



Appendix S

Fisheries and Marine Resource Use Characterisation

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Purpose of EIS

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

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

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

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

NEWCREST MINING LIMITED DISCLAIMER

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

Forward Looking Statements

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

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

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

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

Competent Person's Statement

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

HARMONY GOLD MINING COMPANY LIMITED DISCLAIMER

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

Forward Looking Statements

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

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

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

Competent Person's Statement

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

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

Coffey Environments Australia Pty Ltd

Wafi-Golpu Project

Technical Report

Fisheries and Marine Resource Use Baseline Assessment Report

TR 177

June 2018

EnviroGulf Consulting

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25 June 2018

Document authorisation

Client ref: 532-1208-PF-REP-0005-DOC_E

Quality information

Revision history

Revision	Description	Date	Author	Reviewer	Signatory
Rev A	Draft	28 March 2018	David Balloch	Travis Wood, Daniel Moriarty	Daniel Moriarty
Rev B	Final	25 June 2018	David Balloch	Travis Wood, Daniel Moriarty	Daniel Moriarty

Executive Summary

Background

Wafi Mining Limited and Newcrest PNG 2 Limited (the WGJV Participants) are equal participants in the Wafi-Golpu Joint Venture (the WGJV) and propose to construct, operate and (ultimately) close 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") in the Morobe Province of Papua New Guinea (PNG). The Project is located approximately 300 kilometres (km) north-northwest of Port Moresby and 65km southwest of Lae.

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 nearshore marine characterisation study. This study is based on investigations undertaken in the Coastal Area and reference locations in the Huon Gulf in November 2016, February 2017 and May 2017.

This technical report presents the findings of the fisheries and marine resource use characterisation study. This study relates to the Coastal Area and the broader Huon Gulf marine environment and comprises a desktop review of publicly available information, as well as Project technical reports that characterised the nearshore and offshore marine environment.

Objectives

The overall objective of the desktop review was to characterise the existing fisheries and other marine resource uses of the nearshore and offshore environment in the vicinity of the Coastal Area and the broader Huon Gulf.

Study area

The study area is focussed on the Huon Gulf. Assessments were undertaken to characterise the subsistence and artisanal fisheries and other marine resource uses of the Huon Gulf north coast (east of the Markham River) and the Huon Gulf south coast (south of the Markham River). The former has a very narrow continental shelf with limited marine biological resources, while the latter has a relatively broad continental shelf with offshore islands and reefs, providing a wider range of marine resources that are exploited by local villagers.

The study area also encompasses the deep-slope fish resources of the continental slope and the Markham Canyon that connects to the New Britain Trench within the Solomon Sea.

In addition, a requirement of the study was to characterise PNG's commercial purse seine tuna fishery. Fishing areas lying outside the Huon Gulf study area were therefore included, such as the archipelagic waters of the Bismarck Sea and the western and central Pacific Ocean.

Key findings

A key finding is that the National Fisheries Authority (NFA) advises that there is currently no commercial tuna fishing within the Huon Gulf.

The key findings of the fisheries and marine resource use characterisation study are summarised below.

Subsistence and artisanal fisheries of the Huon Gulf

Subsistence fishing is important to the people living along the coast and nearshore islands of the Huon Gulf, and fish and other marine produce is an important source of protein in their daily diet. Baseline characterisation of subsistence and artisanal fisheries were carried out for the north and south coasts of the Huon Gulf.

Huon Gulf north coast characterisation

- The continental shelf along the Huon Gulf north coast study area (i.e., east of the Markham River) is very narrow (from tens of metres up to a maximum of 200 m from the shore) due to the geological uplifting of the Huon Peninsula. This narrow shelf limits the structural diversity of habitats available to nearshore fish species and thereby limits the quantity of fish available to local villagers.
- Most fishing by villagers along the Huon Gulf north coast is for subsistence purposes and home consumption. Surplus fish may also be sold at the local fish markets at Voco Point and DCA Point in Lae, although villagers interviewed stated that this is rare.
- At Wagang village, the closest village to the proposed Outfall Area, fishing is concentrated on the brackish waters of the lower reaches of the smaller rivers and creeks within ready reach of the village rather than on the coast. However, beach fishing and shallow-water seine net hauling is carried out occasionally. In addition, nearshore waters are regularly fished from outrigger dugout canoes and banana boats using hand reels, passively set anchored and drifting longlines with baited hooks, and occasional trolling when baitfish (e.g., mackerel) disturbing the sea surface are observed from shore.
- At other villages along the Huon Gulf north coast, most coastal fishing is performed from the shoreline (rod-and-line) or in nearshore waters by hand lines or drop lines from outrigger dugout canoes or banana boats. Opportunistic fishing (trolling) for mackerel and tuna-like fish occurs when tuna are observed by villagers to be chasing baitfish within nearshore waters.
- Other fisheries include the fishing and trapping of mud crabs, burrowing mud lobsters and prawns from brackish water areas and the collection of mud clams and gastropod (snails) from the limited and sparse mangrove areas along the Huon Gulf north coast.
- A literature search and inspection of satellite photography (e.g., Google Earth™) did not reveal the presence of any coral reefs along the Huon Gulf north coast between the mouth of the Markham River and the Bukem River at Cape Arkona (approximately 33 km east of the Coastal Area). The nearest patch coral reef patch is located at Cape Arkona. There are more significant areas of fringing or patch coral reefs in a 61-km-long stretch of coast between Cape Arkona and Nababangdu Point (94 km from the Coastal Area). Therefore, subsistence coral reef fisheries of the Huon Gulf north coast are somewhat limited, except offshore at the Tami Islands (95 km from Lae and the Coastal Area) where much larger areas of coral and patch reefs are present.
- Artisanal fishing is limited along the Huon Gulf north coast given the narrowness of the continental shelf, limited nearshore fishing areas and limited stocks of fish, which are mainly exploited for subsistence consumption. However, opportunistic trolling catches of mackerel and rainbow runners can supply sufficient surplus fish for sale at the formal (Lae main market) and informal (Voco Point and DCA Point) fish markets in Lae.

Huon Gulf south coast characterisation

- Most fishing by villagers from Labu, Labu Butu and Labu Miti is based on estuarine fish species inhabiting the Labu Lakes. However, coastal fishing is also undertaken in both the nearshore and offshore waters of broad continental shelf adjacent to the Labu Lakes, and stretching from the Markham River mouth to Salamaua Peninsula. Fish catches that are surplus to family and extended family needs are sold at the Lae fish markets, especially at DCA Point, which is a 10 minute journey from the Labu villages by banana boats (the main means of sea transit).
- The mangroves and estuarine shallow waters of the Labu Lakes provide for shellfisheries, such as the harvesting of crustaceans (e.g., mud crabs, burrowing mud lobsters, prawns and shrimps) and molluscs (e.g., mud clams and gastropod snails), with surplus catch sold at the Lae fish markets.
- Labu fishers also use shallow-water seine netting in the Labu Lakes to catch fish for subsistence consumption and also for use as bait in both nearshore and offshore artisanal fishing (e.g., trolling for rainbow runners and other tuna-like species and drop lining for deeper water fish species, such as snapper and rock cod).
- The fishing community from Labu Miti has access to a fish trap net (about 5 km south of the Coastal Area) that was installed 0.8 km offshore of the village in about 10 to 16 m of water. This fish trap net fishery was installed in October 2015 and was a joint project administered by the National Fisheries Authority and the Morobe Fisheries Management Authority, with funding from the Overseas Fishery Cooperation Foundation of Japan.
- Both subsistence and artisanal fishing takes place in nearshore waters along the coast between the Markham River mouth and the Salamaua Peninsula, as well as at offshore locations such as in the vicinity of the wreck of the Imperial Japanese Navy (IJN) *Kongo Maru*, the Benalla Banks (a shallow, less than 100-m-deep shoal area about 6.5 km northwest of the Salamaua Peninsula) and reefs around the Salamaua Peninsula itself. These areas targeted for subsistence and artisanal fishing range from approximately 5 km south (nearshore waters near Labu) to 30 km south of Lae (Salamaua Peninsula) of the Coastal Area.
- Coral reef subsistence and artisanal fisheries are present along the Huon Gulf south coast, between Salamaua Peninsula and the Gira River mouth, where the broad continental shelf and numerous nearshore and island coral reefs are present. This stretch of coast is approximately 30 km to 175 km south of the Coastal Area.
- Communal village banana boats or dinghies carry reef fish caught on the Benalla Banks and around Salamaua Peninsula in iceboxes to the Lae fish markets. In addition, larger passenger and cargo boats from coastal villages between 65 km and 175 km south of Lae also bring coral reef fish (e.g., coral trout and snapper) to the Lae fish markets.
- Many of the villages along the Huon Gulf south coast trade fish and crustaceans with inland villages, and receive sago, sweet potato and pig meat in return.
- There are few mangroves along the Huon Gulf south coast; however, estuarine areas are found along the lower reaches of rivers flowing to the gulf and also within several coastal lagoons and saline lakes located along the coast. Such areas provide calm subsistence fishing areas when the sea is rough during the southeast trade wind season from May to October. The closest mangrove area is a small area of mangrove vegetation immediately west of Wagang (about 2 km west of the Outfall Area).

Other marine resource uses of the Huon Gulf

There are a number of other non-fish related marine resource uses. These are summarised below.

Turtle hunting and egg collecting

- The hunting of sea turtles and the collection of their eggs for food are ongoing subsistence activities in both the Huon Gulf north and south coasts.
- There are few sea turtle species that nest along the beaches of the Huon Gulf north coast. Villagers from Wagang stated that West Pacific leatherback turtle nesting sites are occasionally observed along the beach between Wagang and the mouth of the Busu River, (which includes the Outfall Area) and that during the nesting season (November to March) their meat is consumed and their eggs collected. The Wagang villagers also indicated that turtle nesting in the area between Wagang and Busu River is much less common than it was many years ago (i.e., in the 1970s). No turtle nests were observed around the proposed Outfall Area between Wagang and the Buso River at the time of the field surveys conducted by Coffey during November 2016 and February 2017 (which was during the nesting period for these turtles) or during follow-up interviews at Wagang in May 2017.
- The sandy beaches of the Huon Gulf south coast are an important nesting area for the West Pacific leatherback turtle and other sea turtle species, which are exploited by coastal villagers for their eggs and occasionally their meat (Kinch, 2006a). In the decade preceding 2014, various educational programs and village-led turtle conservation programs (e.g., Kamiali Wildlife Management Area) and Labu Tale turtle reserve, resulted in the numbers of turtles taken by coastal villagers being drastically reduced during this period. However, in the last few years, there has been a cessation of leatherback turtle conservation program funding and there is currently a major threat to leatherback turtles nesting in the Huon Gulf south coastal area, which is the depredation of nests due to local consumption of eggs, predation by dogs and the periodic consumption of meat of adult nesting females.
- The West Pacific leatherback turtle is known to nest on more than 120 km of beaches along the Huon Gulf south coast. Nesting activity occurs during the dry season from November to March, with peak nesting occurring between December and January when the sea is relatively calm and soft sand covers most beaches. No nesting activity occurs during the wet season.
- The consumption of leatherback turtles is not widely practiced because their oily flesh is considered unpalatable, although direct harvest continues to occur and smoked turtle meat from coastal villages is exchanged for pig meat from inland villages.
- Leatherback turtle egg collection continues along the Huon Gulf south coast but declined significantly over the period 2003 to 2013 due to the implementation of various community-based leatherback turtle conservation measures. However, leatherback turtle egg collection has increased over the period 2013 to date, owing to a reduction and, in some areas, a cessation of turtle conservation measures brought about by a lack of funding and disputes between villagers over landownership claims. In general, turtle eggs are either consumed immediately or shared within a village; though, some may be sold at market to generate income.

Huon Gulf marine traffic and transport

- Lae Port is the main port in PNG with an estimated 2,854 vessel arrivals and departures each year. Lae Port will be the main logistics base for Project equipment brought in by shipping.

- Marine traffic and transport is an important marine resource use and Lae Port is PNG's largest port. Current vessel traffic arriving at the port averages 10.2 vessels/day and 6.6 vessels/day, based on data for the period 14 March to 12 April 2017 and 17 May to 16 June 2017, respectively, for two periods for which marine traffic data were available (Marinetraffic, 2017a, 2017b). These data show variability of the number of ships per month arriving at Lae Port with about 33% fewer vessels arriving at Lae Port during the May to June 2017 period.
- Container and cargo ships (70%) were the dominant vessel type of the total number of vessels (307) of all types visiting Lae Port during the period 14 March 2017 to 12 April 2017, followed by special craft (13%), purse seine tuna vessels (6%), oil, gas and chemical carriers or tankers (6%), tugs (4%) and pleasure craft (1%). Special craft include marine surveying ships, offshore supply vessels and barges. During the period (17 May to 16 June 2017), the proportion of container and cargo ships dropped to 45% of the total number of vessels (205) visiting Lae Port, which indicated that of the 33% fewer vessels arriving at the port during this period, there were proportionately fewer container and cargo ships.
- The port was recently expanded during the Phase I construction of the Lae Tidal Basin, which created a 250-m-long international container wharf that adjoins a 120,000 m^2 container yard and a 60,700 m^2 container storage area. Phase II of the Lae Tidal Basin Project will if developed add further berths on the western side of the tidal basin and a mineral concentrate storage facility.
- A new Malahang fisheries wharf is proposed to the west of Wagang village and the proposed Outfall Area. The new wharf is proposed to be reserved for PNG's domestic and PNG-flagged foreign or chartered purse seine tuna vessels to offload freshly caught tuna for road transport or conveyor belt to the new tuna processing plants and canneries being built at the Malahang Industrial Centre.
- Marine traffic density is highest along the Huon Gulf north coast. This area is the main shipping route for international shipping, coastal shipping and purse seine vessels, as well as small boat traffic used to transport people and goods between the coastal villages and Lae markets. This high-density marine traffic route passes by the Outfall Area.
- Small watercraft form the largest numbers of vessels in the inner Huon Gulf with outboard motor-driven banana boats and dinghies transporting people and their goods to and from DCA Point and Voco Point in Lae to local coastal villages. The busiest routes are between Lae and the coastal villages of Labu, Labu Butu, Labu Miti, Labu Tale, Busama and Salamaua, which are located along that stretch of coast between the Markham River mouth and the Salamaua Peninsula.

Recreation

- The main recreational activities in the Huon Gulf are game fishing, diving and snorkelling over coral reefs and shipwrecks, bathing and swimming.
- The Lae Game Fishing Club is the foremost recreational fishing club in the Huon Gulf. The club's members and guests target wahoo, black and blue marlins, sailfish, dolphinfish, trevallies, Spanish mackerel and tuna, with the main fishing areas well to the east (~100 km) and more than ~10 km south of the Coastal Area. Sport fishing competitions are held regularly.
- The main areas for recreation coral reef diving and snorkelling are the clear-water and diverse coral reefs at the Tami Islands, which are located about 95 km east of the Coastal Area. Other coral reef diving and snorkelling sites are located on the Huon Gulf south coast at the Salamaua Peninsula (30 km southeast of Lae), Kamiali Wildlife Management Area (60 km southeast) and numerous islands off the coast of Morobe LLG, such as Lasanga Island (80 km southeast) and the Fly Islands (85 km southeast).

- A number of marine recreational diving clubs exist to cater for tourists to dive at various shipwreck sites located in the Huon Gulf. In the Huon Gulf, the main dive sites are various Imperial Japanese Navy (IJN) ships sunk during World War II. There is a shallow-dive wreck of the IJN *Kongo Maru* off the coast of Labu Tale that is located 9 km south of the Coastal Area, and two deep-dive wrecks of the IJN *Yokohama Maru* and IJN *Kotoku Maru* are both located in nearshore waters just off the Salamaua Peninsula and 30 km southeast of the Coastal Area.
- Bathing and swimming is a daily activity at coastal villages, with Lae townspeople tending to bathe and swim at the weekends at local Lae beaches, at Wagang beach and Voco Point.

Protected Areas and conservation

- There are a number of sensitive onshore, coastal and marine areas that are either of conservation significance or value, or which may be of direct importance to local communities. However, these are not located near the Coastal Area.
- The nearest official protected area is the Kamiali Wildlife Management Area (WMA), which has a 15,000 ha marine component that is located 60 km southeast of Lae. Local villagers hold title to their territory and traditional tenure over the natural resources of both the land and seaward extension out to 3 nautical miles (about 5.5 km).
- In an effort to balance conservation and exploitation, Kamiali residents crafted and enacted a reef-fish management plan in 2014 for the marine component of the Kamiali WMA. In addition, protection was given to other leatherback nesting sites along the Huon Gulf south coast via the Huon Coast Leatherback Turtle Conservation Project, which began in November 2003 but has now ended, owing to the lack of funding. However, funding for the Kamiali turtle conservation project is continuing by the Bishop Museum in Hawaii (Longenecker et al., 2015).
- The nearest unofficial conservation area is the Labu Tale turtle reserve, whereby villagers of Labu Tale have protected leatherback turtle nests. This reserve is located 17 km south of Lae and has formed the basis of eco-tourism with visitors and tourists visiting the Labu beaches to observe turtles nesting during the peak season (October to March) and later, turtle hatching.
- Although not under any formal protection, the Labu Lakes system includes the only extensive mangrove stands in the inner Huon Gulf and sustains many species of fish and shellfish, which provide the primary source of protein for the communities of Labu, Labu Butu and Labu Miti.

Commercial fishing industry

The National Fisheries Authority (NFA) advises that there is currently no commercial tuna fishing within the Huon Gulf (NFA, pers. com., 2016b). However, commercial fisheries operating outside the Huon Gulf in PNG's Exclusive Economic Zone waters and further afield are summarised below.

Purse seine tuna fishery

- The main commercial fishery is the purse seine tuna fishery that has a fleet of 27 purse seining vessels operating out of Lae, which is their home base. The Lae purse seiner fleet represents 43.5% of PNG's total purse seine fleet of 62 vessels. The fishery itself is located outside of the Huon Gulf.
- The main fishing areas of the purse seine tuna fishery are located within PNG's Exclusive Economic Zone and in the western and central Pacific Ocean. PNG's 3.1 million km^2 fishing zone is the second largest in the South Pacific.
- The target tuna species and 2015 annual average catches of the total PNG-based purse seine fishery are skipjack (150,000 t), yellowfin (50,000 t) and bigeye (5,170 t), while other less common species of tuna (e.g., albacore and Pacific blue-fin) accounted for an annual average catch of about 100 t.

- The main tuna fishing areas focus on tuna located in epipelagic surface waters, where the targeted tuna concentrations have limited connections with deep-water zones greater than 200 m.
- The purse seining vessels represent less than 6% of the monthly marine traffic arriving at or departing from Lae Port.
- Based on a literature review, no tuna species were identified to have spawning grounds within the Huon Gulf. It is possible that juvenile tuna migrate through the wider Solomon Sea, including the Huon Gulf, to productive foraging areas, such as the continental shelf and seamounts to seek out baitfish and other food.

Tuna processing plants and canneries in Lae

- There are four operating tuna processing plants or canneries in Lae with another two proposed for the Malahang Industrial Centre.
- A total of 10 tuna processing plants or canneries are planned for Morobe Province and centred in Lae (NFA, pers. com., 2016b), which represents another four plants that will be constructed in Lae over the next five years. In addition, a total ten operating tuna processing plants or canneries are also planned for Madang Industrial Centre in Madang Province (Celso, 2017).
- Overall, the proposed total of 10 tuna processing plants and canneries in Lae represents more than a doubling of capacity and added value producing a 1 billion/year Kina (US$ 0.3 billion/year) industry.
- The main products from the tuna processing plants and canneries are packaged frozen or cooked tuna loins and canned tuna followed by other processed products, such as canned mackerel, fresh and frozen tuna, fish meal and, in the future, high-value added fresh tuna products frozen to -60° Celsius.

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Glossary

Abbreviations

CEPA	Conservation and Environment Protection Authority
CPUE	catch per unit effort
DEC	Department of Environment and Conservation
DSTP	deep sea tailings placement
EEZ	Exclusive Economic Zone
EIS	environmental impact statement
EU	European Union
FAD	fish aggregating device
FFA	Forum Fisheries Agency
ha	hectares
IFAD	inshore fish aggregating devices
IUCN	International Union for Conservation of Nature
IUU	Illegal, unregulated and unreported fishing
kg	kilograms
km	kilometre
km^2	square kilometres
LLG	Local Level Government
m/kyr	metres per thousand years
m^2	square metres
MoU	Memorandum of Understanding
NFA	National Fisheries Authority
NGO	non-government organisation
nm	nautical mile
PMIZ	Pacific Marine Industrial Zone
PNA	Parties to the Nauru Agreement
PNG	Independent State of Papua New Guinea
PNGPCL	PNG Ports Corporation Limited
SPC	Secretariat of the Pacific Community
t	tonnes
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	Western and Central Pacific Ocean

WGJV	Wafi-Golpu Joint Venture
WMA	Wildlife Management Area

Terms

abyssal zone	Part of the benthic zone that extends from a depth of 2,000 to 6,000 m where the continental slope flattens out.
abyssopelagic zone	Part of the pelagic zone that extends from a depth of 4,000 to 6,000 m below the ocean surface.
artisanal fishery	Small-scale fisheries for subsistence or local, small markets, generally using traditional fishing techniques and small boats.
background	The circumstance, situation, or level of a particular parameter prevailing at the time of assessment; natural or pre-existing level of a variable.
banana boat	A small glass-fibre dinghy usually providing a local rapid transit transport service to people and their goods; typically fitted with an outboard motor.
baseline	A set of reference data sets or analyses used for comparative purposes; it can be based on a reference year or a reference set of (standard) conditions.
bathyal zone	Part of the benthic zone that extends from a depth of 200 to 400 m and forms the continental slope.
bathymetry	The submarine topography of the ocean.
bathypelagic	Part of the pelagic zone that extends from a depth of 1,000 to 4,000 m below the ocean surface.
benthic zone	The ecological region at the lowest level of a body of water, including the sediment surface and some sub-surface layers.
benthic	Defining a habitat or organism found on the sea bottom or pertaining to the seafloor (or bottom) of a water body.
benthos	Organisms that live at or associated with the seafloor. Examples include burrowing clams, sea grasses, sea urchins and acorn barnacles.
Catch	To undertake any activity that results in taking fish out of its environment dead or alive; to bring fish on board a vessel dead or alive; the total number (or weight) of fish caught by a fishing operation.
coastal area	Refers to a distance of few hundred meters inland starting from the lowest low-tide point.
Coastal Area	The Coastal Area includes the proposed Port Facilities Area and the proposed Outfall Area (Project-defined term).
commercial fishery	A term related to the whole process of catching and marketing fish or shellfish for sale. It refers to and includes fisheries resources, fishermen, and related businesses.
continental shelf	Underwater portion (shelf) of the continent, with moderate inclination, extending seaward from the shore to the edge of the continental slope where the inclination increases rapidly. Sometimes conventionally considered as the continent margin between 0 and 200 metres depths.
continental slope	Part of the continental margin; the ocean floor from the continental shelf to the continental rise or oceanic trench. Usually commences at a depth of about 200 m. The continental slope typically has a relatively steep grade from 3 to 6 degrees.
coral reef	The massive deposition of calcium carbonate by coral polyps of colonial stony corals and other organisms producing large living hard structures.

crustaceans	A group of freshwater and saltwater invertebrates with jointed legs and a hard shell of chitin. Includes shrimps, crabs, lobsters, and crayfish.
demersal	Living in close relation with the bottom and depending on it. Cods, groupers, crabs, and lobsters are demersal resources. The term usually refers to the living mode of the adult, e.g., demersal fish.
dinghy	A small open boat usually built from aluminium providing local rapid transport for people and their goods; typically fitted with an outboard motor.
diversity	The state of being diverse. A diversity index is a quantitative measure that reflects how many different types (e.g., species) there are in a dataset, and takes into account how evenly the individuals are distributed among those types. Biological diversity (biodiversity) is the variety of species (of plants, animals, etc.), their genes, and the ecosystems they comprise, in a particular habitat.
dugout canoe	A canoe made from a hollowed tree trunk.
ecosystem services	The benefits people obtain from ecosystems. These include provisioning services, such as food and water; regulating services, such as flood and disease control; cultural services, such as spiritual and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth.
effort	The amount of time and fishing power used to harvest fish; includes gear size, boat size, and horsepower.
epifauna	Animals living on the surface of the seafloor, or attached to submerged objects or animals.
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.
estuary	A coastal ecological ecosystem that is partially enclosed, receives freshwater input from land, and has a horizontal fresh-salt salinity gradient; the average salinity of estuarine waters is defined as being 30 practical salinity units (PSU) for at least 1 month per year.
euphotic zone	The upper region of a body of water into which light penetrates, allowing photosynthesis.
euryhaline	Organisms able to tolerate a wide range of salinity.
hadal zone	Part of the benthic zone that extends beyond 6,000 m and includes deep sea trenches.
hadopelgic zone	Part of the pelagic zone that extends to greater than 6,000 m below the ocean surface.
Huon Gulf north coast study area	Comprises the coast from Markham River mouth to Nababangdu Point and Tami Islands.
Huon Gulf south coast study area	Comprises the coast from Markham River mouth to Gira River mouth.
Inshore	Situated at sea within the three nautical mile coastal water limit.
Katsuobushi	Japanese style filleted, fermented and smoked skipjack tuna meat, which is used as a main ingredient for Japanese soups and as a flavouring.
littoral zone	Part of the benthic zone that extends between 0 and 1 m or the intertidal zone between low and high tide.
macrobenthos	Benthic organisms (animals or plants) whose shortest dimension is greater than or equal to 0.5 mm.
macrofauna	Small animal organisms found in or on the seafloor, normally including fauna of greater than 0.5 mm size.

mesopelagic zone	The intermediate depths of the ocean which receive some sunlight but not enough for photosynthesis; extending from 200 m down to 1,000 m below sea level.
navigable waters	Waters that provide a channel for commerce and transportation of people and goods.
nearshore or coastal water	The region of the sea or seabed relatively close to the shore.
nekton	Marine animals that swim and move independently of water currents.
odontocete	Any toothed whale (i.e., cetacean without baleen plates) of the suborder Odontoceti, such as sperm whales, killer whales, beaked whales, dolphins, and porpoises.
offshore	Situated at sea beyond the three nautical mile coastal water limit.
onshore	Terrestrial or on land.
Outfall Area	The area encompassing the Outfall System, pipeline laydown area, choke station, access track and parking and turnaround area.
Port Facilities Area	The area encompassing the proposed facilities located at the Port Area, including the concentrate filtration plant and materials handling, storage, ship loading facilities and filtrate discharge pipeline.
Pelagic	The part of the water column that us neither close to the bottom nor near to the shore.
photic zone	The depth zone in the ocean extending from the surface to that depth permitting photosynthesis.
seamounts	A mountain rising from the seafloor, which does not reach the water surface.
study area	The Huon Gulf, Solomon Sea (deep sea trenches) and the western and central Pacific Ocean. The Huon Gulf is further broken down into Huon Gulf north coast Study area and Huon Gulf south coast Study area.
subsistence fishery	Refers to fishing, other than sport fishing, that is carried out primarily to feed the family and relatives of the person doing the fishing.
sublittoral zone	Part of the benthic zone that extends from the lowest tide to 200 m depth.
surface mixed layer	The layer of water between the ocean surface and a depth usually ranging between 25 m and 200 m, where the density is about the same as at the surface.
total allowable catch	A catch limit set for a particular fishery, generally for a year or a fishing season
watercraft	A boat or other vessel that travels on water.

1. Introduction

1.1 Background

Wafi Mining Limited and Newcrest PNG 2 Limited (the WGJV Participants) are equal participants in the Wafi-Golpu Joint Venture (the WGJV) and propose to construct, operate and (ultimately) close 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") in the Morobe Province of Papua New Guinea (PNG). The Project is located approximately 300 kilometres (km) north-northwest of Port Moresby and 65km southwest of Lae.

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, any 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 proposed 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 fisheries and marine resource use characterisation study. The study area for this report is the Huon Gulf, Solomon Sea (deep sea trenches) and the western and central Pacific Ocean.

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 key objectives of the fisheries and marine resource use study, based on the study brief dated 15 December 2016 provided by Coffey to EnviroGulf Consulting, are to characterise:

- The existing marine resource uses of the Huon Gulf that may potentially be affected by DSTP. The characterisation will also address tuna fishing, which occurs outside the Huon Gulf.
- The existing and potential fisheries within the Huon Gulf, including fishing intensity, locations, seasonality, and typical catches. This will include artisanal, commercial and recreational fishing areas and activities.
- The existing and potential expansion of the fish processing (cannery) operations in Lae.
- The commercial fisheries of the Huon Gulf or areas further offshore that supply fish to the Lae canneries.
- The customary or small scale fishing activities of local communities within the study area, including typical catch and processing data[1].
- Any other marine resource uses other than fishing (e.g., recreation).

Secondary objectives of the marine resource use study are to determine the following information:

- How large is the commercial fish processing industry in Lae?
- What is the geographical range from which fish are supplied?
- What are the main species and fishing methods used to supply this industry?
- What are the key dependencies of this fishery? For example, what are the markets and international market requirements upon which the industry is based, and is there any potential conflict with using DSTP for tailings management?
- Is there a smaller, but no less important, small-scale pelagic fish industry in villages that sell fish caught commercially to derive an income?
- What other marine recreational uses of the Huon Gulf may be affected (perceived or real) by DSTP?

Investigations of endangered species are provided in a separate nearshore marine characterisation report (Coffey, 2018a).

1.3 Study areas

The study area considered in this report includes the Huon Gulf, Solomon Sea (deep sea trenches) and the western and central Pacific Ocean (WCPO) (tuna fishing areas).

[1] The Wafi-Golpu Project Socioeconomic baseline (Coffey, 2018b) includes more detailed data pertaining to the economic aspects of fisheries and the extent of local community reliance upon commercial and customary / subsistence fisheries operations for food and income.

Figure 1.1 shows a map of the study area that is focussed on the Huon Gulf, including key local level governments (LLGs), towns and villages. For the purposes of the present study, the Huon Gulf is defined as that sea area westward of a line drawn between the following points (from north to south):

- Nababangdu Point (6° 37' 47.51" S, 147° 51' 49.60" E).
- Tami lands (6° 45' 28.42" S, 147° 55' 50.42" E).
- Gira River mouth (8° 0' 7.90" S, 147° 57' 26.32" E).

Nababangdu Point is the easternmost point of the Huon Peninsula located in Yabim Mape Rural LLG near Gingala Village and about 3 km south of Gagidu Station, the principal settlement of Finschhafen. The Tami Islands have been included in the Huon Gulf as they are an important recreational and fishing area, where shallow water and seamounts attract tuna and tuna-like fish. The Gira River mouth in Morobe Rural LLG forms the south eastern coastal border between the Morobe and Northern provinces of PNG (see Figure 1.1).

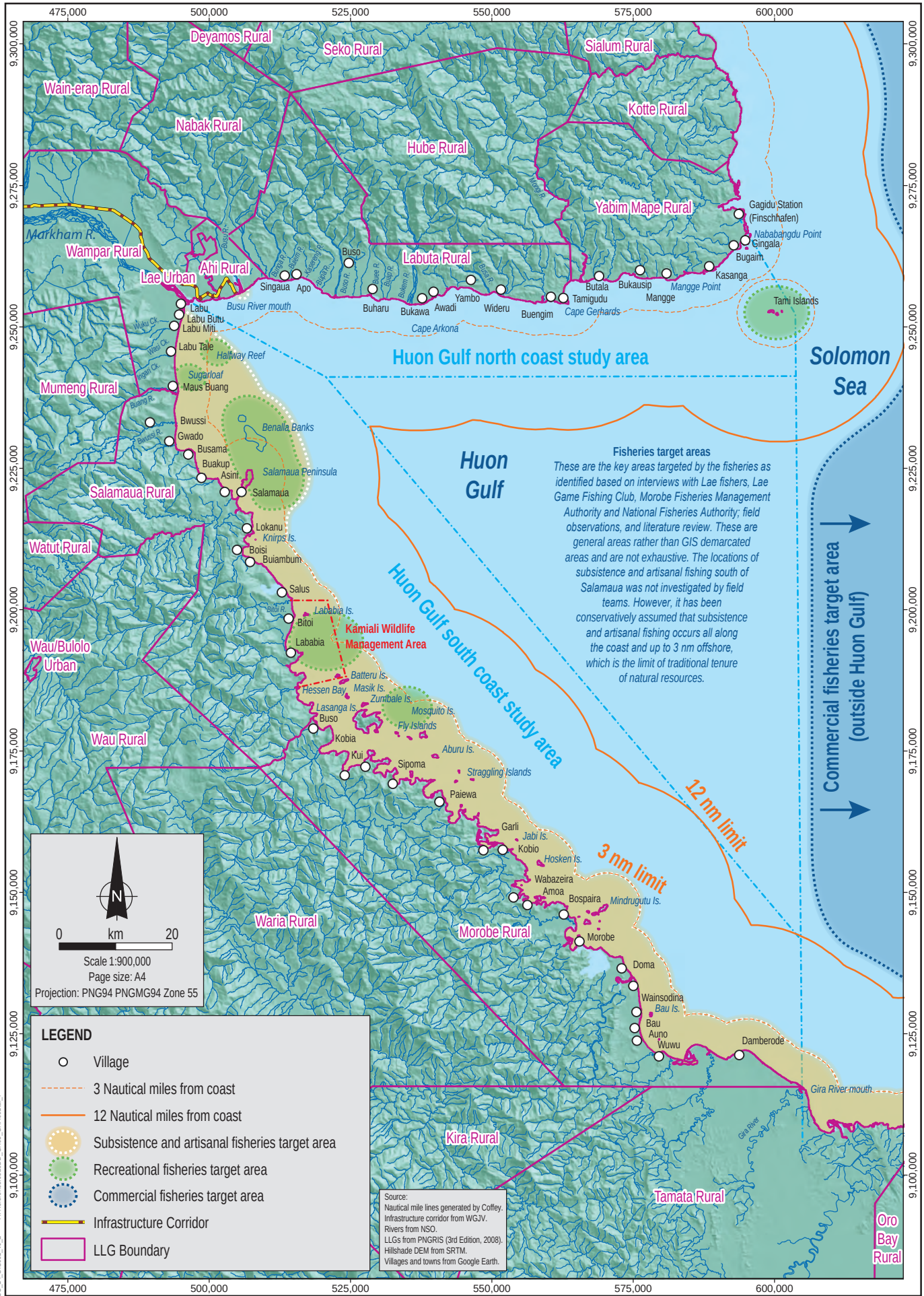
Two areas have been selected for further assessment in relation to nearshore fisheries and other marine resource uses. These are:

- Huon Gulf north coast study area, comprising:
  - Markham River mouth to Nababangdu Point.
  - Tami Islands.
- Huon Gulf south coast study area, comprising:
  - Markham River mouth to Gira River mouth.

