-	-
	Maximum	<0.10	-	-	-	<0.10	-	-	-
Yellowlined snapper *Lutjanus rufolineatus*	Minimum	<0.10	-	-	-	<0.10	-	-	-
	Maximum	<0.10	-	-	-	<0.10	-	-	-
Saddletail snapper *Lutjanus malabaricus*	Minimum	-	-	-	<0.1	-	-	-	<0.1
	Maximum	-	-	-	<0.1	-	-	-	<0.1
Mangrove jack *Lutjanus argentimaculatus*	Minimum	-	-	-	<0.1	-	-	-	<0.1
	Maximum	-	-	-	<0.1	-	-	-	<0.1
Copper		**Liver**				**Muscle**			
Species		**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**	**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**
Oblique-banded snapper *Pristipomoides zonatus*	Minimum	3	-	2.84	-	0.06	-	0.21	-
	Maximum	16	-	64.53	-	0.20	-	2.37	-
Saddle-back snapper *Paracaesio kusakarii*	Minimum	21	4.22	5.99	-	0.09	<0.1	0.17	-
	Maximum	21	14.52	26.63	-	0.09	0.56	2.75	-
Small-toothed jobfish *Aphareus rutilans*	Minimum	12	0.76	6.58	-	0.16	<0.8	0.32	-
	Maximum	32	22.00	27.58	-	0.21	0.62	1.58	-

Banded snapper *Pristipomoides* sp.	Minimum	5.40	3.72	3.52	-	0.10	<0.1	0.22	-
	Maximum	44	22.00	31.76	-	0.59	0.20	1.25	-
Red bass *Lutjanus bohar*	Minimum	16	-	-	-	0.18	-	-	-
	Maximum	16	-	-	-	0.18	-	-	-
Yellowlined snapper *Lutjanus rufolineatus*	Minimum	4.7	-	-	-	0.19	-	-	-
	Maximum	15	-	-	-	0.20	-	-	-
Saddletail snapper *Lutjanus malabaricus*	Minimum	-	-	-	1.80	-	-	-	0.08
	Maximum	-	-	-	6.40	-	-	-	0.11
Mangrove jack *Lutjanus argentimaculatus*	Minimum	-	-	-	6.60	-	-	-	0.11
	Maximum	-	-	-	25	-	-	-	0.13
Mercury		**Liver**				**Muscle**			
Species		**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**	**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**
Oblique-banded snapper *Pristipomoides zonatus*	Minimum	0.08	-	<0.2	-	0.02	-	<0.1	-
	Maximum	1	-	5.03	-	0.20	-	1.46	-
Saddle-back snapper *Paracaesio kusakarii*	Minimum	0.14	<0.2	<0.2	-	0.04	<0.2	<0.1	-
	Maximum	0.14	0.80	0.71	-	0.04	<0.1	0.16	-
Small-toothed jobfish *Aphareus rutilans*	Minimum	0.06	<0.2	<0.2	-	0.02	<0.2	<0.1	-
	Maximum	0.26	<0.2	0.33	-	0.03	0.12	<0.1	-
Banded snapper *Pristipomoides* sp.	Minimum	0.08	<0.2	<0.2	-	0.02	<0.1	<0.1	-
	Maximum	2	2.76	2.94	-	0.52	0.70	1.40	-
Red bass *Lutjanus bohar*	Minimum	2	-	-	-	0.4	-	-	-
	Maximum	2	-	-	-	0.4	-	-	-
Yellowlined snapper *Lutjanus rufolineatus*	Minimum	0.37	-	-	-	0.03	-	-	-
	Maximum	2.6	-	-	-	0.17	-	-	-
Saddletail snapper *Lutjanus malabaricus*	Minimum	-	-	-	0.03	-	-	-	0.05
	Maximum	-	-	-	1.90	-	-	-	0.36
Mangrove jack *Lutjanus argentimaculatus*	Minimum	-	-	-	0.16	-	-	-	0.03
	Maximum	-	-	-	14	-	-	-	0.53

Nickel		Liver				Muscle			
Species		**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**	**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**
Oblique-banded snapper *Pristipomoides zonatus*	Minimum	<0.06	-	<0.06	-	<0.06	-	<0.06	-
	Maximum	<0.06	-	1.83	-	<0.06	-	0.17	-
Saddle-back snapper *Paracaesio kusakarii*	Minimum	<0.06	-	<0.06	-	<0.06	-	<0.06	-
	Maximum	<0.06	-	0.73	-	<0.06	-	<0.06	-
Small-toothed jobfish *Aphareus rutilans*	Minimum	<0.06	-	<0.06	-	<0.06	-	<0.06	-
	Maximum	<0.06	-	0.33	-	<0.06	-	<0.06	-
Banded snapper *Pristipomoides* sp.	Minimum	<0.06	-	<0.06	-	<0.06	-	<0.06	-
	Maximum	<0.06	-	0.65	-	<0.06	-	<0.06	-
Red bass *Lutjanus bohar*	Minimum	<0.06	-	-	-	<0.06	-	-	-
	Maximum	<0.06	-	-	-	<0.06	-	-	-
Yellowlined snapper *Lutjanus rufolineatus*	Minimum	<0.06	-	-	-	<0.06	-	-	-
	Maximum	<0.06	-	-	-	<0.06	-	-	-
Saddletail snapper *Lutjanus malabaricus*	Minimum	-	-	-	<0.06	-	-	-	<0.06
	Maximum	-	-	-	0.06	-	-	-	<0.06
Mangrove jack *Lutjanus argentimaculatus*	Minimum	-	-	-	<0.06	-	-	-	<0.06
	Maximum	-	-	-	<0.06	-	-	-	<0.06
Lead		**Liver**				**Muscle**			
Species		**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**	**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**
Oblique-banded snapper *Pristipomoides zonatus*	Minimum	<0.1	-	<0.1	-	<0.10	-	<0.1	-
	Maximum	0.25	-	0.18	-	0.20	-	<0.1	-
Saddle-back snapper *Paracaesio kusakarii*	Minimum	0.21	<0.3	<0.1	-	0.25	<0.4	<0.1	-
	Maximum	0.21	0.76	<0.1	-	0.25	<0.4	<0.1	-
Small-toothed jobfish *Aphareus rutilans*	Minimum	<0.1	<0.3	<0.1	-	<0.10	<0.4	<0.1	-
	Maximum	<0.1	<0.3	0.12	-	<0.10	<0.4	<0.1	-
Banded snapper *Pristipomoides* sp.	Minimum	<0.1	<0.3	<0.1	-	<0.10	<0.4	<0.1	-
	Maximum	0.20	<0.3	0.12	-	0.20	<0.4	0.12	-

Red bass *Lutjanus bohar*	Minimum	<0.1	-	-	-	<0.1	-	-	-
	Maximum	<0.1	-	-	-	<0.1	-	-	-
Yellowlined snapper *Lutjanus rufolineatus*	Minimum	<0.1	-	-	-	<0.1	-	-	-
	Maximum	<0.1	-	-	-	<0.1	-	-	-
Saddletail snapper *Lutjanus malabaricus*	Minimum	-	-	-	<0.1	-	-	-	<0.1
	Maximum	-	-	-	<0.1	-	-	-	<0.1
Mangrove jack *Lutjanus argentimaculatus*	Minimum	-	-	-	<0.1	-	-	-	<0.1
	Maximum	-	-	-	<0.1	-	-	-	<0.1
Selenium		**Liver**				**Muscle**			
Species		**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**	**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**
Oblique-banded snapper *Pristipomoides zonatus*	Minimum	2.70	-	2.93	-	0.84	-	<0.5	-
	Maximum	6.70	-	35.11	-	1.20	-	0.68	-
Saddle-back snapper *Paracaesio kusakarii*	Minimum	6.80	-	3.19	-	1	-	<0.5	-
	Maximum	6.80	-	10.22	-	1	-	0.99	-
Small-toothed jobfish *Aphareus rutilans*	Minimum	6.70	-	2.97	-	0.88	-	<0.5	-
	Maximum	14	-	13.17	-	1	-	0.73	-
Banded snapper *Pristipomoides* sp.	Minimum	3.10	-	1.43	-	0.76	-	<0.5	-
	Maximum	7.50	-	4.31	-	2.30	-	0.60	-
Red bass *Lutjanus bohar*	Minimum	4.6	-	-	-	1	-	-	-
	Maximum	4.6	-	-	-	1	-	-	-
Yellowlined snapper *Lutjanus rufolineatus*	Minimum	1	-	-	-	0.93	-	-	-
	Maximum	1	-	-	-	1.1	-	-	-
Saddletail snapper *Lutjanus malabaricus*	Minimum	-	-	-	1.70	-	-	-	<0.5
	Maximum	-	-	-	2.80	-	-	-	<0.5
Mangrove jack *Lutjanus argentimaculatus*	Minimum	-	-	-	1.30	-	-	-	0.50
	Maximum	-	-	-	6.50	-	-	-	0.66
Zinc		**Liver**				**Muscle**			
Species		**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**	**Woodlark**	**Misima**	**Lihir**	**Wafi-Golpu**

