Appendix Q

Zooplankton and Micronekton Characterisation

DISCLAIMER

This disclaimer applies to and governs the disclosure and use of this Environmental Impact Statement ("EIS"), and by reading, using or relying on any part(s) of the EIS you accept this disclaimer in full.

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.

Ownership and Copyright

Reliance and Use

The EIS is intended and will be made available to CEPA, for review by CEPA and other applicable agencies of the Government of the Independent State of Papua New Guinea ("**Authorised Agencies**"), for the purpose of considering and assessing the Permit Application in accordance with the Act ("**Authorised Purpose**"), and for no other purpose whatsoever.

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The EIS is based in part on information not within the control of either the WGJV Participants or the Consultants. While the WGJV Participants and Consultants believe that the information contained in the EIS should be reliable under the conditions and subject to the limitations set forth in the EIS, they do not guarantee the accuracy of that information.

No Representations or Warranties

While the WGJV Participants, their Related Bodies Corporate and Consultants believe that the information (including any opinions, forecasts or projections) contained in the EIS should be reliable under the conditions and subject to the limitations set out therein, and provide such information in good faith, they make no warranty, guarantee or promise, express or implied, that any of the information will be correct, accurate, complete or up to date, nor that such information will remain unchanged aѐer the date of issue of the EIS to CEPA, nor that any forecasts or projections will be realised. Actual outcomes may vary materially and adversely from projected outcomes.

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- expressly disclaim any liability for any consequential, special, contingent or penal damages whatsoever.

The basis of the Consultants' engagement is that the Consultants' liability, whether under the law of contract, tort, statute, equity or otherwise, is limited as set out in the terms of their engagement with the WGJV Participants and/or their related bodies corporate.

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The WGJV Participants acknowledge and agree that, for the Authorised Purpose, the EIS may be:

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Development of Project subject to Approvals, Further Studies and Market and Operating Conditions

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.

Forward looking statements inherently involve known and unknown risks, uncertainties and other factors that may cause the Company's actual results, performance and achievements to differ materially from statements in this EIS. Relevant factors may include, but are not limited to, changes in commodity prices, foreign exchange fluctuations and general economic conditions, increased costs and demand for production inputs, the speculative nature of exploration and project development, including the risks of obtaining necessary licences and permits and diminishing quantities or grades of reserves, political and social risks, changes to the regulatory framework within which the Company operates or may in the future operate, environmental conditions including extreme weather conditions, recruitment and retention of personnel, industrial relations issues and litigation.

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.

Non-IFRS Financial Information

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.

Ore Reserves and Mineral Resources Reporting Requirements

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.

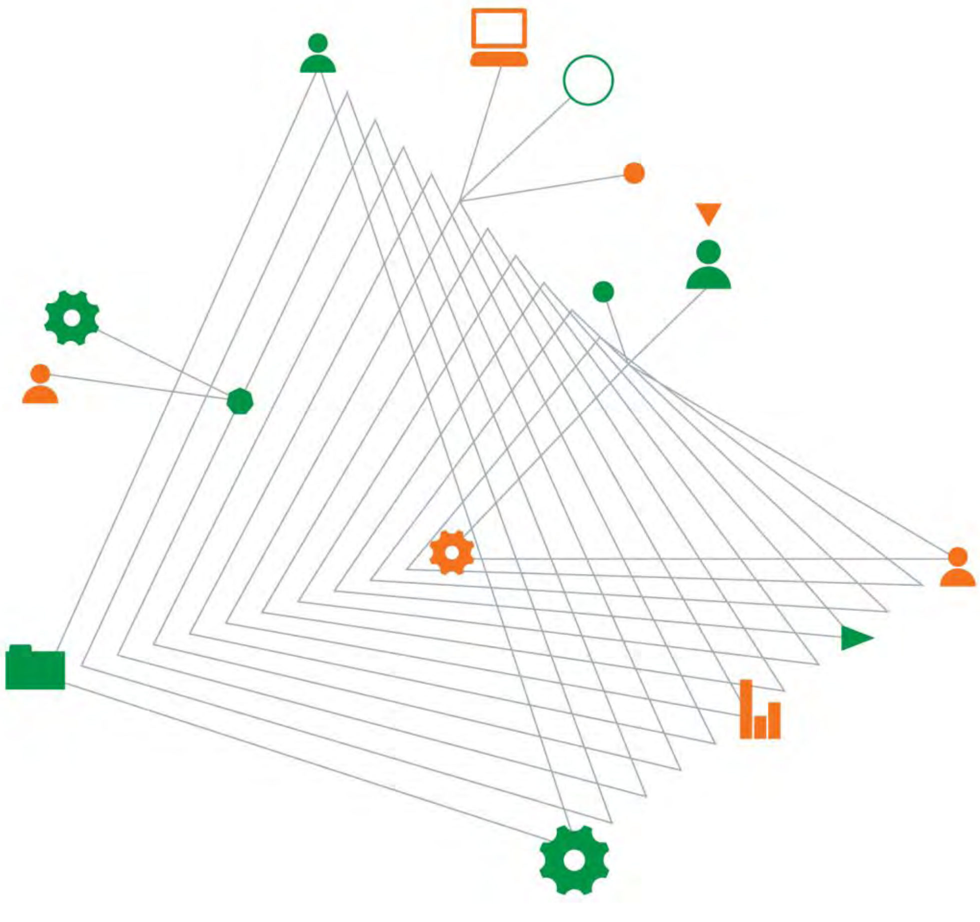
The information in the EIS that relates to Golpu Ore Reserves is based on information compiled by the Competent Person, Mr Pasqualino Manca, who is a member of The Australasian Institute of Mining and Metallurgy. Mr Pasqualino Manca, is a full-time employee of Newcrest Mining Limited or its relevant 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

Zooplankton and micronekton characterisation

25 June 2018



Experience comes to life when it is powered by expertise

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Wafi-Golpu Project

Prepared for
Wafi-Golpu Joint Venture

Prepared by
Coffey Environments Australia Pty Ltd
Level 1, 436 Johnston St
Abbotsford, VIC 3067 Australia
t: +61 3 9290 7000 f: +61 3 9290 7499
ABN: 65 140 765 902

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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” or the “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 the findings of the zooplankton and micronekton characterisation study, based on net sampling undertaken in the vicinity of the proposed Outfall Area and reference locations in the Huon Gulf in March and May 2017. The inclusion of reference sites allows for understanding of the results from the primary area of interest, i.e., within the Markham Canyon, within the regional context. The reference sites for this study were outside the Markham Canyon and approximately 13 km south of the proposed Outfall Area. The location of the sites follows the same general area where the deep-slope and pelagic fish reference sites were located.

Zooplankton are the animal component of plankton, i.e., mostly microscopic (less than 2 cm), free-swimming organisms found in the euphotic zone (the uppermost layer of the ocean that receives sufficient sunlight to permit photosynthesis; usually first 80 m), and which drift with the prevailing currents.

Micronekton are relatively small actively swimming organisms ranging in size between zooplankton (approximately 2 cm), which drift with currents, and larger nekton (more than 10 cm), which have the ability to swim freely without being affected by prevailing currents.

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.

Objectives

The objectives of the zooplankton and micronekton characterisation study were to:

- Describe the mid-water ecology (from 500 m depth to the surface) in the vicinity of the Outfall Area and one or more reference sites in terms of composition and abundance of zooplankton and micronekton, with emphasis on vertical stratification and vertical migration of these aggregations, and their association with key oceanographic variables.
- Describe the distribution and relative abundance of main zooplankton and micronekton taxa, including crustaceans (shrimps), cephalopods and small fishes up to approximately 20 cm in length, collected during two separate surveys.

- Identify the main taxa in zooplankton and micronekton in the samples.
- Determine baseline concentrations of a suite of metals and metalloids in zooplankton samples and selected micronekton taxa against which potential future changes in metal concentrations could be compared.

Study area and survey timing

Sampling of zooplankton and micronekton aggregations was designed to cover the area in the Markham Canyon in the region of the proposed Outfall Area (herein referred to as DSTP study area), and a second area approximately 6 nautical miles south of Lae (herein referred to as 'reference study area') (herein together referred to as the 'study area').

Zooplankton was sampled between 5 and 7 March 2017 at nine sites within the DSTP study area, and at two sites within the reference study area. Micronekton was sampled on 1 May 2017 at two sites within the DSTP study area. Zooplankton and micronekton were sampled during both day and night to allow comparison of the taxa assemblages, and obtain information on vertical migration.

Zooplankton sampling sites included inshore, mid-slope and offshore sites within the DSTP study area, and inshore and offshore sites within the reference study area. Micronekton sampling sites included inshore and offshore sites within the DSTP study area. Inshore sites were those within about 1 km of the shore and/or where the water depth is about 100 m and less than about 200 m. Mid-slope sites were those where seafloor depths typically ranged between about 250 m and 400 m, while 'offshore sites' comprised those furthest from the shore with depths around 500 m or more.

Key findings

The key findings from the zooplankton and micronekton characterisation study are summarised below.

Zooplankton

- Zooplankton occurred at all offshore sites in samples taken from depths between 500 m and the surface, all mid-slope sites between 250 m and the surface and all inshore sites between 100 m and the surface. However, zooplankton abundances in the DSTP study area were highly variable across sampling sites and abundances differed between relatively close sites. The lowest and highest zooplankton abundances were both recorded at inshore sites.
- The actual deepest depth at which zooplankton and micronekton aggregations occur in the DSTP study area could not be determined by net sampling during this study.
- There were no clear relationships between zooplankton abundance and site location, depth or time of sampling. However, vertical migration by zooplankton from deeper to shallower waters at night was evident by the higher abundances at night time in the shallowest samples (uppermost 100 m), particularly at inshore sites P1 and P4, and at offshore site P9.
- The conductivity-temperature-depth (CTD) data obtained in the DSTP study area during the zooplankton and micronekton sampling period showed no indication of water column stratification to a depth of at least 500 m, i.e., no layers of water with sufficiently different salinity and/or temperature profiles to prevent water column mixing. However, the data showed the presence of a pronounced shallow halocline with salinity increasing rapidly from around 24 to 29 practical salinity units (PSU) to 34 to 35 PSU in the uppermost 20 to 25 m of the water column. The vertical and horizontal extent of this shallow surface halocline is likely to vary seasonally depending on rate of river discharge, rainfall and rate of surface evaporation and is unlikely to form a clearly-defined, permanent water column stratification. Furthermore, temperature data from CTD casts in the

DSTP study area showed no obvious thermocline zone. Instead, data showed a gradual decline in temperature with depth from about 31 degrees Celsius (ºC) at the surface to 10ºC to depths of 500 m.

- The absence of discrete water stratification, at least during the study period, suggests that zooplankton and micronekton aggregations have limited or no restriction on movement vertically in the water column.
- Factors which may play a role in driving the vertical and horizontal distribution of zooplankton in the DSTP study area include daily tides, local and wind-driven ocean currents, turbidity of waters, and variable riverine discharge (and associated nutrient inputs) in the upper Huon Gulf. Furthermore, the presence of a shallow halocline is likely to influence vertical distribution of those species of zooplankton considered as ‘euryhaline’, i.e., species able to survive waters with a large salinity range, as well as those species considered as ‘stenohaline’, i.e., those which can only survive in narrow salinity ranges. In that context, purely marine stenohaline species area likely to avoid surface waters which are greatly influenced by fresh water.
- Thirty-eight zooplankton taxa groups were identified across the eleven sites sampled during the March 2017 survey. Of these, 32 taxa groups (84%) were common to all sites, depths and sampling times.
- Taxa composition identified in zooplankton assemblages from the DSTP and reference study areas are indicative of a healthy community typical of tropical marine waters (i.e., numerous, diverse taxa with no dominant one or two taxa).
- The zooplanktonic community of the Huon Gulf was dominated by crustaceans, including krill, copepods, ostracods and the ghost shrimp *Lucifer*, with those taxa accounting for 57% to 90% of the total numbers of taxa collected across all sampled sites. The next most abundant zooplankton groups comprised gelatinous taxa such as siphonophores (hydrozoans) and arrow worms (chaetognaths).
- The diversity of the zooplanktonic community increased from inshore to offshore sites in the proposed DSTP study area. However, there was considerable overlap in taxa groups across all sampled sites, suggesting that the wider area of the Huon Gulf is likely to support similar zooplankton assemblages. The wider Huon Gulf area was not sampled to confirm this hypothesis.
- Multivariate analysis performed on zooplankton data showed that taxa composition and abundance of zooplankton assemblages from offshore sites in the DSTP study area were similar to those from sites sampled in the reference study area (inshore and mid-slope sites), but different from inshore sites in the DSTP study area.
- Vertical migration by zooplankton from deeper to shallower waters at night was evident when comparing relative abundances of day versus night samples. This was evident from the higher abundances of zooplankton in night time samples taken from shallower depths and was observed at inshore sites P1 and P4 as well as mid-slope site P2 and offshore site P3.

Micronekton

- Micronekton occurred in the offshore site from depths between the maximum sampling depth of 500 m and the sea surface, and at the inshore site between 250 m and the surface.
- The greatest micronekton abundance, i.e., 1,564 individuals per 1,000 m^3, was recorded at inshore site MA-I (between 0 to 250 m depth) in the DSTP study area at night. The micronekton assemblages comprised mostly chaetognaths, copepods, siphonophores, decapods and fishes, which were common in all four samples examined.

Metals in zooplankton and micronekton

- Metals concentrations in zooplankton decreased with distance from shore; i.e., were highest at inshore sites and decreased at the mid-slope and offshore sites.
- Metals concentrations in zooplankton were higher in the proposed DSTP study area than the reference study area.
- The higher concentrations of metals in zooplankton in the inshore zone and DSTP study area is consistent with the higher suspended sediment in these areas derived from the major river discharges, as well as surface runoff and wastewater discharges from Lae.
- Metals concentrations in micronekton were highly variable across the different taxa tested. No single taxon showed significantly higher concentrations than any other taxa. Pandalid shrimp had a relatively high copper concentration (17 mg/kg; the next highest concentration being 5.8 mg/kg in a Decapoda A) and *Xenodermichthys nodulosus* had a relatively high arsenic concentration (6.4 mg/kg; the next highest concentration being 1 mg/kg in the pandalid shrimp). The reason for the elevated arsenic in this organism is not clear; however, the relatively high copper concentration in the pandalid shrimp is likely to be due to copper-based blood (haemocyanin) and the larger size of this micronekton.
- Concentrations of most metals (i.e., arsenic, cadmium, copper, lead, mercury, nickel and zinc) were notably higher in micronekton taxa than in zooplankton samples. This finding suggests some level of bioaccumulation or biomagnification from lower trophic levels (e.g., zooplankters) to higher trophic levels (e.g., micronekton).
- Zooplankton in the current study had lower metals concentrations than those sampled from a reference study area (unaffected by the mine operations) at the Lihir DSTP operation.

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Glossary

Abbreviations

°C	degrees Celsius
ANOSIM	analysis of similarities
CAP	canonical analysis of principal coordinates
CTD	conductivity-temperature-depth
DO	dissolved oxygen
DSTP	deep sea tailings placement
EIS	environmental impact statement
kHz	kilohertz
m^3	cubic metres
mg/L	milligrams per litre
mg/kg	milligrams per kilogram
NMDS	non-metric multidimensional scaling
nmi	nautical miles
PNG	Papua New Guinea
PQL	practical quantification limit
PSU	practical salinity units
SAMS	Scottish Association for Marine Science
WGJV	Wafi-Golpu Joint Venture

Terms

bioaccumulation	Increase in concentration of a pollutant from the environment to the first organism in a food chain.
biomagnification	Increase in concentration of a pollutant from one trophic level to another in a food chain.
biovolume	Total volume displaced by wet plankton sample after removal of interstitial water.
Coastal Area	The Coastal Area includes the proposed Port Facilities Area and the proposed Outfall Area.
DSTP outfall	The end of the DSTP outfall pipelines where the tailings discharge into the Markham Canyon.
DSTP study area	The nine zooplankton sampling sites and two micronekton sampling sites within the Markham Canyon, ranging from between approximately 1 to 8 km from the proposed Outfall Area.
canonical analysis	A type or ordination in which group means are represented by points in a multidimensional space.
epipelagic zone	The 0 to 200 m depth zone, seaward of the shelf-slope break; epipelagic zone is the top layer of the ocean that receives enough sunlight for photosynthesis to take place.

halocline	Vertical zone in the oceanic water column where salinity changes rapidly with depth.
micronekton	Actively swimming organisms ranging in size between larger zooplankton (equal or more than 2 cm) which drift with currents, and larger nekton (less than or equal to approximately 10 cm), which have the ability to swim freely without being affected by prevailing currents.
Outfall Area	The area encompassing the Outfall System, pipeline laydown area, choke station, access track and parking and turnaround area.
Outfall System	Includes mix/de-aeration tank and associated facilities, seawater intake pipelines and DSTP outfall pipelines. Located in the Outfall Area.
pelagic	The part of the water column that is neither close to the bottom nor near the shore.
reference study area	The two zooplankton sampling sites outside the Markham Canyon approximately 13 km south of the proposed Outfall Area.
study area	The area comprising both the DSTP study area and the reference study area.
taxa	Plural of taxon; a taxonomic group of any rank, including all subordinate groups, e.g., species, genera, families, classes and orders. Any group of organisms, populations, or taxa considered to be sufficiently distinct from other such groups to be treated as a separate unit. “Taxa groups” in this report refer to various zooplankton and micronekton taxa (animals) mostly from different families and/or orders.
thermocline	Vertical zone in oceanic water column where temperature in upper mixed layer decreases rapidly to much colder deep water below; sometimes referred to as transition layer.
Wafi-Golpu Joint Venture	Wafi-Golpu Joint Venture (acronym: WGJV) being an unincorporated joint venture between the WGJV Participants.
WGJV Participants	The participants in the Wafi-Golpu Joint Venture (WGJV), at the date of this Environmental Impact Statement, being Wafi Mining Limited and Newcrest PNG 2 Limited.
zooplankton	Animal component of plankton; mostly microscopic (equal or less than 2 cm), free-swimming organisms found in the photic zone (layer of the ocean that receives sunlight; usually first 200 m), and which drift with the prevailing currents.
zooplankters	Individual animals which form part of zooplankton aggregations.

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 (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 zooplankton and micronekton characterisation study. The study area for this report comprises an area where net sampling was undertaken in the vicinity of the proposed Outfall Area and reference locations in the Huon Gulf in March and May 2017. The inclusion of reference sites allows for understanding of the results from the primary area of interest, i.e., within the Markham Canyon, within the regional context. The reference sites for this study were outside the

Markham Canyon and approximately 13 km south of the proposed Outfall Area. The location of the sites follows the same general area where the deep-slope and pelagic fish reference sites were located.

Zooplankton are the animal component of plankton, i.e., mostly microscopic (less than 2 cm), free-swimming organisms found in the euphotic zone (the uppermost layer of the ocean that receives sufficient sunlight to permit photosynthesis; usually first 80 m), and which drift with the prevailing currents.

Micronekton are relatively small actively swimming organisms ranging in size between zooplankton (approximately 2 cm), which drift with currents, and larger nekton (more than 10 cm), which have the ability to swim freely against prevailing currents.

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 aim of this characterisation study was to collect and analyse zooplankton and micronekton in the Huon Gulf to characterise the mid-water ecology of zooplankton and micronekton in the vicinity of the Outfall Area and nearby reference sites.

This study also investigated aspects of vertical migration of zooplankton in the water column to examine the likelihood of zooplankton being exposed to any source of elevated dissolved and fine particulate metals, being transported to above the mixed layer depth.

Specifically, the objectives of the zooplankton and micronekton characterisation study were to:

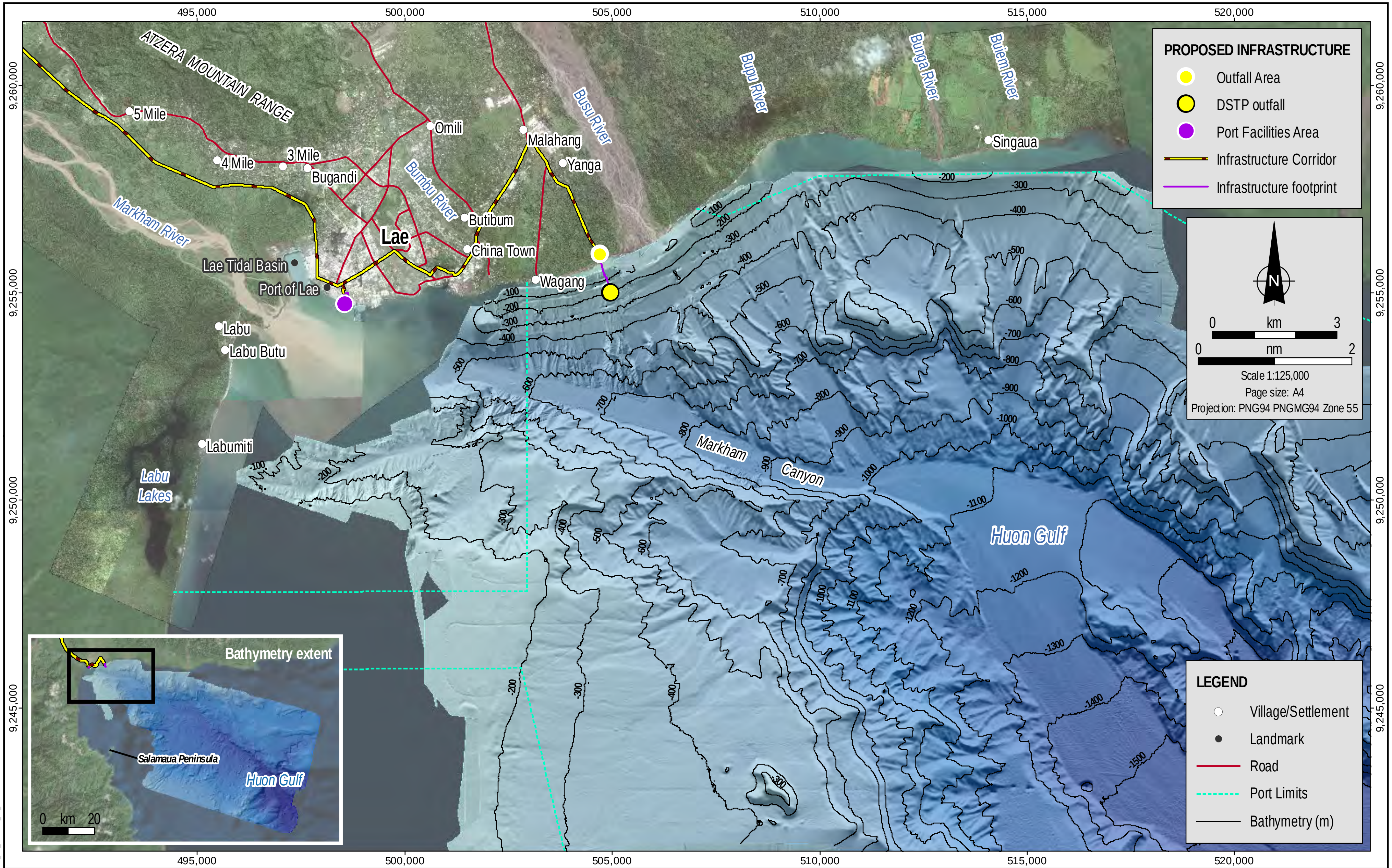
- Describe mid-water ecology (from 500 m depth to the surface) in the DSTP study area and one or more reference sites in terms of composition and abundance of zooplankton and micronekton, with emphasis on vertical migration of these aggregations, and their association with key oceanographic variables.
- Describe the distribution and relative abundance of main zooplankton and micronekton taxa, including crustaceans (shrimps), cephalopods and small fishes up to ~200 mm in length, collected during two separate surveys.
- Identify the main taxa in zooplankton and micronekton aggregations.
- Determine baseline concentrations of a suite of metals and metalloids in zooplankton samples and selected micronekton taxa against which potential future changes in metal concentrations could be compared.
- Provide information to inform the Feasibility Study Update and EIS assessment.

The objectives of this study are consistent with the Draft Guidelines and Criteria for mining operations in Papua New Guinea (PNG) involving DSTP developed by the Scottish Association for Marine Science (SAMS) Research Services Limited (SRSL, 2010).

1.3. Huon Gulf system

The Huon Gulf is located in the Morobe Province in eastern PNG, along the northern Huon Peninsula. The main city is Lae, which is situated in a low coastal plain between the Markham River to the west and the Busu River to the east. Several rivers with high sediment loads discharge into the Huon Gulf, including the large Markham River adjacent to Lae, as well as the Busu, Bumbu, Bupu, Bunga and Buiem rivers to the east.

A major bathymetric feature of the Huon Gulf is a very narrow shelf and the Markham Canyon, a deep formation with steep walls. The canyon floor itself is a relatively gentle slope (approximately 3 degrees). The canyon starts at the mouth of the Markham River and continues in a south easterly direction offshore to depths of over 1,000 m. The steep canyon profile allows terrigenous sediments discharging from the above rivers to be transported and eventually settle over the slopes in deeper waters. An overview of the Huon Gulf system is shown in Figure 1.1.



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

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Wafi-Golpu Project

Huon Gulf system

Figure No: 1.1

MXD Reference: 0520CC_16_GIS001_v0_3

2. Methods

The Draft General Guidelines for DSTP in PNG (SRSL, 2010) informed the zooplankton and micronekton characterisation study methodology, which call for consideration of, *inter alia*:

- Assessment of impact on the pelagic zone during the production period, e.g., increased turbidity and transfer of toxic components to the pelagic food web.
- Influence of DSTP on marine resources, e.g., fisheries.
- The vertical plankton migration zone.

The Draft General Guidelines for DSTP in PNG also direct that *"sampling of sediment, water column, suspended particulate material and benthic and pelagic communities must be carried out using internationally recognised and validated methods and sampling gear and must be statistically valid. It is recognised that for some components such as mega benthos and pelagic fish it may be difficult to obtain the number of samples required to be statistically valid, however every effort should be made to obtain the necessary sample size."*

This zooplankton and micronekton characterisation study was designed using internationally recognised and validated methods for zooplankton and micronekton characterisation (e.g., Suthers & Rissik (2009)), including quantitative data recording to ensure consistency with future sampling needs.

This section describes the survey dates, study team, study areas, sampling methods, sample processing methods and analysis procedures.

2.1. Survey dates and study team

Surveys for the zooplankton and micronekton characterisation study were undertaken in March and May 2017, respectively. Survey dates and personnel who participated in the two surveys are provided in Table 2.1.

Table 2.1: Survey dates and personnel

Survey	Survey dates	Personnel and role
Zooplankton	2 to 5 March 2017	• Dr Francisco J. Neira (Marscco) – survey lead and technical director • Ivan Steward (Coffey) – technician • Greg Heath (Coffey) – technician • Ian Helmond (Coffey) – winch operation
Micronekton	1 May 2017	• Dr Francisco J. Neira (Marscco) – survey lead and technical director • Ivan Steward (Coffey) – technician

An initial micronekton survey was carried out on 5 to 7 March 2017 following completion of the zooplankton survey. However, due to complications with samples during transit from Lae to the laboratory in Tasmania (see Section 2.2.2), micronekton samples from the March 2017 survey were not able to be used and for this reason the collection of micronekton was repeated in May 2017 (see Section 2.2.2).

Logistics and labour assistance was provided by the crew of the Collins Shipping vessel MV *Surveyor*, a 28-m-long vessel that was chartered for the zooplankton and micronekton surveys (Plate 2.1).

Zooplankton and micronekton samples were processed and identified by Dr Kerrie M. Swadling (Rialannah-Ridgeway Trust) (Section 2.4).

2.2. Study areas and sampling design

Sampling of zooplankton and micronekton aggregations was designed to cover the area in the Markham Canyon proposed for the DSTP outfall (herein referred to as 'DSTP study area'), and a second area approximately 6 nautical miles (nmi) south of Lae (herein referred to as 'reference study area') (see Figure 2.1). All field sampling work was carried out from the stern on the MV *Surveyor*. Sampling of zooplankton was successfully completed at nine sites in the proposed DSTP study area and at two sites within the reference study area in March 2017. Sampling of micronekton was completed at two sites in the DSTP study area in May 2017 (Section 2.3.2).

The survey design and sites sampled for the zooplankton and micronekton characterisation studies are detailed in the following sections.

2.2.1. Zooplankton

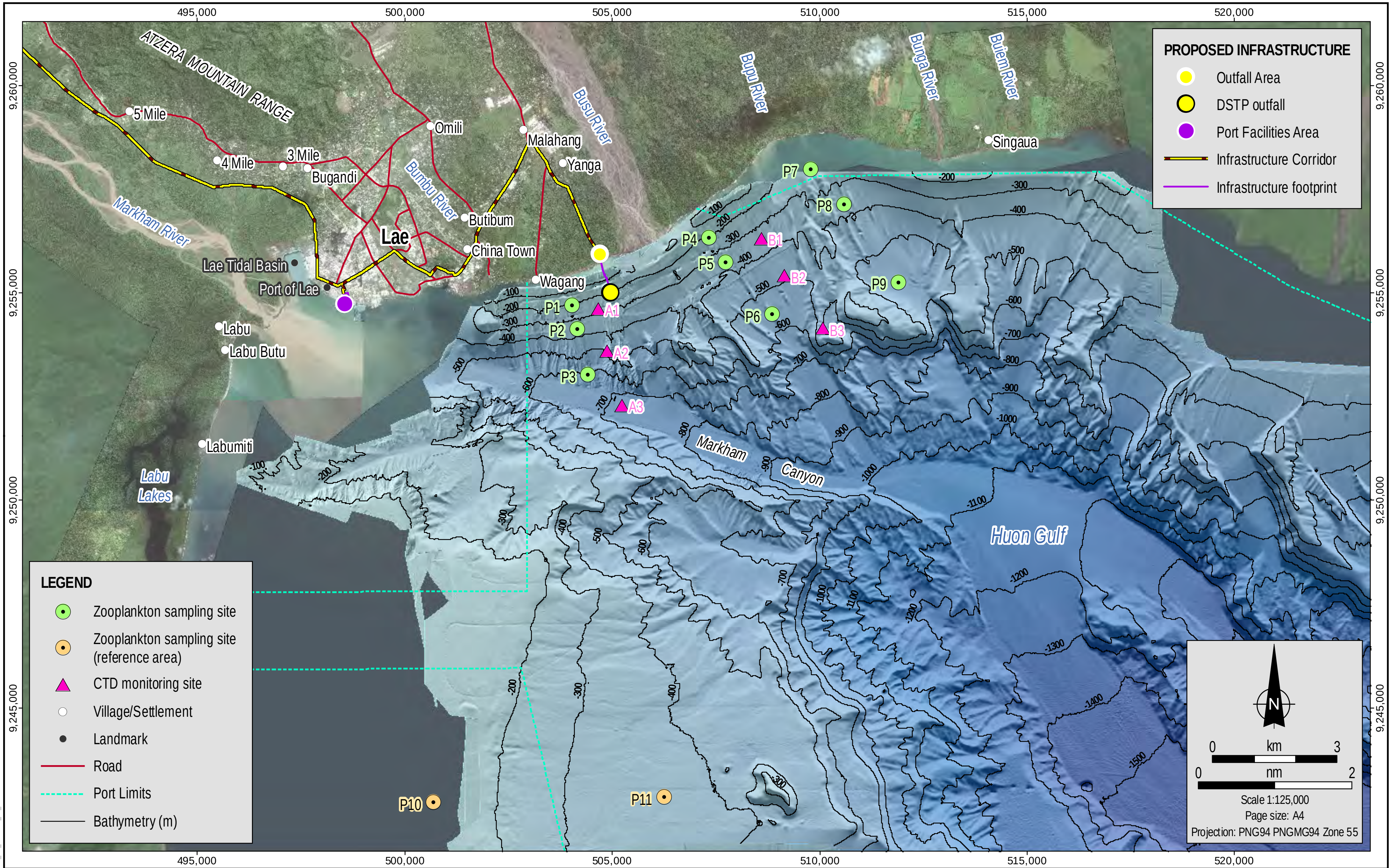
In this study zooplankton are defined as the animal component of plankton, i.e., mostly microscopic (less than 2 cm), free-swimming organisms found in the euphotic zone, and which drift in the direction of the prevailing currents.

