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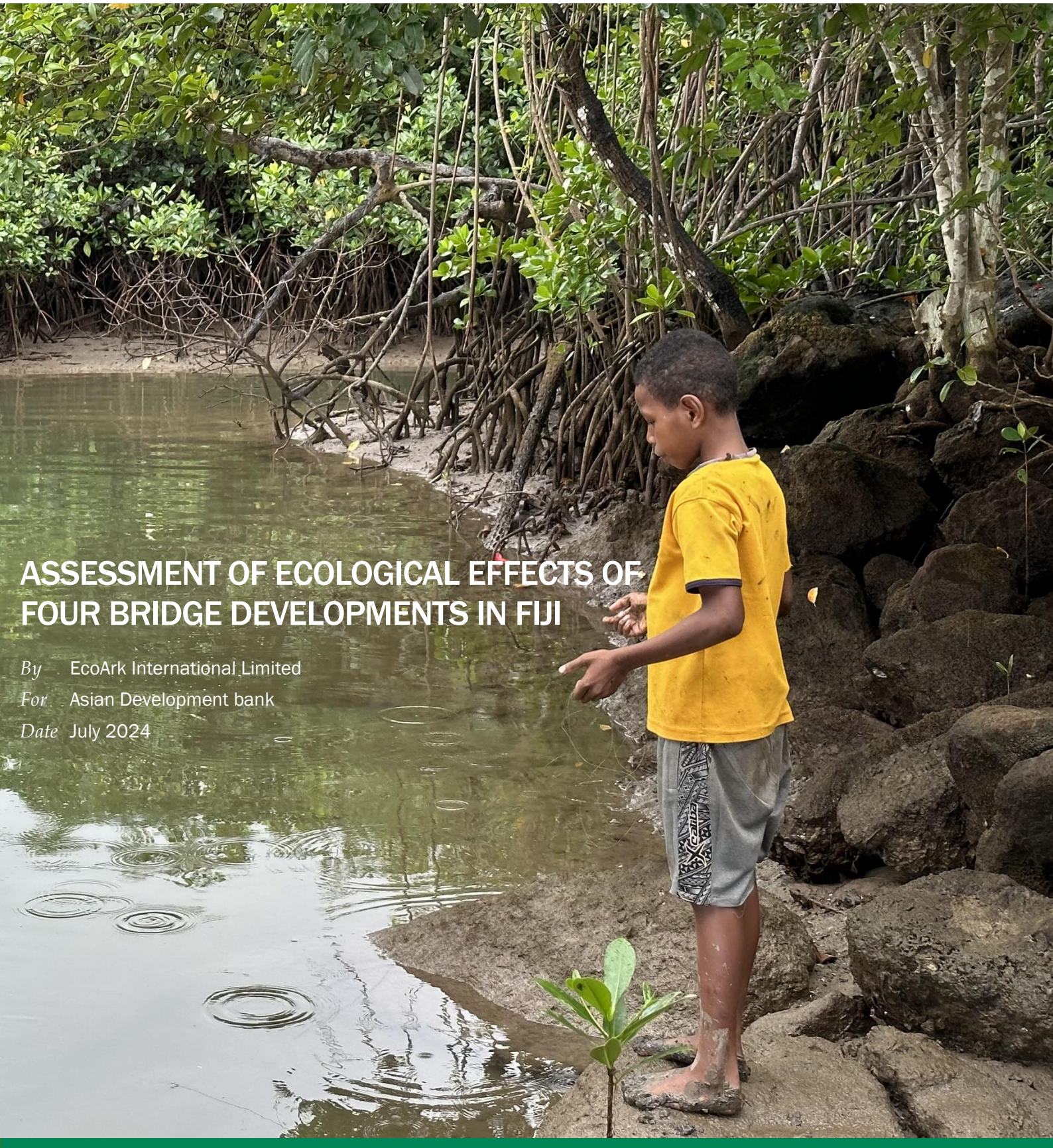

ASSESSMENT OF ECOLOGICAL EFFECTS OF FOUR BRIDGE DEVELOPMENTS IN FIJI

By EcoArk International Limited

For Asian Development bank

Date July 2024

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Preface

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1. Introduction

EcoArk International is conducting an ecological study, commissioned by the Asian Development Bank (ADB), to assess aquatic and terrestrial environments for the Bridge Replacement Project. This involves surveys, secondary research, baseline establishment, and the formulation of strategies to mitigate ecological impacts on aquatic ecosystems, including intertidal, freshwater, and mangrove areas on four bridges which have been identified as an ecological risk.

Beca International Consultants Ltd (BICL) has been engaged by Fiji Roads Authority (FRA) to undertake investigation and design of the priority bridges. A feasibility study and design are currently being undertaken and includes the development of an Environmental and Social Management Plan (ESMP) undertaken in accordance with the Shared Approach for Management of Environmental and Social Risks and Impacts, published by the Pacific Region Infrastructure Facility (PRIF) in June 2021. Beca is also undertaking the water quality assessment of the site.

The ESMP is being undertaken in accordance with Fiji's Environmental Management Act 2005 and WB and ADB safeguards and will address inter alia: (i) natural and critical aquatic and terrestrial habitat; (ii) water quality and estuarine processes; (iii) archaeological and physical cultural resources issues; (iv) socio-economic (including livelihoods) issues and health and safety; (v) climate change; and (vii) analysis of alternatives.

2. Site description and project outline

2.1 Fiji

Fiji consists of an archipelago of more than 330 islands. Viti levu the largest island covers about 57% of the national land area and contains 70% of the population. The island is mountainous with peaks up to 1,300m rising from the shores into tropical forests. Fiji has a year-round warm tropical climate, flow of southeast trade winds and high humidity content and is prone to natural hazards such as flooding and tropical cyclones. These have considerable impacts on the quality of water.

Viti Levu has several river systems, including the Tavua, Ba, Lautoka, Nadi and Sigatoka systems. All these rivers originate from the island's central mountains. Heavy rains fall on the windward (Southeastern) side. The lowlands are well sheltered by the mountains and have a clear dry season.

The Fiji Islands are home to numerous indigenous flora and fauna. Because of their isolation and relatively recent human occupation, Fiji is especially vulnerable to invasive species, to such an extent that invasive species are the primary cause of the extinction of island native species.

2.2 The sites

The four proposed bridge sites within Fiji are all on the island of Viti Levu and will provide an upgrade to the bridges currently present with new structures being built adjacent to the old structures (see Figure 1). The brief plans of these have been provided by BECCA but are in development and subject to change.

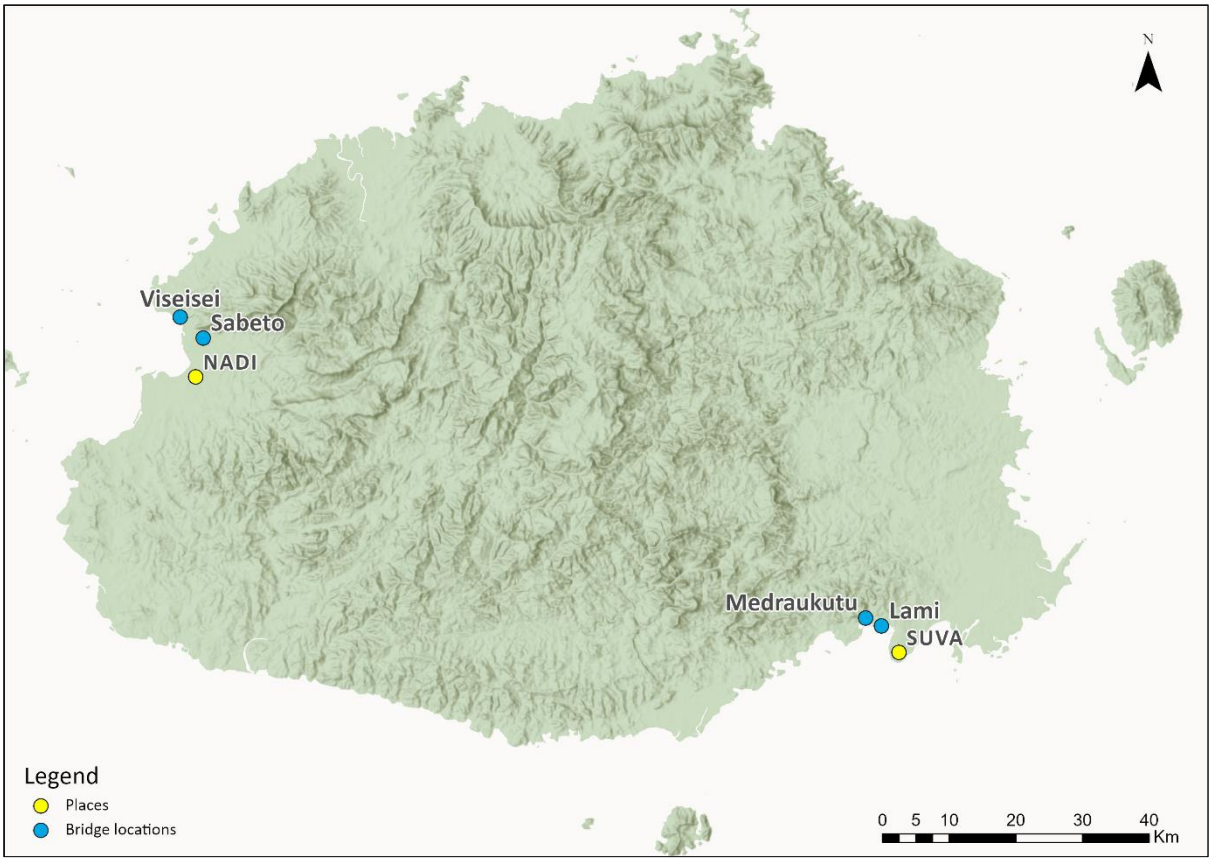


Figure 1. Map of the location of the four proposed bridges.

• Sabeto Bridge – 17°43'12"S 177°27'11"E
This site is located inland and crossed the Sabeto river in an area surrounded by agricultural land. Investigation at this site has been triggered due to an offline replacement and the presence of freshwater bivalves that are collected for food by the community in the immediate and downstream environment.

• Madraukutu Bridge – 18°06'11"S 178°23'19"E
This site is in a low elevation estuarine area with surrounding mangroves. Study is required due to an increase of the overall infrastructure footprint within the mangroves, which will result in mangroves being removed. The mangrove area that will be affected is part of a larger mangrove ecosystem that extends along the coastline and up the river and has been identified as an area used by the community for gathering of food.

• Lami Bridge –18°06'51"S 178°24'42"E
This site is in a low elevation estuarine area with surrounding mangroves. Further study is required due to an increase of the overall infrastructure footprint impacting nearby mangroves.

The mangrove area affected is part of a larger mangrove ecosystem that extends up the river and has been identified as an area used by the community for gathering of food.

• Viseisei Bridge – 17°41'29"S 177°25'14"E
This site is located inland at a low elevation which close to the sea. Further study at this site is required due to an increase of the overall infrastructure footprint within the mangroves, which would result in mangroves being removed. The mangrove area affected is part of a larger mangrove ecosystem that extends up the river and has been identified as an area used by the community for gathering food.

2.3 Project outline

The scope of this assignment is to undertake aquatic and terrestrial ecological studies of four of the ten priority bridge sites, within the project impact area. The aquatic and terrestrial ecological studies will be used to inform the development of an ESMP, to record the baseline conditions, identify risks and impacts, and measures according to the mitigation hierarchy.

EcoArk will be responsible for undertaking studies that will be used to determine the baseline ecological conditions of the study area, the ecological and habitat values, presence of flora and fauna with emphasis on endemic, rare or endangered species of conservation significance, and conduct the impact assessment that will assist with developing the ESMP.

The ecological studies will include recommendations for risk avoidance and/or mitigation to be adopted during construction, in accordance with ADB's Safeguard Policy Statement 2009 (SPS) and WB's ESS6: Biodiversity Conservation and Sustainable Management of Living Natural Resources.

The project is currently at concept design stage therefore the approximate amount of vegetation clearance and temporary vegetation disturbance required to construct the bridges are potentially going to alter this would require the area of impact to be reassessed. Discussions were made with the engineers to avoid and mitigate impacts on the environment keeping in line with the mitigation hierarchy.

Additional water quality samples will be collected for assessment by BECCA at each of the sites. This information will provide additional useful key ecological baseline material.

2.4 ADB and World bank Environmental Safeguard Policies

The ADB's Safeguard Policy Statement 2009 (SPS) set out their commitment to promoting sustainable development in all its activities. The SPS requires that all Programmes and Projects enhance environmental benefits as well as ensure that adverse social and environmental risks and impacts are avoided, minimized, mitigated, and managed.

The overarching objectives of the SPS:

- Avoid adverse impacts of projects on the environment and affected people, where possible.
- Minimize, mitigate, and/or compensate for adverse project impacts on the environment and affected people when avoidance is not possible; and

- Help borrowers/clients to strengthen their safeguard systems and develop the capacity to manage environmental and social risks.

The ecological studies will include recommendations for risk avoidance and/or mitigation to be adopted during construction, in accordance with ADB's Safeguard Policy Statement 2009 (SPS) and WB's ESS6: Biodiversity Conservation and Sustainable Management of Living Natural Resources. An overview of key elements of the SPS is presented below:

Do not implement project activities in areas of critical habitats, unless (i) there are no measurable adverse impacts on the critical habitat that could impair its ability to function, (ii) there is no reduction in the population of any recognized endangered or critically endangered species, and (iii) any lesser impacts are mitigated. If a project is located within a legally protected area, implement additional programs to promote and enhance the conservation aims of the protected area. In an area of natural habitats, there must be no significant conversion or degradation, unless (i) alternatives are not available, (ii) the overall benefits from the project substantially outweigh the environmental costs, and (iii) any conversion or degradation is appropriately mitigated. Use a precautionary approach to the use, development, and management of renewable natural resources.

Mitigation measures will be designed to achieve at least no net loss of biodiversity. They may include a combination of actions, such as post-project restoration of habitats, offset of losses through the creation or effective conservation of ecologically comparable areas that are managed for biodiversity while respecting the ongoing use of such biodiversity by Indigenous Peoples or traditional communities, and compensation to direct users of biodiversity.

2.4.1 Critical habitat

The ADB's Safeguard Policy Statement 2009 (SPS) states: “Critical habitat is a subset of both natural and modified habitat that deserves particular attention. Critical habitat includes areas with high biodiversity value, including habitat required for the survival of critically endangered or endangered species; areas having special significance for endemic or restricted-range species; sites that are critical for the survival of migratory species; areas supporting globally significant concentrations or numbers of individuals of congregatory species; areas with unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services; and areas having biodiversity of significant social, economic, or cultural importance to local communities. Critical habitats include those areas either legally protected or officially proposed for protection, such as areas that meet the criteria of the World Conservation Union classification, the Ramsar List of Wetlands of International Importance, and the United Nations Educational, Scientific, and Cultural Organization’s world natural heritage sites.”

As per ESS6 critical habitat is defined as areas with high biodiversity importance or value, including: (a) habitat of significant importance to critically endangered or endangered species, as listed in the IUCN Red List of threatened species or equivalent national approaches; (b) habitat of significant importance to endemic or restricted-range species; (c) habitat supporting globally or nationally significant concentrations of migratory or congregatory species; (d) highly threatened or unique ecosystems; (e) ecological functions or characteristics that are needed to maintain the viability of the biodiversity values described above in (a) to (d).

Two additional requirements from ADB’s SPS also apply:

…(i) areas with unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services; and, (ii) areas having biodiversity of significant social, economic, or cultural importance to local communities".

No project activity will be implemented in areas of critical habitat unless the following requirements are met: (i) There are no measurable adverse impacts, or likelihood of such, on the critical habitat which could impair its high biodiversity value or the ability to function. (ii) The project is not anticipated to lead to a reduction in the population of any recognized endangered or critically endangered species or a loss in area of the habitat concerned such that the persistence of a viable and representative host ecosystem be compromised.

World bank criteria for assessment

The World Bank ESF under the title for S3.1 defines Critical habitat as:

Critical habitat is defined as areas with high biodiversity importance or value, including:

(a) habitat of significant importance to Critically Endangered or Endangered species, as listed in the IUCN Red List of threatened species or equivalent national approaches;
(b) habitat of significant importance to endemic or restricted-range species;
(c) habitat supporting globally or nationally significant concentrations of migratory or congregatory species;
(d) highly threatened or unique ecosystems;
(e) ecological functions or characteristics that are needed to maintain the viability of the biodiversity values described above in (a) to (d).

ADB criteria for assessment

The criteria for critical habitat defined by ADB (2009) are as follows:

- Criterion 1: The area includes habitat required for the survival of critically endangered (CR) or endangered (EN) species;
- Criterion 2: The area has special significance for endemic or restricted-range species;
- Criterion 3: The area represents a site that is critical for the survival of migratory species; or supports globally significant concentrations or numbers of individuals of congregatory species;
- Criterion 4: The area includes unique assemblages of species that are associated with key evolutionary processes or provide key ecosystem services;
- Criterion 5: The area holds biodiversity of significant social, economic, or cultural importance to local communities;
- Criterion 6: The area is either legally protected or officially proposed for protection, such as areas that meet the criteria of the World Conservation Union classification, the Ramsar List of Wetlands of International Importance, and the United Nations Educational, Scientific, and Cultural Organization's World natural Heritage sites.

Table 1. IFC PS6 criteria and thresholds[1]

Criteria	Thresholds
1: Critically Endangered and Endangered Species	(a) Areas that support globally important concentrations of an IUCN Red-listed EN or CR species (≥ 0.5% of the global population AND ≥ 5 reproductive unitsGN16 of a CR or EN species). (b) Areas that support globally important concentrations of an IUCN Red-listed Vulnerable (VU) species, the loss of which would result in the change of the IUCN Red List status to EN or CR and meet the thresholds in GN72(a). (c) As appropriate, areas containing important concentrations of a nationally or regionally listed EN or CR species
2. Endemic / Restricted Range Species	(a) Areas that regularly hold ≥10% of the global population size AND ≥10 reproductive units of a species.
3. Migratory / Congregatory Species	(a) Areas known to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle. (b) Areas that predictably support ≥10 percent of the global population of a species during periods of environmental stress.
4: Highly Threatened or Unique Ecosystems	a) Areas representing ≥5% of the global extent of an ecosystem type meeting the criteria for IUCN status of CR or EN. b) other areas not yet assessed by IUCN but determined to be of high priority for conservation by regional or national systematic conservation planning.
5: Key Evolutionary Processes	

2.4.2 Determination of Ecologically Appropriate Area of Analysis

IFC PS 6 requires identification of Ecologically Appropriate Area of Analysis (EAAA) to determine the presence of critical habitat for each species with regular occurrence in the project's area of influence, or ecosystem, covered by Criteria 1-4. The boundaries of an EAAA should be determined by taking into account the distribution of species or ecosystems (within and sometimes extending beyond the project's area of influence) and the ecological patterns, processes, features, and functions that are necessary for maintaining them. This approach ensures that all important biodiversity within the project footprint and surrounding vicinity are taken into consideration.

3. Methods

3.1 Desktop review

A desktop assessment was conducted to determine existing conditions in the Study Area and the surroundings to identify habitats and species of potential importance that may be affected by the project and included aerial photography, photos, data relating to the ecology of the wider Project area and relevant experts. Literature review included Government and private sector reports, independent and Government published literature, academic studies, vegetation maps and land use maps. Identifying areas within and surrounding the Project footprint that are listed as having

[1] https://www.ifc.org/content/dam/ifc/doc/2010/20190627-ifc-ps-guidance-note-6-en.pdf

significant ecological values using data from IBA maps, dopa-explorer, data in iNaturalist, the fish database and by checking the IUCN redlists as well as grey literature.

The literature review included reviewing key documents, reports and data including:

- Department of Environment, Government of Fiji (2020). National Biodiversity Strategy and Action Plan 2020–2025, Suva, Fiji. EDNA
- Masibalavu, V. T., and Dutson, G. C. (2006). Important bird areas in Fiji: conserving Fiji's natural heritage. Suva: BirdLife International Pacific Partnership Secretariat. McKenzie, L.J., and Yoshida, R.L. (2007).
- Seagrass-Watch: guidelines for monitoring seagrass habitats in the Fiji Islands in Proceedings of a training workshop (2007). Corpus Christi Teachers College, Laucala Bay, Fiji: Suva.
- BirdLife International (2023) Country profile: Fiji. Downloaded from http://datazone.birdlife.org/country/fiji on 14/07/2023.
- Review of Policy and Legislation Relating to the Use and Management of Mangroves in Fiji
- https://dopa-explorer.jrc.ec.europa.eu/wdpa/555547791

3.2 Relevant Legislation, Guidelines and International Conventions

The following Fijian Government legislation, guidelines and the latest environment national strategies and reports are relevant to the assessment of impacts to terrestrial, marine and freshwater ecology, including:

- Biosecurity Act 2008
- Endangered and Protected Species Act 2002 and Endangered and Protected Species (Amendment) Act 2017
- Fisheries Act [Cap. 158] 1942
- Forest Decree 1992
- Marine Spaces Act [Cap. 158] 1978
- Rivers and Streams Act [Cap. 136] 1882
- Water Supply Act (Cap. 144) 1985
- Fiji National Climate Change Policy – 2012
- Fiji Low Emission Development Strategy 2018- 2050
- Fiji National Adaption Plan Framework - 2017)
- Fiji's National Reports to the United Nations Convention on Biological Diversity (1st to 5th) Fiji Implementation Framework – Thematic Areas Annual Reports
- Fiji Environment Strategy (draft)
- Natural Resource Inventory Reports of the Republic of Fiji – 2010
- Fiji REDD-Plus Policy - 2011
- Fiji Integrated National Waste Management Strategy 2016–2020 (draft)
- Forest Policy – 2007
- Green Growth Framework for Fiji – 2014
- Integrated Coastal Management Programme – 2002
- Mangrove Management Plan (2013)
- National Plan for Disaster Management – 1998
- National Policy Plan for Fijian Mangroves – 1986
- National Rural and Land Use Policy – 2005
- Fiji State of Environment Report - 2013
- Tourism Development Plan – 2007
- Water-shed Management Master Plan – 1998

This study also takes note of the following relevant international agreements:

- Convention on the Conservation of Migratory Species of Wild Animals (CMS) and relevant Memoranda of Understanding
- The Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and SouthEast Asia (IOSEA Marine Turtle MOU)
- The Memorandum of Understanding for the Conservation of Cetaceans and their Habitats in the Pacific Island Region
- Convention on Wetlands of International Importance (Ramsar)
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
- Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits
- Nagoya Protocol on Access to genetic resources and the fair and equitable sharing of benefits arising from their utilization (ABS)
- United Nations Convention on the Law of the Sea (UNCLOS)
- The Cartagena Protocol on Biosafety to the Convention on Biological Diversity
- United Nations Framework Convention on Climate Change (UNFCCC)
- Convention Concerning the Protection of the World Cultural and Natural Heritage (WHC).
- United Nations Conventions on Combating Desertification (UNCCD)

4. Site assessment methodology

Site visits were conducted to verify information from the literature review and to identify and map habitats, describe habitats, and record and identify species within the study area. Site visits were conducted from 27 May- 5 June 2023. Field surveys identified and characterised flora and fauna within the study and assessment areas. Species lists were generated for key species groups to cover the Study Area. Key species groups included plants, molluscs, decapods, and fish.

Identification of protected, threatened, or rare species were a key objective of field studies. Estimates of species abundance/richness and diversity were provided for key species groups surveyed, and special attention was given to habitats and species of conservation interest. Impacts to habitats, species or groups were assessed based on local knowledge and international standards/practice in conservation biology. A precautionary approach was taken for species which were data deficient and have not been assessed by the IUCN. This is critical since many species in Fiji are new to science and are still being named and no assessment has yet taken place.

4.1 Ecologically appropriate area of analysis and the direct area of impact

Because river habitats are longitudinally connected from upstream areas to the marine environment, bridges can affect the surrounding environment by:

- Changing sediment movement, flow, water quality and habitat conditions in the surrounding area
- Blocking upstream and downstream migration of native aquatic fauna
- Result in disturbance to flora and fauna in the surrounding habitat and therefore result in indirect effects

- Result in the removal of surrounding vegetation

The EAAA (Ecological Area of Aquatic Assessment) for aquatic species in this assessment is defined as extending 500 meters both upstream and downstream, and where applicable, into adjacent marine environments. This determination is based on evidence indicating that turbidity and sedimentation at high flow rates can impact areas up to 400 meters away. To account for this and ensure comprehensive coverage of all turbidity effects, a conservative 100-meter buffer has been added. Turbidity is considered one of the most significant factors affecting distance and serves as an effective proxy for assessing pollution impacts.

Bridges can also potentially affect the surrounding riverine/mangrove terrestrial environment by:

- Resulting in direct loss of vegetation and habitat
- Cause shading of vegetation/habitat and associated effects
- Result in disturbance to flora and fauna in the surrounding habitat and therefore indirect effects
- Result in the introduction of invasive species and the associated negative impacts

The EAA in the terrestrial environment considers the project-related impacts across the potentially affected landscape of all the intertidal area within 200 meters of the site and the connected natural terrestrial and intertidal vegetation. The intertidal environment is defined as mangrove, sand, rock or mud flats that undergo regular tidal inundation.

The four proposed bridge development sites all cover an area of land and the aquatic habitat. The Study Area of direct influence is defined as the boundary of the development sites of the 4 bridge areas with a 3m buffer area into the terrestrial and aquatic habitat. This is the area where most of the direct cumulative effects will occur and is the area which is used to calculate direct lost habitat.

4.2 Habitat and vegetation mapping

A habitat map of the study area was produced based on 2019 Government aerial photographs and through assessment from Google earth images, further ground truthing occurred at each potential bridge site. Colour photographs were taken of all habitat types surveyed and other features or species of ecological importance found during the study. The proportion of vegetation by ecotype removed was calculated based on the bridge design plans provided by Beca prior to the field visits.

4.3 Aquatic ecology

4.3.1 eDNA survey protocol

Environmental DNA (eDNA) analysis is a rapidly developing environmental survey technique involves collecting water samples and testing for signatures of target species genetic material. eDNA is a powerful tool to determine the presence of species at low densities, which might include species at risk or hard-to-find species. However, it is important to note that when species are not in the eDNA database the usefulness of this method can be limited. Exceptions being when there are no other species within the genus of concern and presence can therefore be

worked out on this premise. Efforts were made to add species of concern to the database through targeted capture methods undertaken with the purpose of adding their eDNA to the databank and verifying their presence. Efforts were also made to add new species to the databank by collecting their eDNA from museum specimens.