Oblique-banded snapper *Pristipomoides zonatus*	Minimum	23	-	20.09	-	2.60	-	1.73	-
	Maximum	44	-	180.18	-	5.10	-	3.24	-
Saddle-back snapper *Paracaesio kusakarii*	Minimum	46	15.00	29.83	-	3.50	2.12	2.29	-
	Maximum	46	58.80	48.97	-	3.50	6.76	3.24	-
Small-toothed jobfish *Aphareus rutilans*	Minimum	43	24.40	29.39	-	3.30	2.38	2.35	-
	Maximum	75	54.80	54.63	-	3.40	8.36	5.12	-
Banded snapper *Pristipomoides* sp.	Minimum	37	18.00	29.18	-	2.40	1.66	1.79	-
	Maximum	120	58.80	107.71	-	6.50	3.56	3.40	-
Red bass *Lutjanus bohar*	Minimum	80	-	-	-	3.9	-	-	-
	Maximum	80	-	-	-	3.9	-	-	-
Yellowlined snapper *Lutjanus rufolineatus*	Minimum	47	-	-	-	3.5	-	-	-
	Maximum	71	-	-	-	3.7	-	-	-
Saddletail snapper *Lutjanus malabaricus*	Minimum	-	-	-	22	-	-	-	2.20
	Maximum	-	-	-	48	-	-	-	3.40
Mangrove jack *Lutjanus argentimaculatus*	Minimum	-	-	-	34	-	-	-	2.60
	Maximum	-	-	-	48	-	-	-	3.10

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Appendix A – Geographical positions and depth ranges (m) of sites fished in the DSTP Study Area

Transect	Site	Latitude S	Longitude E	Depth stratum (m)
A	A1	-6° 42.856'	147° 7.553'	100-200
	A2	-6° 43.026'	147° 7.544'	200-300
	A3	-6° 43.280'	147° 7.559'	300-400
	A4	-6° 44.218'	147° 7.548'	400-500
	A5	-6° 44.971'	147° 7.549'	500-600
	A6	-6° 45.159'	147° 7.549'	600-700
	A7	-6° 45.315'	147° 7.537'	700-800
B	B1	-6° 42.979'	147° 4.803'	100-200
	B2	-6° 43.179'	147° 4.881'	200-300
	B3	-6° 43.491'	147° 5.024'	300-400
	B4	-6° 44.022'	147° 5.260'	400-500
	B5*	-6° 44.816'	147° 5.612'	500-600
	B6*	-6° 45.234'	147° 5.798'	600-700
	B7	-6° 45.485'	147° 5.927'	700-800
C	C1	-6° 43.709'	147° 3.633'	100-200
	C2	-6° 43.981'	147° 3.765'	200-300
	C3	-6° 44.248'	147° 3.877'	300-400
	C4	-6° 44.859'	147° 4.148'	400-500
	C5	-6° 45.175'	147° 4.286'	500-600
	C6*	-6° 45.475'	147° 4.419'	600-700
	C7	-6° 45.952'	147° 4.632'	700-800
D	D1	-6° 44.372'	147° 2.438'	100-200
	D2	-6° 44.563'	147° 2.531'	200-300
	D3	-6° 44.780'	147° 2.623'	300-400
	D4	-6° 45.147'	147° 2.783'	400-500
	D5	-6° 45.432'	147° 2.919'	500-600
	D6*	-6° 45.670'	147° 3.020'	600-700
	D7	-6° 46.044'	147° 3.187'	700-800
E	E1	-6° 44.497'	147° 1.017'	100-200
	E2	-6° 44.780'	147° 0.984'	200-300
	E3	-6° 44.938'	147° 0.999'	300-400
	E4	-6° 45.165'	147° 0.985'	400-500
	E5	-6° 45.478'	147° 0.993'	500-600

* These sites were not fished due to time and logistics constraints.

Appendix B – Geographical positions and depth ranges (m) of sites fished in the Reference Study Area

Transect / area	**Site**	**Latitude S**	**Longitude E**	**Depth range (m)**
Labu	LABU1	-6° 46.417'	146° 58.457'	42-108
	LABU2	-6° 46.385'	146° 59.113'	100-139
	LABU3	-6° 46.354'	147° 0.148'	210-225
	LABU4	-6° 47.139'	146° 57.875'	22-110
Local Fishing Grounds	LFG1	-6° 47.347'	146° 59.906'	78-101
	LFG2	-6° 48.257'	146° 59.650'	76-93
Sugarloaf Wreck	WRECK1	-6° 48.369'	146° 58.153'	18-25
Sugarloaf	SL1	-6° 48.996'	146° 57.605'	22-28
Halfway Reef	HW1	-6° 50.544'	147° 0.824'	77-120
Benalla Banks	BB1	-6° 56.783'	147° 6.907'	50-165
	BB2	-6° 58.129'	147° 7.156'	46-195
	BB3	-6° 57.576'	147° 7.020'	37-260