Zooplankton sampling was carried out between 2 and 5 March 2017 at nine sites (P1 to P9) within the DSTP study area, and at two sites (P10 and P11) within the reference study area (Figure 2.1).

Sites in the DSTP study area included three inshore, three mid-slope and three offshore sites. The inshore sites P1, P4 and P7, were located between Wagang village, approximately 1.5 km west of the Outfall Area (P1), and the Bupu River (P7), over seafloor depths of 130 m to 135 m (Figure 2.1). The mid-slope sites P2, P5 and P8, were located further offshore over seafloor depths of 300 m to 350 m. The offshore sites P3, P6 and P9, were positioned further south from the mid-slope sites over depths of 550 m and 580 m. The two sampling sites in the reference study area comprised inshore site P10 at a depth of 110 m, and a mid-slope site P11 at a depth of 300 m.

Samples were taken between the surface and three different depths, i.e., 100 m, 250 m and 500 m (depending on site depth limitations), both during daytime (8 am to 4 pm) and night time (7 pm to 1 am). The rationale behind this sampling design was to examine zooplankton aggregations in terms of taxa diversity and abundances of main taxa by: (a) sites at increasing distances from the coast; (b) different depths throughout the water column; and (c) day versus night. The sampling rationale was also designed to account for vertical migration of zooplankton, a well-known feature in all the world's oceans and seas (Hays, 2003).

Sampling in the DSTP study area was successfully completed both during day and night times using a Bongo sampler equipped with two nets (see Section 2.3.1). Reference study area sites were sampled during daytime only. The number of Bongo net tows conducted per site depended on site location and depth.



Source:
CTD monitoring and zooplankton sites, villages, landmarks and infrastructure from WGJV and Coffey.
Roads and Port Limits from Coffey (Port Limits indicative only).
Bathymetry from WGJV survey.
Imagery from WGJV (capture date 2016) and ArcGIS Online (capture date unknown).

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Wafi-Golpu Project

Zooplankton sampling sites

Figure No: 2.1

MXD Reference: 0520CC_16_GIS003_v0_5

Thus, one tow was performed at each inshore site (P1, P4, P7) from 100 m to the surface, two tows at each mid-slope site (P2, P5, P8) from 100 m and 250 m to the surface, and three tows at each offshore site (P3, P6, P9) from 100 m, 250 m and 500 m to the surface. In all, 36 tows were carried out across the DSTP study area covering day and night time sampling, and comprised six, 12 and 18 tows at the inshore, mid-slope and offshore sites, respectively. Three daytime tows were completed in the reference study area, one at inshore site P10 and two at the mid-slope site P11 (Table 2.2).

The combined 39 Bongo net tows conducted during the survey period resulted in a total of 78 zooplankton samples (one sample per individual net, see Section 2.3.1), 21 of which corresponded to daytime samples and the remaining 18 to night samples. Information on the zooplankton sampling effort by site and resultant number of samples as well as daily sampling program, is summarised in Table 2.2 and Table 2.3, respectively.

Table 2.2: Zooplankton sampling effort by site and sample numbers

Site	Location	Area	Depth stratum (m)	Day sample ID	Night sample ID	Day drops	Night drops	Total number drops	Total samples
P1	Inshore	DSTP study area	100 - 0	P11-AM	P11-PM	1	1	2	4
P2	Mid-slope	DSTP study area	100 - 0	P21-AM	P21-PM	2	2	4	8
		DSTP study area	250 - 0	P22-AM	P22-PM				
P3	Offshore	DSTP study area	100 - 0	P31-AM	P31-PM	3	3	6	12
		DSTP study area	250 - 0	P32-AM	P32-PM				
		DSTP study area	500 - 0	P35-AM	P35-PM				
P4	Inshore	DSTP study area	100 - 0	P41-AM	P41-PM	1	1	2	4
P5	Mid-slope	DSTP study area	100 - 0	P51-AM	P51-PM	2	2	4	8
		DSTP study area	250 - 0	P52-AM	P52-PM				
P6	Offshore	DSTP study area	100 - 0	P61-AM	P61-PM	3	3	6	12
		DSTP study area	250 - 0	P62-AM	P62-PM				
		DSTP study area	500 - 0	P65-AM	P65-PM				
P7	Inshore	DSTP study area	100 - 0	P71-AM	P71-PM	1	1	2	4
P8	Mid-slope	DSTP study area	100 - 0	P81-AM	P81-PM	2	2	4	8
		DSTP study area	250 - 0	P82-AM	P82-PM				
P9	Offshore	DSTP study area	100 - 0	P91-AM	P91-PM	3	3	6	12
		DSTP study area	250 - 0	P92-AM	P92-PM				
		DSTP study area	500 - 0	P93-AM	P93-PM				
P10	Inshore	Reference study area	100 - 0	P101-AM	NS	1	NS	1	2
P11	Mid-slope	Reference study area	100 - 0	P111-AM	NS	2	NS	2	4
		Reference study area	250 - 0	P112-AM	NS				
TOTALS						**21**	**18**	**39**	**78**

NS = not sampled

Table 2.3: Daily zooplankton sampling program

Date	Sampling period	Sites sampled	Bongo net drops	Number of samples
2 March	Day	Inshore P1, P4, P7 Mid-slope P8 Offshore P6	5	10
	Night	Inshore P1, P4, P7 Mid-slope P2, P5, P8	6	12
3 March	Day	Mid-slope P2, P5, P8 Offshore P3, P6, P9	10	20
	Night	Mid-slope P2, P5, P8 Offshore P6, P9	5	10
4 March	Day	Inshore P10 Mid-slope P11 Offshore P3, P6, P9	6	12
	Night	Offshore P6, P9	6	12
5 March	Night	Offshore P3	1	2
TOTALS			**39**	**78**

2.2.2. Micronekton

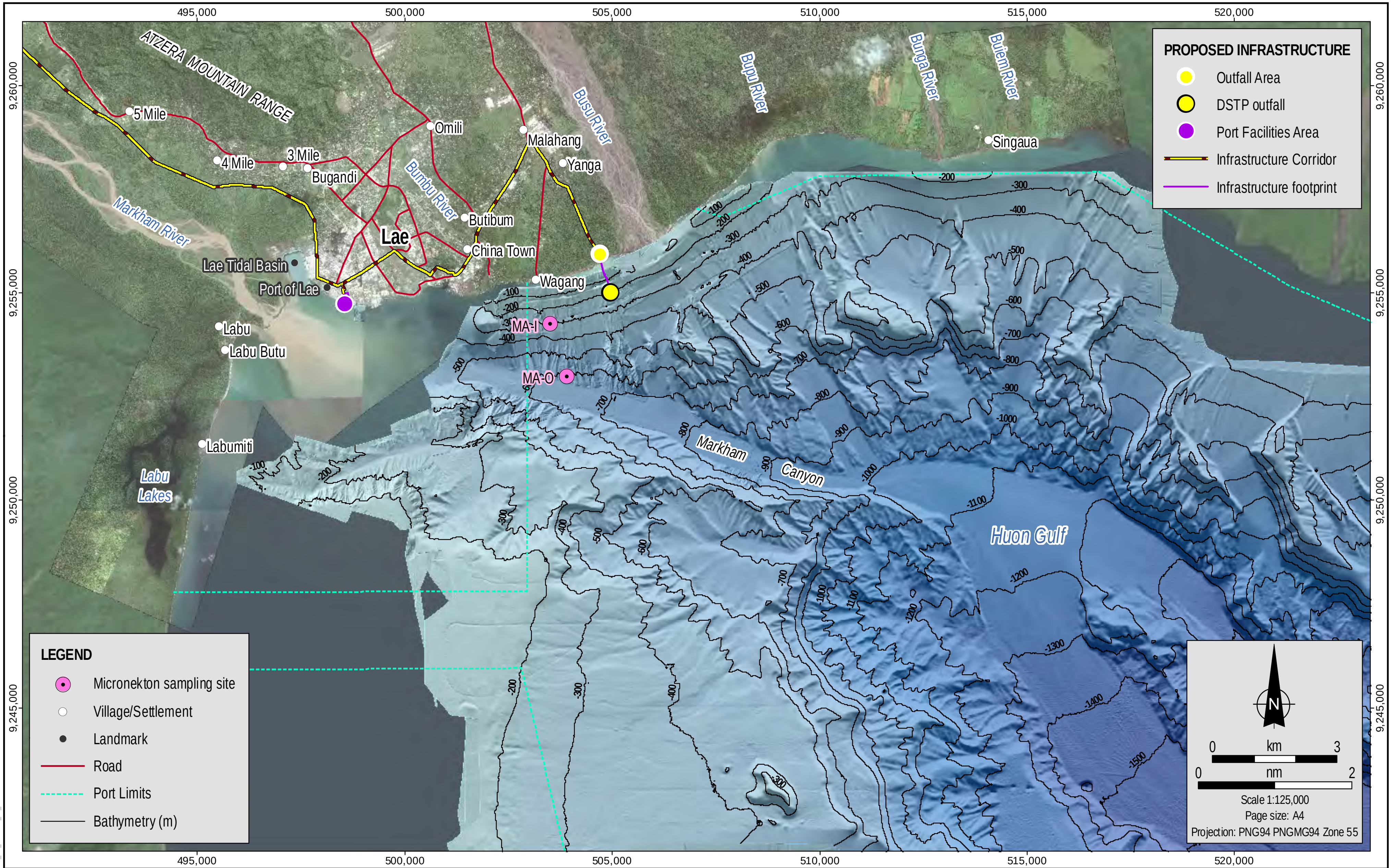
In this study micronekton are defined as small free-swimming marine organisms ranging in size between 2 cm and 10 cm, and can swim against prevailing currents.

Micronekton sampling was initially carried out on 5 to 7 March 2017 with a Tucker trawl net (see Section 2.3.2) in the DSTP and reference study areas. All 28 day/night samples obtained during this survey were frozen on board immediately after collection for taxonomic identification and analysis of metals, but could not be examined due to thawing and subsequent decomposition during their extended transit time between PNG and the intended laboratories. These samples are not discussed further in this report.

A second micronekton survey was completed on 1 May 2017, targeting two sites in the DSTP study area, namely MA-I and MA-O (Figure 2.2):

- MA-I. Site closest to the intended Outfall Area, where seafloor depth is 300 m. Samples at this site were collected to a depth of 250 m.
- MA-O. Site further offshore from MA-I, where seafloor depth is 600 m. Samples at this site were collected to a depth of 500 m.

Micronekton sampling was completed during daytime and at night, resulting in four daytime and four night samples. As with zooplankton, the rationale behind collecting day and night samples was to account for vertical migration of micronekton. Information on the micronekton sampling effort by site and resultant number of samples is summarised in Table 2.4.



MXD Reference: 0520CC_16_GIS004_v0_5

Source:
Micronekton sites, villages, landmarks and infrastructure from WGJV and Coffey.
Roads and Port Limits from Coffey (Port Limits indicative only).
Bathymetry from WGJV survey.
Imagery from WGJV (capture date 2016) and ArcGIS Online (capture date unknown).

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Wafi-Golpu Project

Micronekton sampling sites

Figure No: 2.2

Table 2.4: Micronekton sampling effort by site and sample numbers

Transect/site	Location	Depth stratum (m)	Day sample ID	Night sample ID	Day Tucker trawls	Night Tucker trawls	Total number Tucker trawls	Total number of samples
MA-I	Inshore	250 - 0	MAI-D	MAI-N	1	1	2	2
	Inshore	250 - 0	MAI-D	MAI-N	1	1	2	2
MA-O	Offshore	500 - 0	MAO-D	MAO-N	1	1	2	2
	Offshore	500 - 0	MAO-D	MAO-N	1	1	2	2
TOTALS					**4**	**4**	**8**	**8**

2.3. Sampling methods

The following sections describe the methods used to collect samples of zooplankton and micronekton for this characterisation study.

2.3.1. Zooplankton

Zooplankton was sampled using a Bongo sampler equipped with two 500-micron mesh nets, each 0.6 m in diameter and 3 m long (Plate 2.2). The nets were attached to a stainless-steel and aluminium frame fitted with a 12-kg depressor to facilitate deployment to the desired depth, and a Valeport pressure sensor to monitor and record sampler depth (m) and time during both deployment and retrieval (Plate 2.3). Each net was fitted with a hard cod end with vertical windows covered with 500-micron mesh netting (Plate 2.4). A mechanical General Oceanics flowmeter was attached at the mouth of each net to estimate amount of seawater filtered during each tow. These values are given in Table 2.5, and were used to estimate relative abundances of main taxa collected by each net in each sample (numbers per cubic metre; m^3). Nets were labelled A and B for flowmeter readings and subsequent sample handling (see below).

Deployment and retrieval of the Bongo sampler from MV Surveyor was carried out using the vessel's main deck winch, which is fitted with an 8 mm diameter, 4,000 m long oceanographic wire (Plate 2.5) and fed through a 10-tonne A-frame. The Bongo net was deployed to the desired depth at the scheduled sampling site (i.e., 100 m, 250 m or 500 m), and subsequently towed back on board in a step-wise oblique fashion to ensure similar sampling effort at different depths over a similar time period (Figure 2.3). Depth (m) of the sampler in the water column was monitored live from a PC loaded with the Valeport pressure sensor software (Plate 2.6), along with time (minutes, seconds) to manage duration of oblique tow. Depth readings from the Valeport pressure sensor greatly facilitated depth management of the Bongo sampler during each tow. Deployment time, along with site depth, flowmeter readings from each net (before and after) and GPS site coordinates, were. All tows were conducted from offshore to nearshore, starting from the deepest zone. Depending on current drift at the time of sampling, some tows were also conducted parallel to shore.

Tow times averaged 15 minutes for samples taken from water depths of 250 m and 100 m to the surface, and 20 minutes for samples taken from water depths of 500 m to the surface. Vessel speed during tows varied between 1.0 knots and 2.0 knots. Estimated water volume filtered by the two nets combined during each tow ranged from 400 m^3 to 1,080 m^3 (Table 2.5).

Photo credit: Coffey

Plate 2.1
MV *Surveyor* chartered for the zooplankton and micronekton surveys

Photo credit: Francisco Neira

Plate 2.2
500-micron (µm) mesh Bongo sampler (nets A and B) used for zooplankton sampling

Photo credit: Francisco Neira

Plate 2.3
Bongo sampler with depressor (blue - chained to the bottom of the net) to sink and steady the net in the water column, Valeport pressure sensor (secured to the bottom of the frame) to measure sample depth, and flow meters (positioned at the opening of each net) to estimate volume of filtered water during tow

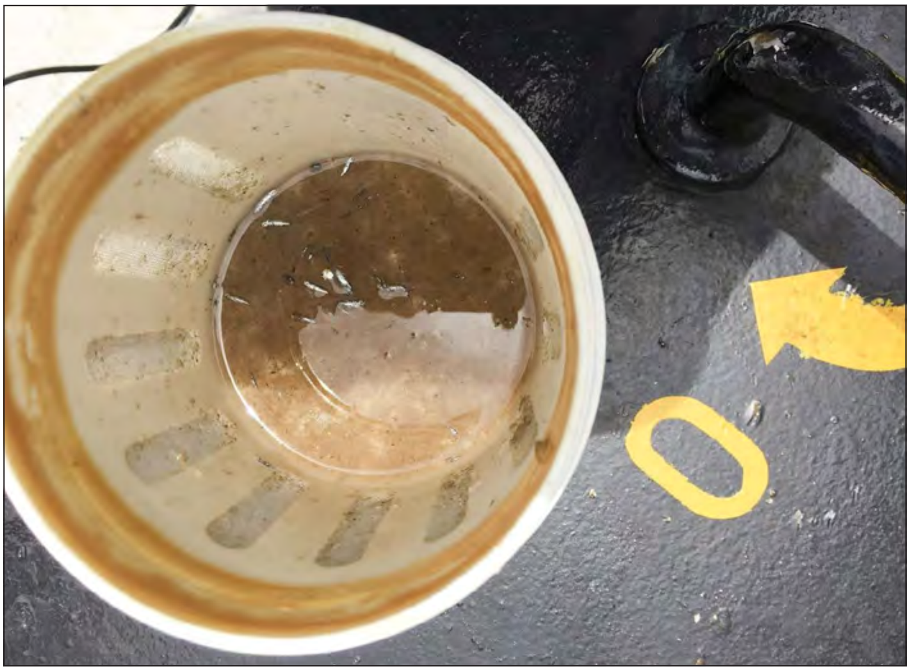


Photo credit: Francisco Neira

Plate 2.4
Cod end with typical plankton sample at the bottom; small juvenile fishes (larvae) are visible at top of sample

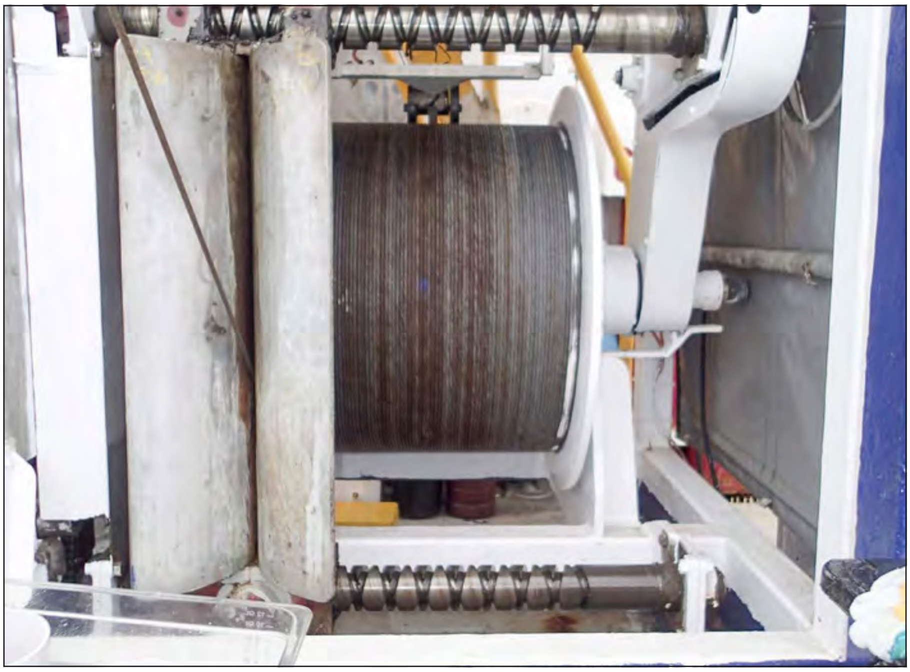


Photo credit: Coffey

Plate 2.5
MV *Surveyor's* main deck winch

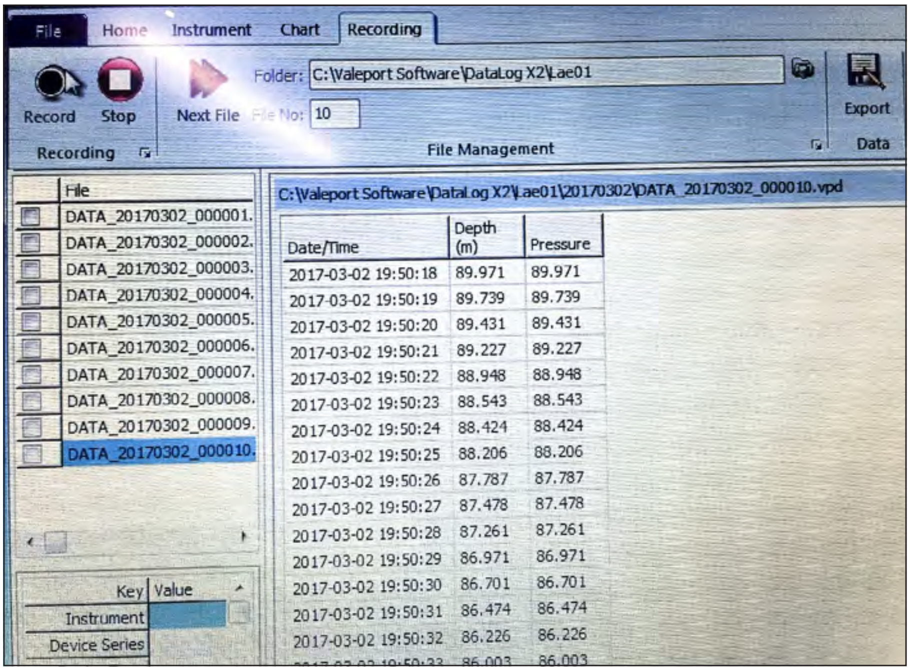
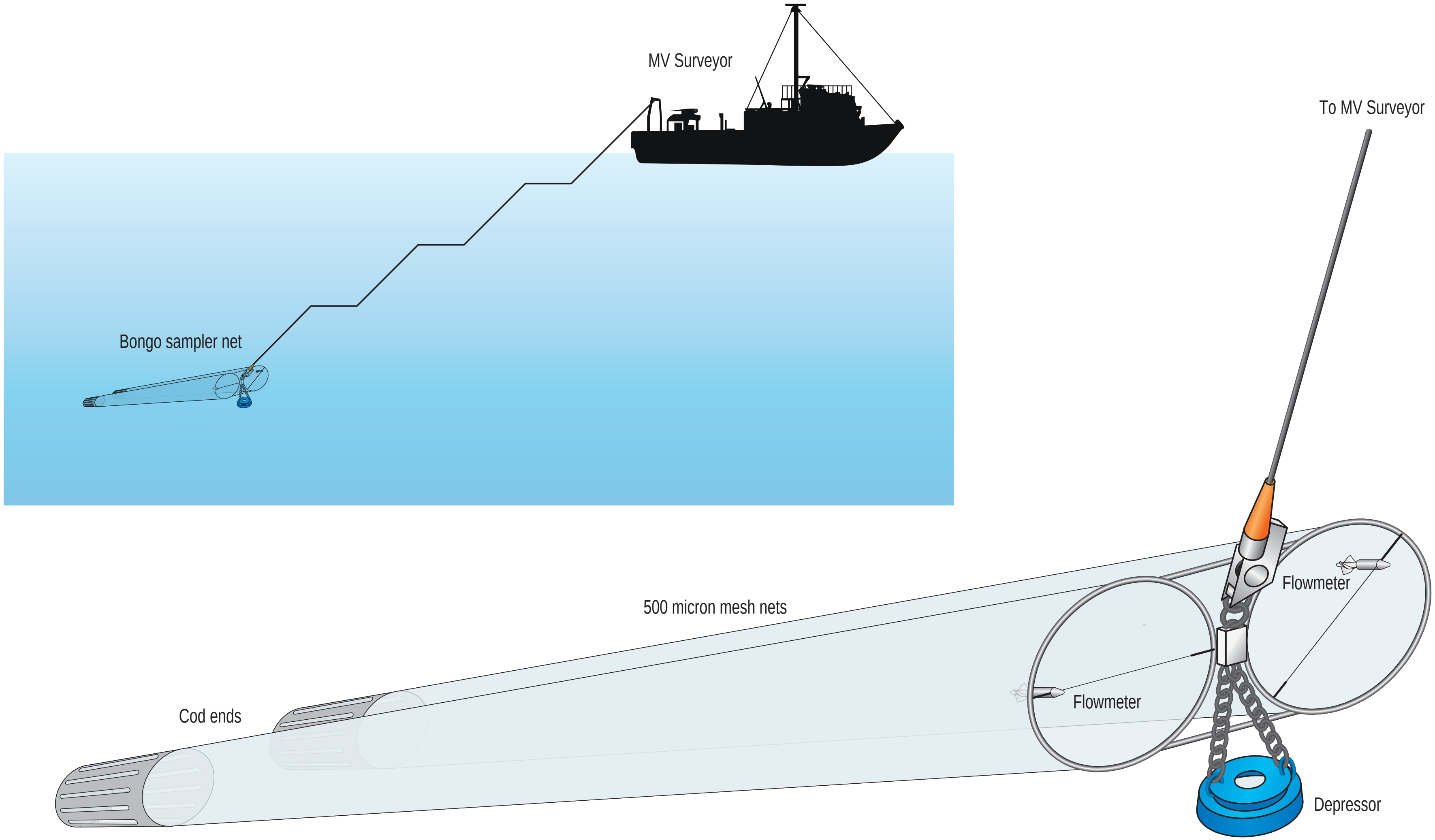


Photo credit: Francisco Neira

Plate 2.6
Screen of PC loaded with Valeport pressure sensor software used to monitor and record live (underway) date/time and depth information of Bongo net and Tucker trawl net during sampling



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Bongo sampler net towed obliquely through the water column

Figure No: 2.3

Following completion of each tow, the Bongo sampler was winched back on board and each net immediately hosed from the outside to wash all zooplankton remaining on the inside of each net thereby ensuring capture of all animals into each cod end. Zooplankton contents from each cod end were either immediately fixed in 10% formalin in 1 L containers for later identification of taxa in the laboratory, or emptied into a digestion tube (Plate 2.7) and stored in an on-board freezer (-20ºC) for subsequent metals analyses. Plastic containers used to store both fixed and frozen zooplankton samples were labelled and coded for sampling site (i.e., P1 to P11), depth (i.e., 100 m, 250 m, 500 m) and time of day (i.e., day, night) (Table 2.2). Selection of which cod end sample to fix or freeze (A or B) was made at random soon after completion of each tow.

All 78 zooplankton samples (formalin-fixed and frozen) were air-freighted to a laboratory in Hobart (Tasmania) for processing within two days of collection (see Section 2.4.1).

Sampling data for zooplankton sites P1 to P11 are provided in Table 2.5, along with date and time sampled, site depth, net volumes and sample handling method.

Table 2.5: Zooplankton sampling data collected during the 2-5 March 2017 survey

Site/depth stratum	Date sampled	Time (EST)	Actual site depth (m)	Net A volume (m^3)	Net B volume (m^3)	Fixed sample	Frozen sample
P1							
100-0 m (D)	2 March	12:15	135	446.2	443.8	Net B	Net A
100-0 m (N)	2 March	19:44	130	393.3	394.6	Net A	Net B
P2							
100-0 m (D)	3 March	08:38	320	433.7	431.6	Net B	Net A
250-0 m (D)	3 March	09:22	350	520.2	526.7	Net A	Net B
100-0 m (N)	2 March	23:05	245	246.1	249.2	Net B	Net A
250-0 m (N)	3 March	20:28	310	299.5	292.8	Net A	Net B
P3							
100-0 m (D)	3 March	14:40	450	256.3	255.4	Net B	Net A
250-0 m (D)	3 March	15:22	350	235.4	233.5	Net B	Net A
500-0 m (D)	4 March	12:04	>600	352.1	247.1	Net B	Net A
100-0 m (N)	4 March	00:33	320	274.3	277.5	Net A	Net B
250-0 m (N)	4 March	23:47	516	255.3	258.5	Net B	Net A
500-0 m (N)	4 March	23:11	>600	400.6	401.4	Net B	Net A
P4							
100-0 m (D)	2 March	13:05	135	369.0	373.0	Net B	Net A
100-0 m (N)	2 March	20:24	126	291.8	254.1	Net B	Net A
P5							
100-0 m (D)	3 March	10:09	318	370.7	376.5	Net B	Net A
250-0 m (D)	3 March	10:55	296	414.3	417.7	Net B	Net A
100-0 m (N)	2 March	22:23	250	337.4	338.7	Net A	Net B
250-0 m (N)	3 March	21:50	320	379.6	378.3	Net B	Net A

Site/depth stratum	Date sampled	Time (EST)	Actual site depth (m)	Net A volume (m^3)	Net B volume (m^3)	Fixed sample	Frozen sample
P6							
100-0 m (D)	2 March	15:42	460	255.4	251.8	Net A	Net B
250-0 m (D)	3 March	13:47	450	299.3	292.8	Net A	Net B
500-0 m (D)	4 March	10:48	560	326.7	320.2	Net B	Net A
100-0 m (N)	3 March	23:50	475	280.4	283.7	Net B	Net A
250-0 m (N)	4 March	22:10	435	231.5	229.0	Net B	Net A
500-0 m (N)	4 March	21:33	535	386.4	381.8	Net A	Net B
P7							
100-0 m (D)	2 March	14:05	120	275.4	277.4	Net B	Net A
100-0 m (N)	2 March	20:59	142	325.9	324.7	Net A	Net B
P8							
100-0 m (D)	2 March	15:02	350	343.3	344.4	Net A	Net B
250-0 m (D)	3 March	11:40	352	299.4	287.7	Net B	Net A
100-0 m (N)	2 March	21:40	372	536.8	541.7	Net B	Net A
250-0 m (N)	3 March	22:43	310	320.9	316.7	Net A	Net B
P9							
100-0 m (D)	3 March	12:12	480	279.3	282.4	Net A	Net B
250-0 m (D)	3 March	13:07	500	310.5	302.1	Net B	Net A
500-0 m (D)	4 March	09:53	>600	222.1	255.8	Net B	Net A
100-0 m (N)	3 March	23:15	475	321.5	326.1	Net A	Net B
250-0 m (N)	4 March	20:49	482	256.6	265.2	Net B	Net A
500-0 m (N)	4 March	20:10	>600	345.2	332.5	Net A	Net B
P10							
100-0 m (D)	4 March	13:43	117	237.4	249.9	Net A	Net B
100-0 m (N)	NS	-	-	-	-	-	-
P11							
100-0 m (D)	4 March	14:33	298	191.0	208.4	Net B	Net A
250-0 m (D)	4 March	15:09	298	238.7	384.4	Net B	Net A
100-0 m (N)	NS	-	-	-	-	-	-
250-0 m (N)	NS	-	-	-	-	-	-
Total samples	-	-	-	-	-	**39**	**39**

D = day; N = night; NS = not sampled

2.3.2. Micronekton

Micronekton was sampled with a Tucker trawl system fitted with a single 4 m long, 1,000-micron (1 mm) mesh net with a 1.4 m wide x 1.0 m high opening, and a 17 cm diameter hard cod end. The top of the net was attached to a stainless-steel bar while the bottom of the net was attached to a weighted galvanized pipe to facilitate continued net opening through trawl deployment and retrieval (Plate 2.8). The system was designed to tow at a 45-degree fishing angle, resulting in 1 m^2 mouth opening. A Valeport pressure sensor was fitted to the top frame net to monitor sampling depth and trawl time.