Since the Project involves a potential DSTP option for tailings management, marine resource uses of the deep-water environments of the Huon Gulf (e.g., continental shelf slopes and canyons) and the neighbouring Solomon Sea (e.g., deep-sea abyssal plains and hadal trenches) are also addressed. Separate oceanographic and modelling studies of the dispersion and deposition of tailings will then determine the extent of any potential pathways of exposure.

The water column of the Huon Gulf and adjoining Solomon Sea may be divided into the five zones listed in Table 1.1. Similarly, the seabed or benthic environment may be divided into five zones (Pinet, 2009), which are also listed in Table 1.1.

Table 1.1 also shows the general locations of the target areas of the key fisheries (subsistence and artisanal; recreational; and commercial) in the study area.



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Project: 754-ENAUABTF100520CC
File Name: 0520DD_SR05_F001.1_GRA

WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Huon Gulf north and south coast study areas and fisheries target areas

Figure No: 1.1

MXD Reference: 0520CC_14_GIS001_v0_2 AI Reference:0520DD_SR05_GRA001.ai_7

Table 1.1: Depth zonation of the pelagic and benthic marine environment

Zone	Depth range (m)	Description
Pelagic environment of open ocean and seas:		
Epipelagic	0–200	Euphotic zone penetrated by photosynthetically active light.
Mesopelagic	200–1,000	Disphotic or twilight zone where some light filters through.
Bathypelagic	1,000–4,000	Zone of complete darkness that includes bioluminescent marine life.
Abyssopelagic	4,000–6,000	Zone of complete darkness that mostly occurs above deep-sea plains.
Hadopelagic	>6,000	Zone of complete darkness that mostly occurs in deep sea trenches.
Seabed or benthic environment of seabed or ocean depths:		
Littoral	0–1	Intertidal zone between low tide and high tide.
Sublittoral	0–200	Lowest tide level to 200 m.
Bathyal	200–2,000	Continental slope.
Abyssal	2,000–6,000	Where the continental slope levels out to form flat expanses of the seabed.
Hadal	>6,000	Includes deep-sea trenches.

Source: Pelagic environment layers by Sea and Sky (2017) and benthic environment layers by Pinet (2009).
This is the maximum possible euphotic zone range in the clear open ocean.

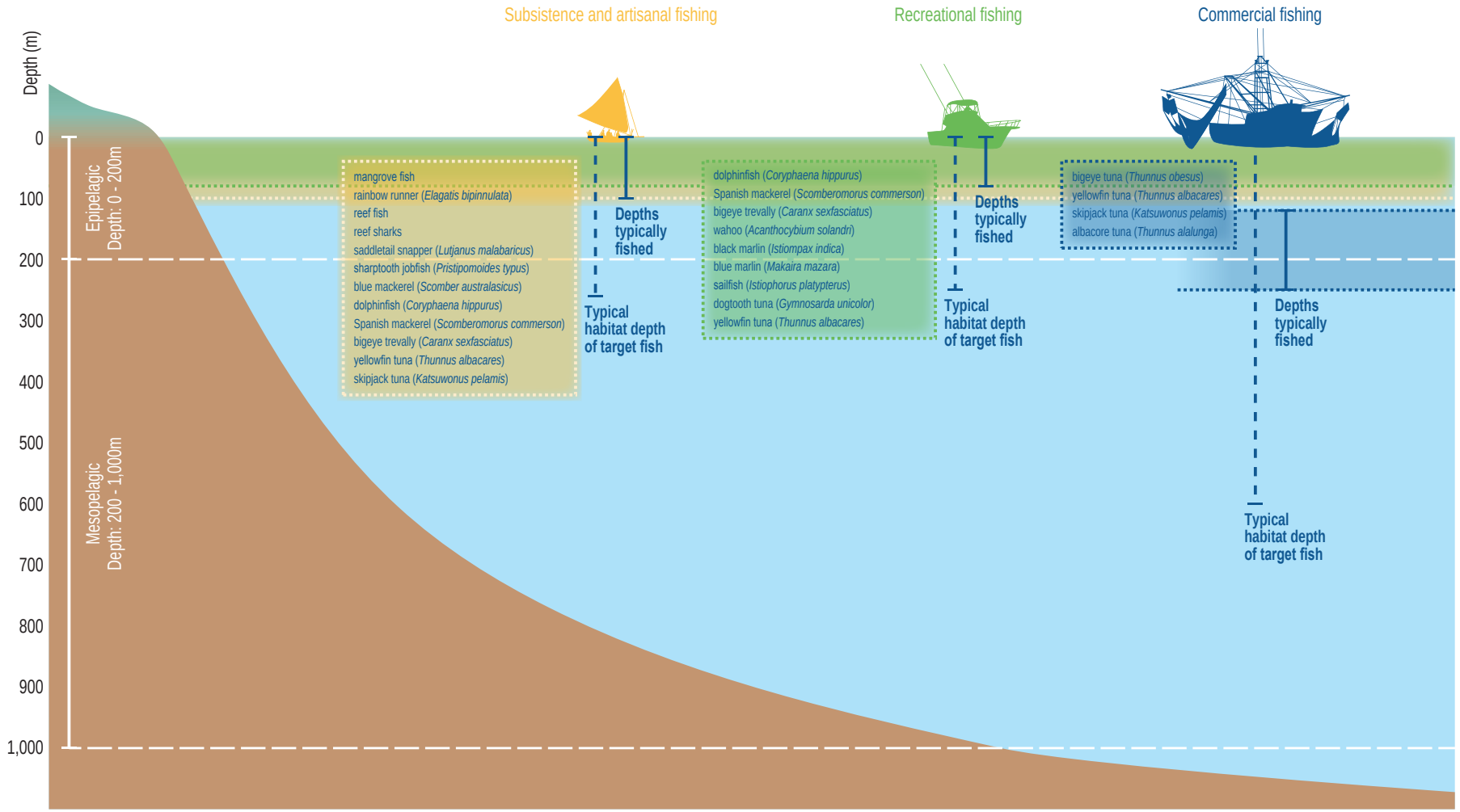
In Table 1.1, the pelagic zone is the open water column outside the influence of the seabed, where there are vertical gradients of physico-chemical parameters, such as light, temperature, salinity and pressure. The pelagic zone includes the entire volume of seawater above the seafloor. This zone may be further divided into two zones; the neritic zone that lies above the continental shelf and the oceanic zone that lies above the ocean floor.

The epipelagic zone includes the euphotic zone where the rate of photosynthesis is sufficient to compensate for losses due to respiration, and the lower boundary is defined as the depth where 1% of surface light is found. The actual depth penetration of light sufficient to support photosynthesis varies with local conditions, and is much reduced in turbid coastal waters such as near the mouth of the Markham and Busu rivers.

The littoral zone includes the intertidal zone between low and high tide; the sublittoral zone includes the continental shelf of the Huon Gulf (lowest tide to 200 m); the bathyal zone includes the continental slope to its base; the abyssal zone includes the relatively flat seabed below the continental rise; and the hadal zone includes the base of the Markham Trench that adjoins the New Britain Trench.

Figure 1.2 presents a diagram of the vertical distribution of the three key fisheries in the study area: subsistence and artisanal; recreational; and commercial. The figure shows the depths at which the three key fisheries target fish. This information was sourced from interviews with local Lae fishers, the deep-slope and pelagic fish report (Coffey, 2018b), interviews with the Lae Game Fishing Club and online information regarding purse seining depths (FAO, 2003). Note that a maximum target depth of 250 m is given for the commercial purse-seine fishery based on the depth of the net drop needed to enclose the fish. In this way the fishery typically targets the schooling tuna within the surface mixed layer and thus shallower than this 250-m depth (FAO, 2003).

The figure also shows, for each fishery, the depth ranges in the water column that the fish species typically inhabit. The depth range given for each fishery is based on a literature review of all key fish species targeted for each fishery, and the maximum collective depth range of all species is presented in the figure. The typical depth ranges were sourced from the widely used website Fish Base Fishbase.org (Fishbase, 2017) and the FAO (FAO, 2017).



coffey A TETRA TECH COMPANY	Date: 04.07.2017 Project: ENAUABTF100520CC File Name: 0520DD_SR05_F001.2_GRA	WAFI-GOLPU JOINT VENTURE Wafi-Golpu Project	Depth ranges of target fish habitat and fishing depths in the study area

Figure No: 1.2

AI Reference: 0520DD_SR05_GRA002.ai_8

2. Methods

This study was based on a literature review of existing information and analyses of new information and data gathered during the targeted field surveys of coastal villages during the social and marine baseline surveys described below.

2.1 Data sources

Data sources for the study include:

- Literature and prior studies in the study area.
- PNG legislation and relevant international guidelines, policies and standards for the purposes of identifying key environmental areas and focus points for the study.
- Existing studies and reports on marine resource use in the study area and surrounding region by PNG authorities:
  - PNG Ports Corporation Limited (PNGPCL).
  - National Fisheries Authority (NFA).
  - National Maritime Safety Authority.
  - Morobe Fisheries Management Authority.
- Project-specific information provided by WGJV, particularly information and data available on marine infrastructure associated with the Coastal Area.

2.1.1 Interviews

During the Coffey nearshore marine surveys in November 2016, February 2017 and March 2017 Coffey interviewed local Project stakeholders with respect to their use of marine resources (Coffey, 2018a). This was carried out in collaboration with the WGJV Community Affairs team.

These interviews included discussions of the marine resources used by villagers in both the nearshore and offshore environment, as well as discussions with national and local fishery management authorities, and the Lae Game Fishing Club. The following interviews were conducted in November 2016:

- Lae Game Fishing Club, Lae.
- National Fisheries Authority, Lae.
- Morobe Fisheries Management Authority, Lae.
- Interviews with seven villagers from Labu Butu at DCA Point fish market.

Two key informant interviews were carried out during the nearshore marine characterisation surveys, (Coffey, 2018a) at the villages of Labu Butu (November 2016) and Wagang (November 2016 and March 2017), which provided more detailed information, such as the following:

- Nature of fishing (frequency, duration and organisation).
- Where fish are caught.
- Fishing gear used.
- Use of traditional methods.
- Fish catch (numbers and weight).

- Type of fish (estuarine, reef, deep-slope and/or pelagic).
- Timing and seasonality of fishing.
- Fate of fish catch.
- Turtle and turtle egg collecting catches.
- Time of year sightings of whales and dugongs.
- Decapod crustacean catches (number or weight).
- Cultural constraints to fishing practices.

Consultation was not exhaustive. Further consultation with coastal communities and state and national authorities will continue during the preparation of the EIS as per the Project's Stakeholder Engagement Plan.

Information and data from these interviews were collated and reported in the present report, as appropriate.

2.1.2 Prior studies within the Huon Gulf

Existing published and unpublished literature was searched for previous studies or surveys undertaken in the study area. Table 2.1 lists examples of key prior studies in the Huon Gulf from which information or data was collated to support the present study. Section 4 lists the references for additional sources of information and data for the Huon Gulf.

Table 2.1: Examples of prior studies in the study area

Source	Relevant topics covered
Previous marine physical studies of Huon Gulf:	
Krause et al., (1970)	Turbidity currents and cable breaks in the western New Britain trench
Nedeco (1970)	Papua and New Guinea Harbours Board, Port Development Study Lae
Von der Borch (1972)	Marine geology of Huon Gulf region New Guinea
Everingham (1973)	A submarine slump and tsunami in the Lae area
Deacon (1993)	Modern shore face sediment facies study of the northern Huon Gulf coast
Liu et al., (1995)	Submarine features of the modern open-sea fan deltas, Huon Peninsula
Galewsky et al., (1996)	Fore-deep tectonics and carbonate platform dynamics in the Huon Gulf
Kuna (1997)	Geological hazards of Lae city, PNG
ECO-Care Engineering (2002)	Lae Port Environmental (Siltation) Study
PNGPCL (2007)	Lae Port Development Project – Environmental Impact Assessment
Renagi (2009)	Markham River: Dispersal patterns and quantities of sediment discharges

Source	Relevant topics covered
Previous marine biological studies in Huon Gulf:	
Kojis and Quinn (1984)	*Acropora palifera* fecundity in two reefs in Huon Gulf
Hermes (1992)	Artisanal fisheries landings at Lae Fisheries Division, Voco Point
Kailola (1995)	Fisheries Resources Profiles, PNG
Benson et al. (2007)	Leatherback turtle studies in the Huon Gulf
NFA (2007)	Review of fisheries and marine resources in Morobe Province
Liviko (2007)	Baseline biological assessment of Hessen Bay, Morobe Province
Kaly and Preston (2007)	Socio-economic survey of small-scale fisheries in Morobe Province
Longenecker et al., (2008)	Marine fish diversity and exploitation at Kamiali WMA*
Longenecker et al., (2009)	Assessment of exploited reef-fish populations at Kamiali WMA
Longenecker et al., (2010)	Population size structure reef-fish populations at Kamiali WMA
Longenecker et al., (2011)	Catch and size structure of exploited reef-fishes at Kamiali WMA
Longenecker et al., (2015)	Evaluation of recently enacted reef-fish management plan at Kamiali WMA
MRF (2015, 2015a)	Community based conservation of leatherback turtles n the Huon Gulf

Note: * WMA denotes Wildlife Management Area.

2.1.3 Project-related field investigation studies

Table 2.2 includes six field studies that were carried out in support of the Project EIS, including nearshore water and sediment quality characterisation, a nearshore marine ecology assessment study, a deep-slope and pelagic fish characterisation study, a benthic video survey of the seabed and benthic habitats, and a socio-economic baseline study.

Table 2.2: Project site-specific field investigations and assessment studies

Source	Relevant topics covered
IHAConsult (2012)	Pre-feasibility DSTP Investigations
IHAConsult (2015)	DSTP scoping study
IHAconsult (2017)	Hydroacoustic Assessment of the Spatial and Temporal Distribution of Fish and Plankton of the Huon Gulf
IHAconsult (2018a)	Physical, Chemical and Biological Sedimentology of the Huon Gulf
IHAconsult (2018b)	Oceanographic Investigations of the Huon Gulf
WorleyParsons (2016)	Nearshore marine ecology assessment study
Coffey (2018a)	Nearshore marine characterisation study
Coffey (2018b)	Deep-slope and pelagic fish characterisation study
Coffey (2018c)	Benthic video characterisation study
Coffey (2018d)	Raw data from socio-economic baseline interviews and land and water resource use interviews (this report was in draft format at time of writing)

2.2 Data limitations

A number of limitations were noted during preparation of this fisheries and marine resource use characterisation study. The key data limitations are summarised below.

2.2.1 Marine traffic and transport

At the time of writing, shipping traffic, density and routing data were not available from the National Maritime Safety Authority Vessel Monitoring System or its Automatic Identification System database, owing to staff and time allocation shortages within this authority.

Analyses of Automatic Identification System data would have allowed a more detailed characterisation of ship types by class (e.g., tonnage and size), marine traffic density and routing information for the Huon Gulf. Notwithstanding, various credible online fleet monitoring websites (e.g., marinetraffic.com and fleetmon.com) were accessed to provide similar but limited levels of marine traffic density and routing information and data suitable for the current fisheries and marine resource use characterisation study.

Information regarding the numbers and types of boats, traffic density and alongshore transit routes used by villagers along the coastline of the Huon Gulf was limited. The numbers and frequency of villagers transiting from their villages to the fish markets in Lae was not captured in sufficient detail to provide traffic density figures. However, limited data on the number of trips taken on a weekly basis was collated from data provided in the Socioeconomic baseline study (Coffey, 2018d).

2.2.2 National Fisheries Authority tuna fisheries data

The NFA provides annual summary data to the Western and Central Pacific Fisheries Commission (WCPFC), the Pacific Islands Forum Fisheries Agency (FFA) and to the Parties to the Nauru Agreement (PNA), as part of its commitments to these agencies. These summaries were accessed from their publications and used in the present study.

2.3 Study team

This marine resource use baseline characterisation was a desktop study by Mr David Balloch, EnviroGulf Consulting.

Additional information and data were obtained from the following EIS supporting studies:

- Nearshore marine characterisation study (Coffey, 2018a).
- Deep-slope and pelagic fish characterisation study (Coffey, 2018b).
- Benthic video characterisation study (Coffey, 2018c).
- Socioeconomic baseline (Coffey, 2018d).

3. Results

This section presents the results of the fisheries and marine resource use characterisation study. Results are presented for the following key categories:

- Subsistence and artisanal fisheries.
- Other minor fisheries.
- Non-fishing marine resource use.
- Commercial fisheries.
- Marine transport and infrastructure.

3.1 Subsistence and artisanal fisheries

3.1.1 General

There has been a strong tradition of fishing in most of the coastal villages of the Huon Gulf. In general, fishing was historically a subsistence activity with the men of the extended family unit using hand-made hooks and lines and using outrigger dugout canoes to fish for reef fish, mangrove fish or tuna as they moved along the coast. Clucas and Curran (1992) provided a historical summary of subsistence and artisanal fisheries in the Morobe Province. In general, they found that fish would be caught, taken to shore and distributed amongst members of the extended family or clan for immediate consumption. If there were too many fish for immediate consumption, the surplus would be smoked to preserve it, or perhaps bartered for other foodstuffs or goods. Following the introduction in the 1970s of outboard motor-driven banana boats and dinghies, this not only allowed coastal villagers to fish with other equipment and to go further for fish, but also to transport their fish relatively quickly to the urban centres such as Lae for sale. However, in the case of those villages that were more remote from Lae, banana boats or dinghies typically carried separate storage boxes for ice and for ice-chilled fish. When the ice-chilled fish storage boxes were full, the catch would be transported to market. The sale of fish has led to more organised fishing and the development of artisanal fisheries along the coast of the Huon Gulf, especially for villages close to the urban centres of Lae and Finschhafen. The following sections provide an update on subsistence and artisanal fisheries based on the field studies undertaken by Coffey (Coffey, 2018a, 2018b and 2018d).

Artisanal fishing groups comprise a number of fishing units usually having one or more outboard motor-driven banana boats or dinghies plus several outrigger dugout canoes. These fishing groups tend to be owned by few individuals from the same village but will operate communally as far as fish preservation and marketing is concerned. Interviews with local fishers during the Coffey nearshore marine characterisation study (Coffey, 2018a) from Labu Tale and Labu Miti indicated that there is ongoing organised fishing (e.g., cooperatives) and that fishers fish individually as well as in ‘large groups with multiple boats’. In the case of some villages close to Lae such as Labu, Labu Miti, Labu Tale, freshly caught fish can be transported to and landed at the informal fish markets at Voco Point and DCA Point within 10 minutes from nearby fishing areas, obviating the need for preservation on ice. In addition, fish are also sold at the formal Lae Main Market at various fish stalls, albeit in small quantities.

A formal fish market has recently opened at the NFA’s Voco Point location (The National, 2017). The Overseas Fishery Cooperation Foundation OFCF of Japan helped finance this jointly-owned NFA and Morobe Fisheries Management Authority project. The Overseas Fishery Cooperation Foundation has installed modern equipment including a plate ice machine, a blast freezer, cool storage, an office, a tool room and a small fish selling and buying point (i.e. a mini fish market). These facilities may help

to expand the development of artisanal and coastal small-scale coastal commercial fisheries in the coming years.

Subsistence and artisanal fishing takes place along the entire coast of the Huon Gulf in both nearshore (3 nm limit) and offshore (12 nm limit) territorial waters.

Morobe Province comprises nine districts of which four have land areas that border on the Huon Gulf. Figure 1.1 in Section 1.3 (study area) shows the coastal LLG areas and the main coastal villages within the Huon Gulf north and south coast study area:

- Huon Gulf north coast study area:
  - Yabim Mape Rural LLG (Finschhafen District).
  - Labuta Rural LLG (Nawae District).
  - Ahi Rural LLG (Lae District).
  - Lae Urban LLG (Lae District).
- Huon Gulf south coast study area:
  - Wampar Rural LLG (Huon District).
  - Salamaua Rural LLG (Huon District).
  - Morobe Rural LLG (Huon District).

The National Fisheries Authority initiated a socioeconomic study of small-scale fisheries in Morobe Province wards and LLGs between 16 July and 1 September 2005 as part of the Coastal Fisheries Management and Development Project (Kaly and Preston, 2007).

The subsistence and artisanal fisheries of the Huon Gulf north and south coasts are characterised separately below.

3.1.2 Huon Gulf north coast

There is very little continental shelf development along the Huon Gulf north coast (east of the Markham River). Where the continental shelf is present, it is very narrow and the 100 m depth contour is very close to the coastline, except in a few locations (e.g., coastline between Mangge Point and Kasanga village (refer Figure 1.1)) where the shelf is wider and coral reefs are present. Figure 3.1 shows a map of the inner Huon Gulf in which deep water (i.e., >100 m isobath) is clearly shown to be very close to shore.

3.1.2.1 Nearshore subsistence fisheries

Coffey (2018a) observed villagers fishing from the beach between Wagang and Singaua (refer Figure 1.1). During interviews, residents of Wagang stated that they commonly fish from the shore along this stretch of coast, including at the mouth of the Busu River (Coffey, 2018a). Most fish caught are generally for personal or village consumption only, which reflects the lower catches of fish along this coast compared to the coast further south (see Section 3.1.3).

Both men and women fish with women tending to fish from the shore, while men fish the nearshore typically out to about 200 m using outrigger dugout canoes, but generally do not fish seaward of 500 m from shore where the water depth over the seabed increases sharply (i.e., continental slope). The fishing methods include rod-and-line from the shore and using handlines and baited hooks from canoes. Other fishing equipment used by Wagang locals includes spear guns, gill nets and cast nets (Coffey, 2018d). The main nearshore fish catches comprise snappers, red emperors, small mackerels (baitfish), trevallies, emperors and sharks. During interviews with people from Wagang, when shown

photographs and specimens of dwarf gulper sharks (the dominant catch in the deep-slope fishing survey [Coffey, 2018b]), they indicated that they had caught this shark on occasion but that it was not a targeted species. Discussions with local fishers at the DCA Point fish market identified that handline methods targeted both demersal and pelagic fishes in water depths usually between 50 m and 100 m, while trolling targeted fishes in near-surface areas of up to 10 m depth. Fishing depths were estimated from discussions with locals at the DCA Point market based on the number of rolls of fishing line that they noted as being dispensed from the reel, with each roll comprising 10 m of fishing line (Coffey, 2018a).

Wagang village subsistence fishing

Coffey investigated marine resource uses at Wagang by interviewing locals during the nearshore marine characterisation study, land and water resource use study and the socioeconomic baseline study. A fishing area, comprising a narrow nearshore rocky reef, was identified by locals as being located between Wagang and the Busu River. The methods of fishing included the use a 3-inch mesh gill net and handline with two single baited hooks. Locals also stated that most of the fishing is conducted from shore further east near the mouth of the Busu River.

The reported fish catch was small and included 10 small mackerel, a red emperor and a small hammerhead shark, all of which were used for subsistence consumption with no fish sold. Other fish occasionally caught are skates or rays and prawns are caught by net.

Results from the Socioeconomic baseline study (Coffey, 2018d) provided site-specific information on subsistence fishing at Wagang. Wagang village and its coastal, creek and brackish waterways locations are shown in Figure 3.2.

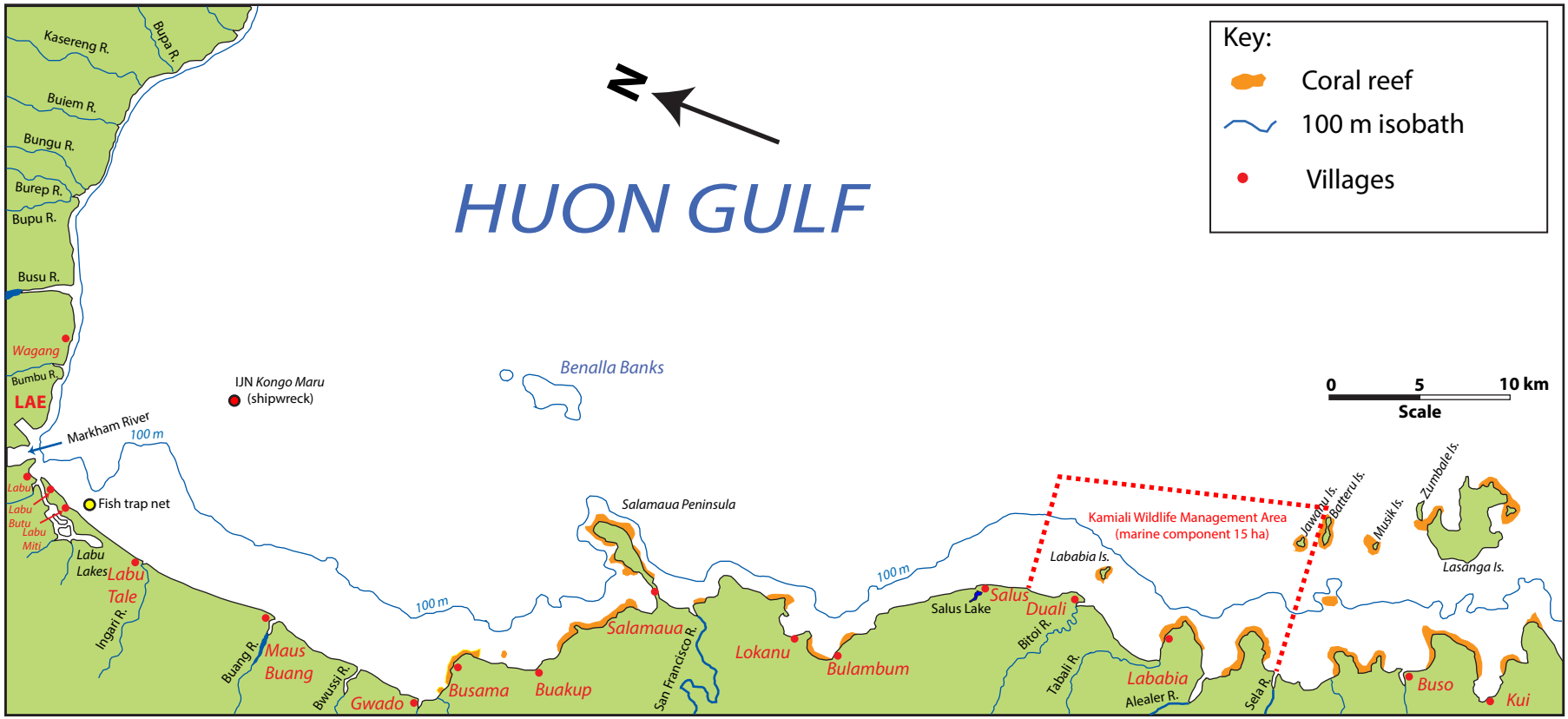
- Coastal subsistence fishing areas include:
  - Entire coastline between Wagang and the Busu River that includes fishing off the shore and within nearshore waters.

River freshwater and brackish water fishing areas (see Figure 3.2) include:

- Rivers and creeks in the vicinity of Wagang village, including:
  - Budac Creek to the north and east of the village.
  - Butibam Creek, north of the village.
  - Nungwa River to the west of the village.
  - Buampu River to the west of Nungwa Creek and the village.

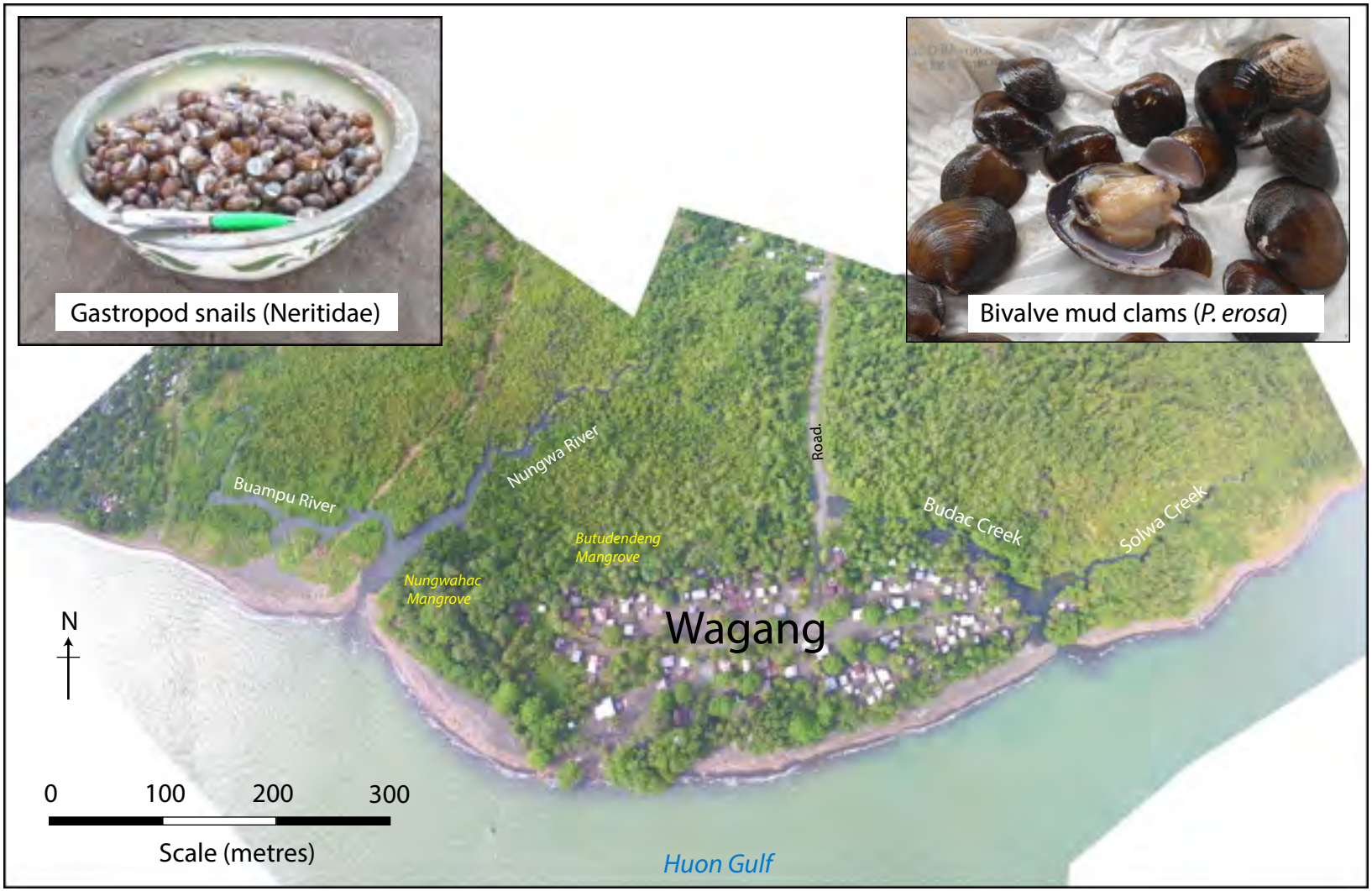
In addition, an area of coastal inland waterways between Wagang and the Busu River is used by women for fishing of eels, decapod crustaceans (e.g., prawns, crabs and mud lobsters) and molluscs (e.g., kina shells, mangrove clams and gastropod snails) in brackish water areas. Plants such as sago and watercress are collected from the freshwater reaches of creeks within this inland waterway area. The inset photographs in Figure 3.2 show example collections of gastropod snails (Neritidae) and the bivalve mud clam (*Polymedosa erosa*) from brackish water areas.

Coffey (2018d) undertook interviews with villagers from Wagang with respect to their subsistence fishing methods and practices. In general, subsistence fishing is undertaken daily by individual or groups of men or women. On a monthly basis, group fishing in the Huon Gulf is undertaken using multiple boats to increase the size of the fish catch, which is consumed by fishers and their families or by the wider village community.



Source: EnviroGulf Consulting.

	EnviroGulf Consulting	Date: 8.5.2017		EnviroGulf Consulting	Figure No: 3.1
		File Name: 177-F3.1	Rev: 1	Wafi-Golpu Project	Inner Huon Gulf showing 100-m isobath and coral reefs



Source: Coffey; Photo credits: Coffey; Mangrove mud clam *P. erosa* denotes *Polymesoda erosa*.

	EnviroGulf Consulting	Date: 28.04.2017		EnviroGulf Consulting	Figure No: 3.2
		File Name: 177-F3.2	Rev: 1	Wafi-Golpu Project	Wagang village, creeks and examples of aquatic produce

The main sources of fish are the freshwater and brackish water reaches of waterways surrounding Wagang village and the coast up to 500 m distance offshore, which corresponds to water depths of approximately 200 to 300 m.

Typical fishing methods include:

- Active fishing methods and gear:
  - Spear, spear guns, diving.
  - Rod-and-line fishing from the beach.
  - Hand lining from outrigger canoes or banana boats in nearshore waters (within 500 m).
  - Beach seining using 50-m-long by 3-m-deep seine nets of 2- to 4-inch stretched mesh size.
  - Gill netting.
  - Circle netting.
- Passive fishing methods and gear:
  - Anchored longline with baited hooks.
  - Drift longline with baited hooks.

Coffey's interview with the NFA noted that stunning methods to capture fish, such as derris root or explosives, are banned (NFA, pers. com., 2016b). Kinch (2006a) notes that derris root and dynamite fishing methods are occasionally employed in the Huon Gulf although the report did not specify where this occurs.

Typical marine pelagic and deep-water catch sizes per fishing trip are less than 10 fish and between five and 25kg in total weight, whereas the typical catch size from freshwater and brackish waterways at the village and along the coast is less than 10 fish and less than five kg in weight. The interviews noted that few coral reef fish were caught due to the absence of coral reefs along the coastline between the mouth of the Markham River to well east of the Busu River mouth.