Appendix C – Morphological and biological data of all specimens of each species

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	AAA label		AAA label											Specimen		Heavy metals		
n	Muscle	Weight muscle (g)	Liver	Weight liver (g)	Fish No.	Date	Transect	Site	Depth stratum	Depth (m)	Family	Genus	Species	TL (mm)	Weight (g, Kg)	Muscle (g)	Liver (g)	Sex
1	M1	31.74	L1	36.64	1	3/Nov/16	A	A4	4	430	Centrophoridae	*Centrophorus*	*C. atromarginatus*	710	2170	31.74	36.64	F
2	M2	18.16	L2	18.55	2	4/Nov/16	B	B2	2	245	Centrophoridae	*Centrophorus*	*C. atromarginatus*	532	776g	18.16	18.55	F
3	M3	14.52	L3	21.4	3	4/Nov/16	B	B1	1	120	Centrophoridae	*Centrophorus*	*C. atromarginatus*	500	698	14.52	21.40	F
4	M4	14.50	L4	23.10	4	4/Nov/16	B	B1	1	105	Centrophoridae	*Centrophorus*	*C. atromarginatus*	520	720	14.50	23.10	M
5	M5	10.92	L5	11.88	5	4/Nov/16	B	B1	1	170	Centrophoridae	*Centrophorus*	*C. atromarginatus*	420	403	10.92	11.88	F
6	M6	20.60	L6	23.00	6	4/Nov/16	B	B2	2	245	Centrophoridae	*Centrophorus*	*C. atromarginatus*	490	683	20.60	23.00	M
7	M7	61.00	L7	51.45	7	4/Nov/16	B	B2	2	250	Sciaenidae	*Protonibea*	*P. diacanthus*	950	6800	61.00	51.45	M 3
8	M8	14.97	L8	31.53	8	4/Nov/16	B	B2	2	290	Centrophoridae	*Centrophorus*	*C. atromarginatus*	535	500	14.97	31.53	M
9	M9	37.55	L9	57.17	9	4/Nov/16	B	B2	2	298	Centrophoridae	*Centrophorus*	*C. atromarginatus*	675	1950	37.55	57.17	F
10	M10	29.20	L10	47.08	10	4/Nov/16	C	C1	1	208	Centrophoridae	*Centrophorus*	*C. atromarginatus*	620	1500	29.20	47.08	F
11	M11	20.41	L11	29.00	11	4/Nov/16	C	C1	1	200	Centrophoridae	*Centrophorus*	*C. atromarginatus*	550	1100	20.41	29.00	F
12	M12	39.67	L12	29.53	12	5/Nov/16	A	A5	5	550	Centrophoridae	*Centrophorus*	*C. granulosus*	1600	30kg	39.67	29.53	F
13	M13	26.80	L13	34.90	13	5/Nov/16	C	C2	2	295	Centrophoridae	*Centrophorus*	*C. atromarginatus*	705	2250	26.80	34.90	F
14	M14	8.50	L14	13.96	14	5/Nov/16	C	C2	2	295	Centrophoridae	*Centrophorus*	*C. atromarginatus*	410	348	8.50	13.96	M
15	M15	19.28	L15	33.33	15	5/Nov/16	C	C2	2	290	Centrophoridae	*Centrophorus*	*C. atromarginatus*	655	1600	19.28	33.33	F
16	M16	22.80	L16	33.27	16	5/Nov/16	C	C2	2	300	Centrophoridae	*Centrophorus*	*C. atromarginatus*	605	1350	22.80	33.27	M
17	M17	46.36	L17	18.27	17	7/Nov/16	LABU	L1	1	105	Lutjanidae	*Lutjanus*	*L. argentimaculatus*	635	3700	46.36	18.27	F 2
18	M18	17.16	L18	35.97	18	7/Nov/16	LABU	L3	2	218	Centrophoridae	*Centrophorus*	*C. atromarginatus*	700	2350	17.16	39.57	F
19	M19	37.83	L19	68.50	19	7/Nov/16	LABU	L3	2	226	Centrophoridae	*Centrophorus*	*C. atromarginatus*	720	2200	37.83	68.50	F
20	M20	6.30	L20	11.44	20	7/Nov/16	LABU	L3	2	226	Centrophoridae	*Centrophorus*	*C. atromarginatus*	410	360	6.30	11.44	F
21	M21	30.64	L21	42.35	21	7/Nov/16	LABU	L3	2	220	Centrophoridae	*Centrophorus*	*C. atromarginatus*	690	2100	30.64	42.35	F
22	M22	12.04	L22	16.37	22	7/Nov/16	LABU	L3	2	220	Centrophoridae	*Centrophorus*	*C. atromarginatus*	460	517	12.04	16.37	F
23	M23	11.86	L23	16.17	23	7/Nov/16	LABU	L2	1	137	Centrophoridae	*Centrophorus*	*C. atromarginatus*	465	514	11.86	16.17	M
24	M24	7.32	L24	25.00	24	7/Nov/16	LABU	L2	1	122	Centrophoridae	*Centrophorus*	*C. atromarginatus*	510	613	7.32	25.00	M
25	M25	7.64	L25	11.8	25	7/Nov/16	LABU	L2	1	122	Centrophoridae	*Centrophorus*	*C. atromarginatus*	450	440	7.64	11.80	F
26	M26	54.24	L26	45.75	26	9/Nov/16	D	D4	4	460	Centrophoridae	*Centrophorus*	*C. atromarginatus*	750	2200	54.24	45.75	M
27	M27	12.34	L27	15.42	27	9/Nov/16	D	D1	1	187	Centrophoridae	*Centrophorus*	*C. atromarginatus*	430	406	12.34	15.42	F
28	M28	23.58	L28	84.19	28	12/Nov/16	C	C3	3	360	Centrophoridae	*Centrophorus*	*C. atromarginatus*	720	2350	23.58	84.19	M
29	M29	31.09	L29	67.39	29	12/Nov/16	C	C3	3	360	Centrophoridae	*Centrophorus*	*C. atromarginatus*	762	2220	31.09	67.39	M
30	M30	18.25	L30	28.93	30	12/Nov/16	D	D3	3	308	Centrophoridae	*Centrophorus*	*C. atromarginatus*	580	1200	18.25	28.93	M
31	M31	36.00	L31	38.51	31	12/Nov/16	D	D3	3	300	Centrophoridae	*Centrophorus*	*C. atromarginatus*	770	2150	36.00	38.51	M
32	M32	44.98	L32	53.22	32	12/Nov/16	C	C3	3	367	Centrophoridae	*Centrophorus*	*C. atromarginatus*	760	2500	44.98	53.22	M
33	M33	15.76	L33	25.05	33	12/Nov/16	E	E3	3	343	Centrophoridae	*Centrophorus*	*C. atromarginatus*	580	1250	15.76	25.05	M
34	M34	23.81	L34	28.71	34	11/Nov/16	E	E3	3	330	Centrophoridae	*Centrophorus*	*C. atromarginatus*	580	1250	23.81	28.71	M
35	M35	21.30	L35	30.36	35	11/Nov/16	E	E2	2	260	Centrophoridae	*Centrophorus*	*C. atromarginatus*	560	1150	21.30	30.36	M
36	M36	33.00	L36	30.35	36	11/Nov/16	E	E3	3	330	Centrophoridae	*Centrophorus*	*C. atromarginatus*	580	1250	33.00	30.35	M
37	M37	39.16	L37	54.12	37	11/Nov/16	E	E3	3	331	Centrophoridae	*Centrophorus*	*C. atromarginatus*	740	2300	39.16	54.12	M
38	M38	18.67	L38	2.14	38	12/Nov/16	Sugarloaf - Wreck	SW1	1	24	Lutjanidae	*Lutjanus*	*L. malabaricus*	340	570	18.67	2.14	F 1
39	M39	29.89	L39	34.39	39	13/Nov/16	E	E5	5	540	Centrophoridae	*Centrophorus*	*C. atromarginatus*	660	2400	29.89	34.39	F
40	M40	17.80	L40	47.9	40	4-Nov-16	C	C1	1	184	Centrophoridae	*Centrophorus*	*C. atromarginatus*	680	2100	17.80	47.90	F

Date	Transect Station	Site	Depth stratum	Fishing time (min)	Time caught	Actual Depth (m)	Family	Genus	Species	Specimen TL (mm)	Weight (g)	Heavy metals Muscle (g)	Muscle AAA label	Sex
4/May/17	D1	1	100-200	120	9:30	180	Centrophoridae	*Centrophorus*	*C. atromarginatus*	509	691	13.20	MD1-1	F
4/May/17	D1	1	100-200	120	9:30	180	Centrophoridae	*Centrophorus*	*C. atromarginatus*	450	517	12.15	MD1-2	M
4/May/17	D1	1	100-200	120	9:30	180	Squalidae	*Squalus*	*S. crassispinus*	405	331	14.83	MD1-3	F
4/May/17	D2	2	200-300	120	11:33	250	Squalidae	*Squalus*	*S. crassispinus*	415	343	7.96	MD2-4	M
4/May/17	D3	3	300-400	120	13:28	346	Centrophoridae	*Centrophorus*	*C. atromarginatus*	478	2300	13.39	MD3-5	M
4/May/17	D4	4	400-500	120	15:32	460	Centrophoridae	*Centrophorus*	*C. cf lusitanicus*	890	9800	15.02	MD4-6	F
7/May/17	A2	2	200-300	120	11:05	300	Squalidae	*Squalus*	*S. crassispinus*	652	1500	19.86	MA2-7	F
7/May/17	B3	3	300-400	120	8:30	386	Centrophoridae	*Centrophorus*	*C. atromarginatus*	561	947	10.77	MB3-8	M
7/May/17	A2	2	200-300	120	10:53	270	Squalidae	*Squalus*	*S. crassispinus*	500	525	17.30	MA2-9	M
7/May/17	A2	2	200-300	120	12:11	290	Squalidae	*Squalus*	*S. crassispinus*	495	509	14.88	MA2-10	M
5/May/17	C3	3	300-400	120	14:35	370	Centrophoridae	*Centrophorus*	*C. cf lusitanicus*	725	2000	27.08	MC3-11	M
7/May/17	A1	1	100-200	120	9:43	100	Lutjanidae	*Lutjanus*	*L. malabaricus*	420	1300	19.72	MA1-12	M
9/May/17	LABU2	2	120	120	14:40	120	Centrophoridae	*Centrophorus*	*C. atromarginatus*	420	591	11.40	MLABU2-13	M
9/May/17	LABU3	3	230	120	13:45	230	Centrophoridae	*Centrophorus*	*C. atromarginatus*	458	437	14.85	MLABU3-14	M
8/May/17	E2	2	200-300	120	10:08	300	Centrophoridae	*Centrophorus*	*C. atromarginatus*	609	1200	16.08	ME2-15	M
8/May/17	E2	2	200-300	120	10:15	300	Centrophoridae	*Centrophorus*	*C. atromarginatus*	580	1100	13.41	ME2-16	M
8/May/17	E2	2	200-300	120	11:48	300	Centrophoridae	*Centrophorus*	*C. atromarginatus*	607	1200	17.23	ME2-17	M
10/May/17	D2	2	200-300	120	9:21	215	Centrophoridae	*Centrophorus*	*C. atromarginatus*	707	4100	27.28	MAS2-18	F
10/May/17	E1	1	100-200	120	10:40	120	Centrophoridae	*Centrophorus*	*C. atromarginatus*	515	672	14.88	MAS1-19	F
10/May/17	E1	1	100-200	120	10:00	124	Muraenesocidae	*Muraenesox*	*M. bagio*	1050	3800	13.83	MAS1-20	F