As with zooplankton sampling, the Tucker trawl was deployed from the stern of the MV *Surveyor* to the maximum desired depth (i.e., 250 m or 500 m), and subsequently towed for 20 minutes at that depth before being brought back on deck in a step-wise oblique fashion (Figure 2.4). Replicate samples were obtained at each site (MA-I and MA-O) for day and night, resulting in a total of 8 samples (Table 2.6). The depth of the Tucker trawl net in the water column was monitored live from a PC loaded with the Valeport pressure sensor software, along with time (minutes, seconds) to manage oblique tow duration during sampling. The time of deployment, depth (m) and GPS site coordinates were recorded.

Total trawling times ranged from 35 minutes to 45 minutes, at vessel speeds between 1.0 and 2.0 knots. The amount of seawater filtered during each trawl was estimated using average tow speed (1.5 knots), mouth opening area and total trawl time, and these values subsequently used to estimate relative abundance of the main taxa collected in each sample (numbers per 1,000 m^3). Water volumes filtered by the Tucker trawl net during the survey ranged from 1,080 m^3 to 1,390 m^3 (Table 2.6).

Following completion of sampling at each site, the Tucker trawl net was winched back on board and the net immediately hosed with seawater from the outside to wash all micronekton on the inside of each net into the cod end for collection. Contents from the cod end from one sample were immediately fixed in 10% formalin in 1 L containers for later identification of the main taxa at a laboratory. Contents from the replicate sample were emptied into zip lock bags and stored in an on-board freezer for subsequent metals analyses. Plastic containers and bags used to store fixed and frozen micronekton samples were labelled with sampling site (i.e., MA-I, MA-O) and time of day (i.e., D, day, and N, night) (Table 2.6).

All eight micronekton samples (formalin-fixed and frozen) were air-freighted to the laboratory in Hobart (Tasmania) for processing within two days of being collected (see Section 2.4.2). Sampling data for micronekton sites MA-I and MA-O are provided in Table 2.6, including date and time sampled, trawl times, volume filtered by trawl and sample handling method.

Table 2.6: Micronekton sampling data from 1 May 2017

Transect/ site	Desired trawl depth (m)	Time of day	Time trawl deployed	Time trawl back on deck	Total trawl time (min)	Sample handling	Volume filtered (m^3)
MA-O	500	D	13:45	14:27	42	Fixed	1,296.4
MA-O	500	D	14:33	15:18	45	Frozen	1,389.0
MA-I	250	D	15:36	16:14	38	Fixed	1,172.9
MA-I	250	D	16:20	16:55	35	Frozen	1,080.3
MA-I	250	N	19:59	20:35	36	Fixed	1,111.2
MA-I	250	N	20:47	21:24	37	Frozen	1,142.1
MA-O	500	N	21:44	22:24	40	Fixed	1,234.7
MA-O	500	N	22:41	23:23	42	Frozen	1,296.4

D = day; N = night

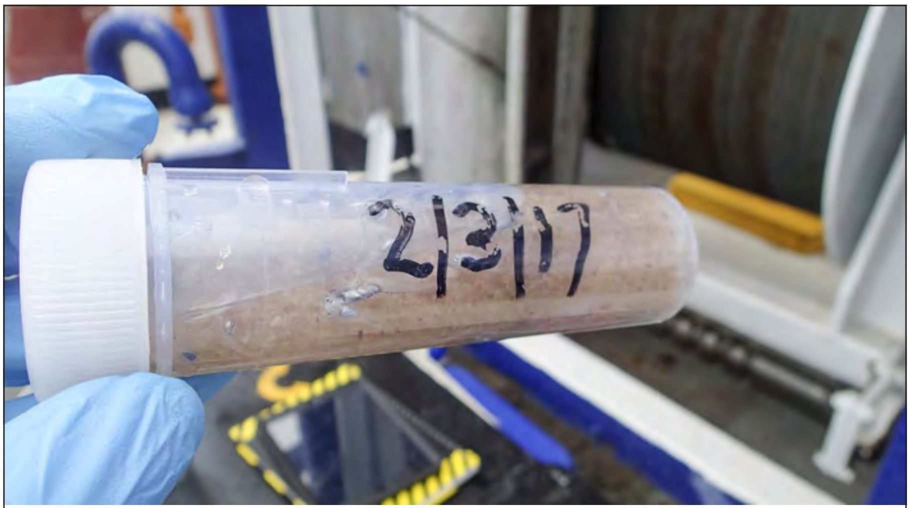
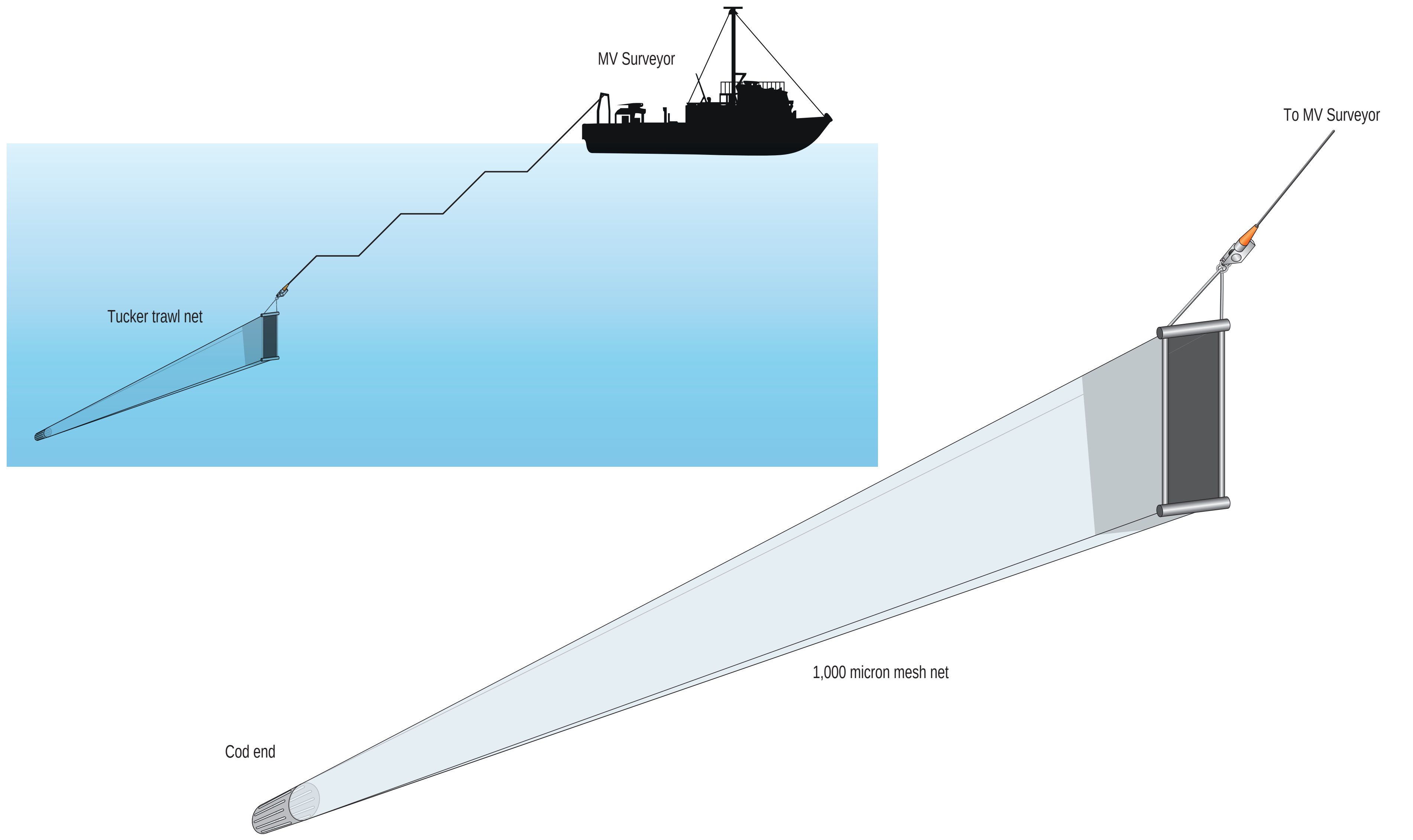


Photo credit: Francisco Neira

Plate 2.7
Digestion tube used to store zooplankton for metals analysis

Photo credit: Francisco Neira

Plate 2.8
Tucker trawl system equipped with single 1,000 micron mesh net used to collect micronekton during the 1 May 2017 survey. Hardware attached to top frame corresponds to Valeport pressure sensor to monitor trawl depth.



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Date: 20.07.2017
Project: ENAUABTF100520DD
File Name: 0520CC_16_F02.04_GRA

WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Tucker trawl net towed obliquely through the water column

Figure No: 2.4

2.4. Sample processing and identification

2.4.1. Zooplankton

All formalin-fixed zooplankton samples (n = 39) were thoroughly washed in the laboratory to remove the formaldehyde preservative, and were subsequently split with a Folsom plankton splitter until between 400 and 1,000 individuals were available for counting. All samples were examined under a Leica M165C stereomicroscope. When necessary, individuals were dissected and mounted onto glass specimen slides so that diagnostic body parts could be examined under an Olympus phase-contrast microscope with up to 400x magnification. Specimens were identified to the lowest taxonomic level possible: to genus or species for most crustaceans (except decapod larvae), family for most siphonophores, and to genus for chaetognaths and appendicularians. Identifications were confirmed using Boltovskoy (1999), Razouls *et al*. (2017) and specialist taxonomic papers. Reference specimens were photographed.

Volume of seawater filtered by the Bongo net sampler determined from flowmeters fitted in the mouth of each net (Section 2.3.1) was used to calculate the abundance of zooplankton as individuals per cubic metre.

Biovolume of each zooplankton sample was determined as displacement volume, whereby the entire sample was first passed through a 100 µm mesh sieve to remove interstitial water, then added to a known volume of filtered seawater in a graduated cylinder of 100 mL or 250 mL depending on sample size. The initial volume was subtracted from the final volume to represent the volume of the zooplankton. Biovolume was expressed as millilitres per cubic metre (mL/m^3).

Following identification and quantification of each sample, 27 of the 39 zooplankton samples were selected for measuring dry mass, according to the standard protocol of Harris *et al*. (2000). Interstitial water was removed from the sample by passing it through a 100 µm mesh sieve. The entire sample was then transferred to a pre-weighed plastic tray and dried in an oven at 60^oC for at least 24 hours. Multiple weight measurements were performed to ensure that the sample was fully dried and had reached constant mass. Weights were determined with a Mettler microbalance to the nearest 0.001 mg. Dry mass was expressed as milligrams per cubic metre. The remaining 12 zooplankton samples, collected from sites P4, P5 and P6 in the DSTP study area, were re-preserved in 4% buffered formaldehyde and archived for future reference.

2.4.2. Micronekton

The four formalin-fixed micronekton samples were thoroughly washed in the laboratory to remove the formaldehyde preservative and all animals in each sample counted. All samples were examined under a Leica M165C stereomicroscope. When necessary, individuals were dissected and mounted onto glass specimen slides so that diagnostic body parts could be examined under an Olympus phase-contrast microscope with up to 400x magnification. Specimens were identified to the lowest taxonomic level possible: to genus or species for most crustaceans (except decapod larvae), family for most siphonophores, to genus for chaetognaths and appendicularians (Boltovskoy, 1999; Razouls *et al*., 2017), and either to family, genus or species in the case of larval and juvenile fishes (Moser, 1996; Neira *et al*., 1998; Froese and Pauly, 2017). Reference specimens were photographed. Biovolume of the four micronekton samples was determined as outlined above (Section 2.4.1), while dry mass was determined for sample MA-O (D) only using the protocol of Harris *et al*. (2000). The remaining three micronekton samples were re-preserved with 4% buffered formaldehyde and archived for future reference.

Volume of seawater sampled by the Tucker trawl net (Section 2.3.2) was used to calculate the abundance of micronekton taxa as individuals per 1,000 m^3.

2.5. Multivariate data analysis

All multivariate analyses were performed using PRIMER version 7 (Plymouth, UK).

To investigate associations between the zooplankton assemblages at the sampling sites (Q-mode analysis), zooplankton abundances were firstly subjected to fourth-root transformation. This transformation is suitable for ecological data where there are many zeros and few large values (Quinn and Keough, 2002), and is recommended when using the Bray-Curtis index as a measure of (dis)similarity. A matrix of Bray-Curtis similarities (Bray and Curtis, 1957) was then constructed for all sites and subjected to canonical analysis of principal coordinates (CAP), a constrained ordination method that finds the axes that best discriminate between groups, i.e., can be used to test differences between the different depth strata and differences between the site positions, including the reference study area sites. The PRIMER's ANOSIM (analysis of similarities) program was used to test the null hypothesis that there were no significant differences in community composition between the strata. SIMPER (similarity percentages) analysis was then applied to identify which species contributed to the top 50% of abundance of each stratum.

Common associations between zooplankton taxa (R-mode analysis) were defined using cluster analysis, followed by non-metric multidimensional scaling (NMDS) ordination. Prior to the analysis, the taxa by station matrix was reduced to a subset of 31 taxa that was common to all time/depth combinations. Indicator values (IndVal) (Dufrêne and Legendre, 1997) were computed to determine indicator taxa and taxa assemblages that characterised groups of samples (IndVal 2.0). The random reallocation procedure of sites to site/depth combinations was used to test the significance of the maximum IndVal calculated for each taxon. A total of 499 permutations were used, and significance was defined as $P < 0.05$. Relative abundance was combined with relative frequency of a taxa's occurrence to site/depth combinations. Each IndVal was calculated as:

$$\text{IndVal}_{ij} = A_{ij}\, B_{ij} \times 100 \qquad (1)$$

Where $A_{ij} = \text{Nindividuals}_{ij}/\text{Nindividuals}_i$ and $B_{ij} = \text{Nsites}_{ij}/\text{Nsites}_j$

Term A_{ij} corresponds to a measure of site specificity, where Nindividuals_{ij} is the mean number of individuals in taxa *i* across sites of group *j*, while Nindividuals_i is the sum of the mean numbers of individuals of taxa *i* over all groups. Term B_{ij} corresponds to a measure of group fidelity, where Nsites_{ij} is the number of sites in cluster *j* where taxa *i* is present, while Nsites_j is the total number of sites in that cluster (Dufrêne and Legendre, 1997).

2.6. Supplementary oceanographic information

2.6.1. CTD data

Data on temperature (^{o}C), salinity (practical salinity units; PSU) and dissolved oxygen (DO; mg/L) by depth (m) were sourced for the DSTP study area from a concurrent oceanographic characterisation study being conducted by IHAconsult (IHAConsult, 2018). The data used in this report are from six of the ten sites located along two transects perpendicular to the coast. Each transect is located close to sites P1 to P9 that were sampled for zooplankton in March 2017 (see Figure 2.1). The western-most transect lies directly offshore from the Outfall Area (sites A1 to A3), whereas the eastern-most transect lays directly offshore between the Busu and Bupu rivers (sites B1 to B3). Data were collected with a Saiv SD208 conductivity-temperature-depth (CTD) profiler procured for the oceanographic study. Details on sampling methods and subsequent data processing are provided in IHAconsult (2017).

Data sourced from IHAconsult (2017) are provided for CTD casts undertaken on 28 February 2017 (sites B1, B2 and B3) and 13 March 2017 (sites A1, A2 and A3). Selected dates correspond to dates just before and after the completion of the zooplankton survey (3 to 5 March 2017). Depth profile data obtained for temperature, salinity and DO were plotted separately for each variable and for each CTD cast on the given dates.

2.6.2. Mixed layer depth

The mixed layer depth refers to the lowest depth where the water column above is characterised by a homogeneous distribution of temperature and salinity due to vertical mixing generated by waves and turbulence from wind stress, currents and other physical processes, leading to a relatively uniform upper mixed density layer. Data on the mixed layer depth were obtained from IHAconsult (2017), and are provided in this characterisation study in the context of examining influence or otherwise of mixed layer depth on vertical distribution of zooplankton aggregations within the DSTP study area at the time of zooplankton sampling. Data are provided for 28 February 2017 and 13 March 2017, which correspond to dates just before and after the completion of the zooplankton survey (3 to 5 March 2017). Details on how the mixed layer depth was estimated based on six different approaches can be found in IHAconsult (2017).

2.7. Metals

The analysis of metals and metalloids concentrations in zooplankton and micronekton was conducted by Advanced Analytical Australia Pty Ltd. This laboratory is accredited by the National Association of Testing Authorities, Australia.

The following metals and metalloids were analysed: 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.

To allow comparison with other results from zooplankton and micronekton sampling in PNG, zooplankton and micronekton were analysed as received – i.e., wet weight basis (no pre-drying) and with no pre-rinsing.

Metals analysis was conducted for bulk zooplankton samples, i.e., a mixture of all zooplankton organisms collected from a given site. Metals analysis was conducted using inductively coupled plasma optical emission spectrometry. This method involves extracting elements from the sample by digestion on a hot block for 80 minutes with hot concentrated nitric acid and hydrogen peroxide. The digested sample is then introduced into the spectrometer for detection of metals concentrations.

Micronekton taxa tested for metals were selected on the basis of: (a) abundance, i.e., were present in sufficient numbers across all four samples collected in the DSTP study area; (b) condition, i.e., were in reasonably good condition following thawing; (c) identification, i.e., were easy to identify to family, genus and/or species; and (d) size, i.e., were of sufficient size to provide tissue samples (100 mg to 200 mg).

Metals analysis for selected taxa captured in micronekton samples was conducted using inductively coupled plasma mass spectrometry. This method involves extracting acid recoverable elements from the sample by digestion on a hot block for 60 minutes with nitric acid. Hydrogen peroxide is then added to help the breakdown of the protein and the sample is replaced on the hot plate for a further 20 minutes. The sample is removed and hydrochloric acid is added to stabilise the sample. The sample is then diluted prior to spectroscopic analysis.

Mercury analysis for both zooplankton samples and individual taxa in micronekton samples was conducted using cold vapour atomic absorption spectrometry. This method involves extraction of mercury from the sample by digestion on a heating block with concentrated nitric acid and hydrogen peroxide. Hydrochloric acid is added to stabilise the mercury. The digested sample is introduced into the spectrometer via a peristaltic pump.

The laboratory analysis implemented a range of quality control measures, including replicate analyses, matrix spikes and the use of method blanks. The results of the quality control analyses (see Appendix A) showed that all blanks gave concentrations below practical quantification limit (PQL) and all matrix spike recoveries were within laboratory limits. Analysis duplicates were mostly within laboratory limits, with the exception of one zooplankton sample which had copper, manganese and nickel outside the limits. Overall, the quality control results indicate the data to be of good quality.

3. Results

3.1. Taxa composition and overall relative abundance

3.1.1. Zooplankton assemblage

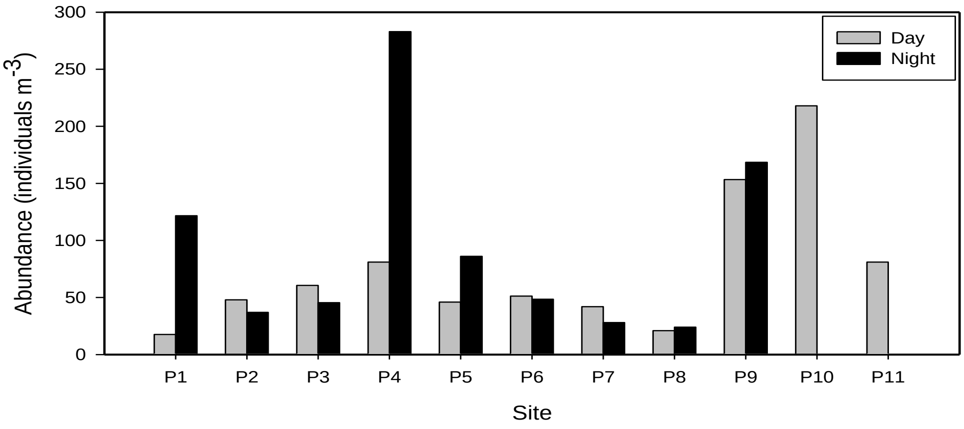
A total of 38 zooplankton taxa groups were identified across the 11 sites sampled in the DSTP and reference study areas in the Huon Gulf during the March 2017 survey. The average zooplankton abundance at sites P1 to P9 in the DSTP study area (day and night) and sites P10 and P11 in the reference study area (daytime samples only) is shown in Figure 3.1. The average percentage contributions of the 16 main zooplankton groups are provided in Table 3.1. In general, the compositions between the two study areas were similar, with the top five groups common to both areas, namely ostracods, copepods, chaetognaths, decapods and siphonophores (Figure 3.2).

The zooplankton assemblage in the Huon Gulf was dominated by crustaceans, principally copepods and ostracods, both of which combined accounted for approximately 35% of the total abundance, followed by decapods (7.5%) and euphausiids (2.5%) ('Other' category represents thaliaceans, appendicularians, amphipods and cnidarians) (Figure 3.2). The other dominant groups were chaetognaths (arrow-worms) which contributed 12%, and gelatinous siphonophores (6%). The remainder of groups, representing less than 0.5% each, included salps (thaliaceans), amphipods, small jellyfish (cnidarians) and appendicularians.

Table 3.1: Main groups of zooplankton taxa that contributed to the top 70% of abundance at the DSTP study area and the reference study area

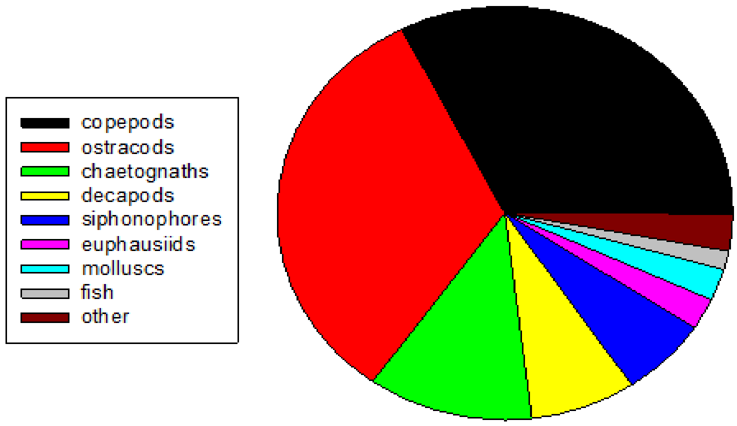
Taxa	Inshore (P1, P4, P7)	Taxa	Mid-slope (P2, P5, P8)	Taxa	Offshore (P3, P6, P9)	Taxa	Reference (P10, P11)
Rutiderma	16.09	*Rutiderma*	17.27	*Rutiderma*	15.7	*Rutiderma*	15.67
Euchaeta	30.36	*Euchaeta*	31.99	*Sagitta*	26.2	*Sagitta*	28.85
Eucalanus	39.25	*Sagitta*	42.04	*Euchaeta*	34.92	*Eucalanus*	35.52
Sagitta	47.72	*Eucalanus*	49.95	*Eucalanus*	43.46	*Oikopleura*	40.77
Dyphyidae	54.91	Dyphyidae	56.71	*Lucifer*	49.92	*Lucifer*	45.44
Lucifer	61.32	*Candacia*	61.4	*Candacia*	54.86	*Copilia*	49.9
Euphausia	67.25	*Lucifer*	65.49	Dyphyidae	59.69	Doliolid	54.23
Calanoid (undetermined)	71.38	Abylidae	69.58	*Euphausia*	64.16	*Acartia*	58.5
-	-	*Euphausia*	73.47	*Halocypris*	68.61	*Euchaeta*	62.35
-	-	-	-	*Limacina*	72.21	Larval fishes	65.79
-	-	-	-	-	-	*Candacia*	69.22
-	-	-	-	-	-	Medusae	72.46

The values in the table show cumulative abundances (%) from the top to bottom of each column.



For mid-slope and offshore sites the values are averaged across all net tows.

Figure 3.1: Average abundance of zooplankton at sites P1 to P9 in the DSTP study area (day and night) and sites P10 and P11 in the reference study area (daytime samples only)



'Other' category represents thaliaceans, appendicularians, amphipods and cnidarians.

Figure 3.2: Percentage contribution of major zooplankton groups identified

The sections below describe abundance information of the main eight zooplankton taxa groups identified during the March 2017 survey. Zooplankton sampling sites shown along bar charts in Figure 3.3 to Figure 3.11 are given as actual site (P1 to P11), each followed by depth stratum from which the sample was provided, where 1 = 100 to 0 m; 2 = 250 m to 0 m; and 5 = 500 to 0 m. Thus, site labelled "P92" corresponds to sample collected at offshore site P9 in the DSTP study area between 250 m and the surface (0 m). The same applies to bar charts shown in Figure 3.17 to Figure 3.19. All these charts correspond to stacked bar charts.

Copepods

Copepods comprise the most abundant group of planktonic crustaceans in marine and freshwater habitats worldwide, and were present in all zooplankton samples. Copepod abundances in the DSTP study area ranged from as low as three individuals per m³ at site P3 (250 m to 0 m) during daytime, to as high as 109 individuals per m³ at site P9 (100 m to 0 m) at night (Figure 3.3). The genera most commonly recorded were the calanoids *Candacia*, *Euchaeta*, *Pleuramamma*, *Rhincalanus*, *Eucalanus*, *Acartia* and *Bestiolina similis*. Cyclopoid copepods in the genera *Sapphirina*, *Copilia* and *Corycaeus* were common, with the occasional presence of the genus *Oithona*. The only harpacticoid copepod genus was *Microsetella*, which was observed in only three samples.

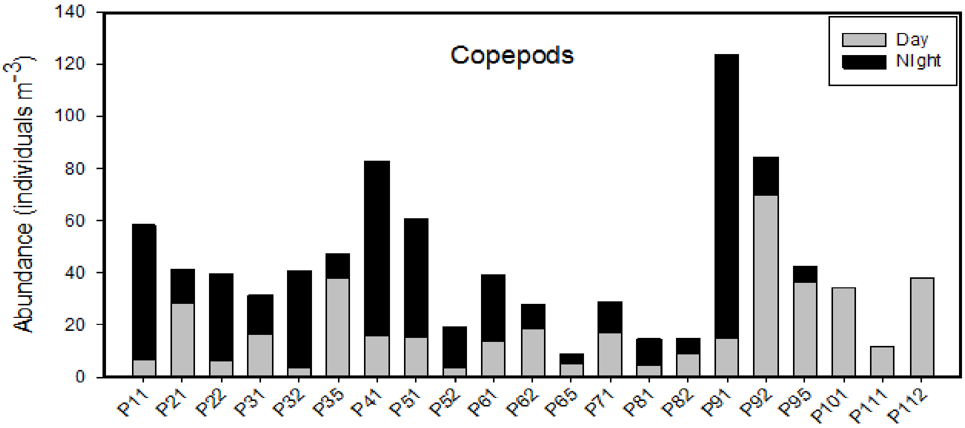


Figure 3.3: Abundance of copepods at sites P1 to P9 in the DSTP study area (day and night) and sites P10 and P11 in the reference study area (daytime samples only)

Ostracods

Ostracods comprise a large group of small crustaceans characterised by enclosure of their bodies within a two-valved shell. Diversity of ostracods in the two study areas was low, with only two genera identified, namely *Rutiderma* (a small ostracod up to 2 mm in length) and *Halocypris*. *Rutiderma* was often the dominant taxon, reaching up to 120 individuals per m³ at site P10 in the reference study area (100 m - 0 m) during daytime, and 161 individuals per m³ at offshore site P9 in the DSTP study area (100 m- 0 m) at night (Figure 3.4).

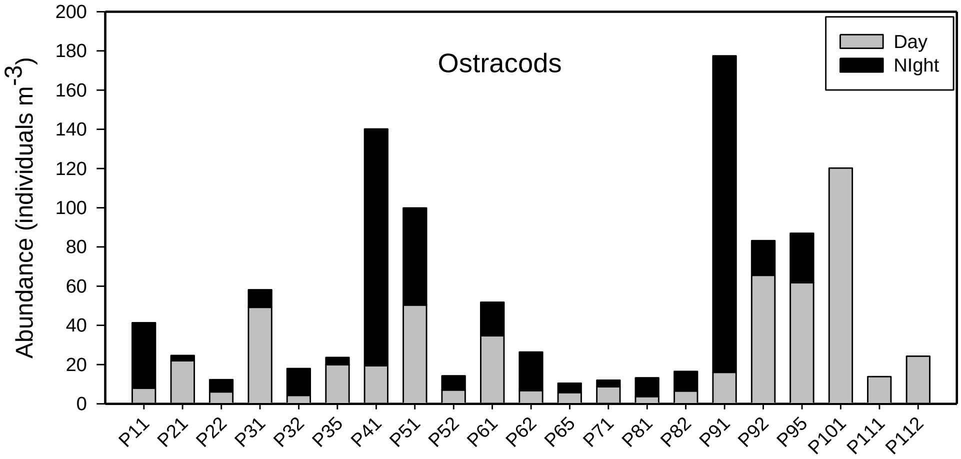


Figure 3.4: Abundance of ostracods at sites P1 to P9 in the DSTP study area (day and night) and sites P10 and P11 in the reference study area (daytime samples only)

Chaetognaths

Chaetognaths, also called arrow-worms, are a gelatinous planktonic group of predators. They prey on a large range of other zooplankton, including copepods, euphausiids and decapod larvae. They were particularly common at the offshore site P9 in the DSTP study area, with as many as 45 individuals per m³ between 100 m and the surface at night (Figure 3.5).