3.1.2.2 Mangroves and coastal lagoon fisheries

There is a limited distribution of mangroves along the north coast of the Huon Gulf, owing to the lack or small size of estuaries and the presence of fast-flowing, turbid rivers and creeks. However, in sheltered bays such as the one between the Bupa and Kasereng rivers, there are small areas of mangrove swamp occupied by small- and large-leaved orange mangroves (*Bruguiera* spp.) with an understorey and fringe along the rivers of tall stilted-mangrove (*Rhizophora apiculata*) (Cook, 1986). The mangrove is separated from the sea by a sandbank facing onto a degraded coral shelf in a shallow bay.

Other small areas of mangrove along the Huon Gulf north coast are located at the following locations (refer Figure 1.1):

- Buee River: lower river reach and mouth.
- Buap River: lower river reach and mouth.
- Lower reach and mouth of an unnamed creek that flows through Yambo.

There are no coastal mangroves between Wagang and the Busu River except two small areas of mangrove vegetation within un-named tributaries of the Nungwa River immediately to the west of Wagang (some 2 km west of the Outfall Area). These are the Butudendeng and Nungawahac mangrove areas, which are shown in Figure 3.2.

There are two small coastal lagoons with one located between the Bulu and Buap rivers and the other, Mundala Lagoon, is located about three km west of Yambo village. These two small coastal lagoons provide nursery habitats for fish and prawns, as well as a subsistence fishery resource. They are respectively located about 25 km and 40 km east of the Outfall Area. Based on a desktop review of available data, typical fish species might include large-scale mullet (*Chelon macrolepis*), mangrove jacks and trevallies (Carangidae). These coastal lagoons, mangroves and the lower reaches of rivers and creeks also provide sheltered fishing areas when the sea is rough, such as during the southeast trade wind season from May to October.

The Huon Gulf north shore mangroves and coastal lagoons also provide a source of shellfish (prawns and crabs) and marine gastropod snails, such as the spired nerite (*Nerita planospira*), sulcate creeper (*Terebralia sulcata*) and the lipped periwinkle (*Monodonta labio*), as well as two periwinkles (*Littorina* spp.) (Cook, 1986).

3.1.2.3 Coral reef fisheries

In the inner Huon Gulf, there are no coral reefs along the north coast between the mouths of the Markham and Busu rivers (refer to Figure 3.1), which is attributable to the high frequency of turbid water intrusion from these two rivers.

Owing to the steep submarine slope being close to the Huon Gulf north shore, any fringing or patch coral reefs would be restricted to shallow water depths to about 30 m, which presents a very narrow band (<50 m wide) along the coastline.

Inspection of naval charts and satellite imagery (e.g., Google Earth™) indicates the presence of small areas of living coral reefs along the Huon Gulf north coast at the following locations, which are shown in Figure 1.1:

- Huon Gulf north coast coral reefs from west to east (distance in brackets from Outfall Area):
  - Coast from Cape Arkona to Yambo village (32 to 40 km east).
  - Coast between Buengim village and Cape Gerhards (56 to 59 km east).
  - Coast between Mangge village and Mangge Point (75 to 70 km east).
  - Coast west of Mangge Point and Kasanga village (79 to 84 km east).
  - Coast east of Kasanga village to Nababangdu Point (84 to 94 km east).
  - Tami Islands (95 km east).

Coral reef area and density increases eastwards from Cape Arkona to Nababangdu Point. Where discharge of turbid waters occurs from the many south-flowing rivers and creeks draining the Huon Peninsula, there are breaks in the longitudinal distribution of the nearshore coral reefs of the Huon Gulf north coast. Due to the importance of the presence of photosynthetic algae for coral growth, coral reefs can only develop in relatively clear water; therefore, coral reefs are unlikely to develop where there are turbid freshwater inflows. However, sediment-tolerant species of soft corals (e.g., Alcyonarians) may be expected to be present at distance from the river and creek inflows.

A literature search and inspection of satellite photography (e.g., Google Earth™) did not reveal any coral reefs along the Huon Gulf north coast, including the Coastal Area. Nevertheless, the species of fish present at the coral reefs of the Huon Gulf south coast (see below) are also likely to be similar to those of the north coast coral reefs, especially those reefs in the clearer waters of the Tami Islands and Nababangdu Point, given that they are located in the same body of water (i.e., the Huon Gulf).

3.1.3 Huon Gulf south coast

The Huon Gulf south coast (south of the Markham River) includes those coastal villages in Wampar Rural, Salamaua Rural and Morobe Rural LLGs (refer Figure 1.1).

The coastline south of the Markham River is low-lying and dominated by swamp for a distance of about 10 km from the river mouth. This is an area of mangrove forest and tidal channels known as the Labu Lakes.

There is a large area (about 30 km^2) of the inner continental shelf between the mouth of the Markham River and Salamaua Peninsula that is relatively flat and shallow (refer Figure 3.1). This area is regularly used by villagers from Labu, Labu Butu, Labu Miti, Labu Tale, Busama and Salamaua as a source of nearshore and offshore fish for both subsistence and artisanal use. Unlike the Huon Gulf north coast, the south coast has a wide inner continental shelf (0 to 200 m depth) that varies in width from 5 km to 10 km. There are many islands, coral atolls and shoals and pinnacles along this stretch of the south coast of the Huon Gulf. Below about 200 m the continental slope falls to the abyssal plain and hadal depths of the Markham Canyon and New Britain Trench in the Solomon Sea.

There are very few coral reefs within the stretch of coastline between the Markham River and Salamaua village. However, some patch reefs are located at Schneider Point near Busama village, as well as the coastline southwards to and including the Salamaua Peninsula. Southwards of the Salamaua Peninsula to the southern limit of the study area (refer to Figure 1.1), there are extensive fringing coral reefs, patch reefs and island reefs.

The fisheries and marine resource uses of the Huon Gulf south coast study area are characterised below.

3.1.3.1 Fishing areas

There are a number of important local fishing grounds along the Huon Gulf south coast (refer Figure 3.1) that are listed below and include:

- Labu Lakes.
- Labu to Labu Miti coastal waters.
- Shipwreck (IJN *Kongo Maru*) near Labu Tale acting as an artificial reef.
- Fish trap net (0.8 km southeast of Labu Miti).
- Inshore fish aggregating devices (FADs).
- Benalla banks (6.5 km north and northwest of Salamaua Point).
- Salamaua Peninsula coral reefs.
- Windrow[2] trolling (e.g., for dolphinfish and tuna-like fish).
- Coastal lagoons (e.g., Salus Lake near Salus village).
- Coastal fringing and patch reefs extending from Salamaua Peninsula to the Gira River mouth.

The key fishing areas are characterised below including methods, gear and fish species caught.

[2] Lines of confluence on sea surface denoted by seaweed or other floating material used by tuna-like fish.

3.1.3.2 Labu Lakes

The Labu Lakes, formerly known as Lake Herzog, is a freshwater and estuarine lake system located in Wampar Rural LLG (Huon District) and about 5 km southwest of Lae. The catchment of the Labu Lakes includes freshwater inflows from Wuku and Wasi creeks, which drain the eastern slopes of the Herzog Mountains.

The lakes are an important fishing and recreational area to people from the nearby villages of Labu, Labu Butu, and Labu Miti. Plate 3.1 shows local villagers on outrigger canoes and swimming in the sheltered waters of the Labu Lakes. During the southeast trade wind season (May to October) when the nearshore coastal waters of the Huon Gulf are rough, the Labu Lakes offers an alternative sheltered water area for fishing.

Plate 3.2 shows boys fishing by rod-and-line on the lakes' shoreline and Plate 3.3 shows local village men seine-net hauling for fish in shallow water at the lakes' edge. The men's seine haul catches are used to supply fresh fish for their families as well as obtaining small fish to be used as bait for trolling for tuna and other fast-swimming fish in the nearby nearshore waters of the Huon Gulf.

Photo credit: Coffey (2018a)

Plate 3.1: Local villagers on Labu Lakes

Photo credit: Coffey (2018a)

Plate 3.2: Rod-and-line fishing by boys in the Labu Lakes

The Labu Lakes are relied upon heavily by local village residents for harvesting fish such as mangrove jack, mullet and trevally, decapod crustaceans such as mud crabs (*Scylla serrata*), burrowing mud lobsters (*Thalassina* spp.) and prawns, and molluscs from both the lakes and mangroves. Mollusc species present in the brackish waters of the Labu Lakes include mangrove horn snails (*Telescopium telescopium*), mud clams (*Polymesoda erosa)*, air-breathing sea slugs (*Onchidium* spp.), and various mangrove gastropod snails (Cerithidae and Neritidae) (WorleyParsons, 2016). Most of the fishing and harvesting of mangrove molluscs is for subsistence reasons, although some excess fish, mud crabs, prawns and molluscs are sold at the fish markets in Lae. The shells of some mollusc species are dried in the sun and then ground to a fine white powder (lime or *kambang* in Tok Pisin) after burning and pulverising, which is then sold as a preferred accompaniment to betel nut consumption.

Photo credit: Coffey (2018a)

Plate 3.3: Shallow water seine-net fishing by men in Labu Lakes

Labu Lakes fish species

Table 3.1 lists the fish species caught in the Labu Lakes and estuary (WorleyParsons, 2016, based on PNG Unitech, 1983). The list has been updated to valid www.fishbase.org nomenclature (Fishbase, 2017) and the latest International Union for Conservation of Nature (IUCN) Red List of Threatened Species categories (IUCN, 2017).

Table 3.1: List of fish species in the Labu Lakes caught for subsistence consumption

Family	Scientific Name	Common Name	*IUCN Status
Dasyatidae	*Himantura granulata*	Mangrove whipray	VU
Anguillidae	*Anguilla obscura*	Pacific short-finned eel	DD
Muraenesocidae	*Muraenesox cinereus*	Daggertooth pike conger	NE
Clupeidae	*Anodontostoma chacunda*	Bony bream	NE
	Sardinella melanura	Black-tipped sardine	NE
	Sardinella albella	Perforated scale sardine	LC
Engraulidae	*Setipinna tenuifilis*	Hairfin anchovy	NE
Ariidae	*Hemipimelodus sp.*	Catfish	DD
	Netuma thalassina	Giant catfish	NE
Ambassidae	*Ambassis interruptus*	Long-spined glass perchlet	NE
	Fibramia amboinensis	Amboina cardinalfish	DD
	Yarica hyalosoma	Humpbacked cardinalfish	LC
	Taeniamia buruensis	Buru cardinalfish	LC
Terapontidae	*Mesopristes cancellatus*	Tapiroid grunter	LC
Eleotridae	*Eleotris fusca*	Dusky sleeper	LC
	Eleotris macrolepis	Orange-bellied gudgeon	NE
Mugilidae	*Chelon macrolepis*	Largescale mullet	LC
	Liza oligolepis	Broad-mouthed mullet	NE
Mullidae	*Upeneus vittatus*	Striped goatfish	NE
	Paraupeneus sp.	Goatfish species	NE

Family	Scientific Name	Common Name	*IUCN Status
Leiognathidae	*Leiognathus equulus*	Common ponyfish	LC
	Gazza achlamys	Silvertooth ponyfish	LC
	Secutor runconius	Deep pugnose ponyfish	NE
Lactariidae	*Lactarius*	False trevally	NE
Carangidae	*Caranx sexfasciatus*	Bigeye trevally	LC
Lutjanidae	*Lutjanus argentimaculatus*	Mangrove Jack	NE
	Lutjanus ehrenbergii	Blackspot snapper	NE
	Lutjanus johnii	Golden snapper	NE
	Lutjanus	Bigeye snapper	NE
	Lutjanus maxweberi	Pygmy snapper	NE
	Lutjanus rivulatus	Blubberlip snapper	NE
	Lutjanus vaigiensis	Mangrove red snapper	NE
Serranidae	*Epinephelus daemelii*	Saddled rockcod	NE
	Epinephelus tauvina	Greasy grouper	DD
Gerreidae	*Gerres filamentosus*	Whipfin silver-biddy	LC
Synodontidae	*Harpadon nehereus*	Bombay-duck	NE
Sciaenidae	*Otolithes ruber*	Tigertooth croaker	NE
	Johnius weberi	Weber's croaker	NE
Lobotidae	*Lobotes surinamensis*	Jumping Cod (tripletail)	LC
Ephippidae	*Platax orbicularis*	Orbicular batfish	NE
Polynemidae	*Polydactylus microstomus*	Small-mouthed threadfin	LC
Haemulidae	*Pomadasys argyreus*	Blue-checked javelinfish	NE
Nemipteridae	*Scolopsis ghanam*	Arabian monocle bream	NE
Scatophagidae	*Scatophagus argus*	Spotted scat	LC

Family	Scientific Name	Common Name	*IUCN Status
Gobiidae	*Sicyopterus gymnauchen*	Red-tailed goby	LC
Toxotidae	*Toxotes jaculatrix*	Banded archerfish	LC
Zenarchopteridae	*Zenarchopterus dispar*	Feathered river-garfish	LC

Source: Adapted from WorleyParsons (2016) and PNG Unitech (1983). Updated species names to Fishbase (2017) valid names and IUCN (2017) Red List status. * IUCN Red List categories are: DD–Data Deficient; LC–Least Concern; VU–Vulnerable; NE–Not Evaluated.

3.1.3.3 Nearshore fisheries

The main fishing methods are hand lining from outrigger canoes, as well as line trolling using outrigger canoes and outboard motor-driven banana boats or dinghies. Cast nets are also occasionally used in shallow water from shore or from outrigger canoe. Rod-and-line fishing and gillnets are also used in the Labu Lakes. The NFA is encouraging local villagers to use coarser nets of two-inch mesh rather than one-inch mesh, so fewer small or juvenile species are caught (NFA, pers. com., 2016a).

Traditional use of crushed derris root to chemically stun fish is discouraged by the NFA (NFA, pers. com., 2016b); however, at some coastal villages (e.g., Lababia) people continue to use derris root to catch large numbers of fish when required for feasts or other large gatherings (Longenecker et al., 2015).

In terms of surface trolling, there are several areas where tuna-like fish are caught. These areas include the Benalla Banks, which is a shallow area 6.5 km northwest of the Salamaua Peninsula, and a number of anchored floating Fish Aggregating Devices (FADs) of which one is located off the coast of Lababia. In all, there are twelve inshore anchored floating FADs in the Huon Gulf (NFA, pers. com., 2016b). However, a literature search did not reveal their exact locations. In general, these low-cost inshore FADs draw tuna to nearshore areas, allowing subsistence and artisanal fishers to catch them, thereby supplementing the fishers' food and income needs (Rosegrant et al., 2015).

A trial handline fishery was conducted in 2005 with 10 boats solely owned and operated by local fishermen in Madang and Morobe provinces; however, this reduced to five boats by 2010 (Kumoru, 2010). While there is some growth potential for this fishery, most of the vessels failed to continue fishing mainly due to lack of proper business management, and the high operational cost for artisanal operators during its inception (NFA, 2016a). The total catch by these vessels was estimated to not exceed 10 t per year and was generally sold to fish processing companies as well as local supermarkets. While NFA (2016a) mentioned this fishery in its annual report to the WCPFC's 12th Regular Session of the Scientific Committee in Bali, Indonesia (3 to 11 August 2016), a literature search did not reveal any current information on this fishery for 2016.

Nearshore fish catch

Table 3.2 lists typical coastal fish catches from fishing areas used by villagers from Labu Butu and Labu Miti based on interviews with key informants during the Coffey nearshore marine characterisation study (Coffey, 2018a) about fisheries and marine resource use.

Table 3.2: Typical coastal fish catches by Labu Butu and Labu Miti fishers

Village/ interviewee no.	Boat	Fishing area/depth	Methods	Species	Time spent fishing (hours)	Total catch (kg)	Catch consumed (kg)
Labu Butu (#1)	Canoe	Labu Lakes and coast	Cast net, gillnet, handline	Mangrove jack, trevally, snapper, red emperor	6.5	38.5	5.0
Labu Butu (#2)	Canoe	Labu coast	Handline	Trevally, snapper, red emperor	7.0	8.4*	0.0
Labu Butu (#3)	Canoe	Benalla banks (40–50 m depth)	Cast net, gillnet, handline	Mackerel, red emperor, hammerhead shark	2.0	8.0	0.0
Labu Butu (#4)	Canoe	Labu coast	Surface trolling above 50 m water depth	Mackerel and silver trevally	7.0	83	0.0
Labu Miti (#5)	75 HP outboard dinghy	Labu coast	Handline	Rainbow runner	5.0	N/A	0

* Total catch of 8.4 kg sold for K135.00. N/A denotes not available.

As an example of the value of fish sold by villagers, one interviewee from Labu Butu village sold all his catch (Plate 3.4) to purchasers at DCA Point fish market in Lae. The fish were caught using a handline and baited hooks on the continental shelf near Labu Butu at a depth of 70 m and over a period of seven hours of fishing effort.

Photo credit: Coffey (2018a).

Plate 3.4: Labu Butu fisherman's catch on sale at DCA Point fish market

Example sales of selected fish from the total catch by interviewee #2 in Table 3.2 above were:

- 2.5 kg trevally sold for K40.00.
- 1.25 kg trevally sold for K20.00.
- 3.1 kg snapper sold for K50.00.
- 1.5 kg red emperor sold for K25.00.

Plate 3.5 shows (a) the outrigger dugout canoe that was used by interviewee #4 in Table 3.2 above to troll for fish off the coast of Labu Butu and (b) the catch of mackerel and silver trevally.

Fish frequently caught in shallow nearshore waters include the large-scale mullet (*Chelon macroplepis*), which is the most common species encountered in the local fish catches in Lae. This species is also more frequently found in the Markham River than in the Labu Lakes. Mullets are characteristic of brackish water fish fauna, and juvenile mullet enter river estuaries and coastal lagoons in large schools, especially during the rainy season (WorleyParsons, 2016).

(a) Photo credit: Coffey (2018a).

(b) Photo credit: Coffey (2018a).

Plate 3.5: Outrigger canoe (a) and surface trolling fish catch (b)

In Table 3.2 above, one of the interviewees only caught rainbow runner (*Elagatis bipinnulata*) using a handline from an outboard-driven dinghy. Plate 3.6 shows 13 of the 45 strings of individual rainbow runners on sale at the DCA Point informal fish market.

Photo credit: Coffey (2018a).

Plate 3.6: Rainbow runners (*Elagatis bipinnulata*) on sale at DCA Point fish market

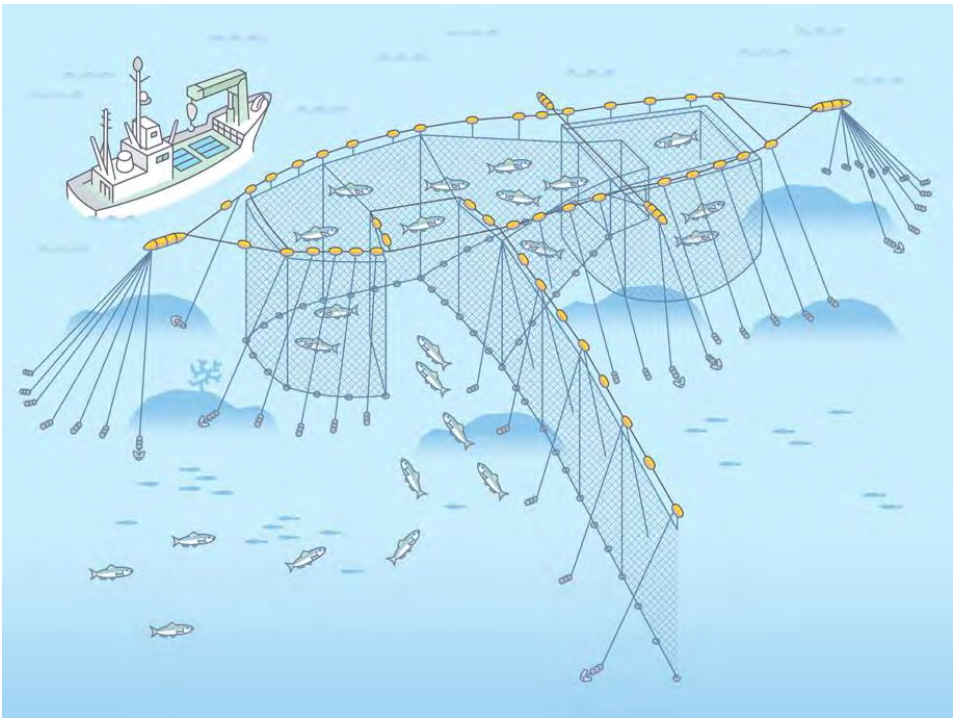
Separate key informant interviews with villagers from Labu Tale indicated that the main fish caught were ‘deep-slope’ fish; however, the records of fish caught indicate that pelagic fish rather than demersal fish were caught. The key species were tuna, rainbow runners, dolphinfish, mackerel, and barracudas, most of which are associated with surface waters.

3.1.3.4 Fish trap net fishery

A fish trap net trial fishery was established in October 2015 in an area offshore of Labu Miti village in the inner Huon Gulf as an economic development project by the NFA in association with the Morobe Fisheries Management Authority and the Overseas Fishery Cooperation Foundation of Japan (Overseas Fishery Cooperation Foundation, 2017; NFA, pers. com., 2016b). Figure 3.3 shows a diagram of the fish trap net that was installed 0.8 km southeast of Labu Miti in shallow (15 m deep) nearshore water. The trap net is of a type called a ‘drop net’ that is widely used on the coast of Japan.

The fish trap net fishery is operated by between 10 and 15 fishers from Labu Miti acting as a community fishing group. Plate 3.7 shows Labu Miti fishers hauling in trapped fish from the fish trap net and Plate 3.8 shows a typical catch being taken ashore at Labu Miti. This trap net targets a variety of fish including mackerel (*Scomberomorus* spp.), rainbow runner (*Elagatis bipinnulata*), mahi-mahi (*Coryphaena* spp.) (Coffey, 2018a) and numerous small pelagic fish (refer Plate 3.8). Typical catches varied between 20 and 50 kg of shallow-water pelagic fish during fish trials (Overseas Fishery Cooperation Foundation, 2017).

During past trialling of the fish trap nets and training of community fishing groups in using the trap nets, each community fishing group has access to 90% of the fresh fish sales, 5% of NFA-Overseas Fishery Cooperation Foundation funding for replacement of fixed assets (outboard motors and boats) and 5% for the operation fund to cover all operating expenses including personnel expenses. Operating expenses includes fish trap net maintenance, such as net lifting, net reinstallation (where necessary), cleaning and repair (Overseas Fishery Cooperation Foundation, 2017).



Source: MAFF (2017).

Figure 3.3: Diagram of fish trap net anchored offshore of Labu Miti village, Huon Gulf

Source: Overseas Fishery Cooperation Foundation (2016)

Plate 3.7: Collecting fish at the fish trap net offshore of Labu Miti

The NFA considers that the fish trap net fisheries contribute to promoting employment, increasing cash income and securing food for the coastal community involved in the fishery, and is one of the key measures for coastal fishery development by PNG (NFA, pers. com., 2016b)

Source: Overseas Fishery Cooperation Foundation (2017)

Plate 3.8: Taking catch from fish trap net to shore at Labu Miti

3.1.3.5 Coastal Reef Fisheries

The coastal artisanal and subsistence fisheries that focus on coral reefs is poorly documented. However, the National Fisheries Authority initiated a socioeconomic study of small-scale fisheries in

Morobe Province between 16 July and 1 September 2005 as part of the Coastal Fisheries Management and Development Project (Kaly and Preston, 2007). This socioeconomic study provided additional information on coral reef fish catches.

A number of studies of the reefs in the Kamiali Wildlife Management Area including the northern part of Hessen Bay have been carried out in the past (Liviko, 2000; Longenecker et al., 2011, 2012a and 2012b). The Kamiali Wildlife Management Area is located 60 km southwest of the Coastal Area.

Table 3.3 lists the coral reef fishes from the Kamiali Wildlife Management Area (Longenecker et al., 2011).

Table 3.3: List of coral reef fishes from Kamiali Wildlife Management Area

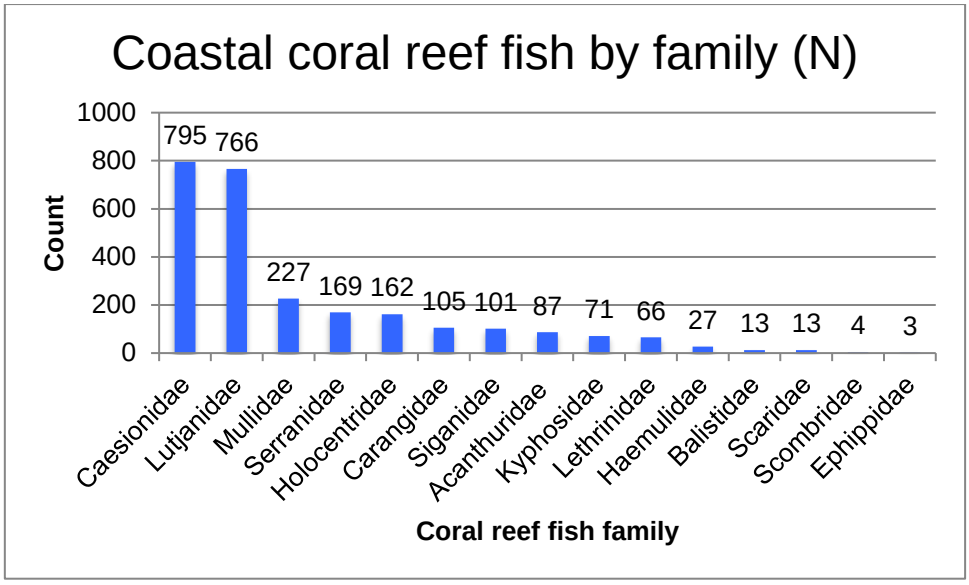
Family	Species	Common name	Count*	Mean Length (cm)
Acanthuridae	*Naso hexacanthus*	Sleek unicornfish	74	44
	Naso lopezi	Elongate unicornfish	3	59
	Naso vlamingii	Bignose unifcornfish	10	36
Balistidae	*Canthidermis maculata*	Rough triggerfish	13	33
Caesionidae	*Caesio cuning*	Redbelly yellowtail fusilier	795	16
Carangidae	*Carangoides bajad*	Orange-spotted trevally	34	26
	Carangoides plagiotaenia	Barcheek trevally	26	26
	Caranx melampygus	Bluefin trevally	32	26
	Caranx papuensis	Brassy trevally	13	62
Ephippidae	*Platax pinnatus*	Dusky batfish	9	26
	Platax teira	Longfin batfish	3	36
Haemulidae	*Diagramma pictum*	Painted sweetlips	8	25
	Plectorhinchus lineatus	Yellow-banded sweetlips	19	36
Holocentridae	*Myripristis adusta*	Shadowfin soldierfish	13	18
	Myripristis kuntee	Shoulderbar soldierfish	58	12
	Myripristis violacea	Lattice soldierfish	52	13
	Myripristis vittata	Whitetip soldierfish	20	11
	Neoniphon sammara	Sammara squirrelfish	14	14

Family	Species	Common name	Count*	Mean Length (cm)
	Sargocentron caudimaculatum	Silverspot squirrelfish	5	15
Kyphosidae	*Kyphosus cinerascens*	Blue sea chub	66	30
	Kyphosus vaigiensis	Brassy chub	5	21
Lethrinidae	*Lethrinus erythropterus*	Longfin emperor	5	22
	Monotaxis grandoculis	Mumpnose big-eye bream	61	25
Lutjanidae	*Lutjanus argentimaculatus*	Mangrove Jack	4	48
	Lutjanus biguttatus	Two-spot snapper	347	14
	Lutjanus boutton	Molucccan snapper	159	14
	Lutjanus carponotatus	Stripey snapper	28	20
	Lutjanus fulvus	Blacktail snapper	39	18
	Lutjanus gibbus	Humpback red snapper	20	21
	Lutjanus kasmira	Bluestriped snapper	3	15
	Lutjanus monostigma	One-spot snapper	4	21
	Lutjanus rivulatus	Blubberlip snapper	4	31
	Lutjanus russellii	Moses' snapper	75	22
	Lutjanus semicinctus	Blackbanded snapper	42	20
	Lutjanus vitta	Brownstripe snapper	19	14
	Macolor niger	Black-and-white snapper	5	28
	Macolor macularis	Midnight snapper	17	31
Mullidae	*Mulloidichthys vanicolensis*	Yellowfin goatfish	7	21
	Parupeneus barberinus	Dash-and-dot goatfish	121	15
	Parupeneus cyclostomus	Gold-saddle goatfish	13	18
	Parupeneus multifasciatus	Manybar goatfish	69	14
	Parupeneus trifasciatus	Doublebar goatfish	28	80

Family	Species	Common name	Count*	Mean Length (cm)
	Mulloidichthys vanicolensis	Yellowfin goatfish	7	21
Scaridae	*Scarus flavipectoralis*	Yellowfin parrotfish	13	20
Scombridae	*Gymnosarda unicolor*	Dogtooth tuna	17	59
	Scomberomorus commerson	Narrow-barred Spanish mackerel	4	95
Serranidae	*Anyperodon leucogrammicus*	Slender grouper	11	26
	Cephalopholis boenak	Brown-barred rockcod	10	17
	Cephalopholis cyanostigma	Blue-spotted rockcod	62	19
	Cephalopholis microprion	Dot-head rockcod	20	13
	Cephalopholis sexmaculata	Sixband rock cod	3	21
	Cephalopholis urodeta	Flagtail rockcod	6	18
	Plectropomus areolatus	Spotted coral trout	10	18
	Plectropomus leopardus	Leopard coral trout	6	34
	Plectropomus oligacanthus	Vermicular cod	41	32
Siganidae	*Siganus javus*	Java rabbitfish	33	25
	Siganus lineatus	Gold-lined rabbitfish	65	26
	Siganus puellus	Masked rabbitfish	3	22

Source: Adapted from Longenecker et al. (2011).
* Refer to source for how counts were performed.

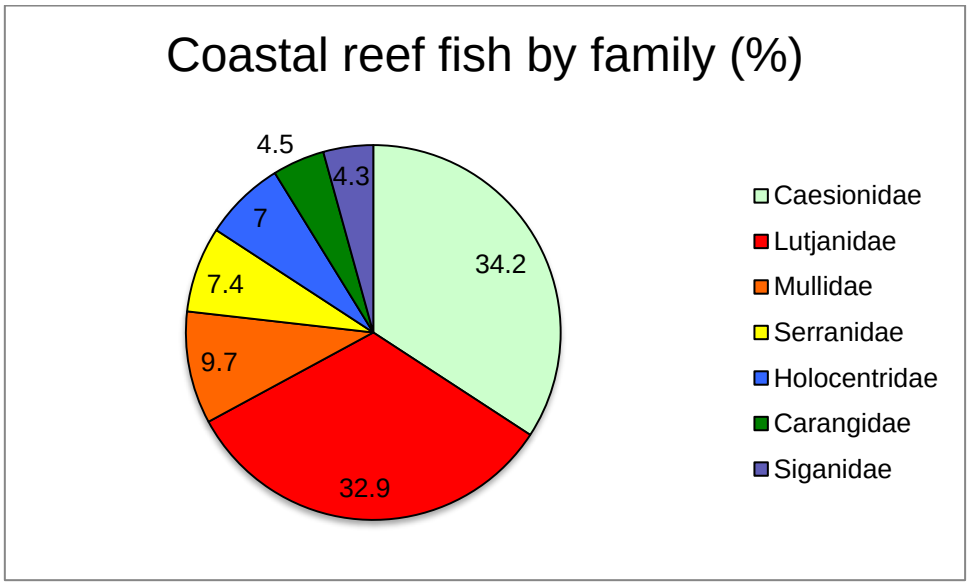
Figure 3.4 shows the key fish families that contribute the highest numbers of the coastal coral reef fish surveyed at Kamiali Wildlife Management Area (Longenecker et al., 2011).



Source: Adapted from Longenecker et al. (2011). N denotes count.

Figure 3.4: Composition of coastal coral reef fish surveyed at Kamiali Wildlife Management Area

Figure 3.5 shows the percentage contribution of the top seven families of coastal coral reef fish surveyed at the Kamiali Wildlife Management Area. The two dominant fish families are the fusiliers (Caesionidae) and tropical snappers (Lutjanidae), each family accounting for about one-third of the total. The fusilier family was dominated by the presence of one species, the redbelly yellowtail (*Caesio cuning*). The tropical snappers comprised 13 species of which the juveniles of two species were numerically dominant; namely, the two-spot snapper (*Lutjanus biguttatus*) and the Molucccan snapper (*Lutjanus boutton*).



Source: Adapted from Longenecker et al. (2011).

Figure 3.5: Percentage coastal coral reef by fish family at Kamiali WMA

Based on numerically dominant coastal coral reef fish and considering the largest fish likely to be caught by villages within the Kamiali Wildlife Management Area, the key species of value for sale would be Spanish mackerel (*Scomberomorus commerson*), brassy trevally (*Caranx papuensis*) dogtooth tuna (*Gymnosarda unicolor*) and mangrove jack (*Lutjanus argentimaculatus*). However, the long distance between Kamiali Wildlife Management Area villages and the Lae fish markets (approximately 60 km) inhibits the sale of fish, owing to transportation costs and preservation. Further detailed information on the Kamiali Wildlife Management Area is given in Section 3.3.5.1.

The socioeconomic survey of small-scale fisheries in Morobe Province (Kaly and Preston, 2007) provided information on the key fish species or groups comprising subsistence and small-scale fishery catches, which included coral reef fish as a major component. Based on the findings from interviews of 600 village households spread across Morobe Province, the dominant fish species or groups comprising most of the catch used for local consumption or sale were reef fish (75.6%), deep-water snappers (39.4%), snappers (33.9%), tuna (28.7%) and offshore pelagic fish (22.8%). The predominance of reef fish in the total fish catches would be expected to be higher for the Huon Gulf south coast if the data from the socio-economic study by Kaly and Preston (2007) included only those households from villages along the south coast. Notwithstanding, the socio-economic survey highlights the importance of reef fish within the total fish catches from the Huon Gulf.