At each of the four bridge sites water samples were collected at the proposed bridge location, upstream and where possible downstream of the proposed bridges. These sites were considered replicates to gain a fuller understanding of taxon potentially impacted by development at the site. Water was taken from various parts of the water column to reduce the chance that stratification of eDNA within the water column did not result in species being missed.

Water samples were collected by an ecologist using standard water eDNA test kits which include a mixing bag, sterilised sampler, and a pair of gloves. Water was collected by filling either a collection bag or a clean bottle on a sample grabber pole, positioned with the bottle opening facing upstream. Water for eDNA analysis was then filtered from each site using sterile syringes. At each bridge site, 2 to 4 samples were collected. One to two were collected at the proposed bridge site and another upstream and another downstream from the site where it was possible. Each sample was collected by passing up to 1400 ml of water (mean = 748 ml) through a 1.2-micron disc filter. Filtration was undertaken on-site to reduce eDNA degradation during transport of water samples. A preservative was added to the filters after filtering to minimise eDNA degradation.

Clean, nonpowdered, single-use gloves were worn during sample collection and filter removal. Care was taken to prevent the gloves from touching any contaminated surfaces, such as equipment that had not been sterilized using a solution of 10% bleach applied with a spray bottle between sites. In cases where entering the stream was necessary, samples were collected upstream of the standing location to reduce the potential for contamination from boots, clothing, or equipment. These activities were done to avoid contaminating of the site with eDNA from another area.

Filters were stored out of sunlight and at ambient temperature before being transported to the laboratory for processing. DNA processing was undertaken by a specialist lab, Enviro DNA Pty., in Australia. Due to the preservative in each filter, refrigeration was not necessary for these samples.

Processing of eDNA

Freshwater species identification was based on DNA metabarcoding and high-throughput DNA sequencing technologies from water samples collected at the sites and up and down-stream. The specialist labs conducted DNA library preparation, high-throughput DNA sequencing, and ran extensive bioinformatics pipelines resulting in Fish, Decapods, Invertebrates, and Mollusc species identification. More specifically, DNA metabarcoding compares DNA sequences recovered from the samples to genetic reference libraries enabling identification of the species. In cases where the identity could not be adequately resolved to a single species (e.g., due to shared haplotypes), either a list of multiple species is included, or the lowest taxonomic rank without further classification was assigned.

Attempts were made to add additional species were added to the reference libraries for future identification. We were however unsuccessful in obtaining samples of these additional species (Table 2). Further eDNA of key species added in the future to verify presence.

4.4 Targeted fish surveys

Fish traps were established at each site within 15 meters of the proposed bridge sites for one trap night and day including both the dusk and dawn periods when fish movement is greatest. The following nets were used at each site: 2 Fyke nets (Mesh size of 15 mm, 2 funnel throats), 2 minnow traps, and 2 kilwell. Kilwell traps were all set in or directly beside mangroves to target key fish species of interest which favour mangrove habitat. The mouth of the fyke nets were submerged to allow fish to enter the net. Nets were marked using flagging tape and the gps. All captures were identified to species level where possible. If any species were not possible to identify a reference species was kept for later ID.

4.5 Targeted bivalve surveys

Kai/freshwater mussels (*Batissa violacea*) in Fiji grow in the lower freshwater reaches of rivers, between the upper limit of saltwater penetration, and the upper reaches of the rivers.

Freshwater mussels (kai) had been identified as a matter of concern at the Sabeto site and were also potentially present at the Viseisei Bridge site. The saltwater conditions at Lami and Madraukutu Bridge are inappropriate habitat and surveys were not carried out in these areas.

The survey method involved snorkelling surveys which searched the substrate for bivalves while swimming along four 50m transects. Advantages to snorkel surveys include increased spatial area and depth of surveys and less disturbance to natural communities. A 1.5 person-hour visual search was conducted systematically from the upstream to downstream end of the survey site. Visibility was high within 2m depth and was reduced at areas greater than this requiring some diving down to greater depths. Visibility was adequate for identifying freshwater mussel areas. Where mussel species were present at a depth which made surveys possible four 1-meter square areas were selected (2 at the bridge site and 2 below the bridge site) for density counts.

5. Fauna and Flora survey rationale

Fauna and flora species considered for management are those species listed under:

- An IUCN Red listed Threatened species.
- Listed in the Appendices of the Convention on International Trade in Endangered Species (CITES).
- Listed in the Endangered Species Protection Act (2002) and any subsequent amendment.
- Identified in Fiji's Biodiversity Strategy and Action Plan (NBSAP 2007)
- Threatened species, known by local experts, but not yet listed in the national and international documents.
- Culturally important
- Occurs in an endangered ecosystem.
- Endemic to Fiji and potentially present

Terrestrial and aquatic surveys, literature reviews and speaking to in country experts allowed classification of the potential species at risk in the area. Where the presence of any suitable habitat for species was documented within the footprint, it is assumed on a conservative basis that their presence cannot be discounted. Therefore, relevant taxa specific measures are later proposed to mitigate/offset potential impacts.

Species which are data deficient have inadequate information to make a direct, or indirect, assessment of its risk of extinction. We have taken a precautionary approach and for the purpose of this study for these species and assumed they are present so that mitigation actions are appropriately considered.

6. Assessment of effects methodology

Ecological impacts of the Project were assessed based upon the ecological resources identified as being at risk from the present development scenarios. Both negative and positive impacts were considered, and cumulative impacts of this and other projects were assessed. Mitigation measures were developed to reduce negative impacts, and residual impacts following implementation of all feasible mitigation measures. Impact assessment and development of mitigation measures were conducted in accordance with the Ecological Impact Assessment guidelines (EcIA) (Roper-Lindsey et al., 2018). A description and assessment of terrestrial, marine and freshwater ecological values is provided for the bridges and surrounding locale (project footprint).

The significance of ecological impacts is evaluated based primarily on the following criteria:

- Habitat quality.
- Species affected.
- Size/abundance of habitats/organisms affected.
- Duration of impacts.
- Reversibility of impacts; and
- Magnitude of environmental changes.

Impacts are generally ranked as "minor", "moderate" or "severe", although in a few cases a ranking of "minimal" (less than "minor") may be given. The ranking of a given impact will vary based on the criteria listed above. For example, an impact might be ranked as "minor" if it affected only common species and habitats, or if it affected only small numbers of individuals or small areas, whereas it might be ranked as "severe" if it affected rare species or habitats, large numbers of individuals or large areas. A degree of professional judgement is involved in the evaluation of impacts.

7. Literature Review

Fiji's terrestrial biodiversity consists of approximately 2641 known vascular plants (35% endemic), over 5024 insect species, more than 100 terrestrial molluscs and crustaceans, over 120 bird species of which ten are endemic, 18 mammals, 36 reptile species, 3 amphibians and 99 freshwater fish species. 98% of Fiji's endemic species are terrestrial and 1.7% are marine. Land based mammal species comprise native bats and introduced rodents and domestic animals. Thirteen reptile species in Fiji are listed as globally threatened and 55 species of plants are currently listed as globally threatened by IUCN.

Over 2000 species of fish are recorded from Fiji's coastal and marine areas (SOE 2020, Government of Fiji 2017). At present, 166 species from 47 families of freshwater and estuarine fishes in the Fiji Islands are recognised. Of these, 10 are non-native species and at least 13 species are considered endemic to the Fijian Islands (table 3). Further species have recently

been identified and are still being named (table 3). Sixty-four freshwater fish species are recorded. Many freshwater species in Fiji are widespread in the Pacific and Indo-pacific area.

Fiji's marine fish fauna consists of 1198 species of reef, pelagic and deepwater fish, only 45 species marine fish are listed as globally threatened on the IUCN Red List including 27 shark and ray species and 18 other fish. Whilst many fish species are not listed as threatened (due to their larger range and ability to occupy a variety of freshwater, estuarine and marine habitats), a large number (40%) are listed as Data Deficient, including several of the endemic species (See Table 2).

Fijis marine fauna also consists of 6 turtle species, 760 species of gastropods and bivalves, 4 species of sea snakes, 422 species of algal flora, and 33 mangrove and mangrove associated species. Fiji's invertebrate fauna has received little attention and many groups have not been studied at all.

Fiji freshwater mollusc fauna consists of 9 families and 71 species, of which 30 (43%) are endemic (Haynes, 2015). There are 28 species of *Truncatelloidean* (springs snails) gastropods in the genus *Fluviopupa* in Fiji [2][3]. Two endemic gastropods, *Acochlidium fijiense* and *Fijidoma maculata* are of conservation interest though they have not been evaluated by the IUCN (Table 2).

The Ecologically Appropriate Area of Assessment (EAAA) for molluscs is defined as the area within 500 meters up or downstream of the site. The aquatic mollusc species of concern are unlikely to occur at any of the 4 bridge sites since the habitat is not appropriate and/or the species are unlikely to occur within the EAAAs. No critical habitat is triggered by this species group at any of the four sites (see Table 2).

Table 2. Mollusc species IUCN status, distribution, and likelihood of occurrence at the bridge sites. The species potentially triggering critical habitat are highlighted in grey.

Species names	IUCN status	Distribution	Life history information	Habitat within the EAAA	Critical Habitat Rationale
Acochlidium fijiense	Not evaluated by IUCN	Endemic to Fiji and likely a restricted-range species; *Acochlidium fijiense* has only been recorded from the Nasekawa River (Vanua Levu) and Lami River (Viti Levu) despite searches in other rivers on these two islands.	Surveys conducted by Haynes and Kenchington between 1983 and 1988 showed that *A. fijiense* lives under stones and rocks in shallow parts of streams (60-140 mm deep) influenced by the tide, but where there is no inflow of sea water. It is difficult to detect as it is well camouflaged, blending in with the stones under which it lives. This species was most abundant in the months October and July, and individuals were also reproductively	Unlikely to occur as habitat not appropriate at any of the sites and has only been discovered in one small area outside the EAAA. Experts suggest it is not likely to be present at any of the sites.	Not Critical Habitat: the species is not considered likely to occur within the EAAAs.

[2] Haase, M., Ponder, W.F., and Bouchet, P. (2006). The genus *Fluviopupa Pilsbry* from Fiji. Journal of Molluscan Studies, 72, 119-135.

[3] Zielske, S and Haase, M. (2014). New insights into tateid gastropods and their radiation on Fiji based on anatomical and molecular methods (Caenogastropoda: Truncatelloidea). Zoological Journal of the Linnean Society 172, 71– 102

			mature in the month of July.		
Fijidoma maculata	Not evaluated by IUCN	Endemic to Fiji and potentially a restricted-range species; found only on Viti Levu. They are found in the headwaters.	There is not much known on this species. Species found in the headwaters and requires a habitat of stones with a fast-flowing current. They can be found in patches on stones in fast flowing current. They feed on algal film and are eaten by fish.	Unlikely to occur in EAAAs as habitat not appropriate.	Not Critical Habitat: the species is not considered likely to occur within the EAAAs.
Septaria sp.	5 species in Fiji, Not evaluated by IUCN	Endemic to Fiji and potentially restricted-range	Prefer fast flowing freshwater streams (Ovalau, Tavenui)	Unlikely to occur in EAAAs as habitat not appropriate at any of the sites	Not Critical Habitat: the species are not considered likely to occur within the EAAAs.

7.1 Freshwater fish and crustaceans

Fijian freshwater fish species are dominated by diadromous migratory species which must move between the freshwater and the ocean to complete their life cycle. It is estimated that more than 98% of freshwater ichthyofauna in Fiji are diadromous, with amphidromous and catadromous species dominating life history strategies[4]. Amphidromous gobiids that migrate across a broad range of habitats throughout their life cycle make up most migratory species. As part of this assessment, we consider if ADB Criteria 3 of critical habitats: The area represents a site that is critical for the survival of migratory species; or supports globally significant concentrations or numbers of individuals of congregatory species is triggered.

All migratory fishes rely on water flow for their passage up and downstream. The reduction in forest cover along rivers and streams, especially in the terminal reaches, and infrastructure development such as dams and weirs have deleterious effects on the migration routes of the Fijian ichthyofauna[5]. The presence of invasive species such as tilapia and sedimentation can also impact migration[6]. For example, some species (e.g., gobies), also require clean rocks and river bottoms to physically move along the riverbed. Sedimentation interferes with their movement between habitats and can potentially prevent migration movement altogether7. As many freshwater fishes in Fiji move across multiple habitats during their life cycles, the

[4] Jenkins, A.P.; Jupiter, S.D.; Qauqau, I.; Atherton, J. The Importance of Ecosystem-Based Management for Conserving Aquatic Migratory Pathways on Tropical High Islands: A Case Study from Fiji. Aquat. Conserv. Mar. Freshw. Ecosyst. 2010, 20, 224–238

5 Copeland Lekima K. F., Boseto David T., Jenkins Aaron P. (2016) Freshwater ichthyofauna of the Pacific-Asia Biodiversity Transect (PABITRA) Gateway in Viti Levu, Fiji. Pacific Conservation Biology 22, 236-241

[6] Canonico, G. C., Arthington, A. H., McCrary, J. K., and Thieme, M. L. (2005). The effects of introduced tilapias on native biodiversity. Aquatic Conservation: Marine and Freshwater Ecosystems 15, 463–483.

[7] Jenkins, A.P.; Jupiter, S.D. Spatial and Seasonal Patterns in Freshwater Ichthyofaunal Communities of a Tropical High Island in Fiji. Environ. Biol. Fishes 2011, 91, 261–274.

management area for these species covers the entire river catchment including the estuarine and marine ecosystems.[8]

Given the lack of population and spatial information on critical habitats for key trigger species, a precautionary approach is adopted. The EAAAs may serve as critical habitats for certain key life history events, with species migrating to or through these sites, potentially triggering Criteria 3. Criteria 3 is met if, on a cyclical or regular basis, ≥1% of the global population of a migratory or congregatory species is present at any point in their lifecycle. Despite the numerous rivers in Fiji, it is calculated that >1% of the population could be present at the lower river sites based on the following rationale:

The lower river systems, where the bridges are located, serve as convergence points for all upper catchments, channelling migratory species (fish and crustaceans) through these areas to fulfil critical life history activities such as ocean spawning. For instance, the Sabeto River drains the Sabeto and Mountain Evan Ranges of Western Viti Levu, funnelling all migratory species from this catchment through the lower Sabeto River during their migration. Additionally, some species are restricted to a few catchments in Viti Levu, and not all rivers have suitable habitats, such as mangroves, which are critical nurseries. Appropriate hydrological flows, necessary for spawning, are also not present in all rivers. Assuming a 20% recruitment rate in areas where only 2 Rivers have appropriate features in the receiving area of the catchment 10% of the population would be recruiting through some of these rivers. This is likely to be the case for a number of species while others are more likely to have 1-5% of the population migrating through the area.

Criteria 2: The site holds at least 10% of the global population of one or more endemic range restricted species is potentially triggered for the fish species *Parioglossus triquetrus* (see Table 3). The habitat requirements for this species are met at all three mangrove sites: Madraukutu, Viseisei, and Lami. Although there is no direct evidence of their presence, the habitat is suitable, and the species has been found very close to two sites. Given the lack of population and spatial data, and the fact that only 11 individuals have been previously identified, indicating the species may be threatened, a precautionary approach is recommended. To address this, recommendations will be included in the BMP for further work on this species, including eDNA collection for future identification (no DNA is currently available to confirm presence of the species) and pre-surveys at Madraukutu, Viseisei, and Lami Bridge sites, as well as the surrounding areas.

[8] Jenkins, A. P. (2009). Freshwater and estuarine fishes of Fiji: current taxonomic knowledge and priorities for conservation. In 'Proceedings of the Inaugural Fiji Islands Conservation Science Forum'. (Eds A. P. Jenkins, S. R. Prasad, J. Bacchiochi, P. A. Skelton and N. Yakub.) pp. 50–51. (Ecosystem Based Management Project – Fiji: Suva.)

Table 3. Freshwater fish their endemic status, distribution, and likelihood of occurrence at any of the bridge sites. The species potentially triggering critical habitat are highlighted in grey. The bridge sites Lami(L), Madraukutu (M), Sabeto (S) and Viseisei (V) triggered and the Criterion triggered are noted.

Scientific name	IUCN status	Distribution and habitat use	Likelihood of occurrence within the EAAA	Critical Habitat Rationale	L	M	S	V
Neoconger tuberculatus (Castle, 1965), Common name: Swollengut worm eel	Data deficient	Only known from larvae collected in eastern Australia and 1 adult collected in a tributary of the Rewa, Viti Levu and 2 adults collected in Tavoro river, Taveuni. With this distribution, it seems unlikely that this is a restricted-range species. Habitat: Burrowing species inhabiting muddy bottom areas. Euryhaline, spawn at sea, occur in small numbers and usually only in the lower reaches of rivers and estuaries.	The species is recorded in mangrove habitat. Mangrove habitat is present at three of the project sites (exception the Sabeto site which does not have mangroves present). Information on the population is not readily available. No records of the species have been recorded within the EAAAs.	Not Critical Habitat: The species is not currently considered threatened and is unlikely to be a restricted-range species. While individuals may use the project site, they are not considered likely to be in globally significant concentrations, and there is no reason to suspect the sites are particular migratory stopover or bottleneck areas.	no	no	no	no
Yirrkala gjellerupi (Weber and de Beaufort, 1916) Common name: Duna/Freshwater snake eel	Data deficient	This species is known from one species collected in northern New Guinea (Digoel River) 200km inland from the sea and four specimens 4km up Savura Creek Viti Levu, Fiji in the western South Pacific collected in 2003 (McCosker et al. 2007). With this distribution, it seems unlikely that this is a restricted-range species. Likely to be an estuarine breeder and migration between the estuary and adjacent aquatic habitats. Likely to have a marine larvae phase. Burrowing species collected in course river sand a river bends.	Potentially present in all sites. Information on the population is not readily available. No records of the species have been recorded within the EAAAs.	Not Critical Habitat: The species is not currently considered threatened and is unlikely to be a restricted-range species. While individuals may use the project site, they are not considered likely to be in globally significant concentrations, and there is no reason to suspect the sites are particular migratory stopover or bottleneck areas.	no	no	no	no
Hippicthys albomaculosus	Data deficient	*Hippichthys albomaculosus* occurs in the fresh and brackish waters of Vanua Levu Island, Fiji (Jenkins and Mailautoka 2010). Only known from a small side tributary of the Dreketi River, Vanua Levu Island. 22 specimens, collected from a small mangrove covered tributary stream, schooling at the bank.	Unlikely to be present as not previously found on Viti Levu. However, habitat is appropriate within the EAAAs given that the species have been previously found in both in fresh and brackish	Not Critical Habitat: the species is not considered likely to occur within Viti Levu.	no	no	no	no

		Likely to be estuarine spawners migrating between the nearby aquatic environment.	waters near mangroves and in nearby freshwater environments. Information on the population is not readily available. No records of the species have been recorded within the EAAAs.					
Microphis ??? Common name: smooth freshwater pipefish	Not Assessed	Recently discovered species. Thought to be endemic and possibly a new genus. Found in the lower part of the Nakoronawa River in Kaduvu and the middle of the Kavula River above Lekutu Vanua Levu. Likely to be freshwater spawners who enter estuaries briefly. Found in freshwater in the shallows near banks with vegetation.	No records of the species have been recorded within the EAAAs. Unlikely to be present in Viti Levu and within the EAAA.	Not Critical Habitat: the species is not considered likely to occur within Viti Levu.	no	no	no	no
Glossogobius sp. (Hoese and Jenkins in prep)	Likely to be least concern.	Amphidromous species which is common and widespread across Fiji. Endemic and potentially a restricted-range species.	Not a species of concern however likely to be migrating through the sites.	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that all 4 sites sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle qualifying them as Critical Habitat under Criterion 3.	Yes, c3	Yes, c3	Yes, c3	Yes, c3
Redigobius leveri, previously reported as Gobius leveri (Ryan 1980). Common name: Levers' goby	Data deficient	This species is endemic to Fiji and is known only from the islands of Viti Levu, Vanua Levu and Taveuni. It is potentially a restricted-range species. Records exist from the Rewa River and Savura Creek (Viti Levu); Dreketi River and Kubulau (Vanua Levu) and Tavoro Creek (Taveuni). Present in all the high islands of Fiji. Only found in clear shallow flowing water in well	Unlikely to be present at any of the sites as fully freshwater resident utilising different habitat than that available at the 4 sites. No records of the species have been recorded within the EAAAs.	Not Critical Habitat: the species is not considered likely to occur within the EAAAs.	no	no	no	no

		forested areas and entirely absent in degraded waters. This is one of only two fully freshwater resident fishes, parental care of demersal eggs. quite common (approx. 20% of sites) in less disturbed freshwater areas throughout survey; likely widespread in less disturbed freshwaters of larger islands.						
Redigobius lekutu Common name: Lekutu goby	Data deficient	Freshwaters; creeks and rivers; below about 150 m elevation; rest on bottom or mid-water schooling; solitary or in groups; carnivore; benthic invertebrates; parental care of demersal eggs, presumed Vanua Levu endemic; known only from the upper Lekutu River system in Vanua Levu. This was collected at a site in the upper Lekutu River and is a new species to science. Is probably the rarest freshwater fish in Fiji. This is because it has only been encountered in a single small pool in the upper Lekutu River in Vanua Levu. It was present in abundance with no other species present in this isolated pool. This species is likely to exhibit parental care of demersal eggs, like others in the genus, and is not an amphidromous or migratory fish and is therefore likely site restricted.	Unlikely to be present at any of the sites as only found in Vanua Levu and habitat not appropriate. No records of the species have been recorded within the EAAAs.	Not Critical Habitat: the species is not considered likely to occur within Viti Levu.	no	no	no	no
Parioglossus triquetrus	Data deficient	Only known from 11 specimens collected in Naikorokoro Creek, Viti Levu. Creek is near Pacific Harbour and near Monfort boys' home, Viti Levu. Collected in muddy habitat near creek mouth. It is thus an endemic, restricted-range species. This genus is known to utilise mangrove swamps and creeks. Found in Marine Intertidal areas-Utilize Mangrove Submerged Roots. Genus often burrows in sand and mud, hover above the substrate to feed on zooplankton. Eggs are deposited in burros	The species is recorded in mangrove habitat. Mangrove habitat is present at three of the project sites (exception Sabeto). Information on the population is not readily available. No records of the species have been recorded within the EAAAs, but it is not clear that sufficient searches have	Potential Critical Habitat: Suitable habitat potentially exists at three of the project sites (exception Sabeto). Though the species was not found at the sites, it is possible the EAAAs regularly hold ≥10% of the global population size AND ≥10 reproductive units of a species of the global population occur at the three sites (exception Sabeto), qualifying these as Critical Habitat under Criterion 2.	Yes, c2	Yes, c2	No	Yes, c2

		and guarded by parents; larvae are pelagic.	been undertaken to demonstrate absence from any of the EAAAs. Species was in a Creek about 15 km west of Lami.	Madraukutu is the site of highest risk.				
Schismatogobius vitiensis Comon name: Fijian scaleless goby (Jenkins and Boseto, 2005)	Least concern	This species is endemic to Fiji and thus a restricted-range species. It has been recorded from several rivers on three major islands: Viti Levu, Vanua Levu and Taveuni (Jenkins and Boseto 2005). Amphidromous: spawns in freshwater and hatched larvae pass to sea to return post larvae to freshwater. Adults live in clear, fast flowing freshwater streams on sand, gravel, and pebble substrate.	Likely to migrate through all the sites. Otherwise, utilising habitat outside the EAAAs.	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical basis, ≥ 1 percent of the global population of this migratory species may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	Yes, c3	Yes, c3	Yes, c3	Yes, c3
Schismatogobius chrysonotus (Orange-spotted Scaleless Goby)	Not evaluated by IUCN	Fresh water; lowland creeks and rivers; below about 50 m elevation; rests on bottom; often buried in sand and pebbles, solitary or in small groups; carnivore; insects, larvae; presumed amphidromous; 41 mm SL; Fiji Islands endemic and therefore a restricted-range species; collected in Viti Levu, Vanua Levu, and Taveuni, presumed to be widespread in clear freshwater streams of the larger islands. Collected from 7 sites of 66 sites surveyed by David Boseto for MSc. Recently discovered new species to science.	Likely to migrate through all the sites. Otherwise, utilising habitat outside the EAAAs.	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through all 4 of the sites, qualifying them as Critical Habitat under Criterion 3.	Yes, c3	Yes, c3	Yes, c3	Yes, c3
Stenogobius (insularigobius) n. sp. Common name: teardrop goby	Not evaluated by IUCN	Recently discovered. Common species, Amphidromous, known from Viti and Vanua Levu but likely to occur on all high islands. Endemic to Fiji, and thus a restricted-range species.	Information on the population is not readily available. Likely to migrate through all the sites. Otherwise, utilising habitat outside the EAAAs.	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	Yes, c3	Yes, c3	Yes, c3	Yes, c3
Sicyopus (c.f. Juxtastiphodon) sp., Sicyopus	Not evaluated by IUCN	Found in fast moving fresh water; creeks and rivers; below about 20 m	Unlikely to be present as Tavenui	Not Critical Habitat: the species is not	no	no	no	no

"merielae" n. sp. (Jenkins & Boseto, in preparation) – Meriel's Goby		elevation; rests on bottom; solitary or in groups; carnivore; small crustaceans and fishes; presumably amphidromous; Fiji Islands endemic and therefore a restricted-range species; highly likely to be a Taveuni Island endemic restricted to fused rock wall streams; known only from specimens collected in Waitavala Creek, Taveuni.	restricted endemic. No records of the species have been recorded within the EAAAs. The species is recorded to occur in fast moving streams and this habitat type is not present within the EAAAs.	considered likely to occur outside Taveuni.				
Stiphodon sp.1, Isabella's goby	Not evaluated by IUCN	Collected on Viti Levu, Vanua Levu, Tavenui and Kadavu. Endemic, and thus a restricted-range species. Found in swift clear streams over rocky bottoms. Amphidromous	Likely to migrate through the sites otherwise utilising habitat outside the EAAAs.	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	Yes, c3	Yes, c3	Yes, c3	Yes, c3
Stiphodon sp.2 (Jenkins, Boseto and Watson)	Not evaluated by IUCN	Collected on Viti Levu, Vanua Levu, Tavenui and Kadavu. Endemic, and thus a restricted-range species. Found in swift clear streams over rocky bottoms. Amphidromous	Likely to migrate through all the sites for key life history events. Otherwise, utilising habitat outside the EAAAs.	Potential Critical Habitat: The 4 EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	Yes, c3	Yes, c3	Yes, c3	Yes, c3
Lentipes kaaea (Watson, keith and Marquet 2002) Common name: rednosed goby	Least concern	Species has been collected in New Caledonia, Vanuatu, Soloman islands and Fiji. In Fiji collected in Tavenui island from a single stream (waitavala) and from Kadavu from Wana Ck, Nakaseleka. Amphidromous- spawns in freshwater which hatch in the sea, return post larvae to freshwater. In swift, clear high gradient streams.	Unlikely to be present at any sites as only in Taveuni. No records of the species have been recorded within the EAAAs.	Not Critical Habitat: the species is not considered likely to occur outside Taveuni.				
Akihito sp.	Not evaluated by IUCN	Likely to be habitat restricted to the fused rock wall streams of	Unlikely to be present at any	Not Critical Habitat: the species is not				

Common name: Taveuni free-tongue goby		northwestern Taveuni but because they are likely amphidromous species, and their populations can exist in upper, middle, or lower reaches of these types of streams they are therefore ranked lower in terms of rarity. Endemic, and thus a restricted-range species.	sites as only in Taveuni. No records of the species have been recorded within the EAAAs.	considered likely to occur outside Taveuni.				
Sicyopterus n. sp. (Boseto, in preparation) – Tavoro Goby	Not evaluated by IUCN	Freshwater species; lowland creeks and rivers; below about 40 m elevation; rests on bottom; solitary or in groups; herbivore; filamentous algae growing on rock surfaces; hatching and larval stage presumably occurs at sea, postlarval stage to adult in freshwater; an undescribed species likely to be a Fiji endemic, most closely resembles S. lagocephalus (Pallas 1770) but with several meristic differences including much lower transverse scale counts. This is a new species to science. Endemic, and thus a restricted-range species.	Information on the population is not readily available. Potentially present. Status unclear.	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	Yes, c3	Yes, c3	Yes, c3	Yes, c3
Datnia kneri / (Bleeker, 1876) (Terapontidae) Common name: Orange-spotted Therapon/Reve	Not evaluated, likely threatened by mangrove clearance	Recorded in Kadavu, Viti levu, Taveuni and Totoya but likely to also be in Vanua levu and other islands. Endemic, and thus a restricted-range species. Juveniles found in freshwater all the way to mid catchments and adults tend to be in low reach freshwater and estuarine environments. Thought to be a catadromous obligate: spawns in the sea and juveniles and subadults must access freshwater. Found in mouth of creeks with silt in substrate mangrove forest. Species is usually found in estuarine mangroves habitats. Important food fish seen in the market.	The species is recorded in mangrove habitat. Mangrove habitat is present at three of the project sites. Juveniles and subadults could be present at the Sabeto site where there are no mangroves. Information on the population is not readily available. Potentially present. Status unclear.	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3. It is not considered likely, however, that >10% of the species' population occurs at any of the sites at any time, thus meaning they do not qualify as Critical Habitat under Criterion 2.	Yes, c3	Yes, c3	Yes, c3	Yes, c3

Crustaceans

Fiji's known crustaceans include 10 species of palaemonid prawns (all native to Fiji except *M. rosenbergii*), 14 species of shrimp of which only three (21%) are endemic (*C. devaneyi, C. fijiana*

and *C. nudirostris*) (Table 2) and three crab species (*Varuna litterata, Labuanium trapezoideum* and *Utica gracilipes*), which are widely distributed throughout the Indo-Pacific region.