The most common genus present was *Sagitta* (Plate 3.1), with *S. enflata* and *S. bieri* the only two species identified.

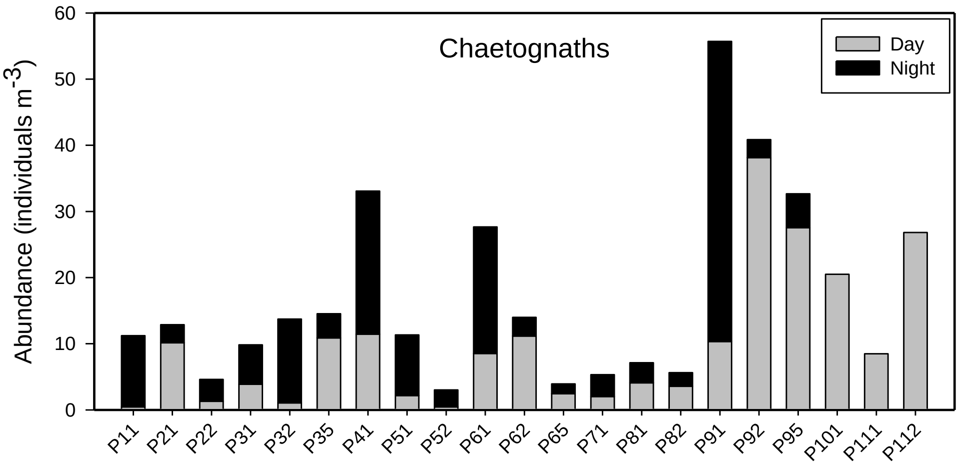


Figure 3.5: Abundance of chaetognaths at sites P1 to P9 in the DSTP study area (day and night) and sites P10 and P11 in the reference study area (daytime samples only)

Decapods

Decapod larvae were represented in samples by zoea of crabs, alima larvae of stomatopods and the ghost shrimp *Lucifer*. *Lucifer* was the most common of the decapods observed, representing between 95% and 100% of all decapods in a sample. The greatest number of decapods, 48 individuals per m³, was recorded at offshore site P9 in the DSTP study area at night, between 100 m and the surface (Figure 3.6).

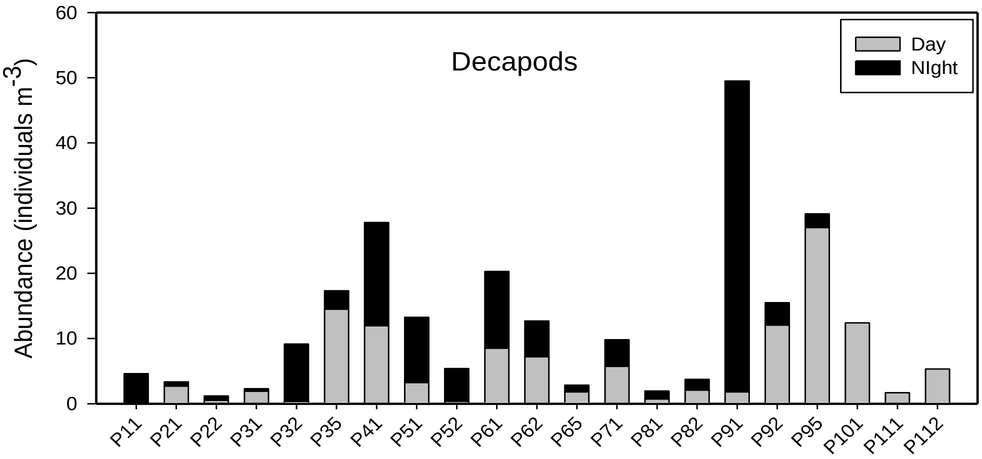


Figure 3.6: Abundance of decapods at sites P1 to P9 in the DSTP study area (day and night) and sites P10 and P11 in the reference study area (daytime samples only)

Siphonophores

Siphonophores (see Plate 3.2) are a gelatinous group in the class Hydrozoa; they can form colonies that sometimes number hundreds of zooids. The two common families observed were Ablyidae and Diphyidae. They prey on small animals by using their stinging cells to subdue their prey, including fish and crustaceans. Siphonophores were common in samples, reaching a maximum abundance of 32 individuals per m^3 at inshore site P4 in the DSTP study area at night, between 100 m and the surface (Figure 3.7).

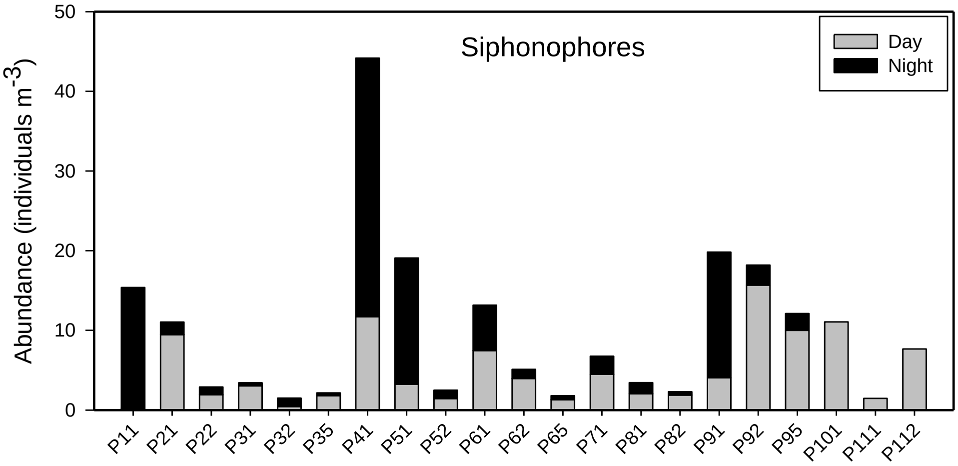


Figure 3.7: Abundance of siphonophores at sites P1 to P9 in the DSTP study area (day and night) and sites P10 and P11 in the reference study area (daytime samples only)

Euphausiids

Euphausiids comprise well-known krill-type planktonic crustaceans, which can be distinguished from other similar crustaceans by their external gills that are visible near the front appendages. Both larval and adult euphausiids were observed in zooplankton samples in the two study areas, with two species identifiable. The most common was *Euphausia sibogae*, while there were fewer numbers of *Stylocheiron* sp. The maximum abundance of euphausiids obtained reached 12 individuals per m^3 at inshore site P4 in the DSTP study area at night, between 100 m and the surface (Figure 3.8).

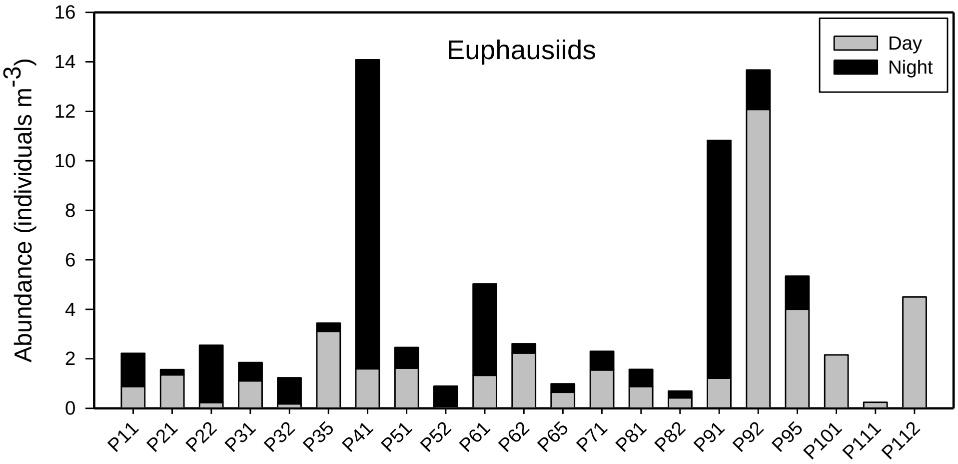


Figure 3.8: Abundance of euphausiids at sites P1 to P9 in the DSTP study area (day and night) and sites P10 and P11 in the reference study area (daytime samples only)

Fish

Larvae from various bony fish families, including several from the mesopelagic families Myctophidae (lanternfishes), Gonostomatidae (bristlemouths) and Trachichthyidae (slimehead) (Plate 3.3 and Plate 3.4), were found in the zooplankton samples collected during the March 2017 survey. These larval fish were generally no longer than 5 mm in length. Maximum larval fish abundances were recorded at offshore site P9 in the DSTP study area, with 10 individuals per m^3 between 100 m and the surface at night, and seven individuals per m^3 between 250 m and the surface during daytime (Figure 3.9).

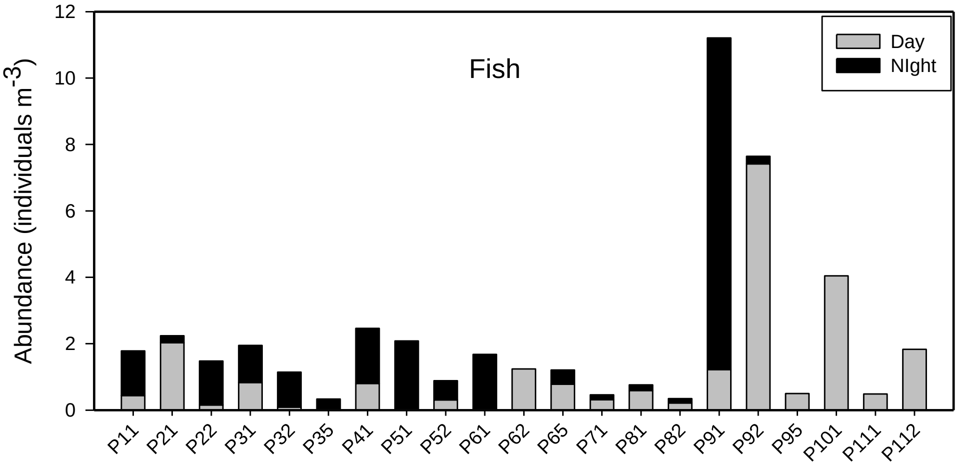


Figure 3.9: Abundance of larval fishes at sites P1 to P9 in the DSTP study area (day and night) and sites P10 and P11 in the reference study area (daytime samples only)

Molluscs

Molluscs (Plate 3.4) were mainly represented by pteropods from the genera *Cavolina* and *Clio*. In addition, two specimens of the heteropod *Firoloida desmaresti* were found at site P10 in the reference study area, between 100 m and the surface. Juvenile gastropods were also observed in a few samples. Molluscs reached up to 10 individuals per m^3 at offshore site P9 in the DSTP study area during daytime, between 250 m and the surface (Figure 3.10).

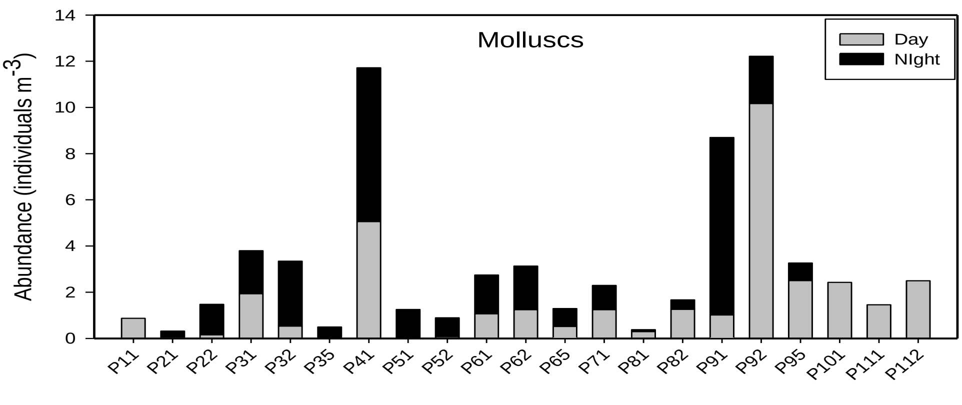


Figure 3.10: Abundance of molluscs at sites P1 to P9 in the DSTP study area (day and night) and sites P10 and P11 in the reference study area (daytime samples only)

Photo credit: Kerrie Swadling

Plate 3.1
Sagitta
(chaetognathid; phylum Chaetognatha)

Photo credit: Kerrie Swadling

Plate 3.2
Siphonophore
(phylum Cnidaria, family Dyphyidae)

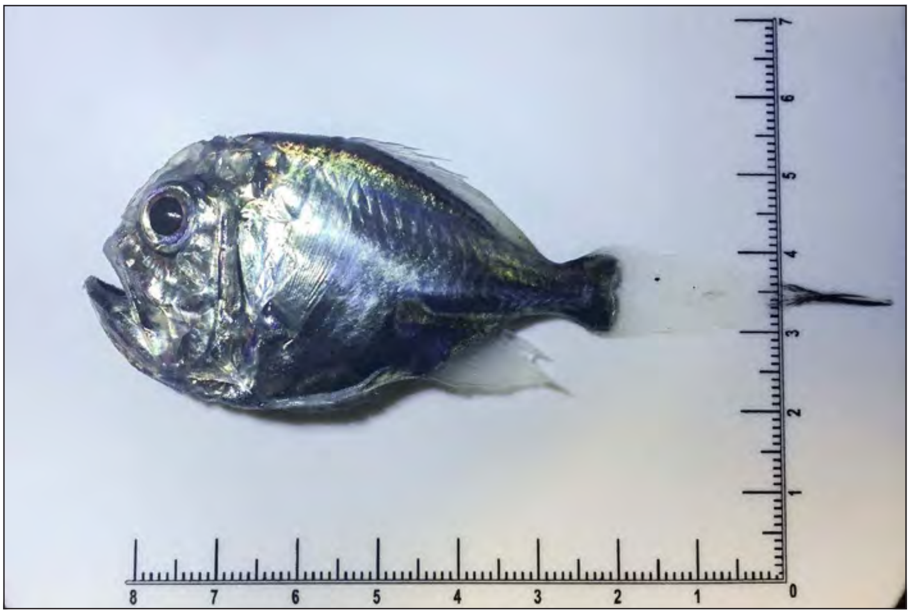


Photo credit: Francisco Neira

Plate 3.3
Early juvenile slimehead
(possibly *Hoplostethus* sp.,
family Trachichthyidae)
collected in night plankton sample

Photo credit: Kerrie Swadling

Plate 3.4
Larva of slimehead fish
(family Trachichthyidae)

Other groups

Several groups were recorded in the zooplankton samples collected in the DSTP and reference study areas during the March 2017 survey, and were present in abundances generally of less than one individual per m^3 (Figure 3.11). These groups included thaliaceans (salps and doliolids), polychaetes, amphipods and small cnidarians. The salp *Thalia democratica* (Plate 3.6) was present in both its solitary and aggregate forms. Doliolids were present as individuals of *Doliolum* sp. and several early-life (nurse) stages were also observed. Polychaetes were generally identified as larvae, although a few specimens of the holoplanktonic species *Tomopteris* sp. (which remains its entire life in plankton and does not settle over seafloor sediments like almost all benthic polychaete worms) were also observed. Amphipods were rare, and were only observed on five occasions. Cnidarians of the subfamily anthomedusae were observed but were often in very poor condition and could not be identified further.

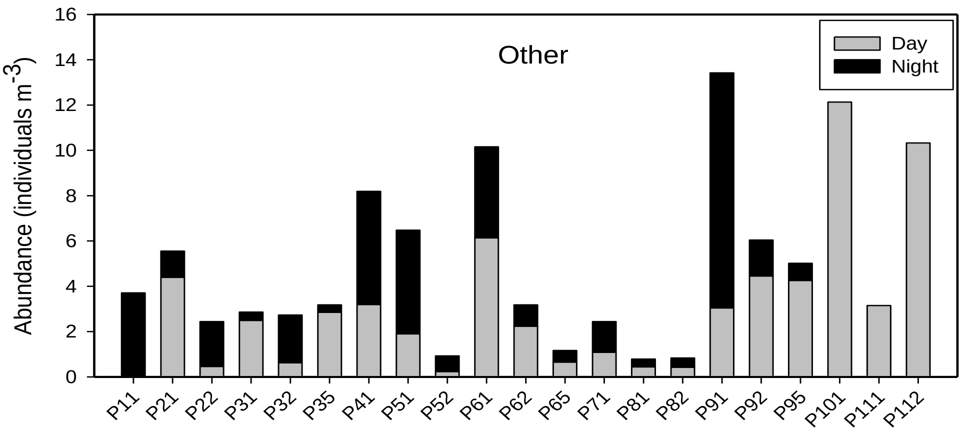
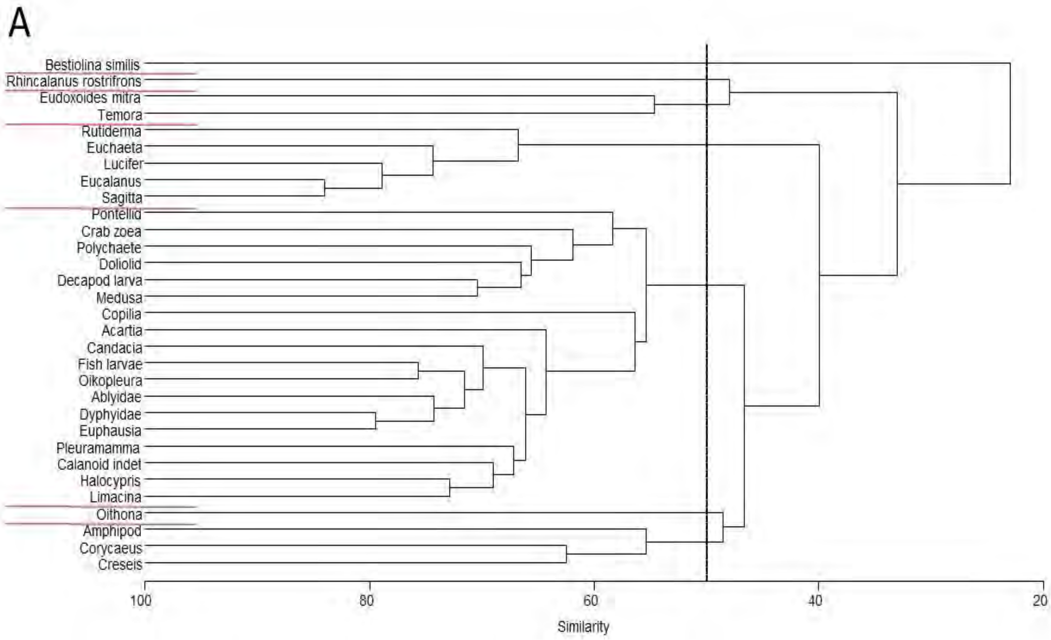


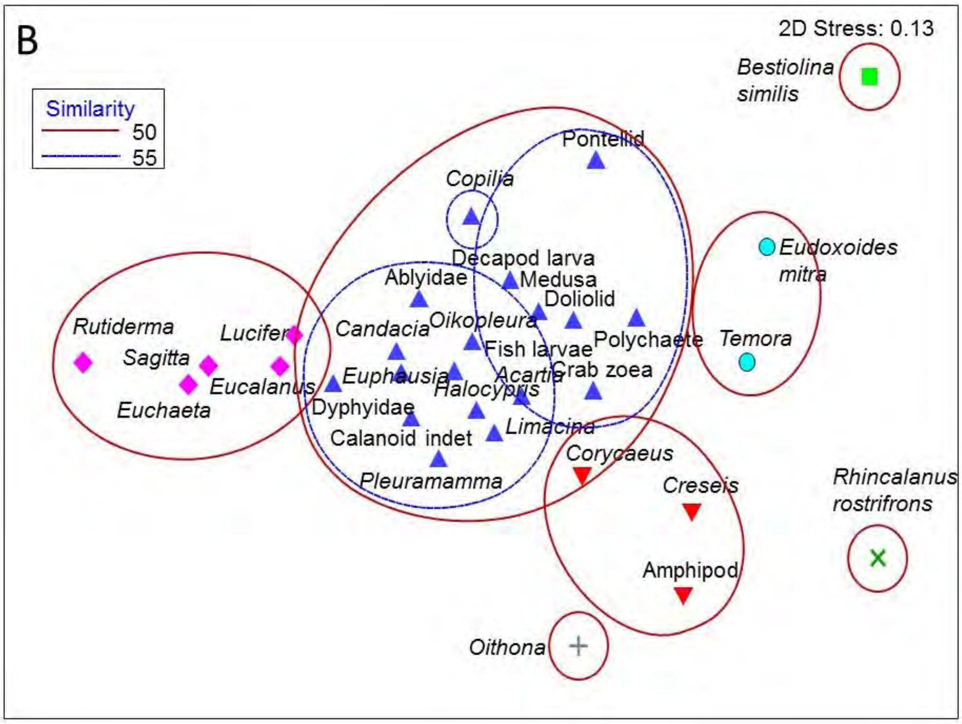
Figure 3.11: Abundance of other groups at sites P1 to P9 in the DSTP study area (day and night) and sites P10 and P11 in the reference study area (daytime samples only)

Taxa associations

Associations amongst the 31 taxa identified as occurring at sites in the DSTP and reference study areas at each depth stratum and day/night combination were analysed using cluster and NMDS (Figure 3.12). Three main clusters were separated at 50% similarity, while the largest group was further separated at 55%. There were also four small clusters of one or two taxa: (1) *Bestiolina similis*; (2) *Rhincalanus rostrifrons* (Plate 3.7); (3) *Oithona* and (4) *Temora* and *Eudoxoides mitra*. The remaining 26 taxa clustered together as groups: (5) *Rutiderma*, *Lucifer* (Plate 3.8), *Sagitta*, *Euchaeta* and *Eucalanus*; (6) *Corycaeus*, *Creseis* and amphipods; and (7a) Pontellid copepods, crab zoea (Plate 3.9), polychaetes, decapod larvae (Plate 3.10) and medusa, and (7b) *Acartia*, *Candacia*, larval fishes (Plate 3.11), Oikopleura, families Abylidae and Dyphyidae, as well as *Euphausia* (Plate 3.12), *Pleuramamma*, *Halocypris*, *Limacina* and unidentified copepods.

Zooplankton occurred at all offshore sites from depths between 500 m and the surface, at all mid-slope sites between 250 m and the surface and at all inshore sites between 100 m and the surface. A plot of the first two canonical axes from the CAP for samples from each depth stratum (represented by the three coloured symbols) and all taxa is shown in Figure 3.13. Results from the ANOSIM indicated that only the 100 m to 0 m and 500 m to 0 m strata were significantly different at $P < 0.05$, i.e., distances between pairs of samples between those depth strata (from the Bray-Curtis similarity matrix) were greater than distances between samples within each stratum. However, when the time of day that samples were collected was nested within depth stratum (as indicated by N and D for each





A. Dendrogram of the inverse (R-mode) cluster analysis showing associations between taxa at a similarity of 50%. Bray-Curtis similarity index with UPGMA linkage.

B. NMDS inverse ordination plot. Groups identified at 50% similarity are indicated by dark red line and at 55% by blue line The low stress value of 0.13 indicates a goodness of fit between the groups of data.

Figure 3.12: Taxa associations

Photo credit: Kerrie Swadling

Plate 3.5
Squid
(cephalopod; phylum Mollusca, class Cephalopoda)

Photo credit: Kerrie Swadling

Plate 3.6
Thalia democratica
(salp; phylum Chordata, subphylum Tunicata)

Photo credit: Kerrie Swadling

Plate 3.7
Rhincalanus
(copepod; subphylum Crustacea, class Maxillopoda)

Photo credit: Kerrie Swadling

Plate 3.8
Lucifer
(decapod crustacean; subphylum Crustacea, class Malacostraca)

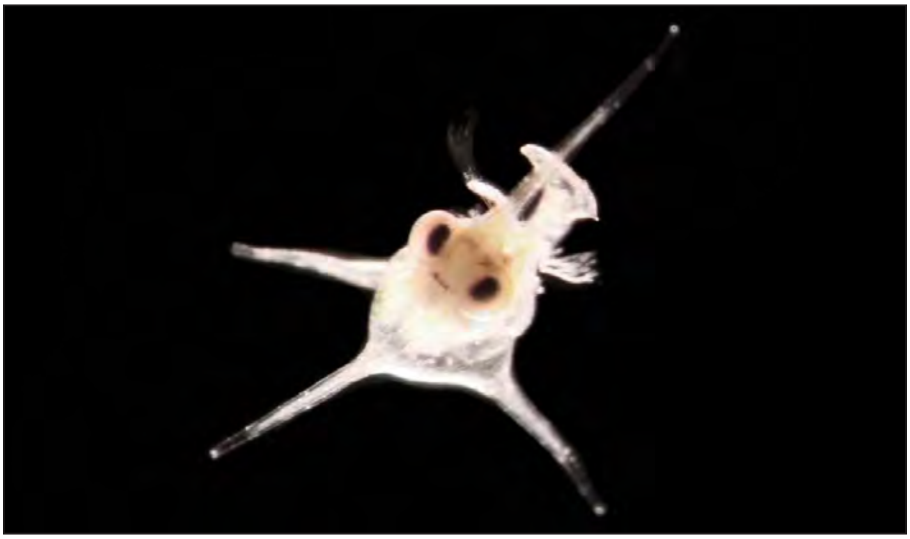


Photo credit: Kerrie Swadling

Plate 3.9
Crab zoea larva
(crustacean decapod)

Photo credit: Kerrie Swadling

Plate 3.10
Crab megalopa larva
(decapod crustacean)

Photo credit: Kerrie Swadling

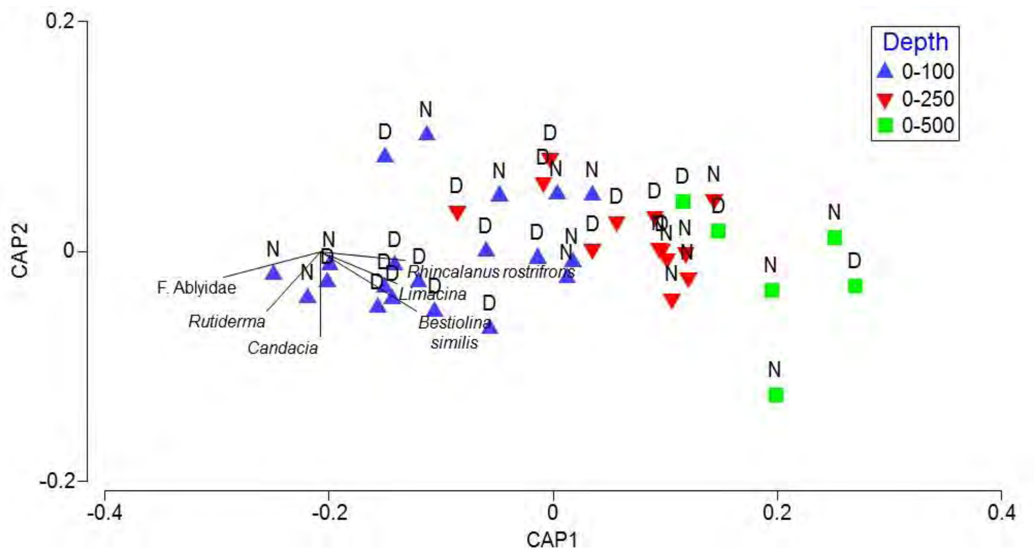
Plate 3.11
Larva of *Bregmaceros* sp. (codlet),
(family Bregmacerotidae)

Photo credit: Kerrie Swadling

Plate 3.12
Euphausia
(krill; subphylum Crustacea,
class Malacostraca)

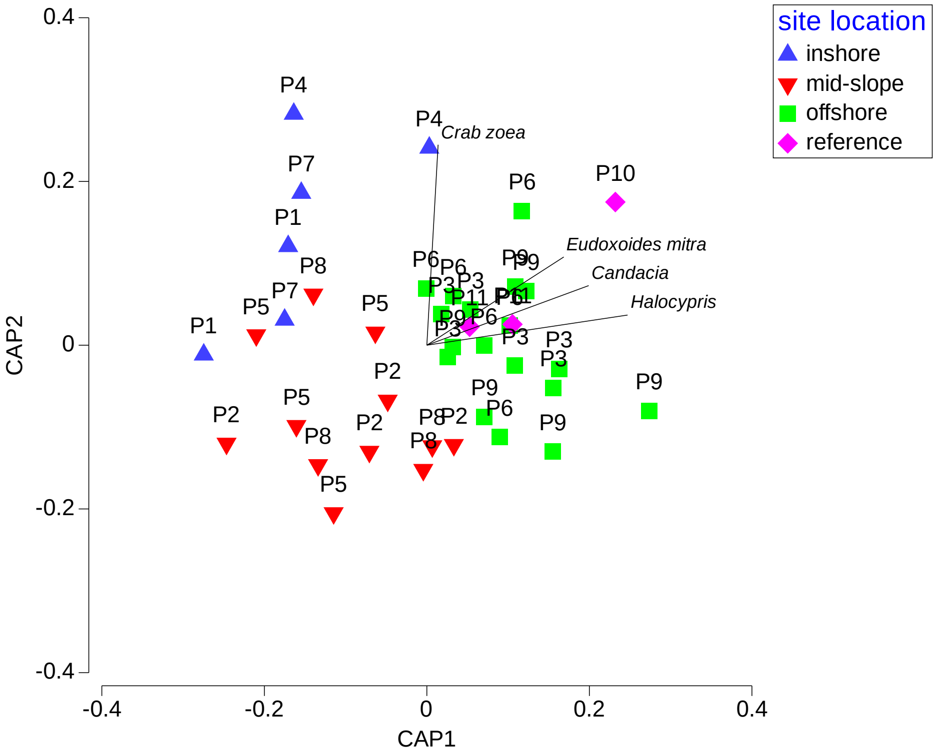
depth symbol), the ANOSIM showed no significant differences between day and night samples. PRIMER structures the vectors so that they are directional lines emanating from a common point of origin and pointing in the direction along which the taxon numbers increase. The point of origin is arbitrary and PRIMER defaults to the left-hand side of a plot. The vectors plotted on Figure 3.14 show that the copepods *Rhincalanus rostrifrons* and *Bestiolina similis*, and the pteropod *Limacina* were more common in the two deeper strata (i.e., their numbers increase towards right hand quadrant of the plot, where the deeper sites are located, while the copepod *Candacia*, the ostracod *Rutiderma* and siphonophores of the family Ablyidae were common in the shallowest stratum (samples clustered towards the left-hand side of the plot)).