3.1.3.6 Inshore fish aggregating devices

Inshore fish aggregating devices (IFADs) are currently being piloted and funded by the NFA to target food security and poverty alleviation. As at 2015, fifty IFADs have been deployed in Milne Bay, East Sepik, West Sepik and Manus provinces, and construction of 45 more FADs are planned for Madang, Morobe and Bougainville provinces. At present there are twelve IFADs in the Huon Gulf (NFA, pers. com., 2016a) that promote fishing and, hence, higher landings of fish for sale that fishers and their families are not able to consume. However, based on a literature search and communication with the NFA (NFA, pers. com., 2016a), the actual locations and current status of these IFADs are not known.

3.2 Other minor fisheries

A number of minor fisheries operate within the Huon Gulf and further afield in PNG. These minor fisheries are summarised below.

3.2.1 Domestic demersal deep slope fishery

In the early 2000s, a Draft Deep-water Snapper Management Plan was presented to the Morobe Province Fisheries Stakeholder Meeting in Lae for discussion and future implementation (Kinch, 2006b). However, a literature review did not reveal any recent activities in relation to the exploitation of Morobe Province's deep-water fish resources.

Under the EU-funded Rural Coastal Fisheries Development Programme previous deep-water snapper fishing was centred on Kavieng, New Ireland Province, where a number of EU-funded loans with private sector partners saw the introduction of small-scale fishing boats based on an 8.2-m-long glass fibre design built at Samarai Plastics in Milne Bay Province. Three small-scale fishing boats were introduced in Lae in 2004 for demersal fishing in the Huon Gulf. However, the artisanal component of the deep-water snapper fishery declined partially due to the inefficient, petrol-driven boats used in the fishery, as well as fuel cost increase and lack of local markets to land the catches (Kinch, 2006b). A literature review did not reveal any current proposals for trialling a deep-water snapper fishery in the Huon Gulf.

Fishing for snappers and groupers in deep water (>100 m) beyond coral reef slopes was first introduced to PNG by the South Pacific Commission during exploratory surveys of West New Britain in 1979 (Fusimalohi & Crossland, 1980). The principal gear employed was the Samoan design of a

wooden hand reel and a long line that has since become popular throughout the South Pacific. The results from a study of deep-water fish of the north coast of West New Britain Province by Fusimalohi and Crossland (1980) showed the presence of 20 species of deep-slope fish from seven families, which were dominated by deep-water snappers (Lutjanidae: eight species), trevallies (Carangidae: five species), one grouper (Serranidae: *Epinephelus morrhua*) species and sharks. The best fishing depths were found to be from 150 to 200 m where most fishing effort was subsequently concentrated there. However, sharks posed a problem by their attack on deep-slope fish when hooked or during hauling to the surface.

Little is known about the demersal deep-sea fish stocks in Morobe Province, although they are likely to include snappers, emperors, jacks, rock cods and groupers. In general, deep-water fish occur either solitarily or in small groups and exhibit different depth preferences. Jacks and emperors inhabit shallower water (<120 m), while deep-water jobfish and snappers (*Pristipomoides* spp.) and some groupers and cods (Serranidae) inhabit deeper waters, around 120 to 240 m, while red snappers (*Etelis* spp.) and several groupers (*Epinephelus* spp.) inhabit even deeper waters (NFA, 2007a).

Deep-water or deep-slope fish are caught with bottom longlines or droplines. Discussions with local Labu villagers identified that dropline fishing using baited hooks targeted demersal fish species in water depths usually between 50 and 100 m, but generally not deeper than 100 m (Coffey, 2018b). Curved hooks baited mainly with locally caught mackerel tuna (*Euthynnus affinis*) are used by Labu fishers in deeper offshore water areas.

A deep-slope fish characterisation study of the inner Huon Gulf was carried out by staff from Marscco, Coffey and WGJV comprising dedicated fishing surveys in waters greater than 100 m deep in November 2016 and May 2017 (Coffey, 2018b). Four species of sharks from the families Centrophoridae and Squalidae, and one species of bony fish each from the families Lutjanidae, Sciaenidae and Muraenesocidae, were captured during the two surveys. The centrophorids comprised 25 dwarf gulper sharks (*Centrophorus atromarginatus*; Plate 3.9), five long-finned gulper sharks (*C. lusitanicus*) and one gulper shark (*C. granulosus*; Plate 3.10), while squalids comprised five individuals of a single fatspine spurdog species (*Squalus crassispinus*). Bony fishes included one individual of each saddletail snapper (*Lutjanus malabaricus*), black-spotted croaker (*Protonibea diacanthus*; Plate 3.11) and common conger pike eel (*Muraenesox baggio*).

Photo credit: Coffey (2018b).

Plate 3.9: A dwarf gulper shark (*Centrophorus atromarginatus*) from the inner Huon Gulf

Photo credit: Coffey (2018b).

Plate 3.10: Gulper shark (*Centrophorus granulosus*) from the inner Huon Gulf

Photo credit: Coffey (2018b).

Plate 3.11: Blackspotted croaker (*Protonibea diacanthus*) from the inner Huon Gulf

Table 3.4 shows catch per unit effort (CPUE) for deep-slope fish catches in PNG for West New Britain (Fusimalohi & Crossland, 1980) and the Huon Gulf north coast (Coffey, 2018b) and a number of Pacific Ocean island nations for comparison.

During the November 2016 deep-slope fish survey (Coffey, 2018b) and despite the capture of a large 30 kg pregnant dwarf gulper shark, the catch-per-unit-effort (converted to weight of fish (kg) per line hour (kg/line-hour)) in the Outfall Area was low at 1.3 kg/line-hour compared to the CPUEs (same kg/line-hour units) for deep-slope fish catches within PNG and other Pacific Ocean countries. If the large, pregnant dwarf gulper shark (as an outlier) is removed from the November 2016 data set, the CPUE is reduced to 0.93 kg/line-hour. During the smaller second survey in May 2017, the CPUE was 0.57 kg/line-hour.

Table 3.4: Demersal deep-slope fish catch-per-unit-effort (CPUE) in Pacific countries

Country	Location	Kg/line-hour	Reference
Federated States of Micronesia	Kosrae Island	9.6	Mead and Crossland (1979)
Fiji	Viti Levu	9.3	Mead (1980)

Country	Location	Kg/line-hour	Reference
New Caledonia	New Caledonia	7.6	Fusimalohi and Grandperrin (1979)
Niue	Niue	7.0	Mead (1980)
Federated States of Micronesia	Yap Island	6.9	Mead and Crossland (1980)
Kingdom of Tonga	Tonga	5.7	Mead (1979)
Papua New Guinea	W. New Britain	4.9	Fusimalohi and Crossland (1980)
American Samoa	American Samoa	4.4	Mead (1978)
Kingdom of Tonga	Tonga	3.6	Mead (1978)
Republic of Vanuatu	Tanna Island	3.1	Fusimalohi (1979)
Niue	Niue	2.8	Fusimalohi (1978)
Papua New Guinea	Inner Huon Gulf	1.3	Coffey (2018b)

Notes: *Results based on November 2016 survey deep-slope fish CPUE data from transects A to E near the Outfall Area, which is a deep-slope area more comparable to the other studies.

The data in Table 3.4 is presented graphically in Figure 3.6, which clearly shows that the deep-slope fish CPUE from the Outfall Area in the Huon Gulf north coast is the lowest amongst the 11 other Pacific island sites for which comparable CPUE data are available.

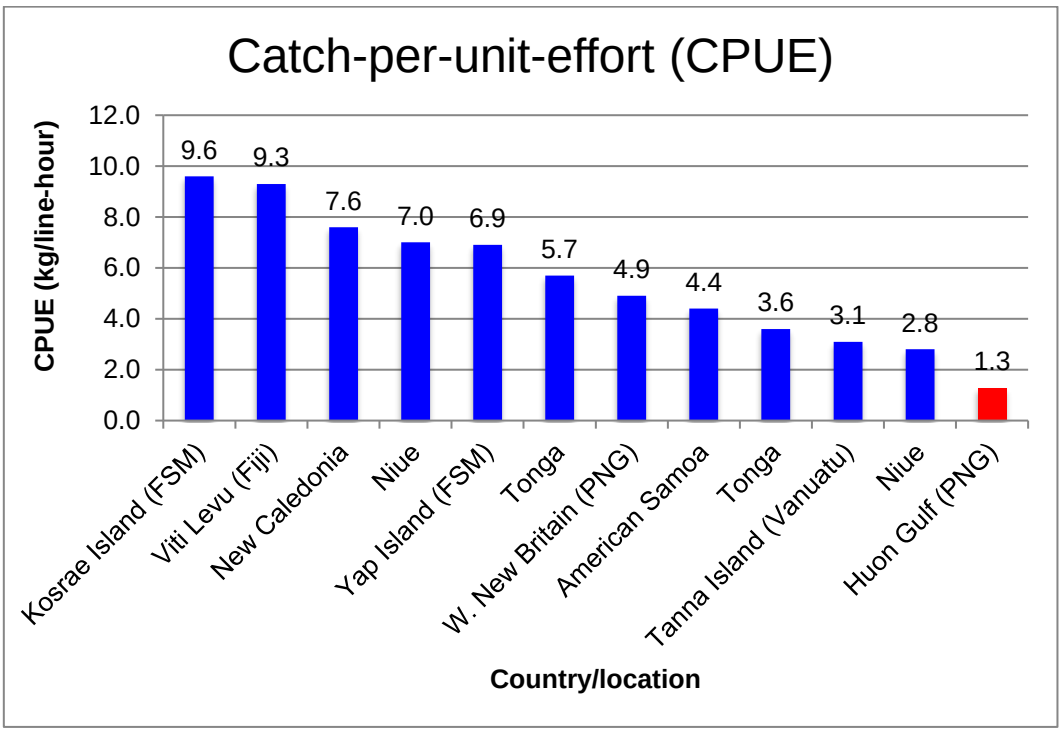


Figure 3.6: Comparison of demersal deep-slope fish catches in Pacific countries

The low CPUE of 1.3 kg/line-hour for the Huon Gulf north coast (transects A to E in Coffey, 2018b) probably reflects the existence of a very narrow continental shelf, lack of biologically productive coral reefs, high turbidity of the water column and a preponderance of soft bottom sediments of the continental slope derived from terrigenous bed sediments and settled suspended sediments from riverine inflows (e.g., Markham, Bumbu and Buso rivers). In contrast, most of the deep-slope fishery assessments in other parts of PNG and other Pacific countries were carried out on the continental slopes below coral barrier and fringing reefs on broad continental shelves. The continental slopes in the other parts of PNG and other Pacific countries were also more structurally diverse; that is, having more well-defined, incised canyons with rocky wall habitats, which are absent in the inner Huon Gulf.

Coffey (2018b) compared the deep-slope fish CPUE results of both the November 2016 and May 2017 surveys with those obtained from other DSTP-associated studies in PNG. Deep-slope fish CPUE across all depth strata over the DSTP and reference study areas averaged 0.09 kg/hook-hour and 0.11 kg/hook-hour for the November 2016 and May 2017 surveys, respectively. Both these deep-slope fish CPUEs in the inner Huon Gulf were considerably lower than the average of 0.50 kg/hook-hour recorded at Wamunon Bay on the north coast of Woodlark Island (Coffey, 2012) and lower than the 0.19 kg/hook-hour recorded at Niolam Island in the Lihir Group of islands (NSR, 1996).

There is currently no deep-slope commercial fishery in the Huon Gulf. There is limited subsistence or artisanal fishing for deep-slope fish by local villagers along both the north and south coasts of the Huon Gulf. Villagers from Labu Butu and Labu Tale, interviewed during Coffey's nearshore marine characterisation study (Coffey, 2018a), indicated that they caught 'deep-slope fish' (a specific term used in the Coffey's catch landing questionnaires). However, they are more likely to have caught bottom 'deep-water fish', as the areas that were fished and marked on interviewer maps were mostly located on the broad but shallow (100 to 200 m depth) continental shelf between the Markham River and Salamaua Peninsula. In addition, villagers from Labu Tale fish along the coral reefs of the Salamaua Peninsula that includes deeper water areas of the reefs where there is a steep drop off to deep water.

3.2.2 Bêche-de-mer fishery

Bêche-de-mer is the trade name of the dried product obtained from sea cucumbers that are harvested by subsistence and artisanal fishers in PNG. In an attempt to replenish stocks, the bêche-de-mer fishery in PNG was non-operational between September 2009 and December 2016, as it was under a national sea cucumber harvesting moratorium due to overexploitation. The harvesting moratorium ended on 1 January 2017 by the Fisheries and Marine Resources Minister (Barclay et al., 2017; Hakalits, 2017).

The NFA prepared a revised National Bêche-de-mer Fishery Management Plan, which was gazetted in September 2016 in advance of the 1 January 2017 re-opening of the sea cucumber fishery. The management plan includes a designated closed season from October to March every year that coincides with the peak spawning period for tropical sea cucumbers. In addition, the management plan strengthens the total allowable catch of sea cucumbers, such that each PNG province participating in the bêche-de-mer fishery will have an allocated total allowable catch set at a level appropriate for each province, which will require ongoing stock assessments. When provincial total allowable catches have been reached, bêche-de-mer fishing will be required to cease in that province (Barclay et al., 2016).

In the past, the bêche-de-mer fishery in Morobe Province was managed under the 2002 National Bêche-de-Mer Fishery Management Plan. The plan allocated a total allowable catch of 30 t comprising 10 t of high-value species and 20 t of low-value species to Morobe Province. Table 3.5 presents the annual landings of sea cucumber species at Lae during the annual season of 2005–2006, prior to the PNG-wide bêche-de-mer fishery moratorium in September 2009. Most of the historical catch of bêche-de-mer in Morobe Province was from the Huon Gulf south coast between

Salamaua Peninsula and the southern border with Northern Province at the mouth of the Gira River, where there was a preponderance of suitable habitat, such as sandy embayments, coral reef flats, inter-reefal sandy areas and patches of seagrass. There is a general lack of bêche-de-mer habitat within the inner Huon Gulf areas near the Coastal Area and coastline between the Markham River and Busama (refer Figure 1.1).

Table 3.5: Historical annual landings of bêche-de-mer at Lae (2005–2006 season)

Family	Latin name	Common name	Count (N)	%	Grade
Holothuriidae	*Actinopyga mauritiana*	Surf redfish	1,580	12.8	High
Stichopodidae	*Stichopus hermanni*	Curryfish	1,538	12.4	High
Holothuriidae	*Holothuria atra*	Lollyfish	1,240	10.0	High
Holothuriidae	*Bohadschia argus*	Tigerfish/Leopardfish	1,207	9.7	High
Holothuriidae	*Actinopyga lecanora*	Stonefish	1,084	8.7	High
Stichopodidae	*Thelenota ananas*	Prickly redfish	954	7.7	High
Holothuriidae	*Holothuria coluber*	Snakefish	894	7.2	Low
Holothuriidae	*Holothuria fuscogilva*	White teatfish	819	6.6	High
Holothuriidae	*Bohadschia similis*	Brown-spotted sandfish	665	5.4	Low
Holothuriidae	*Pearsonothuria graeffei*	Flowerfish	524	4.2	Low
Stichopodidae	*Thelenota anax*	Amberfish	470	3.8	Low
Holothuriidae	*Holothuria nobilis*	Black testfish	378	3.0u	High
Stichopodidae	*Stichopus chloronotus*	Greenfish	302	2.4	High
Holothuriidae	*Actinopyga miliaris*	Big blackfish	288	2.3	High
Holothuriidae	*Holothuria fuscopunctata*	Elephant trunkfish	147	1.2	Low
Stichopodidae	*Stichopus horrens*	Dragonfish	108	0.8	Low
Holothuriidae	*Holothuria edulis*	Pinkfish	68	0.5	Low
Holothuriidae	*Holothuria scabra*	Sandfish	46	0.4u	High
Holothuriidae	*Bohadschia vitiensis*	Brown sandfish	42	0.3v	High
		Totals	12,354	100.0	–

Source: NFA (2016a).

Bêche-de-mer collection and production is a straightforward process and is therefore attractive for rural coastal communities of the Huon Gulf. If managed properly, bêche-de-mer can provide a sustainable source of income for local coastal communities. However, sea cucumber harvesting is susceptible to over-exploitation because they are large, easily seen and collected, and do not require sophisticated fishing equipment or processing. Therefore, close management of this fishery and a provincial quota system are being considered by the NFA based on the analysis by Barclay et al., (2016) to ensure that the fishery remains sustainable.

3.2.3 Trochus and other shell fisheries

Shells such as trochus shell (*Trochus niloticus*), goldlip pearl oyster (*Pinctada maxima*), black lip pearl oyster (*P. margaritifera*) and green snail (*Turbo marmoratus*) have regularly been harvested in PNG.

Trochus are fished largely for their shell and exported for fashion jewellery, accessories and mother-of-pearl buttons and, to a much lesser extent, the flesh is a subsistence food resource. In general, about 60 per cent of the global trochus harvest comes from the Pacific Islands, with Japan and Asia replacing Europe as the market destinations for many Pacific goods (Yaman, 2009).

Freshly harvested trochus are dried in the sun; however, some trochus meat is consumed by fishers' families and other members of a village community (Teh et al., 2014).

There are also six species of giant clams that are harvested in PNG:

- Giant clam (Tridacna gigas).
- Fluted giant clam (T. squamosa).
- Maxima clam (T. maxima).
- Southern giant clam (T. derasa).
- Boring clam (T. crocea).
- Bear paw clam (Hippopus hippopus).

There is a paucity of information on subsistence consumption of giant clams in PNG (Yaman, 2009). In 1988, the purchase and export of wild giant clams was banned by the (then) Department of Environment and Conservation (DEC) (now the PNG Conservation and Environment Protection Authority, CEPA). This ban was lifted in 1995 on the understanding that a management plan for the sustainable harvest of giant clams was in place. The giant clam fishery was again closed in 2000 due to irregularities with CITES[3] export permits. The ban remains in place (NFA, pers. com., 2016a).

There is limited information on giant clam stocks in PNG, except for Milne Bay Province where the dominant species is the boring clam that had densities of 14.86/ha, which was followed by maxima clam densities of 1.79/ha and then fluted giant clams with densities of 1.37/ha. All other clams had densities of less than 1/ha. Trochus and giant clams are found where there is coral reef and particularly in the case of giant clams, where water clarity sufficient to support symbiotic algae living within the clams' mantle tissues (as is the case for reef building corals themselves). As discussed above, such reef habitat is absent from the inner Huon Gulf. The stocks of clams in fringing and patch reefs, as well as the inter-reefal areas along the Huon Gulf south coast are not known, as there have been no recent appraisals. However, the coastal area between Salamaua Peninsula and the Gira River mouth (refer Figure 1.1 and Figure 3.1) has the greatest expanse of coral reefs and inter-reefal habitats where giant clams are typically found.

[3] The Convention on International Trade in Endangered Species of Wild Fauna and Flora, 1975.

3.2.4 Shark fin fishery

Shark finning is banned in PNG EEZ waters (NFA, pers. com., 2016b). Shark finning refers to the removal of fins from sharks, often while the shark is alive. There is no shark fin fishery operating in the Huon Gulf and, as shark finning is banned, there is unlikely to be a black market trade in shark fins.

3.2.5 Edible shellfish

In the inner Huon Gulf, edible shellfish include estuarine and mangrove crustaceans (e.g., mud crabs, mud lobsters, prawns and shrimps) and mangrove molluscs (e.g., mud clams and gastropod snails). Women in the Labu Lakes area collect prawns using handheld nets. The catch is used either for home consumption with surplus catch for sale at the Lae fish markets.

The shells of selected species of mangrove mollusc are ground to form a calcium carbonate (lime) powder that is used as a preferred accompaniment to the chewing of betel nut. Mangrove mud crabs and burrowing mud lobsters from the Labu Lakes are occasionally sold at the Lae fish markets.

Marine crabs, lobsters and molluscs are mainly harvested from or caught on the coral reefs along the south coast of the Huon Gulf from Salamaua Peninsula to the southern border of Morobe Province with Northern Province. These coral reef shellfish are mainly for local consumption; however, lobsters are occasionally on sale at the Lae fish markets.

3.3 Non-fishing marine resource use

3.3.1 Sea turtle hunting and egg collecting

The hunting of sea turtles for food and the collection of their eggs are ongoing subsistence activities in PNG's maritime provinces. Table 3.6 lists the marine turtle species known to be present in the Huon Gulf.

Table 3.6: List of sea turtles species known or expected to be present in the Huon Gulf

Common name	Species name	IUCN Red List category
Olive ridley	*Lepidochelys olivacea*	Vulnerable
Loggerhead*	*Caretta caretta*	Critically Endangered
Hawksbill	*Eretmochelys imbricata*	Critically Endangered
Green	*Chelonia mydas*	Endangered
Leatherback**	*Dermochelys coriacea*	Critically Endangered

* denotes South Pacific subpopulation; ** denotes West Pacific leatherback subpopulation.

Two of the world's seven sea turtle species are unlikely to be present in the Huon Gulf. These are the flatback turtle (*Natator depressus*) that is present in northern Australia and the Gulf of Papua, and the Kemp's ridley (*Lepidochelys kempii*) that is generally distributed in the Atlantic Ocean.

The green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricata*) and West Pacific leatherback turtle (*Dermochelys coriacea*) are commonly found within the Huon Gulf and mainly along the south coast. The green turtle is listed as Endangered on the IUCN Red List, while both the hawksbill turtle and West Pacific leatherback turtle are listed as Critically Endangered (IUCN, 2017).

The following sections characterises sea turtle hunting and egg collection along the Huon Gulf north and south coasts.

Huon Gulf north coast

There are few sea turtle species that nest along the beaches of the Huon Gulf north coast. However, according to some Wagang villagers who were interviewed by Coffey in 2016 and 2017 (Coffey, 2018a), three leatherback turtles (or fewer) were claimed to be caught between Wagang and the Busu River each year between November and February, with approximately 150 to 200 eggs harvested per nest when found. The turtles are also slaughtered for their meat. The interviewed villagers from Wagang (Philip, pers. com., 2016) also noted the presence of turtles resembling hawksbill and green turtles along the coast near Wagang, occasionally being visible in the water when surfacing for air. No turtle nests were observed around the proposed Outfall Area near Wagang at the time of the surveys during November 2016 and February 2017 (which is during the nesting period for these turtles) or during follow-up interviews at Wagang in May 2017 (Coffey, 2018a). The Wagang villagers also indicated that turtle nesting in the area between Wagang and Busu River is much less common than it was many years ago (i.e., in the 1970s).

Huon Gulf south coast

The West Pacific leatherback turtle (*Dermochelys coriacea*), which is listed as Critically Endangered on the IUCN Red List, is known to nest on more than 120 km of beaches along the Huon Gulf south coast. Egg harvesting is still widely practiced and is perpetuated partly because beaches along the Huon Coast south coast are used as pathways for local village people that go to and from their gardens or to visit neighbouring villages or hamlets, and because local fishers use the beaches at night to catch fish. However, in the last few years (2013-2015) land users and families have spread along the coast, which has led to some civil unrest between villages and among clans resulting in different groups claiming coastal lands and adjoining beaches. For example, at the south end of the Labu Tale beach, civil unrest between Labu Tale and Busama prevents people from walking the beaches freely between the two main villages (MRF, 2015, 2015a). The civil unrest has led to a major reduction in leatherback turtle conservation activities and the general population increase has led to an increase in turtle egg collection, which poses a threat to the West Pacific leatherback turtle population of the Huon Gulf.

In general, turtle eggs are either consumed immediately or shared within a village; though some may be sold at market to generate income. It appears the consumption of leatherback turtles was not widely practiced because their oily flesh was considered unpalatable (Quinn et al. 1985), although direct harvest continues to occur. However, at Paiawa during the decade from 1996 to 2006, hunters regularly killed and smoked leatherback turtle meat to trade with mountain peoples for pig meat (Kinch 2006a). A literature search did not reveal current levels of leatherback turtle hunting along the Huon Gulf south coast.

Since sea turtles have high economic and prestige value, it is understandably difficult for local people to perceive the spatial and temporal scale of stock-replacement processes in such a highly mobile, slow-growing and long-lived species (Benson et al., 2012), and consequently the impacts that unrestrained harvesting can have on population viability over the long term. During the period 2003 to 2013, a succession of turtle conservation activities has educated coastal villagers to the importance of protecting leatherback turtles nesting on beaches on their lands.

Leatherback turtles during the decade from 1996 to 2006 were killed at Kobo, Ewa (south of Kobo), Sapa, Maiama, Salus, Paiawa and Busama (Kinch, 2006a). It is likely that this practice is ongoing but perhaps to a lesser degree given the activities of leatherback turtle conservation groups and the coastal communities' recognition of the importance of protection of turtle nests, improved education and receipt of funds from turtle research and conservation groups. However, funding of turtle

conservation projects along the Huon Gulf south coast has ceased in recent years (Coffey, 2018a; MRF, 2015 and 2015a). Since the cessation of conservation program funding, locals stated that they no longer protect turtles and instead consume leatherback turtle eggs and the meat from green sea turtle (*Chelonia mydas*, IUCN Red Listed as Endangered). It appears that with the apparent reduction or cessation of conservation funding, a major threat to turtles nesting in the Huon Gulf south coastal area is the depredation of nests for local consumption of eggs, and the periodic consumption of meat from adult nesting females.

Additional information on sea turtle ecology and conservation is given in Section 3.3.5.3.

3.3.2 Saltwater crocodile hunting

Saltwater crocodiles (*Crocodylus porosus*) are found in all rivers of the Huon Gulf coast (WorleyParsons, 2016). Saltwater crocodiles take a wide variety of prey, although juveniles are restricted to smaller items such as insects, amphibians, crustaceans, small reptiles and fish. Prey items include crustaceans (e.g., mud crabs) and vertebrates (e.g., turtles, snakes, shore and wading birds).

Along the Huon Gulf north coast, crocodiles in the wild are generally absent in the urban coastline of Lae or between Wagang and Busu River (i.e., location of the proposed Outfall Area). However, a crocodile was caught at Lae Yacht Club in June 2017 (Wissink, pers. com., 2017). There is a commercial crocodile farm near ‘9 mile’ suburb in Lae.

Small numbers of crocodiles are occasionally caught by villagers in rivers along the Huon Gulf south coast rivers between the Salamaua Peninsula and the mouth of the Gira River (refer Figure 1.1). The skins of killed crocodiles are sold occasionally to traders based in Lae.

3.3.3 Recreation

The main recreational activities in the Huon Gulf include game fishing, diving and snorkelling on coral reefs and shipwrecks and, bathing and swimming. The recreational activities are characterised below.

3.3.3.1 Marine recreational fishing

Marine recreational fishing is a leisure activity that takes place mainly in larger urban areas of PNG, and participants are mostly resident expatriates or visiting tourists (FAO, 2017). There is no formal management of marine recreational fishing in PNG.

In the Huon Gulf, the Lae Game Fishing Club is the foremost marine recreational fishing club. Plate 3.12 shows the Lae Game Fishing Club marina. Lae Game Fishing Club members and their guests target wahoo, black and blue marlins, sailfish, dolphinfish, trevallies, Spanish mackerel and tuna, and sport fishing competitions are held regularly (LGFC, 2017). Plate 3.13 shows an example of a blue marlin caught during a fishing trip. While the Lae Game Fishing Club encourages ‘catch and release’ fishing, it is up to a club member’s discretion and the rule does not appear to be strictly enforced. A key Lae Game Fishing Club recreational fishing area is the Tami Islands (refer Figure 1.1) where shoals and seamounts attract tuna, billfish and game fish. The small islands and cays of the Tami Islands group also allows club vessels to moor and allow club members to rest or picnic in the area between fishing trips.

Photo credit: M. Stiliyanov, Lae Game Fishing Club (LGFC, 2017).

Plate 3.12: Aerial view of Lae Yacht Club, home to the Lae Game Fishing Club

In Plate 3.13, while the blue marlin was photographed at the side of the fishing boat, blue marlins are not taken but are tagged by Lae Game Fishing Club staff. Other targeted fishing areas include Lababia, Halfway Reef, and the Benalla Banks (LGFC, pers. com., 2016); however, the frequently turbid waters along the coast of the inner Huon Gulf near the fishing club and Wagang village are not a targeted fishing area. The Benalla Banks are located 6.5 km northwest of Salamaua Peninsula and are also fished by villagers from Labu to Salamaua. Dogtooth tuna and blue marlin are regularly caught at the Tami Islands, whereas wahoo, marlin, Spanish mackerel and yellowfin tuna are regularly caught at the Benalla Banks northeast of Salamaua Peninsula. Following the most recent El Niño event, billfish are reported to be increasing in numbers as water temperatures have lowered by 2 to 3 degrees Celsius (LGFC, 2016, pers. com.).

Source: Lae Game Fishing Club (LGFC, 2017).

Plate 3.13: Example of blue marlin caught by Lae Game Fishing Club

In general, a typical recreational catch rate in PNG is between 8 and 20 kg/person/per trip, or an annual recreational catch rate of 200 kg/person/trip based on two recreational trips/month over a 10-month period (Teh et al., 2014).

3.3.3.2 Recreational diving and snorkelling

Recreational diving and snorkelling takes place at coral reefs and over shipwrecks in the Huon Gulf and further afield in the Solomon Sea.

Coral reef diving and snorkelling

The main areas for recreational coral reef diving and snorkelling is the clear-water and diverse coral reefs at the Tami Islands, which are located about 95 km from Lae and 12 km offshore of the Huon Gulf north coast. Other coral reef diving and snorkelling sites are located on the Huon Gulf south coast at the Salamaua Peninsula, Kamiali Wildlife Management Area and the numerous islands off the coast of Morobe LLG (e.g., Lasanga Island and the Fly Islands).

Shipwreck diving

A number of marine recreational diving clubs exist to cater for tourists to dive at various shipwreck sites located in the Huon Gulf and nearby waters of Milne Bay Province. There are five shipwreck sites within the Huon Gulf comprising Imperial Japanese Navy (IJN) ships that were sunk by the Allies during World War II in the Huon Gulf. These sites include:

- IJN *Tenyo Maru*: a 6,952 t cargo ship located 100 m offshore of DCA Point near Lae (a shallow-dive wreck).
- IJN *Kongo Maru*: an 8,738 t merchant cruiser wreck located off Labu Tale (a shallow-dive wreck).
- IJN *Myoko Maru*: a 4,165 t cargo ship wreck located off Wagang (about 1.5 km to the west) (mostly disintegrated and not used as a diving site).
- IJN *Yokohama Maru*: a 6,241 t passenger and cargo ship wreck located at Salamaua sitting upright in 74 m of water off Salamaua Peninsula about 32 km south-southeast of Lae. This is a deep-dive wreck for experienced divers only.
- IJN *Kotoku Maru*: a 4,000 t troop ship wreck located 500 m from the IJN *Yokohama Maru* wreck at Salamaua Peninsula about 32 km south-southeast of Lae.

These shipwrecks are characterised further in Section 3.3.7 (Maritime Archaeology).

3.3.4 Bathing and swimming

Recreational bathing and swimming by Lae townspeople, Wagang villagers and visitors from elsewhere in Morobe Province takes place regularly in the shoreline waters of the Huon Gulf north shore, including Wagang beach and Voco Point (Coffey, 2018a). Plate 3.14 shows weekend bathers and swimmers at Wagang beach, which is the closest beach to Lae. The Wagang beach area accumulates a large number of logs that are delivered by the Markham River and other coastal rivers draining the Huon Peninsula.

In Plate 3 16 logs have been placed in piles on the beach by Wagang villagers, which will be used for fuel and which may be considered as another marine resource use even though derived from inland rivers.

Photo credit: Coffey (2018a).

Plate 3.14: Lae people undertaking weekend swimming at Wagang beach, Lae

3.3.5 Protected areas and conservation programs

There are a number of sensitive onshore, coastal and marine areas that are either of conservation significance or are of direct importance to local communities that exploit both terrestrial and aquatic (estuarine and marine) biological resources for subsistence purposes. These are summarised below.

3.3.5.1 Official conservation and protected areas

There are two established conservation or protected areas in Morobe Province that have an integral marine component. These are:

- Kamiali Wildlife Management Area – which is located in the Huon Gulf south coast about 65 km southeast of the Coastal Area.
- Yopno, Uruwa and Som (YUS) Conservation Area – which is located about 270 km by sea from the Coastal Area and therefore outside the Project's area of influence.

The characteristics of these conservation or protected areas are summarised below.

Kamiali Wildlife Management Area

The Kamiali Wildlife Management Area was set up and managed by Kamiali residents in 1996 (Longenecker et al., 2015). The Wildlife Management Area is located in Salamaua Rural LLG about 75 km southeast of Lae and the Coastal Area.

The Kamiali Wildlife Management Area comprises 32,000 ha on land and 15,000 ha of adjacent sea. The villagers hold traditional tenure over the natural resources of both the land and the sea out to 3 nm (about 5.5 km).

In the interest of conserving their natural resources, and thus preserving their traditional lifestyle, Kamiali leaders in 2006 signed a Memorandum of Understanding (MoU) with the Bishop Museum of Hawaii outlining the development of a world-class remote scientific research station at Lababia in the Kamiali Wildlife Management Area. Visiting researchers pay fees for research permits, field

assistance, lodging and meals, which provide incomes for funding educational costs and community-based development projects.

In an effort to balance conservation and exploitation, Kamiali residents crafted and enacted a reef-fish management plan in 2014 (Longenecker et al., 2014). The goal of this management plan was to promote sustainable fishing; that is, the harvesting of fish in a manner that does not result in their long-term decline and allowing future generations to continue sustainable fishing practices. The management plan also recognised one of the Kamiali villagers' traditional fishing method that uses crushed derris root to catch fish by chemical stunning. Derris root is used by villagers along the southern coast of the Huon Gulf mainly to ensure large fish catches for festive occasions; however, the practice is considered illegal by the NFA (NFA, pers. com., 2106a, 2016b).