Many of these crustacean species migrate up and down the catchment for critical life history events. *C. devaneyi*, *C. fijiana* and *C. nudirostris* potentially trigger the criteria for critical habitat defined by ADB *Criteria 3 (Teir 2) (see Table 4).*

C. nudirostris and C. devaneyi, would only potentially trigger criteria 3 at Lami and Madraukutu bridge during migration for the larval phase since they only occur on that side of the catchment according to the IUCN redlist.

Table 4. Endemic freshwater crustaceans their IUCN status Least concern (LC) and Data deficient (DD), distribution, and likelihood of occurrence at the bridge sites. The species potentially triggering critical habitat (CH) criteria are highlighted in grey. The bridge sites Lami(L), Madraukutu (M), Sabeto (S) and Viseisei (V) triggered and the Criterion triggered are noted.

Name	IUCN status	Distribution	Life history information	Presence at the sites	Critical Habitat Rationale	L	M	S	V
Caridina fijiana	LC	Viti Levu, Fiji. According to Choy (1983, 1991), *C. fijiana* is primarily a montane species recorded from altitudes above 600 m. Endemic, and thus a restricted-range species.		Adults will be outside the sites of interest. Migration may occur through all four sites for reproductive purposes.	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that >1% of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	Yes C3	Yes C3	Yes C3	Yes C3
Caridina nudirostris	DD	At present it is known only from the island of Viti Levu. Nanuku & Wainisavulevu Creeks, central Viti Levu, 160-700 m altitude. Endemic, and thus a restricted-range species.	Montane species having a few, large eggs thus suggesting abbreviated or direct larval development	Adults these will be outside the sites of interest which are not freshwater or outside the geographic range. The species maybe however maybe utilising the two sites- Lami and Madraukutu bridge for larval development. This area is therefore considered potentially important for migration of this species.	Potential Critical Habitat: The EAAAs are not habitat except possibly at Lami and Madraukutu bridge during migration. At that time, it is possible that >1% of the global population may migrate through those two sites, qualifying them as Critical Habitat under Criterion 3.	Yes C3	Yes C3	No	No
Caridina devaneyi	DD	The species is only known from the type series collected in 1933 from a single stream near Suva, Fiji (Choy 1991) and from two sites- stream at 8-mile Point near Suva, Viti Levu, Fiji Islands and recently	Amphidromous freshwater shrimps utilise freshwater as adults but require saline environments for larval development. Lecithotrophic larval development trait may be	*Caridina devaneyi* adults these will be outside the sites of interest as the habitat is not suitable or outside the geographic range, two sites- Lami and Madraukutu bridge maybe used for larval development. This area is therefore	Potential Critical Habitat: The EAAAs are not habitat except possibly at Lami and Madraukutu bridge during migration. At that time, it is possible that >1% of the global population may migrate through those two sites, qualifying them as	Yes, C3	Yes, C3	No	No

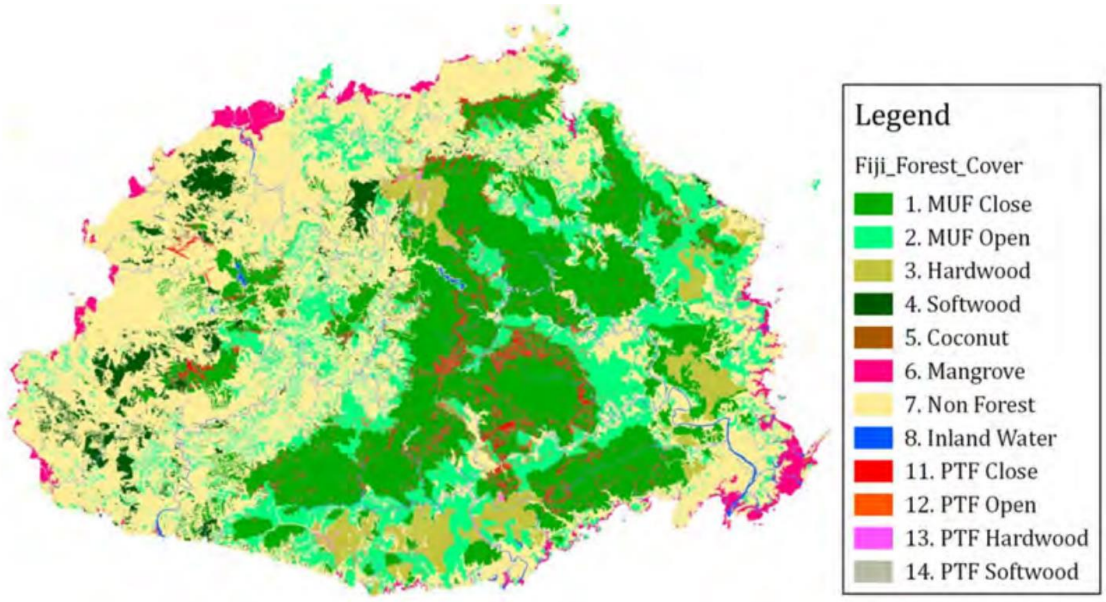
		found in the Tunuloa catchment, Vanua Levu (Ref: Tunuloa BIORAP – a rapid biodiversity assessment, archaeological survey of the Tunuloa catchment and Mataqali consultations to confirm interest to formalize existing Terrestrial Protected Area). Distribution potentially limited. Endemic, and thus a restricted range species.	selected in amphidromous shrimp species that inhabit the upper portions of rivers or streams, in which breeding and larval hatching occur. Thus, the newly hatched larvae require a relatively longer period for downstream transport in food-limited freshwater environments until they reach the sea.	considered potentially important for breeding migration of this limited distribution species.	Critical Habitat under Criterion 3.				

7.2 Mangroves

Fiji has the third-largest mangrove area (41,000 ha) in the Pacific Island Countries (Figure 2). Mangrove forests are an important ecosystem in Fiji because a large portion of Fiji's population, infrastructure, and economic activities are centred around coastal areas. Mangrove resources are one of the main livelihood support systems for coastal/deltaic dwellers. The flora consists of seven obligate species (Watling 1985,1986). These include the Rhizophora hybrid `*Selala*' (*R.stylosa x R. samoensis*). There are no endemic mangrove species and no terrestrial vertebrates known to be confined to mangroves in Fiji.

Mangrove forests provide various important ecological traits and ecosystem services including but not limited to:

- Habitat for a wide range of species including birds, reptiles, crustaceans, molluscs, etc.
- Nutrient filter and sediment trap.
- Spawning/breeding and nesting grounds for birds and fish.
- Habitat for numerous juvenile life stages, especially reef fishes of commercial importance.
- Buffer to coastal energy (storms, high wave energy).



Source: Ministry of Forestry

Figure 2. Vegetation Map of Viti Levu

7.2.1 Mangrove legal status

In 1933 all Mangroves were constituted Forest Reserve and were managed by the Forestry Department but in 1974 a cabinet Decision deproclaimed all Mangrove Reserves, (Legal Notice 52 of 1975), after which all Mangroves came under the jurisdiction of the Lands Survey Dept as an integral part of Foreshore. The same cabinet paper (CP 74(234)) instituted re-compensation for loss of Fishing Rights[9].

Mangroves are included within the Environmental Management Plan (2005) and the Protected Species Act (2002) and have been included as priority habitats for conservation and restoration under Fiji's Emission Development strategy 2018-2050 (MoE, 2018).

8. Madraukutu Bridge Ecological Values

8.1 Terrestrial ecology

The bridge site lies on the foreshore permeating into an area of natural habitat consisting of medium to high quality mixed mangrove forest (see Figure 3-6). The mangrove vegetation is dominated by *Bruguiera gymnorhiza, Rhizophora stylosa* and *Rhizophora samoensis.* The study area had a low plant diversity and simple structure. The mangrove trees in the natural forest were 5-20m in height. The narrow fringing belt of Rhizophera mangroves sp. on the coastal edge is consistent with that found along this coast of Fiji with a change of mangrove species dominance further inland.

The mangrove trees present on the East side of the bridge covered an area from the current present bridge and roadside all the way to the rocky foreshore. A medium quality area consisting

[9] A MANGROVE MANAGEMENT PLAN FOR FIJI (PHASE 1) – FEBRUARY 1983, Dick wattling

of mangrove habitat which had previously been disturbed had young 1-meter-tall mangrove plants covering a 2 by 3-meter area. Other than this small area where there had been previous anthropogenic disturbance the rest of the area was considered high quality natural habitat with old growth mangrove trees 5-7 meters tall. There were no alien trees present. Mangrove density was 8-12 trees per meter squared (n=4) on the East side of the bridge in the area where plants would be removed and predominantly covered the high-quality natural mangrove habitat.

Access to the West side of the bridge could only be assessed from the bridge due to the presence of an aggressive dog. However, the area of mangroves within 4 meters of the shore was considered high quality natural habitat with the mangrove area formed largely by native mangrove plants. Here human activity had not modified the area's primary ecological functions. The habitat further was increasingly modified within 6-8 meters of the road with increasing numbers of alien plants. Further sensitive natural intertidal estuarine habitat is immediately adjacent and intersects with the planned area for the bridge (see Figure 3). No terrestrial species threatened or known to be rare was found in the terrestrial study area.

Despite the occurrence of natural areas of mangrove forest at the proposed site, in the larger surrounding landscape there is strong evidence of human disturbance, clearance, and mangrove fragmentation (see Figure 3). The greater mangrove area covers an area of approximately 2.91ha.

Based on the current design, the estimated clearing of native mangrove vegetation for the proposal is approximately 2,349m^2 (inclusive of the 3m buffer surrounding the bridge where some damage may occur) on the outer edge of the larger mangrove ecosystem (see figures 3-6). The direct area of estimate is 8.07% of the total mangrove area (Table 5).

Table 5. Percentage of mangrove directly impacted and remaining following the proposed removal for bridge development.

Site	Total mangrove area (m^2)	Mangrove directly impacted (m^2)	Total remaining (m^2)	Mangrove direct effected (%)	Mangrove remaining following direct impact (%)
Madraukutu	29,100	2349	26751	8.07	91.93

8.2 Aquatic ecology

The Madraukutu bridge site is adjacent to the Suva harbour area. The estuarine area is approximately 27m wide at the proposed development point and intertidal. The substrate substrates are muddy. The site is of high ecological value.

The eDNA sampling locations were: 1) at the proposed bridge site and 2) 54 meters within the mangroves. There was good water flow during the survey periods and good-water quality.

EDNA sampling revealed that there are 13 species of fish and 3 species of crustacean and 13 mollusc species using the Madraukutu bridge site (See appendix Tables 38-42). Netting and

trapping did not add further species to the species list above that provided through eDNA sampling (Appendix, Tables 38-42) but provided an additional baseline of what was present (See appendix). No additional targeted species such as *Parioglossus triquetrus* were captured. The Tilapia (*Oreochromis spp.*) present within the site is likely to impact the native fish species present and could be led to future declines.

Many of the Fijian fish and crustacean species migrate up and downstream (are amphidromous) to complete critical life history. Given that the eDNA sampling only occurred during one period it is expected that species that will utilise the river site for key migratory life history events will be underrepresented.

Figure 3.The mangrove area surrounding the proposed bridge area shows high fragmentation.

Figure 4. The affected area of mangrove and marine habitat on a) the east side and b) west of the proposed bridge.

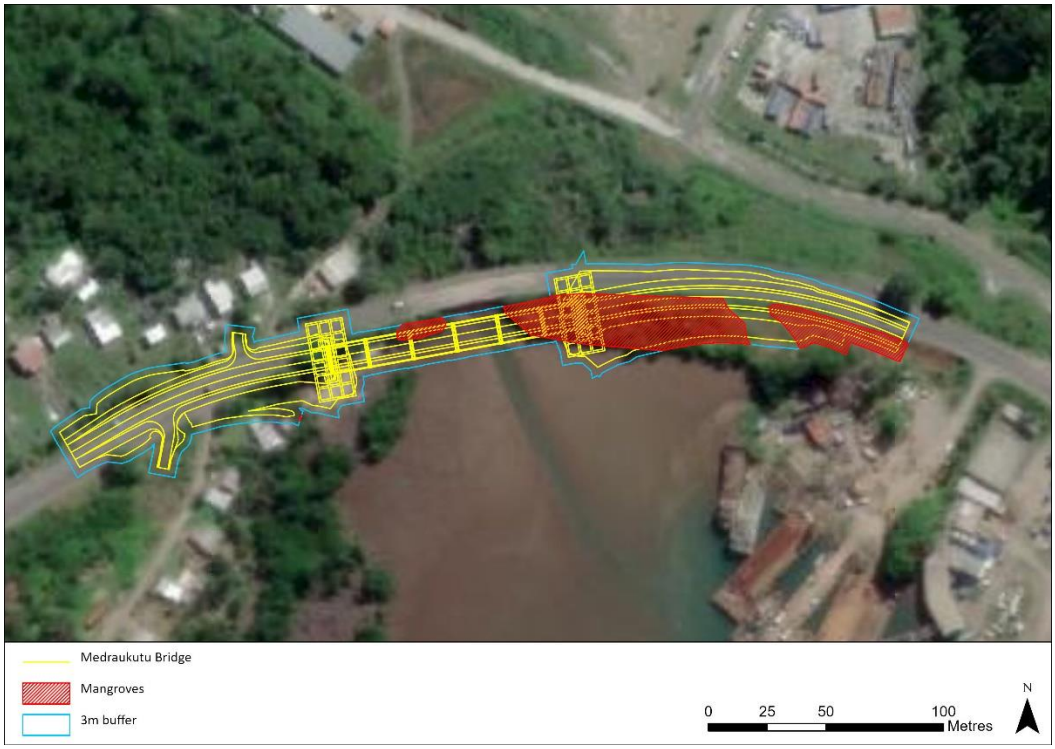


Figure 5. The proposed bridge and area of natural habitat (mangrove) which would be removed (including 3m buffer area).

Figure 6. The natural and modified habitat surrounding the proposed bridge site.

9. Madraukutu Bridge critical habitat triggers

Literature reviews, database surveys, eDNA surveys and field visits identified no endangered species of conservation significance based on the IUCN Red List of Threatened Species as present at the bridge site, or within the EAAA of the site. However, there are endemic and range restricted species of both crustacean and fish species which are data deficient and have not yet been evaluated by the IUCN for which the habitat is suitable (See Table 2 and 3). Of these eight fish species and three endemic freshwater crustaceans are only potentially present during key life cycle events or during migration. We have taken a precautionary approach and assumed they are present on a migratory bases whereby they trigger criteria 3 for critical habitat (See table 6 and 7).

Table 6. Freshwater fish triggering critical habitat and criterion triggered.

Scientific name	Critical Habitat Rationale	Criterion Triggered
Glossogobius sp. (Hoese and Jenkins in prep)	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that all 4 sites sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle qualifying them as Critical Habitat under Criterion 3.	3
Parioglossus triquetrus	Potential Critical Habitat: Suitable habitat potentially exists. Though the species was not found at the sites, it is possible the EAAAs regularly hold ≥10% of the global population size AND ≥10 reproductive units of a species of the global population occur, qualifying these as Critical Habitat under Criterion 2. Madraukutu is considered the site of highest risk.	2
Schismatogobius vitiensis Comon name: Fijian scaleless goby(Jenkins and Boseto, 2005)	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical basis, ≥ 1 percent of the global population of this migratory species may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Schismatogobius chrysonotus (Orange-spotted Scaleless Goby)	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through all 4 of the sites, qualifying them as Critical Habitat under Criterion 3.	3
Stenogobius (insularigobius) n. sp. Common name: teardrop goby	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Stiphodon sp.1, Isabella's goby	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Stiphodon sp.2 (Jenkins, Boseto and Watson)	Potential Critical Habitat: The 4 EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Sicyopterus n. sp. (Boseto, in preparation) – Tavoro Goby	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Datnia kneri / (Bleeker, 1876) (Terapontidae) Common name: Orange-spotted Therapon/Reve	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3. It is not considered likely, however, that >10% of the species' population occurs at any of the sites at any time, thus meaning they do not qualify as Critical Habitat under Criterion 2.	3

Table 7. Endemic freshwater crustaceans triggering critical habitat (CH) criteria and rational at Madraukutu.

Name	Critical Habitat Rationale	Criterion Triggered
Caridina fijiana	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that >1% of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Caridina nudirostris	Potential Critical Habitat: The EAAAs are 3 habitat 3 at 3 Madraukutu bridge during migration. At that time, it is possible that >1% of the global population may migrate through this site, qualifying them as Critical Habitat under Criterion 3.	3
Caridina devaneyi	Potential Critical Habitat: The EAAAs are not habitat except possibly at Lami and Madraukutu bridge during migration. At that time, it is possible that >1% of the global population may migrate through those two sites, qualifying them as Critical Habitat under Criterion 3.	3

There are also two species *Datnia kneri /Mesopristes kneri* and *Parioglossus triquetrus* which are data deficient/not evaluated by the IUCN which maybe present all year. Both species are known from areas outside the EAAAs and are lacking information on population status and spatial coverage.

For *Datnia kneri /Mesopristes kneri* appropriate habitat requirements are met at this project site. This species was not however present in any of the eDNA samples collected (there was no unidentified Terapontidae genus in the eDNA) at any of the sites. This suggests that the species was not present during the survey periods at this site. Expert opinion suggests that it is unlikely the EAAAs regularly holds ≥10% of the global population size AND ≥10 reproductive units of a species. The threshold for Criteria 2 is therefore not meet for this species. However, this species triggers Criteria 3 since they are likely to migrate through the site (Table 6).

Parioglossus triquetrus is an endemic. The species has previously been recorded in a Creek 15 km west of Lami. Which is relatively close to Madraukutu bridge site. This area where the species was found previously is however a smaller tributary, so the habitat was different from this project site. The habitat requirements of this species are suitable at the Madraukutu bridge site given that mangroves are present.

No records of the species have been recorded within the EAAA. Individuals were seen in the mangroves while doing snorkel surveys and no *Parioglossus triquetrus* were captured during the surveys despite effort. However, the species is known to be difficult to capture. Further, *Parioglossus triquetrus* was not in the eDNA library which did not allow this species to be identified directly through the eDNA samples. There is unidentified Gobiidae in the eDNA samples which could be *Parioglossus triquetrus.*

It is possible that the Madraukutu EAAA potentially regularly holds ≥10% of the global population size AND ≥10 reproductive units of a species. Therefore, consideration is given to potential project-related adverse impacts and on a precautionary bases it has triggered Criteria 2 at this site (Table 6).

9.1 Critical Habitat-qualifying ecosystems

ADB Criterion 4 states " The area includes unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services;"

Criterion 4 relates to specific landscape features which are critical for ecological functions. Examples of these within the sites includes riparian zones and rivers, dispersal/migration

corridors (rivers), hydrological regimes, and keystone or habitat-forming species (mangroves and freshwater mussels).

The rivers, estuaries, and mangrove surrounding Madraukutu provide critical shelter and food for aquatic species and function as migration corridors maintaining key life cycle events. The mangrove river systems are recognised as key ecosystem providers e.g., breeding and nursery habitats for fish species, storms and floods, erosion control functioning locally and regionally as important ecosystem services. By providing these ecosystem services they trigger critical habitat criterion 4.

9.2 Protected Areas

There is one protected area in the vicinity of the Madraukutu bridge project (Figure 7). Madraukutu bridge is in a designated locally managed marine area. This area is called Vueti Navakavu and has been designated as a Locally Managed Marine Area at National level in 2001. Vueti Navakavu MPA is now a permanent reserve, which was initiated by the community and later declared through the defined cultural protocol systems. It covers 18.70 km^2 and it is managed by Qoliqoli Committee. The community's vision is to improve the management and protection of their marine area to provide a healthy and vibrant ecosystem that will support abundant and diverse marine life for food source and secured income sources. Mangroves are included under protection as they are considered important fish spawning areas.

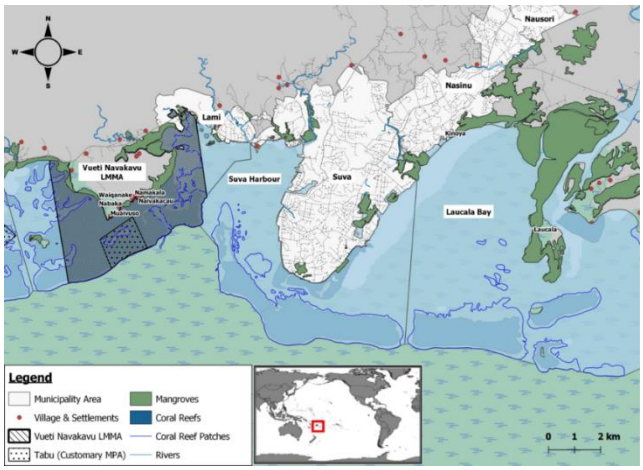


Figure 7. The Vueti Navakavu LMMA.

The reserve is not formally designated or gazetted under national law, and as such does not have formal recognition under Fijian laws that can be enforced by the local community. The community-based marine protected area is supported though by the national government's legal framework for “customary fishing rights areas" within the Fiji Fisheries Act.

9.3 Critical habitat criteria triggered

The critical habitat triggered at the Madraukutu by each of the ADB criteria are outlined (Table 7).

Table 8. ADB criteria critical habitat triggered at the by Madraukutu bridge site.

Criteria	Thresholds	Critical habitat triggered
1: Critically Endangered and Endangered Species	(a) Areas that support globally important concentrations of an IUCN Red-listed EN or CR species (≥ 0.5% of the global population AND ≥ 5 reproductive unitsGN16 of a CR or EN species). (b) Areas that support globally important concentrations of an IUCN Red-listed Vulnerable (VU) species, the loss of which would result in the change of the IUCN Red List status to EN or CR and meet the thresholds in GN72(a). (c) As appropriate, areas containing important concentrations of a nationally or regionally listed EN or CR species	no
2. Endemic / Restricted Range Species	(a) Areas that regularly hold ≥10% of the global population size AND ≥10 reproductive units of a species.	Yes, potentially holds ≥10% of the global population size AND ≥10 reproductive units of the species *Parioglossus triquetrus*
3. Migratory / Congregatory Species	(a) Areas known to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle. (b) Areas that predictably support ≥10 percent of the global population of a species during periods of environmental stress.	Yes, likely to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a number of migratory or congregatory species
4. Critical habitat qualifying processes/ecosystems	The area includes unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services	Yes, provides key ecosystem services
5: The area holds biodiversity of significant social, economic, or cultural importance to local communities		Yes, significant fishing area
Criterion 6: Protection		Yes, within a protected area

10. Ecological effects

This section of the report considers the potential impacts of project operation on terrestrial mangrove, freshwater, and intertidal ecology. Ecological effects on both the terrestrial and aquatic varies during construction and during operation are both summarised in (Table 8 and 9). Ecological impacts may operate over a longer timescale, as populations and species take time to respond to environmental changes (time-lag).

10.1 Construction effects

Severity and spatial extent of the effects will depend on construction practices, timing of construction activities and controls, river flows, composition of substrate, and effectiveness of erosion controls.

10.1.1 Noise and disturbance

Considerable noise and visual disturbance may be generated during site formation and construction, potentially affecting the distribution and behaviour of fauna of the adjacent/remaining habitats. Due to the ranking of conservation importance of the species recorded, and the temporary nature of the impact, potential impacts to fauna from this source are likely to be minor if construction activities occur outside the wet season when critical migration and life cycle activities occur. There is a possibility, however, that mangroves are used for some critical life history stages, e.g. nursery grounds, by some of the sensitive species.