A CAP based on site location (distance from shore) is shown in Figure 3.14. There is a clear separation between inshore, mid-slope and offshore sites in the DSTP study area, with offshore sites being driven by higher abundances of the siphonophore *Eudoxoides mitra*, the copepod Candacia, the larger ostracod, Halocypris and zoea (early juveniles) of crabs. Sites P10 and P11 in the reference study area clustered with the offshore sites P3, P6 and P9 in the DSTP study area. The taxa that contributed to the top ~70% of abundance at the sites in the DSTP and reference study areas are shown in Table 3.2. The number of taxa contributing increased from inshore (8 groups) to mid-slope (9) to offshore (10) sites, although there was considerable overlap in the top groups. The reference sites contained a slightly different suite of taxa and had the highest taxa diversity (12).



Sampling time is shown as D (day) and N (night).
Axes represent the strength of the correlation between the data cloud and the hypothesis of differences between the groups
Significant (correlation = 0.4) taxonomic drivers are shown by the vectors.

Figure 3.13: Plot of canonical analysis of principal coordinates (CAP) for zooplankton-site relationships over the three sampling depth strata



Sites are shown without reference to sampling time. Note that point of origin of the vectors on the plot is arbitrary. Significant (correlation = 0.4) taxonomic drivers are shown by the vectors.

Figure 3.14: Plot of canonical analysis of principal coordinates for zooplankton-site relationships at sites P1 to P9 in the DSTP study area, and sites P10 and P11 in the reference study area

3.1.2. Micronekton

Micronekton occurred at the offshore site from depths between 500 m and the surface (MA-O), and at the inshore site between 250 m and the surface (MA-I). Day and night samples collected from the two sites in the DSTP study area on 1 May 2017 were used to describe abundance and distribution of micronekton: MA-I (D, N) and MA-I (D, N). The greatest micronekton abundance, i.e., 1,564 individuals per 1,000 m^3, was recorded at site MA-I at night, whereas abundances in the other three samples ranged between 750 individuals per 1,000 m^3 and 950 individuals per 1,000 m^3 (Figure 3.15). Main taxa found in micronekton samples included chaetognaths, copepods, siphonophores and decapods, which were common in all samples, with occasional peaks in other groups such as the small ostracod *Rutiderma* sp., which was abundant at the offshore site MA-O at night (Figure 3.16). More fish were observed in micronekton than zooplankton samples, with 15 taxa noted in the former samples.

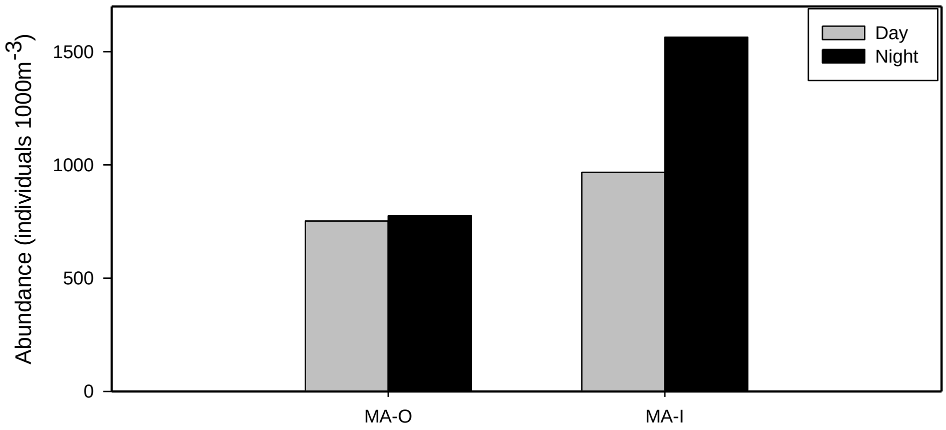
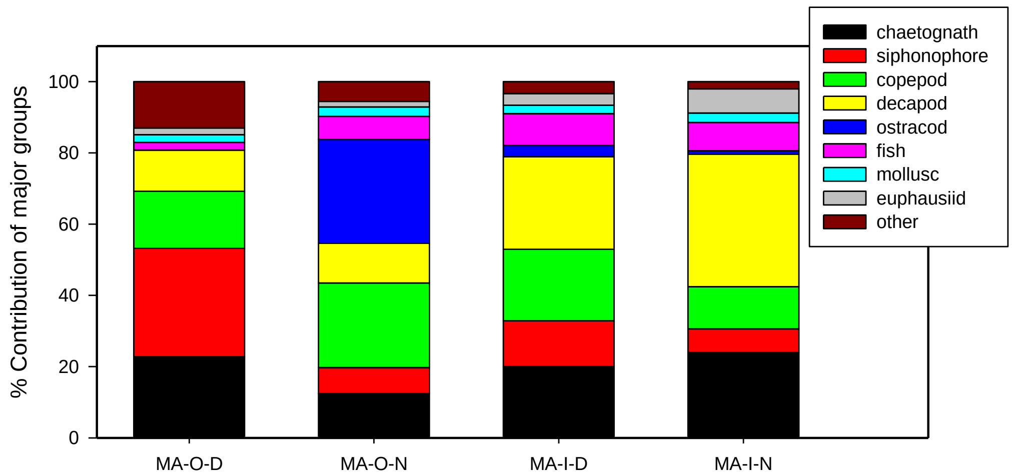


Figure 3.15: Average abundance of all micronekton taxa collected at sites MA-O and MA-I in the DSTP study area during day and night hours



'Other' category represents thaliaceans, appendicularians, amphipods, cnidarians and polychaetes

Figure 3.16: Percentage contribution of major micronekton groups identified from samples collected in the DSTP study area in the Huon Gulf in May 2017

3.1.3. Indicator zooplankton taxa for depth strata

Mean abundances of each zooplankton taxon collected for each time/depth are shown in Table 3.2, highlighting those taxa that scored an IndVal of greater than 25%. Table 3.2 also shows the taxa that contributed to the top 50% of abundance as determined by SIMPER analysis. All depths showed high abundances of *Rutiderma*, *Sagitta*, *Euchaeta* and *Eucalanus*. Other taxa that contributed high abundances were *Copilia* in the 100 m to 0 m stratum during daytime, crab zoea, decapod larvae and dyphyids in the 100 m to 0 m stratum at night, copepods (*Rhincalanus rostrifrons*, *Acartia*, *Bestiolina similis*), and amphipods and the ghost shrimp *Lucifer* in the 500 m to 0 m stratum during daytime. No indicator taxa were identified in the 250 m to 0 m stratum during daytime or at night, or the 500 m to 0 m stratum at night.

Table 3.2: List of most common 31 zooplankton taxa identified at all depth strata and day/night samples

Taxa	Depth strata (m)					
	100 - 0 m		250 - 0 m		500 - 0 m	
	Day	Night	Day	Night	Day	Night
Ablyidae	1.75	2.68	1.63	0.24	0.93	0.09
Acartia	0.76	0.63	0.73	0.62	**1.57**	0.06
Amphipods	0.17	0.17	0.15	0.15	**0.85**	0.06
Bestiolina similis	0.02	0.01	0.09	0.21	**0.46**	0.28
Calanoid indet	0.63	2.19	0.85	1.93	**3.84**	0.90
Candacia	2.16	0.84	1.38	1.72	2.47	0.65
Copilia	**1.14**	0.81	0.46	0.31	0.47	0.01
Corycaeus	0.30	0.53	0.24	0.41	0.60	0.12
Crab zoea larvae	0.37	**0.92**	0.31	0.23	0.30	0.17
Creseis	0.27	0.34	0.40	0.13	0.17	0.03
Decapod larva	1.16	**1.65**	0.27	0.19	0.25	0.19
Doliolids	0.69	0.45	0.55	0.16	0.96	0.01
Dyphyidae	2.79	**6.74**	2.73	0.91	2.90	0.83
Eucalanus	4.95	7.13	5.35	3.47	7.17	1.65
Euchaeta	4.70	**23.34***	9.13*	9.19*	6.15	2.07
Eudoxoides mitra	0.59	0.05	0.30	0.03	0.54	0.06
Euphausia	1.24	3.34	2.34	1.03	2.59	0.07
Larval fishes	0.96	2.05	1.61	0.56	0.43	0.25
Halocypris	0.60	0.72	0.88	0.99	1.87	1.06
Limacina	0.38	0.87	1.21	0.94	0.71	0.62
Lucifer	2.98	7.76	3.36	3.36	**13.73***	1.63
Medusae	0.63	0.65	0.59	0.26	0.13	0.15
Oikopleura	1.21	1.68	0.77	0.45	0.52	0.16
Oithona	0.10	**0.50**	0.23	0.06	0.17	0.06
Pleuramamma	0.19	2.14	1.87	0.82	1.88	0.51
Polychaetes	0.39	0.26	0.46	0.14	0.25	0.15
Pontellids	0.300	0.52	0.09	0.19	0.17	0.06
Rhincalanus rostrifrons	0.01	0.01	0.36	0.09	**1.01**	0.11
Rutiderma	30.85*	44.47*	16.30*	11.46*	27.28*	10.1*
Sagitta	7.45*	13.46	11.78*	4.36*	13.62*	3.42*
Temora	0.28	0.12	0.31	0.24	0.25	0.05

Asterisk (*) denotes those taxa that contributed to the top 50% of abundance (as determined by SIMPER analysis).
BOLD represents an IndVal of greater than 25% for that taxon

3.2. Net-based evidence of vertical migration

Close examination of zooplankton samples shows evidence of vertical migration of zooplankton from deeper to shallower waters at night. For example, zooplankton abundances in the 100 m to 0 m stratum at the offshore site P9 in the DSTP study area were considerably greater at night than during daytime, suggesting that taxa residing in waters below depths of 100 m during daytime had migrated into the upper 100 m at night (Figure 3.17). Further evidence of zooplankton vertical migration is also shown by the higher night zooplankton abundances at inshore sites P1 (100-0 m) and P4 (100-0 m) as well as mid-slope sites P2 (250-0 m) and P5 (100-0 m and 250-0m), and offshore site P3 (250-0 m) (Figure 3.17).

Indications of vertical migration are less pronounced when examining site depth patterns in the zooplankton biovolumes (Figure 3.18) and the dry mass (Figure 3.19). Biovolumes appear to be similar between day and night samples at each sampled site, while dry mass appeared to be slightly higher in the night samples. Samples from sites P4, P5 and P6 in the DSTP study area were retained as archived material and not processed for dry weight, and therefore are not included in Figure 3.19.

Zooplankton sampling sites shown along the x-axis of bar charts in Figure 3.17 to Figure 3.19 below are given as actual site (P1 to P11), each followed by depth stratum from which sample was provided, where 1 = 100 to 0 m; 2 = 250 m to 0 m; and 5 = 500 to 0 m. Thus, site labelled “P92” corresponds to sample collected at offshore site P9 in the DSTP study area between 250 m and the surface (0 m).

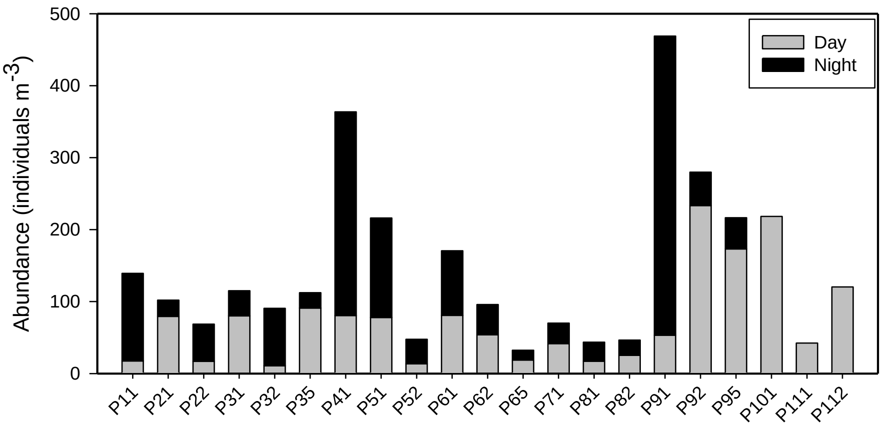


Figure 3.17: Abundance of zooplankton in all depth strata at sites P1 to P9 in the DSTP study area (day and night) and sites P10 and P11 in the reference study area (day samples only)

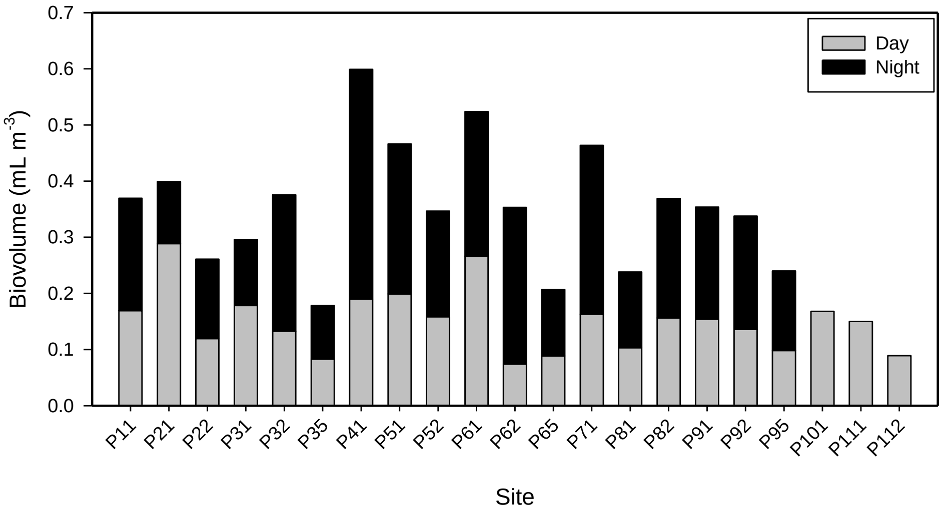


Figure 3.18: Biovolume of zooplankton in all depth strata at sites P1 to P9 in the DSTP study area (day and night) and sites P10 and P11 in the reference study area (day samples only)

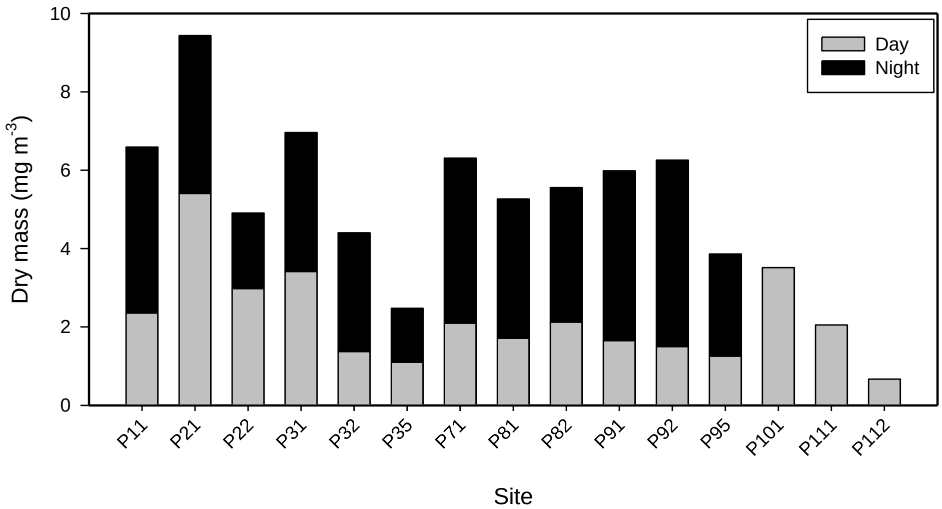


Figure 3.19: Dry mass of zooplankton during daytime and night-time collections at six of the nine sites in the DSTP study area, and daytime collections at the two sites in the reference study area (P10, P11)

3.3. CTD profiling and mixed layer depth

This section summarises the CTD profiling results obtained by IHAconsult (2017). The influence of conductivity, temperature and density on the movement of zooplankton aggregations is discussed in Section 4.2.

Temperature profiles were very similar at all six sites both on 28 February 2017 (sites B1 to B3) and 13 March 2017 (sites A1 to A3), with temperatures showing no clear thermal structure, as defined by a thermocline zone (transition layer) but a steady cooling gradient through to the deepest depths sampled at all sites (Figure 3.20). Average water temperatures at sites B1 to B3 in late February 2017 show a gradual decline from 30.0ºC at the surface to 18.5ºC at the bottom of the epipelagic zone, and to 11.7ºC at a depth of nearly 400 m in offshore site B3 (Figure 3.20). The slightly cooler temperatures in surface waters less than 1 m deep are likely the result of significant freshwater input from a combined effect of rain and associated surface coverage of river discharge; such input is clearly visible in salinity profiles obtained at these sites which show pronounced haloclines to a depth of 20 m (see below).

Salinity profiles on 28 February 2017 (sites B1 to B3) and 13 March 2017 (sites A1 to A3) show a distinct halocline in the top 20 m to 25 m from the surface, with salinities increasing rapidly from 24 to 29 PSU to around 34.5 PSU over that depth range, before gradually increasing to full-strength seawater (~35 to 36 PSU) and remaining consistently over 35.5 PSU from depths of 150 m (Figure 3.21). The presence of a halocline in the top 20 m to 25 m of the upper layer can be associated with the prevalent freshwater input from rivers draining into the Huon Gulf, which appear to dominate the surface waters of the Huon Gulf at that time of year.

Average salinities at sites B1 to B3 in February 2017 show a marked increase from 27 to 29 PSU within the first top metre of the surface to 34.5 PSU at a depth of 20 m, followed by another less obvious increase to a maximum of 36.4 PSU just below a depth of 150 m, before a slight drop to 35.9 PSU and remaining largely unchanged to a depth of nearly 400 m at offshore site B3 (Figure 3.21). Salinity profiles at sites A1 to A3 in March 2017 are almost identical to those at sites B1 to B3, with also strong haloclines in the first 20 m from the surface followed by a very gradual increase to 36.5 PSU at around 140 m, and a very slight decline to 35.8 PSU to depths of around 500 m (Figure 3.21).

Dissolved oxygen (DO) profiles on 28 February 2017 (sites B1 to B3) and 13 March 2017 (sites A1 top A3) were almost identical, with average DO concentrations starting at 6.4 mg/L at the surface before reaching a distinct average peak of 6.7 mg/L at depths between 15 m and 25 m, and a subsequent noticeable decline to 4.5 mg/L in deeper waters (Figure 3.22). A second distinct spike in average DO concentrations between 5.1 mg/L and 5.4 mg/L is noticeable at depths of around 92 m to 95 m at sites B2 and B3 in February 2017, and sites A2 and A3 in March 2107 (Figure 3.22).

Surface mixed layer depths estimated by IHAconsult (2017) for the DSTP study area using six different approaches ranged from 10 m to 27 m on 28 February 2017, and 11 m to 21 m on 13 March 2017, the period closest to the zooplankton and micronekton sampling. More recently (June to December 2017), the maximum surface mixed layer has been determined to range from 62 to 96 m (IHAConsult, 2018). However, the lack of temperature stratification in upper waters coupled with the lack of a halocline in the deeper salinity profiles in February and May 2017, suggests a non-obvious surface mixed surface layer near the Outfall Area at the time of the zooplankton and micronekton sampling.

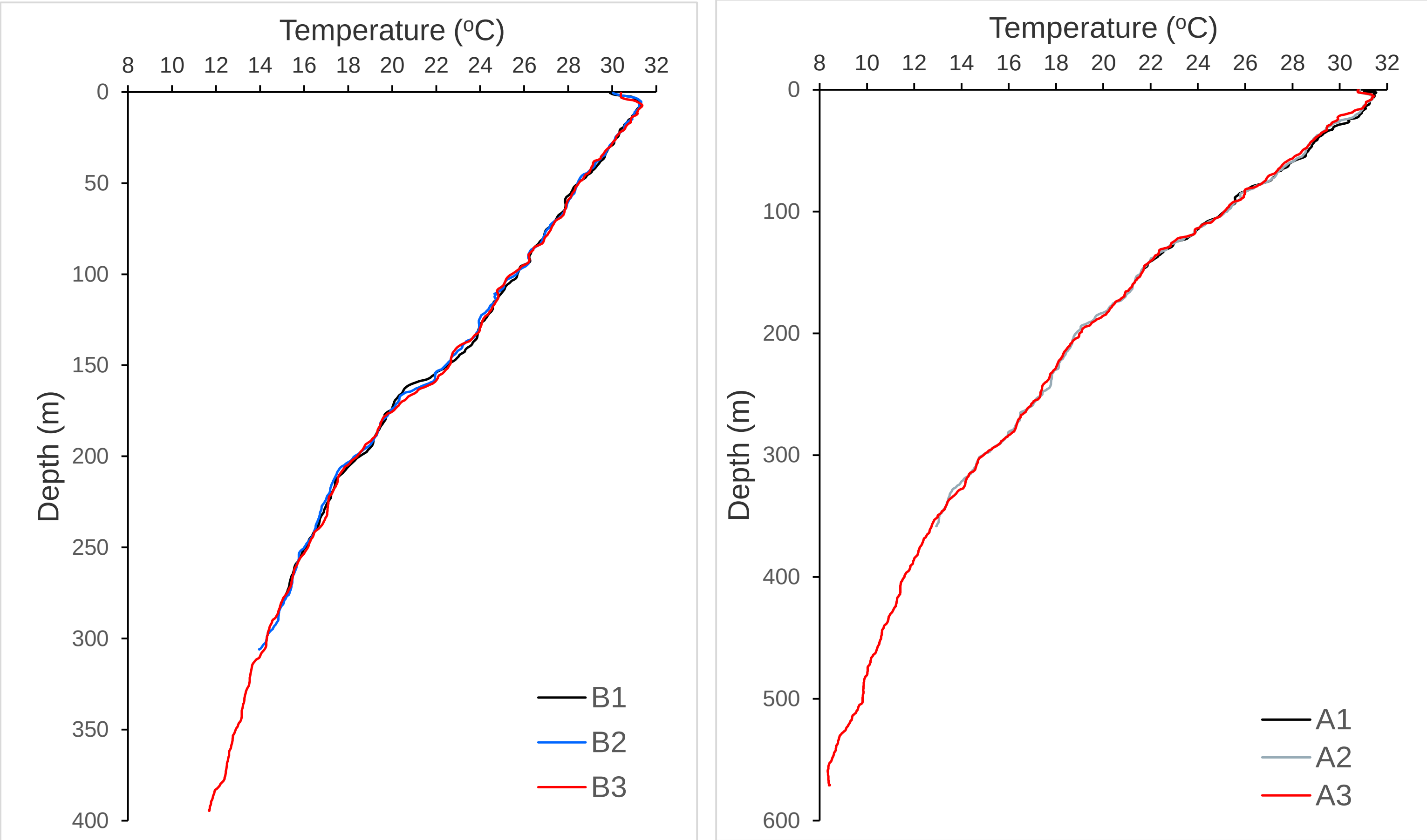


Figure 3.20: Temperature profiles (ºC) obtained in the DSTP study area at sites B1-B3 (left), and A1-A3 (right)

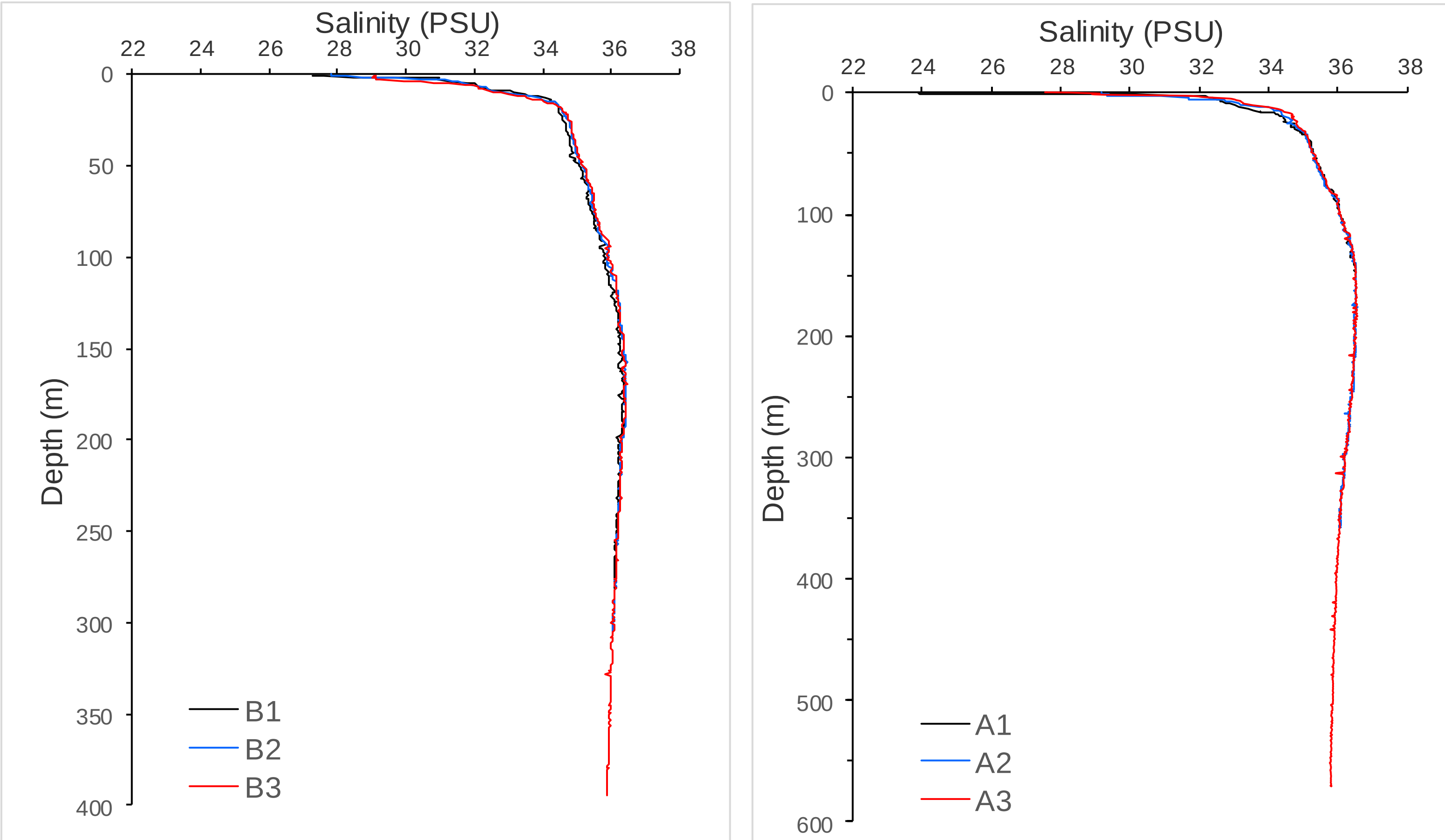


Figure 3.21: Salinity profiles (PSU) obtained in the DSTP study area at sites B1-B3 (left), and A1-A3 (right)

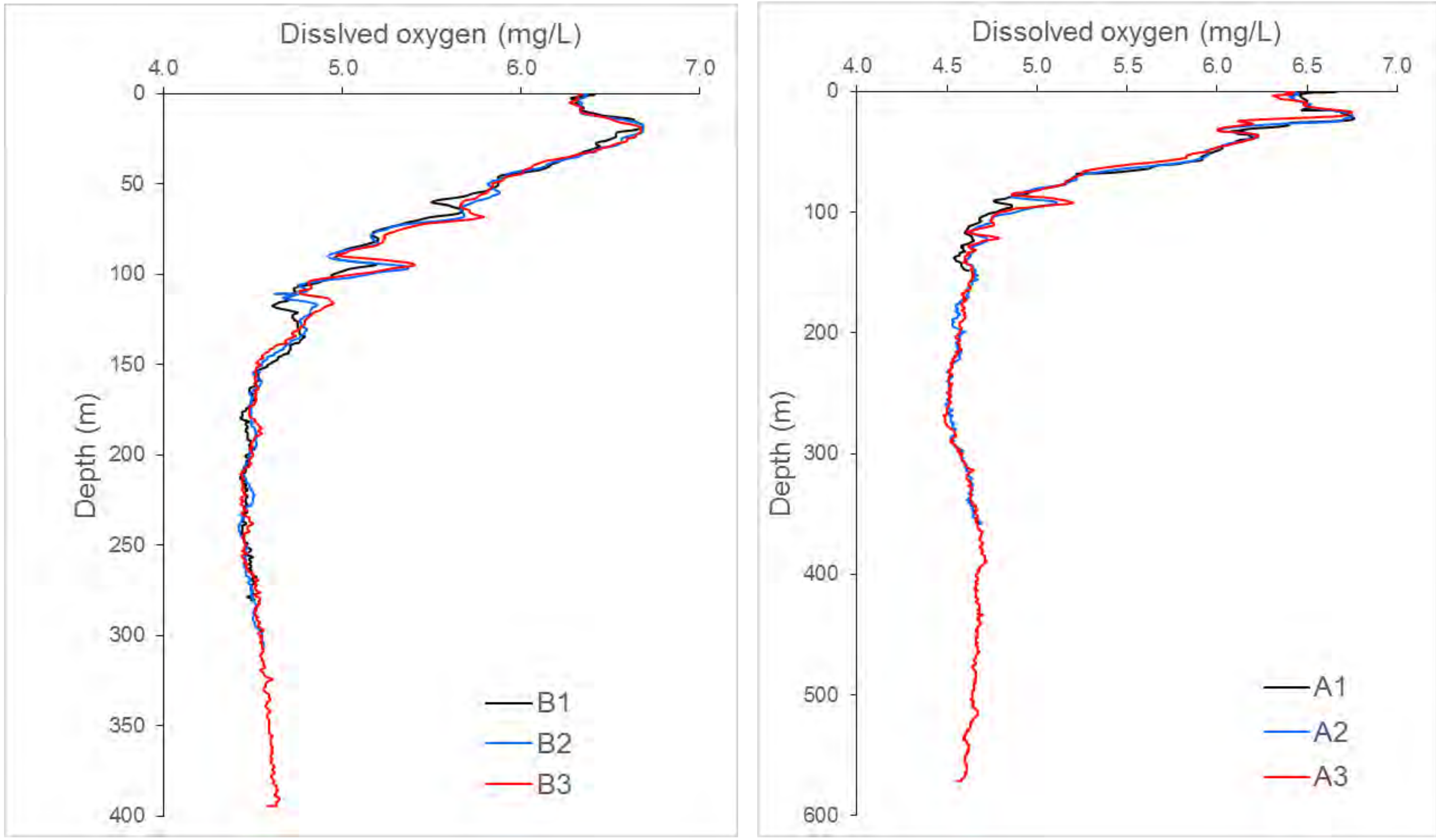


Figure 3.22: Dissolved oxygen profiles (mg/L) obtained in the DSTP study area at sites B1-B3 (left), and A1-A3 (right)

3.4. Metal concentrations

Details of the 38 zooplankton samples collected in March 2017 and the 21 micronekton taxa collected in May 2017 are provided in Table 3.3 and Table 3.4 respectively. The zooplankton samples are labelled in terms of distance of site from the coast (i.e., inshore, mid-slope or offshore) and depth strata (i.e., 1 = 100 to 0 m, 2 = 250 to 0 m or 5 = 500 to 0 m) at which the sample was obtained.