Appendix D – Laboratory fish tissue metals analysis report

REPORT OF ANALYSIS

Laboratory Reference: A16/4468Q [R00]

Client:	Coffey Environments Australia Pty Ltd - VIC 126 Trenerry Crescent Abbotsford VIC 3067	**Order No:**	520
		Project:	Metal Analysis - Fish Tissue
		Sample Type:	Fish Tissue
		No. of Samples:	108
Contact:	Ivan Steward	**Date Received:**	17/11/2016
		Date Completed:	28/11/2016

Laboratory Contact Details:

Client Services Manager: Trent Biggin
Technical Enquiries: Andrew Bradbury
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Fax: +61 7 3268 1238
Email: brisbane@advancedanalytical.com.au
andrew.bradbury@advancedanalytical.com.au

Attached Results Approved By:

Rama Nimmagadda
Technical Manager

Comments:
All samples tested as submitted by client. All attached results have been checked and approved for release.
This is the Final Report and supersedes any reports previously issued with this reference number.
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Accreditation No.15109

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Batch Number: A16/4468Q [R00]
Project Reference: Metal Analysis - Fish Tissue

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/1 M1 03/11/2016	/2 M2 04/11/2016	/3 M3 04/11/2016	/4 M4 04/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	6.9	13	14	20
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	0.19	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	2.4	0.24	0.30	0.24
Iron	04-008	mg/kg	2.0	1.3	1.0	1.7
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	2.2	0.60	0.32	0.31
Manganese	04-008	mg/kg	0.132	<0.1	<0.1	0.119
Nickel	04-008	mg/kg	0.073	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	0.71	<0.5	<0.5	0.55
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	3.7	2.5	2.6	2.7

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/5 M5 04/11/2016	/6 M6 04/11/2016	/7 M7 04/11/2016	/8 M8 04/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	15	14	0.96	13
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.43	0.15	0.13	0.62
Iron	04-008	mg/kg	1.8	0.81	0.78	1.5
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.27	0.40	0.26	0.73
Manganese	04-008	mg/kg	0.115	0.108	<0.1	0.118
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	<0.5	<0.5	<0.5	0.57
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.6	2.1	2.2	2.6

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Batch Number: A16/4468Q [R00]

Project Reference: Metal Analysis - Fish Tissue

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/9 M9 04/11/2016	/10 M10 04/11/2016	/11 M11 04/11/2016	/12 M12 05/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	9.7	9.2	18	33
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.13	0.22	0.30	0.11
Iron	04-008	mg/kg	1.1	1.5	1.2	0.64
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.71	0.58	0.39	1.5
Manganese	04-008	mg/kg	<0.1	0.118	<0.1	<0.1
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	0.58	0.59	0.60	0.67
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.8	3.2	2.6	3.3

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/13 M13 05/11/2016	/14 M14 05/11/2016	/15 M15 05/11/2016	/16 M16 05/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	11	15	7.8	13
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.12	0.26	0.18	0.21
Iron	04-008	mg/kg	1.9	1.9	1.3	1.1
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.96	0.16	0.68	1.3
Manganese	04-008	mg/kg	<0.1	0.104	0.112	<0.1
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	0.53	<0.5	0.61	0.57
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.9	2.5	2.6	2.7

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Batch Number: A16/4468Q [R00]
Project Reference: Metal Analysis - Fish Tissue

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/17 M17 07/11/2016	/18 M18 07/11/2016	/19 M19 07/11/2016	/20 M20 07/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	<0.4	17	24	23
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.13	0.21	0.17	0.22
Iron	04-008	mg/kg	3.4	1.4	0.81	1.2
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.53	0.96	0.67	0.25
Manganese	04-008	mg/kg	<0.1	0.110	0.103	0.105
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	0.66	0.55	<0.5	<0.5
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	3.1	2.9	3.1	2.2

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/21 M21 07/11/2016	/22 M22 07/11/2016	/23 M23 07/11/2016	/24 M24 07/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	18	24	16	19
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.14	0.18	0.20	0.18
Iron	04-008	mg/kg	1.3	1.1	1.2	2.9
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.99	0.016	0.18	0.53
Manganese	04-008	mg/kg	<0.1	0.109	<0.1	0.106
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	0.69	0.61	0.62	0.55
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.8	2.4	2.4	2.7

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Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/25 M25 07/11/2016	/26 M26 09/11/2016	/27 M27 09/11/2016	/28 M28 12/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	12	24	12	20
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	0.15
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.19	0.12	0.18	0.16
Iron	04-008	mg/kg	1.6	0.88	1.2	2.0
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.21	0.71	0.12	0.99
Manganese	04-008	mg/kg	0.102	<0.1	<0.1	0.102
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	<0.5	<0.5	<0.5	0.63
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.4	2.1	2.4	2.7

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/29 M29 12/11/2016	/30 M30 12/11/2016	/31 M31 12/11/2016	/32 M32 12/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	12	13	20	36
Cadmium	04-008	mg/kg	<0.05	<0.05	0.074	0.058
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.25	0.13	0.26	0.16
Iron	04-008	mg/kg	1.5	0.88	1.3	1.1
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	1.3	0.79	1.2	1.2
Manganese	04-008	mg/kg	0.103	<0.1	0.142	<0.1
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	0.51	0.50	0.61	<0.5
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.6	2.4	2.9	2.5

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Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/33 M33 12/11/2016	/34 M34 11/11/2016	/35 M35 11/11/2016	/36 M36 11/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	12	27	13	16
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.12	0.14	0.24	0.12
Iron	04-008	mg/kg	0.90	1.4	1.2	1.1
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	1.2	1.4	1.4	0.80
Manganese	04-008	mg/kg	<0.1	0.103	0.116	<0.1
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	<0.5	0.51	<0.5	<0.5
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.5	2.8	2.6	2.5

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/37 M37 11/11/2016	/38 M38 12/11/2016	/39 M39 13/11/2016	/40 M40 04/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	34	2.8	13	22
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.31	0.11	0.14	0.15
Iron	04-008	mg/kg	1.4	0.71	1.2	1.5
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	1.1	0.051	1.5	0.89
Manganese	04-008	mg/kg	0.112	<0.1	<0.1	0.103
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	<0.5	<0.5	<0.5	<0.5
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.3	2.2	3.0	2.9

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Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/41 L1 03/11/2016	/42 L2 04/11/2016	/43 L3 04/11/2016	/44 L4 04/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	7.5	7.4	15	7.6
Cadmium	04-008	mg/kg	9.8	1.8	1.6	0.84
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	3.9	1.4	1.7	1.4
Iron	04-008	mg/kg	47	88	100	66
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	1.5	0.17	0.072	0.065
Manganese	04-008	mg/kg	0.279	0.422	0.588	0.557
Nickel	04-008	mg/kg	<0.06	<0.06	0.065	0.072
Selenium	04-008	mg/kg	0.78	1.5	0.89	1.2
Silver	04-008	mg/kg	0.20	<0.1	0.11	<0.1
Zinc	04-008	mg/kg	13	8.0	11	7.1

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/45 L5 04/11/2016	/46 L6 04/11/2016	/47 L7 04/11/2016	/48 L8 04/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	13	15	4.0	9.0
Cadmium	04-008	mg/kg	0.46	2.3	4.5	2.2
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	1.1	2.4	20	1.4
Iron	04-008	mg/kg	81	93	86	62
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.043	0.12	0.34	0.13
Manganese	04-008	mg/kg	0.587	0.454	0.567	0.311
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	0.97	0.93	4.0	0.75
Silver	04-008	mg/kg	<0.1	0.17	0.23	<0.1
Zinc	04-008	mg/kg	8.6	9.2	45	8.0

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Batch Number: A16/4468Q [R00]
Project Reference: Metal Analysis - Fish Tissue

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/49 L9 04/11/2016	/50 L10 04/11/2016	/51 L11 04/11/2016	/52 L12 05/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	8.0	11	6.6	5.9
Cadmium	04-008	mg/kg	3.3	2.7	1.1	12
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	2.3	1.7	1.7	5.0
Iron	04-008	mg/kg	100	100	64	100
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.37	0.056	4.4	0.67
Manganese	04-008	mg/kg	0.210	0.478	0.352	0.178
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	0.073
Selenium	04-008	mg/kg	0.56	0.85	1.0	1.7
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	0.12
Zinc	04-008	mg/kg	11	9.3	6.7	15