10.2 Terrestrial ecology

10.2.1 Site formation

Natural Mangrove habitat will be removed from Madraukutu site during development for bridge placement. Natural habitat loss will require mitigation and offsetting (refer residual impacts-mangrove habitat loss) to ensure a net benefit.

In addition to the direct loss of vegetation for bridge placement, the project may impact vegetation by:

- unauthorised clearing outside the subprojects site boundary
- clearing elsewhere e.g., to store materials.
- causing damage to surrounding vegetation through erosion (refer Suspended solid)
- changes to water quality (Suspended solid/water quality)
- introduction of invasive species (refer invasive species).

At Madraukutu the loss of vegetation increases habitat fragmentation. The increased isolation that may be caused by the proposal is not likely to have an appreciable impact however since functional connectivity would remain in the study areas. The effects could be offset or mitigated through mangrove restoration in both additional sites (offset) and restoration of mangroves in the sites surrounding the new bridge which are damaged by construction (mitigation). Post construction monitoring would ensure construction has not led to additional destabilisation effects on nearby mangroves surrounding the proposed bridges. Monitoring can also ensure that no more than the advised proportion of mangrove has been removed during construction activities.

10.2.2 Invasive species.

Invasive species have the potential to be spread by the construction e.g., through tracking of seeds on vehicles or machinery. Pathogens and invasive species may also be carried on, or in, materials, equipment (including vessels used to transport materials or workers) and any workers

brought to the sites. This includes materials, equipment and workers bought from other countries or elsewhere in Fiji.

10.3 Intertidal ecology

10.3.1 Intertidal Construction Works

There will be no reclamation involved in the proposed development. Construction works within the intertidal zone, however, would be required for Madraukutu. The area of seabed effected for the site is sandy and muddy bottomed. Due to the small scale of construction works involved, impacts are ranked as largely minimal in nature if sedimentation impacts can be contained.

10.3.2 Suspended solid.

Construction activities, may also impact indirectly upon the intertidal marine environment through re-suspension of sediment from excavation, dredging and site formation activities, and site runoff at Madraukutu. Re-deposition of suspended solids has the potential to affect marine benthic communities and to alter seabed characteristics. No seabed assemblages of high conservation value have been recorded within the study site. Outside the study site in the greater area there is coral reefs and there is likely to be seagrass. It is recommended to avoid impacts on these ecosystems by containing and minimising sedimentation during construction activities to as close to the site of the bridge development as possible.

A plan is needed to ensure the implementation of appropriate design and management techniques to reduce sedimentation risks during construction are low particularly during dredging or when piles are being placed. Turbidity curtains are one method which could be used to create a temporary barrier to ensure silt and debris are contained during construction. Provided sedimentation risks can be manged no unacceptable indirect impacts to marine ecological resources are predicted to occur during the construction and operations if turbidity readings are within the acceptable range <25 NTUs outside the turbidity curtains and/or 15 meters from the site edge.

10.4 Aquatic ecology

10.4.1 Suspended solid/water quality.

Environment construction activities and dredging could result in the increased sediment loading and site runoff of streams and changes in turbidity may impact adversely upon aquatic populations particularly sessile species.

High suspended and deposited sediments can smoother habitats and reduce the photosynthesis of benthic plants. Suspended sediments can also impact on aquatic biota by clogging the food filtering or trapping apparatus of stream insects as well as the gills of fish, reducing the feeding efficiency (particularly for visual predators). This is a concern at all the sites.

Multiple fish species present in the wider catchment migrate both upstream and downstream within streams and rivers during different stages within their lifecycle. High suspended sediment can slow or prevent the migration of native fish species. In a study on juvenile whitebait (banded

kokopu in New Zealand), fewer fish migrated upstream at turbidity > 25 NTU[10]. The study speculated that if the rate of migration of juvenile banded kokopu was slowed there could potentially be fewer juvenile fish reaching adult habitat, fish could potentially be subject to increased risk of predation and may not reach preferred upstream habitats while they are still able to climb as juveniles.

Through the implementation of appropriate design and management sedimentation risks can be managed reducing the level of effect to low. Management tools include: 1) turbidity barriers which can be used to lessen the spread of fine particles and 2) timing construction to avoid the rainy season and key migration periods for sensitive species. A turbidity meter should be used to measure the turbidity outside of the construction area impact site to ensure that turbidity readings are within the acceptable range of <25 NTUs outside turbidity curtains and 15 meters from the construction site edge.

10.4.2 Pollution incidents

Local ecological populations may also be adversely affected by pollution incidents attributed to fuel leaks and oil spills associated with construction and maintenance operations on site.

Cement is a construction related material which can have adverse on freshwater life. Cement has the potential to be discharged to the downstream receiving environment. Cement wash water and runoff from recently placed cement are of particular concern within aquatic habitats due to their detrimental effect on in stream fauna. Crushed concrete is also increasingly used as back-fill material and more frequently as contractors seek ways to be more sustainable and reuse materials.

Cement wash water and runoff has a high lime content which is water soluble (dissolves easily in water) and can drastically increase the pH of a waterway. The alkalinity can kill or severely burn aquatic life. For fish, the alkalinity is exceptionally damaging to sensitive gill structures. In addition to alkalinity, cement wash, and runoff can similarly increase the loading of fine sediment resulting in the same effects on instream fauna and habitat as those identified above for suspended/deposited sediment.

Concrete structures can leach and cause alkaline water. In addition to potential mortality of fauna, localised increases in pH (alkaline conditions) from leaching from concrete structures may also create a barrier to fish passage. These effects can be limited through careful management.

There is a particularly high risk of discharge of contaminants following discrete wet weather events or during prolonged periods of wet weather. Appropriate design and management can reduce these risks.

10.5 Impacts on fish and crustacean species of concern

Direct impacts on migratory fish and crustacean species are unlikely if there is minimal disruption to the flow of the river during the wet season (Nov-April) and key activities such as pile construction is limited to outside critical life history and migration periods. This will ensure any fish and crustacean migration is not obstructed during construction works within the riverbed and

[10] Richardson, J., Rowe, D.K., Smith, J.P.2001. Effects of turbidity on the migration of juvenile banded kokopu (*Galaxias fasciatus)* in a natural stream, New Zealand. Journal of Marine and Freshwater Research, 35:1, 191-196, DOI: 10.1080/00288330.2001.9516989

safeguard against risks. Timing construction outside the migratory wet season reduces the severity of the effect of construction to no more than minor.

Any impacts on most potential resident species of concern, should they be present, are likely to be small and predominantly limited to the construction phase. Such impacts are likely at Madraukutu given mangroves will be removed, and represent habitat for such species. Provided careful mitigation activity is taken e.g., care involving cement/concrete should ensure minimal effects. These species cannot be assessed against measurable impacts without known populations on site. Increasing the amount of suitable habitat for these species through the restoration of mangrove habitat should offset the losses of any individuals and associated habitat lost during construction allowing for net gains for these species to be achieved.

The most significant potential for impacts at a particular species is to the fish species of concern *Parioglossus triquetrus*, although this species is not confirmed from Madraukutu, its limited global distribution means that - if it is present - it may have a significant part of its global population present. Approximately 8% of the remaining mangrove at Madraukutu is planned to be removed. If *Parioglossus triquetrus* is present, this is likely to represent a significant impact. As such, on a precautionary basis, all efforts should be made to reduce mangrove loss at Madraukutu, and adequate restoration of mangrove should occur at or near Madraukutu to fully achieve a net gain of this habitat (and thus this species, if present).

10.6 Operational effects

10.6.1 Terrestrial impacts

The presence of the bridge structures will cause some shading of the riverbank and bed thereby potentially altering the aquatic flora present in the direct vicinity of the bridge. This impact is predicted to be minimal for Madraukutu bridge since it will be highly localised and when mangroves are shaded only a small area will be impacted. Furthermore, mangrove forest is not particularly sensitive to shading. Mitigation measures are not likely to be effective and are not deemed necessary.

10.6.2 Aquatic impacts

The physical presence of bridges during operation post construction can also affect aquatic ecological populations in several ways. Physical developments such as bridge pillars, dredging and alteration of embankments, and roading construction can result in channelization, and deep pool formation resulting in an ecological disturbance for aquatic fauna if habitat corridors become severed.

Disturbances from bridge construction can be mitigated if normal water flow is maintained despite the blocking effect of embankments and bridge piers. This objective can be achieved through designs that favour long spans and hydraulically shaped piers. Abutments should be set back from the normal wetted perimeter of the watercourse to avoid constriction of the channel and reduction of the flow area.

The length of the spans required are determined by the bridge design of the engineers. However, the longer the spans the greater contact with waterways can be reduced thereby reducing freshwater impacts.

Abutments and piers should be designed and constructed to provide the least amount of hydraulic resistance. Where piers are required, hydraulic shaped piers will minimize local scour and reduce obstruction of flow reducing impacts on the aquatic benthic environment. Piers should be constructed with ends which are tapered upstream and downstream in the direction of the main flow.

10.7 Cumulative impacts

The potential biodiversity impacts of the bridge proposals must be considered because of the construction and operation of the proposal within the existing environment. The proposal would not act alone in causing impacts to biodiversity. The incremental effects of multiple sources of impact (past, present, and future) are referred to as cumulative impacts and provide an opportunity to consider the proposal within a strategic context. The accumulating impacts of historic vegetation clearing for urban development, agriculture, and development and maintenance of infrastructure have contributed to the loss of biodiversity within the Fijian landscape. The proposed developments are not found to be a major contributor to cumulative impacts upon local marine, terrestrial or aquatic ecology.

11. Avoid, minimise, and mitigate impacts.

ADB require that mitigation of ecological impacts be sought in the following order of priority: (1) avoid, (2) minimise, (3) compensate on-site and (4) compensate off-site. At each stage, residual impacts should be re-assessed to determine whether there is a need to proceed to the next stage of mitigation. The following measures are proposed to mitigate the impacts discussed in the preceding section.

11.1 Avoidance and minimisation

The primary method to avoid impacts is to locate activities away from areas of known or potential high biodiversity value. Where possible the road alignment and bridge design has been located to avoid loss of mangrove. Further loss of mangroves should also be minimised as possible with no heavy machinery being placed on the mangrove areas unless this unavoidable.

11.2 Mitigation measures

Once all practicable steps to avoid or minimise impacts have been implemented at the detailed design phase, mitigation measures would be implemented to lessen the potential ecological impacts of the proposal. Mitigation measures are to be undertaken during the construction and operational phases and are outlined in Tables 9 and 10 below.

Table 9. Activities and potential effects on aquatic ecology at Madraukutu during the various phases of the operation are summarised in the following table.

Construction phase		
Construction Activities	**Potential impact**	**Proposed Mitigation activity**
Drainage works and use of vehicles	• Negative impact on flora and fauna from increased sediment (increased turbidity) loading of river, mangrove and marine areas	• Implement robust erosion and sediment control measures. Where practical use management methods such as turbidity curtains and turbidity meters outside the area in combination with phasing of construction work to minimise sedimentation and disturbance to aquatic fauna and flora • Operation of heavy equipment should be confined to dry stable areas to reduce the amount of mud and heavily silted water at the construction site which could enter the watercourse. • Stabilise exposed areas as soon as possible. • Avoid discharge of sediment into water • Avoid or minimise sediment release downstream. • Retain vegetation on the bank. • When excavation is required within the channel, as in the placement of footings for abutments or piers, measures should be taken to separate the excavation area from the flow by cofferdams. • Storage of fuel, equipment, and construction materials to minimise the risk of soil contamination or water pollution. • A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures installed.
Materials management	• Harm to aquatic flora and fauna from oil, fuel, cement, or other substances entering watercourses	• All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below)
Physical impacts- Dredging and bridge pillar	• Habitat loss and direct mortality of sensitive flora and fauna	• Development of a species-specific management plan for species of concern • Where needed turbidity barriers will be used during construction to prevent fine material from going offshore or entering other sensitive environments. • Ensure minimal disruption to the flow of the river during the wet season
	• Potential barrier to fish and shrimp migration along the river corridor	• Minimize turbulence and flow contraction because turbulence inhibits or prevents passage • Construct bridge bottoms with natural stream substrates • Construction should be phased to be outside the key periods of faunal migration.
Debris from construction	• Any debris left on the seabed from the construction activity can become a projectile during severe wave activity, and this may cause damage to sensitive benthic resources.	• A swim through by an Ecologist will be done at the site after construction when the turbidity is back to normal. The inspection will ensure that all debris are removed off site and that the stream riverbeds are appropriately restored.
Operation phase/ongoing site maintenance		
Activities	**Potential impact**	**Proposed Mitigation activity**
Physical presence of the bridge	• Changes to deposition, depth and water velocities may result in the loss of sensitive plant, invertebrate, and fish species	• Design bridge to avoid and reduce environment impacts e.g., maintain a constant grade along the length of the bridge. • Effective stabilisation of altered landforms to minimise soil erosion. • Construct during periods of low flow to minimize impacts to fish and the potential for water pollution from suspended solids

	• Potential downstream changes to the aquatic community	• During construction, minimize disturbance to the length of the natural stream channel and the natural flow of the water
Materials management from ongoing site maintenance	• Direct and indirect effects from oil, fuel or other substances entering the aquatic environment	• A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures undertaken.

Table 10. Activities and potential effects on terrestrial ecology during the various phases of the operation are summarised in the following table.

Construction phase		
Construction Activities	**Potential impact**	**Proposed Mitigation activity**
Earthworks and excavations	• Loss of mangrove habitat, fragmentation, or severance at two of the sites	• The subproject site boundary will be clearing marked on a plan and marked out on the site and approved by the Engineer/supervision consultant prior to the commencement of clearing. Only vegetation identified on the plan will be removed. • Ensure vegetation clearance is restricted to within the subproject site boundary and is the minimum practically required for the proposed works, including allowance for shading. The proposed site boundary will be approved by SP and the PIC prior to the commencement of clearing. • Cleared vegetation will be removed from the subproject site and disposed of at a location approved of by an Environment Safeguards Expert (noting cleared vegetation includes weeds and potentially weed seeds). Vegetation will not be permanently stockpiled on site or pushed into existing vegetation adjacent to the site. • Where possible machinery storage and materials lay down areas will be established in previously disturbed areas to avoid increasing the footprint of the project site and will avoid placement in areas of mangrove. • Further habitats should be created to compensate for habitat losses and to improve the landscape and ecological potential for the site where possible
	• Disturbance to sensitive species on and near the site and changes in distribution, activity patterns	• This effect is considered minimal for these ecosystems and mitigation is not required
	• Compaction of soil and associated effects on the surrounding mangroves	• Use of techniques to minimise compaction of soil, such as restricting access during wet conditions, and using protective boarding and low ground pressure machinery. If necessary, soil should be carefully removed and stored for subsequent reinstatement.
Invasive species introduction	• Negative ecological impacts due to the introduction of invasive species	• An invasive species management will be developed with the aim to prevent or manage invasive species introductions
Operation phase/ongoing site maintenance		
Construction Activities	**Potential impact**	**Proposed Mitigation activity**
Physical presence of bridge	• Loss of mangrove habitat and associated ecosystem services	• Further habitats should be created to compensate for habitat losses and to improve the landscape and ecological potential for the site
	• Destabilisation of nearby mangroves	• Monitoring in the years post construction to ensure there is no further loss of nearby mangroves

11.3 Working with concrete, cement and lime

Concrete and cement are used extensively in construction. Many activities require in situ pouring of concrete into purpose-built boxing or form work or installing pre-cast structures into waterways. Cement and lime are also used for pavement and trench back-fill stabilisation works.

Uncured concrete, concrete slurry, cement and lime fines, dust, or washings can make water highly alkaline (pH of 11–13). This highly alkaline water will injure and kill fish and other freshwater life that encounter it. Water contaminated with concrete, cement and lime cannot be diluted or filtered to a safe level for discharge to the receiving environment, so washings, dust, fines, or slurry must not enter stormwater or freshwater receiving environments.

Concrete, cement and lime-contaminated water must be collected in a contained area and removed from site, to avoid discharging to the receiving freshwater environment. Even once cured, concrete structures will leach for some time when immersed in water, producing alkaline water. Pre-cast structures need to be soaked, with soakage water replaced (and appropriately discharged away from any of the sites) periodically. Where pre-cast structures cannot be used and in situ pouring is required, this must be done in the dry (e.g., the use of Coffer dams) and the structure may need to be soaked as described above before removing the coffer dam and exposing the structure to the waterway.

11.4 Preventing invasive species

Mitigation measures to prevent the introduction or spread of invasive species and pathogens will include:

- The contractor must obtain all required biosecurity and phyto-sanitary clearances (e.g., permits) for any material or equipment imported into Fiji.
- The contractor will obtain all permits and clearances for import of any materials and equipment to be used for the project as required by Biosecurity Fiji.
- Materials will be inspected, and any equipment imported for project purposes will be steam-cleaned and certified under biosecurity and phyto-sanitary procedures away from the sites prior to mobilization.
- Immediately following clearing and construction, restoration, and planting of the site in the mangrove areas will occur to minimise the establishment of weeds at each location.
- Weed hygiene measures will be implemented to prevent introduction or spread of invasive species, including cleaning machinery before it enters and leaves the subproject sites. Inspection of the replanting and identification of any potentially risky weeds/invasive species should occur both during construction and immediately following construction by an appropriately qualified ecologist.

12. Management measures to address CH triggers

Although all efforts have been made to avoid ecological effects at the Madraukutu bridge site complete avoidance of effects is not possible. It has been necessary to mitigate and minimise potential ecological impacts and effects. A number of mitigation measures are required at this site to address each of the critical habitat triggers (Table 11).

Table 11. Management measures to address specific critical habitat triggers.

Criteria triggered	Critical habitat triggered	Management measures to address
1: Critically Endangered and Endangered Species	No	No additional measures required
2. Endemic / Restricted Range Species	Yes, potentially >10% of the species' population occurs and ≥10 reproductive units of a species of endemic range restricted fish *Parioglossus triquetrus* maybe present	• Ensure vegetation clearance is restricted to within the subproject site boundary and is minimised to the area of bridge placement • Implement robust erosion and sediment control measures. Where practical use management methods such as turbidity curtains and turbidity meters outside the area in combination with phasing of construction work to minimise sedimentation and disturbance to aquatic fauna and flora • When excavation is required within the channel, as in the placement of footings for abutments or piers, measures should be taken to separate the excavation area from the flow by cofferdams. Storage of fuel, equipment, and construction materials to minimise the risk of soil contamination or water pollution. • Use of techniques to minimise compaction of soil, such as restricting access during wet conditions, and using protective boarding and low ground pressure machinery. If necessary, soil should be carefully removed and stored for subsequent reinstatement. • A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures installed. • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below) • Development of a species-specific management plan for species of concern • Restoration of lost mangrove habitat and additional mangroves planted • An invasive species management will be developed with the aim to prevent or manage invasive species introductions • Further habitats will be created to compensate for habitat losses and to improve the landscape and ecological potential for the site • Monitoring in the years post construction to ensure there is no further loss of nearby mangroves
3. Migratory / Congregatory Species	Yes, likely to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species	• Ensure vegetation clearance is restricted to within the subproject site boundary and is minimised to the area of bridge placement • Minimize turbulence and flow contraction because turbulence inhibits or prevents passage • Construct bridge bottoms with natural stream substrates • Construction should be phased to be outside the key periods of faunal migration.

		• Ensure minimal disruption to the flow of the river during the wet season • Design bridge to avoid and reduce environment impacts e.g., maintain a constant grade along the length of the bridge. • An invasive species management will be developed with the aim to prevent or manage invasive species introductions • Monitoring in the years post construction to ensure there is no further loss of nearby mangroves • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below)
4. Critical habitat qualifying processes/ecosystems	Yes, provides key ecosystem services	• Ensure vegetation clearance is restricted to within the subproject site boundary and is minimised to the area of bridge placement • Monitoring in the years post construction to ensure there is no further loss of nearby mangroves • An invasive species management will be developed with the aim to prevent or manage invasive species introductions • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below) • Further habitats will be created to compensate for habitat losses and to improve the landscape and ecological potential for the site • Monitoring in the years post construction to ensure there is no further loss of nearby mangroves
5: The area holds biodiversity of significant social, economic, or cultural importance to local communities	Yes, important local fishing area	• Ensure vegetation clearance is restricted to within the subproject site boundary and is minimised to the area of bridge placement • Implement robust erosion and sediment control measures. Where practical use management methods such as turbidity curtains and turbidity meters outside the area in combination with phasing of construction work to minimise sedimentation and disturbance to aquatic fauna and flora • When excavation is required within the channel, as in the placement of footings for abutments or piers, measures should be taken to separate the excavation area from the flow by cofferdams. Storage of fuel, equipment, and construction materials to minimise the risk of soil contamination or water pollution. • Use of techniques to minimise compaction of soil, such as restricting access during wet conditions, and using protective boarding and low ground pressure machinery. If necessary, soil should be carefully removed and stored for subsequent reinstatement.

		• A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures installed. • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below) • Development of a species-specific management plan for species of concern • Restoration of lost mangrove habitat and additional mangroves planted • An invasive species management will be developed with the aim to prevent or manage invasive species introductions • Further habitats will be created to compensate for habitat losses and to improve the landscape and ecological potential for the site • Monitoring in the years post construction to ensure there is no further loss of nearby mangroves
Criterion 6: Protection	Yes, protected area	Liaison needed with communities

13. Residual impacts

As required by the ADB SPS, a no-net-loss of biodiversity values is required to be achieved. Although efforts have been made to avoid, minimise, and mitigate potential ecological impacts from the proposal, some residual impacts would occur in the form of terrestrial habitat loss and loss of soft sediment habitat at the Madraukutu bridge site.

Approximately 2,349m^2 of mangrove at Madraukutu (~9% of the area present) may be lost owing to this project (Table 11). It is good practice and aligned with ADB safeguards to compensate for all such loss of natural habitat. The best option is likely to be restoration of degraded or destroyed areas of mangrove at or near the project sites – this will represent an offset for project impacts on mangrove. Where this is not feasible, owing to a limited area or land use restrictions, restoration of degraded/lost mangrove should occur as near to the sites as feasible. New mangrove habitat (i.e., on mudflats where mangroves have never previously occurred) should not be created, as this may impact other species. A replanting plan should be developed with a qualified ecologist and through community liaison prior to construction occurring. Particular attention will be needed for this site, where impacts on mangrove are predicted to be significant.

The habitat identified at the Madraukutu site is Natural high condition habitat largely of native origin, and/or where human activity has not essentially modified the primary ecological functions and species composition. There is only a small amount of disturbance present with some vegetation removal, waste, and minor introduction of invasive species.

Increasing the amount of suitable habitat for fish and crustacean species through the additional restoration of mangrove habitat should offset any the losses of individuals during construction by allowing for net gain habitat for key species to be achieved.

Natural soft sediment habitat under the water will be modified and lost as habitat for native species at the Madraukutu site in the locations where piers are placed and potentially also will impact habitat within 2 meters of the piers (Table 12). Impacts on the soft sediment area calculated to be lost underwater through pier placement is small and not significant therefore offsets are not considered necessary (see table 12).

Table 12. Modified habitat by habitat type

Site	Habitat type residual impacts	Habitat Type condition	Habitat Type Area (B)
Madraukutu	Mangrove	Natural	2,349m^2
Madraukutu	Soft sediment	Natural	30 m^2

13.1 Residual Mangrove habitat impact

The following formula has been used to calculate the Habitat impact area of the residual values of the impacted mangrove habitat:

Area of Habitat Type (A) x Habitat Type Condition (B) = Habitat Impact area (C)

Table 13.Residual values of the impacted mangrove habitats

Habitat type and site	Habitat Type condition	Condition Score (A)	Habitat Type Area (B)	Habitat Impact Area (C) in Habitat hectares (HH)
Mangrove-Madraukutu	Natural	0.95	2,349m^2	0.2232 HH

The number of Habitat Hectares that require to be offset to achieve a no-net loss of biodiversity values of the mangrove sites is 2,349 HH for mangrove in the Madraukutu site.

However, a ratio of 1:6 is required by the Fijian Ministry of Environment as a replanting offset of the area of mangrove lost. This ratio will more than compensate for the loss of mangrove habitat removed for this project even if only a 50% condition score is achieved (See table 14).

Table 14. Calculation of the mangrove condition that the x6 area would achieve in the project timeframe

Habitat type and area	Habitat Type Area (A)	Ratio (B) 1:6	Condition Score (C) achieved following restoration	Habitat Restoration area with 1:6 ratio and 50% quality achieved. Habitat hectares (HH)
Mangrove-Madraukutu	2,349m^2	14,094 m^2	0.5	0.7047 HH

A further offset option is the restoration of degraded mangrove habitat. Further calculations would be needed to calculate the final size of the offset site required should this option be selected since the size of the restoration area required is dependent on the condition of the habitat currently present.

The area of mangrove replanting should, follow the Guidelines for Best Practice Mangrove Planting in Fiji [11] to increase the likelihood of restoration success and prevent another valuable ecological habitat such as the intertidal zone habitat being converted. Recommendations include only planting mangroves on areas they have occurred previously to prevent the conversion of other important natural habitat and to increase the chance of success.

The time recommended for management of the offset areas is 20 years. This would cover the period needed for the mangrove restoration to reach maturity.

Compensatory planting locations have not been identified. Community consultations to determine location and ensure community support are required. However, as much as possible restoration should occur near to the mangrove sites of impact. Where possible the area directly adjacent to the bridge area should also be restored to reduce the area of impact and associated edge effects.

14. Post construction monitoring

Monitoring programs are recommended:

- A qualified engineer and ecologist should evaluate bridge impacts on erosion and riparian areas to ensure habitat integrity throughout the construction phase.
- Post construction monitoring by both a qualified ecologist and an engineer within 3 weeks on construction being completed should ensure construction has not led to destabilisation effects on nearby mangroves and that no more than the advised proportion of mangrove has been removed during construction activities.
- Monitor success of offset/mitigation mangrove planting at 2-, 5- and 10-years post planting to ensure planting success and a net gain was achieved should be undertaken by a qualified ecologist.
- Ecological health (fish survival is not impacted by construction) using eDNA sampling to ensure migration is not impacted this should be undertaken by a qualified ecologist during construction and 1 year following construction.
- The habitat requirements for Parioglossus triquetrus are met at this site. further work on this species is recommended including eDNA collection for future identification (no DNA is currently available to confirm presence of the species) and pre-surveys at the sites, as well as the surrounding areas.

Monitoring of turbidity is required daily during the construction phase to ensure levels are not higher than <25 NTUs outside turbidity curtains within 15 meters of the edge of the construction area.