A selection of the metals presented in this section are shown graphically, for both the zooplankton and micronekton samples. This section only graphs those metals whose concentrations (on a wet weight concentration basis, mg/kg) were mostly detected to be above the practical quantification limits (PQL) (and therefore suitable to be shown visually).

Table 3.3: Details of zooplankton samples collected for metals analyses during March 2017

Sample number	Date	Site label	Station number	Location	Depth strata (m)	Time collected
1	4/03/2017	P65	6	Offshore	500 - 0	am
2	4/03/2017	P101	10	Inshore	100 - 0	am
3	4/03/2017	P35	3	Offshore	500 - 0	am
4	4/03/2017	P92	9	Offshore	250 - 0	am
5	4/03/2017	P95	9	Offshore	500 - 0	am
6	4/03/2017	P92	9	Offshore	250 - 0	pm
7	3/03/2017	P91	9	Offshore	100 - 0	pm
8	3/03/2017	P31	3	Offshore	100 - 0	pm
9	3/03/2017	P61	6	Offshore	100 - 0	pm
10	4/03/2017	P112	11	Mid-slope	250 - 0	am
11	4/03/2017	P111	11	Mid-slope	100 - 0	am
12	4/03/2017	P95	9	Offshore	250 - 0	pm
13	3/03/2017	P32	3	Offshore	250 - 0	am
14	3/03/2017	P51	5	Mid-slope	100 - 0	am
15	3/03/2017	P82	8	Mid-slope	250 - 0	am
16	3/03/2017	P22	2	Mid-slope	250 - 0	pm
17	3/03/2017	P82	8	Mid-slope	250 - 0	pm
18	3/03/2017	P62	6	Offshore	250 - 0	am
19	3/03/2017	P31	3	Offshore	100 - 0	am
20	3/03/2017	P91	9	Offshore	100 - 0	am
21	3/03/2017	P52	5	Mid-slope	250 - 0	pm
22	3/03/2017	P22	2	Mid-slope	250 - 0	am
23	3/03/2017	P52	5	Mid-slope	250 - 0	am
24	2/03/2017	P21	2	Mid-slope	100 - 0	pm
25	2/03/2017	P41	4	Inshore	100 - 0	am
26	2/03/2017	P81	8	Mid-slope	100 - 0	pm

Sample number	Date	Site label	Station number	Location	Depth strata (m)	Time collected
27	2/03/2017	P71	7	Inshore	100 - 0	pm
28	2/03/2017	P21	2	Mid-slope	100 - 0	am
29	2/03/2017	P71	7	Inshore	100 - 0	am
30	2/03/2017	P81	8	Mid-slope	100 - 0	am
31	2/03/2017	P11	1	Inshore	100 - 0	pm
32	2/03/2017	P11	1	Inshore	100 - 0	am
33	2/03/2017	P61	6	Offshore	100 - 0	am
34	4/03/2017	P35	3	Offshore	500 - 0	pm
35	4/03/2017	P65	6	Offshore	500 - 0	pm
36	4/03/2017	P32	3	Offshore	250 - 0	pm
37	4/03/2017	P62	6	Offshore	250 - 0	pm
38	2/03/2017	P51	5	Mid-slope	100 - 0	pm

Table 3.4: Details of micronekton taxa collected for metals analyses during May 2017

Sample Number	Date	Site label	Taxa type	Sample description	Location	Depth strata (m)	Time collected
1	1/05/2017	MA-O-D	Juvenile fish	*Xenodermichthys nodulosus*	Offshore	500 - 0	am
2	1/05/2017	MA-O-N	Juvenile fish	*Xenodermichthys nodulosus*	Offshore	500 - 0	pm
3	1/05/2017	MA-O-N	Juvenile fish	*Xenodermichthys nodulosus*	Offshore	500 - 0	pm
4	1/05/2017	MA-O-D	Larval fish	*Chauliodus sloani*	Offshore	500 - 0	am
5	1/05/2017	MA-O-D	Larval fish	*Chauliodus sloani*	Offshore	500 - 0	am
6	1/05/2017	MA-O-D	Larval fish	*Bregmaceros* sp.	Offshore	500 - 0	am
7	1/05/2017	MA-I-D	Larval fish	Gonostomatid A	Inshore	250 - 0	am
8	1/05/2017	MA-I-D	Larval fish	Gonostomatid A	Inshore	250 - 0	am
9	1/05/2017	MA-I-N	Juvenile fish	Anguilliform	Inshore	250 - 0	pm
10	1/05/2017	MA-I-N	Juvenile fish	Anguilliform	Inshore	250 - 0	pm
11	1/05/2017	MA-I-D	Larval fish	Trachichthyid	Inshore	250 - 0	am
11	1/05/2017	MA-I-D	Larval fish	Trachichthyid	Inshore	250 - 0	am
12	1/05/2017	MA-O-N	Larval fish	Conger eel	Offshore	500 - 0	pm
13	1/05/2017	MA-I-D	Larval fish	Gonostomatid B	Inshore	250 - 0	am
14	1/05/2017	MA-O-N	Crustacean	Mysidacea	Offshore	500 - 0	pm
15	1/05/2017	MA-O-N	Crustacean	Pandalid	Offshore	500 - 0	pm
16	1/05/2017	MA-O-N	Crustacean	Decapoda A	Offshore	500 - 0	pm

Sample Number	Date	Site label	Taxa type	Sample description	Location	Depth strata (m)	Time collected
17	1/05/2017	MA-I-D	Larval fish	Gonostomatid A	Inshore	250 - 0	am
18	1/05/2017	MA-O-N	Larval fish	*Bregmaceros* sp.	Offshore	500 - 0	pm
19	1/05/2017	MA-I-D	Crustacean	Pandalid	Inshore	250 - 0	am
20	1/05/2017	MA-I-N	Crustacean	Decapoda B	Inshore	250 - 0	pm
20	1/05/2017	MA-I-N	Crustacean	Decapoda B	Inshore	250 - 0	pm
21	1/05/2017	MA-O-N	Mollusc	Pteropoda	Offshore	500 - 0	pm

3.4.1. Zooplankton

Concentrations of each metal analysed on the 38 zooplankton samples are provided in Table 3.5 to Table 3.13. Each table provides data on minimum, maximum, median, mean, first and third quartile concentrations, as well as the number of samples. The PQLs are also provided for each metal. Results are given for the DSTP study area samples as well as the reference study area samples.

The raw laboratory data are presented in Appendix A.

Averaged metal concentrations from zooplankton samples grouped into their respective zones and depth strata are shown in Figure 3.23. The box and whisker plots were configured with the whiskers showing the first and third quartiles.

Metal concentrations in zooplankton samples generally decreased with increasing distance from the coast, i.e., from inshore to offshore sites. Additionally, metals concentrations in the reference study area sites were generally lower than the minimum obtained from samples in the DSTP study area except in the cases of As and Cd, whose concentrations were within the lower range of those detected in the DSTP study area (Figure 3.23).

Arsenic

Concentrations of As across zooplankton samples ranged between less than 0.4 mg/kg and 3 mg/kg. The highest As concentration (3 mg/kg) was detected in a mid-slope sample collected in the 100 m to 0 m depth range (Table 3.5).

Table 3.5: Arsenic concentrations (mg/kg) in zooplankton samples collected in March 2017

Arsenic (PQL = 0.4 mg/kg)		Minimum	First quartile	Median	Third quartile	Maximum	Mean	No. samples
DSTP study area								
Inshore	**100 - 0 m**	0.83	0.97	1.5	1.75	2.2	1.45	5
Mid-slope	**100 - 0 m**	1.0	1.4	1.5	1.68	3.0	1.68	6
	250 - 0 m	0.92	1.05	1.33	1.46	1.9	1.32	6
Offshore	**100 - 0 m**	0.82	1.23	1.3	1.3	1.7	1.27	6
	250 - 0 m	0.47	0.60	0.82	1.34	1.9	1.01	6
	500 - 0 m	<0.4	0.94	1.2	1.2	1.6	1.15	6

Arsenic (PQL = 0.4 mg/kg)		Minimum	First quartile	Median	Third quartile	Maximum	Mean	No. samples
Reference study area								
Inshore	**100 - 0 m**	1.2	1.2	1.2	1.2	1.2	1.2	1
Mid-slope	**100 - 0 m**	1.0	1.0	1.0	1.0	1.0	1.0	1
	250 - 0 m	0.61	0.61	0.61	0.61	0.61	0.61	1

Cadmium

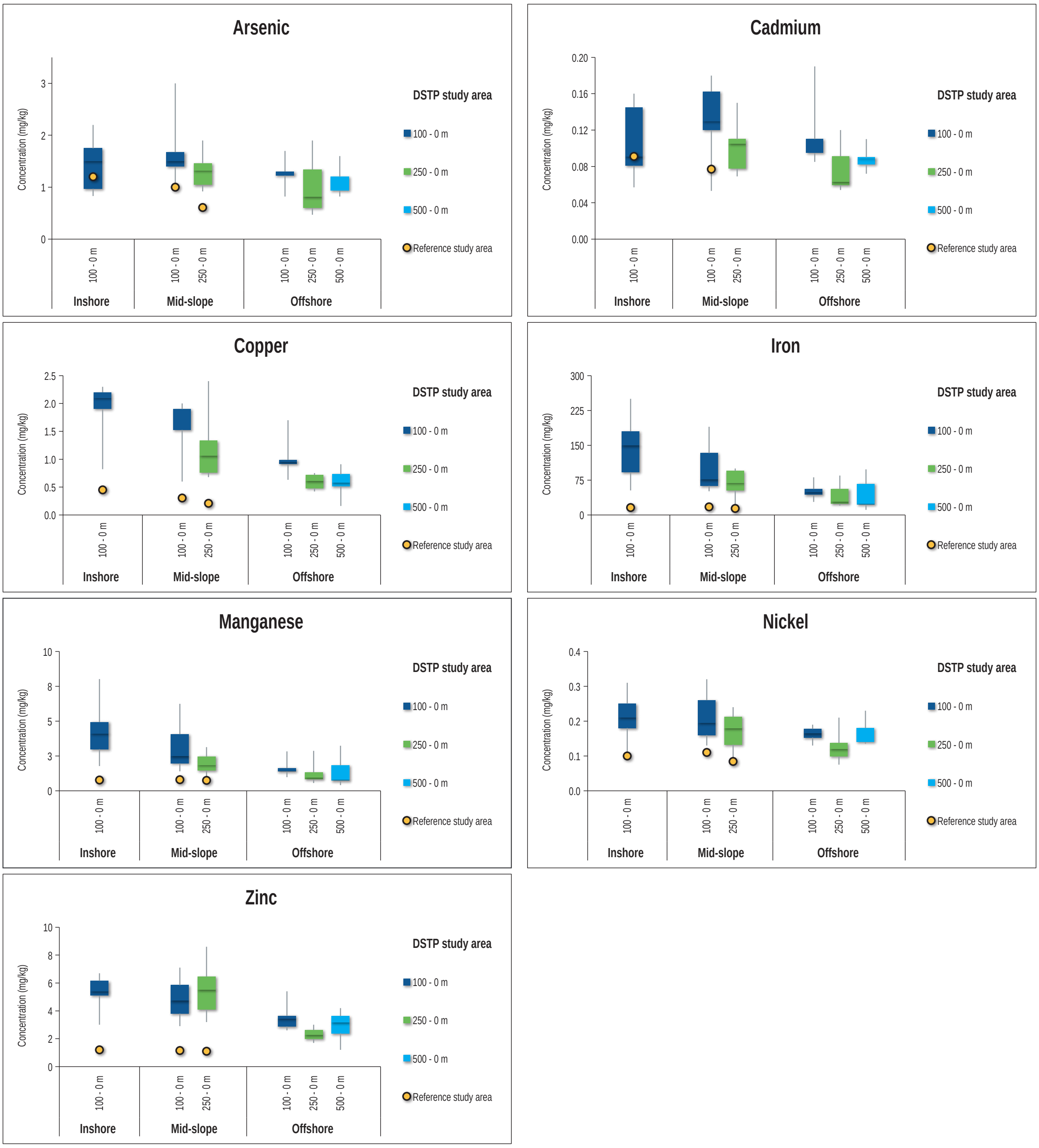
Concentrations of Cd across zooplankton samples ranged between less than 0.05 mg/kg and 0.19 mg/kg. The highest Cd concentration (0.19 mg/kg) was detected in an offshore sample collected in the 100 m to 0 m depth range (Table 3.6).

Table 3.6: Cadmium concentrations (mg/kg) in zooplankton samples collected in March 2017

Cadmium (PQL = 0.05 mg/kg)		Minimum	First quartile	Median	Third quartile	Maximum	Mean	No. samples
DSTP study area								
Inshore	**100 - 0 m**	0.06	0.08	0.09	0.15	0.16	0.11	5
Mid-slope	**100 - 0 m**	0.05	0.12	0.13	0.16	0.18	0.13	6
	250 - 0 m	0.07	0.08	0.11	0.11	0.15	0.1	6
Offshore	**100 - 0 m**	0.09	0.1	0.11	0.11	0.19	0.12	6
	250 - 0 m	0.05	0.06	0.06	0.09	0.12	0.08	6
	500 - 0 m	<0.05	0.08	0.09	0.09	0.11	0.09	6
Reference study area								
Inshore	**100 - 0 m**	0.09	0.09	0.09	0.09	0.09	0.09	1
Mid-slope	**100 - 0 m**	0.08	0.08	0.08	0.08	0.08	0.08	1
	250 - 0 m	<0.05	<0.05	<0.05	<0.05	<0.05	-	1

Chromium

Concentrations of Cr across zooplankton samples ranged between less than 0.1 mg/kg and 0.24 mg/kg. The highest Cr concentration (0.24 mg/kg) was recorded in an inshore sample collected in the 100 m to 0 m depth range (Table 3.7).



Note:
The whiskers show minimum and maximum values (bottom and top respectively), outer box borders show the 25th and 75th quartiles (bottom and top respectively), and the mid-lines denote the median values.

coffey A TETRA TECH COMPANY	Date: 21.03.2018 Project: 754-ENAUABTF100520CC File Name: 0520CC_16_F03.23_GRA	WAFI-GOLPU JOINT VENTURE Wafi-Golpu Project	Concentrations of As, Cd, Cu, Fe, Mn, Ni and Zn in zooplankton samples collected in March 2017 from the DSTP and reference study areas	Figure No: 3.23

AI Reference: 0520CC_16_GRA001.ai_4

Table 3.7: Chromium concentrations (mg/kg) in zooplankton samples collected in March 2017

Chromium (PQL = 0.1 mg/kg)		Minimum	First quartile	Median	Third quartile	Maximum	Mean	No. samples
DSTP study area								
Inshore	**100 - 0 m**	0.12	0.17	0.19	0.20	0.24	0.18	5
Mid-slope	**100 - 0 m**	0.11	0.11	0.15	0.19	0.23	0.16	6
	250 - 0 m	0.15	0.15	0.15	0.18	0.21	0.17	6
Offshore	**100 - 0 m**	0.11	0.11	0.11	0.11	0.11	0.11	6
	250 - 0 m	0.13	0.13	0.13	0.13	0.13	0.13	6
	500 - 0 m	0.10	0.11	0.12	0.12	0.13	0.12	6
Reference study area								
Inshore	**100 - 0 m**	<0.1	<0.1	<0.1	<0.1	<0.1	-	1
Mid-slope	**100 - 0 m**	<0.1	<0.1	<0.1	<0.1	<0.1	-	1
	250 - 0 m	<0.1	<0.1	<0.1	<0.1	<0.1	-	1

Copper

Concentrations of Cu across zooplankton samples ranged between 0.16 and 2.4 mg/kg. The highest Cu concentration (2.4 mg/kg) was recorded in a mid-slope sample collected in the 250 m to 0 m depth range (Table 3.8).

Table 3.8: Copper concentrations (mg/kg) in zooplankton samples collected in March 2017

Copper (PQL = 0.05 mg/kg)		Minimum	First quartile	Median	Third quartile	Maximum	Mean	No. samples
DSTP study area								
Inshore	**100 - 0 m**	0.82	1.90	2.10	2.2	2.3	1.86	5
Mid-slope	**100 - 0 m**	0.6	1.53	1.9	1.9	2.0	1.62	6
	250 - 0 m	0.68	0.76	1.06	1.34	2.4	1.22	6
Offshore	**100 - 0 m**	0.63	0.91	0.96	0.99	1.7	1.02	6
	250 - 0 m	0.42	0.48	0.61	0.72	0.75	0.6	6
	500 - 0 m	0.16	0.52	0.58	0.73	0.91	0.58	6
Reference study area								
Inshore	**100 - 0 m**	0.45	0.45	0.45	0.45	0.45	0.45	1
Mid-slope	**100 - 0 m**	0.31	0.31	0.31	0.31	0.31	0.31	1
	250 - 0 m	0.21	0.21	0.21	0.21	0.21	0.21	1

Iron

Concentrations of Fe across zooplankton samples ranged between 11.0 and 250.0 mg/kg. The highest Fe concentration (250 mg/kg) was recorded in an inshore sample collected in the 100 m to 0 m depth range (Table 3.9).

Table 3.9: Iron concentrations (mg/kg) in zooplankton samples collected in March 2017

Iron (PQL = 0.5 mg/kg)		Minimum	First quartile	Median	Third quartile	Maximum	Mean	No. samples
DSTP study area								
Inshore	**100 - 0 m**	53.0	92.0	150.0	180.0	250.0	145.0	5
Mid-slope	**100 - 0 m**	51.0	62.75	76.5	133.0	190.0	100.67	6
	250 - 0 m	23.0	52.75	69.25	95.13	100.0	68.75	6
Offshore	**100 - 0 m**	28.0	43.25	49.5	55.75	81.0	51.17	6
	250 - 0 m	20.0	24.25	28.5	56.0	85.0	41.67	6
	500 - 0 m	11.0	22.5	24.5	67.0	98.0	43.5	6
Reference study area								
Inshore	**100 - 0 m**	16.0	16.0	16.0	16.0	16.0	16.0	1
Mid-slope	**100 - 0 m**	17.5	17.5	17.5	17.5	17.5	17.5	1
	250 - 0 m	14.0	14.0	14.0	14.0	14.0	14.0	1

Lead

Concentrations of Pb across zooplankton samples ranged between less than 0.1 mg/kg and 0.21 mg/kg. The highest Pb concentration (0.21 mg/kg) was recorded in a mid-slope sample collected in the 250 m to 0 m depth range (Table 3.10). Only 4 of the 38 samples recorded Pb concentrations above the PQL of 1 mg/kg, with the rest being below the PQL.

Table 3.10: Lead concentrations (mg/kg) in zooplankton samples collected in March 2017

Lead (PQL = 0.1 mg/kg)		Minimum	First quartile	Median	Third quartile	Maximum	Mean	No. samples
DSTP study area								
Inshore	**100 - 0 m**	0.1	0.1	0.1	0.1	0.1	0.1	5
Mid-slope	**100 - 0 m**	<0.1	<0.1	<0.1	<0.1	<0.1	-	6
	250 - 0 m	0.1	0.13	0.16	0.18	0.21	0.16	6
Offshore	**100 - 0 m**	<0.1	<0.1	<0.1	<0.1	<0.1	-	6
	250 - 0 m	<0.1	<0.1	<0.1	<0.1	<0.1	-	6
	500 - 0 m	0.1	0.1	0.1	0.1	0.1	0.1	6
Reference study area								
Inshore	**100 - 0 m**	<0.1	<0.1	<0.1	<0.1	<0.1	-	1
Mid-slope	**100 - 0 m**	<0.1	<0.1	<0.1	<0.1	<0.1	-	1
	250 - 0 m	<0.1	<0.1	<0.1	<0.1	<0.1	-	1

Mercury

Concentrations of Hg across all zooplankton samples were below the PQL of 0.01 mg/kg, and are therefore not tabulated here.

Manganese

Concentrations of Mn across zooplankton samples ranged between 0.41 and 8.02 mg/kg. The highest Mn concentration (8.02 mg/kg) was recorded in an inshore sample collected in the 100 m to 0 m depth range (Table 3.11).

Table 3.11: Manganese concentrations (mg/kg) in zooplankton samples collected in March 2017

Manganese (PQL = 0.1 mg/kg)		Minimum	First quartile	Median	Third quartile	Maximum	Mean	No. samples
DSTP study area								
Inshore	**100 - 0 m**	1.78	2.99	4.11	4.94	8.02	4.37	5
Mid-slope	**100 - 0 m**	1.4	1.97	2.48	4.06	6.24	3.16	6
	250 - 0 m	0.86	1.45	1.86	2.45	3.13	1.95	6
Offshore	**100 - 0 m**	0.97	1.39	1.42	1.63	2.83	1.62	6
	250 - 0 m	0.56	0.82	0.96	1.33	2.87	1.26	6
	500 - 0 m	0.41	0.73	0.79	1.83	3.23	1.35	6
Reference study area								
Inshore	**100 - 0 m**	0.77	0.77	0.77	0.77	0.77	0.77	1
Mid-slope	**100 - 0 m**	0.79	0.79	0.79	0.79	0.79	0.79	1
	250 - 0 m	0.75	0.75	0.75	0.75	0.75	0.75	1

Nickel

Concentrations of Ni across zooplankton samples ranged between less than 0.06 mg/kg and 0.32 mg/kg. The highest Ni concentration (0.32 mg/kg) was recorded in a mid-slope sample collected in the 100 m to 0 m depth range (Table 3.12).

Table 3.12: Nickel concentrations (mg/kg) in zooplankton samples collected in March 2017

Nickel (PQL = 0.06 mg/kg)		Minimum	First quartile	Median	Third quartile	Maximum	Mean	No. samples
DSTP study area								
Inshore	**100 - 0 m**	0.1	0.18	0.21	0.25	0.31	0.21	5
Mid-slope	**100 - 0 m**	0.13	0.16	0.2	0.26	0.32	0.21	6
	250 - 0 m	0.09	0.13	0.18	0.21	0.24	0.17	6
Offshore	**100 - 0 m**	0.13	0.15	0.17	0.18	0.19	0.16	6
	250 - 0 m	0.08	0.1	0.12	0.14	0.21	0.13	6
	500 - 0 m	<0.06	0.14	0.14	0.18	0.23	0.17	6
Reference study area								
Inshore	**100 - 0 m**	0.1	0.1	0.1	0.1	0.1	0.1	1
Mid-slope	**100 - 0 m**	0.11	0.11	0.11	0.11	0.11	0.11	1
	250 - 0 m	0.08	0.08	0.08	0.08	0.08	0.08	1

Selenium

Concentrations of Se across all zooplankton samples were below the PQL of 0.5 mg/kg, and are therefore not tabulated here.

Silver

Concentrations of Ag across all zooplankton samples were below the PQL of 0.1 mg/kg, and are therefore not tabulated here.

Zinc

Concentrations of Zn across zooplankton samples ranged between 1.1 and 8.6 mg/kg. The highest Zn concentration (8.6 mg/kg) was recorded in a mid-slope sample collected in the 250 m to 0 m depth range (Table 3.13).

Table 3.13: Zinc concentrations (mg/kg) in zooplankton samples collected in March 2017

Zinc (PQL = 0.2 mg/kg)		Minimum	First quartile	Median	Third quartile	Maximum	Mean	No. samples
DSTP study area								
Inshore	**100 - 0 m**	3.0	5.1	5.4	6.15	6.7	5.27	5
Mid-slope	**100 - 0 m**	2.9	3.80	4.75	5.85	7.1	4.87	6
	250 - 0 m	3.2	4.1	5.55	6.48	8.6	5.55	6
Offshore	**100 - 0 m**	2.6	2.88	3.45	3.65	5.4	3.55	6
	250 - 0 m	1.7	1.98	2.3	2.63	3.0	2.32	6
	500 - 0 m	1.2	2.39	3.18	3.63	4.2	2.94	6
Reference study area								
Inshore	**100 - 0 m**	1.2	1.2	1.2	1.2	1.2	1.2	1
Mid-slope	**100 - 0 m**	1.15	1.15	1.15	1.15	1.15	1.15	1
	250 - 0 m	1.1	1.1	1.10	1.1	1.1	1.1	1

3.4.2. Micronekton

Metal concentrations for 21 selected micronekton taxa caught in the May 2017 survey are provided in Table 3.14 to Table 3.25 and shown in Figure 3.24. Each table provides data on minimum, maximum, and mean concentration as well as the standard deviation and the number of specimens. The PQLs are also provided for each metal.

The raw laboratory data are presented in Appendix A.

Averaged metal concentrations (± 95th percentile values) across same micronekton taxa are presented in Figure 3.24; mean values correspond to cases with at least two specimens per taxa.

Arsenic

Concentrations of As across micronekton taxa ranged between 0.19 and 6.4 mg/kg. The highest As concentration (6.4 mg/kg) was detected in a juvenile *Xenodermichthys nodulosus* caught in an offshore sample collected between 500 m and 0 m (Table 3.14).

Table 3.14: Arsenic concentrations (mg/kg) in micronekton taxa collected in the DSTP study area in May 2017

Arsenic (PQL = 0.1 mg/kg)							
Location	**Depth strata (m)**	**Taxa**	**Minimum**	**Maximum**	**Mean**	**n**	**StDev**
Inshore	250 - 0	Decapoda B	0.43	0.43	0.43	1	-
		Gonostomatid A	0.29	0.64	0.44	3	0.18
		Gonostomatid B	0.9	0.9	0.9	1	-
		Pandalid	1.0	1.0	1.0	1	-
		Anguilliform	0.26	0.45	0.36	2	0.13
		Trachichthyid	0.52	0.52	0.52	1	-
Offshore	500 - 0	Pandalid	0.65	0.65	0.65	1	-
		Bregmaceros sp.	0.33	0.36	0.35	2	0.02
		Chauliodus sloani	0.5	0.59	0.55	2	0.06
		Conger eel	0.44	0.44	0.44	1	-
		Decapoda A	0.19	0.19	0.19	1	-
		Mysidacea	0.24	0.24	0.24	1	-
		Pteropoda	0.37	0.37	0.37	1	-
		Xenodermichthys nodulosus	5.0	6.4	5.53	3	0.76

Cadmium

Concentrations of Cd across micronekton taxa ranged between 0.02 and 2.1 mg/kg. The highest Cd concentration (2.1 mg/kg) was detected in a pandalid shrimp caught in an offshore sample collected between 500 m and 0 m (Table 3.15).