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/53 L13 05/11/2016	/54 L14 05/11/2016	/55 L15 05/11/2016	/56 L16 05/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	8.1	5.0	9.8	9.9
Cadmium	04-008	mg/kg	6.5	0.46	3.4	6.7
Chromium	04-008	mg/kg	<0.1	<0.1	0.11	<0.1
Copper	04-008	mg/kg	1.6	1.3	1.3	2.0
Iron	04-008	mg/kg	92	31	96	120
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.023	0.050	0.052	0.74
Manganese	04-008	mg/kg	0.338	0.363	0.264	0.145
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	0.75	0.92	0.64	<0.5
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	12	4.5	10	15

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Batch Number: A16/4468Q [R00]

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Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/57 L17 07/11/2016	/58 L18 07/11/2016	/59 L19 07/11/2016	/60 L20 07/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	1.3	6.8	8.6	11
Cadmium	04-008	mg/kg	7.8	4.9	1.8	0.90
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	0.23
Copper	04-008	mg/kg	25	1.8	2.7	0.98
Iron	04-008	mg/kg	260	89	130	47
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	14	0.055	0.048	0.063
Manganese	04-008	mg/kg	0.997	0.207	0.542	0.548
Nickel	04-008	mg/kg	<0.06	0.095	<0.06	0.14
Selenium	04-008	mg/kg	6.5	0.59	0.88	1.2
Silver	04-008	mg/kg	0.70	0.11	0.22	<0.1
Zinc	04-008	mg/kg	48	11	10	7.5

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/61 L21 07/11/2016	/62 L22 07/11/2016	/63 L23 07/11/2016	/64 L24 07/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	16	6.8	7.9	18
Cadmium	04-008	mg/kg	2.8	0.31	0.34	0.78
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	1.3	1.1	1.0	1.6
Iron	04-008	mg/kg	91	37	55	91
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.048	0.052	0.049	1.5
Manganese	04-008	mg/kg	0.231	0.564	0.475	0.416
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	0.82	1.2	1.4	0.75
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	8.4	5.8	5.7	7.2

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Batch Number: A16/4468Q [R00]
Project Reference: Metal Analysis - Fish Tissue

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/65 L25 07/11/2016	/66 L26 09/11/2016	/67 L27 09/11/2016	/68 L28 12/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	5.2	11	3.3	10
Cadmium	04-008	mg/kg	0.43	4.8	0.55	23
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.72	1.1	1.4	1.2
Iron	04-008	mg/kg	40	55	40	58
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.043	0.054	0.048	0.051
Manganese	04-008	mg/kg	0.445	<0.1	0.454	0.108
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	0.95	<0.5	1.4	0.65
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	0.13
Zinc	04-008	mg/kg	4.5	9.1	5.5	14

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/69 L29 12/11/2016	/70 L30 12/11/2016	/71 L31 12/11/2016	/72 L32 12/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	11	17	3.4	12
Cadmium	04-008	mg/kg	20	5.4	3.3	10
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	1.7	2.4	0.57	1.6
Iron	04-008	mg/kg	110	180	17	49
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.047	0.052	0.052	0.048
Manganese	04-008	mg/kg	0.306	0.546	<0.1	0.169
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	1.6	1.0	1.0	0.73
Silver	04-008	mg/kg	0.19	0.24	<0.1	<0.1
Zinc	04-008	mg/kg	22	22	3.5	12

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Batch Number: A16/4468Q [R00]
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Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/73 L33 12/11/2016	/74 L34 11/11/2016	/75 L35 11/11/2016	/76 L36 11/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	4.8	1.2	3.9	9.5
Cadmium	04-008	mg/kg	2.0	0.32	3.0	1.7
Chromium	04-008	mg/kg	0.11	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.51	0.056	0.27	1.6
Iron	04-008	mg/kg	66	6.1	38	100
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.048	0.048	0.053	0.051
Manganese	04-008	mg/kg	0.118	<0.1	<0.1	0.290
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	<0.5	<0.5	<0.5	0.58
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	5.9	0.63	6.3	8.2

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/77 L37 11/11/2016	/78 L38 12/11/2016	/79 L39 13/11/2016	/80 L40 04/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	16	19	8.4	20
Cadmium	04-008	mg/kg	14	2.3	4.6	3.8
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	2.7	6.4	2.2	2.7
Iron	04-008	mg/kg	73	640	110	44
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.032	0.032	0.052	0.037
Manganese	04-008	mg/kg	0.253	1.56	0.245	0.307
Nickel	04-008	mg/kg	<0.06	<0.06	0.063	<0.06
Selenium	04-008	mg/kg	0.62	2.7	0.90	0.64
Silver	04-008	mg/kg	0.25	<0.1	0.11	<0.1
Zinc	04-008	mg/kg	16	48	11	10

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Batch Number: A16/4468Q [R00]
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Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/81 MM1 05/11/2016	/82 MM2 05/11/2016	/83 MM3 05/11/2016	/84 MM4 05/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	1.8	5.7	<0.4	0.41
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.11	0.14	0.66	0.11
Iron	04-008	mg/kg	0.89	1.3	16	0.56
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.050	0.19	0.71	0.033
Manganese	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	<0.5	<0.5	0.67	0.53
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.5	3.4	4.8	2.8

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/85 MM5 05/11/2016	/86 MM6 09/11/2016	/87 MM7 09/11/2016	/88 MM8 09/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	2.6	3.9	0.83	3.6
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.12	0.088	0.16	0.082
Iron	04-008	mg/kg	1.1	0.80	1.3	0.78
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.053	0.21	0.35	0.20
Manganese	04-008	mg/kg	<0.1	<0.1	<0.1	0.101
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	0.50	<0.5	<0.5	<0.5
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.6	2.2	2.4	2.5

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Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/89 MM9 10/11/2016	/90 MM10 10/11/2016	/91 MM11 10/11/2016	/92 MM12 12/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	2.3	5.0	0.55	6.2
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.10	0.19	0.29	0.10
Iron	04-008	mg/kg	0.74	1.5	4.2	1.0
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.24	0.25	0.34	0.36
Manganese	04-008	mg/kg	<0.1	<0.1	0.105	<0.1
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	<0.5	<0.5	1.1	<0.5
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.6	3.1	4.2	2.3

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/93 MM13 12/11/2016	/94 MM14 11/11/2016	/95 LL1 05/11/2016	/96 LL2 05/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	0.40	0.60	4.4	12
Cadmium	04-008	mg/kg	<0.05	<0.05	5.5	1.7
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.41	0.59	4.3	2.7
Iron	04-008	mg/kg	8.3	7.1	35	120
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.58	0.44	0.40	0.93
Manganese	04-008	mg/kg	<0.1	<0.1	2.41	0.941
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	0.063
Selenium	04-008	mg/kg	0.87	0.72	2.2	2.0
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	4.4	3.4	49	32

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Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/97 LL3 05/11/2016	/98 LL4 05/11/2016	/99 LL5 05/11/2016	/100 LL6 09/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	0.71	1.3	4.2	16
Cadmium	04-008	mg/kg	2.6	0.16	0.36	2.0
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	5.6	6.6	17	4.7
Iron	04-008	mg/kg	680	100	570	190
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	1.9	0.16	0.72	0.94
Manganese	04-008	mg/kg	1.29	1.16	2.21	1.04
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	2.9	1.3	2.7	2.8
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	49	34	55	48

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/101 LL7 09/11/2016	/102 LL8 09/11/2016	/103 LL9 10/11/2016	/104 LL10 10/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	2.6	13	3.5	7.7
Cadmium	04-008	mg/kg	6.3	2.1	1.4	1.3
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	5.1	2.8	1.8	2.7
Iron	04-008	mg/kg	210	160	48	760
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	1.3	0.93	0.40	0.51
Manganese	04-008	mg/kg	1.74	0.962	0.927	1.32
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	4.2	2.1	1.8	2.8
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	58	36	22	35

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Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/105 LL11 10/11/2016	/106 LL12 12/11/2016	/107 LL13 12/11/2016	/108 LL14 11/11/2016
Trace Elements						
Arsenic	04-008	mg/kg	1.4	10	1.3	2.4
Cadmium	04-008	mg/kg	0.74	2.8	2.8	1.8
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	2.6	2.6	3.0	5.7
Iron	04-008	mg/kg	540	91	430	820
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.73	1.9	2.0	0.89
Manganese	04-008	mg/kg	1.32	1.31	1.54	1.62
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	2.9	1.7	3.0	3.7
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	35	29	42	38

Method	Method Description
04-008	Metals in food by ICP-OES
04-006	Mercury in food by CVAAS, mg/kg

Result Comments
[<] Less than
[INS] Insufficient sample for this test
[NA] Test not required
*Analyte is not covered by NATA scope of accreditation.
- Spike recovery for Fe sample No.57 could not be accurately determined due to a significant background analyte concentration.