[11] A Review of Mangrove Planting, D. WATLING, 2021

15. Madraukutu bridge site conclusion

We conclude that the key period of impact will be: 1) during the construction phase of the project, and specifically to water quality (i.e., unmitigated discharge of sediments and potential concrete contamination) and 2) due to the removal of the mangrove vegetation. Management plans are needed to ensure these do not have an impact. It is also important that limits on key construction activities during aquatic migration periods (during the wet season Nov-April) should be maintained when migratory key trigger species are potentially utilising the area.

We conclude that potential significant environmental impacts can be addressed if appropriate management and mitigation options are undertaken in addition to offsetting/mitigation for the loss of mangrove habitat, there will be no measurable adverse impacts, or likelihood of such, on the aquatic or mangrove habitat which could impair its high biodiversity value or the ability to function after planned mitigation and offset measures. Impacts are not expected to be anywhere near the level that could impair the ability of the Critical Habitat to perform ecological functions

Following the implementation of the management and mitigation measures, including those for residual effect it is concluded that at Madraukutu bridge site the ADB SPS and ESS6 and World bank ESF ESS6 requirements are fulfilled allowing the project to go ahead in an area of Critical Habitat (CH).

16. Viseisei Bridge Ecological Values

16.1 Terrestrial ecology

The proposed bridge site is 600m upstream from the vuda/vunda river mouth which is also called Varangge Creek/Vuda river. The proposed location of the bridge covers a section of a large and relatively undisturbed high quality natural mixed Rhizophora mangrove forest. The total area of natural mangrove forest is 21 hectares (Figure 8-9).

On the western side of the bridge the natural habitat mangrove forest impacted by the proposed development is dominated *Rhizophora stylosa* and *Rhizophora samoensis* mangrove species with little sign of anthropogenic disturbance. On the east side of the bridge in addition to *Rhizophora stylosa* and *Rhizophora samoensis* mangrove species various other common obligatory mangrove plant species which can tolerate brackish conditions such as *Cocos nucifera* (coconut), *Pandanus verus*, *Hibiscus tiliaceus* also occurred within the vegetation. The western side of the proposed bridge the area was inundated and only mangroves were present with no herb or grass ground cover. Within this mature intact area of impacted mangrove forest, two one-meter square plots had on average 11 large mature mangrove trees and 15 mangrove seedlings <60 cm in height (n= 4), Canopy height was approximately 20-23 m. No species threatened or known to be rare were found in the Study Area. The Study Area supported plant species typical of those types of habitats and had a low plant diversity and simple structure. Despite this the site is of high natural habitat quality and high ecological value.

Based on the current design, the estimated clearing of natural habitat mangrove vegetation for the proposal is 1,912 m^2. This area includes a 3m buffer area surrounding the proposed bridge design (Figure 8 and 9). This is a small proportion of the overall surrounding mangrove habitat (Table 15). Loss of this vegetation will however contribute to further fragmentation of mangrove habitat. This effect is higher because the area of clearance is positioned at a central location within the mangrove habitat.

Table 15. Percentage of mangrove directly impacted and remaining following the proposed removal for bridge development.

	Total mangrove area (m^2)	Mangrove directly impacted (m^2)	Total remaining (m^2)	Mangrove direct effected (%)	Mangrove remaining following direct impact (%)
Viseisei	210000	1912	208088	0.91	99.09

16.2 Aquatic ecology

The Varaciva catchment area in which the Vuda river or Varangge Creek occurs has a small watershed area. At the proposed bridge development site, the river is approximately 40m wide and has a maximum depth of approximately 9 meters. The edge sediment was muddy with some rocky areas. The river flow was swift with good clarity to 3 meters on the survey days.

EDNA sampling occurred 20 meters upstream from the proposed bridge and at the proposed bridge location. Edna testing at and near to the proposed bridge site revealed that up to 24 species of fish, 3 species of crustacean (shrimps and crabs) and 8 mollusc species (See appendix). Snorkel surveys were conducted at the bridge and downstream from the bridge. No kai/freshwater mussel were found in the area. Netting and trapping did not add further species to the species list above that provided through eDNA sampling (Appendix, tables 37-41).

Additional targeted surveys for specimens of *Parioglossus* and other gobies utilising kilwell bait traps were not successful in capturing any additional species. The freshwater fish utilising the area are likely to include migratory species which pass this site seasonally. However, surveys have not occurred during the best period for detecting these species (the wet season). We take a precautionary approach and assume they are present at key migration periods.

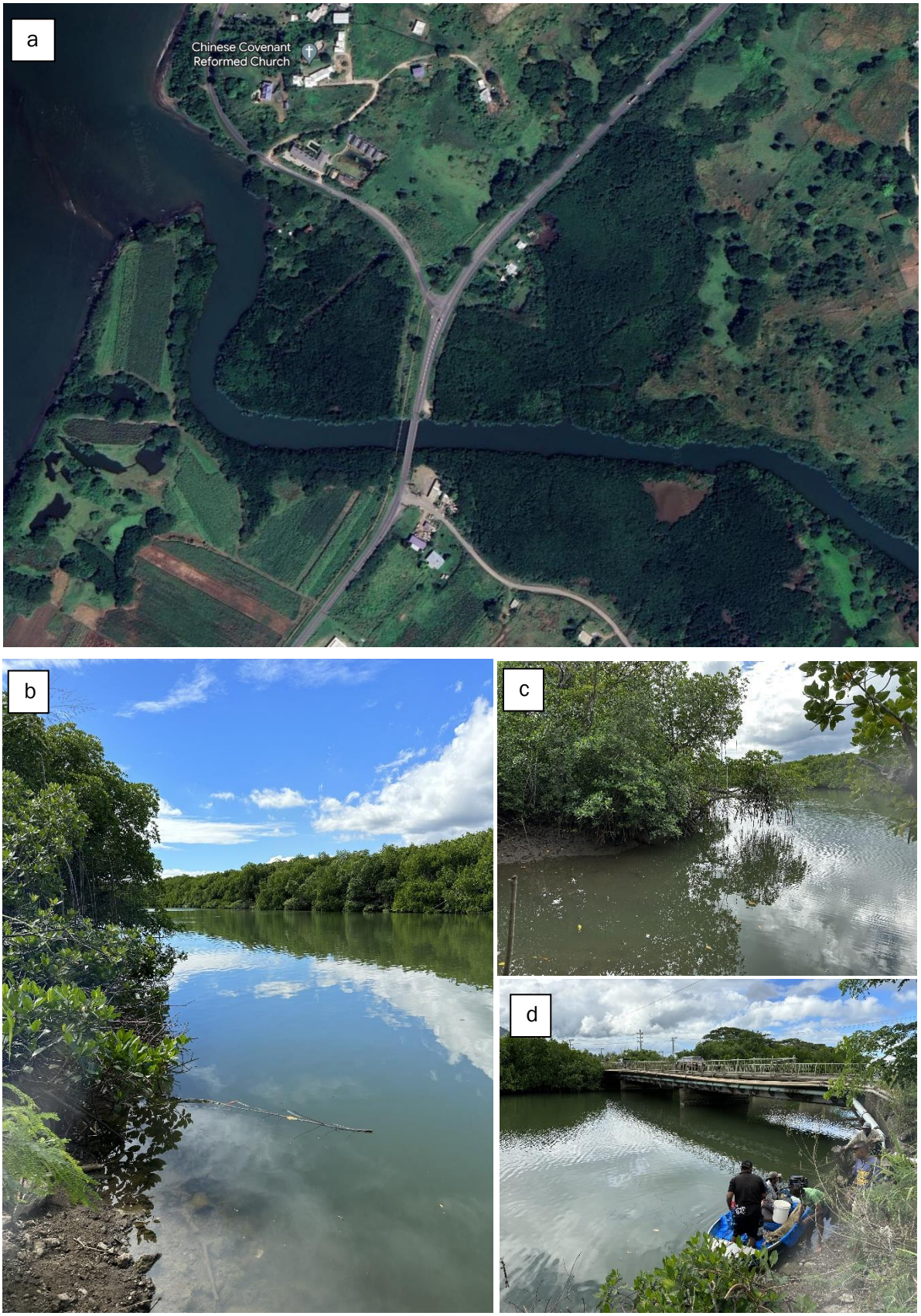


Figure 8. a) landscape depiction of the mangroves surrounding the site the proposed bridge is located immediately north of the current bridge, b) western bank looking upstream showing healthy mangroves to the river edge, c) within the mangroves on the western.

Figure 9. The proposed bridge design and area of mangroves which will be potentially removed includes a 3-meter buffer impact zone and the surrounding modified and natural habitat.

17. Viseisei Bridge critical habitat triggers

Literature reviews, database surveys, eDNA surveys and field visits identified no endangered species of conservation significance based on the IUCN Red List of Threatened Species as present at the Viseisei bridge site, or within the EAAA of the site. However, there are endemic or range restricted species fish species which are data deficient or have not yet been evaluated by the IUCN for which the habitat is suitable (See Table 16). The majority of these species of crustaceans and fish are only potentially present during migration triggering criteria 3 for critical habitat. We have taken a precautionary approach and assumed they are present at key times in the year (See table 16-17).

There are also two species *Datnia kneri /Mesopristes kneri* and *Parioglossus triquetrus* which are data deficient/not evaluated by the IUCN which maybe present all year. Both species are known from areas outside the EAAAs and are lacking information on population status and spatial coverage.

For *Datnia kneri /Mesopristes kneri* appropriate habitat requirements are met at this project site. This species could also trigger Criteria 3 since they migrate. This species was not however present in any of the eDNA samples collected (there was no unidentified Terapontidae genus in the eDNA) at any of the sites. This suggests that the species was not present during the survey periods at this site. *Datnia kneri* therefore does not trigger criteria 2.

Table 16. Freshwater fish triggering critical habitat and criterion triggered at Viseisei.

Scientific name	Critical Habitat Rationale	Criterion Triggered
Glossogobius sp. (Hoese and Jenkins in prep)	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that all 4 sites sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle qualifying them as Critical Habitat under Criterion 3.	3
Parioglossus triquetrus	Potential Critical Habitat: Suitable habitat potentially exists. Though the species was not found at the sites, it is possible the EAAAs regularly hold ≥10% of the global population size AND ≥10 reproductive units of a species of the global population occur, qualifying these as Critical Habitat under Criterion 2.	2
Schismatogobius vitiensis Comon name: Fijian scaleless goby(Jenkins and Boseto, 2005)	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical basis, ≥ 1 percent of the global population of this migratory species may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Schismatogobius chrysonotus (Orange-spotted Scaleless Goby)	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through all 4 of the sites, qualifying them as Critical Habitat under Criterion 3.	3
Stenogobius (insularigobius) n. sp. Common name: teardrop goby	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Stiphodon sp.1, Isabella's goby	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Stiphodon sp.2 (Jenkins, Boseto and Watson)	Potential Critical Habitat: The 4 EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Sicyopterus n. sp. (Boseto, in preparation) – Tavoro Goby	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Datnia kneri / (Bleeker, 1876) (Terapontidae) Common name: Orange-spotted Therapon/Reve	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3. It is not considered likely, however, that >10% of the species' population occurs at any of the sites at any time, thus meaning they do not qualify as Critical Habitat under Criterion 2.	3

Table 17. Endemic freshwater crustaceans triggering critical habitat (CH) criteria and rational at Viseisei.

Name	Critical Habitat Rationale	Criterion Triggered
Caridina fijiana	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that >1% of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3

Parioglossus triquetrus is endemic. The habitat requirements of this species are met by this project site given that mangroves are present. No records of the species have been recorded within the EAAA. No potential individuals were seen in the mangroves or while doing snorkel surveys and no individuals were captured during the surveys despite effort. However, the species is known to be difficult to capture.

Parioglossus triquetrus was not in the eDNA library which did not allow this species to be identified directly through the eDNA samples. Furthermore, there is unidentified Gobiidae in the eDNA samples which could be *Parioglossus triquetrus*. This species could trigger Criteria 2 and therefore consideration is given to potential project-related adverse impacts (table 16).

17.1 Critical Habitat-qualifying ecosystems

ADB Criterion 4 states " The area includes unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services;"

Criterion 4 relates to specific landscape features which are critical for ecological functions. Examples of these within the sites includes riparian zones and rivers, dispersal/migration corridors (rivers), hydrological regimes, and keystone or habitat-forming species (mangroves and freshwater mussels).

The rivers, estuaries, and mangrove surrounding Viseisei provide critical shelter and food for aquatic species and function as migration corridors maintaining key life cycle events. The mangrove river systems are recognised as key ecosystem providers e.g., breeding and nursery habitats for fish species, storms and floods, erosion control functioning locally and regionally as important ecosystem services. By providing these ecosystem services they trigger critical habitat criterion 4.

17.2 Critical habitat criteria triggered

The critical habitat triggered at the Viseisei is outlined (See Table 16)

Table 18. Critical habitat triggered.

Criteria	Thresholds	Critical habitat triggered
1: Critically Endangered and Endangered Species	(a) Areas that support globally important concentrations of an IUCN Red-listed EN or CR species (≥ 0.5% of the global population AND ≥ 5 reproductive unitsGN16 of a CR or EN species). (b) Areas that support globally important concentrations of an IUCN Red-listed Vulnerable (VU) species, the loss of which would result in the change of the IUCN Red List status to EN or CR and meet the thresholds in GN72(a). (c) As appropriate, areas containing important concentrations of a nationally or regionally listed EN or CR species	no
2. Endemic / Restricted Range Species	(a) Areas that regularly hold ≥10% of the global population size AND ≥10 reproductive units of a species.	Yes, potentially hold ≥10% of the global population size AND ≥10 reproductive units of *Parioglossus triquetrus.*
3. Migratory / Congregatory Species	(a) Areas known to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle. (b) Areas that predictably support ≥10 percent of the global population of a species during periods of environmental stress.	Yes, likely to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species
4. Critical habitat qualifying processes/ecosystems	The area includes unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services	Yes, provides key ecosystem services
5: The area holds biodiversity of significant social, economic, or cultural importance to local communities		Yes, important fishing area
Criterion 6: Protection		None identified

18. Ecological effects

This section of the report considers the potential impacts of project operation on terrestrial mangrove, freshwater, and intertidal ecology at the Viseisei bridge site. Ecological effects on both the terrestrial and aquatic varies during construction and during operation are both summarised in (Table 17 and 18). Ecological impacts may operate over a longer timescale, as populations and species take time to respond to environmental changes (time-lag).

18.1 Construction effects

Severity and spatial extent of the effects will depend on construction practices, timing of construction activities and controls, river flows, composition of substrate, and effectiveness of erosion controls.

18.1.1 Noise and disturbance

Considerable noise and visual disturbance may be generated during site formation and construction, potentially affecting the distribution and behaviour of fauna of the

adjacent/remaining habitats. Due to the ranking of conservation importance of the species recorded, and the temporary nature of the impact, potential impacts to fauna from this source are likely to be minor if construction activities occur outside the wet season when critical migration and life cycle activities occur. There is a possibility, however, that mangroves are used for some critical life history stages, e.g. nursery grounds, by some sensitive species.

18.2 Terrestrial ecology

18.2.1 Site formation

Natural Mangrove habitat will be removed from Viseisei bridge site. Natural habitat loss will require mitigation and offsetting (refer residual impacts-mangrove habitat loss) to ensure a net benefit.

In addition to the direct loss of vegetation for bridge placement, the project may impact vegetation by:

- unauthorised clearing outside the subprojects site boundary
- clearing elsewhere e.g., to store materials.
- causing damage to surrounding vegetation through erosion (refer Suspended solid)
- changes to water quality (Suspended solid/water quality)
- introduction of invasive species (refer invasive species).

At Viseisei the loss of vegetation would fragment habitat. The increased isolation that may be caused by the proposal is not likely to have an appreciable impact however since functional connectivity would remain in the study areas. The effects could be offset or mitigated through mangrove restoration in both additional sites (offset) and restoration of mangroves in the sites surrounding the new bridge which are damaged by construction (mitigation). Post construction monitoring would ensure construction has not led to additional destabilisation effects on nearby mangroves surrounding the proposed bridges. Monitoring can also ensure that no more than the advised proportion of mangrove has been removed during construction activities.

18.2.2 Invasive species.

Invasive species have the potential to be spread by the construction e.g., through tracking of seeds on vehicles or machinery. Pathogens and invasive species may also be carried on, or in, materials, equipment (including vessels used to transport materials or workers) and any workers brought to the sites. This includes materials, equipment and workers bought from other countries or elsewhere in Fiji.

18.3 Aquatic ecology

18.3.1 Suspended solid/water quality.

Environment construction activities and dredging could result in the increased sediment loading and site runoff of streams and changes in turbidity may impact adversely upon aquatic populations particularly sessile species.

High suspended and deposited sediments can smoother habitats and reduce the photosynthesis of benthic plants. Suspended sediments can also impact on aquatic biota by clogging the food filtering or trapping apparatus of stream insects as well as the gills of fish, reducing the feeding efficiency (particularly for visual predators). This is a concern at all the sites.

Multiple fish species present in the wider catchment migrate both upstream and downstream within streams and rivers during different stages within their lifecycle. High suspended sediment can slow or prevent the migration of native fish species. In a study on juvenile whitebait (banded kokopu in New Zealand), fewer fish migrated upstream at turbidity > 25 NTU[12]. The study speculated that if the rate of migration of juvenile banded kokopu was slowed there could potentially be fewer juvenile fish reaching adult habitat, fish could potentially be subject to increased risk of predation and may not reach preferred upstream habitats while they are still able to climb as juveniles.

A plan is needed to ensure the implementation of appropriate design and management techniques to reduce sedimentation risks during construction are low particularly during dredging or when piles are being placed. Through the implementation of appropriate design and management sedimentation risks can be managed reducing the level of effect to low. Management tools include turbidity barriers which can be used to lessen the spread of fine particles and timing construction to avoid the rainy season and avoid key migration periods for sensitive species. A turbidity meter should be used to measure the turbidity outside of the construction area impact site to ensure that turbidity readings are within the acceptable range of <25 NTUs outside turbidity curtains.

18.3.2 Pollution incidents

Local ecological populations may also be adversely affected by pollution incidents attributed to fuel leaks and oil spills associated with construction and maintenance operations on site.

Cement is a construction related material which can have adverse on freshwater life. Cement has the potential to be discharged to the downstream receiving environment. Cement wash water and runoff from recently placed cement are of particular concern within aquatic habitats due to their detrimental effect on in stream fauna. Crushed concrete is also increasingly used as back-fill material and more frequently as contractors seek ways to be more sustainable and reuse materials.

Cement wash water and runoff has a high lime content which is water soluble (dissolves easily in water) and can drastically increase the pH of a waterway. The alkalinity can kill or severely burn aquatic life. For fish, the alkalinity is exceptionally damaging to sensitive gill structures. In addition to alkalinity, cement wash, and runoff can similarly increase the loading of fine sediment resulting in the same effects on instream fauna and habitat as those identified above for suspended/deposited sediment.

Concrete structures can leach and cause alkaline water. In addition to potential mortality of fauna, localised increases in pH (alkaline conditions) from leaching from concrete structures may also create a barrier to fish passage. These effects can be limited through careful management.

[12] Richardson, J., Rowe, D.K., Smith, J.P.2001. Effects of turbidity on the migration of juvenile banded kokopu (*Galaxias fasciatus)* in a natural stream, New Zealand. Journal of Marine and Freshwater Research, 35:1, 191-196, DOI: 10.1080/00288330.2001.9516989

There is a particularly high risk of discharge of contaminants following discrete wet weather events or during prolonged periods of wet weather. Appropriate design and management can reduce these risks.

18.4 Impacts on fish and crustacean species of concern

Direct impacts on migratory fish and crustacean species are unlikely if there is minimal disruption to the flow of the river during the wet season (Nov-April) is ensured and key activities such as pile construction is limited to outside critical life history and migration periods. This will enable any fish and crustacean migration is not obstructed during construction works within the riverbed and ensure these risks are unlikely. Timing construction outside the migratory wet season reduces the severity of the effect of construction to no more than minor.

Any impacts on most potential resident species of concern, should they be present, are likely to be small and predominantly limited to the construction phase. Such impacts are more likely at Viseisei since mangroves will be removed, and potentially represent habitat for such species. Provided careful mitigation activity is taken e.g., care involving cement/concrete should ensure minimal effects. These species cannot be assessed against measurable impacts without known populations on site. Increasing the amount of suitable habitat for these species through the restoration of mangrove habitat should however offset the losses of any individuals and associated habitat during construction and should allow for net gains of these species to be achieved.

The most significant potential for impacts to a particular species is to *Parioglossus triquetrus*, which may be resident at Viseisei. Although this species is not confirmed, its limited global distribution means that - if it is present - it may have a significant part of its global population present at one of these sites. Impacts on habitat at this site is not significant given the proportion of the mangrove area impacted.

18.5 Operational effects

18.5.1 Terrestrial impacts

The presence of the bridge structures will cause some shading of the riverbank and bed thereby potentially altering the aquatic flora present in the direct vicinity of the bridge. This impact is predicted to be minimal for the Viseisei bridge site since it will be highly localised and when mangroves are shaded only a small area will be impacted. Furthermore, mangrove forest is not particularly sensitive to shading. Mitigation measures are not likely to be effective and are not deemed necessary.

18.5.2 Aquatic impacts

The physical presence of bridges during operation post construction can also affect aquatic ecological populations in several ways. Physical developments such as bridge pillars, dredging and alteration of embankments, and roading construction can result in channelization, and deep pool formation resulting in an ecological disturbance for aquatic fauna if habitat corridors become severed.

Disturbances from bridge construction can be mitigated if normal water flow is maintained despite the blocking effect of embankments and bridge piers. This objective can be achieved through designs that favour long spans and hydraulically shaped piers. Abutments should be set back from the normal wetted perimeter of the watercourse to avoid constriction of the channel and reduction of the flow area.

The length of the spans required are determined by the bridge design by the engineers. However, the longer the spans the more contact with waterways is reduced thereby reducing freshwater impacts.

Abutments and piers should be designed and constructed to provide the least amount of hydraulic resistance. Where piers are required, hydraulic shaped piers will minimize local scour and reduce obstruction of flow reducing impacts on the aquatic benthic environment. Piers should be constructed with ends which are tapered upstream and downstream in the direction of the main flow.

18.6 Cumulative impacts

The potential biodiversity impacts of the bridge proposals must be considered because of the construction and operation of the proposal within the existing environment. The proposal would not act alone in causing impacts to biodiversity. The incremental effects of multiple sources of impact (past, present, and future) are referred to as cumulative impacts and provide an opportunity to consider the proposal within a strategic context. The accumulating impacts of historic vegetation clearing for urban development, agriculture, and development and maintenance of infrastructure have contributed to the loss of biodiversity within the Fijian landscape. The proposed developments are not found to be a major contributor to cumulative impacts upon local marine, terrestrial or aquatic ecology.

19. Avoid, minimise, and mitigate impacts.

ADB require that mitigation of ecological impacts be sought in the following order of priority: (1) avoid, (2) minimise, (3) compensate on-site and (4) compensate off-site. At each stage, residual impacts should be re-assessed to determine whether there is a need to proceed to the next stage of mitigation. The following measures are proposed to mitigate the impacts discussed in the preceding section.

19.1 Avoidance and minimisation

The primary method to avoid impacts is to locate activities away from areas of known or potential high biodiversity value. Where possible the road alignment and bridge design has been located to avoid loss of mangrove. Further loss of mangroves should be minimised with no heavy machinery being placed on the mangrove areas unless this is not avoidable.

19.2 Mitigation measures

Once all practicable steps to avoid or minimise impacts have been implemented at the detailed design phase, mitigation measures would be implemented to lessen the potential ecological impacts of the proposal. Mitigation measures are to be undertaken during the construction and operational phases and are outlined in Tables 19 and 20 below.

Table 19. Activities and potential effects on aquatic ecology during the various phases of the operation are summarised in the following table

Construction phase		
Construction Activities	**Potential impact**	**Proposed Mitigation activity**
Drainage works and use of vehicles	• Negative impact on flora and fauna from increased sediment (increased turbidity) loading of river, mangrove and marine areas	• Implement robust erosion and sediment control measures. Where practical use management methods such as turbidity curtains and turbidity meters outside the area in combination with phasing of construction work to minimise sedimentation and disturbance to aquatic fauna and flora • Operation of heavy equipment should be confined to dry stable areas to reduce the amount of mud and heavily silted water at the construction site which could enter the watercourse. • Stabilise exposed areas as soon as possible. • Avoid discharge of sediment into water • Avoid or minimise sediment release downstream. • Retain vegetation on the bank. • When excavation is required within the channel, as in the placement of footings for abutments or piers, measures should be taken to separate the excavation area from the flow by cofferdams. • Storage of fuel, equipment, and construction materials to minimise the risk of soil contamination or water pollution, • A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures installed.
Materials management	• Harm to aquatic flora and fauna from oil, fuel, cement, or other substances entering watercourses	• All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below) • Development of a species-specific management plan for species of concern
Physical impacts- Dredging and bridge pillar	• Habitat loss and direct mortality of sensitive flora and fauna • Potential barrier to fish and shrimp migration along the river corridor	• Where needed turbidity barriers will be used during construction to prevent fine material from going offshore or entering other sensitive environments. • Ensure minimal disruption to the flow of the river during the wet season • Minimize turbulence and flow contraction because turbulence inhibits or prevents passage, • Construct bridge bottoms with natural stream substrates, • Construction should be phased to be outside the key periods of faunal migration.
Debris from construction	• Any debris left on the seabed from the construction activity can become a projectile during severe wave activity, and this may cause damage to sensitive benthic resources.	• A swim through by an Ecologist will be done at the site after construction when the turbidity is back to normal. The inspection will ensure that all debris are removed off site and that the beds are appropriately restored.
Operation phase/ongoing site maintenance		
Activities	**Potential impact**	**Proposed Mitigation activity**
Physical presence of the bridge	• Changes to deposition, depth and water velocities may result in the loss of sensitive plant, invertebrate, and fish species	• Design bridge to avoid and reduce environment impacts e.g., maintain a constant grade along the length of the bridge. • Effective stabilisation of altered landforms to minimise soil erosion.

		• Construct during periods of low flow to minimize impacts to fish and the potential for water pollution from suspended solids
	• Potential downstream changes to the aquatic community	• During construction, minimize disturbance to the length of the natural stream channel and the natural flow of the water
Materials management from ongoing site maintenance	• Direct and indirect effects from oil, fuel or other substances entering the aquatic environment	• A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures undertaken.

Table 20. Activities and potential effects on terrestrial ecology during the various phases of the operation are summarised in the following table.