Table 3.15: Cadmium concentrations (mg/kg) in micronekton samples collected in the DSTP study area in May 2017

Cadmium (PQL = 0.02 mg/kg)							
Location	**Max depth (m)**	**Taxa**	**Minimum**	**Maximum**	**Mean**	**n**	**StDev**
Inshore	250 - 0	Decapoda B	0.18	0.18	0.18	1	-
		Gonostomatid A	0.07	0.09	0.08	3	0.01
		Gonostomatid B	0.06	0.06	0.06	1	-
		Pandalid	0.57	0.57	0.57	1	-
		Anguilliform	0.10	0.28	0.19	2	0.13
		Trachichthyid	0.03	0.03	0.03	1	-

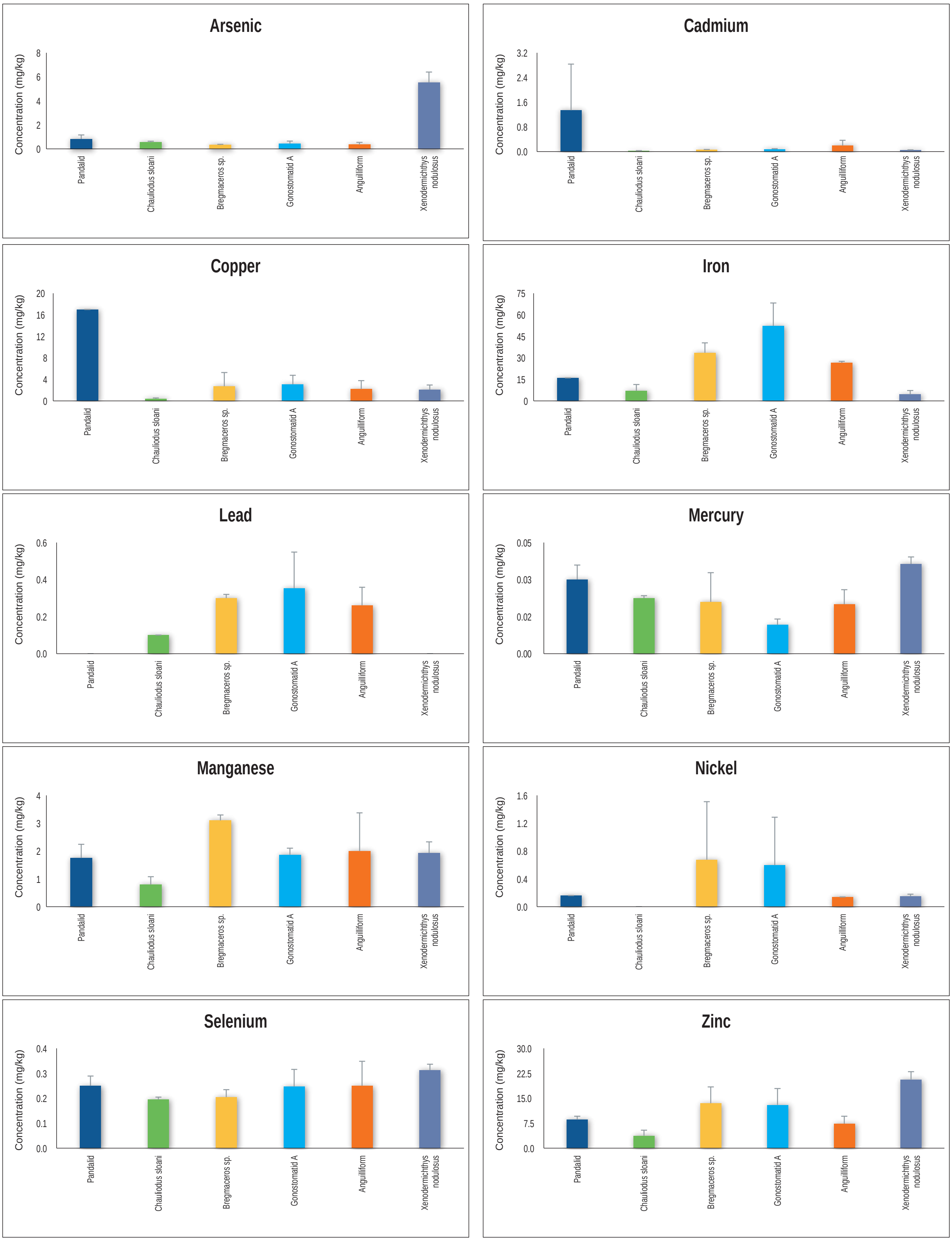
Location	Max depth (m)	Taxa	Minimum	Maximum	Mean	n	StDev
Offshore	500 - 0	Pandalid	2.1	2.1	2.1	1	-
		Bregmaceros sp.	0.07	0.07	0.07	2	0.0
		Chauliodus sloani	0.02	0.03	0.03	2	0.0
		Conger eel	0.07	0.07	0.07	1	-
		Decapoda A	0.08	0.08	0.08	1	-
		Mysidacea	0.06	0.06	0.06	1	-
		Pteropoda	0.19	0.19	0.19	1	-
		Xenodermichthys nodulosus	0.05	0.05	0.05	3	0.0

Chromium

Concentrations of Cr across micronekton taxa ranged between less than 0.1 mg/kg and 0.26 mg/kg. The highest Cr concentration (0.26 mg/kg) was detected in a juvenile *Xenodermichthys nodulosus* caught in an offshore sample collected between 500 m and 0 m (Table 3.16).

Table 3.16: Chromium concentrations (mg/kg) in micronekton samples collected in the DSTP study area in May 2017

Chromium (PQL = 0.1 mg/kg)							
Location	**Max depth (m)**	**Taxa**	**Minimum**	**Maximum**	**Mean**	**n**	**StDev**
Inshore	250 - 0	Decapoda B	<0.1	<0.1	-	1	-
		Gonostomatid A	<0.1	<0.1	-	3	-
		Gonostomatid B	<0.1	<0.1	-	1	-
		Pandalid	<0.1	<0.1	-	1	-
		Anguilliform	<0.1	<0.1	-	2	-
		Trachichthyid	<0.1	<0.1	-	1	-
Offshore	500 - 0	Pandalid	<0.1	<0.1	-	1	-
		Bregmaceros sp.	<0.1	<0.1	-	2	-
		Chauliodus sloani	<0.1	<0.1	-	2	-
		Conger eel	<0.1	<0.1	-	1	-
		Decapoda A	<0.1	<0.1	-	1	-
		Mysidacea	<0.1	<0.1	-	1	-
		Pteropoda	0.25	0.25	0.25	1	-
		Xenodermichthys nodulosus	0.11	0.26	0.19	3	0.11



Note:
Error bars denote 95th percentile values.

Concentrations of As, Cd, Cu, Fe, Pb, Hg, Mn, Ni, Se and Zn in micronekton taxa collected in the DSTP study area in May 2017

Figure No: 3.24

Copper

Concentrations of Cu across micronekton taxa ranged between 0.34 and 17.0 mg/kg. The highest Cu concentration (17.0 mg/kg) was detected in a pandalid shrimp caught in an offshore sample collected between 500 m and 0 m, as well as another pandalid shrimp caught in an inshore sample collected between 250 m and 0 m (Table 3.17).

Table 3.17: Copper concentrations (mg/kg) in micronekton samples collected in the DSTP study area in May 2017

Copper (PQL = 0.05 mg/kg)							
Location	**Max depth (m)**	**Taxa**	**Minimum**	**Maximum**	**Mean**	**n**	**StDev**
Inshore	250 - 0	Decapoda B	5.8	5.8	5.8	1	-
		Gonostomatid A	2.2	4.8	3.07	3	1.50
		Gonostomatid B	3.4	3.4	3.4	1	-
		Pandalid	17.0	17.0	17.0	1	-
		Anguilliform	1.4	3.0	2.2	2	1.13
		Trachichthyid	2.5	2.5	2.5	1	-
Offshore	500 - 0	Pandalid	17.0	17.0	17.0	1	-
		Bregmaceros sp.	1.4	4.0	2.7	2	1.84
		Chauliodus sloani	0.34	0.46	0.4	2	0.08
		Conger eel	1.8	1.8	1.8	1	-
		Decapoda A	1.7	1.7	1.7	1	-
		Mysidacea	4.8	4.8	4.8	1	-
		Pteropoda	3.8	3.8	3.8	1	-
		Xenodermichthys nodulosus	1.4	2.9	2.07	3	0.76

Iron

Concentrations of Fe across micronekton taxa ranged between 3.0 and 210.0 mg/kg. The highest Fe concentration (210.0 mg/kg) was detected in a pteropod specimen caught in an offshore sample collected between 500 m and 0 m (Table 3.18).

Table 3.18: Iron concentrations (mg/kg) in micronekton samples collected in the DSTP study area in May 2017

Iron (PQL = 1.5 mg/kg)							
Location	**Max depth (m)**	**Taxa**	**Minimum**	**Maximum**	**Mean**	**n**	**StDev**
Inshore	250 - 0	Decapoda B	17	17	17	1	-
		Gonostomatid A	41	68	52.3	3	14.01
		Gonostomatid B	160	160	160	1	-
		Pandalid	16	16	16	1	-
		Anguilliform	26	27	26.5	2	0.71
		Trachichthyid	99	99	99	1	-
Offshore	500 - 0	Pandalid	16	16	16	1	-
		Bregmaceros sp.	30	37	33.5	2	4.95
		Chauliodus sloani	4.9	9.3	7.1	2	3.11
		Conger eel	3.0	3.0	3.0	1	-
		Decapoda A	19	19	19	1	-
		Mysidacea	11	11	11	1	-
		Pteropoda	210	210	210	1	-
		Xenodermichthys nodulosus	3.0	7.3	4.5	3	2.43

Lead

Concentrations of Pb across micronekton taxa ranged between less than 0.1 mg/kg and 0.55 mg/kg. The highest Pb concentration (0.55 mg/kg) was detected in larvae of gonostomatid A caught in an inshore sample collected between 250 m and 0 m (Table 3.19).

Table 3.19: Lead concentrations (mg/kg) in micronekton samples collected in the DSTP study area in May 2017

Lead (PQL = 0.1 mg/kg)							
Location	**Max depth (m)**	**Taxa**	**Minimum**	**Maximum**	**Mean**	**n**	**StDev**
Inshore	250 - 0	Decapoda B	0.21	0.21	0.21	1	-
		Gonostomatid A	0.23	0.55	0.35	3	0.17
		Gonostomatid B	0.1	0.1	0.1	1	-
		Pandalid	<0.1	<0.1	-	1	-
		Anguilliform	0.21	0.31	0.26	2	0.07
		Trachichthyid	<0.1	<0.1	-	1	-

Location	Max depth (m)	Taxa	Minimum	Maximum	Mean	n	StDev
Offshore	500 - 0	Pandalid	<0.1	<0.1	-	1	-
		Bregmaceros sp.	0.29	0.31	0.30	2	0.01
		Chauliodus sloani	0.10	0.10	0.10	2	-
		Conger eel	<0.1	<0.1	-	1	-
		Decapoda A	<0.1	<0.1	-	1	-
		Mysidacea	<0.1	<0.1	-	1	-
		Pteropoda	0.24	0.24	0.24	1	-
		Xenodermichthys nodulosus	<0.1	<0.1	-	3	-

Mercury

Concentrations of Hg across micronekton taxa ranged between less than 0.01 mg/kg and 0.13 mg/kg. The highest Hg concentration (0.13 mg/kg) was detected in a conger eel larva caught in an offshore sample collected between 500 m and 0 m (Table 3.20).

Table 3.20: Mercury concentrations (mg/kg) in micronekton samples collected in the DSTP study area in May 2017

Mercury (PQL = 0.01 mg/kg)							
Location	**Max depth (m)**	**Taxa**	**Minimum**	**Maximum**	**Mean**	**n**	**StDev**
Inshore	250 - 0	Decapoda B	0.02	0.02	0.02	1	-
		Gonostomatid A	0.01	0.01	0.01	3	0.0
		Gonostomatid B	0.01	0.01	0.01	1	-
		Pandalid	0.03	0.03	0.03	1	-
		Anguilliform	0.02	0.02	0.02	2	0.0
		Trachichthyid	0.03	0.03	0.03	1	-
Offshore	500 - 0	Pandalid	0.03	0.03	0.03	1	-
		Bregmaceros sp.	0.02	0.03	0.02	2	0.01
		Chauliodus sloani	0.02	0.02	0.02	2	0.0
		Conger eel	0.13	0.13	0.13	1	-
		Decapoda A	0.02	0.02	0.02	1	-
		Mysidacea	0.01	0.01	0.01	1	-
		Pteropoda	0.1	0.1	0.1	1	-
		Xenodermichthys nodulosus	0.03	0.04	0.04	3	0.0

Manganese

Concentrations of Mn across micronekton taxa ranged between 0.34 and 8.8 mg/kg. The highest Mn concentration (8.8 mg/kg) was detected in a pteropod specimen caught in an offshore sample collected between 500 m and 0 m (Table 3.21).

Table 3.21: Manganese concentrations (mg/kg) in micronekton samples collected in the DSTP study area in May 2017

Manganese (PQL = 0.1 mg/kg)							
Location	**Max depth (m)**	**Taxa**	**Minimum**	**Maximum**	**Mean**	**n**	**StDev**
Inshore	250 - 0	Decapoda B	1.1	1.1	1.1	1	-
		Gonostomatid A	1.7	2.1	1.87	3	0.21
		Gonostomatid B	3.2	3.2	3.2	1	-
		Pandalid	1.5	1.5	1.5	1	-
		Anguilliform	1.3	2.7	2.0	2	0.99
		Trachichthyid	2.7	2.7	2.7	1	-
Offshore	500 - 0	Pandalid	2.0	2.0	2.0	1	-
		Bregmaceros sp.	3.0	3.2	3.1	2	0.14
		Chauliodus sloani	0.65	0.94	0.8	2	0.21
		Conger eel	0.34	0.34	0.34	1	-
		Decapoda A	0.83	0.83	0.83	1	-
		Mysidacea	1.6	1.6	1.6	1	-
		Pteropoda	8.8	8.8	8.8	1	-
		Xenodermichthys nodulosus	1.6	2.3	1.93	3	0.35

Nickel

Concentrations of Ni across micronekton taxa ranged between less than 0.1 mg/kg and 1.3 mg/kg. The highest Ni concentration (1.3 mg/kg) was detected in a specimen of *Bregmaceros* sp. caught in an offshore sample collected between 500 m and 0 m (Table 3.22).

Table 3.22: Nickel concentrations (mg/kg) in micronekton samples collected in the DSTP study area

Nickel (PQL = 0.1 mg/kg)							
Location	**Max depth (m)**	**Taxa**	**Minimum**	**Maximum**	**Mean**	**n**	**StDev**
Inshore	250 - 0	Decapoda B	<0.1	<0.1	-	1	-
		Gonostomatid A	0.24	1.3	0.6	3	0.61
		Gonostomatid B	0.36	0.36	0.36	1	-
		Pandalid	<0.1	<0.1	-	1	-
		Anguilliform	0.14	0.14	0.14	2	-
		Trachichthyid	0.25	0.25	0.25	1	-
Offshore	500 - 0	Pandalid	0.16	0.16	0.16	1	-
		Bregmaceros sp.	0.25	1.1	0.68	2	0.6
		Chauliodus sloani	<0.1	<0.1	-	2	-
		Conger eel	<0.1	<0.1	-	1	-
		Decapoda A	0.54	0.54	0.54	1	-
		Mysidacea	0.14	0.14	0.14	1	-
		Pteropoda	0.97	0.97	0.97	1	-
		Xenodermichthys nodulosus	0.13	0.18	0.15	3	0.03

Selenium

Concentrations of Se across micronekton taxa ranged between 0.13 and 0.53 mg/kg. The highest Se concentration (0.53 mg/kg) was detected in a conger eel larva caught in an offshore sample collected between 500 m and 0 m (Table 3.23).

Table 3.23: Selenium concentrations (mg/kg) in micronekton samples collected in the DSTP study area

Selenium (PQL = 0.1 mg/kg)							
Location	**Max depth (m)**	**Taxa**	**Minimum**	**Maximum**	**Mean**	**n**	**StDev**
Inshore	250 - 0	Decapoda B	0.28	0.28	0.28	1	-
		Gonostomatid A	0.18	0.3	0.25	3	0.06
		Gonostomatid B	0.31	0.31	0.31	1	-
		Pandalid	0.23	0.23	0.23	1	-
		Anguilliform	0.2	0.3	0.25	2	0.07
		Trachichthyid	0.22	0.22	0.22	1	-

Location	Max depth (m)	Taxa	Minimum	Maximum	Mean	n	StDev
Offshore	500 - 0	Pandalid	0.27	0.27	0.27	1	-
		Bregmaceros sp.	0.19	0.22	0.21	2	0.02
		Chauliodus sloani	0.19	0.2	0.2	2	0.01
		Conger eel	0.53	0.53	0.53	1	-
		Decapoda A	0.18	0.18	0.18	1	-
		Mysidacea	0.23	0.23	0.23	1	-
		Pteropoda	0.13	0.13	0.13	1	-
		Xenodermichthys nodulosus	0.29	0.33	0.31	3	0.02

Silver

Concentrations of Ag across micronekton taxa ranged between less than 0.05 mg/kg and 0.26 mg/kg. The highest Ag concentration (0.26 mg/kg) was detected in a pandalid specimen caught in an inshore sample collected between 250 m and 0 m (Table 3.24).

Table 3.24: Silver concentrations (mg/kg) in micronekton samples collected in the DSTP study area

Silver (PQL = 0.05 mg/kg)							
Location	**Max depth (m)**	**Taxa**	**Minimum**	**Maximum**	**Mean**	**n**	**StDev**
Inshore	250 - 0	Decapoda B	0.05	0.05	0.05	1	-
		Gonostomatid A	<0.05	<0.05	-	3	-
		Gonostomatid B	<0.05	<0.05	-	1	-
		Pandalid	0.26	0.26	0.26	1	-
		Anguilliform	<0.05	<0.05	-	2	-
		Trachichthyid	<0.05	<0.05	-	1	-
Offshore	500 - 0	Pandalid	0.23	0.23	0.23	1	-
		Bregmaceros sp.	<0.05	<0.05	-	2	-
		Chauliodus sloani	<0.05	<0.05	-	2	-
		Conger eel	<0.05	<0.05	-	1	-
		Decapoda A	<0.05	<0.05	-	1	-
		Mysidacea	<0.05	<0.05	-	1	-
		Pteropoda	<0.05	<0.05	-	1	-
		Xenodermichthys nodulosus	<0.05	<0.05	-	3	-

Zinc

Concentrations of Zn across micronekton taxa ranged between 2.9 and 23 mg/kg. The highest Zn concentration, 23 mg/kg, was detected in a *Xenodermichthys nodulosus* taxa caught in an offshore sample collected between 500 and 0 m (Table 3.25).

Table 3.25: Zinc concentrations (mg/kg) in micronekton samples collected in the DSTP study area

Zinc (PQL = 0.2 mg/kg)							
Location	**Max depth (m)**	**Taxa**	**Minimum**	**Maximum**	**Mean**	**n**	**StDev**
Inshore	250 - 0	Decapoda B	11	11	11	1	-
		Gonostomatid A	10	18	13	3	4.36
		Gonostomatid B	13	13	13	1	-
		Pandalid	8.1	8.1	8.1	1	-
		Anguilliform	6.2	8.5	7.35	2	1.63
		Trachichthyid	8.8	8.8	8.8	1	-
Offshore	500 - 0	Pandalid	9.1	9.1	9.1	1	-
		Bregmaceros sp.	11	16	13.5	2	3.54
		Chauliodus sloani	2.9	4.6	3.75	2	1.2
		Conger eel	6.6	6.6	6.6	1	-
		Decapoda A	7.3	7.3	7.3	1	-
		Mysidacea	12	12	12	1	-
		Pteropoda	7.2	7.2	7.2	1	-
		Xenodermichthys nodulosus	19	23	20.67	3	2.08

4. Discussion

4.1. Taxa diversity and abundance

4.1.1. Zooplankton

Thirty-eight zooplankton taxa groups were identified across the nine sites in the DSTP study area and the two sites in the reference study area during the March 2017 survey. The suite of taxa recorded during the present study shared some similarities with that reported in a study that investigated the impact of DSTP disposal of tailings from the Lihir gold mine on the east coast of Niolam Island in PNG (Brewer *et al*., 2012). However, one obvious cause of the differences in zooplankton profiles between the two studies resulted from the use of two different plankton net mesh sizes to collect samples, i.e., a 500-micron mesh nets in the present study in contrast to a 150-micron mesh nets in the Lihir survey (Brewer *et al*., 2012). Due to the much smaller mesh aperture, it is not surprising that the 150-micron mesh nets used in the Lihir study caught many more smaller copepods, such as those in the genera *Oithona*, *Oncaea* and the *Clausocalanus*/*Paracalanus* group, along with juveniles and naupliar (larval) stages of copepods (Table S2 in Brewer *et al*., 2012). The 500 µm net used in the current study captured copepods, including calanoids such as *Pleuramamma*, *Rhincalanus*, *Eucalanus* and *Euchaeta*. However, no copepod naupliar stages were observed in the 500-micron mesh net samples.

While there is little published information on zooplankton assemblages in the tropical Pacific region, the consensus is that diversity is higher, body size is smaller and abundance is lower than that in oceans at higher latitudes (Rombouts *et al*., 2010; Yasuhara *et al*., 2012). In this context, it is not unexpected that the suite of copepod families found during this zooplankton study in the Huon Gulf were similar to those reported from other Pacific regions (e.g., Hurai and Tsuda, 2015).

The inshore, mid-slope and offshore sites sampled in the DSTP study area supported a similar suite of taxa, though the number of groups that contributed to the top 70% in terms of abundance increased slightly from inshore to offshore sites, and was highest at the sites in the reference study area. In addition, similarity between the DSTP and reference study areas was high, with at least 60% of the taxa found throughout the two areas surveyed. The latter finding indicates that, at present, the zooplankton assemblage in the Huon Gulf is likely to be similar over a wider area than that covered in this study. Multivariate analysis performed on zooplankton data showed that taxa composition and abundance of zooplankton assemblages from offshore sites in the DSTP study area were similar to those from sites sampled in the reference study area (inshore and mid-slope sites), but different from inshore sites in the DSTP study area.

The manner in which Bongo net samples were collected during the zooplankton survey in this study, i.e., using oblique tows from depths of 500 m, 250 m and 100 m direct to the surface, precludes making detailed observations on the vertical distribution of main identified taxa groups. However, close examination of net samples collected strongly suggests that zooplankton taxa undertake vertical migration by night, a well-known feature of zooplankton assemblages in all world's oceans (Hays, 2003). This migration was evident at the offshore site P9 in the DSTP study area, where abundances were higher at depth during day and increased in the upper waters at night. For example, copepods such as *Pleuramamma* are known to migrate into surface waters at night (Hays, 1996), and its high abundance in the 100 m to 0 m depth stratum at night supports the view of vertical migration into surface waters at night. Further evidence of vertical migration by zooplankton from deeper to shallower waters at night was evidenced by the higher abundances at night time in the shallowest samples (uppermost 100 m) at inshore sites P1 and P4.

4.1.2. Micronekton

The small number of micronekton samples available from the DSTP study area was insufficient to make detailed or comparative observations in relation to overall diversity in the Huon Gulf. Based on the microscopic analysis of the four samples, it appeared that there was a ‘background’ assemblage similar to that found in zooplankton samples, with groups such as *Lucifer*, siphonophores, and the copepods *Euchaeta* and *Eucalanus* all present in the micronekton. Added to those were adults of euphausiid genera *Stylochieron* and *Euphausia* (in the *E. sibogae* suite), large penaid prawns and fish including larvae and juveniles of mesopelagic fishes of the family Myctophidae (lanternfishes) and Alepocephalidae (slickheads) (Plate 4.1), juveniles and adult viperfish (*Chauliodus sloani*) (Plate 4.2), and ’leptocephalus‘ stage larvae of anguilliform (eels) fishes (Plate 4.3). The small number of available samples could also have accounted for the fact that no adult myctophids were captured in the Tucker trawls, even though these zooplanktivorous fishes comprise one of the most abundant and diverse vertebrate groups occurring in the mesopelagic zone of all the world’s oceans (Dypvik and Kaartvedt, 2013). However, it may also be possible that this group is poorly represented in the Markham Canyon and perhaps other deep areas elsewhere in PNG waters, as suggested by the similarly low catches of lanternfishes reported by Brewer *et al*. (2012) during the Lihir study from 42 micronekton tows between 50 m and 550 m

4.2. Oceanographic conditions

Water column stratification can influence the vertical distribution of zooplankton and micronekton. The CTD data obtained in the DSTP study area during the period of zooplankton and micronekton sampling showed no clear indication of water column stratification to depths of at least 500 m., i.e., no persistent layers of water with strongly different salinity and temperature profiles. The oceanographic data did, however, show the presence of a shallow surface halocline with salinity increasing rapidly from around 24 to 29 PSU to 34 to 35 PSU in the first 20 to 25 m down from the surface.

The presence of a very shallow halocline indicates that the overall freshwater input from all nearby coastal rivers which discharge to the DSTP study area, coupled with rain, is the main driver of the local oceanography to at least the 20 m to 25 m depth of water. The shallow halocline is likely to influence vertical distribution of those species of zooplankton considered as “euryhaline”, i.e., able to survive waters with large salinity range, as well as those species considered as “stenohaline”, i.e., those which can only survive in narrow salinity ranges. In that context, purely marine stenohaline species will not be able to survive in waters greatly influenced by fresh water in the upper-most water column.

The absence of clearly-defined water stratification, at least during the study period, suggests that there is limited restriction on the movement of zooplankton and micronekton aggregations vertically in the water column and suggests that they may occur throughout the entire water column to depths of up to 500 m. The maximum depth of zooplankton and micronekton aggregations cannot be assessed without bioacoustics measurements.

The lowest vertical limit of zooplankton distribution is likely to be closely driven by maximum euphotic zone depth (i.e., which receives enough sunlight to allow photosynthesis to support phytoplankton communities), which has been determined during a separate oceanographic study to be 60 m (IHAconsult, 2018).

Photo credit: Francisco Neira

Plate 4.1
Juvenile slickhead
(*Xenodermichthys nodulosus*;
family Alepocephalidae)
caught in night time micronekton
sample MA-I (250 m to surface)

Photo credit: Francisco Neira

Plate 4.2
Juvenile viperfish
(*Chauliodus sloani.*, family Stomiidae),
caught in night plankton sample and daytime
micronekton MA-I (250 m to surface).

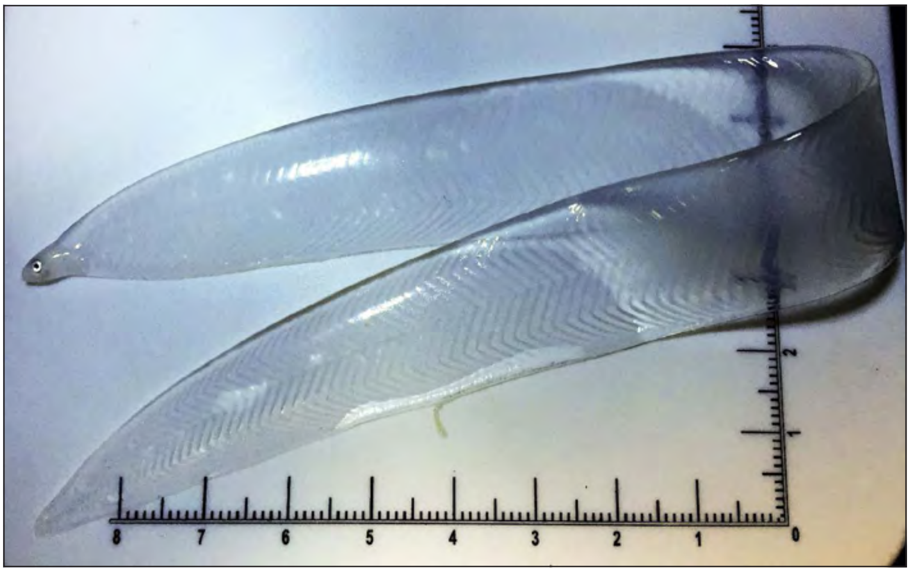


Photo credit: Francisco Neira

Plate 4.3
Leptocephalus larva
("glass eel" stage) of fish from
Order Anguilliformes (eels, morays)
collected in night plankton sample

4.3. Metals in zooplankton and micronekton

Concentrations of most metals in bulk zooplankton samples collected during the current baseline characterisation study decreased with distance from shore; i.e., were highest at inshore sites and decreased at the mid-slope and offshore sites. Furthermore, metal concentrations in zooplankton samples collected from the reference study area (an inshore site and a mid-slope site) were lower than in samples from the DSTP study area except in the case of arsenic and cadmium, whose concentrations were similar to the lowest values detected in zooplankton samples from the DSTP study area.

The higher concentrations of metals in inshore zooplankton samples from the DSTP study area could be primarily associated with riverine discharges (e.g., from the Markham and Busu rivers), which are likely to inject substantial loads of particulate metals to the DSTP study area. Other potential local sources of metals may also include anthropogenic inputs such as stormwater runoff and wastewater discharges from Lae and surrounding coastal villages. In this context, it is relevant that concentrations of metals from inshore zooplankton samples have also been reported to be markedly higher compared to open sea samples in coastal marine habitats elsewhere in the world, and have likewise been attributed both to direct river discharge (e.g., Pempkowiak *et al*., 2006) or a combined effect of upwelling, riverine and anthropogenic sources (e.g., Ferreira et al, 2005; Wan Ying Lim et al., 2012). Oceanographic investigations to date have detected no evidence of upwelling at the Outfall Area (IHAconsult, 2018). Regardless of the source, however, it is not possible to determine under the scope of this study whether the higher metal concentrations of the inshore samples are due to combined bioaccumulation by individual zooplankters, or due to suspended particulate matter adhering to their body surfaces, with suspended particulate matter playing an important role on metal adsorption especially for copper (Rossi and Jamet, 2008). Body surfaces include the exoskeleton in crustaceans such as copepods and ostracods, which were amongst the most abundant taxa identified in the zooplankton samples collected during the present study.

Past work involving testing of metals in zooplankton in PNG include the study by Brewer *et al*. (2012 which collected samples offshore from the Lihir gold mine at Niolam Island, from marine waters away from the mine discharge site (reference sites). Comparisons between results of the current study (all sites) and those from Lihir (reference sites only) show that the ranges of metal concentrations in zooplankton samples from the current study were generally lower than those reported for the Lihir geothermally active reference study area (Table 4.1 and refer to Brewer et al. 2012).

Concentrations of metals measured in micronekton taxa were highly variable across the different taxa tested. However, no single taxon consistently showed significantly higher metals concentrations than any other taxa. Pandalid shrimp had a relatively high copper concentration (17 mg/kg; the next highest concentration being 5.8 mg/kg in a Decapoda A) and *Xenodermichthys nodulosus* had a relatively high arsenic concentration (6.4 mg/kg; the next highest concentration being 1 mg/kg in the pandalid shrimp). The reason for the elevated arsenic in this organism is not clear; however, the relatively high copper concentration in the pandalid shrimp is likely to be due to copper-based blood (haemocyanin) and the larger size of this micronekton. Metals concentrations in micronekton did not display any clear spatial differences, with generally similar concentrations recorded in the samples of various taxa, from both inshore and offshore locations.

Concentrations of most metals (i.e., arsenic, cadmium, copper, lead, mercury, nickel and zinc) were noticeably higher in micronekton taxa than in zooplankton samples. While this finding suggests some level of bioaccumulation or biomagnification of these metals from lower trophic levels (e.g., zooplankters) to higher trophic levels (e.g., macrozooplankters and micronekton), bioaccumulation pathways and/or biomagnification were not assessed as part of this scope. As with zooplankton, a possible association between suspended particulate matter adhering to the body surfaces of micronekton, and metals concentrations, may also be present.

Table 4.1: Metal concentration ranges (mg/kg, wet weight) in zooplankton samples

Metal	Wafi Golpu (DSTP study area)	Wafi Golpu (reference study area)
Cu	0.16 - 2.4	0.21 - 0.45
Fe	11.0 - 250.0	14.0 - 17.5
Mn	0.41 - 8.02	0.75 - 0.79
Cd	<0.05 - 0.19	<0.05 - 0.09
Zn	1.2 - 8.6	1.1 - 1.2
As	<0.4 - 3.0	0.61 - 1.2
Hg	<0.01	<0.01
Pb	<0.1 - 0.21	<0.1
Ni	<0.06 - 0.32	0.08 - 0.11
Cr	0.1 - 0.24	<0.1
Co	Not tested	Not tested
Se	<0.5	<0.5
Ag	<0.1	<0.1
Al	Not tested	Not tested

Where single values are given, this is where all values were less than PQL.