Dugongs (*Dugong dugon*) are occasionally reported in the Kamiali Wildlife Management Area, especially within the limited areas where seagrasses grow. According to locals interviewed during the nearshore marine characterisation study (Coffey, 2018a), dugongs have been caught in the past near Lababia. The distribution of dugong to the north of the Kamiali Wildlife Management Area is not known but likely to be sparse owing to the increasing reduction or absence of seagrasses towards the Markham River, where the high suspended sediment plumes and higher rates of sedimentation are not conducive to seagrass establishment or growth. However, interviews with villagers from Labu Tale village during the Coffey nearshore marine characterisation study (Coffey, 2018a) reported that a dugong was caught by a fisherman off the mouth of the Buang River (also known as *Maus Buang*) south of Labu Tale in 1988.

The Kamiali Wildlife Management Area includes important nesting beaches for the leatherback turtle (*Dermochelys coriacea*) within the Huon Gulf south coast. The leatherback turtle conservation program is addressed separately below in Section 3.3.5.3.

YUS Conservation Area

The YUS Conservation Area is located on the northern side of Huon Peninsula. It was established in 2009 as PNG's first conservation area, and named after the Yopno, Uruwa and Som rivers that flow through the conservation area.

The shoreline and adjacent fringing coral reef and patch reefs within the 46 ha marine component of the YUS Conservation Area are located about 270 km by sea from the Coastal Area and, therefore, are outside the Project's area of influence.

3.3.5.2 Unofficial conservation or protected areas

At least three conservation or protected areas have been unofficially nominated for classification by various groups (e.g., Non-Government Organisations and the IUCN) as a conservation area. These are the Labu Tale turtle reserve and the Salamaua Peninsula Marine Park.

Labu Tale turtle reserve

An area called the 'Labu Tale Turtle Reserve' is based on nesting female leatherback turtles (*Dermochelys coriacea*) along a stretch of sandy shoreline in the vicinity of Labu Tale (refer Figure 1.1). However, this reserve is not officially recognised or a declared Conservation Park, Wildlife Management Area or protected by any specific PNG legislation.

Leatherback turtle information and data for this area is given in more detail in Section 3.3.5.3 below.

Salamaua Peninsula marine park

This is a long standing proposal by the International Union for Conservation of Nature (IUCN, 1991) for the establishment of a marine park at the Salamaua Peninsula, about 37 km south of Lae. However, little information, data, reasons or specific marine ecological features or values was given for its inclusion.

Kamiali Wildlife Management Area turtle reserve

The Kamiali Wildlife Management Area turtle reserve is located on an 11-km-long sandy beach on the northern side of Nassau Bay between the Bitoi River (south arm) and Tabali Creek. The collection of turtle eggs or killing of turtles is not permitted in the Wildlife Management Area.

3.3.5.3 Leatherback turtle conservation in the Huon Gulf

The largest PNG nesting population of the West Pacific leatherback (*Dermochelys coriacea*), which is listed as Critically Endangered on the IUCN Red List (Tiwari et al, 2013), occurs primarily along the south coast of the Huon Gulf. This comprises a metapopulation of a single genetic stock distinct from the East Pacific leatherback population, and the almost extinct Malaysian population (Gaspar et al., 2012).

The leatherback turtle is known to nest on more than 120 km of beaches along the Huon Gulf south coast (WorleyParsons, 2016). Nesting activity occurs during the dry season from November to March, with peak nesting occurring between December and January when the sea is relatively calm and soft sand covers most beaches. No nesting activity occurs during the wet season. Leatherback turtle females may nest several times during a season. Female leatherbacks usually produce three to 10 clutches of 60 to 90 eggs in a reproductive season, with eggs hatching in about 60 to 70 days (Sato, 2016). Between nesting (inter-nesting) events, the females generally remain close to the nesting beaches. After nesting, the turtles migrate over deep waters in a southeastern direction to high latitude waters of the South Pacific Ocean (Benson et al, 2007; Sato, 2016).

The West Pacific leatherback turtle has received international attention including efforts by international conservation organisations involving village communities along the Huon Gulf south coast.

Historical leatherback turtle conservation activities (2003-2012)

The Huon Coast Leatherback Turtle Conservation Project began at the Kamiali Wildlife Management Area in November 2003 and by late 2005 expanded to incorporate three additional communities of Labu Tale, Busama and Paiawa, which were identified via aerial surveys (Benson et al. 2007). During the 2006/07 nesting season, three additional communities of Sapa, Kobo and Salus were incorporated into the project. The Huon Coast Leatherback Turtle Conservation Project sites are located 20 to 60 km southeast of Lae and the Coastal Area, and in total (as of the 2006/07 nesting season) resulted in approximately 20 km of monitored (or protected) beach.

The Western Pacific Regional Fishery Management Council funded several leatherback turtle recovery projects in the Western Pacific, which included PNG projects that involved research, monitoring and practical field-based conservation initiatives (Pilcher, 2012). A community development incentive scheme operated during the period from 2010 to 2012 by the Marine Research Foundation of Sabah in Malaysia, with funding from the Western Pacific Regional Fishery Management Council (Pilcher, 2012). Partial funding was also obtained from the U.S. Fish and Wildlife Marine Turtle Conservation and the then PNG Department of Environment and Conservation (now the PNG Conservation and Environment Protection Authority, CEPA).

Communities became aware that the community development incentive funding was intended to support legacy community-based projects (e.g., improving fresh water supplies, building or expanding school facilities, and developing or improving church and aid outpost facilities), which served as reminders of the important role of conserving turtles in community life. In addition, the potential cash influx to the community that can be generated through participation in conservation initiatives was far greater than the cash that could be earned through egg trade or barter (MRF, 2015a).

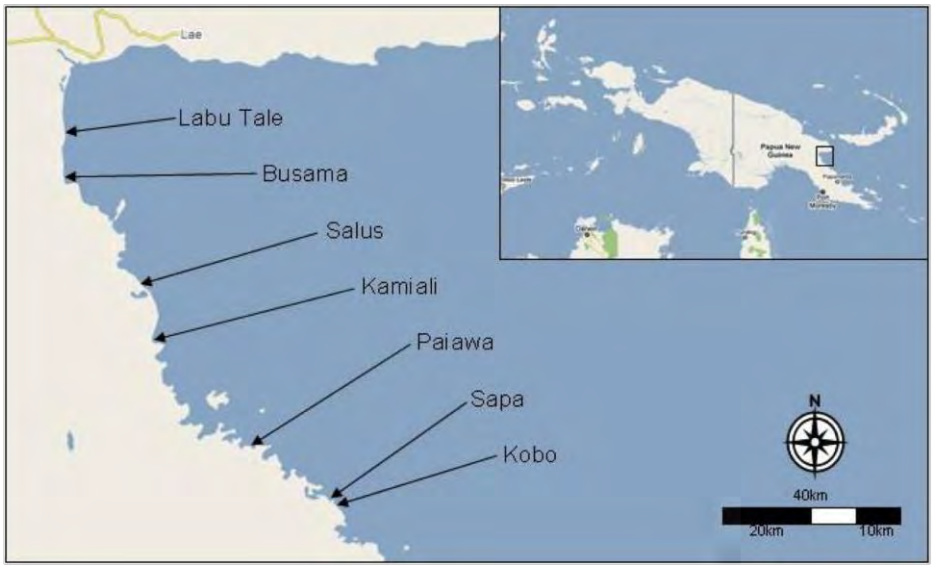
The main objectives of community-based leatherback turtle conservation activities are to:

- Enhance hatchling production by reducing egg harvest and predation.
- Integrate the local community in monitoring and conservation activities.
- Relocate turtle nests that were deposited below the high tide line and believed to be in danger of inundation or erosion.
- Explore future sustainable use and resource management strategies of leatherback turtle eggs to support a viable nesting population while preserving indigenous, traditional practices.

During the period 2003 to 2012, communities in each village agreed to conserve the adult female turtles, their eggs and hatchlings. The Marine Research Foundation developed agreements with each community, which stated clearly the turtle conservation project objectives, remuneration packages and work duties and responsibilities.

Leatherback conservation activities and community-based programs were undertaken at six locations on the Huon Gulf south coast. Figure 3.7 shows the locations of the six leatherback turtle beaches surveyed during the period 2010-2011, which was a productive nesting season (Pilcher, 2012).

At each of the sites, leatherback turtle nests were identified and protected either with a bamboo grid on sandy areas (Plate 3.15) or a cradle device (Plate 3 16) which serve to prevent villager poaching and dog predation. Predation by feral and domestic dogs has been documented and is considered a ‘great threat’ to nests and hatchlings along the Huon Coast (Kisokau, 2005; Pilcher, 2006). A lesser threat is from monitor lizards (*Varanus indicus*) and there is virtually no threat from feral or domesticated pigs (*Sus scrofa papuensis*) as coastal villagers tended not to keep pigs (Kinch, 2006a).



Source: Pilcher (2012)

Figure 3.7: Seven villages involved in community-based leatherback turtle conservation

Table 3.7 presents data on the number of egg clutches and the success of nesting, incubation and emergence of leatherback turtles at six study sites in the 2010-2011 nesting season (Pilcher, 2011). Data were not presented for the Salus site shown in Figure 3.7. During this nesting season, a total of 562 nesting attempts were recorded, of which 35 were false crawls and 527 resulted in nests. Of the 527 nests deposited, seven were lost to erosion (1.3%), five were poached (0.9%) and one (0.2%) was lost when dogs managed to dig through the protective bamboo grids.

In Table 3.7 hatching (or emergence) success varied between the study sites. Of note in Table 3.7 is the lower overall emergence or hatchling success rate at Busama (23%), compared to Kamiali (67%) and Labu Tale (65%). No explanation was given by Pilcher (2011) for the differences in hatching success between the Busama and Labu Tale study sites, given the similarity of the two beaches that are separated only by the Bwussi River. Notwithstanding, the total production of leatherback turtle hatchlings derived from the product of the number of successful nets, clutch size and hatching success was 21,820 hatchlings for the 2010-2011 nesting season (Pilcher, 2011).

The percentage of leatherback turtle nests by study site is shown in Figure 3.8. As in previous seasons (i.e., prior to 2010), the 7-km-long nesting beach at Busama recorded the largest proportion of nesting activity (54%), with Kamiali (16%) and Labu Tale (11%) recording the next highest nesting activities.

Photo credit: Nicholas Pilcher (Pilcher 2012).

Plate 3.15: Marking and protecting a leatherback turtle nest with bamboo grid

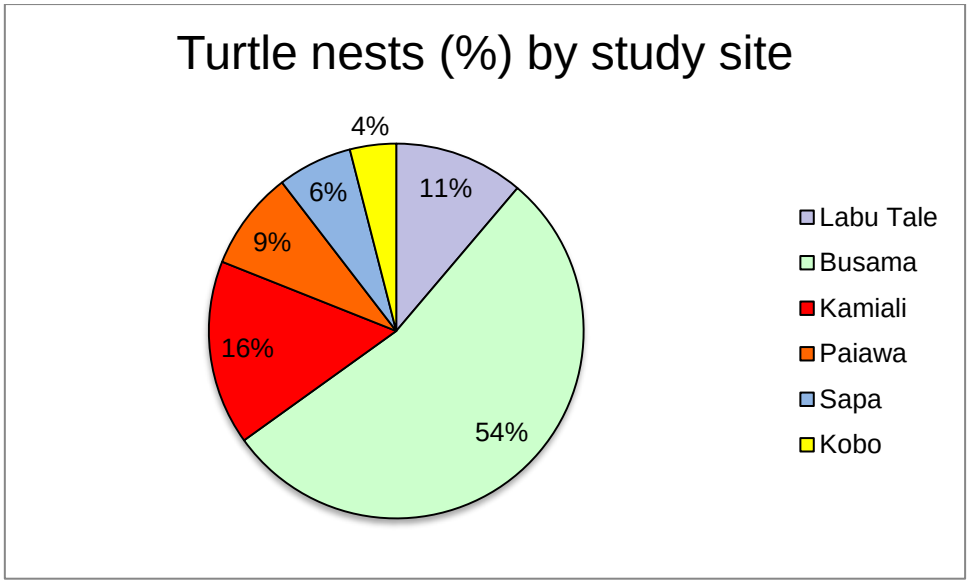
Photo credit: Nicholas Pilcher (Pilcher, 2011).

Plate 3 16: Marking and protecting a leatherback turtle nest with a cradle device

Table 3.7: Leatherback turtles nesting, incubation and emergence success at six sites

Village	Labu Tale	Busama	Kamiali	Paiawa	Sapa	Kobo
Beach length (km)	3.19	6.94	4.48	1.86	7.7	2.16
Census (No. of days)	218	185	180	180	180	180
Clutches laid (No.)	59	284	84	45	34	21
Nesting success (%)	84	81	100	100	92	95
Incubation success (%)	79	26	77	N/A	N/A	N/A
Emergence success (%)	65	23	67	N/A	N/A	N/A

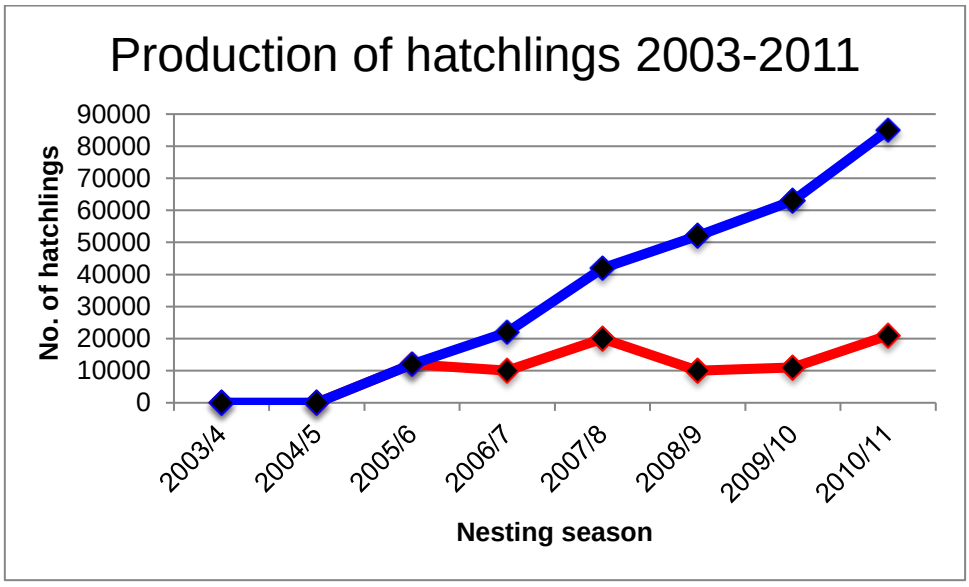
Source: Pilcher (2012).



Source: Pilcher (2011)

Figure 3.8: Percentage of turtle nests by study sites along Huon Gulf south coast

Figure 3.9 shows the production of leatherback turtle hatchlings at the six study sites. Figure 3.9 shows the effectiveness of the Marine Research Foundation operated leatherback turtle conservation program with an estimated more than 80,000 hatchlings being released over the period 2005 to 2011. This contrasts with the two nesting seasons between 2003 and 2005 with zero per cent (0%) hatchling emergence prior to the introduction of bamboo grids and cradle devices for protection from poaching and predation by dogs, as well as community agreements. Given that there were nesting beaches not monitored in the studies by Pilcher (2011 and 2012), such as beaches near Salus, estimates of hatchling numbers are likely to be underestimated.



Source: Adapted from Pilcher (2011); Notes: blue line is cumulative number of hatchlings; red line is annual number of hatchlings.

Figure 3.9: Production of leatherback hatchings at six beach study sites (2003–2011)

Encouragingly, extensive nest protection and the present increased beach area under conservation ensure significant numbers of hatchlings survive the beach phase and promote recruitment to the younger age classes. This and the elimination of mortality of the remaining adults on nesting beaches have the potential to turn around the long-term decline. However, turtle conservation activities along the Huon Gulf south coast have declined in recent years (see below).

Recent leatherback turtle conservation activities (2013 to 2015)

MRF (2015, 2015a) presented an update on turtle conservation projects along the Huon Gulf south coast during the period 2013 to 2015, the key findings of which are summarised below:

- Due to the complication of land use issues on the ground, population spread and inter-clan conflict along the south coast, no land use agreements were struck with any of the villages in 2015.
- In 2013-2014 no nesting activity was reported between Busama and Bwussi; however, nesting activity was noticed between Bwussi and Maus Buang (see Figure 1.1 for village locations). Additional issues were associated with poaching within unmanned portions of the beach, with 50% to 75% of nests assumed to have been poached. No nesting data was provided for 2014-2015.
- At Labu Tale, nesting activity was reported to be 'slow' to begin with. It peaked in December 2013 and ended in January 2014 with a total of 36 nests identified. None successfully produced hatchlings: 18 were poached, 12 lost to tidal erosion and six lost to dog predation.
- At Labu Miti, three leatherback turtle nests were reported from casual observations during 2014 to 2015. All of these nests were lost to erosion or poaching. The beach at Labu Miti experiences large scale erosion and lacks stability in places resulting in many nests become exposed, making predation and poaching of eggs more likely in the area.
- During the 2013-2014 season four nests were observed at Kamiali, with an additional 'few' seen in February 2014. However the local community made the decision to allow all of these nests to be harvested, with money being the primary motive.

Overall, the long-term trend is for numbers of around 20,000 hatchlings annually along the Huon Gulf south coast. This trend would likely have continued up to the present (i.e., 2017), if based on continued implementation by village community members, and thus countering the long-term decline of leatherback turtles nesting in the Huon Gulf. However, the funding for ongoing turtle conservation projects was not guaranteed and, in recent years, funding of turtle conservation projects along the Huon Gulf south coast has ceased (Coffey, 2018a), so the long-term trend of 20,000 hatchlings annually is now unlikely to be sustainable.

Current leatherback turtle conservation activities (2016 to 2017)

In the last two years (2016 to 2017), due to continued pressure from increased population along the Huon Gulf south coast, civil unrest arising from inter-village and inter-clan coastal and adjoining beach claims, the lack of community-based leatherback turtle village agreements with conservation agencies and NGOs, and the almost complete cessation of leatherback turtle conservation program funding (Coffey, 2018a), there is currently a major threat to leatherback turtles nesting on the beaches of the Huon Gulf south coast. To address this threat, direct take of nesting turtles and their eggs, dog depredation of nests, and civil unrest needs to be greatly reduced or eliminated (MRF, 2015, 2015a; NOAA Fisheries, 2016). However, the Kamiali Wildlife Management Area leatherback turtle conservation project (some 75 km southeast of the Coastal Area) continues to be funded by the Bishop Museum in Hawaii (Longenecker et al., 2015), which maintains a turtle conservation research station at Kamiali village.

In addition, new funding for leatherback nesting beach conservation programs is currently being proposed by the National Oceanic and Atmospheric Administration and National Marine Fisheries

Service of the United States in their 2016-2020 priority action plan for West Pacific leatherback turtles, which includes funding to be allocated to PNG (NOAA Fisheries, 2016).

3.3.6 Marine-based eco-tourism

Morobe Province attracts small numbers of tourists annually. In 2006, Morobe Province received 3,557 business visitors (62% of total visitors) and 2,168 holiday visitors (38%). These figures are only for international visitors and do not take into consideration domestic tourists.

There are already a few guesthouses established along the northern and southern coastline of the Huon Gulf. One guesthouse is commercially orientated and located at '12 Mile' outside of Lae, while the others were projects developed by the Village Development Trust. In discussions with Village Development Trust and Morobe Tourism, there are no data on occupancy rates for the guesthouses in the Salamaua and Morobe LLG areas. Most visitations to Village Development Trust-controlled guesthouses are by Village Development Trust staff themselves, or in the case of the Kamiali Guesthouse by NGOs.

3.3.7 Maritime archaeology

The Huon Gulf is an area of interest in terms of World War II maritime archaeology. A number of Imperial Japanese Navy (IJN) warships, minesweepers and cargo vessels were sunk by the Allies in the Huon Gulf, as well as in neighbouring areas in PNG, as were a small number of USS navy ships. In addition, a number of both US and Japanese aircraft were shot down or had engine failure over the Huon Gulf. Table 3.8 lists some of the known shipwrecks in the Huon Gulf, though the locations of some of the ships are not known. The bathymetric surveys for the Project did not identify any shipwrecks in the vicinity of the proposed Outfall Area or proposed tailings deposition areas. The IJN Myoko Maru was identified near Wagang in shallow water above the proposed DSTP outfall depth).

Table 3.8: Known shipwrecks in the Huon Gulf

Vessel	Type	Gross Tonnage (t)	Location	Date Sank
IJN *Tenyo Maru*	Minesweeper	5,689	DCA Point (100 m offshore)	10 March 1942
IJN *Myoko Maru*	Cargo ship	4.165	Wagang (100 m offshore) known as the 'Malahang wreck' where it beached (but it is now buried in sand below the seabed surface and very little of the wreck remains)	8 January 1942
IJN *Kongo Maru*	Merchant cruiser	8,738	9.5 km offshore of Labu Tale at 06°49'S, 147°2'E	10 March 1942
IJN *Kotoku Maru*	Troop ship	4,000	Salamaua broken up 500 m from IJN *Yokohama Maru* wreck (see below)	30 July 1942
IJN *Yokohama Maru*	Troop/cargo ship	6.241	5 km east of Salamaua Peninsula	10 March 1942

Vessel	Type	Gross Tonnage (t)	Location	Date Sank
IJN *No.2 Tama Maru*	Minesweeper	N/A	Salamaua (unknown location), may have been salvaged	N/A

Source: Pacific Wrecks (2017). Note: Original US long tons converted to metric tonnes.

A number of allied aeroplanes were shot down or lost engine power over the Huon Gulf, which included the following:

- C-47A-35-DL Dakota (Serial number (S/N) 42-23851): Engine failure during take-off from Nadzab Airport and ditched in the Huon Gulf 15 km offshore of Lae on 8 December 1943.
- F-6D Mustang (S/N 44-14621): Engine failure during take-off from Nadzab Airport and ditched in the Huon Gulf 180 m offshore of DCA Point on 1 December 1944.
- P51 D-20-NA Mustang (S/N 44-63651): Fighter aircraft shot down over Huon Gulf 25 km after taking off from Nadzab airport in Lae on April 1945.
- B26 Marauder (S/N 40-1467): shot down by Zeros over Huon Gulf about 3 km offshore of Lae (date unknown).
- P-40k-1-CU Warhawk ("Pistoff") (S/N 42-45979): US fighter aircraft with engine failure ditched in the Huon Gulf offshore of Lasanga Island and about 65 km from Lae on 14 July 1943.
- G4M1 Model 11 'Betty' Japanese bomber shot down over Huon Gulf by US ship machine gunfire (location not stated) on 22 September 1942.

A literature review did not reveal the presence of the recorded sites of any aeroplane wrecks in the Huon Gulf and inspection of various recreational Lae and international diving websites did not reveal the presence of any shallow-water aeroplane wrecks. It is likely that most of the aeroplanes shot down were over the deep-water section of the Huon Gulf and, hence, may be expected to be located on the continental slope and/or canyons of the Huon Gulf. Over the seven decades since World War II, these deep-water aeroplane wrecks are most likely to have been covered by terrigenous sediments from the turbid inflows of the Markham River and rivers draining the Huon Peninsula (e.g., Buso and Busu rivers).

3.4 Commercial fisheries

Papua New Guinea has a 200 nautical mile (nm) Exclusive Economic Zone (EEZ), which is also its declared fishing zone that is highly productive in terms of offshore pelagic tuna. The PNG tuna resource is part of the larger migrating tuna resource of the western and central Pacific Ocean, which is shared by other Pacific Island countries and territories, as well as the Pacific coasts of the Philippines and Indonesia (NFA, 2007a, 2007b).

Around 20% of the world's total tuna stock is found in PNG's 2.5 million km^2 EEZ. The fishing industry has grown from a dependency on access fees in the early 1980s to a more diversified sector, with significant downstream tuna processing today.

3.4.1 Regulatory framework

The National Fisheries Authority (NFA) is a non-commercial statutory authority established and operating under the *Fisheries Management Act 1998* and related regulations. The NFA is responsible for regulating the commercial fisheries of PNG.

3.4.1.1 Legislation

The main act in PNG relating to fisheries is the *Fisheries Management Act 1998*.

3.4.1.2 International Conventions

Papua New Guinea is either a signatory to or has ratified a number of international conventions that relate to commercial fisheries. The relevant conventions are summarised below.

Honolulu Convention (2000)

The Honolulu Convention, 2000 is the shortened title of the Convention for the Conservation and Management of Highly Migratory Fish Stocks in the western and central Pacific Ocean. This is the key convention relevant to PNG's purse seine tuna fishery.

The western and central Pacific Ocean provides at least 60 per cent of the world's supply of raw tuna. Since 1994, efforts have been ongoing to develop a comprehensive conservation and management regime in this region. In 1995, the UN Fish Stocks Agreement[4] provided the impetus for changes to international fisheries law and, on 5 September 2000, the Honolulu Convention was concluded and signed. Papua New Guinea signed the Honolulu Convention on 17 January 2001 with its entry into force on 19 June 2004 (WCPFC, 2017).

The preamble of the Honolulu Convention provides: "coastal States and States fishing in the region shall cooperate with a view to ensuring conservation and promoting the objective of optimum utilization of highly migratory fish stocks throughout their range." The Honolulu Convention also increases the economic opportunities for western and central Pacific states to benefit from the tuna resource and clarifies the legal rights over the resource.

3.4.1.3 Commercial Tuna Fishing Industry Codes

Papua New Guinea is a member state of various groups that encourage tuna purse seine fisheries to be established on an economic and sustainable basis. The various agreements, declarations and implementing arrangements are summarised below.

Parties to the Nauru Agreement

The Parties to the Nauru Agreement (PNA) set out key objectives to control terms and conditions of tuna fishing in their waters (PNA, 2010). Papua New Guinea is a member state of the PNA, which also includes the Federated States of Micronesia, Kiribati, Marshall Islands, Nauru, Palau, Solomon Islands and Tuvalu. Figure 3.10 shows the PNA member states as well as all 26 countries that are members of the Western and Central Pacific Fisheries Commission.

The Palau Arrangement

The Palau Arrangement details the role for the PNA through regular management meetings in managing the tuna stocks, as well as establishing the role and responsibilities of the PNA Office. Amended in 2015, the Palau Arrangement sets out rules for the purse seine Vessel Day Scheme, a unique PNA scheme to sell a limited number of fishing days (PNA, 2016). The objective of the Vessel Day Scheme is to maximise the net fee revenues from the tuna fisheries on an economically and ecologically sustainable basis.

[4] Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (United Nations Fish Stocks Agreement or UNFSA).

PNA First Implementing Arrangement

The PNA First Implementing Arrangement (PNA, 2008) began a regional fishing vessel register. This was later followed by development of a Vessel Monitoring System. Under the Vessel Monitoring System, all licensed fishing vessels are required to fit an Automatic Location Communicator that monitors the vessel's position, speed, and course. In this way, fishing vessels are under continuous electronic monitoring.

PNA Second Implementing Arrangement

The PNA Second Implementing Arrangement (PNA, 1990) established Minimum Terms and Conditions for fishing in PNA waters, which is now applicable across the Pacific Islands.

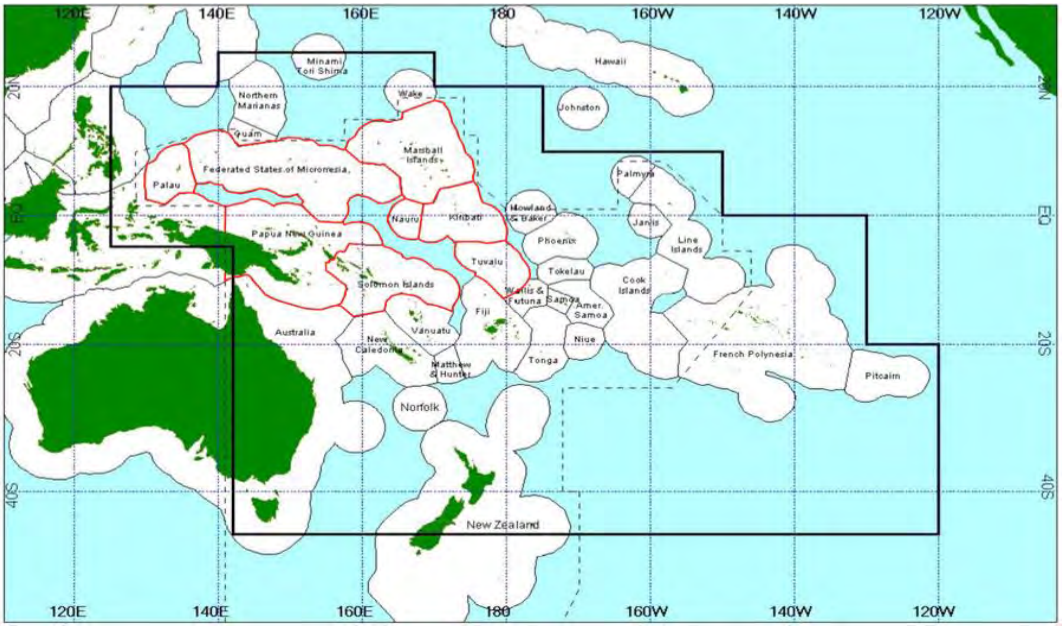
Third PNA Implementing Arrangement

The Third PNA Implementing Arrangement (as Amended in 2010) (PNA, 2010) set out the following further terms and conditions:

- Decreed fishing vessels will no longer be allowed to fish in high seas pockets as a condition of their licenses.
- Banned Fishing Aggregating Devices (FADs, a device used to attract tuna which often results in the capture of juvenile fish) by purse seine fishing vessels for set time periods.
- Introduced catch retention (to stop dumping of lower value tuna overboard from purse seine fishing vessels).

Bikenibeu Declaration

Signed in Tarawa, Kiribati in 2009 (PNA, 2009), the Bikenibeu Declaration set up the PNA Office to serve its members by strategic fisheries conservation and management, initiatives to maximize profitability and benefits for Pacific Islanders and promotion of PNA waters as a globally-recognised, sustainably-managed and certified tuna fishery.



Source: Adapted from PNA (2017). Red outline denotes Exclusive Economic Zones of PNA member countries.

Figure 3.10: Parties to the Nauru Agreement (PNA) on tuna fisheries

Koror Declaration

Signed in Palau, in 2010, at the First PNA Presidential Summit, the Koror Declaration (PNA, 2010a):

- Confirmed and supported the Vessel Day Scheme (whereby fishing is limited by a set number of fishing days).
- Closed off high seas areas between latitude 10°N and 20°S and between longitude 170°E and 140°W to purse seine vessels licensed by the parties to the declaration.
- Endorsed plans to proceed with the full assessment for Marine Stewardship Council certification of the skipjack fishery as sustainable.

Pacific Islands Forum Fisheries Agency

Papua New Guinea is a member of the Pacific Islands Forum Fisheries Agency (FFA, 2017), which is based in Honiara, Solomon Islands. The FFA was established to help countries sustainably manage their fishery resources that fall within their 200 nm EEZs. The FFA is an advisory body providing expertise, technical assistance and other support to its members who make sovereign decisions about their tuna resources and participate in regional decision-making on tuna management.

The FFA facilitates the observer program for FAA member countries and, as at 2015, there were 366 trained observers assigned to PNG tuna fishery vessels (Table C18 in Terawasi & Reid, 2017). All PNG purse seine vessels have FFA-trained observers on board who make notes of what is happening when the fishing vessel is fishing, how much and what type of tuna and by-catch species are caught. This data is fed back to the FFA's central database.

Secretariat of the Pacific Community

Papua New Guinea has been a member country of the Secretariat of the Pacific Community (SPC) since 1983 (SPC, 1983). The SPC works towards the well-being of Pacific people through the effective and innovative application of science and knowledge, guided by a deep understanding of Pacific Island contexts and cultures. The SPC's vision is for a region of peace, harmony, security, social inclusion and prosperity, so that all Pacific people can lead free, healthy and productive lives.

In the past, the SPC's Oceanic Fisheries Programme has assisted PNG with the NFA's tuna tagging project. Tagging tuna, and then releasing them and seeing where they are recaptured, provides vital information on the abundance and health of stocks, as well as how quickly the fish grow and how far they travel. The SPC continues to assist Papua New Guinea with tuna tagging, stock assessment, data entry, status reports and training, as well as assistance with attendance at conferences and workshops.

The SPC Division of Fisheries, Aquaculture and Marine Ecosystems (FAME) provides the 22 SPC member countries and territories with the information they need to make informed decisions on the management and development of their aquatic resources, and help to provide the tools and strengthen the capacity needed to implement these decisions.

Western and Central Pacific Fisheries Commission

Papua New Guinea is a member of the Western and Central Pacific Fisheries Commission (WCPFC), which was established by the Honolulu Convention for the WCPF (WCPF Convention), which entered into force on 19 June 2004 (see conventions above).

The WCPFC aims include the principles from the United Nations Fish Stocks Agreement (1995) such as the application of the precautionary approach, management decisions to be based on the best

available science, ecosystem considerations and recognition of special requirements of Pacific Island small states.

The WCPFC is primarily concerned with the management of fishing vessels that use longlines and purse seines, as well as troll lines, pole-and-line gear and other small scale fishing methods, including some artisanal methods. The WCPFC develops conservation and management measures that are often specific to fishing gear types, primarily because different gear types target different species.

The WCPFC coordinates very closely with the FFA, whose members are also members of the WCPFC. The SPC is another important relationship for the WCPFC as the SPC's Oceanic Fisheries Programme serves as the Commission's Science Services Provider and Data Manager. This relationship ensures that there is no duplication of effort in the area of collection and processing of scientific data on fishing activities in the region used to catch tuna.

The WCPFC Tuna Fishery Yearbook (2017) provides the most recent compilation and update of annual catch estimates in the WCPFC Statistical Area from 1950 (or start of data) to 2015. The statistics include tables of catches of the main commercial species of tuna (and other pelagic species) from each of the main industrial fishing methods employed in the WCPFC region, including longline, pole-and-line, purse seine and troll, and from each member country's fleet.

European Union Interim Partnership Agreement

The European Union (EU) concluded an interim Economic Partnership Agreement with PNG in 2007. The European Parliament approved the agreement on 19 February 2011, while the National Parliament of PNG ratified it on 25 May 2011.