Construction phase		
Construction Activities	**Potential impact**	**Proposed Mitigation activity**
Earthworks and excavations	• Loss of mangrove habitat, fragmentation, or severance at two of the sites	• The subproject site boundary will be clearing marked on a plan and marked out on the site and approved by the Engineer/supervision consultant prior to the commencement of clearing. Only vegetation identified on the plan will be removed. • Ensure vegetation clearance is restricted to within the subproject site boundary and is the minimum practically required for the proposed works. The proposed site boundary will be approved by SP and the PIC prior to the commencement of clearing. • Cleared vegetation will be removed from the subproject site and disposed of at a location approved of by an Environment Safeguards Expert (noting cleared vegetation includes weeds and potentially weed seeds). Vegetation will not be permanently stockpiled on site or pushed into existing vegetation adjacent to the site. • Where possible machinery storage and materials lay down areas will be established in previously disturbed areas to avoid increasing the footprint of the project site and will avoid placement in areas of mangrove. • Further habitats should be created to compensate for habitat losses and to improve the landscape and ecological potential for the site where possible
	• Disturbance to sensitive species on and near the site and changes in distribution, activity patterns	• This effect is considered minimal for these ecosystems and mitigation is not required
	• Compaction of soil and associated effects on the surrounding mangroves	• Use of techniques to minimise compaction of soil, such as restricting access during wet conditions, and using protective boarding and low ground pressure machinery. If necessary, soil should be carefully removed and stored for subsequent reinstatement.
Invasive species introduction	• Negative ecological impacts due to the introduction of invasive species	• An invasive species management will be developed with the aim to prevent or manage invasive species introductions
Operation phase/ongoing site maintenance		
Construction Activities	**Potential impact**	**Proposed Mitigation activity**
Physical presence of bridge	• Loss of mangrove habitat and associated ecosystem services	• Further habitats should be created to compensate for habitat losses and to improve the landscape and ecological potential for the site
	• Destabilisation of nearby mangroves	• Monitoring in the years post construction to ensure there is no further loss of nearby mangroves

19.3 Working with concrete, cement and lime

Concrete and cement are used extensively in construction. Many activities require in situ pouring of concrete into purpose-built boxing or form work or installing pre-cast structures into waterways. Cement and lime are also used for pavement and trench back-fill stabilisation works.

Uncured concrete, concrete slurry, cement and lime fines, dust, or washings can make water highly alkaline (pH of 11–13). This highly alkaline water will injure and kill fish and other freshwater life that encounter it. Water contaminated with concrete, cement and lime cannot be diluted or filtered to a safe level for discharge to the receiving environment, so washings, dust, fines, or slurry must not enter stormwater or freshwater receiving environments.

Concrete, cement and lime-contaminated water must be collected in a contained area and removed from site, to avoid discharging to the receiving freshwater environment. Even once cured, concrete structures will leach for some time when immersed in water, producing alkaline water. Pre-cast structures need to be soaked, with soakage water replaced (and appropriately discharged away from any of the sites) periodically. Where pre-cast structures cannot be used and in situ pouring is required, this must be done in the dry (e.g., the use of Coffer dams) and the structure may need to be soaked as described above before removing the coffer dam and exposing the structure to the waterway.

19.4 Preventing invasive species

Mitigation measures to prevent the introduction or spread of invasive species and pathogens will include:

- The contractor must obtain all required biosecurity and phyto-sanitary clearances (e.g., permits) for any material or equipment imported into Fiji.
- The contractor will obtain all permits and clearances for import of any materials and equipment to be used for the project as required by Biosecurity Fiji.
- Materials will be inspected, and any equipment imported for project purposes will be steam-cleaned and certified under biosecurity and phyto-sanitary procedures away from the sites prior to mobilization.
- Immediately following clearing and construction, restoration, and planting of the site in the mangrove areas will occur to minimise the establishment of weeds at each location.
- Weed hygiene measures will be implemented to prevent introduction or spread of invasive species, including cleaning machinery before it enters and leaves the subproject sites. Inspection of the replanting and identification of any potentially risky weeds/invasive species should occur both during construction and immediately following construction by an appropriately qualified ecologist.

20. Residual impacts

As required by the ADB SPS, a no-net-loss of biodiversity values is required to be achieved. Although efforts have been made to avoid, minimise, and mitigate potential ecological impacts from the proposal, some residual impacts would occur in the form of terrestrial habitat loss and loss of soft sediment habitat at the bridge site at Viseisei.

Approximately 1,912 m^2 of mangroves at Viseisei (<1% of the area present) may be lost owing to this project (Table 21. Modified habitat by habitat type). It is good practice and aligned with ADB safeguards to compensate for all such loss of natural habitat. The best option is likely to be restoration of degraded or destroyed areas of mangrove at or near the project sites – this will represent an offset for project impacts on mangrove. Where this is not feasible, owing to a limited area or land use restrictions, restoration of degraded/lost mangrove should occur as near to the sites as feasible. New mangrove habitat (i.e., on mudflats where mangroves have never previously occurred) should not be created, as this may impact other species. A replanting plan should be developed with a qualified ecologist and through community liaison prior to construction occurring.

The habitat identified at these two sites is Natural high condition habitat largely of native origin, and/or where human activity has not essentially modified the primary ecological functions and species composition. There is only a small amount of disturbance present with some vegetation removal, waste, and minor introduction of invasive species.

Increasing the amount of suitable habitat for fish and crustacean species through the additional restoration of mangrove habitat should offset any the losses of individuals during construction by allowing for a net gain of habitat for key species to be achieved.

Natural soft sediment habitat under the water will be modified and lost as habitat for native species where piers are placed and potentially will impact habitat within 2 meters of the piers (Table 21. Modified habitat by habitat type). The current engineering plans have 2-3 piers placed in under the water in Viseisei. Impacts on the soft sediment area calculated to be lost underwater through pier placement is small and not significant therefore offsets are not considered necessary (see Table 21).

Table 21. Modified habitat by habitat type

Site	Habitat type residual impacts	Habitat Type condition	Habitat Type Area (B)
Viseisei	Mangrove	Natural	1,912 m^2
Viseisei	Soft sediment	Natural	120 m^2

20.1 Residual Mangrove habitat impact

The number of Habitat Hectares that require to be offset to achieve a no-net loss of biodiversity values of the mangrove sites is 1,912 HH for mangrove in Viseisei (Table 22).

Table 22.Residual values of the impacted mangrove habitats

Habitat type and site	Habitat Type condition	Condition Score (A)	Habitat Type Area (B)	Habitat Impact Area (C) in Habitat hectares (HH)
Mangrove-Viseisei	Natural	0.95	1,912 m^2	0.1816 HH

The following formula has been used to calculate the Habitat impact area of the residual values of the impacted mangrove habitat:

Area of Habitat Type (A) x Habitat Type Condition (B) = Habitat Impact area (C)

However, a ratio of 1:6 is required by the Fijian Ministry of Environment as a replanting offset of the area of mangrove lost. This ratio will more than compensate for the loss of mangrove habitat removed for this project even if only a 50% condition score is achieved (See Table 23).

Table 23. Calculation of the mangrove condition that the x6 area would achieve in the project timeframe

Habitat type and area	Habitat Type Area (A)	Ratio (B) 1:6	Condition Score (C) achieved following restoration	Habitat Restoration area with 1:6 ratio and 50% quality achieved. Habitat hectares (HH)
Mangrove-Viseisei	1,912 m^2	11,472 m^2	0.5	0.5736 HH

A further offset option is the restoration of degraded mangrove habitat. Further calculations would be needed to calculate the final size of the offset site required should this option be selected since the size of the restoration area required is dependent on the condition of the habitat currently present.

The area of mangrove replanting should, follow the Guidelines for Best Practice Mangrove Planting in Fiji [13] to increase the likelihood of restoration success and prevent another valuable ecological habitat such as the intertidal zone habitat being converted. Recommendations include only planting mangroves on areas they have occurred previously to prevent the conversion of other important natural habitat and to increase the chance of success.

The time recommended for management of the offset areas is 20 years. This would cover the period needed for the mangrove restoration to reach maturity.

Compensatory planting locations have not been identified. Community consultations to determine location and ensure community support are required. However, as much as possible restoration should occur near to the mangrove sites of impact. Where possible the area directly adjacent to the bridge area should also be restored to reduce the area of impact and associated edge effects.

21. Post construction monitoring

Monitoring programs are recommended to:

- A qualified engineer and ecologist should evaluate bridge impacts on erosion and riparian areas to ensure habitat integrity throughout the construction phase.

[13] A Review of Mangrove Planting, D. WATLING, 2021

- Post construction monitoring by both a qualified ecologist and an engineer within 3 weeks on construction being completed should ensure construction has not led to destabilisation effects on nearby mangroves and that no more than the advised proportion of mangrove has been removed during construction activities.
- Monitor success of offset/mitigation mangrove planting at 2-, 5- and 10-years post planting to ensure planting success and a net gain was achieved should be undertaken by a qualified ecologist.
- Monitoring of turbidity is required daily during the construction phase to ensure levels are not higher than < 25 NTUs outside turbidity curtains.
- Ecological health (fish survival is not impacted by construction) using eDNA sampling to ensure migration and resident fish are not impacted this should be undertaken by a qualified ecologist during construction and 1 year following construction.
- The habitat requirements for *Parioglossus triquetrus* are met at this site. further work on this species is recommended including eDNA collection for future identification (no DNA is currently available to confirm presence of the species) and pre-surveys at the sites, as well as the surrounding areas.

22. Management measures to address CH triggers

Although all efforts have been made to avoid ecological effects at the Viseisei Bridge site complete avoidance of effects is not possible. It has also been necessary to mitigate and minimise potential ecological impacts and effects. A number of mitigation and offset measures are required at this site to address each of the critical habitat triggers (See Table 24)

Table 24. Critical habitat triggered and associated management measures to address each trigger.

Criteria triggered	Critical habitat triggered	Management measures to address
1: Critically Endangered and Endangered Species	No	No additional measures required
2. Endemic / Restricted Range Species	Yes, it is possible >10% of the species' population occurs AND ≥10 reproductive units of a species of *Parioglossus triquetrus* maybe present	• Ensure vegetation clearance is restricted to within the subproject site boundary • Implement robust erosion and sediment control measures. Where practical use management methods such as turbidity curtains and turbidity meters outside the area in combination with phasing of construction work to minimise sedimentation and disturbance to aquatic fauna and flora • When excavation is required within the channel, as in the placement of footings for abutments or piers, measures should be taken to separate the excavation area from the flow by cofferdams. Storage of fuel, equipment, and construction materials to minimise the risk of soil contamination or water pollution. • Use of techniques to minimise compaction of soil, such as restricting access during wet conditions, and using protective boarding and low ground pressure machinery. If necessary, soil should be carefully removed and stored for subsequent reinstatement. • A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures installed. • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below) • Restoration of lost mangrove habitat and additional mangroves planted • An invasive species management will be developed with the aim to prevent or manage invasive species introductions • Monitoring in the years post construction to ensure there is no further loss of mangroves and that restoration was successful
3. Migratory / Congregatory Species	Yes, likely to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species	• Minimize turbulence and flow contraction because turbulence inhibits or prevents passage • Construct bridge bottoms with natural stream substrates • Construction should be phased to be outside the key periods of faunal migration. • Ensure minimal disruption to the flow of the river during the wet season • Design bridge to avoid and reduce environment impacts e.g., maintain a constant grade along the length of the bridge. • An invasive species management will be developed with the aim to prevent or manage invasive species introductions

		• Monitoring in the years post construction to ensure there is no further loss of nearby mangroves and replanted mangroves restoration has been successful • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below)
4. Critical habitat qualifying processes/ecosystems	Yes, provides key ecosystem services	• Monitoring in the years post construction to ensure there is no further loss of nearby mangroves • An invasive species management will be developed with the aim to prevent or manage invasive species introductions • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below) • Ensure vegetation clearance is restricted to within the subproject site boundary
5: The area holds biodiversity of significant social, economic, or cultural importance to local communities	Yes, important local fishing area	• Ensure vegetation clearance is restricted to within the subproject site boundary • Implement robust erosion and sediment control measures. Where practical use management methods such as turbidity curtains and turbidity meters outside the area in combination with phasing of construction work to minimise sedimentation and disturbance to aquatic fauna and flora • When excavation is required within the channel, as in the placement of footings for abutments or piers, measures should be taken to separate the excavation area from the flow by cofferdams. Storage of fuel, equipment, and construction materials to minimise the risk of soil contamination or water pollution. • Use of techniques to minimise compaction of soil, such as restricting access during wet conditions, and using protective boarding and low ground pressure machinery. If necessary, soil should be carefully removed and stored for subsequent reinstatement. • A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures installed. • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out

		onsite. (Further detail is provided in the Working with concrete, cement and lime section below) • Development of a species-specific management plan for species of concern • Restoration of lost mangrove habitat and additional mangroves planted • An invasive species management will be developed with the aim to prevent or manage invasive species introductions • Further habitats will be created to compensate for habitat losses and to improve the landscape and ecological potential for the site • Monitoring in the years post construction to ensure there is no further loss of nearby mangroves
Criterion 6: Protection	No	No additional measures required

23. Viseisei bridge site conclusion

We conclude that the key period of impact will be: 1) during the construction phase of the project, and specifically to water quality (i.e., unmitigated discharge of sediments and potential concrete contamination) and 2) due to the removal of the mangrove vegetation. Management plans are needed to ensure these do not have an impact. It is also important that limits on key construction activities during aquatic migration periods (during the wet season Nov-April) are maintained when migratory trigger species are potentially utilising the area.

We conclude that the significant environmental impacts of the Viseisei bridge development can be addressed if appropriate management and mitigation options are undertaken in addition to offsetting/mitigation for the loss of mangrove habitat. As a result, there will be no measurable adverse impacts, or likelihood of such, on the terrestrial or aquatic habitat which would impair its high biodiversity value or the ability to function after the planned mitigation and offset measures. Impacts are not expected to be anywhere near the level that could impair the ability of the Critical Habitat to perform ecological functions.

Following the implementation of the management and mitigation measures, including those for residual effect it is concluded that at Viseisei the ADB SPS and ESS6 and World bank ESF ESS6 requirements are fulfilled allowing the project to go ahead in an area of Critical Habitat (CH).

24. Sabeto Bridge Ecological Values

24.1 Terrestrial ecology

The land use adjacent to the Sabeto river, where the proposed bridge is located, is highly modified habitat with residential and farmland with little to no natural vegetation cover remaining and only large, introduced grasses growing along the banks alongside agricultural land (Figure 10-11).

Based on the current design, the closest sensitive terrestrial habitat is over 3000 m downstream where an intact mangrove ecosystem is present outside the EAAA. The vegetation of this site is too distant to be impacted by the proposed development. No native mangrove vegetation was present at the site. No terrestrial species threatened or known to be rare was found in the study site. The terrestrial habitat at this site is therefore of little ecological interest is defined as modified habitat (Figure 10-11).

Figure 10. a) Landscape visual of the site of proposed bridge development and the surrounding vegetation and b) a picture of the vegetation on the Sabato river bank where the proposed bridge would be layed.

24.2 Aquatic ecology

The Sabeto river drains the Mount Evans Ranges and flows in a south westerly and then westerly direction into Nadi Bay. The river itself has many names along its route, including Lutunakuve Creek, Nasasa Creek, Nanggara Creek, Tuvatu Creek (near the Tuvatu Gold mine), and Savuleiringa Creek. The river mouth is at Nadi Bay.

The Sabeto River drains the Sabeto and Mount Evans Ranges of western Viti Levu, Fiji. The river's catchment is narrow and elongate. It is underlain by sedimentary, intrusive, volcanic and volcaniclastic rocks. The catchment extends over 137 km2 and reaches an altitude of 1195 m asl on its northeastern margin. The trunk stream is 34.8 km long (Kushaal Raj). It rises at an elevation of just over 1000 m on the northern rim of the great amphitheatre within which lies the village of Navilawa. The river flows west to reach the ocean at Nadi Bay. The river possesses few significant tributaries capable of introducing coarse sediment into the main channel. Between 15 -18 km downstream, the river flows in a relatively confined valley and the hillslope and channel

systems are closely linked. Beyond that point, the valley widens, and the presence of a floodplain means that the channel is dissociated from the surrounding hillsides.

The mean annual rainfall is 1864 mm, with a drier winter (the mean precipitation in July is 49 mm) and a wet summer (the mean precipitation in January is 312 mm), although high daily falls may be expected at any time of the year. Major erosion due to extreme flooding has been observed on the riverbanks (Kushaal Raj).

At the proposed bridge development site, the river is approximately 41m across at the proposed site of the new bridge development and at its deepest point approximately 5-6m. The edge and bottom substrate are predominantly fine muddy sediment however water clarity was high on the days when surveys occurred.

EDNA Sampling in May-June 2023 at three points along the river: located 1) 150 meters upstream, 2) at the proposed bridge site and 3) 40 meters downstream. These sampling locations detected a total of 23 species of fish, 6 species of crustacean (2 crab species and 4 freshwater shrimp species) and 16 species within the Mollusca taxon (gastropods and bivalves) using the Sabeto river at or close to the proposed bridge site (See appendix Tables 38-4).

Of the identified fish species most are classified as least concern. There are a couple of data deficient species, but these have extremely wide distributions such as long finned eels. Freshwater flora remain unstudied. The freshwater fish utilising the area are likely to include migratory species. However, surveys have not occurred during the best period for detecting these species. We take a precautionary approach and assume they are present at key migration periods.

Results from the snorkel surveys showed freshwater mussel or kai (*Batissa violacea*) an important local resource for the local people were located during under the proposed bridge site and downstream from the site. The species was predominantly in the deeper water where there is firm sediment rather than soft silt. Average estimated density in the 1-meter plots where the freshwater mussel (kai) was present was calculated at 55 individuals/m^2 where the proposed bridge will be developed and 32 individuals/m^2 in the area below the bridge. Surprisingly, kai was not detected in the eDNA tests. This may be because of stratification of the water column. The aquatic area is of high ecological value because of the presence of these species.

Figure 11. Critical and modified habitat surrounding the proposed Sabato bridge.

25. Sabeto Bridge critical habitat triggers

Literature reviews, database surveys, eDNA surveys and field visits identified no endangered species of conservation significance based on the IUCN Red List of Threatened Species as present at the Sabeto bridge site, or within the EAAA of the site.

However, there are endemic or range restricted species of both crustacean and fish species which are data deficient or have not yet been evaluated by the IUCN for which the habitat at Sabeto is suitable. These species are potentially present undertaking life cycle events during migration. We have taken a precautionary approach and assumed they are present at key times in the year and trigger Critical habitat criteria 3 (See table 25-26).

Is one species *Datnia kneri /Mesopristes kneri* which is data deficient/not evaluated by the IUCN, which maybe present all year. This species is known from areas outside the EAAAs and are lacking information on population status and spatial coverage. Expert opinion suggests that the EAAA is unlikely to regularly hold ≥10% of the global population size AND ≥10 reproductive units of a species. Critical habitat criteria 2 is therefore not triggered (Table 25).

Criteria 3 of critical habitat in Sabeto is triggered however, since this this area is known to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of various migratory or congregatory species during their lifecycle (See Table 25-26).

The EAAA holds biodiversity of significant social, economic, or cultural importance to local communities in the form of bivalves. This triggers ADB criteria 5. No other critical habitat criteria thresholds are meet (Table 28). No protected areas of concern were identified so Criteria 6 was not triggered.

Table 25. Freshwater fish triggering critical habitat and criterion triggered at Sabeto.

Scientific name	Critical Habitat Rationale	Criterion Triggered
Glossogobius sp. (Hoese and Jenkins in prep)	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that at Sabeto, on a cyclical or otherwise regular basis supports, ≥ 1 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle qualifying them as Critical Habitat under Criterion 3.	3
Schismatogobius vitiensis Comon name: Fijian scaleless goby(Jenkins and Boseto, 2005)	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical basis, ≥ 1 percent of the global population of this migratory species may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Schismatogobius chrysonotus (Orange-spotted Scaleless Goby)	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through all 4 of the sites, qualifying them as Critical Habitat under Criterion 3.	3
Stenogobius (insularigobius) n. sp. Common name: teardrop goby	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Stiphodon sp.1, Isabella's goby	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Stiphodon sp.2 (Jenkins, Boseto and Watson)	Potential Critical Habitat: The 4 EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Sicyopterus n. sp. (Boseto, in preparation) – Tavoro Goby	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Datnia kneri / (Bleeker, 1876) (Terapontidae) Common name: Orange-spotted Therapon/Reve	Potential Critical Habitat: At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3. Potentially habitat outside of migration it is not considered likely, however, that >10% of the species' population occurs at any of the sites at any time, thus meaning this species does not trigger Critical Habitat under Criterion 2.	3

Table 26. Endemic freshwater crustaceans triggering critical habitat (CH) criteria and rational at Sabeto.

Name	Critical Habitat Rationale	Criterion Triggered
Caridina fijiana	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that >1% of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3

25.1 Critical habitat criteria triggered

The critical habitat triggered at the Sabeto is outlined (See Table 27).

Table 27. ADB critical habitat criteria triggered.

Criteria	Thresholds	Critical habitat triggered
1: Critically Endangered and Endangered Species	(a) Areas that support globally important concentrations of an IUCN Red-listed EN or CR species (≥ 0.5% of the global population AND ≥ 5 reproductive unitsGN16 of a CR or EN species). (b) Areas that support globally important concentrations of an IUCN Red-listed Vulnerable (VU) species, the loss of which would result in the change of the IUCN Red List status to EN or CR and meet the thresholds in GN72(a). (c) As appropriate, areas containing important concentrations of a nationally or regionally listed EN or CR species	no
2. Endemic / Restricted Range Species	(a) Areas that regularly hold ≥10% of the global population size AND ≥10 reproductive units of a species.	no
3. Migratory / Congregatory Species	(a) Areas known to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle. (b) Areas that predictably support ≥10 percent of the global population of a species during periods of environmental stress.	Yes, likely to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a number of migratory or congregatory species.
4. Critical habitat qualifying processes/ecosystems	The area includes unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services	Yes, key ecosystem services are provided for by kai at the site.
5: The area holds biodiversity of significant social, economic, or cultural importance to local communities		Yes, important area for collection of kai.
6: Protection		no

26. Ecological effects

This section of the report considers the potential impacts of project operation on terrestrial and freshwater ecology. Ecological effects on both the terrestrial and aquatic varies during construction and during operation are both summarised in (See Table 28). Ecological impacts may operate over a longer timescale, as populations and species take time to respond to environmental changes (time-lag).

26.1 Construction effects

Severity and spatial extent of the effects will depend on construction practices, timing of construction activities and controls, river flows, composition of substrate, and effectiveness of erosion controls.

26.1.1 Noise and disturbance

Considerable noise and visual disturbance may be generated during site formation and construction, potentially affecting the distribution and behaviour of fauna of the adjacent/remaining habitats. Due to the ranking of conservation importance of the species recorded, and the temporary nature of the impact, potential impacts to fauna from this source are likely to be minor if construction activities occur outside the wet season when critical migration and life cycle activities occur.

26.2 Terrestrial ecology

26.2.1 Site formation

No natural vegetation types will be removed at the Sabeto bridge site. The terrestrial habitats found within the Study Areas of Sabeto bridge is disturbed and surrounded by developed/urbanised area and therefore there are little terrestrial ecological constraints to the development. The impact on the terrestrial environment and fauna is minor for both these sites. However, there could still be negative effects from:

- unauthorised clearing outside the projects site boundary
- clearing elsewhere e.g., to store materials.
- causing damage to surrounding vegetation through erosion (refer Suspended solid)
- changes to water quality (Suspended solid/water quality)
- introduction of invasive species (refer invasive species).

26.2.2 Invasive species.

Invasive species have the potential to be spread by the construction e.g., through tracking of seeds on vehicles or machinery. Pathogens and invasive species may also be carried on, or in, materials, equipment (including vessels used to transport materials or workers) and any workers brought to the sites. This includes materials, equipment and workers bought from other countries or elsewhere in Fiji.

26.3 Aquatic ecology

26.3.1 Suspended solid/water quality.

Environment construction activities and dredging could result in the increased sediment loading and site runoff of streams and changes in turbidity may impact adversely upon aquatic populations particularly sessile species.

High suspended and deposited sediments can smoother habitats and reduce the photosynthesis of benthic plants. Suspended sediments can also impact on aquatic biota by clogging the food filtering or trapping apparatus of stream insects as well as the gills of fish, reducing the feeding efficiency (particularly for visual predators). This is a concern at the Sabeto bridge site.

Multiple fish species present in the wider catchment migrate both upstream and downstream within streams and rivers during different stages within their lifecycle. High suspended sediment can slow or prevent the migration of native fish species. In a study on juvenile whitebait (banded kokopu in New Zealand), fewer fish migrated upstream at turbidity > 25 NTU[14]. The study speculated that if the rate of migration of juvenile banded kokopu was slowed there could potentially be fewer juvenile fish reaching adult habitat, fish could potentially be subject to increased risk of predation and may not reach preferred upstream habitats while they are still able to climb as juveniles.

Smothering benthic communities is the key concern for maintaining the native freshwater mussels, kai at the Sabeto site. A species-specific management plan for Kai is required to reduce the severity of the effect for moderate to minor. Key components of the Kai management plan and are discussed below (section 13.5). The use of turbidity curtains at this site would further limit the area of impact on Kai from sedimentation. A turbidity meter should be used to measure the turbidity outside of the construction area impact site to ensure that turbidity readings are within the acceptable range of <25 NTUs outside turbidity curtains. Through the implementation of appropriate design and management sedimentation risks can be managed reducing the level of effect to low.

26.3.2 Pollution incidents

Local ecological populations may also be adversely affected by pollution incidents attributed to fuel leaks and oil spills associated with construction and maintenance operations on site.

Cement is a construction related material which can have adverse on freshwater life. Cement has the potential to be discharged to the downstream receiving environment. Cement wash water and runoff from recently placed cement are of particular concern within aquatic habitats due to their detrimental effect on in stream fauna. Crushed concrete is also increasingly used as back-fill material and more frequently as contractors seek ways to be more sustainable and reuse materials.

Cement wash water and runoff has a high lime content which is water soluble (dissolves easily in water) and can drastically increase the pH of a waterway. The alkalinity can kill or severely burn aquatic life. For fish, the alkalinity is exceptionally damaging to sensitive gill structures. In addition to alkalinity, cement wash, and runoff can similarly increase the loading of fine sediment resulting in the same effects on instream fauna and habitat as those identified above for suspended/deposited sediment.

Concrete structures can leach and cause alkaline water. In addition to potential mortality of fauna, localised increases in pH (alkaline conditions) from leaching from concrete structures may also create a barrier to fish passage. These effects can be limited through careful management.