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QUALITY ASSURANCE REPORT

TEST	UNITS	Blank	Duplicate Sm#	Duplicate Results	Spike Sm#	Spike Results
Arsenic	mg/kg	<0.4	A16/4468Q-1	6.9 || 6.7 || RPD: 3	A16/4468Q-1	79%
Cadmium	mg/kg	<0.05	A16/4468Q-1	<0.05 || <0.05	A16/4468Q-1	77%
Chromium	mg/kg	<0.1	A16/4468Q-1	0.19 || 0.10 || RPD: 62	A16/4468Q-1	76%
Copper	mg/kg	<0.05	A16/4468Q-1	2.4 || 1.8 || RPD: 29	A16/4468Q-1	88%
Iron	mg/kg	<0.5	A16/4468Q-1	2.0 || 1.5 || RPD: 29	A16/4468Q-1	73%
Lead	mg/kg	<0.1	A16/4468Q-1	<0.1 || <0.1	A16/4468Q-1	71%
Mercury	mg/kg	<0.01	A16/4468Q-1	2.2 || 1.9 || RPD: 15	A16/4468Q-1	105%
Manganese	mg/kg	<0.1	A16/4468Q-1	0.132 || 0.112 || RPD: 16	A16/4468Q-1	76%
Nickel	mg/kg	<0.06	A16/4468Q-1	0.073 || 0.064 || RPD: 13	A16/4468Q-1	75%
Selenium	mg/kg	<0.5	A16/4468Q-1	0.71 || 0.60 || RPD: 17	A16/4468Q-1	80%
Silver	mg/kg	<0.1	A16/4468Q-1	<0.1 || <0.1	A16/4468Q-1	85%
Zinc	mg/kg	<0.2	A16/4468Q-1	3.7 || 3.0 || RPD: 21	A16/4468Q-1	71%

TEST	Units	Blank	Duplicate Sm#	Duplicate Results	Spike Sm#	Spike Results
Arsenic	mg/kg	<0.4	A16/4468Q-11	18 || 18 || RPD: 0	A16/4468Q-21	116%
Cadmium	mg/kg	<0.05	A16/4468Q-11	<0.05 || <0.05	A16/4468Q-21	105%
Chromium	mg/kg	<0.1	A16/4468Q-11	<0.1 || <0.1	A16/4468Q-21	100%
Copper	mg/kg	<0.05	A16/4468Q-11	0.30 || 0.29 || RPD: 3	A16/4468Q-21	86%
Iron	mg/kg	<0.5	A16/4468Q-11	1.2 || 1.1 || RPD: 9	A16/4468Q-21	99%
Lead	mg/kg	<0.1	A16/4468Q-11	<0.1 || <0.1	A16/4468Q-21	96%
Mercury	mg/kg	<0.01	A16/4468Q-11	0.39 || 0.39 || RPD: 0	A16/4468Q-21	107%
Manganese	mg/kg	<0.1	A16/4468Q-11	<0.1 || <0.1	A16/4468Q-21	101%
Nickel	mg/kg	<0.06	A16/4468Q-11	<0.06 || <0.06	A16/4468Q-21	99%
Selenium	mg/kg	<0.5	A16/4468Q-11	0.60 || <0.5	A16/4468Q-21	111%
Silver	mg/kg	<0.1	A16/4468Q-11	<0.1 || <0.1	A16/4468Q-21	85%
Zinc	mg/kg	<0.2	A16/4468Q-11	2.6 || 2.7 || RPD: 4	A16/4468Q-21	104%

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Batch Number: A16/4468Q [R00]
Project Reference: Metal Analysis - Fish Tissue

TEST	Units	Blank	Duplicate Sm#	Duplicate Results	Spike Sm#	Spike Results
Arsenic	mg/kg	<0.4	A16/4468Q-21	18 || 19 || RPD: 5	A16/4468Q-40	117%
Cadmium	mg/kg	<0.05	A16/4468Q-21	<0.05 || <0.05	A16/4468Q-40	104%
Chromium	mg/kg	<0.1	A16/4468Q-21	<0.1 || <0.1	A16/4468Q-40	100%
Copper	mg/kg	<0.05	A16/4468Q-21	0.14 || 0.14 || RPD: 0	A16/4468Q-40	86%
Iron	mg/kg	<0.5	A16/4468Q-21	1.3 || 1.0 || RPD: 26	A16/4468Q-40	103%
Lead	mg/kg	<0.1	A16/4468Q-21	<0.1 || <0.1	A16/4468Q-40	95%
Mercury	mg/kg	<0.01	A16/4468Q-21	0.99 || 1.0 || RPD: 1	A16/4468Q-40	99%
Manganese	mg/kg	<0.1	A16/4468Q-21	<0.1 || <0.1	A16/4468Q-40	100%
Nickel	mg/kg	<0.06	A16/4468Q-21	<0.06 || <0.06	A16/4468Q-40	99%
Selenium	mg/kg	<0.5	A16/4468Q-21	0.69 || 0.62 || RPD: 11	A16/4468Q-40	112%
Silver	mg/kg	<0.1	A16/4468Q-21	<0.1 || <0.1	A16/4468Q-40	82%
Zinc	mg/kg	<0.2	A16/4468Q-21	2.8 || 2.9 || RPD: 4	A16/4468Q-40	108%

TEST	Units	Blank	Duplicate Sm#	Duplicate Results	Spike Sm#	Spike Results
Arsenic	mg/kg	<0.4	A16/4468Q-31	20 || 21 || RPD: 5	A16/4468Q-57	108%
Cadmium	mg/kg	<0.05	A16/4468Q-31	0.074 || 0.075 || RPD: 1	A16/4468Q-57	101%
Chromium	mg/kg	<0.1	A16/4468Q-31	<0.1 || <0.1	A16/4468Q-57	100%
Copper	mg/kg	<0.05	A16/4468Q-31	0.26 || 0.30 || RPD: 14	A16/4468Q-57	76%
Iron	mg/kg	<0.5	A16/4468Q-31	1.3 || 1.4 || RPD: 7	A16/4468Q-57	#
Lead	mg/kg	<0.1	A16/4468Q-31	<0.1 || <0.1	A16/4468Q-57	96%
Mercury	mg/kg	<0.01	A16/4468Q-31	1.2 || 1.2 || RPD: 0	A16/4468Q-57	87%
Manganese	mg/kg	<0.1	A16/4468Q-31	0.142 || 0.107 || RPD: 28	A16/4468Q-57	100%
Nickel	mg/kg	<0.06	A16/4468Q-31	<0.06 || <0.06	A16/4468Q-57	100%
Selenium	mg/kg	<0.5	A16/4468Q-31	0.61 || 0.61 || RPD: 0	A16/4468Q-57	105%
Silver	mg/kg	<0.1	A16/4468Q-31	<0.1 || <0.1	A16/4468Q-57	86%
Zinc	mg/kg	<0.2	A16/4468Q-31	2.9 || 3.0 || RPD: 3	A16/4468Q-57	114%

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TEST	Units	Blank	Duplicate Sm#	Duplicate Results	Spike Sm#	Spike Results
Arsenic	mg/kg	<0.4	A16/4468Q-40	22 || 22 || RPD: 0	A16/4468Q-81	101%
Cadmium	mg/kg	<0.05	A16/4468Q-40	<0.05 || <0.05	A16/4468Q-81	100%
Chromium	mg/kg	<0.1	A16/4468Q-40	<0.1 || <0.1	A16/4468Q-81	97%
Copper	mg/kg	<0.05	A16/4468Q-40	0.15 || 0.15 || RPD: 0	A16/4468Q-81	89%
Iron	mg/kg	<0.5	A16/4468Q-40	1.5 || 1.6 || RPD: 6	A16/4468Q-81	100%
Lead	mg/kg	<0.1	A16/4468Q-40	<0.1 || <0.1	A16/4468Q-81	92%
Mercury	mg/kg	<0.01	A16/4468Q-40	0.89 || 1.0 || RPD: 12	A16/4468Q-81	109%
Manganese	mg/kg	<0.1	A16/4468Q-40	0.103 || 0.106 || RPD: 3	A16/4468Q-81	98%
Nickel	mg/kg	<0.06	A16/4468Q-40	<0.06 || <0.06	A16/4468Q-81	95%
Selenium	mg/kg	<0.5	A16/4468Q-40	<0.5 || 0.55	A16/4468Q-81	105%
Silver	mg/kg	<0.1	A16/4468Q-40	<0.1 || <0.1	A16/4468Q-81	85%
Zinc	mg/kg	<0.2	A16/4468Q-40	2.9 || 2.9 || RPD: 0	A16/4468Q-81	105%