In relation to PNG commercial tuna fisheries, the interim EU Economic Partnership Agreement includes:

- Duty-free and quota-free exports from PNG to the EU as of 1 January 2008, including fishery products such as canned tuna and tuna loins.
- Duties and quotas can be reintroduced if imports from the EU disturb or threaten to disturb the PNG economy.
- Improved rules of origin for processed fisheries products from PNG.
- Mandatory adoption of EU sanitary and phytosanitary measures to help PNG fish product exporters to meet EU import food health and safety standards.
- Customs and trade facilitation including better cooperation between the EU and PNG.

The interim Economic Partnership Agreement ensures favourable conditions for PNG in terms of rules of origin for fisheries (EU, 2011). Papua New Guinea is exempt from the use of originating fish for the manufacturing of processed and preserved fishery products, as would normally be required by the EU's standard rules of origin (i.e., 'global sourcing'). In other words, global sourcing is a concession that allows PNG to source fish from any vessel regardless of vessel ownership, flag or registration as long as it meets EU sanitary and phytosanitary conditions (i.e., tuna are safe to eat) and the EU's illegal, unreported and unregulated (IUU) regulations. The purpose of this arrangement is to support the development of onshore processing capacity for fish (mainly tuna) in PNG and other Pacific States, in order to create local employment (in particular for women) and income. This concession appears to have already directly contributed to new investment in enhanced tuna processing capacity in PNG. This arrangement also takes into account the specific circumstances of the Pacific region, including the:

- Limited fishing capacity of PNG's fishing fleet.

- Limited supply of "wholly obtained fish"[5] to meet on-land demand.
- Limited onshore fish processing capacity.
- Low risk of destabilising EU markets due to large inflows of fishery products from PNG and other Pacific states.

Global sourcing implies that regardless of where the fish is caught or the status of the vessel's flag, registration or ownership, the fish is deemed as 'originating' from PNG as long as it is being sufficiently processed from its natural state (fresh or frozen) into pre-cooked, packaged or canned product. However, the following conditions apply:

- Fish and fish products globally sourced must meet mandatory EU SPS requirements.
- Fish and fish products are not sourced through IUU methods.

The NFA is the competent authority for ensuring food safety measures comply with EU sanitary and phytosanitary requirements. The NFA has been accredited by the EU Directorate General for Health and Consumer Protection (DG SANCO, now DG Santé), which is the directorate general dealing with food safety and to ensure Europe's food is safe and wholesome. The NFA monitors and implements EU health regulations and undertakes regular inspections and audits on EU-accredited facilities, such as fishing vessels and tuna processing plants and canneries, etc. The NFA's steps and measures to address EU sanitary and phytosanitary requirements include:

- PNG Standards for Fisheries Products 2009.
- Procedures Manual.
- Quality systems manual.
- Monitoring Plan.
- Memorandum of Understanding with the Philippines.

A report by the European Commission (2014) looked at the impact of global sourcing on development in PNG, on the sustainable management of marine resources in the western and central Pacific Ocean, and on the tuna processing industry. The report concluded:

- Existing canneries in PNG have so far made only limited use of global sourcing. There are, however, five major investment projects[6] planned, which will lead to an increase of direct and indirect employment in PNG and mostly for PNG nationals, particularly women.
- Relevant conservation and sustainable management measures are in place at the national, provincial and regional levels; however, the effectiveness of these measures needs to be improved.
- As a result of the planned investments in the sector, the market share of PNG in the EU will increase.

[5] Definitions of "wholly obtained" fish are: a) crew nationality (i.e., at least 50% crew (including masters and officers) are PNG Nationals; or b) vessel ownership (i.e., a vessel must be PNG-registered or PNG-flagged; or c) leased or chartered vessels are treated as "PNG vessels" to undertake fishing in PNG's EEZ waters.
[6] The five major projects are Nambawan Seafoods Limited, Hailisheng Group and Dongwon Fishing at the Malahang Industrial Centre in Lae and RD Tuna Processors and Sapmer-Piriou Joint Venture at Madang Industrial Centre in Madang.

Illegal, unreported and unregulated fishing

Illegal, unreported and unregulated (IUU) refers to fishing activities conducted by foreign vessels without permission in waters under the jurisdiction of another state, or which contravene its fisheries law and regulations in some other manner.

The EU supports the sustainable management of fishery stocks, which is also a major pillar in its strategy for the Pacific. Global sourcing is a concession that allows PNG to source fish from any vessel regardless of vessel ownership, flag or registration as long as it meets EU sanitary and phytosanitary conditions and the new EU IUU Regulation from 1 January 2010.

The PNG industry is Dolphin Safe compliant and tuna are legally harvested and safe to eat (NFA, pers. com., 2016a). There is little evidence of IUU tuna fishing in PNG Waters (Pokajam, 2010).

3.4.1.4 Non-government Organisations

Papua New Guinea interacts with non-government organisations (NGOs) directly or indirectly through its membership of the PNA, WCPFC and the Pacific Islands Forum Fisheries Committee. For example, the following NGOs, listed alphabetically, are currently actively involved in promulgating ecologically sustainable tuna fisheries in the western and central Pacific Ocean fishing area:

- Conservation International
- Earth Island Institute (EII)
- Environmental Defence Fund
- Greenpeace
- International Seafood Sustainability Foundation
- Marine Stewardship Council
- Marine Stewardship Council-Certified Sustainable Seafood
- Nature Conservancy
- Organisation for the Promotion of Responsible Tuna Fisheries
- Pacific Island Tuna Industry Association
- Seafood Legacy
- Sustainable Fisheries Partnership Foundation
- World Tuna Purse Seine Organisation
- World Wide Fund for Nature

The Marine Stewardship Council is an international non-profit organisation established to address the problem of unsustainable fishing and safeguard seafood supplies for the future. The Marine Stewardship Council labelling process requires compliance of strict handling processes: fish must be stored at the right temperature, and high hygiene standards respected on the vessel and by the staff handling the fish. The Marine Stewardship Council issues a blue Marine Stewardship Council label to confirm that tuna has been sustainably fished.

In April 2013, PNG issued a directive to all tuna purse seining fleets to start landing Marine Stewardship Council -certified skipjack tuna to processing plants associated with the PNA initiative *Pacifical*, which markets PNA Marine Stewardship Council-certified tuna internationally (Agritrade, 2013). It is the first PNA member to give such an instruction to fleet owners operating within its exclusive economic zone (EEZ).

Marine Stewardship Council-certified skipjack and yellowfin tuna processed at the Lae processing plants or canneries means that the tuna were caught by purse seiners targeting free schools of tuna (i.e., not associated with fish aggregation devices (FADs)) in PNA's WPCO. The current Marine Stewardship Council Certificate Code for this WPCO purse seine fishery is F-ACO-0103, which expired on 20 June 2017 (MSC, 2017).

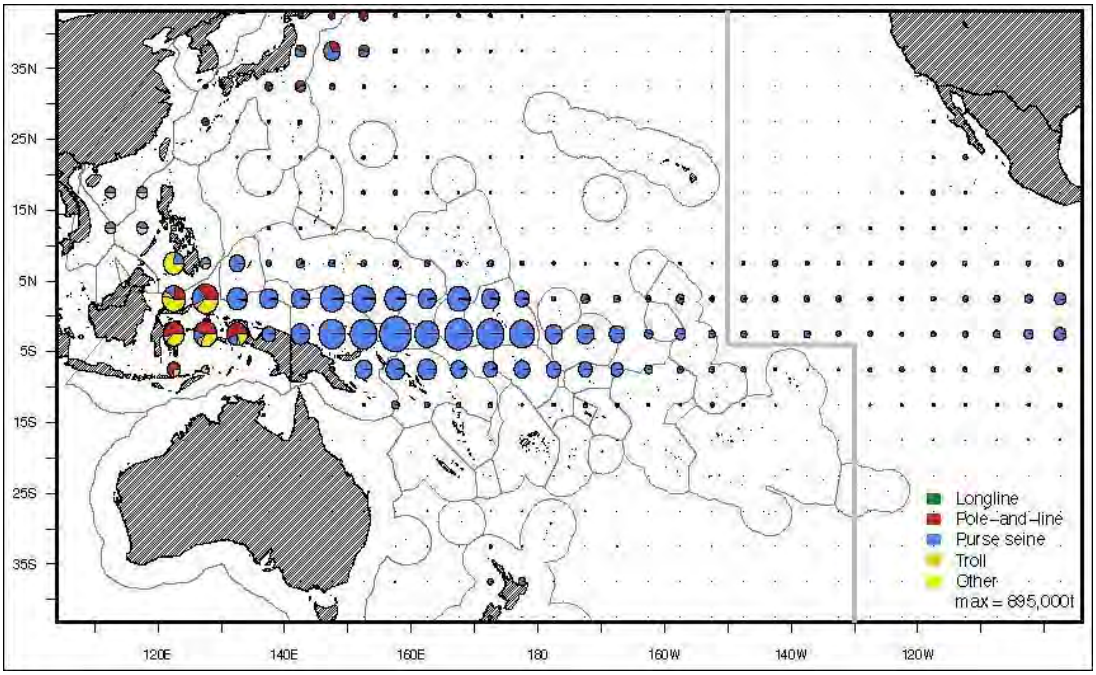
3.4.2 Tuna fisheries

The tuna fishery is the most valuable commercial and industrial-scale fishery in PNG. Papua New Guinea has a 200nm declared fishing zone that is highly productive in terms of pelagic tuna species because of its western Pacific geographical and climatic location. The tuna species of principal interest in PNG's declared fishing zone are skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), bigeye (*T. obesus*) and albacore (*T. alalunga*).

3.4.2.1 Tuna distribution in the Western and Central Pacific Ocean

Three tuna fisheries assessment reports (Brouwer et al., 2015; WCPFC, 2017; NFA, 2016a) provided current information on the tuna fisheries of the western and central Pacific Ocean. The tuna fishery in the western and central Pacific Ocean (refer to Figure 3.10), encompassed by the Convention Area of the Western and Central Pacific Fisheries Commission, is diverse, ranging from small-scale, artisanal operations in the coastal waters of Pacific states, to large-scale, industrial purse seine, pole-and-line and longline operations in the exclusive economic zones (EEZs) of Pacific states and in international waters (high seas).

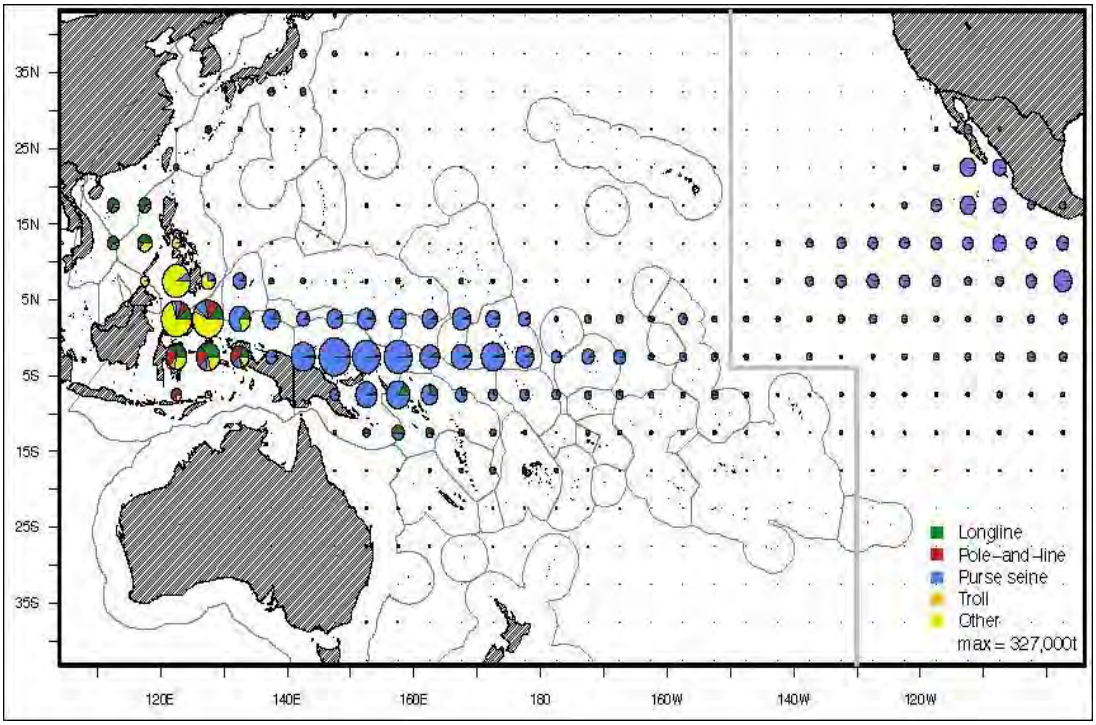
Figure 3.11 shows the distribution and total cumulative catch (t) of skipjack tuna in the western and central Pacific Ocean over the period 2006–2015 (Brouwer et al., 2015). Of note is the high catches of skipjack tuna in the western central Pacific Ocean between latitudes 5°N and 5°S, which includes part of PNG's EEZ and those of the other PNA and WCPFC member states (refer Figure 3.10).



Source: Brouwer et al. (2015).

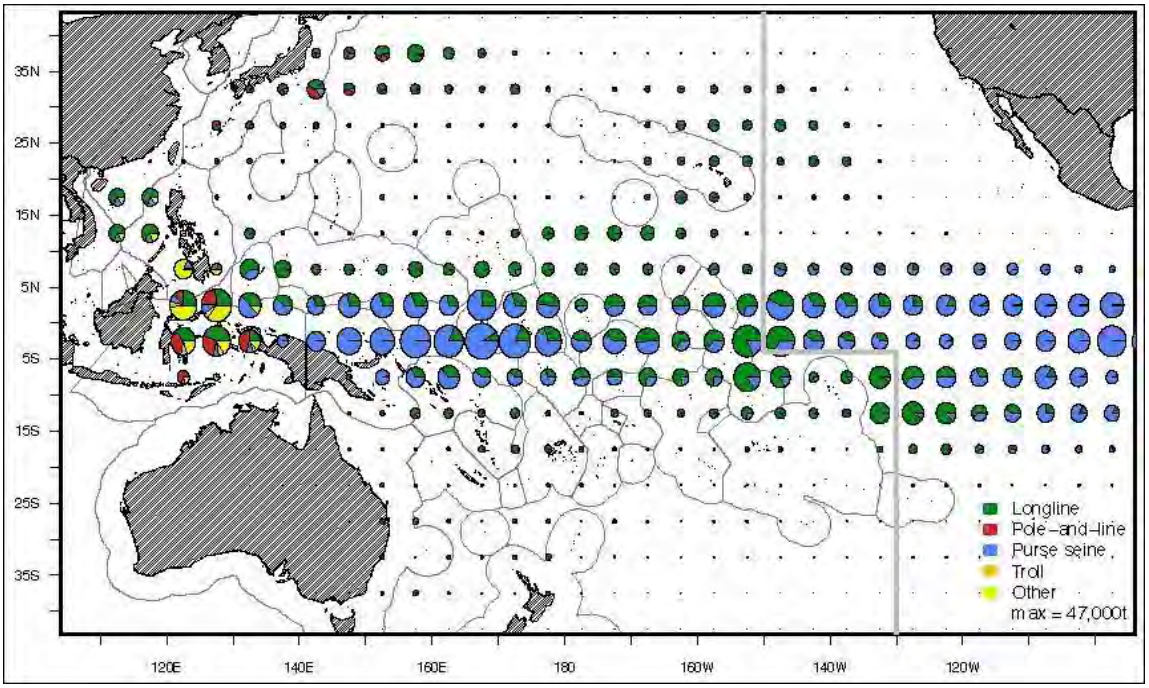
Figure 3.11: Distribution and cumulative (2006–2015) catch (t) of skipjack tuna in the western and central Pacific Ocean

Figure 3.12 shows the western and central Pacific Ocean distribution and cumulative catch of yellowfin tuna over the period 2006 to 2015, which indicates high catches in PNG's EEZ and those of other PNA and WCPFC member states. Similarly, Figure 3.13 shows the distribution and cumulative catch of bigeye tuna in the western and central Pacific Ocean during the period 2006 to 2015, which also includes relatively high catches in PNG's EEZ and those of other PNA and WCPFC member states between the equator and latitude 5°S.



Source: Brouwer et al. (2015).

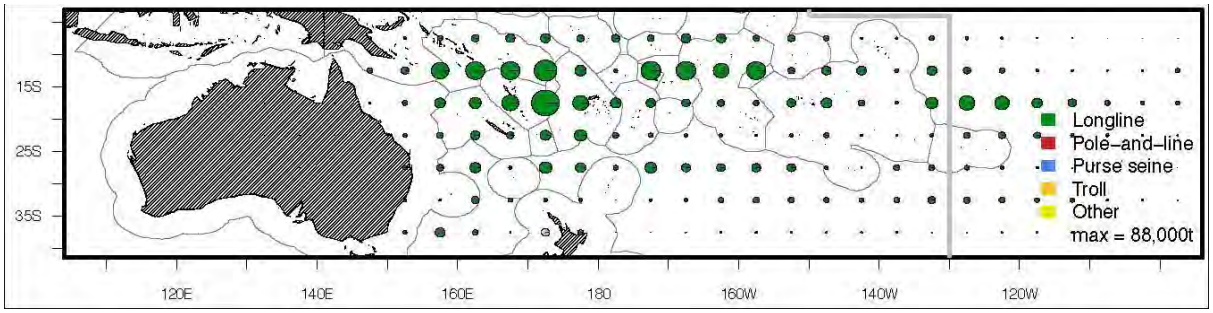
Figure 3.12: Distribution and cumulative (2006–2015) catch (t) of yellowfin tuna in the western and central Pacific Ocean



Source: Brouwer et al. (2015).

Figure 3.13: Distribution and cumulative (2006–2015) catch (t) of bigeye tuna in the western and central Pacific Ocean

Figure 3.14 shows the distribution and cumulative catch of albacore tuna[7] in the western and central Pacific Ocean over the period 2006 to 2015, which are mainly found at latitudes between 10°S and 20°S, including the south and southeast EEZ of PNG. Albacore tuna in PNG are generally caught by longline fishing vessels that use Port Moresby as a home base.



Source: Brouwer et al. (2015).

Figure 3.14: Distribution and cumulative (2006–2015) catch (t) of albacore tuna in the western and central Pacific Ocean

[7] Note that Figure 3.14 is truncated and different from the previous three figures, since longline targeted albacore tuna are located only south of the equator.

Tuna Spawning Grounds

A short desktop study was undertaken to identify breeding and spawning areas in the western and central Pacific Ocean with an aim to identifying any commercial tuna species that may breed or spawn in the Huon Gulf or adjoining Solomon Sea. The findings of this study are summarised below.

In the scientific literature, potential tuna spawning areas were based on either histological analysis of ovaries or larval occurrence, or both. Figure 3.15 shows the key spawning areas of various commercial tuna species.

Bigeye tuna (Thunnus obesus) spawning areas

The Banda Sea in southeastern Indonesia is a major spawning area for bigeye tuna (WWF, 2017). However, Kiyofuji et al., (2015) also note spawning areas in the Indian Ocean within waters of the EEZ of southeastern Indonesia, Timor Leste and northwest Australia. Therefore, this tuna species is most unlikely to spawn in the Solomon Sea including the Huon Gulf.

Albacore tuna (Thunnus alalunga) spawning areas

Albacore is a migratory species of tuna undertaking seasonal movements between spatially and temporally separated spawning and foraging areas.

Most albacore tuna spawning areas are found between 50°N and 40°S but lie outside 10°N or 10°S of the equator with spawning occurring during the austral and boreal spring and summer months in areas where surface water temperatures are greater than 24°C (Evans et al., 2016). While there is a potential for a small albacore spawning area within the Solomon Sea south of 10°S, which includes the Woodlark Basin and southeastern Solomon Sea but excludes the Huon Gulf, which lies between 6.5°S and 7.5°S. Overall, it is unlikely that albacore tuna spawn in the central or northern Solomon Sea or the western Solomon Sea that adjoins the Huon Gulf; therefore, albacore tuna spawning in the Huon Gulf is most unlikely due to its lower latitude location.

Southern bluefin tuna (Thunnus maccoyii) spawning areas

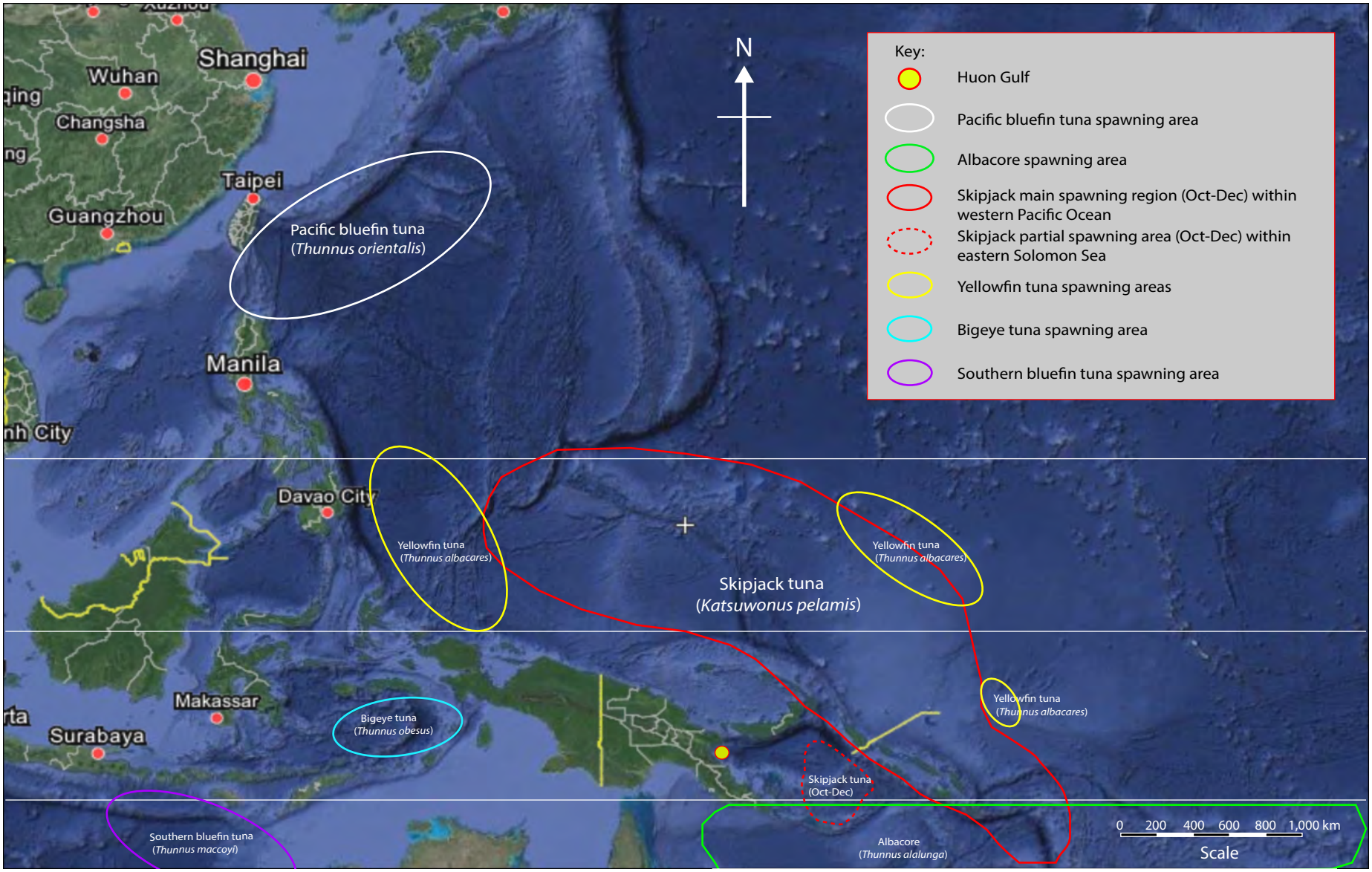
The only known spawning area of southern bluefin tuna is located in a region of the Indian Ocean within the EEZs of Indonesia, Timor Leste and northwestern Australia (WWF, 2017). Therefore, this species is most unlikely to spawn in the Solomon Sea including the Huon Gulf.

Pacific bluefin tuna (Thunnus orientalis) spawning areas

The only known spawning area is in the Philippine Sea that straddles the northeastern EEZ of The Philippines, Taiwan and the southwestern territorial waters of Japan (WWF, 2017). Therefore, this species is most unlikely to spawn in the Solomon Sea including the Huon Gulf.

Yellowfin tuna (Thunnus albacares)

Kiyofuji et al. (2015) assessed from larval distributions that yellowfin tuna spawning takes place seasonally (April-September) in higher latitudes (Taiwan and Northern Philippines) but that some degree of spawning takes place throughout the year within a zone at least 10°N and 10°S of the equator. The nearest seasonal (July-September) yellowfin tuna spawning areas to the Huon Gulf are the Gulf of Papua and Solomon Islands. These latter yellowfin spawning areas are located more than 1,500 km from the Huon Gulf. Therefore, yellowfin tuna spawning is most unlikely to take place in the Huon Gulf and adjoining Solomon Sea.



Source: Commercial tuna spawning areas based on Ueyanagi, 1969; Ashida et al., 2009; Kiyofuji et al., 2015; WWF, 2017.

	EnviroGulf Consulting	Date: 3.10.2017		EnviroGulf Consulting	Commercial tuna spawning areas in the western Pacific Ocean and Indian Ocean
		File Name: 167-F3.15	Rev: 1	Wafi-Golpu Project	Figure No: 3.15

Skipjack tuna (Katsuwonus pelamis)

Ashida et al., (2009) noted that skipjack tuna spawn all year around in the western and central Pacific Ocean based on ovarian maturity descriptions.

This finding is confirmed by examination of data on skipjack tuna larval distribution by Ueyanagi (1969) who reported that skipjack tuna larvae appeared all year around in the tropical region of western and central Pacific Ocean. Skipjack tuna are also known to spawn multiple times in areas where the sea surface temperature is higher than 24℃ (Matsumoto et al. 1984).

Kiyofuji et al. (2015) assessed the potential spawning areas of skipjack tuna based on the spatial and seasonal distributions of skipjack tuna larvae. Overall, skipjack larvae tend to be distributed mainly within the western Pacific Ocean. Kiyofuji et al. (2015) also found occurrences of skipjack tuna larvae in the Solomon Sea during Quarter 2 (April-June), Quarter 3 (July-September) and Quarter 4 (October-December). During Quarter 2 (April-June) skipjack tuna larvae were distributed in the eastern and southeastern Solomon Sea, which excludes the Huon Gulf. During Quarter 3 (July-September), skipjack tuna larvae were sparsely distributed in most of the Solomon Sea, but excluded the Huon Gulf. During Quarter 4 (October-December), skipjack tuna larvae were distributed in the eastern half of the Solomon Sea, which excluded the Huon Gulf. The main skipjack tuna spawning period is during Quarter 4 (October-December) and is centred on a large area of the West Pacific Ocean to the north and northeast of PNG; however, during this quarter, there is a small skipjack tuna spawning area within the eastern Solomon Sea, which forms less than 5% of the potential total western Pacific Ocean skipjack spawning area (refer to Figure 3.15). This small eastern Solomon Sea skipjack spawning areas lies well outside the Huon Gulf by some 650 km; therefore, skipjack tuna spawning is unlikely to take place in the Huon Gulf.

In conclusion, there does not appear to be any known tuna spawning areas within the Huon Gulf based on the literature review. It is possible that some skipjack tuna larvae may be passively carried by the New Guinea Coastal Current that flows in a northwestern direction from the eastern and southern Solomon Sea to the Vitiaz Strait and, thus, may occasionally be observed passing the eastern boundary of the Huon Gulf. However, this does not signify that the Huon Gulf is a tuna spawning area. Juvenile tuna are known to migrate through the wider Solomon Sea, including the Huon Gulf, to productive foraging areas, such as the continental shelf and seamounts to seek out baitfish and other food.

3.4.2.2 National Tuna Fishery Management and Development Plan

The PNG tuna fisheries are guided by the National Tuna Fishery Management and Development Plan, which established an overall management structure and an application framework for all tuna fisheries. This include licence limits, catch and effort controls, gear restrictions, the use of Fish Aggregating Devices (FADs) and other management tools for the purpose of tuna resource conservation and management, as well as combating IUU fishing activities. The plan is updated where necessary to conform to PNG development plans as well as regional and international obligations and agreements to which PNG is a signatory.

The PNG tuna fisheries currently comprise purse seine and longline sectors with a small handline sector (Usu et al., 2014; NFA, 2016a). A pole-and-line tuna fishery was operated in the 1970s and mid 1980s but this fishery is no longer operational.

Sustainable tuna fisheries management

The National Tuna Fishery Management and Development Plan directs sustainable tuna fisheries management. A number of projects are currently being undertaken to provide information and data for sustainable management of the tuna fisheries (Martin, 2015). These projects include:

- Tuna tagging projects.
- Tuna port sampling projects.

These projects are briefly described below.

Tuna tagging project

A K3.1 million tuna-tagging project was funded jointly by the Government of PNG Department of Planning and Monitoring and the SPC with the objective of determining the migratory range of tuna stocks. This was completed in 2015. The results are currently being analysed and are not available for reporting.

Tuna port-sampling project

An ongoing tuna port-sampling project has the objective of determining the size and population of tuna fish stocks. As of 2015, more than one million fish samples from 56 vessels have been sampled (Martin, 2015).

3.4.2.3 Purse seine Tuna Fishery

The purse seine sector is a mix of both domestic and foreign access vessels. The purse seine tuna fishery in PNG represents a balance of both domestic industry development and foreign distant water fishing nations access agreements. The domestic sector comprises PNG flag vessels and PNG-chartered vessels classified as locally-based foreign, which support onshore tuna processing facilities mainly in Lae and Madang.

PNG's domestic purse seine tuna fishery development is currently using a model whereby a fishing licence is granted on the condition that the vessel's tuna catch is processed in PNG (NFA, 2007b). Vessels under this scheme are either re-flagged to PNG or are given incentives by way of reduced licence fees and allowing them to fish within archipelagic waters.

Purse seine tuna fishing areas and targeted species

The purse seine fleet targets three main species of tuna: skipjack, yellowfin and bigeye. However, a number of tuna-like fish and by-catch species are also caught.

PNG-flagged vessels fish primarily within the country's EEZ waters, which extend seawards to the 200 nm limit, whereas the PNG-chartered vessels fish both in PNG waters and waters outside of PNG and usually within PNA or WCPFC waters (refer Figure 3.10).

PNG-flagged commercial tuna fisheries are prohibited to operate within 12 nm of land, island or reef, and purse seine vessels are permitted only to transit, offload catch or transfer catch to another vessel within the 12 nm limit. Within the remaining PNG waters, tuna fishing grounds include archipelagic waters and the country's EEZ. However, no commercial purse seine tuna fishery operates within any part of the Huon Gulf, including seaward of the 12 nm coastal limit within the gulf.

Purse seine fleet

The purse seine fleet in PNG is estimated to comprise 62 vessels, of which 27 vessels use Lae Port as a home base.

Table 3.9 provides information and data on the purse seiner fleet in PNG.

Table 3.9: Tuna fishing purse seine fleet owners and numbers

Company granted licences	Parent company and nationality linkage	Parent company relationship to vessels	Number of purse seiners
*Frabelle (PNG) Ltd	Frabelle, Philippines	Owner	11
*Frabelle Fishing Corporation	Frabelle, Philippines	Owner	4
Pacific Blue Sea Fishing	Philippines	Owner	1
*Nambawan Seafoods PNG Ltd.	Unknown	Unknown	Unknown
*Dologen Ltd	PNG	Operates with Frabelle	1
Rell & Renn Fishing (PNG) Limited	Philippines	Owner	1
RD Fishing (PNG) Ltd	RD, Philippines	Owner	17
South Seas Tuna Corporation Ltd (SSTC)	Fishery Co. Ltd. (FCF), Taiwan	Agent for Taiwanese and other owners	14
Fair Well Fishery (PNG) Ltd	Fair Well Fishery Co. Ltd., Taiwan	Owner	5
*Majestic Seafoods Corporation	Thai Union, Thailand; Century Canning Corporation and Frabelle, Philippines	Believed to be Frabelle	8
		Total number of purse seiners =	**62**

Source: Annual report of the NFA (2016a), Nicol et al., (2009), Usu et al., (2010, 2012).* Denotes companies located in Lae.

Table 3.10 presents a list of PNG-located purse seine vessels according to the European Commission's Directorate General for Health (DG Santé, 2017), which puts the number of vessels at 36.

Table 3.10: Tuna fishing purse seiner fleet characteristics as at April 2017

Company granted licences	Location	Province	Number of purse seiners
Frabelle (PNG) Limited	Lae	Morobe	15
Majestic Seafood Corporation Ltd.	Lae	Morobe	8
South Sea Tuna Corporation Limited	Wewak	East Sepik	7
RD Fishing Limited	Madang	Madang	2

Company granted licences	Location	Province	Number of purse seiners
Nicoland Seafood Limited	Port Moresby	National Capital District	2
Tunamax Fishery (PNG) Ltd.	Port Moresby	National Capital District	2

Source: DG Santé (2017)

A typical purse seine fishing vessel, the FV *Red Tulip 888* built in 1976 and owned by Frabelle (PNG) Limited, has the following characteristics:

- Overall length (LOA): 52.89 m
- Beam: 11.33 m
- Gross tonnage (GRT): 1,145 t
- Deadweight tonnage (DWT): 874 t

In 2015, 24 PNG-flagged vessels were active with a total of 3,143 days spent fishing and searching in PNG waters and the Western and Central Pacific Fisheries Commission convention area. In the same year (2015), a total of 29 locally based foreign vessels with a total of 3,243 days fishing or searching in PNG waters and the WCPFC convention area. Tuna purse seiner vessels pay for each day they fish.

Purse seine tuna catches

Table 3.11 gives the annual purse seine tuna catches for the years from 2010 to 2015 (WCPFC, 2017). The total catch estimate of 2015 by PNG purse seine vessels was 214,669 tonnes (t), most of which was caught by PNG-flagged or contracted vessels outside of PNG waters.