There is a particularly high risk of discharge of contaminants following discrete wet weather events or during prolonged periods of wet weather. Appropriate design and management can reduce these risks.

[14] Richardson, J., Rowe, D.K., Smith, J.P.2001. Effects of turbidity on the migration of juvenile banded kokopu (*Galaxias fasciatus)* in a natural stream, New Zealand. Journal of Marine and Freshwater Research, 35:1, 191-196, DOI: 10.1080/00288330.2001.9516989

26.4 Impacts on fish and crustacean species of concern

Direct impacts on migratory fish and crustacean species are unlikely if there is minimal disruption to the flow of the river during the wet season (Nov-April) is ensured and key activities such as pile construction is limited to outside critical life history and migration periods. This will enable any fish and crustacean migration is not obstructed during construction works within the riverbed and ensure these risks are unlikely. Timing construction outside the migratory wet season reduces the severity of the effect of construction to no more than minor.

26.5 Operational effects

26.5.1 Aquatic impacts

The physical presence of bridges during operation post construction can affect aquatic ecological populations in several ways. Physical developments such as bridge pillars, dredging and alteration of embankments, and roading construction can result in channelization, and deep pool formation resulting in an ecological disturbance for aquatic fauna if habitat corridors become severed.

Disturbances from bridge construction can be mitigated if normal water flow is maintained despite the blocking effect of embankments and bridge piers. This objective can be achieved through designs that favour long spans and hydraulically shaped piers. Abutments should be set back from the normal wetted perimeter of the watercourse to avoid constriction of the channel and reduction of the flow area.

The length of the spans required are determined by the bridge design by the engineers. However, the longer the spans the more contact with waterways can be reduced reducing freshwater impacts.

Abutments and piers should be designed and constructed to provide the least amount of hydraulic resistance. Where piers are required, hydraulic shaped piers will minimize local scour and reduce obstruction of flow reducing impacts on the aquatic benthic environment. Piers should be constructed with ends which are tapered upstream and downstream in the direction of the main flow.

26.5.2 Management of effects on freshwater mussels (Kai)

At Sabeto Bridge freshwater mussels/kai were present around the area where the bridge will be constructed as well as downstream within the potential area of impact. Freshwater mussels (kai) are not threatened but are an important food source for local people and provide an important ecosystem service. They are sensitive to:

- Poor water quality
- Sedimentation-siltation
- Direct impacts to substrate and river bottom
- Changes in local hydraulics- both during construction and permanent changes

Construction activities in or near water bodies can have substantial effects on freshwater mussels through hydrologic alterations and siltation. Incidental loss of mussels can result directly

from construction efforts or indirectly by habitat alteration in the immediate vicinity of construction sites. An example of a direct effect would be burial while dredging, and an example of an indirect effect would be changes in habitat which may interfere with growth or reproduction.

The area of direct effects is the locations where mussels were likely to die or be displaced during or shortly after construction activities for example the dredging area and the area where piers would be added. The indirect-effects can occur due to scouring, sedimentation, and pooling from construction-related changes in river flow Indirect impacts can occur 50 to 100 m upstream of the bridge and 50 to 200 m downstream of the bridge. The effect is determined to be moderate, and mitigation is required to minimize impacts so freshwater mussels will continue to occur in this area and maintain their important ecological function.

26.6 Cumulative impacts

The potential biodiversity impacts of the bridge proposals must be considered because of the construction and operation of the proposal within the existing environment. The proposal would not act alone in causing impacts to biodiversity. The incremental effects of multiple sources of impact (past, present, and future) are referred to as cumulative impacts and provide an opportunity to consider the proposal within a strategic context. The accumulating impacts of historic vegetation clearing for urban development, agriculture, and development and maintenance of infrastructure have contributed to the loss of biodiversity within the Fijian landscape. The proposed developments are not found to be a major contributor to cumulative impacts upon local terrestrial or aquatic ecology.

27. Avoid, minimise, and mitigate impacts.

ADB require that mitigation of ecological impacts be sought in the following order of priority: (1) avoid, (2) minimise, (3) compensate on-site and (4) compensate off-site. At each stage, residual impacts should be re-assessed to determine whether there is a need to proceed to the next stage of mitigation. The following measures are proposed to mitigate the impacts discussed in the preceding section.

27.1 Avoidance and minimisation

The primary method to avoid impacts is to locate activities away from areas of known or potential high biodiversity value. Where possible the road alignment and bridge design has been located to avoid effects on natural areas of aquatic and terrestrial fauna.

27.2 Mitigation measures

Once all practicable steps to avoid or minimise impacts have been implemented at the detailed design phase, mitigation measures would be implemented to lessen the potential ecological impacts of the proposal. Mitigation measures are to be undertaken during the construction and operational phases and are outlined in Tables 28 and 29 below.

Table 28. Activities and potential effects on aquatic ecology during the various phases of the operation are summarised in the following table.

Construction phase		
Construction Activities	**Potential impact**	**Proposed Mitigation activity**
Drainage works and use of vehicles	• Negative impact on flora and fauna from increased sediment (increased turbidity) loading of river, mangrove and marine areas	• Implement robust erosion and sediment control measures. Where practical use management methods such as turbidity curtains and turbidity meters outside the area in combination with phasing of construction work to minimise sedimentation and disturbance to aquatic fauna and flora • Operation of heavy equipment should be confined to dry stable areas to reduce the amount of mud and heavily silted water at the construction site which could enter the watercourse. • Stabilise exposed areas as soon as possible. • Avoid discharge of sediment into water • Avoid or minimise sediment release downstream. • Retain vegetation on the bank. • When excavation is required within the channel, as in the placement of footings for abutments or piers, measures should be taken to separate the excavation area from the flow by cofferdams. • Storage of fuel, equipment, and construction materials to minimise the risk of soil contamination or water pollution, • A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures installed.
Materials management	• Harm to aquatic flora and fauna from oil, fuel, cement, or other substances entering watercourses	• All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below) • Development of a species-specific management plan for species of concern e.g., freshwater mussels/kai
Physical impacts- Dredging and bridge pillar	• Habitat loss and direct mortality of sensitive flora and fauna • Potential barrier to fish and shrimp migration along the river corridor	• Where needed turbidity barriers will be used during construction to prevent fine material from further impacting kai. • Ensure minimal disruption to the flow of the river during the wet season • Minimize turbulence and flow contraction because turbulence inhibits or prevents passage, • Construct bridge bottoms with natural stream substrates, • Construction should be phased to be outside the key periods of faunal migration.
Debris from construction	• Any debris left on the seabed from the construction activity can become a projectile during severe wave activity, and this may cause damage to sensitive benthic resources.	• A swim through by an Ecologist will be done at the site after construction when the turbidity is back to normal. The inspection will ensure that all debris are removed off site and that the riverbeds are appropriately restored.
Operation phase/ongoing site maintenance		
Activities	**Potential impact**	**Proposed Mitigation activity**
Physical presence of the bridge	• Changes to deposition, depth and water velocities may result in the loss of sensitive plant, invertebrate, and fish species	• Design bridge to avoid and reduce environment impacts e.g., maintain a constant grade along the length of the bridge. • Effective stabilisation of altered landforms to minimise soil erosion.

		• Construct during periods of low flow to minimize impacts to fish and the potential for water pollution from suspended solids
	• Turbidity may contribute to reduced ecological diversity • Potential downstream changes to the aquatic community	• Reintroduction of sensitive species e.g., kai/freshwater muscles to ensure ecological processes and key species for consumption are maintained • During construction, minimize disturbance to the length of the natural stream channel and the natural flow of the water
Materials management from ongoing site maintenance	• Direct and indirect effects from oil, fuel or other substances entering the aquatic environment	• A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures undertaken.

Table 29. Activities and potential effects on terrestrial ecology during the various phases of the operation are summarised in the following table.

Construction phase		
Construction Activities	**Potential impact**	**Proposed Mitigation activity**
Invasive species introduction	• Negative ecological impacts due to the introduction of invasive species	• An invasive species management will be developed with the aim to prevent or manage invasive species introductions

27.3 Working with concrete, cement and lime

Concrete and cement are used extensively in construction. Many activities require in situ pouring of concrete into purpose-built boxing or form work or installing pre-cast structures into waterways. Cement and lime are also used for pavement and trench back-fill stabilisation works.

Uncured concrete, concrete slurry, cement and lime fines, dust, or washings can make water highly alkaline (pH of 11–13). This highly alkaline water will injure and kill fish and other freshwater life that encounter it. Water contaminated with concrete, cement and lime cannot be diluted or filtered to a safe level for discharge to the receiving environment, so washings, dust, fines, or slurry must not enter stormwater or freshwater receiving environments.

Concrete, cement and lime-contaminated water must be collected in a contained area and removed from site, to avoid discharging to the receiving freshwater environment. Even once cured, concrete structures will leach for some time when immersed in water, producing alkaline water. Pre-cast structures need to be soaked, with soakage water replaced (and appropriately discharged away from any of the sites) periodically. Where pre-cast structures cannot be used and in situ pouring is required, this must be done in the dry (e.g., the use of Coffer dams) and the structure may need to be soaked as described above before removing the coffer dam and exposing the structure to the waterway.

27.4 Preventing invasive species

Mitigation measures to prevent the introduction or spread of invasive species and pathogens will include:

- The contractor must obtain all required biosecurity and phyto-sanitary clearances (e.g., permits) for any material or equipment imported into Fiji.
- The contractor will obtain all permits and clearances for import of any materials and equipment to be used for the project as required by Biosecurity Fiji.
- Materials will be inspected, and any equipment imported for project purposes will be steam-cleaned and certified under biosecurity and phyto-sanitary procedures away from the sites prior to mobilization.
- Weed hygiene measures will be implemented to prevent introduction or spread of invasive species, including cleaning machinery before it enters and leaves the subproject sites. Inspection of the replanting and identification of any potentially risky weeds/invasive species should occur both during construction and immediately following construction by an appropriately qualified ecologist.

27.5 Minimise and mitigating impacts on Kai

It is recommended that at the proposed Sabeto bridge site undertakes active management of freshwater mussel/kai and develops a Kai management plan. This should be completed by an appropriately qualified ecologist prior to any construction activities occurring). We provide specific recommendations to mitigate the risks to the species at the Sabeto bridge development sites to these species. This can be achieved by:

- Stabilizing sediment and using methods such as sediment curtains during construction to reduce the area of impact.
- Following completion of the construction phase kai mussels should be recovered in the bridge site so ecosystem services and food sources are preserved (e.g., water filtration)

27.5.1 Translocation of kai

Prior to any disturbance of the riverbanks or bed associated with the bridge developments; a translocation program should be undertaken for reestablishment of kai on site post construction. Seeding locations upstream from the site should be identified.

Following completion of the construction phase of the developments, similar numbers of mussels should be relocated to the bridge sites to avoid density dependent impacts on the population and to ensure the ecosystem services (particularly water filtration) provided by the species are maintained at the impact sites. The water quality (particularly DO^2 and turbidity) of the impact site should be monitored to ensure that conditions are suitable before the mussels are released back on site. Monitoring post development in year 1, 2 should occur after the development to ensure success of the translocation.

A kai management plan should include a detailed description and plan for translocation of kai back to the site at Sabeto Bridge and monitoring plan to ensure success. The kai management plan should be developed by a qualified ecologist prior to construction commencing.

28. Residual impacts

As required by the ADB SPS, a no-net-loss of biodiversity values is required to be achieved. Although efforts have been made to avoid, minimise, and mitigate potential ecological impacts from the proposal, some residual impacts would occur in the form of loss of soft sediment habitat at the Sabeto Bridge site.

Natural soft sediment habitat under the water will be modified and lost as habitat for native species at all four of the sites in the locations where piers are placed and potentially also will impact habitat within 2 meters of the piers (Table 30). The current engineering plans have 3 piers under water in Sabato. Impacts on the soft sediment area calculated to be lost underwater through pier placement is small and not significant therefore offsets are not considered necessary (see table 30).

Table 30. Modified habitat by habitat type

Site	Habitat type residual impacts	Habitat Type condition	Habitat Type Area (B)
Sabeto	Soft sediment	Natural	30 m^2

29. Post-construction monitoring

Monitoring programs are recommended to:

- A qualified engineer should evaluate bridge impacts on erosion to ensure habitat integrity throughout the construction phase.
- Monitor the success of kai restoration a week after seeding and 1, 2- and 5-years post restoration should occur by a qualified ecologist.
- Ecological health (fish survival is not impacted by construction) using eDNA sampling or physical sampling, should be undertaken by a qualified ecologist during construction and 1 year following construction.
- Monitoring of turbidity is required daily during the construction phase to ensure levels are not higher than < 25 NTUs outside turbidity curtains (Set within 10m from the bridge).
- Once all practicable steps to avoid or minimise impacts have been implemented at the detailed design phase, mitigation measures would be implemented to lessen the potential ecological impacts of the proposal. Mitigation measures are to be undertaken during the construction and operational phases and are outlined in Tables 31 and 32 below.

30. Management measures to address CH triggers

Although all efforts have been made to avoid ecological effects at the Sabeto Bridge site complete avoidance of effects is not possible. It has also been necessary to mitigate and minimise potential ecological impacts and effects. A number of mitigation measures are required at this site to address each of the critical habitat triggers (Table 31).

Table 31. Critical habitat triggered and associated management measures to address each trigger.

Criteria triggered	Critical habitat triggered	Management measures to address
1: Critically Endangered and Endangered Species	No	No additional measures required
2. Endemic / Restricted Range Species	No	No additional measures required
3. Migratory / Congregatory Species	Yes, likely to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species	• Minimize turbulence and flow contraction because turbulence inhibits or prevents passage • Construct bridge bottoms with natural stream substrates • Construction should be phased to be outside the key periods of faunal migration. • Ensure minimal disruption to the flow of the river during the wet season • Design bridge to avoid and reduce environment impacts e.g., maintain a constant grade along the length of the bridge. • An invasive species management will be developed with the aim to prevent or manage invasive species introductions • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below)
4. Critical habitat qualifying processes/ecosystems	Yes, provides key ecosystem services	• An invasive species management will be developed with the aim to prevent or manage invasive species introductions • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below) • Development of a species-specific management plan for species of concern is designed and implemented E.g. kai • Implement robust erosion and sediment control measures. Where practical use management methods such as turbidity curtains and turbidity meters outside the area in combination with phasing of construction work to minimise sedimentation and disturbance to aquatic fauna and flora • When excavation is required within the channel, as in the placement of footings for abutments or piers,

		measures should be taken to separate the excavation area from the flow by cofferdams. Storage of fuel, equipment, and construction materials to minimise the risk of soil contamination or water pollution.
5: The area holds biodiversity of significant social, economic, or cultural importance to local communities	Yes, important local clam collection area	• Implement robust erosion and sediment control measures. Where practical use management methods such as turbidity curtains and turbidity meters outside the area in combination with phasing of construction work to minimise sedimentation and disturbance to aquatic fauna and flora • When excavation is required within the channel, as in the placement of footings for abutments or piers, measures should be taken to separate the excavation area from the flow by cofferdams. Storage of fuel, equipment, and construction materials to minimise the risk of soil contamination or water pollution. • A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures installed. • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below) • Development of a species-specific management plan for species of concern (kai) • An invasive species management will be developed with the aim to prevent or manage invasive species introductions
Criterion 6: Protection	No	No additional measures required

31. Sabato bridge site conclusion

We conclude that the key period of impact will be: during the construction phase of the project, and specifically to water quality (i.e., unmitigated discharge of sediments and potential concrete contamination). Management plans are needed to ensure these do not have an impact. It is also important that limits on key construction activities during aquatic migration periods (during the wet season Nov-April) should be maintained when migratory key trigger species are potentially utilising the area.

We conclude that potential significant environmental impacts can be addressed if appropriate management and mitigation options are undertaken in addition to mitigation for the restoration of freshwater mussel habitat, there will be no measurable adverse impacts, or likelihood of such, on the aquatic habitat which could impair its high biodiversity value or the ability to function after planned mitigation and offset measures. Impacts are not expected to be anywhere near the level that could impair the ability of the Critical Habitat to perform ecological functions.

Following the implementation of the management and mitigation measures at the Sabato site, including those for residual effect it is concluded that the ADB SPS and ESS6 and World bank ESF ESS6 requirements for allowing a project to go ahead in an area of Critical Habitat (CH).

32. Lami bridge Ecological Values

32.1 Terrestrial Ecology

The current proposed bridge site is located approximately 20 meters from the edge of a natural mixed Rhizophora mangrove habitat. The mangrove forest is dominated by *Rhizophora stylosa* and *Rhizophora samoensis.* Mangrove associated species and backshore species including *Hibiscus tiliaceus* were also found on the edge habitat. The larger mangrove habitat to the Northeast and in the centre of the river to the North was mature and high quality showing little sign of anthropogenic disturbance. Accessible trees in the Larger Northeast mangrove fragment measured 2-5 meters in height and were at a density of 8-12 trees per meter (n=4). No terrestrial species threatened or known to be rare was found in the Study Area.

Based on the current design, the estimated clearing of natural habitat mangrove vegetation for the proposal will result in no mangrove clearance (See Figure 12-15). The terrestrial area outside the mangrove site where the development is proposed had modified habitat, where the natural habitat has been altered, through the introduction of alien species of plants with lawn, planted garden and trees (Figure 12 and 15). This habitat is of little ecological value.

Figure 12. The areas of impact for the proposed Lami bridge.

Natural intertidal marine habitat is immediately adjacent to the bridge site and intersects with the planned area for the bridge development. The Assessment Area cover intertidal sandflat and subtidal habitats. The substrate is mainly sand with shell fragment. A walk through of the greater site area revealed no close seagrass during low tide within 50m of the site. There has been no long-term monitoring of changes in biodiversity in soft shores in Fiji and only a few studies of selected organisms have been made. The rarity of these species could therefore not be determined. This area is considered natural habitat.

The intertidal soft sediment zone is also considered migratory fish habitat and is included in the critical habitat measure (Figure 15). Currently the development is calculated to impact 2,082m^2 of natural habitat and 15,583m^2 of modified habitat. Of this 2,082m^2 is calculated to be critical fish habitat.

Figure 13. Natural and modified areas surrounding the proposed bridge structure are made up of mangroves, estuary, and intertidal habitat.

Figure 14. mangrove areas (red) surrounding the proposed bridge development (yellow).

Figure 15. The critical habitat intertidal and river habitat surrounding the proposed bridge development.

32.2 Aquatic ecology

The Lami River is approximately 9.5 kilometres in length and an estimated terrain elevation above sea level of 13 metres. It has two major tributaries and discharges to Laucala Bay. The total area of the catchment is approximately 21.54 square kilometres. River erosion is visible in different areas, as most of the banks are composed of soft soil and logs have also been found blocking the flow of the waterway.

At the proposed bridge development site, the mouth of the river is approximately 51m across. The edge and bottom substrate are predominantly sandy sediment, water clarity was high on the days when surveys occurred. EDNA sampling occurred at low tide. Edna samples were taken 15m above the proposed bridge and at the proposed bridge site. 18 species of fish were detected. No crustacean (shrimp or crab) and molluscan taxon were detected in the eDNA sampling (See appendix tables 38-42). This should not be interpreted as absence of species in these taxa. It is likely that the absence of these taxon according to the DNA technician is because the filter was likely to be clogged prior to any mollusc eDNA being collected. Netting and trapping did not add further fish species to the total species number provided through eDNA sampling (Appendix, table 38-42).

EDNA surveys revealed no species of concern. However, several species of concern were not within the eDNA database library during the analysis period which would prevent them being identified except through elimination e.g., the only species of that genus. Additional targeted surveys for specimens of *Parioglossus* and other gobies utilising kilwell traps in the mangrove area were not successful in finding any additional species at the site. Of the identified fish

species, several species were invasive. However, tilapia was not detected at this site. The lack of tilapia is likely to result in a higher fish diversity being maintained in this area.

The freshwater fish and crustaceans moving through this site are likely to include migratory species. However, surveys have not occurred during the best period for detecting these species. Migratory freshwater species are likely to utilise the site and as with the other sites we take a precautionary approach and assume they are present at key migration periods. The site is of high ecological value.

33. Lami bridge critical habitat triggers

Literature reviews, database surveys, eDNA surveys and field visits identified no endangered species of conservation significance based on the IUCN Red List of Threatened Species as present at the Lami bridge site, or within the EAAA of the site. However, there are endemic or range restricted species of both crustacean and fish species which are data deficient or have not yet been evaluated by the IUCN for which the habitat is potentially suitable (See Table 32 and 33). Some of these species are only likely to be present during key life cycle events where it is likely ≥ 1 percent of the global population of this migratory species migrate through the site triggering criteria 3 for critical habitat (See table 32-33). We have taken a precautionary approach and assumed they are present at key times in the year (See table 33-32).

There are also two species *Datnia kneri /Mesopristes kneri* and *Parioglossus triquetrus* which are data deficient/not evaluated by the IUCN which maybe present all year. Both species are known from areas outside the EAAAs and are lacking information on population status and spatial coverage.

For *Datnia kneri /Mesopristes kneri* appropriate habitat requirements are met at this project site. This species could also trigger Criteria 3 since they migrate. This species was not however present in any of the eDNA samples collected (there was no unidentified Terapontidae genus in the eDNA) at any of the sites. This suggests that the species was not present during the survey periods. Expert opinion suggests it is not likely, that >10% of the species' population occurs at the Lami EEEAs, meaning this species does not trigger Critical Habitat under Criterion 2.

Parioglossus triquetrus is endemic. The habitat requirements of this species are met by this project site given that mangroves are present. No records of the species have been recorded within the EAAA and no *Parioglossus triquetrus* were captured during the surveys despite effort. No potential individuals were seen in the mangroves or while doing snorkel surveys. However, the species is known to be difficult to capture. *Parioglossus triquetrus* was not in the eDNA library which did not allow this species to be identified directly through the eDNA samples. Furthermore, there is unidentified Gobiidae in the eDNA samples which could be *Parioglossus triquetrus*.

The species has previously been recorded in a Creek 15 km west of Lami. Which is relatively close to the Lami bridge site. The site where the species as previously seen is a smaller tributary, so the habitat was somewhat different than this project site. It is possible the EAAAs regularly hold ≥10% of the global population size AND ≥10 reproductive units of the global population of *Parioglossus triquetrus* qualifying these as Critical Habitat under Criterion 2. Consideration is given to potential project-related adverse impacts on this species.

Table 32. Freshwater fish triggering critical habitat and criterion triggered at Lami.

Scientific name	Critical Habitat Rationale	Criterion Triggered
Glossogobius sp. (Hoese and Jenkins in prep)	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical basis, ≥ 1 percent of the global population of this migratory species may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Parioglossus triquetrus	Potential Critical Habitat: Suitable habitat potentially exists. Though the species was not found at the sites, it is possible the EAAAs regularly hold ≥10% of the global population size AND ≥10 reproductive units of a species of the global population occur, qualifying these as Critical Habitat under Criterion 2.	2
Schismatogobius vitiensis Comon name: Fijian scaleless goby(Jenkins and Boseto, 2005)	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical basis, ≥ 1 percent of the global population of this migratory species may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Schismatogobius chrysonotus (Orange-spotted Scaleless Goby)	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through all 4 of the sites, qualifying them as Critical Habitat under Criterion 3.	3
Stenogobius (insularigobius) n. sp. Common name: teardrop goby	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Stiphodon sp.1, Isabella's goby	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Stiphodon sp.2 (Jenkins, Boseto and Watson)	Potential Critical Habitat: The 4 EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Sicyopterus n. sp. (Boseto, in preparation) – Tavoro Goby	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Datnia kneri / (Bleeker, 1876) (Terapontidae) Common name: Orange-spotted Therapon/Reve	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that on a cyclical or otherwise regular basis, ≥ 1 percent of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3. It is not considered likely, however, that >10% of the species' population occurs at any of the sites at any time, therefore this species does not trigger Critical Habitat under Criterion 2.	3

Table 33. Endemic freshwater crustaceans triggering critical habitat (CH) criteria and rational at Lami.

Name	Critical Habitat Rationale	Criterion Triggered
Caridina fijiana	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that >1% of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Caridina nudirostris	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that >1% of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3
Caridina devaneyi	Potential Critical Habitat: The EAAAs are not habitat except during migration. At that time, it is possible that >1% of the global population may migrate through the sites, qualifying them as Critical Habitat under Criterion 3.	3

33.1 Critical Habitat-qualifying ecosystems

ADB Criterion 4 states " The area includes unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services;"

Criterion 4 relates to specific landscape features which are critical for ecological functions. Examples of these within the sites includes riparian zones and rivers, dispersal/migration corridors (rivers), hydrological regimes, and keystone or habitat-forming species (mangroves and freshwater mussels).

The rivers, estuaries, and mangrove surrounding Lami provide critical shelter and food for aquatic species and function as migration corridors maintaining key life cycle events. The mangrove river systems are recognised as key ecosystem providers e.g., breeding and nursery habitats for fish species, storms and floods, erosion control functioning locally and regionally as important ecosystem services. By providing these ecosystem services they trigger critical habitat criterion 4.

33.2 Critical habitat criteria triggered

The critical habitat triggered at the Lami is outlined in table 34. No protected areas of concern were identified so Criteria 6 was not triggered.

Table 34. ADB criteria critical habitat triggered.

Criteria	Thresholds	Critical habitat triggered
1: Critically Endangered and Endangered Species	(a) Areas that support globally important concentrations of an IUCN Red-listed EN or CR species (≥ 0.5% of the global population AND ≥ 5 reproductive unitsGN16 of a CR or EN species). (b) Areas that support globally important concentrations of an IUCN Red-listed Vulnerable (VU) species, the loss of which would result in the change of the IUCN Red List status to EN or CR and meet the thresholds in GN72(a). (c) As appropriate, areas containing important concentrations of a nationally or regionally listed EN or CR species	No
2. Endemic / Restricted Range Species	(a) Areas that regularly hold ≥10% of the global population size AND ≥10 reproductive units of a species.	Yes, potentially ≥10% of the global population size AND ≥10 reproductive units of *Parioglossus triquetrus* present
3. Migratory / Congregatory Species	(a) Areas known to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle. (b) Areas that predictably support ≥10 percent of the global population of a species during periods of environmental stress.	Yes, likely to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species
4. Critical habitat qualifying processes/ecosystems	The area includes unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services	Yes, provides key ecosystem services
5: The area holds biodiversity of significant social, economic, or cultural importance to local communities		Yes, important local fishing area
Criterion 6: Protection		No

34. Ecological effects

This section of the report considers the potential impacts of project operation on terrestrial mangrove, freshwater, and intertidal ecology at the Lami bridge site. Ecological effects on terrestrial and aquatic varies during construction and operation are summarised in (Table 35 and 36). Ecological impacts may operate over a longer timescale, as populations and species take time to respond to environmental changes (time-lag).