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Appendix A - Laboratory results – metals analysis of zooplankton and micronekton

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REPORT OF ANALYSIS

Laboratory Reference: A17/0979Q [R00]

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

Contact: Travis Wood

Project: Metal Analysis - Plankton

r **No:**
Sample Type: Plankton
No. of Samples: 38
Date Received: 14/03/2017
Date Completed: 22/03/2017

Laboratory Contact Details:

Client Services Manager: Trent Biggin
Technical Enquiries: Rama Nimmagadda
Telephone: +61 2 9888 9077
Email: sydney@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.
Accredited for compliance with ISO/IEC 17025. This document shall not be reproduced, except in full.

ilac-MRA

NATA
Accreditation No.15109

Issue Date: 22 March 2017

Advanced Analytical Australia Pty ltd
ABN 20 105 644 979
11 Julius Avenue,
North Ryde NSW 2113 Australia

Ph: + 61 2 9888 9077
Fax: + 61 2 9888 9577
contact@advancedanalytical.com.au
www.advancedanalytical.com.au

Laboratory Reference: A17/0979Q [R00]
Project: Metal Analysis - Plankton

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/1 P65 AM 04/03/2017	/2 P101AM 04/03/2017	/3 P35 AM 04/03/2017	/4 P92 AM 04/03/2017
Trace Elements						
Arsenic	04-008	mg/kg	0.93	1.2	0.82	0.54
Cadmium	04-008	mg/kg	0.089	0.091	0.072	0.054
Chromium	04-008	mg/kg	<0.1	<0.1	0.10	<0.1
Copper	04-008	mg/kg	0.48	0.45	0.78	0.45
Iron	04-008	mg/kg	24	16	81	32
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	<0.01	<0.01	<0.01	<0.01
Manganese	04-008	mg/kg	0.801	0.770	2.17	1.08
Nickel	04-008	mg/kg	0.13	0.10	0.18	0.095
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	2.9	1.2	3.7	1.7

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/5 P95 AM 04/03/2017	/6 P92 PM 04/03/2017	/7 P21 PM 03/03/2017	/8 P31 PM 03/03/2017
Trace Elements						
Arsenic	04-008	mg/kg	<0.4	1.9	1.3	1.3
Cadmium	04-008	mg/kg	<0.05	0.12	0.11	0.11
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.16	0.74	0.96	0.90
Iron	04-008	mg/kg	11	24	47	57
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	<0.01	<0.01	<0.01	<0.01
Manganese	04-008	mg/kg	0.408	0.843	1.39	1.69
Nickel	04-008	mg/kg	<0.06	0.14	0.18	0.17
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	1.2	2.4	5.4	3.7

Advanced Analytical Australia Pty ltd
ABN 20 105 644 979
11 Julius Avenue,
North Ryde NSW 2113 Australia
Ph: + 61 2 9888 9077
Fax: + 61 2 9888 9577
contact@advancedanalytical.com.au
www.advancedanalytical.com.au

Laboratory Reference: A17/0979Q [R00]
Project: Metal Analysis - Plankton

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/9 P61 PM 03/03/2017	/10 P112 AM 04/03/2017	/11 P111 AM 04/03/2017	/12 P95 PM 04/03/2017
Trace Elements						
Arsenic	04-008	mg/kg	1.2	0.61	1.0	1.6
Cadmium	04-008	mg/kg	0.085	<0.05	0.077	0.11
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	0.63	0.21	0.31	0.58
Iron	04-008	mg/kg	28	14	19	22
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	<0.01	<0.01	<0.01	<0.01
Manganese	04-008	mg/kg	0.970	0.750	0.824	0.714
Nickel	04-008	mg/kg	0.13	0.084	0.11	0.14
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	2.7	1.1	1.1	2.2

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/13 P32 AM 03/03/2017	/14 951 AM 03/03/2017	/15 P82 AM 03/03/2017	/16 P22 PM 03/03/2017
Trace Elements						
Arsenic	04-008	mg/kg	0.86	1.4	0.96	0.92
Cadmium	04-008	mg/kg	0.065	0.14	0.069	0.070
Chromium	04-008	mg/kg	<0.1	0.11	<0.1	<0.1
Copper	04-008	mg/kg	0.75	2.0	0.69	0.68
Iron	04-008	mg/kg	20	51	23	51
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	<0.01	<0.01	<0.01	<0.01
Manganese	04-008	mg/kg	0.562	1.40	0.857	1.35
Nickel	04-008	mg/kg	0.075	0.15	0.086	0.12
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	1.9	3.8	3.9	3.2

Advanced Analytical Australia Pty ltd
ABN 20 105 644 979
11 Julius Avenue,
North Ryde NSW 2113 Australia
Ph: + 61 2 9888 9077
Fax: + 61 2 9888 9577
contact@advancedanalytical.com.au
www.advancedanalytical.com.au

Laboratory Reference: A17/0979Q [R00]
Project: Metal Analysis - Plankton

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/17 P82 PM 03/03/2017	/18 P62 AM 03/03/2017	/19 P31 AM 03/03/2017	/20 P91 AM 03/03/2017
Trace Elements						
Arsenic	04-008	mg/kg	1.3	0.47	1.7	1.3
Cadmium	04-008	mg/kg	0.11	0.059	0.19	0.11
Chromium	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-008	mg/kg	1.4	0.42	1.7	1.0
Iron	04-008	mg/kg	58	64	52	42
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	<0.01	<0.01	<0.01	<0.01
Manganese	04-008	mg/kg	1.76	1.41	1.44	1.39
Nickel	04-008	mg/kg	0.17	0.13	0.19	0.15
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	6.4	2.2	3.4	3.5

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/21 P52 PM 03/03/2017	/22 P22 AM 03/03/2017	/23 P52 AM 03/03/2017	/24 P21 AM 02/03/2017
Trace Elements						
Arsenic	04-008	mg/kg	1.3	1.5	1.9	1.0
Cadmium	04-008	mg/kg	0.090	0.11	0.15	0.053
Chromium	04-008	mg/kg	<0.1	0.15	0.21	<0.1
Copper	04-008	mg/kg	0.99	0.98	2.4	0.60
Iron	04-008	mg/kg	61	100	100	60
Lead	04-008	mg/kg	<0.1	0.1	0.21	<0.1
Mercury	04-006	mg/kg	<0.01	<0.01	<0.01	<0.01
Manganese	04-008	mg/kg	1.58	3.13	2.62	2.07
Nickel	04-008	mg/kg	0.16	0.22	0.24	0.13
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	5.9	4.7	8.6	2.9

Advanced Analytical Australia Pty ltd
ABN 20 105 644 979
11 Julius Avenue,
North Ryde NSW 2113 Australia
Ph: + 61 2 9888 9077
Fax: + 61 2 9888 9577
contact@advancedanalytical.com.au
www.advancedanalytical.com.au

Laboratory Reference: A17/0979Q [R00]
Project: Metal Analysis - Plankton

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/25 P41 AM 02/03/2017	/26 P81 PM 02/03/2017	/27 P71 PM 02/03/2017	/28 P21 AM 02/03/2017
Trace Elements						
Arsenic	04-008	mg/kg	1.5	1.7	2.2	1.6
Cadmium	04-008	mg/kg	0.081	0.12	0.091	0.12
Chromium	04-008	mg/kg	0.19	<0.1	0.24	0.11
Copper	04-008	mg/kg	1.9	1.9	2.2	1.4
Iron	04-008	mg/kg	180	82	250	71
Lead	04-008	mg/kg	0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	<0.01	<0.01	<0.01	<0.01
Manganese	04-008	mg/kg	4.11	2.89	8.02	1.93
Nickel	04-008	mg/kg	0.25	0.20	0.31	0.19
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	5.1	5.9	5.4	3.8

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/29 P71 AM 02/03/2017	/30 P81 AM 02/03/2017	/31 P11 PM 02/03/2017	/32 P11 AM 02/03/2017
Trace Elements						
Arsenic	04-008	mg/kg	0.83	1.4	1.7	0.97
Cadmium	04-008	mg/kg	0.057	0.17	0.13	0.16
Chromium	04-008	mg/kg	<0.1	0.23	0.12	0.18
Copper	04-008	mg/kg	0.82	1.9	1.9	2.3
Iron	04-008	mg/kg	53	190	93	150
Lead	04-008	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	<0.01	<0.01	<0.01	<0.01
Manganese	04-008	mg/kg	1.78	6.24	2.95	4.94
Nickel	04-008	mg/kg	0.10	0.32	0.18	0.21
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	3.0	7.1	5.7	6.7

Advanced Analytical Australia Pty ltd
ABN 20 105 644 979
11 Julius Avenue,
North Ryde NSW 2113 Australia
Ph: + 61 2 9888 9077
Fax: + 61 2 9888 9577
contact@advancedanalytical.com.au
www.advancedanalytical.com.au

Laboratory Reference: A17/0979Q [R00]
Project: Metal Analysis - Plankton

Laboratory Reference:	-	-	/33	/34	/35	/36
Client Reference:	-	-	P61 AM	P35 PM	P65 PM	P32 PM
Date Sampled:	-	-	02/03/2017	04/03/2017	04/03/2017	04/03/2017
Analysis Description	Method	Units				
Trace Elements						
Arsenic	04-008	mg/kg	0.82	1.2	1.2	0.78
Cadmium	04-008	mg/kg	0.090	0.082	0.089	0.061
Chromium	04-008	mg/kg	0.11	0.13	<0.1	0.13
Copper	04-008	mg/kg	0.95	0.91	0.58	0.58
Iron	04-008	mg/kg	81	98	25	85
Lead	04-008	mg/kg	<0.1	0.1	<0.1	<0.1
Mercury	04-006	mg/kg	<0.01	<0.01	<0.01	<0.01
Manganese	04-008	mg/kg	2.83	3.23	0.796	2.87
Nickel	04-008	mg/kg	0.16	0.23	0.14	0.21
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	2.6	4.2	3.4	3.0

Laboratory Reference:	-	-	/37	/38
Client Reference:	-	-	P62 PM	P51 PM
Date Sampled:	-	-	04/03/2017	02/03/2017
Analysis Description	Method	Units		
Trace Elements				
Arsenic	04-008	mg/kg	1.5	3.0
Cadmium	04-008	mg/kg	0.10	0.18
Chromium	04-008	mg/kg	<0.1	0.18
Copper	04-008	mg/kg	0.64	1.9
Iron	04-008	mg/kg	25	150
Lead	04-008	mg/kg	<0.1	<0.1
Mercury	04-006	mg/kg	<0.01	<0.01
Manganese	04-008	mg/kg	0.810	4.45
Nickel	04-008	mg/kg	0.11	0.28
Selenium	04-008	mg/kg	<0.5	<0.5
Silver	04-008	mg/kg	<0.1	<0.1
Zinc	04-008	mg/kg	2.7	5.7

Advanced Analytical Australia Pty ltd
ABN 20 105 644 979
11 Julius Avenue,
North Ryde NSW 2113 Australia
Ph: + 61 2 9888 9077
Fax: + 61 2 9888 9577
contact@advancedanalytical.com.au
www.advancedanalytical.com.au

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
[*] Not covered by NATA scope of accreditation.
- Spike recovery for Fe could not be accurately determined due to a significant background analyte concentration.

Sample 21 duplicate failed due to the heterogeneity of the sample.

Advanced Analytical Australia Pty ltd
ABN 20 105 644 979
11 Julius Avenue,
North Ryde NSW 2113 Australia
Ph: + 61 2 9888 9077
Fax: + 61 2 9888 9577
contact@advancedanalytical.com.au
www.advancedanalytical.com.au

Laboratory Reference: A17/0979Q [R00]
Project: Metal Analysis - Plankton

QUALITY ASSURANCE REPORT

TEST	UNITS	Blank	Duplicate Sm#	Duplicate Results	Spike Sm#	Spike Results
Arsenic	mg/kg	<0.4	A17/0979Q-1	0.93 || 0.94 || RPD: 1	A17/0979Q-1	107%
Cadmium	mg/kg	<0.05	A17/0979Q-1	0.089 || 0.091 || RPD: 2	A17/0979Q-1	102%
Chromium	mg/kg	<0.1	A17/0979Q-1	<0.1 || <0.1	A17/0979Q-1	96%
Copper	mg/kg	<0.05	A17/0979Q-1	0.48 || 0.51 || RPD: 6	A17/0979Q-1	97%
Iron	mg/kg	<0.5	A17/0979Q-1	24 || 24 || RPD: 0	A17/0979Q-1	#
Lead	mg/kg	<0.1	A17/0979Q-1	<0.1 || <0.1	A17/0979Q-1	89%
Mercury	mg/kg	<0.01	A17/0979Q-1	<0.01 || <0.01	A17/0979Q-1	80%
Manganese	mg/kg	<0.1	A17/0979Q-1	0.801 || 0.771 || RPD: 4	A17/0979Q-1	94%
Nickel	mg/kg	<0.06	A17/0979Q-1	0.13 || 0.14 || RPD: 7	A17/0979Q-1	91%
Selenium	mg/kg	<0.5	A17/0979Q-1	<0.5 || <0.5	A17/0979Q-1	107%
Silver	mg/kg	<0.1	A17/0979Q-1	<0.1 || <0.1	A17/0979Q-1	100%
Zinc	mg/kg	<0.2	A17/0979Q-1	2.9 || 3.0 || RPD: 3	A17/0979Q-1	99%

TEST	Units	Blank	Duplicate Sm#	Duplicate Results	Spike Sm#	Spike Results
Arsenic	mg/kg	<0.4	A17/0979Q-11	1.0 || 1.0 || RPD: 0	A17/0979Q-21	106%
Cadmium	mg/kg	<0.05	A17/0979Q-11	0.077 || 0.077 || RPD: 0	A17/0979Q-21	101%
Chromium	mg/kg	<0.1	A17/0979Q-11	<0.1 || <0.1	A17/0979Q-21	98%
Copper	mg/kg	<0.05	A17/0979Q-11	0.31 || 0.30 || RPD: 3	A17/0979Q-21	102%
Iron	mg/kg	<0.5	A17/0979Q-11	19 || 16 || RPD: 17	A17/0979Q-21	#
Lead	mg/kg	<0.1	A17/0979Q-11	<0.1 || <0.1	A17/0979Q-21	90%
Mercury	mg/kg	<0.01	A17/0979Q-11	<0.01 || <0.01	A17/0979Q-21	78%
Manganese	mg/kg	<0.1	A17/0979Q-11	0.824 || 0.765 || RPD: 7	A17/0979Q-21	108%
Nickel	mg/kg	<0.06	A17/0979Q-11	0.11 || 0.11 || RPD: 0	A17/0979Q-21	93%
Selenium	mg/kg	<0.5	A17/0979Q-11	<0.5 || <0.5	A17/0979Q-21	104%
Silver	mg/kg	<0.1	A17/0979Q-11	<0.1 || <0.1	A17/0979Q-21	97%
Zinc	mg/kg	<0.2	A17/0979Q-11	1.1 || 1.2 || RPD: 9	A17/0979Q-21	113%

Advanced Analytical Australia Pty ltd
ABN 20 105 644 979
11 Julius Avenue,
North Ryde NSW 2113 Australia
Ph: + 61 2 9888 9077
Fax: + 61 2 9888 9577
contact@advancedanalytical.com.au
www.advancedanalytical.com.au

Laboratory Reference: A17/0979Q [R00]
Project: Metal Analysis - Plankton

TEST	Units	Blank	Duplicate Sm#	Duplicate Results
Arsenic	mg/kg	[NT]	A17/0979Q-21	1.3 || 1.4 || RPD: 7
Cadmium	mg/kg	[NT]	A17/0979Q-21	0.090 || 0.11 || RPD: 20
Chromium	mg/kg	[NT]	A17/0979Q-21	<0.1 || 0.15
Copper	mg/kg	[NT]	A17/0979Q-21	0.99 || 1.3 || RPD: 27
Iron	mg/kg	[NT]	A17/0979Q-21	61 || 100 || RPD: 48
Lead	mg/kg	[NT]	A17/0979Q-21	<0.1 || <0.1
Mercury	mg/kg	[NT]	A17/0979Q-21	<0.01 || <0.01
Manganese	mg/kg	[NT]	A17/0979Q-21	1.58 || 2.33 || RPD: 38
Nickel	mg/kg	[NT]	A17/0979Q-21	0.16 || 0.22 || RPD: 32
Selenium	mg/kg	[NT]	A17/0979Q-21	<0.5 || <0.5
Silver	mg/kg	[NT]	A17/0979Q-21	<0.1 || <0.1
Zinc	mg/kg	[NT]	A17/0979Q-21	5.9 || 7.1 || RPD: 18

TEST	Units	Blank	Duplicate Sm#	Duplicate Results
Arsenic	mg/kg	[NT]	A17/0979Q-31	1.7 || 1.8 || RPD: 6
Cadmium	mg/kg	[NT]	A17/0979Q-31	0.13 || 0.16 || RPD: 21
Chromium	mg/kg	[NT]	A17/0979Q-31	0.12 || 0.12 || RPD: 0
Copper	mg/kg	[NT]	A17/0979Q-31	1.9 || 2.3 || RPD: 19
Iron	mg/kg	[NT]	A17/0979Q-31	93 || 91 || RPD: 2
Lead	mg/kg	[NT]	A17/0979Q-31	<0.1 || <0.1
Mercury	mg/kg	[NT]	A17/0979Q-31	<0.01 || <0.01
Manganese	mg/kg	[NT]	A17/0979Q-31	2.95 || 3.02 || RPD: 2
Nickel	mg/kg	[NT]	A17/0979Q-31	0.18 || 0.18 || RPD: 0
Selenium	mg/kg	[NT]	A17/0979Q-31	<0.5 || <0.5
Silver	mg/kg	[NT]	A17/0979Q-31	<0.1 || <0.1
Zinc	mg/kg	[NT]	A17/0979Q-31	5.7 || 6.6 || RPD: 15

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.

Advanced Analytical Australia Pty ltd
ABN 20 105 644 979
11 Julius Avenue,
North Ryde NSW 2113 Australia
Ph: + 61 2 9888 9077
Fax: + 61 2 9888 9577
contact@advancedanalytical.com.au
www.advancedanalytical.com.au

REPORT OF ANALYSIS

Laboratory Reference: A17/2122 [R00]

Client:	Coffey Environments Australia Pty Ltd - VIC 126 Trenerry Crescent Abbotsford VIC 3067	**Order No:**	520
		Project:	Metal Analysis - Micronekton
		Sample Type:	small crustaceans / fish
		No. of Samples:	21
Contact:	Travis Wood	**Date Received:**	01/06/2017
		Date Completed:	8/06/2017

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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NATA Accreditation No.15109

Advanced Analytical Australia Pty Ltd
ABN 20 105 644 979
11 Julius Avenue
North Ryde NSW 2113 Australia
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Fax: + 61 2 9888 9577
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Batch Number: A17/2122 [R00]
Project Reference: Metal Analysis - Micronekton

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/1 Xenodermichthys 01/05/2017	/2 Xenodermichthys 01/05/2017	/3 Xenodermichthys 01/05/2017	/4 Chauliodus sloani 01/05/2017
Trace Elements						
Arsenic	04-016	mg/kg	6.4	5.2	5.0	0.50
Cadmium	04-016	mg/kg	0.047	0.048	0.054	0.022
Chromium	04-016	mg/kg	<0.1	0.11	0.26	<0.1
Copper	04-016	mg/kg	2.9	1.4	1.9	0.34
Iron	04-016	mg/kg	3.0	3.2	7.3	4.9
Lead	04-016	mg/kg	<0.1	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.039	0.036	0.034	0.023
Manganese	04-016	mg/kg	2.3	1.6	1.9	0.65
Nickel	04-016	mg/kg	0.18	0.13	0.14	<0.1
Selenium	04-016	mg/kg	0.33	0.29	0.32	0.19
Silver	04-016	mg/kg	<0.05	<0.05	<0.05	<0.05
Zinc	04-016	mg/kg	23	20	19	2.9

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Batch Number: A17/2122 [R00]
Project Reference: Metal Analysis - Micronekton

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/5 Chauliodus sloani 01/05/2017	/6 Bregmaceros 01/05/2017	/7 Family Gonostomatidae A 01/05/2017	/8 Family Gonostomatidae A 01/05/2017
Trace Elements						
Arsenic	04-016	mg/kg	0.59	0.36	0.64	0.39
Cadmium	04-016	mg/kg	0.028	0.067	0.091	0.072
Chromium	04-016	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-016	mg/kg	0.46	1.4	2.2	2.2
Iron	04-016	mg/kg	9.3	37	41	48
Lead	04-016	mg/kg	0.10	0.29	0.23	0.28
Mercury	04-006	mg/kg	0.022	0.015	0.014	0.011
Manganese	04-016	mg/kg	0.94	3.0	1.8	1.7
Nickel	04-016	mg/kg	<0.1	0.25	0.24	0.25
Selenium	04-016	mg/kg	0.20	0.22	0.30	0.26
Silver	04-016	mg/kg	<0.05	<0.05	<0.05	<0.05
Zinc	04-016	mg/kg	4.6	11	11	10

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Batch Number: A17/2122 [R00]

Project Reference: Metal Analysis - Micronekton

Laboratory Reference: **Client Reference:** **Date Sampled:** **Analysis Description**	- - - **Method**	- - - **Units**	**/9** **Snake Fish** **01/05/2017**	**/10** **Snake Fish** **01/05/2017**	**/11** **Trachichthyid** **01/05/2017**	**/12** **Conger eel** **01/05/2017**
Trace Elements						
Arsenic	04-016	mg/kg	0.45	0.26	0.52	0.44
Cadmium	04-016	mg/kg	0.28	0.10	0.028	0.073
Chromium	04-016	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-016	mg/kg	1.4	3.0	2.5	1.8
Iron	04-016	mg/kg	27	26	99	3.0
Lead	04-016	mg/kg	0.21	0.31	<0.1	<0.1
Mercury	04-006	mg/kg	0.017	0.023	0.033	0.13
Manganese	04-016	mg/kg	2.7	1.3	2.7	0.34
Nickel	04-016	mg/kg	<0.1	0.14	0.25	<0.1
Selenium	04-016	mg/kg	0.20	0.30	0.22	0.53
Silver	04-016	mg/kg	<0.05	<0.05	<0.05	<0.05
Zinc	04-016	mg/kg	6.2	8.5	8.8	6.6

Laboratory Reference: **Client Reference:** **Date Sampled:** **Analysis Description**	- - - **Method**	- - - **Units**	**/13** **Family Gonostomatidae B** **01/05/2017**	**/14** **Mysidacea** **01/05/2017**	**/15** **Pandalidae** **01/05/2017**	**/16** **Decapoda sp. A** **01/05/2017**
Trace Elements						
Arsenic	04-016	mg/kg	0.90	0.24	0.65	0.19
Cadmium	04-016	mg/kg	0.055	0.055	2.1	0.080
Chromium	04-016	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-016	mg/kg	3.4	4.8	17	1.7
Iron	04-016	mg/kg	160	11	16	19
Lead	04-016	mg/kg	0.10	<0.1	<0.1	<0.1
Mercury	04-006	mg/kg	0.013	0.012	0.027	0.015
Manganese	04-016	mg/kg	3.2	1.6	2.0	0.83
Nickel	04-016	mg/kg	0.36	0.14	0.16	0.54
Selenium	04-016	mg/kg	0.31	0.23	0.27	0.18
Silver	04-016	mg/kg	<0.05	<0.05	0.23	<0.05

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Fax: + 61 2 9888 9577
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Batch Number: A17/2122 [R00]
Project Reference: Metal Analysis - Micronekton

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/13 Family Gonostomatidae B 01/05/2017	/14 Mysidacea 01/05/2017	/15 Pandalidae 01/05/2017	/16 Decapoda sp. A 01/05/2017
Zinc	04-016	mg/kg	13	12	9.1	7.3

Laboratory Reference: Client Reference: Date Sampled: Analysis Description	- - - Method	- - - Units	/17 Family Gonostomatidae A 01/05/2017	/18 Bregmaceros 01/05/2017	/19 Pandalidae 01/05/2017	/20 Decapoda sp. B 01/05/2017
Trace Elements						
Arsenic	04-016	mg/kg	0.29	0.33	1.0	0.43
Cadmium	04-016	mg/kg	0.072	0.065	0.57	0.18
Chromium	04-016	mg/kg	<0.1	<0.1	<0.1	<0.1
Copper	04-016	mg/kg	4.8	4.0	17	5.8
Iron	04-016	mg/kg	68	30	16	17
Lead	04-016	mg/kg	0.55	0.31	<0.1	0.21
Mercury	04-006	mg/kg	0.010	0.027	0.033	0.017
Manganese	04-016	mg/kg	2.1	3.2	1.5	1.1
Nickel	04-016	mg/kg	1.3	1.1	<0.1	<0.1
Selenium	04-016	mg/kg	0.18	0.19	0.23	0.28
Silver	04-016	mg/kg	<0.05	<0.05	0.26	0.052
Zinc	04-016	mg/kg	18	16	8.1	11

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North Ryde NSW 2113 Australia
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Fax: + 61 2 9888 9577
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Batch Number: A17/2122 [R00]
Project Reference: Metal Analysis - Micronekton

Laboratory Reference: **Client Reference:** **Date Sampled:** **Analysis Description**	- - - **Method**	- - - **Units**	**/21** **Pteropoda** **01/05/2017**
Trace Elements			
Arsenic	04-016	mg/kg	0.37
Cadmium	04-016	mg/kg	0.19
Chromium	04-016	mg/kg	0.25
Copper	04-016	mg/kg	3.8
Iron	04-016	mg/kg	210
Lead	04-016	mg/kg	0.24
Mercury	04-006	mg/kg	0.10
Manganese	04-016	mg/kg	8.8
Nickel	04-016	mg/kg	0.97
Selenium	04-016	mg/kg	0.13
Silver	04-016	mg/kg	<0.05
Zinc	04-016	mg/kg	7.2

Method	Method Description
04-016	Metals in food and marine/freshwater biota by ICP-MS, mg/kg
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.

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Batch Number: A17/2122 [R00]
Project Reference: Metal Analysis - Micronekton

QUALITY ASSURANCE REPORT

TEST	UNITS	Blank	Duplicate Sm#	Duplicate Results	Spike Sm#	Spike Results
Arsenic	mg/kg	<0.1	A17/2122-1	6.4 || 6.6 || RPD: 3	A17/2122-2	105%
Cadmium	mg/kg	<0.02	A17/2122-1	0.047 || 0.049 || RPD: 4	A17/2122-2	85%
Chromium	mg/kg	<0.1	A17/2122-1	<0.1 || <0.1	A17/2122-2	97%
Copper	mg/kg	<0.05	A17/2122-1	2.9 || 3.1 || RPD: 7	A17/2122-2	92%
Iron	mg/kg	<1.5	A17/2122-1	3.0 || 3.1 || RPD: 3	A17/2122-2	91%
Lead	mg/kg	<0.1	A17/2122-1	<0.1 || <0.1	A17/2122-2	91%
Mercury	mg/kg	<0.01	A17/2122-1	0.039 || 0.034 || RPD: 14	A17/2122-2	92%
Manganese	mg/kg	<0.1	A17/2122-1	2.3 || 2.3 || RPD: 0	A17/2122-2	90%
Nickel	mg/kg	<0.1	A17/2122-1	0.18 || 0.18 || RPD: 0	A17/2122-2	92%
Selenium	mg/kg	<0.1	A17/2122-1	0.33 || 0.32 || RPD: 3	A17/2122-2	102%
Silver	mg/kg	<0.05	A17/2122-1	<0.05 || <0.05	A17/2122-2	84%
Zinc	mg/kg	<0.2	A17/2122-1	23 || 24 || RPD: 4	A17/2122-2	95%

TEST	Units	Blank	Duplicate Sm#	Duplicate Results	Spike Sm#	Spike Results
Arsenic	mg/kg	<0.1	A17/2122-20	0.43 || 0.45 || RPD: 5	A17/2122-20	99%
Cadmium	mg/kg	<0.02	A17/2122-20	0.18 || 0.19 || RPD: 5	A17/2122-20	84%
Chromium	mg/kg	<0.1	A17/2122-20	<0.1 || <0.1	A17/2122-20	100%
Copper	mg/kg	<0.05	A17/2122-20	5.8 || 6.1 || RPD: 5	A17/2122-20	98%
Iron	mg/kg	<1.5	A17/2122-20	17 || 18 || RPD: 6	A17/2122-20	114%
Lead	mg/kg	<0.1	A17/2122-20	0.21 || 0.22 || RPD: 5	A17/2122-20	91%
Mercury	mg/kg	<0.01	A17/2122-20	0.017 || 0.019 || RPD: 11	A17/2122-20	99%
Manganese	mg/kg	<0.1	A17/2122-20	1.1 || 1.1 || RPD: 0	A17/2122-20	110%
Nickel	mg/kg	<0.1	A17/2122-20	<0.1 || 0.11	A17/2122-20	97%
Selenium	mg/kg	<0.1	A17/2122-20	0.28 || 0.28 || RPD: 0	A17/2122-20	96%
Silver	mg/kg	<0.05	A17/2122-20	0.052 || 0.055 || RPD: 6	A17/2122-20	84%
Zinc	mg/kg	<0.2	A17/2122-20	11 || 11 || RPD: 0	A17/2122-20	103%

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Batch Number: A17/2122 [R00]

Project Reference: Metal Analysis - Micronekton

TEST	Units	Blank	Duplicate Sm#	Duplicate Results
Arsenic	mg/kg	[NT]	A17/2122-11	0.52 || 0.54 || RPD: 4
Cadmium	mg/kg	[NT]	A17/2122-11	0.028 || 0.032 || RPD: 13
Chromium	mg/kg	[NT]	A17/2122-11	<0.1 || <0.1
Copper	mg/kg	[NT]	A17/2122-11	2.5 || 2.6 || RPD: 4
Iron	mg/kg	[NT]	A17/2122-11	99 || 100 || RPD: 1
Lead	mg/kg	[NT]	A17/2122-11	<0.1 || 0.11
Mercury	mg/kg	[NT]	A17/2122-11	0.033 || 0.032 || RPD: 3
Manganese	mg/kg	[NT]	A17/2122-11	2.7 || 2.8 || RPD: 4
Nickel	mg/kg	[NT]	A17/2122-11	0.25 || 0.25 || RPD: 0
Selenium	mg/kg	[NT]	A17/2122-11	0.22 || 0.22 || RPD: 0
Silver	mg/kg	[NT]	A17/2122-11	<0.05 || <0.05
Zinc	mg/kg	[NT]	A17/2122-11	8.8 || 9.0 || 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%
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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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