Table 3.11 indicates that about 70% of the purse seine tuna catch is skipjack tuna, 25% is yellowfin tuna, 3% is bigeye tuna and the remainder (2%) is other tuna-like fish and other by-catch species.

Table 3.11: PNG purse seine tuna catches during the five-year period 2010-2015

Year	Vessels active	Skipjack tuna		Yellowfin tuna		Bigeye tuna		Other by-catch	Total catch (t)
		Catch (t)	%	Catch (t)	%	Catch (t)	%	Catch (t)	
2010	45	148,054	72	51,116	25	6,014	3	89	205,273
2011	49	121,159	75	36,303	22	4,422	3	57	161,941
2012	51	165,522	70	63,690	27	6,951	3	107	236,270
2013	51	135,776	70	51,230	27	5,961	3	103	193,070
2014	55	173,891	74	53,318	23	7,671	3	102	234,982
2015	51	158,028	74	49,671	23	6,813	3	157	214,669

Source: WCPFC (2017).

Total catches by PNG flagged vessels have been increasing in the last five years (2011 to 2015) while a decline was observed for locally based foreign vessels as more of these vessels are reflagging to PNG (NFA, pers. com., 2016a).

Figure 3.16 shows the annual PNG purse seine tuna catch by species for 2010 to 2015 inclusive. The main species caught is skipjack tuna with annual average catch of around 150,000 t. The next main species of tuna caught was yellowfin tuna, with an annual average catch of around 50,000 t. The least caught species was bigeye tuna, which has an annual average catch of about 5,170 t. Other less common tuna species (e.g., albacore and Pacific bluefin tuna) accounted for an average annual catch of around 100 t.

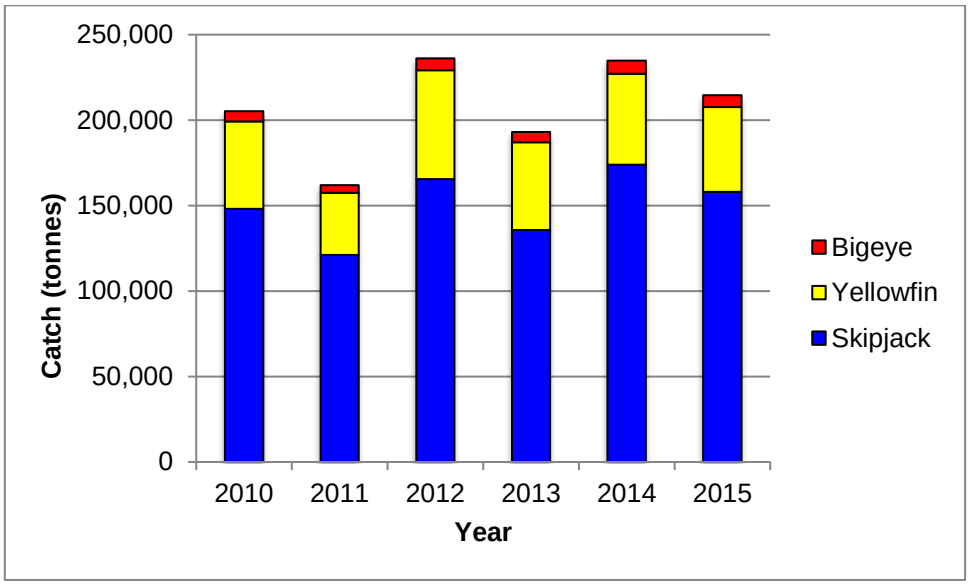


Figure 3.16: Annual PNG purse seine tuna catches in all waters (2010-2015)

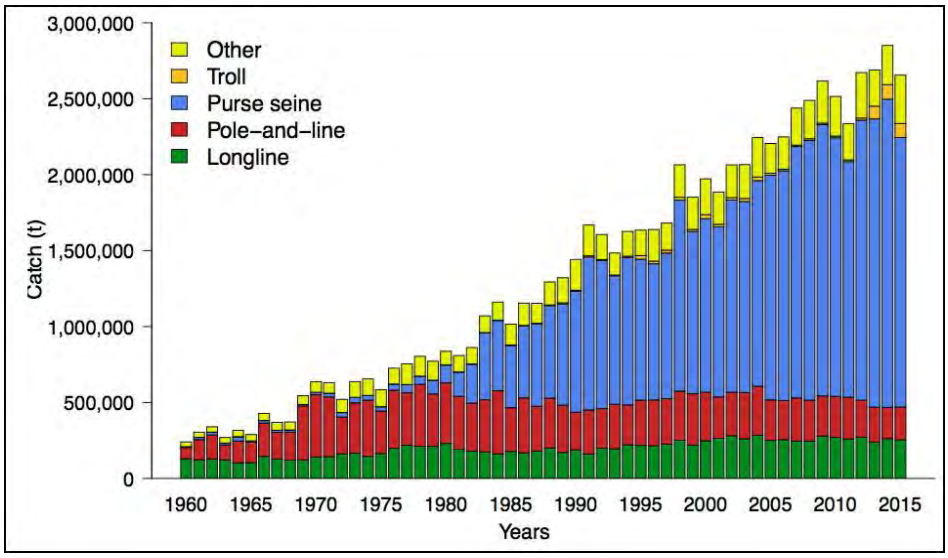
Table 3.12 lists tuna catch and effort estimates for foreign purse seiners in PNG's declared fishing zone and EEZ. On average, skipjack tuna is the main species caught (78.3%) followed by yellowfin tuna (20.3%), bigeye tuna (0.92) and other tuna (0.15%). An indication of average catch per unit effort (CPUE) is approximately 25 t per fishing day for tuna caught by the fleet of foreign purse seiners.

Table 3.12: Catch and effort estimates for foreign purse seiners in PNG waters (2011-2014)

Year	Fishing days	Catch (t) / species				
		Skipjack	Yellowfin	Bigeye	Others	Total
2011	14,648	340,950	83,236	3,044	440	427,670
2012	14,498	286,642	66,980	3,393	829	357,844
2013	14,980	287,764	71,030	2,977	424	362,195
2014	8,907	134,352	51,033	2,292	434	188,111
2015	1,736	32,154	11,337	1,037	27	44,555
Average	10,954	216,373	56,723	2,548	430	276,075

Source: NFA (2016a)

Figure 3.17 shows the annual total tuna catches (1960 to 2015) by fishing gear in the Western and Central Pacific Fisheries Commission convention area, which includes PNG's EEZ.

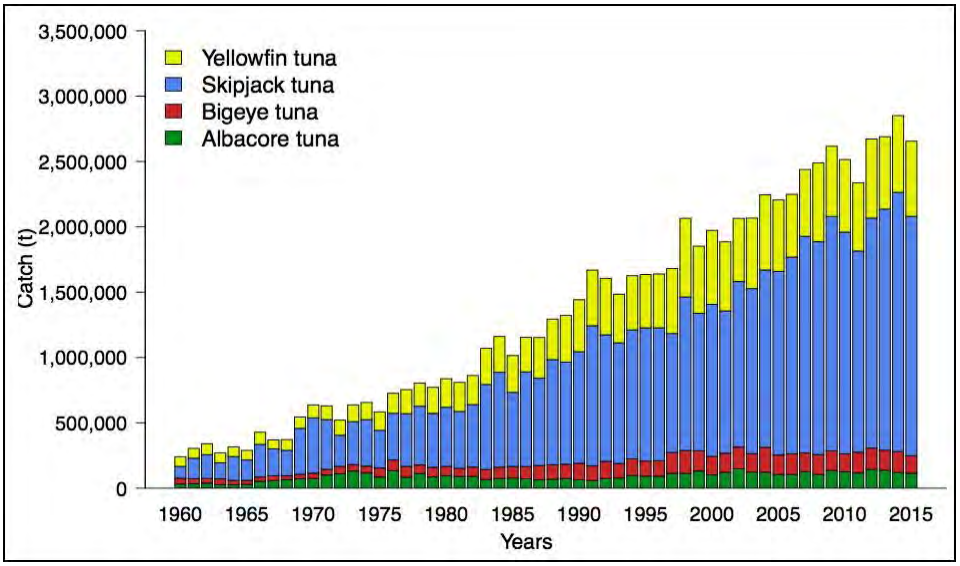


Source: Brouwer et al. (2015).

Figure 3.17: Total tuna catch by fishing gear in the WCPFC convention area

In Figure 3.17 purse seining is shown to be the dominant tuna fishing method having progressively higher annual total catch rates than other fishing methods. In PNG, purse seine vessels and catches increased gradually from the late 1970s, prior to which the pole-and-line fleets provided the main supply of tuna for canning and export. However, the pole-and-line fishery was dependent on live bait supplies, which imposed limitations on the areas of its operation. The higher production capabilities of purse seine vessels effectively took over as the major source of tuna from the 1980s to the present.

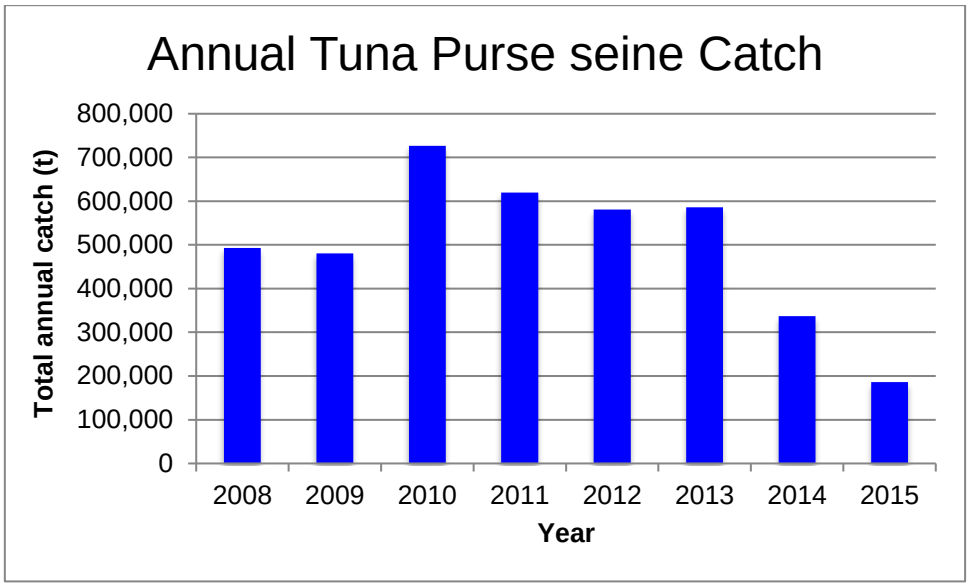
Figure 3.18 shows the annual total tuna catches by species in the WCPFC convention area, with skipjack being the dominant tuna species caught followed by yellowfin, bigeye and albacore tuna.



Source: Brouwer et al. (2015).

Figure 3.18: Total tuna catch by key species in the WCPFC convention area

Figure 3.19 shows the annual tuna purse seine catch in PNG's declared fishing zone between 2008 and 2015 (Terawasi & Reid, 2017).



Source: Terawasi and Reid (2017).

Figure 3.19: Annual tuna purse seine catch (t) in PNG's declared fishing zone

In Figure 3.19, there was a peak tuna purse seine annual catch of 236,060 t in 2010, which has declined to 186,247 t in 2015. The current expansion of onshore tuna processing plants and canneries in both Lae and Madang is most likely to increase the demand for both locally caught tuna (i.e., PNG declared fishing zone) and tuna caught in the fishing areas of member states of the WCPFC and/or FFA for onshore processing in PNG.

Vertical distribution of purse seine targeted tuna

Initially, development of purse seining in the tropical western Pacific by American and Japanese purse seiners was not successful (Gillett 2007; Gillett et al., 2002). The characteristically clear water and deeper thermocline in the equatorial western Pacific created conditions unfavourable for purse-seining, as the tuna schools tended to be smaller, faster-moving, and could dive deeper than in the eastern Pacific, where the shallower thermocline tended to confine the fish to depths where the nets could more easily enclose the fish.

Green (1967) observed a relationship between successful tuna catches and depth to thermocline in the eastern tropical Pacific, where highest catch success came from areas of thin surface mixed layers over thermoclines of sharp temperature gradients. As the schools of tuna preferentially inhabit the surface mixed layer above the thermocline, the nets that were designed for the temperate and eastern central Pacific were unsuitable for use in the western central Pacific due to the much deeper thermocline and clearer water. The fish escaped below the net before it could be closed and were not constrained by the thermocline, which extended below the depth of the net. The adjustments required to overcome this problem included much deeper nets and more powerful purse winches, power blocks and associated deck machinery capable of handling these nets (Itano, 1998). Following these engineering amendments, purse seine catches continued to increase.

The preferential depth distribution of the tuna (particularly skipjack and yellowfin) is within the surface mixed layer above the thermocline. However, some tuna species, particularly yellowfin *(Thunnus albacares)* and bigeye (*Thunnus obesus)* make excursions into deeper water below the thermocline as determined from tracking studies, (Hunter et al., 1986). Studies by Brill et al., (2005), found that

bigeye tuna have distinctive depth distributions and vertical movement patterns, where they remain in the uniform temperature surface layer at night and can descend to depths greater than 500 m at dawn. They thus mirror the vertical migrations of the small nektonic organisms of the deep sound scattering layer and exploit these as a food resource. In contrast, skipjack tuna and yellowfin tuna preferentially occupy the surface mixed layer above the thermocline and generally limit their forays to depths where water temperatures are no more than 8 ^{o}C below surface layer temperatures, and ambient dissolved oxygen concentrations are above 3.5 ml/L (Brill et al., 2005). However, forays of some (usually large) individuals of yellowfin tuna have been tracked into much deeper water (Dagorn et al., 2006)[8], exceeding the presumed temperature and dissolved oxygen tolerances.

Purse seine tuna fishery by-catch

There are a number of whale shark (*Rhincodon typus*) interactions with purse seine fishing gear. Most encounters are incidental, as purse seine vessel masters are required not to target or fish in an area where on-board observers have spotted the presence of a whale shark. The presence of a whale shark, like a floating log, acts as a FAD, which attracts some tuna species.

There are a number of cetacean interactions with purse seine fishing gear. Observational data from 2015 (NFA, pers. com., 2016a) indicates incidental captures of rough-toothed dolphins (*Steno bredanensi*), pantropical spotted dolphins (*Stenella attenuata*), sperm whales (*Physeter macrocephalus*) and false killer whales (*Pseudorca crassidens*).

3.4.2.4 Domestic commercial tuna longline fishery

Most of the tuna longline fleet is located in Port Moresby due to easier access to the longline tuna fishing grounds along the south coast of PNG. The longline sector is a citizen-only activity and all vessels fish exclusively in PNG EEZ waters, including the 6 to 12 nm limit zone as allowed under the National Tuna Fisheries Management and Development Plan, 2014 (PNG Government, 2014). However, distant water fishing nation longline vessels are prohibited from fishing within the 6 to 12 nm limit zone (PNG Government, 2014).

The longline fishery was originally based on foreign vessel access but in the mid-1990s a policy on domestication enabled the fishery to become a national activity only (NFA, 2016a). Longline ventures in Wewak, Lae, Kimbe, Rabaul, and Kavieng have all failed due to freight costs and logistical problems. While this situation continues, the productive fishing grounds in the Bismarck and Solomon seas will likely remain unexploited by domestic longline fishing vessels. The logistics of getting fish (e.g., sashimi-grade tuna) out of the country to the premier markets in Japan will continue to be the major constraint on the industry, and may require dedicated freight aircraft to move fish from provincial towns to the capital (Brownjohn, 2013).

Usu et al. (2014) provide information on the PNG-based tuna longline fleet, which indicated that the number of tuna longline vessels reduced significantly from 27 active vessels in 2012 to 10 active vessels in 2014.

Domestic tuna longline catches and by-catches

According to the NFA (2016a), the target catches by tuna longline vessels in PNG waters are dominated by yellowfin tuna with an average of 2,068 t in the last five years (2011-2015), followed by albacore (321 t) and bigeye (44 t). The overall estimated catch in 2015 was 1,919 t with an estimated

[8] A yellowfin tuna (134 cm fork length) caught near an anchored fish aggregating device (FAD) in the Seychelles (Western Indian Ocean) was equipped with an internally implanted archival tag and released. The fish was recaptured 98 days later, having spent 85% of its time shallower than 75 m (maximum thermocline depth experienced by the fish) but, over the course of the track, it performed three deep dives to 578 m, 982 m and 1,160 m.

effort of 35,190 'hundred hooks'. This was an increase from the 2014 estimate of 1,069 t with 16,163 'hundred hooks' (NFA, 2016a). According to the Pacific Islands FFA, the total tuna catch in 2015 for the 10 operating longline vessels in PNG's domestic longline tuna fishery was 1,78 (FFA, 2016) based on annual reporting data from the NFA. This highlights the need for the NFA to produce its own official fishery data in its annual reports (the last NFA annual report was for the year 2012).

In addition to target tuna species, the by-catch includes rainbow runners (*Elagatis bipinnulata*), blue marlin (*Makaira mazara*), swordfish (*Xiphias gladius*), black marlin (*Istiompax indica*) and striped marlin (*Kajikia audax*). Sharks species also make up a significant amount of the by-catch with a combined average of 110 t. The principal shark species incidentally caught are blue sharks (*Prionace glauca*), silky shark (*Carcharhinus falciformis*), shortfin mako shark (*Isurus oxyrinchus*) oceanic white tip sharks (*Carcharhinus longimanus*), thresher sharks (*Alopias vulpinus*) and various unidentified sharks. Smaller species such as rainbow runners caught within 3 and 12 nm from the shore (mainland or islands) are sold at the Lae Main Market, as well as the street markets at DCA Point and Voco Point. Some by-catch fish is sold as food for mining companies' mess halls as well as to fishing vessel crews (NFA, pers. com., 2016b). Shark by-catch is commonly discarded and shark-finning is banned in PNG.

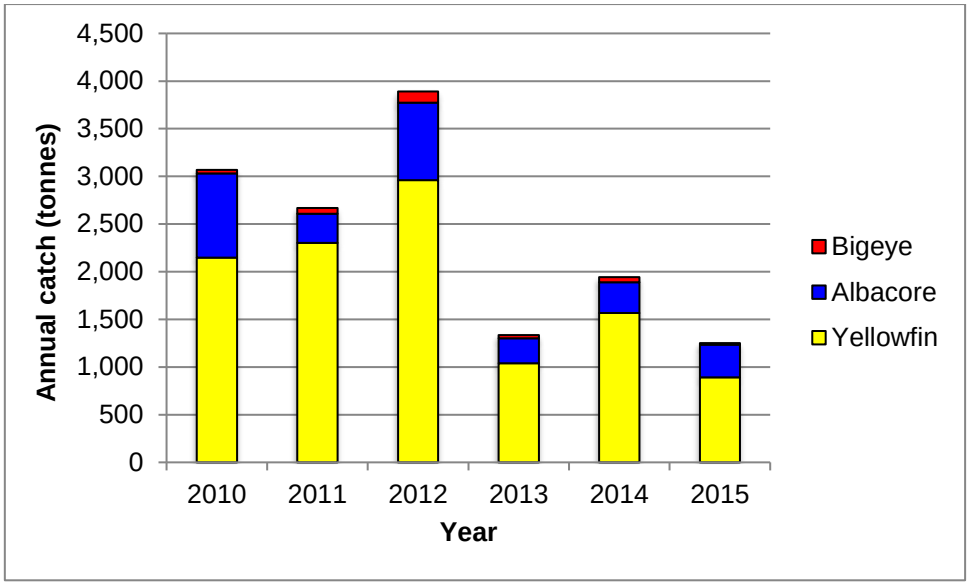
Table 3.13 presents the number of active vessels engaged in the domestic longline tuna fishery and the annual catches of tuna between 2010 and 2015. There has been a significant decline in the number of vessels active in the PNG longline fishery over the period 2012 (36 active vessels) to 2015 (13 active vessels) with about a three-fold reduction in the average annual tuna catch. The reduction in the number of vessels and, therefore, catches reflects the freight costs and logistical problems highlighted above.

Table 3.13: Number of vessels active and tuna catches of PNG longline fishery

Year	Vessels active	Albacore tuna		Bigeye tuna		Yellowfin tuna		Total Catch (t)
	N	Catch (t)	%	Catch (t)	%	Catch (t)	%	
2010	27	883	24	39	1	2,147	59	3,069
2011	35	305	9	59	2	2,303	69	2,667
2012	36	811	17	119	3	2,961	62	3,891
2013	15	261	13	32	2	1,041	52	1,334
2014	10	323	12	52	2	1,568	60	1,943
2015	13*	345	27	15	1	891	69	1,251

Source: WCPFC (2017). * Usu et al. (2014) and FFA (2016) both state that the number of active tuna longline vessels was 10.

Figure 3.20 shows the main species of tuna caught in the PNG longline fishery, as well as the decline of this fishery.



Source: WCPFC (2017).

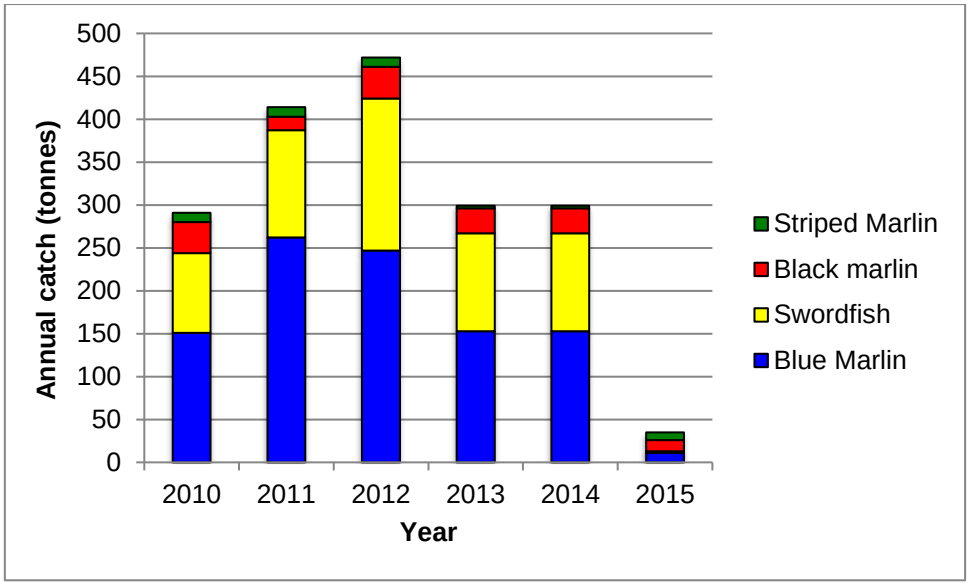
Figure 3.20: Annual PNG longline tuna catches (2010-2015)

As noted above, the domestic longline tuna fishery also catches a number of by-catch species, which include billfish and sharks. Table 3.14 shows the annual catches of billfish in PNG waters and Figure 3.21 shows the annual catches of by-catch species of billfish between 2010 and 2015 that also shows the sharp decline is by-catch species from 2012 (472 t) to 2015 (35 t), which represents a 13.5-fold decrease in by-catch.

Table 3.14: Number of vessels active and billfish catches of PNG longline fishery

Year	Vessels active	Blue marlin		Black marlin		Striped marlin		Swordfish		Total catch (t)
	N	Catch (t)	%	Catch (t)	%	Catch (t)	%	Catch (t)	%	
2010	27	151	4	36	1	11	0	93	3	291
2011	35	262	8	16	0	11	0	125	4	414
2012	36	247	5	37	1	11	0	177	4	472
2013	15	153	8	29	1	3	0	114	6	299
2014	10	153	6	29	1	3	0	114	4	299
2015	13	11	1	13	1	9	1	2	0	35

Source: WCPFC (2017).



Source: WCPFC (2017).

Figure 3.21: Annual PNG longline billfish by-catches (2010-2015)

No domestic tuna longline fishing vessels currently use Lae Port or fishery wharves near Lae as a home base. According to the WCPFC (2017), eight tuna longline vessels owned by Fair Well Investments Limited are listed as based in Port Moresby.

3.4.3 Tuna processing plants and canneries

Information about onshore-based tuna processing plants and canneries was obtained from a literature search and from interviews with NFA staff (NFA, pers. com., 2016a, 2016b). The results of the review and interviews are presented in this section.

3.4.3.1 Sector overview

PNG's 3.1 million km^2 fishing zone is the second largest in the South Pacific (refer Figure 3.1), yielding up to 20 per cent of the global annual tuna catch. However, until recently, the country was losing an estimated two-thirds of its potential downstream and value-added business due to a lack of domestic processing facilities. A major policy change in global sourcing (as noted in Section 3.4.1.3) which has allowed PNG greater control over the fleets operating in its waters has proved to be a key driver of growth in the tuna fisheries sector. In the past 10 years, PNG witnessed significant growth in the fisheries sector due to political stability and support on downstream processing through an export-led growth strategy, thus increasing contribution from the fisheries sector from 3% to 5% of GDP (Martin, 2015).

Previously, operations were dominated by several bi-lateral annual access arrangements, which granted the fleets of signatory nations open access to PNG's fisheries zone. Under the newly introduced "vessel day" scheme, which was rolled out by the NFA, PNG can prioritise vessels opting to have their catch processed onshore when distributing its fishing licences. The reform has triggered a wave of new investment, which is boosting downstream and value-added activities, as well as paving the way for the USD $408 million fisheries sector to transform itself into a billion-dollar industry (OBG, 2013).

A total of K350 million is expected from Foreign Direct Investments (FDIs) during 2015 to 2020 (Martin, 2015). These FDIs are for constructing fishery wharves and new tuna processing plants and canneries.

In the medium- to longer-term, 10 operating tuna processing plants or canneries are envisaged for Lae (NFA, 2016a) and a further 10 processing plants are also planned for the Madang Industrial Centre, formerly known as the Pacific Marine Industrial Zone or PMIZ (Celso, 2017), in Madang Province.

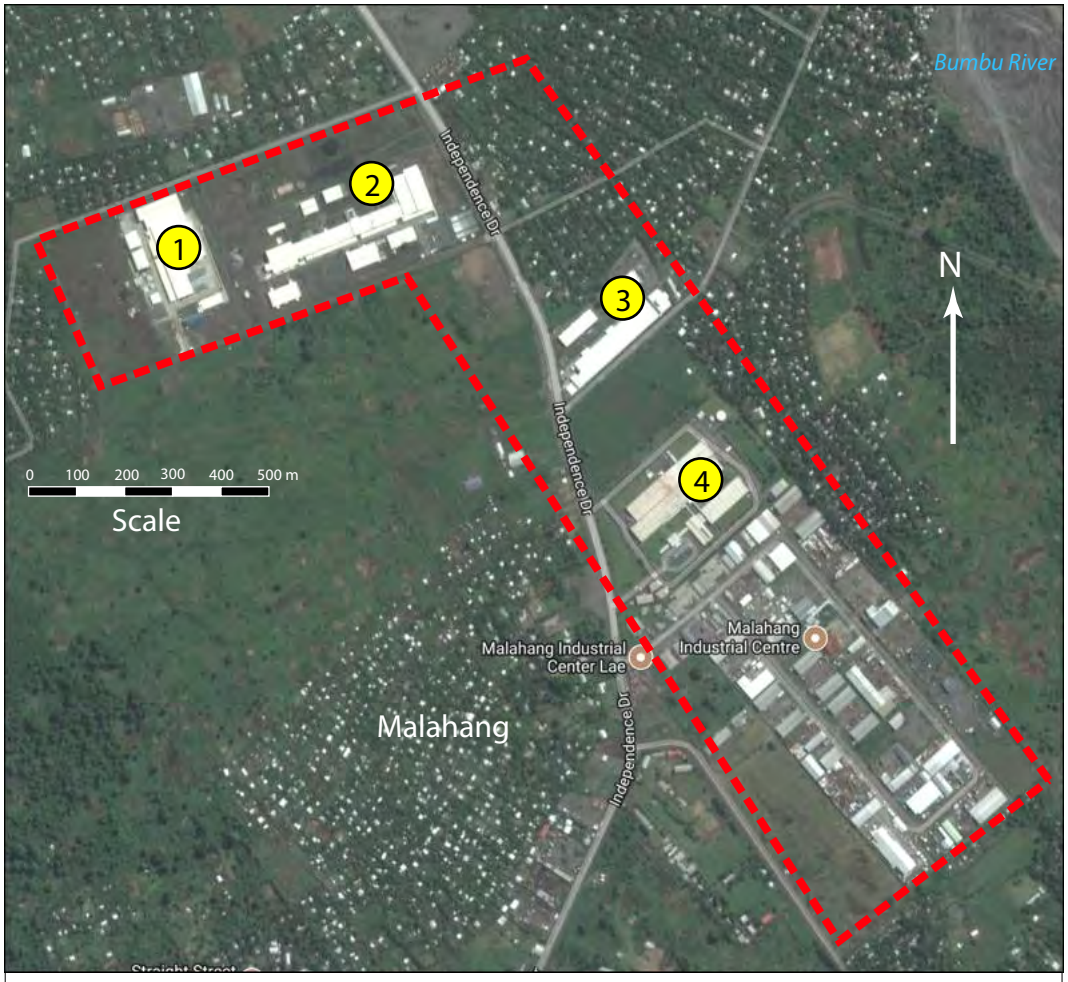
The PNG Government sees the fisheries industry as key to its plans for developing sustainable economic activity long term. A key priority of the PNG Government is to promote and market PNG fish and fishery products to overseas markets and to attract FDI. The FDIs in Malahang Industrial Centre in Lae and the Madang Industrial Centre near Madang will lead PNG to achieve economies of scale and competitiveness internationally in tuna processing. These new facilities are expected to pave the way for PNG to become the world's second-largest exporter of tinned fish, ahead of both the Philippines and Ecuador. Further expansion is also expected to create more jobs for PNG Nationals.

The main markets for PNG tuna are Thailand, the Philippines, American Samoa and Japan for frozen tuna; and the European Union (EU) for canned tuna and cooked loins. Chilled tuna goes to Japan, and fishmeal goes mainly to Australia, Sri Lanka and Japan.

Morobe Province tuna processing plants and canneries

Table 3.15 presents a list of operating and proposed tuna processing plants and canneries at Lae. Figure 3.22 shows the locations of the existing tuna processing plants or canneries in Lae, as well as the Malahang Industrial Centre where new tuna processing plants or canneries are proposed to be located.

Frabelle and Century Canning of the Philippines joined Thailand's Thai Union at the US $30 million Majestic Seafoods development near Lae, which launched in early October 2013 and is the region's largest fish processing plant, with a capacity of 350 t/d of processed tuna. Majestic Seafoods has its own expansion plans, initially concentrating on selling to the local PNG market. Six of its PNG-flagged purse seine vessels are being replaced and a second wharf has been built. Further improvements include a second freezer to store single-cooked tuna, which customers can eat straight away, and which will be exported to France and Germany initially.



Legend:

Malahang Industrial Centre boundary

4 Existing tuna processing plant or cannery

Source: Coffey and EnviroGulf Consulting.

EnviroGulf Consulting	Date: 14.06.2017	EnviroGulf Consulting	Malahang Industrial Centre and existing tuna processing plants	Figure No: 3.22
	File Name: 177-FX3.22 Rev: 1	Wafi-Golpu Project		

Table 3.15: Existing and proposed tuna processing plants in Morobe Province

Existing processing plant or cannery:	Location and investment value	Processed Products	Markets	Capacity
Existing processing plants or canneries:				
Frabelle Fishing Corporation (Lae) (2006)*	Lae Full EU-compliant	Canned tuna, primarily skipjack, but some yellowfin Cooked loins: mostly yellowfin tuna, but some skipjack fish meal Own label: canned tuna in oil, fancy packs, red meat, and chunks/ solid/flakes in oil/brine	80% canned tuna production to EU (Germany, UK, Netherlands, others) and cooked loins to EU (Spain and Italy) 20% canned tuna production sold in PNG	1,290 t/d capacity 80 t/d production Direct jobs: 2,061 Indirect jobs: 5,625
Nambawan Seafoods Ltd (2015)	Malahang Industrial Centre, Lae Investment value: US$22 million (K70 million)	Loins and canned tuna	Not known, assumed to be Chinese Taipei and East Asia	200 t/d of loins and canned tuna Direct jobs: 3,500 Indirect jobs: 7,000
International Food Corporation (IFC), Malaysia (1992)	Lae	Own label (*Besta*) for canned mackerel. Moving into tuna canning market.	Malaysia and East Asia.	120 t/d capacity Direct jobs: 1,800 Indirect jobs: 4,500
Majestic Seafoods Ltd (2013)	Lae Investment value US $49.6 million (K158 million)	Canned tuna and loins	All products exported to EU	350 t/d capacity 150 t/d operation Direct jobs: 3,500 Indirect jobs: 7,000
Proposed:				
Dongwon Fishing (South Korea)	Malahang Industrial Centre, Lae Investment value US $35 million (K 110 million)	Fresh and frozen fish	Not known, assumed to be South Korea and East Asia	200 t/d capacity 120 t/d operation Direct jobs: 2,000 Indirect jobs: 4,000

Existing processing plant or cannery:	Location and investment value	Processed Products	Markets	Capacity
Hailisheng Group (China)	Malahang Industrial Centre, Lae Investment value: US$25 million (K80 million)	Loins and canned tuna	Not known, assumed to be China and East Asia	300 t/d Direct jobs: 1,000 Indirect jobs: 2,000

Source: McCoy et al. (2015). * Years in brackets denotes year of agreement signed with the PNG Government.

The Nambawan Seafoods cannery is a joint venture between the FCF Fishing Co. Ltd. (Chinese Taipei), Trans Pacific Journey Fishing Corporation (Philippines) and TSP Marine Industries (Philippines), and is capable of processing 150 t/d.

The International Food Corporation had a previous agreement with PNG government to take mackerel, but is now proposing to build a US $23 million (K72 million) 120 t/d tuna processing plant at its existing site in Lae, which will provide for 1,800 direct jobs and 4,500 indirect jobs. IFC is currently holding talks with a Japanese company (Setouchi Holdings) interested in bigeye and yellowfin tuna. Setouchi Holdings operates a successful sashimi tuna processing plant in Indonesia (The National, 2016).