TEST	Units	Blank	Duplicate Sm#	Duplicate Results	Spike Sm#	Spike Results
Arsenic	mg/kg	<0.4	A16/4468Q-50	11 || 9.8 || RPD: 12	A16/4468Q-101	98%
Cadmium	mg/kg	<0.05	A16/4468Q-50	2.7 || 2.4 || RPD: 12	A16/4468Q-101	96%
Chromium	mg/kg	<0.1	A16/4468Q-50	<0.1 || <0.1	A16/4468Q-101	94%
Copper	mg/kg	<0.05	A16/4468Q-50	1.7 || 1.6 || RPD: 6	A16/4468Q-101	87%
Iron	mg/kg	<0.5	A16/4468Q-50	100 || 96 || RPD: 4	A16/4468Q-101	119%
Lead	mg/kg	<0.1	A16/4468Q-50	<0.1 || <0.1	A16/4468Q-101	88%
Mercury	mg/kg	<0.01	A16/4468Q-50	0.056 || 0.061 || RPD: 9	A16/4468Q-101	98%
Manganese	mg/kg	<0.1	A16/4468Q-50	0.478 || 0.443 || RPD: 8	A16/4468Q-101	95%
Nickel	mg/kg	<0.06	A16/4468Q-50	<0.06 || 0.076	A16/4468Q-101	91%
Selenium	mg/kg	<0.5	A16/4468Q-50	0.85 || 0.71 || RPD: 18	A16/4468Q-101	100%
Silver	mg/kg	<0.1	A16/4468Q-50	<0.1 || <0.1	A16/4468Q-101	83%
Zinc	mg/kg	<0.2	A16/4468Q-50	9.3 || 8.8 || RPD: 6	A16/4468Q-101	115%

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TEST	Units	Blank	Duplicate Sm#	Duplicate Results
Arsenic	mg/kg	[NT]	A16/4468Q-57	1.3 || 1.3 || RPD: 0
Cadmium	mg/kg	[NT]	A16/4468Q-57	7.8 || 7.6 || RPD: 3
Chromium	mg/kg	[NT]	A16/4468Q-57	<0.1 || <0.1
Copper	mg/kg	[NT]	A16/4468Q-57	25 || 24 || RPD: 4
Iron	mg/kg	[NT]	A16/4468Q-57	260 || 270 || RPD: 4
Lead	mg/kg	[NT]	A16/4468Q-57	<0.1 || <0.1
Mercury	mg/kg	[NT]	A16/4468Q-57	14 || 14 || RPD: 0
Manganese	mg/kg	[NT]	A16/4468Q-57	0.997 || 1.02 || RPD: 2
Nickel	mg/kg	[NT]	A16/4468Q-57	<0.06 || <0.06
Selenium	mg/kg	[NT]	A16/4468Q-57	6.5 || 6.8 || RPD: 5
Silver	mg/kg	[NT]	A16/4468Q-57	0.70 || 0.68 || RPD: 3
Zinc	mg/kg	[NT]	A16/4468Q-57	48 || 48 || RPD: 0

TEST	Units	Blank	Duplicate Sm#	Duplicate Results
Arsenic	mg/kg	[NT]	A16/4468Q-72	12 || 12 || RPD: 0
Cadmium	mg/kg	[NT]	A16/4468Q-72	10 || 9.8 || RPD: 2
Chromium	mg/kg	[NT]	A16/4468Q-72	<0.1 || <0.1
Copper	mg/kg	[NT]	A16/4468Q-72	1.6 || 1.5 || RPD: 6
Iron	mg/kg	[NT]	A16/4468Q-72	49 || 51 || RPD: 4
Lead	mg/kg	[NT]	A16/4468Q-72	<0.1 || <0.1
Mercury	mg/kg	[NT]	A16/4468Q-72	0.048 || 0.041 || RPD: 16
Manganese	mg/kg	[NT]	A16/4468Q-72	0.169 || 0.167 || RPD: 1
Nickel	mg/kg	[NT]	A16/4468Q-72	<0.06 || <0.06
Selenium	mg/kg	[NT]	A16/4468Q-72	0.73 || 0.68 || RPD: 7
Silver	mg/kg	[NT]	A16/4468Q-72	<0.1 || <0.1
Zinc	mg/kg	[NT]	A16/4468Q-72	12 || 12 || RPD: 0

TEST	Units	Blank	Duplicate Sm#	Duplicate Results
Arsenic	mg/kg	[NT]	A16/4468Q-81	1.8 || 1.8 || RPD: 0
Cadmium	mg/kg	[NT]	A16/4468Q-81	<0.05 || <0.05
Chromium	mg/kg	[NT]	A16/4468Q-81	<0.1 || <0.1
Copper	mg/kg	[NT]	A16/4468Q-81	0.11 || 0.11 || RPD: 0
Iron	mg/kg	[NT]	A16/4468Q-81	0.89 || 1.0 || RPD: 12
Lead	mg/kg	[NT]	A16/4468Q-81	<0.1 || <0.1
Mercury	mg/kg	[NT]	A16/4468Q-81	0.050 || 0.048 || RPD: 4
Manganese	mg/kg	[NT]	A16/4468Q-81	<0.1 || <0.1
Nickel	mg/kg	[NT]	A16/4468Q-81	<0.06 || <0.06
Selenium	mg/kg	[NT]	A16/4468Q-81	<0.5 || <0.5
Silver	mg/kg	[NT]	A16/4468Q-81	<0.1 || <0.1
Zinc	mg/kg	[NT]	A16/4468Q-81	2.5 || 2.5 || RPD: 0

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Batch Number: A16/4468Q [R00]
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TEST	Units	Blank	Duplicate Sm#	Duplicate Results
Arsenic	mg/kg	[NT]	A16/4468Q-91	0.55 || 0.53 || RPD: 4
Cadmium	mg/kg	[NT]	A16/4468Q-91	<0.05 || <0.05
Chromium	mg/kg	[NT]	A16/4468Q-91	<0.1 || <0.1
Copper	mg/kg	[NT]	A16/4468Q-91	0.29 || 0.30 || RPD: 3
Iron	mg/kg	[NT]	A16/4468Q-91	4.2 || 3.8 || RPD: 10
Lead	mg/kg	[NT]	A16/4468Q-91	<0.1 || <0.1
Mercury	mg/kg	[NT]	A16/4468Q-91	0.34 || 0.30 || RPD: 13
Manganese	mg/kg	[NT]	A16/4468Q-91	0.105 || 0.105 || RPD: 0
Nickel	mg/kg	[NT]	A16/4468Q-91	<0.06 || <0.06
Selenium	mg/kg	[NT]	A16/4468Q-91	1.1 || 1.2 || RPD: 9
Silver	mg/kg	[NT]	A16/4468Q-91	<0.1 || <0.1
Zinc	mg/kg	[NT]	A16/4468Q-91	4.2 || 3.5 || RPD: 18

TEST	Units	Blank	Duplicate Sm#	Duplicate Results
Arsenic	mg/kg	[NT]	A16/4468Q-101	2.6 || 2.7 || RPD: 4
Cadmium	mg/kg	[NT]	A16/4468Q-101	6.3 || 6.3 || RPD: 0
Chromium	mg/kg	[NT]	A16/4468Q-101	<0.1 || <0.1
Copper	mg/kg	[NT]	A16/4468Q-101	5.1 || 5.1 || RPD: 0
Iron	mg/kg	[NT]	A16/4468Q-101	210 || 200 || RPD: 5
Lead	mg/kg	[NT]	A16/4468Q-101	<0.1 || <0.1
Mercury	mg/kg	[NT]	A16/4468Q-101	1.3 || 1.2 || RPD: 8
Manganese	mg/kg	[NT]	A16/4468Q-101	1.74 || 1.89 || RPD: 8
Nickel	mg/kg	[NT]	A16/4468Q-101	<0.06 || 0.076
Selenium	mg/kg	[NT]	A16/4468Q-101	4.2 || 4.1 || RPD: 2
Silver	mg/kg	[NT]	A16/4468Q-101	<0.1 || <0.1
Zinc	mg/kg	[NT]	A16/4468Q-101	58 || 57 || RPD: 2

Comments:
RPD = Relative Percent Deviation
[NT] = Not Tested
[N/A] = Not Applicable
'#' = Spike recovery data could not be calculated due to high levels of contaminants
Acceptable replicate reproducibility limit or RPD: 30%
Acceptable matrix spike & LCS recovery limits: Trace elements 70-130%
Organic analyses 50-150%
SVOC & speciated phenols 10-140%
Surrogates 10-140%

When levels outside these limits are obtained, an investigation into the cause of the deviation is performed before the batch is accepted or rejected, and results are released.