Madang Province Tuna Processing Plants and Canneries

The Madang tuna processing plants and canneries are included in the current report for completeness in characterising PNG's tuna processing industry, although these plants are well outside the study area. Table 3.16 lists operating and proposed tuna processing plants or canneries in Madang Province.

The main existing tuna processing plant at Madang is RD Tuna Processors established in 1995. RD Tuna has formed a joint venture with the Fairwell Fishery Group of Chinese Taipei and Tri Marine International of the United States of America under the name Niugini Tuna Limited, which is proposed to process around 200 t/d of tuna and provide 3,000 direct jobs. The processing plant is proposed to be located at the Madang Industrial Centre north of Madang.

Niugini Tuna Limited is a tripartite joint venture (between RD Corporation of Philippines, Fairwell Fishery Group of Chinese Taipei and Tri Marine International of Singapore) that proposes to build a 200 t/d tuna loins and canning plant at the Madang Industrial Centre. The proposed integrated fisheries development project by Niugini Tuna Limited will include tuna fishing, tuna loins and canning, as well as fishmeal processing.

Table 3.16: Existing and proposed tuna processing plants in Madang Province

Processing plant or cannery:	Location	Process products	Markets	Capacity
Existing:				
RD Tuna Processors (1995*)	Madang	Canned tuna, primarily skipjack but some yellowfin Cooked loins (mostly yellowfin, but some skipjack) Fish meal Chunks/ solid/flakes in oil/brine Own Labels: *Dolly* and *Diana*	70% canned tuna to EU (Germany, UK, Netherlands, Denmark, others); private label 30% canned tuna production sold mostly in PNG, some to Vanuatu and Solomon Islands. Cooked loins (mostly yellowfin) to EU (Spain and Italy)	200 t/d capacity, 120 t/d production Direct jobs: 3,280 Indirect jobs: 7,500
Proposed:				
Niugini Tuna Limited	Madang Industrial Centre, Madang US$28 million (K92 million)	Tuna fishing Tuna loins and canning, and fishmeal	Asia	200 t/d Direct jobs: 3,000 Indirect jobs: 900
Sapmer-Piriou Joint Venture (France)	Madang Industrial Centre. Investment value: US$400 million (K1,300 million)	High-value added fresh tuna products at -60°C	EU mainly (France, Germany, Spain and Italy)	300 t/d capacity 150 t/d Direct jobs: 2,500 Indirect jobs: 5,000

Source: McCoy et al. (2015). * Years in brackets denotes year of agreement signed with the PNG Government.

The 215 ha site of the Pacific Marine Industrial Zone (PMIZ) located 30 km north of Madang was a flagship project of PNG's fisheries industry for several years. It was designed to create greater economies of scale and greater efficiency for fish processing factories, port facilities, power generation and waste water processing. The PMIZ was renamed as the Madang Industrial Centre as its activities will be broadened beyond fisheries.

There are two proposed tuna processing plants or canneries:

- Niugini Tuna Limited: a partnership between the R D Corporation of the Philippines, Fairwell Fishery Group of Taiwan and Tri Marine International of the USA is considering building a tuna processing plant in the Madang Industrial Centre.
- French Sapmer-Piriou Joint Venture: this French joint venture is considering building a tuna processing plant at the Madang Industrial Centre and constructing a 300-m-long fisheries wharf and a dry dock and shipyard in Madang Harbour.

Other proposed PNG tuna processing plants, canneries and infrastructure

Cencon Packaging (Philippines) proposes to construct a US $30 million tuna can-making plant in Lae to supply PNG's tuna canneries (PAPUANG, 2017).

Admiralty Offshore (PNG) Limited (Philippines) is a joint venture between Rell & Renn Fishing Corporation (Philippines) and Manus Provincial Government plans to establish a *katsuobushi* (dried tuna) plant and a fresh fish operation on Manus Island.

South Seas Tuna Corporation (SSTC) is a joint venture company of FCF Fisheries Company of Chinese Taipei and the Jaczon Group of The Netherlands and proposes to build a fully integrated tuna processing facility at Wewak in East Sepik Province (SSTC, 2017).

3.4.3.2 Total processed tuna exports

Table 3.17 presents a summary of the total processed tuna exports from PNG in the period 2006 to 2010.

Table 3.17: Total PNG tuna exports (tonnes) between 2006 and 2010

Year	Canned tuna	Cooked loins	Frozen tuna	Chilled tuna	Fish meal	Total
2006	16,380	11,986	33,159	1,667	6,142	69,334
2007	14,654	11,525	40,364	1,395	5,484	73,422
2008	12,177	10,031	44,145	1,302	4,752	72,407
2009	15,742	11,249	38,233	666	5,552	71,442
2010	16,980	10,955	32,335	345	4,538	65,153

Source: NFA (2011).

Proposed Malahang Fisheries Wharf Project

A sealed road with footpaths has been built from Lae to the proposed Malahang fisheries wharf site near Wagang village. The proposed Malahang fisheries wharf is expected to support the three new tuna fish processing plants or canneries (i.e., Nambawan Seafoods Ltd, Hailisheng Group and Dongwon Fishing) at the new Malahang Industrial Centre in Lae. The objective of this new wharf would be to speed up purse seine vessels offloading fresh tuna to the existing processing plants in Lae and the Malahang Industrial Centre, as well as proposed new tuna processing plants and canneries to be sited in the Malahang Industrial Centre, hence avoiding queuing times at the Lae Port.

3.4.4 Domestic longline shark commercial fishery

A commercial longline shark fishery operated for several years in PNG waters and was managed under a separate management plan from the tuna longline fishery. The NFA (2011) developed a Shark Longline Management Plan to govern this fishery, which was based primarily on oceanic shark species. Longline shark fishing is prohibited with the 6 nm of land, islands or declared reefs.

The fishery was limited to nine vessels, setting approximately 1,200 hooks per day, with a total allowable catch of 2,000 t dressed weight per year. Based on observer data collected during 2002, an average hook depth of 72.3 m (range 35 to 108 m) was measured (Kumoru, 2003).

The shark longline fishery in PNG was closed in mid-2014 by a WCPFC measure, owing to high catches of silky sharks (*Carcharhinus falciformis*) whose population was in a steady decline. However, the domestic longline tuna fishery continues to inadvertently catch sharks as by-catch and, for the 2014–2015 fishing season, the longline tuna fishery released 180 live and 108 dead silky sharks (NFA, 2016a). Another shark species of concern due to a declining population was the oceanic whitetip shark (*Carcharhinus longimanus*), with 11 live and 70 dead individuals released by the longline tuna fishery in 2014-2015 (NFA, 2016a). These low levels of mortality of by-catch silky sharks (108 dead) and ocean white tip sharks (70 dead) compared to the shark longline annual catches in 2013-2014 of 796.12 t and 7.66 t, respectively.

Prior to closure in mid-2014, the main shark longline fishing areas were centred on the Gulf of Papua, Manus Island and northwestern New Ireland Province, as well as the outer Huon Gulf and adjoining Solomon Sea. While there is now no commercial longline shark fishery operating in the Huon Gulf, sharks are caught in the gulf by subsistence and artisanal fishers (see Section 3.2).

Table 3.18 presents previous annual catch data for sharks during the period 2010 to 2015. Note that no sharks were caught in 2015 due to the mid-2014 closure of the longline shark fishery. However, these estimates of longline catches of key shark species are considered ‘uncertain’ in WCPFC (2017), because of potential under-reporting or low coverage of observer data.

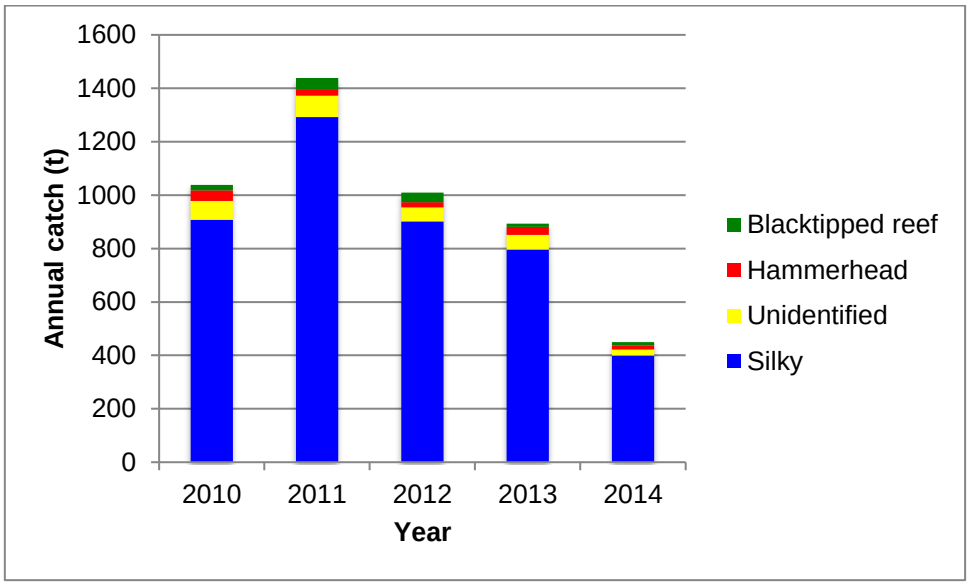
Table 3.18: Domestic commercial longline shark fishery catches (t) prior to mid-2014 closure

Year	2010	2011	2012	2013	2014	Average
Species / Effort (Hook hours)	22,790	27,934	20,717	16,367	6,129	18,808
Blacktip shark	18.93	2.81	1.31	5.59	7.45	9.22
Blacktip reef shark	19.75	43.98	36.53	11.17	12.79	24.85
Blue shark	10.21	18.93	16.08	16.59	9.38	14.24
Galapagos shark	0.99	0.29	0.06	2.89	2.69	1.38
Grey reef shark	23.87	8.42	2.59	4.68	2.10	8.33
Smooth hammerhead shark	39.15	22.34	18.64	31.06	15.09	25.26
Oceanic whitetip shark	12.90	7.15	3.74	7.42	7.66	7.77
Silky shark	907.26	1,292.90	902.46	796.12	399.27	859.60

Year	2010	2011	2012	2013	2014	Average
Silvertip shark	6.37	0.45	0.39	0.38	0.30	1.58
Tiger shark	8.76	2.15	1.21	2.16	0.16	2.89
Unidentified sharks	71.72	80.25	52.65	54.61	22.60	56.37
Totals	1,119.90	1,479.66	1,045.64	932.65	479.48	1,011.47

Source: NFA (2016a).

Figure 3.23 shows the PNG annual longline catches of the four main shark species from 2010 to 2014, which were targeted by the longline shark fishery before its closure in mid-2014.



Source: NFA (2016a).

Figure 3.23: Annual catch (t) of shark species during the period 2010 to 2014

In 2014, the total catch of the shark longline fleet was estimated to be 576.57 t and the value of this catch was estimated to be K3.7 million (Usu et al., 2014). Based on the average catches over the period 2010 to 2014 in Table 3.18, the main shark species caught in descending order by weight were 859.6 t of silky sharks, 56.37 t of unidentified sharks, 25.26 t of smooth hammerhead sharks (*Sphyrna zygaena*) and 24.85 t of black-tipped reef sharks (*Carcharhinus melanopterus*) (NFA, 2016a).

3.5 Marine transport and infrastructure

Marine traffic and shipping lane information and data within the Huon Gulf were obtained from marinetraffic.com (Marinetraffic, 2017), in the absence of similar information and data pending from the National Maritime Safety Authority. Additional details on yearly commercial vessel calls at Lae Port were obtained from review of a regulatory demand forecast for PNG Ports Corporation (Deloitte, 2013).

The Lae Port is the largest port in PNG for imports and exports, and is the main access point for goods delivered or brought by road from towns in the Highland Region (e.g., Mount Hagen and Goroka).

Annual throughput in the Lae Port has been growing at about the rate of population growth with import/export tonnages (increasingly containerised) accounting for about a third of the total and most of the growth.

3.5.1 Lae Port

Lae Port is the busiest port in PNG, handling approximately 4Mt of cargo (51% of PNG cargo trading) in 2012 with containerised trade a substantial component of throughput (PNG Ports Corporation, 2012). The Lae Tidal Basin has added another two container berths to Lae Port. The status of Lae as an industrial city and logistical hub for industry is a factor behind the significant cargo movements through its port. Existing and planned wharves at Lae Port (PNGPCL, 2017) are listed in Table 3.19.

Table 3.19: Lae Port wharves

Wharf No.	Purposes	Length (m)	Width (m)	Water depth (m below LAT*)
Existing wharves:				
1	Main overseas wharf	154.5	12.0	12.0
2.	Main overseas wharf	92.3	34.5	12.0
3	Main overseas wharf	220.0	34.5	12.0
3b	Extension of Wharf 3	108.0	34.5	13.7
4	Coastal wharf	54.0	13.0	4.9
5	Coastal wharf	52.5	13.0	3.0
–	Tidal basin eastern wharf	250.0	39.6	14.0
–	Tanker berth	69.3	10.0	13.7
–	Liquefied Natural Gas berth	54.8	–	6.1
–	Barge ramp	12.0	–	–
Existing wharves:				
Proposed wharves:				
–	Malahang fisheries wharf to the west of Wagang village	–	–	–
–	Tidal basin western wharves	–	–	–

Source: PNGPCL (2017). * LAT denotes lowest astronomical tide. – denotes data not available.

The Asian Development Bank funded the Lae Tidal Basin Project, which involved dredging out a swamp tidal basin area to the west of the existing wharves to form a new 700 m by 400 m harbour. The eastern side of the new harbour is a 250-m-long international container wharf that adjoins a

120,000 m^2 container yard and a 60,700 m^2 container stacking area (Plate 3.17). Another two 250-m-long international berths will result in the tripling of capacity of the Lae Port.

A key part of the overall Lae Port development is Huon Industrial Park, which is proposed to store wet (general fuels and chemicals) cargo, dry bulk materials and feed stocks.

Photo credit: WorleyParsons (2016).

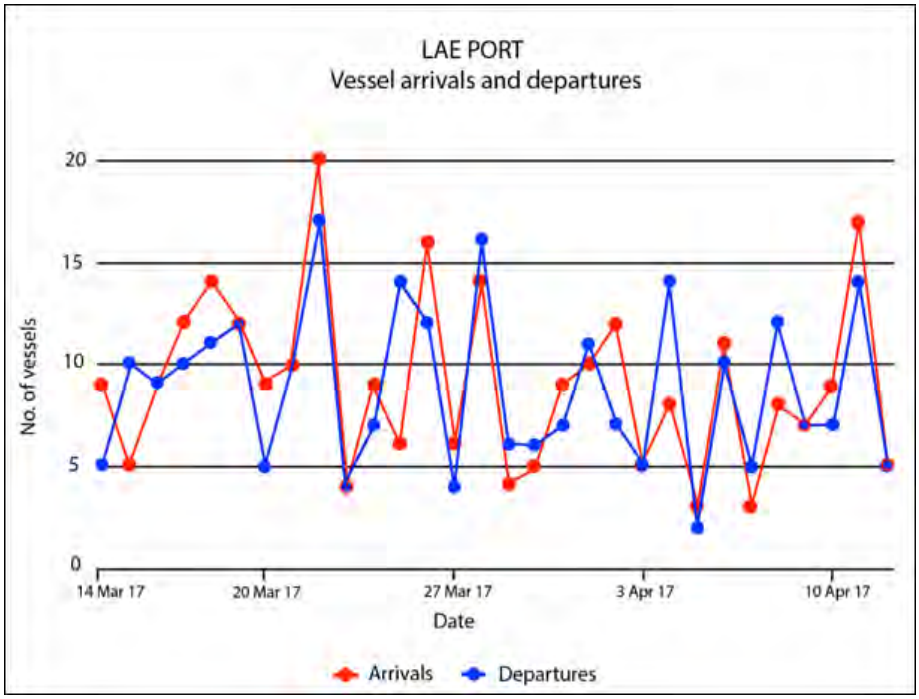
Plate 3.17: Lae Port and Lae Tidal Basin

Recent levels of vessel traffic at Lae Port

A literature review did not find any comprehensive or detailed statistics on the numbers or types of marine traffic marine using Lae Port. However, monthly snapshots of the daily numbers and types of vessels arriving at and departing from Lae were obtained for two separate monthly periods using a shipping traffic monitoring website (Marinetraffic, 2017a, 2017b). Information on annual vessel calls between 2009 and 2012 was also obtained from Deloitte (2013).

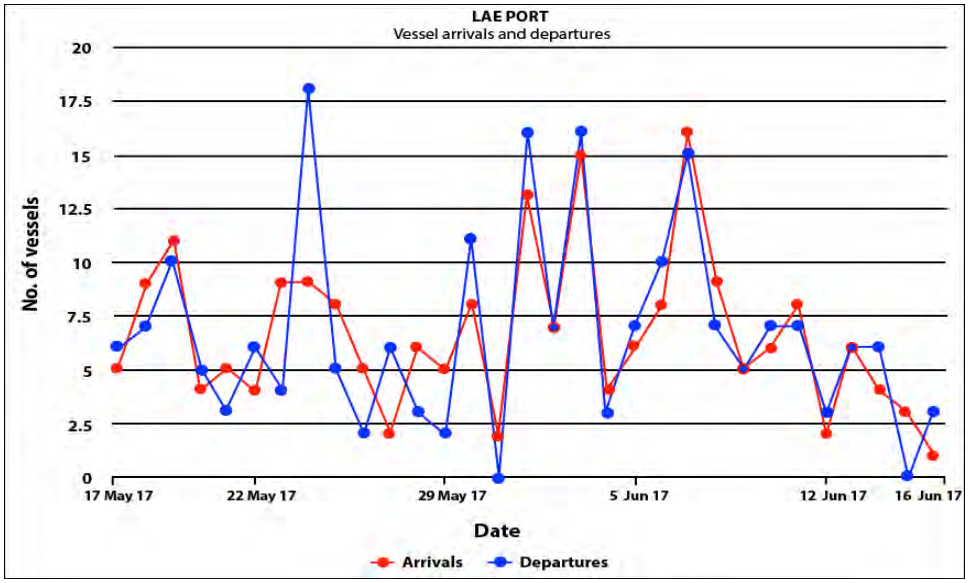
Numbers of vessels using Lae Port

Figure 3.24 shows Lae Port 30-day marine traffic for the period 14 March 2017 through 12 April 2017 (Marinetraffic, 2017a) and Figure 3.25 shows similar traffic data for the 31-day period 17 May 2017 through 16 June 2017 (Marinetraffic, 2017b). A total of 271 vessels/month with an average of 9.0 vessels/day arrived at Lae Port during the March-April 2017 period. In comparison, a total of 206 vessels/month with an average of 6.6 vessels/day arrived at Lae Port during the May-June 2017 period. These data show variability of the number of ships per month arriving at Lae Port with about 24% fewer vessels arriving at Lae Port during the May-June 2017 period. Combining the average numbers of vessels arriving at Lae Port over 61 days (i.e., the two periods), the average number of vessels of all types arriving at Lae Port is estimated to be 2,854 vessels per year.



Source: Adapted from Marinetraffic (2017a).

Figure 3.24: Lae Port vessel arrivals and departures (14 March to 12 April 2017)



Source: adapted from Marinetraffic (2017b).

Figure 3.25: Lae Port vessel arrivals and departures (17 May to 16 June 2017)

Deloitte (2013) provides marine traffic data for Lae Port between 2005 and 2012, with the number of vessel visits to Lae Port from those data sources being much lower from than the above extrapolated figure of 2,854 vessels per year. For example, according to Deloitte (2013), Lae Port received 1,067 vessel calls per year on average between 2009 and 2012. However, the marine traffic data used by Deloitte (2013) only assessed overseas and coastal container ships, break bulk cargo ships, and fuel and palm oil cargo vessels and excluded all other types of vessels arriving at the port. This likely

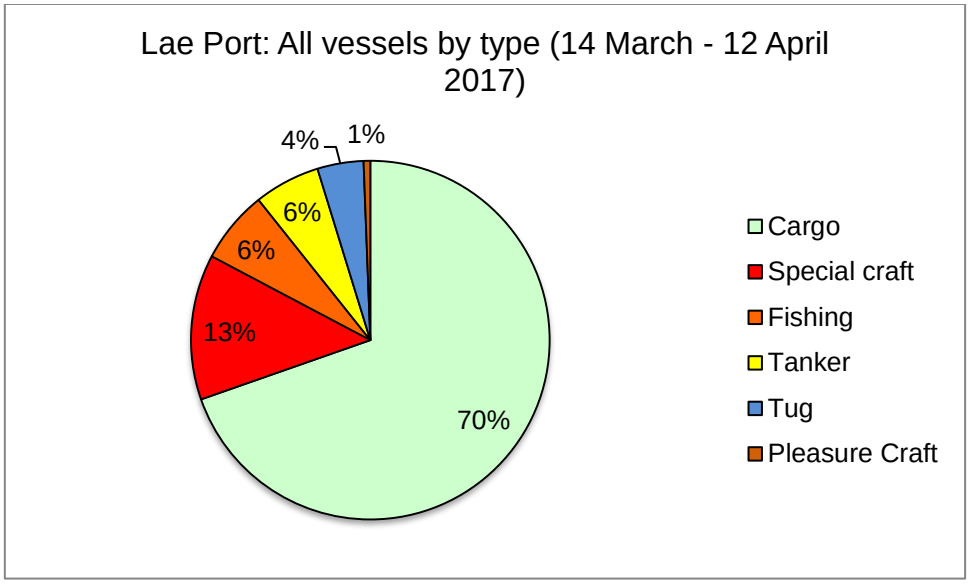
explains the higher traffic volumes extrapolated from the monthly marine traffic data (Marinetraffic 2017a; 2017b).

When Lae Port is busy, arriving vessels may be put on hold in PNGPCL-designated anchorage areas, two of which are located offshore of the Labu coastal area. A third anchorage area is located off DCA Point, which is about 4.5 km west of the Outfall Area.

The number of vessels using Lae Port is anticipated to rise significantly if the container wharves on the eastern side of the Lae Tidal Basin become fully operational, and if the proposed new wharves of the western side of the basin are constructed. Additional facilities for fishing vessels entering Lae Port will include the proposed Malahang fisheries wharf that may be constructed at a site to the west of Wagang village.

Percentage of vessels by type

Figure 3.26 shows the vessels by type visiting Lae Port during the period from 14 March to 12 April 2017, and Figure 3.27 shows the same data during the period from 17 May to 16 June 2017. The dominant type of shipping was cargo vessels (i.e., container ships and break bulk[9] vessels), accounting for 70% of traffic. The next predominant type of shipping was specialist vessels (or 'special craft' as denoted by Marinetraffic, 2017a, 2017b), such as offshore supply vessels, research vessels and barges, which accounted for 13% of the total vessel traffic. Fishing vessels (mainly tuna purse seiners) and oil, gas and chemical tankers both accounted for 6% each of the total vessel traffic. Various tugs and a pilot boat accounted for 4% of the monthly vessel traffic and 1% of the monthly traffic was attributable to visiting pleasure boats (cruisers and yachts) and likely to include some vessels of the Lae Game Fishing Club.



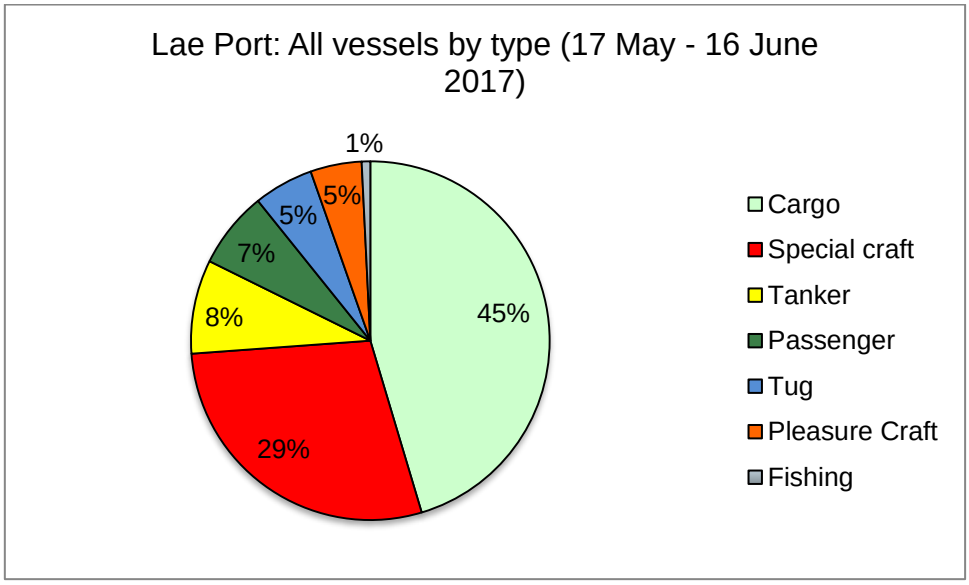
Source: MarineTraffic (2017a).

Figure 3.26: All vessels by type in Lae Port (14 March 2017 – 12 April 2017)

In Figure 3.27, the dominant type of shipping visiting Lae Port during the May–June 2017 period was also cargo vessels, accounting for 45.4% of traffic. The next predominant types of shipping in

[9] Break bulk vessels are general cargo vessels that carry goods that must be loaded individually, and not in containers nor in bulk as with oil or grain.

descending order were specialist vessels (28.5%), tankers (8.5%), passenger vessels (6.9%), tugs (5.4%) and pleasure craft (4.6%).



Source: MarineTraffic (2017b).

Figure 3.27: All vessels by type in Lae Port (17 May 2017 – 16 June 2017)

During the period May-June 2017, there were fewer cargo ships (45%) visiting Lae Port compared to the March-April 2017 period when cargo ships accounted for 70% of the port traffic. The reduction in the number of cargo vessels was reflected in the reduction of the total number of ships visiting Lae Port, which dropped from 271 vessels/month to 206 vessels/month for the two reporting periods.

3.5.2 Marine traffic density

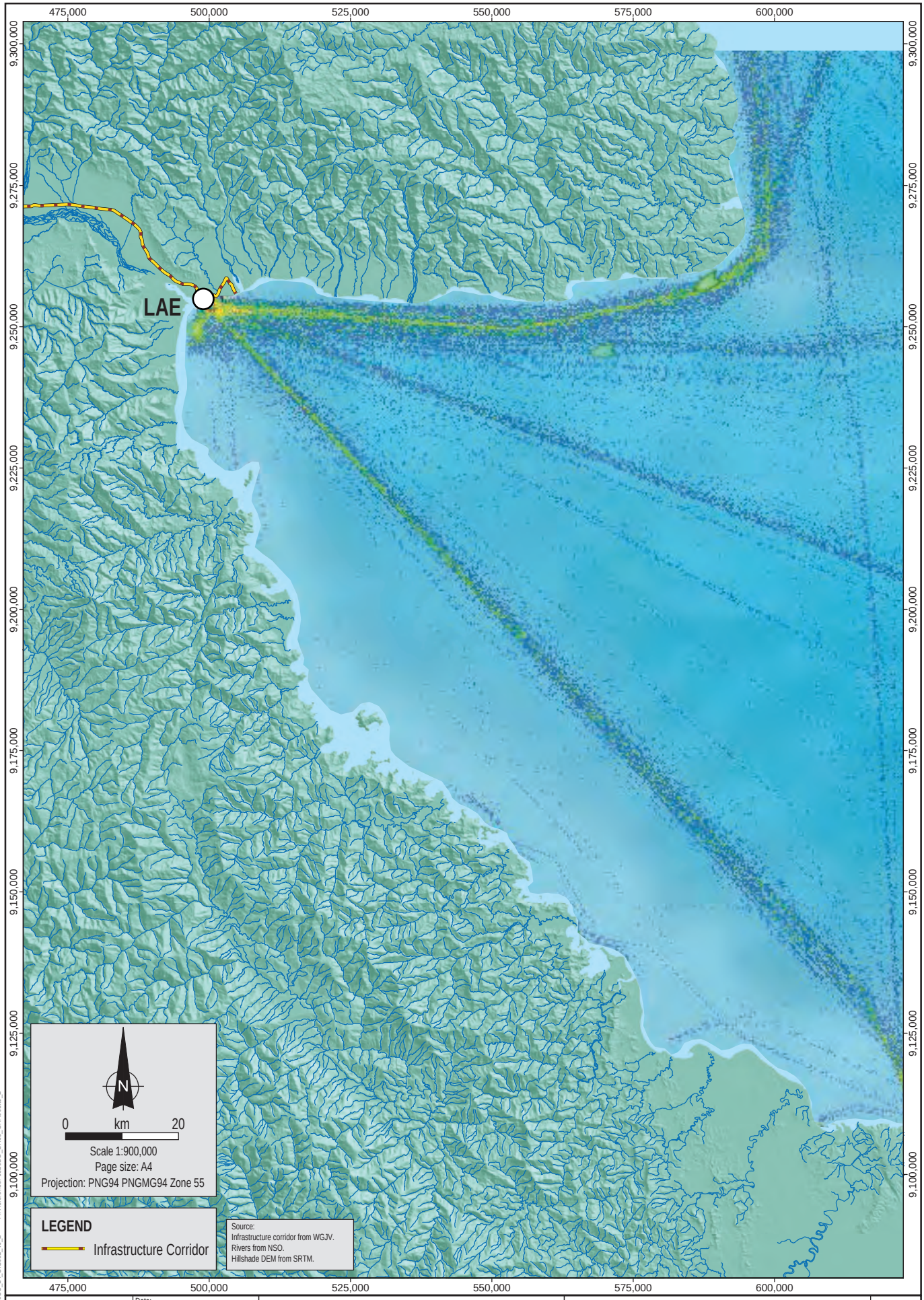
An important marine resource use is that of marine transport. Many vessels arriving at, or leaving, the Lae Port will pass in close proximity to the Coastal Area in the inner Huon Gulf.

Figure 3.28 shows marine traffic density in the Huon Gulf for those ships, boats and other vessels that have transponders or otherwise are identifiable through PNG's Vessel Monitoring System and/or Automatic Identification System, which are operated by the National Maritime Safety Authority. This figure is based on a snapshot of annualised 2016 vessel traffic in the Huon Gulf taken on 24 April 2017 and is based on a vessel traffic monitoring website (Marinetraffic, 2017c).

In Figure 3.28, shipping routes with relatively high marine traffic density are shown by different colours, which for PNG, approximate to the following approximate frequencies:

- Red: indicates >1,000 vessel trips/year.
- Orange: 500 to <1,000 vessel trips/year.
- Yellow: 250 to <500 vessel trips/year.
- Green: 100 to <250 vessel trips/year.
- Blue: <100 vessel/trips/year plus individual ship tracks.

The red and orange colours are located within and immediately adjacent to Lae Port.



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Date: 17.10.2017
Project: 754-ENAUABTF100520CC
File Name: 0520DD_SR05_F003.27_GRA

WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Marine traffic density in the Huon Gulf

Figure No: 3.28

International Shipping

Most international ships arriving at Lae Port are container ships with some of the larger ships using the new wharf in the Lae Tidal Basin, which has a large hardstand for container storage and holding. Other visiting international ships are oil, gas and chemical bulk carriers, which have access to dedicated wharves at Lae Port. Occasional passenger cruise ships visit Lae Port from time to time, for example, two passenger ships visited Lae Port during the period 17 May to 16 June 2017 (see Section 3.5.1).

Coastal Shipping

Due to PNG's dispersed population, coastal shipping services take on special significance in providing access to rural communities. Innumerable small wharves, jetties and beach landings provide the basic infrastructure for maritime transport services, but the majority of these is in poor condition and carries very little traffic. A number of passenger boats or ferries are located at Voco Point, where people can take scheduled trips on smaller passenger/cargo vessels to the Huon Gulf south coast major villages, as well as larger passenger/cargo vessels to Finschhafen, Siassi, Kavieng, Kimbe, Rabaul and Madang.

Small Watercraft

Small watercraft includes outrigger dugout canoes and outboard motor-driven banana boats and dinghies, which are used by local people regularly carrying goods and people to and from the various markets in Lae. The busiest routes in the Huon Gulf north coast study area are between Lae (mainly Voco Point, the new boat landing area in the Lae Tidal Basin, and the DCA Point fish market) and the villages of Labuta Rural and Yabim Rural LLGs along the Huon Gulf north coast and the villages of Wampar Rural and Salamaua Rural LLGs along the Huon Gulf south coast.

The busiest routes in the Huon Gulf south coast study area are between the villages of Labu, Labu Miti, and Labu Tale in Wampar Rural LLG and Lae (Voco point and DCA Point (Plate 3.18)), with average journey times of between 10 and 15 minutes from these villages to Lae. Other busy routes from the southern coast of the Huon Gulf are transits from the villages of Gwado, Busama, Buakup, Asini and Salamaua in Salamaua Rural LLG (refer Figure 1.1 for locations).

Along the Huon Gulf north coast, small watercraft transit routes between Lae and the coastal villages east of Wagang cross the location of the proposed Outfall Area.

Pleasure Craft

Visiting yachts and motor cruisers call into Lae on an ad hoc basis. Some of the larger vessels are associated with ships' cruises for coral reef and shipwreck diving expeditions or tours, as well as for ecotourism (e.g., leatherback turtle nesting at Labu Tale and Lababia). Pleasure craft also include those vessels associated with the Lae Game Fishing Club and shipwreck diving organisations based in Lae.

Photo credit: Coffey (2018a).

Plate 3.18: DCA Point small boat landing area

3.5.3 Coastal wharves and jetties

A number of current and proposed wharves and jetties service the fishing industry. In the Huon Gulf there is a current proposal to construct fisheries wharf near Wagang village, which is summarised below.

Malahang Fisheries Wharf Project

A sealed road with footpaths, Sipaia Road, has been built from Lae to Wagang village. This road will service the proposed Malahang fisheries wharf on the coast near Wagang and to the west of the village. The new wharf will be located approximately 2 km west of the proposed Outfall Area but the final location has yet to be confirmed.

The proposed fisheries wharf would allow berthing of purse seine fishing vessels (e.g., typically 50 m long with a beam of 12 m) to supply freshly caught tuna to the three new tuna fish processing plants and canneries (i.e., Nambawan Seafoods Ltd, Hailisheng Group and Dongwon Fishing) at the Malahang Industrial Centre in Lae.

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