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REPORT OF ANALYSIS

Laboratory Reference: A17/1818Q [R00]

Client: Coffey Environments Australia Pty Ltd - VIC
126 Trenerry Crescent
Abbotsford VIC 3067

Contact: Ivan Steward

Order No: 520
Project: Metal Analysis - Fish Tissue
Sample Type: Fish Tissue
No. of Samples: 40
Date Received: 15/05/2017
Date Completed: 23/05/2017

Laboratory Contact Details:

Client Services Manager: Trent Biggin
Technical Enquiries: Andrew Bradbury
Telephone: +61 7 3268 1228
Fax: +61 7 3268 1238
Email: brisbane@advancedanalytical.com.au
andrew.bradbury@advancedanalytical.com.au

Attached Results Approved By:

Rama Nimmagadda
Technical Manager

Comments:
All samples tested as submitted by client. All attached results have been checked and approved for release.
This is the Final Report and supersedes any reports previously issued with this reference number.
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Accreditation No.15109

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Batch Number: A17/1818Q [R00]
Project Reference: Metal Analysis - Fish Tissue

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/1 MD1-1 N/A	/2 MD1-2 N/A	/3 MD1-3 N/A	/4 MD2-4 N/A
Trace Elements						
Arsenic	04-008	mg/kg	18	14	21	14
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.12	0.077	0.11	0.17
Iron	04-008	mg/kg	2.6	0.93	3.0	1.8
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.21	0.16	0.081	0.11
Manganese	04-008	mg/kg	<0.1	0.113	<0.1	<0.1
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	<0.5	<0.5	<0.5	<0.5
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.3	2.1	2.3	2.0

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/5 MD3-5 N/A	/6 MD4-6 N/A	/7 MA2-7 N/A	/8 MB3-8 N/A
Trace Elements						
Arsenic	04-008	mg/kg	23	16	5.5	8.9
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.090	0.14	0.12	0.086
Iron	04-008	mg/kg	2.2	2.2	1.2	2.2
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.35	0.97	0.74	0.51
Manganese	04-008	mg/kg	0.111	<0.1	<0.1	<0.1
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	<0.5	0.52	0.53	<0.5
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.2	2.7	2.5	1.9

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Batch Number: A17/1818Q [R00]
Project Reference: Metal Analysis - Fish Tissue

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/9 MA2-9 N/A	/10 MA2-10 N/A	/11 MC3-11 N/A	/12 MA1-12 N/A
Trace Elements						
Arsenic	04-008	mg/kg	8.8	17	38	3.7
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.16	0.17	0.086	0.090
Iron	04-008	mg/kg	2.7	4.0	2.4	1.1
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.75	0.38	0.35	0.058
Manganese	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	<0.5	<0.5	<0.5	<0.5
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.4	2.5	2.1	2.8

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/13 MLABU2-13 N/A	/14 MLABU3-14 N/A	/15 ME2-15 N/A	/16 ME2-16 N/A
Trace Elements						
Arsenic	04-008	mg/kg	30	16	17	13
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	<0.1	<0.1	0.12	0.19
Copper	04-008	mg/kg	0.095	0.074	0.11	0.12
Iron	04-008	mg/kg	1.5	2.4	4.0	8.8
Lead	04-008	mg/kg	0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.30	0.14	0.99	1.1
Manganese	04-008	mg/kg	<0.1	0.103	<0.1	0.104
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	<0.5	0.52	0.53	0.56
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.1	2.0	2.1	2.3

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Batch Number: A17/1818Q [R00]
Project Reference: Metal Analysis - Fish Tissue

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/17 ME2-17 N/A	/18 MAS2-18 N/A	/19 MAS1-19 N/A	/20 MAS1-20 N/A
Trace Elements						
Arsenic	04-008	mg/kg	9.9	9.3	13	32
Cadmium	04-008	mg/kg	<0.05	<0.05	<0.05	<0.05
Chromium	04-008	mg/kg	0.16	0.12	<0.1	<0.1
Copper	04-008	mg/kg	0.098	0.11	0.11	0.10
Iron	04-008	mg/kg	2.8	2.5	1.7	1.4
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.77	0.53	0.22	0.24
Manganese	04-008	mg/kg	<0.1	<0.1	0.178	0.121
Nickel	04-008	mg/kg	<0.06	<0.06	<0.06	<0.06
Selenium	04-008	mg/kg	0.50	<0.5	<0.5	<0.5
Silver	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Zinc	04-008	mg/kg	2.0	2.0	2.4	2.6

Method	Method Description
04-008	Metals in food by ICP-OES
04-006	Mercury in food by CVAAS, mg/kg

Result Comments

[<] Less than
[INS] Insufficient sample for this test
[NA] Test not required
*Analyte is not covered by NATA scope of accreditation.
Samples 21 through 40 not reported due to samples exploding in lab during digestion.

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Batch Number: A17/1818Q [R00]
Project Reference: Metal Analysis - Fish Tissue

QUALITY ASSURANCE REPORT

TEST	UNITS	Blank	Duplicate Sm#	Duplicate Results	Spike Sm#	Spike Results
Arsenic	mg/kg	<0.4	A17/1818Q-1	18 || 18 || RPD: 0	A17/1818Q-2	93%
Cadmium	mg/kg	<0.05	A17/1818Q-1	<0.05 || <0.05	A17/1818Q-2	86%
Chromium	mg/kg	<0.1	A17/1818Q-1	<0.1 || <0.1	A17/1818Q-2	98%
Copper	mg/kg	<0.05	A17/1818Q-1	0.12 || 0.11 || RPD: 9	A17/1818Q-2	95%
Iron	mg/kg	<0.5	A17/1818Q-1	2.6 || 2.5 || RPD: 4	A17/1818Q-2	106%
Lead	mg/kg	<0.1	A17/1818Q-1	<0.1 || <0.1	A17/1818Q-2	92%
Mercury	mg/kg	<0.01	A17/1818Q-1	0.21 || 0.22 || RPD: 5	A17/1818Q-2	92%
Manganese	mg/kg	<0.1	A17/1818Q-1	<0.1 || <0.1	A17/1818Q-2	81%
Nickel	mg/kg	<0.06	A17/1818Q-1	<0.06 || <0.06	A17/1818Q-2	100%
Selenium	mg/kg	<0.5	A17/1818Q-1	<0.5 || <0.5	A17/1818Q-2	99%
Silver	mg/kg	<0.1	A17/1818Q-1	<0.1 || <0.1	A17/1818Q-2	77%
Zinc	mg/kg	<0.2	A17/1818Q-1	2.3 || 2.2 || RPD: 4	A17/1818Q-2	102%

TEST	Units	Blank	Duplicate Sm#	Duplicate Results
Arsenic	mg/kg	[NT]	A17/1818Q-11	38 || 38 || RPD: 0
Cadmium	mg/kg	[NT]	A17/1818Q-11	<0.05 || <0.05
Chromium	mg/kg	[NT]	A17/1818Q-11	<0.1 || <0.1
Copper	mg/kg	[NT]	A17/1818Q-11	0.086 || 0.087 || RPD: 1
Iron	mg/kg	[NT]	A17/1818Q-11	2.4 || 2.3 || RPD: 4
Lead	mg/kg	[NT]	A17/1818Q-11	<0.1 || <0.1
Mercury	mg/kg	[NT]	A17/1818Q-11	0.35 || 0.35 || RPD: 0
Manganese	mg/kg	[NT]	A17/1818Q-11	<0.1 || <0.1
Nickel	mg/kg	[NT]	A17/1818Q-11	<0.06 || <0.06
Selenium	mg/kg	[NT]	A17/1818Q-11	<0.5 || <0.5
Silver	mg/kg	[NT]	A17/1818Q-11	<0.1 || <0.1
Zinc	mg/kg	[NT]	A17/1818Q-11	2.1 || 2.0 || RPD: 5

Comments:

RPD = Relative Percent Deviation
[NT] = Not Tested
[N/A] = Not Applicable
'#' = Spike recovery data could not be calculated due to high levels of contaminants
Acceptable replicate reproducibility limit or RPD: 30%
Acceptable matrix spike & LCS recovery limits: Trace elements 70-130%
Organic analyses 50-150%
SVOC & speciated phenols 10-140%
Surrogates 10-140%

When levels outside these limits are obtained, an investigation into the cause of the deviation is performed before the batch is accepted or rejected, and results are released.

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