34.1 Construction effects

Severity and spatial extent of the effects will depend on construction practices, timing of construction activities and controls, river flows, composition of substrate, and effectiveness of erosion controls.

34.1.1 Noise and disturbance

Considerable noise and visual disturbance may be generated during site formation and construction, potentially affecting the distribution and behaviour of fauna of the adjacent/remaining habitats. Due to the ranking of conservation importance of the species recorded, and the temporary nature of the impact, potential impacts to fauna from this source are likely to be minor if construction activities occur outside the wet season when critical migration and life cycle activities occur.

34.2 Terrestrial ecology

34.2.1 Site formation

The Lami bridge site has mangrove habitat of ecological value. Removal of these mangroves is avoided by aligning the bridge on the seaward side of the road where only disturbed vegetation habitat remains. However, there could still be indirect loss of natural vegetation loss through the Lami bridge placement project, the project may impact vegetation by:

- unauthorised clearing outside the subprojects site boundary
- clearing elsewhere e.g., to store materials.
- causing damage to surrounding vegetation through erosion (refer Suspended solid)
- changes to water quality (Suspended solid/water quality)
- introduction of invasive species (refer invasive species).

Post construction monitoring would ensure construction has not led to additional destabilisation effects on nearby mangroves surrounding the proposed Lami bridge and that none of the surrounding mangrove has been removed during construction activities. The impact on the terrestrial environment and fauna is likely to be minor for the Lami bridge site.

34.2.2 Invasive species.

Invasive species have the potential to be spread by the construction e.g., through tracking of seeds on vehicles or machinery. Pathogens and invasive species may also be carried on, or in,

materials, equipment (including vessels used to transport materials or workers) and any workers brought to the sites. This includes materials, equipment and workers bought from other countries or elsewhere in Fiji.

34.3 Intertidal ecology

34.3.1 Intertidal Construction Works

Construction works within the intertidal zone, would be required at Lami. The area of seabed effected for this site is sandy bottomed. Due to the small scale of construction works involved, impacts are ranked as largely minimal in nature if sedimentation impacts can be contained.

34.3.2 Suspended solid.

Construction activities, may indirectly impact upon the intertidal marine environment through re-suspension of sediment from excavation, dredging and site formation activities, and site runoff at the Lami site. Re-deposition of suspended solids has the potential to affect marine benthic communities and to alter seabed characteristics. No seabed assemblages of high conservation value have been recorded within the study site. Outside the study site in the greater area there is coral reefs and there is likely to be seagrass. It is recommended to avoid impacts on these ecosystems by containing and minimising sedimentation during construction activities to as close to the site of the bridge development as possible.

A plan is needed to ensure the implementation of appropriate design and management techniques to reduce sedimentation risks during construction are low particularly during dredging or when piles are being placed. Turbidity curtains are one method which would be very useful to create a temporary barrier to ensure silt and debris are contained during construction. Provided sedimentation risks can be manged no unacceptable indirect impacts to marine ecological resources are predicted to occur during the construction and operations if turbidity readings are within the acceptable range <25 NTUs outside the turbidity curtains.

34.4 Aquatic ecology

34.4.1 Suspended solid/water quality.

Environment construction activities and dredging could result in the increased sediment loading and site runoff of streams and changes in turbidity may impact adversely upon aquatic populations particularly sessile species.

High suspended and deposited sediments can smoother habitats and reduce the photosynthesis of benthic plants. Suspended sediments can also impact on aquatic biota by clogging the food filtering or trapping apparatus of stream insects as well as the gills of fish, reducing the feeding efficiency (particularly for visual predators). This is a concern at all the sites.

Multiple fish species present in the wider catchment migrate both upstream and downstream within streams and rivers during different stages within their lifecycle. High suspended sediment can slow or prevent the migration of native fish species. In a study on juvenile whitebait (banded

kokopu in New Zealand), fewer fish migrated upstream at turbidity > 25 NTU[15]. The study speculated that if the rate of migration of juvenile banded kokopu was slowed there could potentially be fewer juvenile fish reaching adult habitat, fish could potentially be subject to increased risk of predation and may not reach preferred upstream habitats while they are still able to climb as juveniles.

Through the implementation of appropriate design and management sedimentation risks can be managed reducing the level of effect to low. Management tools include turbidity barriers which can be used to lessen the spread of fine particles and timing construction to avoid the rainy season and avoid key migration periods for sensitive species. A turbidity meter should be used to measure the turbidity outside of the construction area impact site to ensure that turbidity readings are within the acceptable range of <25 NTUs outside turbidity curtains.

34.4.2 Pollution incidents

Local ecological populations may also be adversely affected by pollution incidents attributed to fuel leaks and oil spills associated with construction and maintenance operations on site.

Cement is a construction related material which can have adverse on freshwater life. Cement has the potential to be discharged to the downstream receiving environment. Cement wash water and runoff from recently placed cement are of particular concern within aquatic habitats due to their detrimental effect on in stream fauna. Crushed concrete is also increasingly used as back-fill material and more frequently as contractors seek ways to be more sustainable and reuse materials.

Cement wash water and runoff has a high lime content which is water soluble (dissolves easily in water) and can drastically increase the pH of a waterway. The alkalinity can kill or severely burn aquatic life. For fish, the alkalinity is exceptionally damaging to sensitive gill structures. In addition to alkalinity, cement wash, and runoff can similarly increase the loading of fine sediment resulting in the same effects on instream fauna and habitat as those identified above for suspended/deposited sediment.

Concrete structures can leach and cause alkaline water. In addition to potential mortality of fauna, localised increases in pH (alkaline conditions) from leaching from concrete structures may also create a barrier to fish passage. These effects can be limited through careful management.

There is a particularly high risk of discharge of contaminants following discrete wet weather events or during prolonged periods of wet weather. Appropriate design and management can reduce these risks.

34.5 Impacts on fish and crustacean species of concern

Direct impacts on migratory fish and crustacean species are unlikely if there is minimal disruption to the flow of the river during the wet season (Nov-April) is ensured and key activities such as pile construction is limited to outside critical life history and migration periods. This will enable any fish and crustacean migration is not obstructed during construction works within the

[15] Richardson, J., Rowe, D.K., Smith, J.P.2001. Effects of turbidity on the migration of juvenile banded kokopu (*Galaxias fasciatus)* in a natural stream, New Zealand. Journal of Marine and Freshwater Research, 35:1, 191-196, DOI: 10.1080/00288330.2001.9516989

riverbed and ensure these risks are unlikely. Timing construction outside the migratory wet season reduces the severity of the effect of construction to no more than minor.

Any impacts on most potential resident species of concern, should they be present, are likely to be small and predominantly limited to the construction phase. Such impacts are most likely when mangroves will be removed. Provided careful mitigation activity is taken e.g., care involving cement/concrete should ensure minimal effects. These species cannot be assessed against measurable impacts without known populations on site.

The most significant potential for impacts at a particular species is to *Parioglossus triquetrus*, which may be resident in the Lami site. Although this species is not confirmed from any of the sites, its limited global distribution means that - if it is present - it may have a significant part of its global population present at one of these sites. Impacts on habitat at Lami is expected to be low and are not significant.

34.6 Operational effects

34.6.1 Aquatic impacts

The physical presence of bridges during operation post construction can also affect aquatic ecological populations in several ways. Physical developments such as bridge pillars, dredging and alteration of embankments, and roading construction can result in channelization, and deep pool formation resulting in an ecological disturbance for aquatic fauna if habitat corridors become severed.

Disturbances from bridge construction can be mitigated if normal water flow is maintained despite the blocking effect of embankments and bridge piers. This objective can be achieved through designs that favour long spans and hydraulically shaped piers. Abutments should be set back from the normal wetted perimeter of the watercourse to avoid constriction of the channel and reduction of the flow area.

The length of the spans required are determined by the bridge design by the engineers. However, the longer the spans the more contact with waterways can be reduced thereby reducing freshwater impacts.

Abutments and piers should be designed and constructed to provide the least amount of hydraulic resistance. Where piers are required, hydraulic shaped piers will minimize local scour and reduce obstruction of flow reducing impacts on the aquatic benthic environment. Piers should be constructed with ends which are tapered upstream and downstream in the direction of the main flow.

34.7 Cumulative impacts

The potential biodiversity impacts of the bridge proposals must be considered because of the construction and operation of the proposal within the existing environment. The proposal would not act alone in causing impacts to biodiversity. The incremental effects of multiple sources of impact (past, present, and future) are referred to as cumulative impacts and provide an opportunity to consider the proposal within a strategic context. The accumulating impacts of

historic vegetation clearing for urban development, agriculture, and development and maintenance of infrastructure have contributed to the loss of biodiversity within the Fijian landscape. The proposed developments are not found to be a major contributor to cumulative impacts upon local marine, terrestrial or aquatic ecology.

35. Avoid, minimise, and mitigate impacts

ADB require that mitigation of ecological impacts be sought in the following order of priority: (1) avoid, (2) minimise, (3) compensate on-site and (4) compensate off-site. At each stage, residual impacts should be re-assessed to determine whether there is a need to proceed to the next stage of mitigation. The following measures are proposed to mitigate the impacts discussed in the preceding section.

35.1 Avoidance and minimisation

The primary method to avoid impacts is to locate activities away from areas of known or potential high biodiversity value. Where possible the road alignment and bridge design has been located to avoid loss of mangrove. Further loss of mangroves should also be minimised as possible with no heavy machinery being placed in the mangrove areas in areas surrounding the Lami bridge site.

35.2 Mitigation measures

Once all practicable steps to avoid or minimise impacts have been implemented at the detailed design phase, mitigation measures would be implemented to lessen the potential ecological impacts of the proposal. Mitigation measures are to be undertaken during the construction and operational phases and are outlined in Tables 35 and 36 below.

Table 35. Activities and potential effects on aquatic ecology during the various phases of the operation at Lami are summarised in the following table.

Construction phase		
Construction Activities	**Potential impact**	**Proposed Mitigation activity**
Drainage works and use of vehicles	• Negative impact on flora and fauna from increased sediment (increased turbidity) loading of river, mangrove and marine areas	• Implement robust erosion and sediment control measures. Where practical use management methods such as turbidity curtains and turbidity meters outside the area in combination with phasing of construction work to minimise sedimentation and disturbance to aquatic fauna and flora • Operation of heavy equipment should be confined to dry stable areas to reduce the amount of mud and heavily silted water at the construction site which could enter the watercourse. • Stabilise exposed areas as soon as possible. • Avoid discharge of sediment into water • Avoid or minimise sediment release downstream. • Retain vegetation on the bank. • When excavation is required within the channel, as in the placement of footings for abutments or piers, measures should be taken to separate the excavation area from the flow by cofferdams.

Materials management	• Harm to aquatic flora and fauna from oil, fuel, cement, or other substances entering watercourses	• Storage of fuel, equipment, and construction materials to minimise the risk of soil contamination or water pollution, • A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures installed. • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below)
Physical impacts- Dredging and bridge pillar	• Habitat loss and direct mortality of sensitive flora and fauna • Potential barrier to fish and shrimp migration along the river corridor	• Where needed turbidity barriers will be used during construction to prevent fine material from going offshore or entering other sensitive environments. • Ensure minimal disruption to the flow of the river during the wet season • Minimize turbulence and flow contraction because turbulence inhibits or prevents passage • Construct bridge bottoms with natural stream substrates, • Construction should be phased to be outside the key periods of faunal migration.
Debris from construction	• Any debris left on the river bed from the construction activity may cause damage to sensitive benthic resources.	• A swim through by an Ecologist will be done at the site after construction when the turbidity is back to normal. The inspection will ensure that all debris are removed off site and that the bed is appropriately restored.
Operation phase/ongoing site maintenance		
Activities	**Potential impact**	**Proposed Mitigation activity**
Physical presence of the bridge	• Changes to deposition, depth and water velocities may result in the loss of sensitive plant, invertebrate, and fish species • Potential downstream changes to the aquatic community	• Design bridge to avoid and reduce environment impacts e.g., maintain a constant grade along the length of the bridge. • Effective stabilisation of altered landforms to minimise soil erosion. • Construct during periods of low flow to minimize impacts to fish and the potential for water pollution from suspended solids • During construction, minimize disturbance to the length of the natural stream channel and the natural flow of the water
Materials management from ongoing site maintenance	• Direct and indirect effects from oil, fuel or other substances entering the aquatic environment	• A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures undertaken.

Table 36. Activities and potential effects on terrestrial ecology at the Lami site during the various phases of the operation are summarised in the following table.

Construction phase		
Construction Activities	**Potential impact**	**Proposed Mitigation activity**
Earthworks and excavations Invasive species introduction	• Disturbance to sensitive species on and near the site and changes in distribution, activity patterns • Negative ecological impacts due to the introduction of invasive species	• This effect is considered minimal for these ecosystems and mitigation is not required • An invasive species management will be developed with the aim to prevent or manage invasive species introductions
Operation phase/ongoing site maintenance		
Construction Activities	**Potential impact**	**Proposed Mitigation activity**
Physical presence of bridge	• Destabilisation of nearby mangroves	• Monitoring in the years post construction to ensure there is no loss of nearby mangroves

35.3 Working with concrete, cement and lime

Concrete and cement are used extensively in construction. Many activities require in situ pouring of concrete into purpose-built boxing or form work or installing pre-cast structures into waterways. Cement and lime are also used for pavement and trench back-fill stabilisation works.

Uncured concrete, concrete slurry, cement and lime fines, dust, or washings can make water highly alkaline (pH of 11–13). This highly alkaline water will injure and kill fish and other freshwater life that encounter it. Water contaminated with concrete, cement and lime cannot be diluted or filtered to a safe level for discharge to the receiving environment, so washings, dust, fines, or slurry must not enter stormwater or freshwater receiving environments.

Concrete, cement and lime-contaminated water must be collected in a contained area and removed from site, to avoid discharging to the receiving freshwater environment. Even once cured, concrete structures will leach for some time when immersed in water, producing alkaline water. Pre-cast structures need to be soaked, with soakage water replaced (and appropriately discharged away from any of the sites) periodically. Where pre-cast structures cannot be used and in situ pouring is required, this must be done in the dry (e.g., the use of Coffer dams) and the structure may need to be soaked as described above before removing the coffer dam and exposing the structure to the waterway.

35.4 Preventing invasive species

Mitigation measures to prevent the introduction or spread of invasive species and pathogens will include:

- The contractor must obtain all required biosecurity and phyto-sanitary clearances (e.g., permits) for any material or equipment imported into Fiji.
- The contractor will obtain all permits and clearances for import of any materials and equipment to be used for the project as required by Biosecurity Fiji.

- Materials will be inspected, and any equipment imported for project purposes will be steam-cleaned and certified under biosecurity and phyto-sanitary procedures away from the sites prior to mobilization.
- Weed hygiene measures will be implemented to prevent introduction or spread of invasive species, including cleaning machinery before it enters and leaves the subproject sites. Inspection of the replanting and identification of any potentially risky weeds/invasive species should occur both during construction and immediately following construction by an appropriately qualified ecologist.

36. Management measures to address CH triggers

Although all efforts have been made to avoid ecological effects at the Lami Bridge site complete avoidance of effects is not possible. It has also been necessary to mitigate and minimise potential ecological impacts and effects. Mitigation measures are required at this site to address each of the critical habitat triggers (See Table 37)

Table 37. Management measures to address specific critical habitat triggers at the Lami site.

Criteria triggered	Critical habitat triggered	Management measures to address
1: Critically Endangered and Endangered Species	No	No additional measures required
2. Endemic / Restricted Range Species	Yes, potentially ≥10% of the global population size AND ≥10 reproductive units of *Parioglossus triquetrus* present	• Implement robust erosion and sediment control measures. Where practical use management methods such as turbidity curtains and turbidity meters outside the area in combination with phasing of construction work to minimise sedimentation and disturbance to aquatic fauna and flora • When excavation is required within the channel, as in the placement of footings for abutments or piers, measures should be taken to separate the excavation area from the flow by cofferdams. Storage of fuel, equipment, and construction materials to minimise the risk of soil contamination or water pollution. • Use of techniques to minimise compaction of soil, such as restricting access during wet conditions, and using protective boarding and low ground pressure machinery. If necessary, soil should be carefully removed and stored for subsequent reinstatement. • A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures installed. • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below) • Development of a species-specific management plan for species of concern • An invasive species management will be developed with the aim to prevent or manage invasive species introductions
3. Migratory / Congregatory Species	Yes, likely to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species	• Ensure vegetation clearance is restricted to within the subproject site boundary and is minimised to the area of bridge placement • Minimize turbulence and flow contraction because turbulence inhibits or prevents passage • Construct bridge bottoms with natural stream substrates • Construction should be phased to be outside the key periods of faunal migration. • Ensure minimal disruption to the flow of the river during the wet season • Design bridge to avoid and reduce environment impacts e.g., maintain a constant grade along the length of the bridge. • An invasive species management will be developed with the aim to prevent or manage invasive species introductions • Monitoring in the years post construction to ensure there is no loss of nearby mangroves • All practical measures must be taken to prevent cement and cement products entering flowing water, including

		but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. • Post construction monitoring
4. Critical habitat qualifying processes/ecosystems	Yes, provides key ecosystem services	• Monitoring in the years post construction to ensure there is no loss of nearby mangroves • An invasive species management will be developed with the aim to prevent or manage invasive species introductions • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. • Post construction monitoring
5: The area holds biodiversity of significant social, economic, or cultural importance to local communities	Yes, important local fishing area	• Implement robust erosion and sediment control measures. Where practical use management methods such as turbidity curtains and turbidity meters outside the area in combination with phasing of construction work to minimise sedimentation and disturbance to aquatic fauna and flora • When excavation is required within the channel, as in the placement of footings for abutments or piers, measures should be taken to separate the excavation area from the flow by cofferdams. Storage of fuel, equipment, and construction materials to minimise the risk of soil contamination or water pollution. • Use of techniques to minimise compaction of soil, such as restricting access during wet conditions, and using protective boarding and low ground pressure machinery. If necessary, soil should be carefully removed and stored for subsequent reinstatement. • A risk assessment is carried out for each substance to be used or stored on site and the appropriate containment measures installed. • All practical measures must be taken to prevent cement and cement products entering flowing water, including but not limited to a) Avoiding flowing water coming into contact with the concrete until the concrete is firmly set. b) Using boxing or other similar devices to contain wet cement during construction of the structure. c) If any concrete is spilled beyond the boxing, pouring of concrete must stop immediately and all concrete must be removed from the watercourse. d) No equipment used in the pouring of concrete should be washed out onsite. (Further detail is provided in the Working with concrete, cement and lime section below) • An invasive species management will be developed with the aim to prevent or manage invasive species introductions • Monitoring in the years post construction
Criterion 6: Protection	No	No additional measures required

37. Post construction monitoring

Monitoring programs are recommended to:

- A qualified engineer should evaluate bridge impacts on erosion to ensure habitat integrity in the surrounding area throughout the construction phase.
- Post construction monitoring by both a qualified ecologist and an engineer within 3 weeks on construction being completed should ensure construction has not led to destabilisation effects on nearby mangroves.
- Monitoring of turbidity is required daily during the construction phase to ensure levels are not higher than < 25 NTUs outside turbidity curtains.
- Ecological health (fish survival is not impacted by construction) using eDNA sampling to ensure migration and resident fish are not impacted this should be undertaken by a qualified ecologist during construction and 1 year following construction.
- The habitat requirements for *Parioglossus triquetrus* are met at this site. further work on this species is recommended including eDNA collection for future identification (no DNA is currently available to confirm presence of the species) and pre-surveys at the sites, as well as the surrounding areas.

38. Lami bridge site conclusion

We conclude that the key period of impact will be: during the construction phase of the project, and specifically to water quality (i.e., unmitigated discharge of sediments and potential concrete contamination). Management plans are needed to ensure these do not have an impact. It is also important that limits on key construction activities during aquatic migration periods (during the wet season Nov-April) should be maintained when migratory trigger species are potentially utilising the area.

We conclude that potential significant environmental impacts can be addressed if appropriate management and mitigation options are undertaken there will be no measurable adverse impacts, or likelihood of such, on the aquatic or terrestrial habitat which could impair its high biodiversity value or the ability to function after planned mitigation and offset measures. Impacts are not expected to be anywhere near the level that could impair the ability of the Critical Habitat to perform ecological functions

Following the implementation of the management and mitigation measures, including those for residual effect it is concluded that at the Lami site the ADB SPS and ESS6 and World bank ESF ESS6 requirements are fulfilled allowing the project to go ahead in an area of Critical Habitat (CH).

39. Conclusion

This biodiversity assessment has investigated the potential impacts to terrestrial and aquatic flora and fauna associated with the proposed development of four bridges in Fiji, Lami, Madrakutu, Sabeto and Viseisei. The investigation has involved desktop investigation and field surveys.

The rivers, estuaries, and mangrove surrounding the three project areas (Lami, Madrakutu and Viseisei) provide critical shelter and food for aquatic species and function as migration corridors maintaining key life cycle events. The mangrove river systems are recognised as key ecosystem providers e.g., breeding and nursery habitats for fish species, storms and floods, erosion control functioning locally and regionally as important ecosystem services. By providing these ecosystem services they trigger critical habitat criterion 4.

The project is not anticipated to lead to a net reduction in the population of any IUCN listed Critically Endangered, Endangered species. However, we have identified some non-threatened migratory species (many of which are also restricted-range species) which trigger ADB Critical Habitat criterion 3 during migration. Though these species have not been found at the sites, many of the species are very poorly-known, and habitat at some of the sites is appropriate for some of the species. As a result, we have taken a precautionary approach and considered these species potentially present. The project should assume these species are present, and plan mitigation and offsets accordingly in order to achieve no net loss or, preferably, a net gain for the species. This should be quite straightforward with standard mitigation measures and simple, low-cost offset measures to restore/replant areas of mangroves, in alignment with requirements under national law.

The outcomes of this work were used to assess potential impacts on biodiversity associated with preferred options design. We conclude that the key period of impact will be: 1) during the construction phase of the project, and specifically to water quality (i.e., unmitigated discharge of sediments and potential concrete contamination) and due to the removal of the mangrove vegetation. Management plans will be needed to ensure these do not have an impact. It is also important that limits on key construction activities during aquatic migration periods (during the wet season Nov-April) should be maintained when migratory trigger species are potentially utilising the area.

We conclude that potential significant environmental impacts can be addressed if appropriate management and mitigation options are undertaken in addition to offsetting/mitigation for the loss of mangrove habitat and restoration of freshwater mussel habitat, there will be no measurable adverse impacts, or likelihood of such, on the aquatic or mangrove habitat which could impair its high biodiversity value or the ability to function after planned mitigation and offset measures. Impacts are not expected to be anywhere near the level that could impair the ability of the Critical Habitat to perform ecological functions at any of the four sites.

40. Appendix

Table 38. EDna Metadata for all of the four bridge sites

Site	Replicate	Location	Latitude	Longitude	Sample type	Notes	Collection date	Volume	Assays
SR	1	Sabeto River	-17.72014361	177.4534386	Sample	Sabeto River - Top left bank, water at lowest	29/05/2023	90	Fish, Decapod, Invertebrate, Mollusca
SR	2	Sabeto River	-17.72024187	177.4534852	Sample	Sabeto River - Upstream, 150m up from bridge	29/05/2023	90	Fish, Decapod, Invertebrate, Mollusca
SR	3	Sabeto River	-17.72021573	177.4532853	Sample	Sabeto River - from top water centre of river off current bridge	29/05/2023	100	Fish, Decapod, Invertebrate, Mollusca
VC	1	Varangge Creek	-17.6912269	177.420392	Sample	Viseisei Bridge - Up river from current bridge 3m viseisei town side	29/05/2023	1400	Fish, Decapod, Invertebrate, Mollusca
VC	2	Varangge Creek	-17.69141735	177.4205424	Sample	Viseisei Bridge - Taken from current bridge centre, low tide	29/05/2023	1300	Fish, Decapod, Invertebrate, Mollusca
VC	3	Varangge Creek	-17.69098463	177.4204495	Sample	Viseisei Bridge - 25m up fromcurrentbridge	29/05/2023	1000	Fish, Decapod, Invertebrate, Mollusca
LR	1	Lami River	-18.11406635	178.4116549	Sample	LamiInside river - side, under current bridge low tide	1/06/2023	900	Fish, Decapod, Invertebrate, Mollusca
LR	2	Lami River	-18.1142274	178.4116101	Sample	Lami - On open ocean side, low tide	1/06/2023	800	Fish, Decapod, Invertebrate, Mollusca
SH	1	Suva Harbour	-18.1028146	178.388413	Sample	Medraukutu - Up river 30 m	1/06/2023	900	Fish, Decapod, Invertebrate, Mollusca
SH	2	Suva Harbour	-18.1031694	178.38888	Sample	Medraukutu - Under bridge,mid to low tide	1/06/2023	900	Fish, Decapod, Invertebrate, Mollusca

Table 39. Fish taxon by sample detection table with sequence reads.

	Class	Order	Family	Genus	Species	Common Name	Status	Threat status	SR 1	SR 2	SR 3	VC 1	VC 2	VC 3	LR 1	LR 2	SH 1	SH 2
Fish	Actinopteri					Fish, unassigned			2022	831	5681	2106	630	9831	1170	2735	4352	29407
	Actinopteri	Anguilliformes	Anguillidae	*Anguilla*		Genus of freshwater eels			790	66	653	0	3882	0	0	0	0	0
	Actinopteri	Anguilliformes	Anguillidae	*Anguilla*	*Anguilla marmorata*	Giant mottled eel	Native	LC	0	581	0	0	2832	0	0	0	0	0
	Actinopteri	Anguilliformes	Anguillidae	*Anguilla*	*Anguilla obscura*	Pacific shortfinned eel	Native	Data Deficient but extremely large distribution	0	785	3939	0	0	0	0	277	0	0
	Actinopteri	Anguilliformes	Muraenidae			Family of moray eels			0	0	0	0	0	0	0	0	25	0
	Actinopteri	Anguilliformes	Muraenidae	*Strophidon*	*Strophidon sathete*	Slender giant moray	Native	LC	0	0	0	0	0	0	0	0	81566	12612
	Actinopteri	Anguilliformes	Ophichthidae	*Ophichthus*		Genus of snake eels		Potentially two LC species	205	0	0	0	0	0	0	0	0	0
	Actinopteri	Beloniformes	Zenarchopteridae	*Zenarchopterus*	*Zenarchopterus dispar*	Feathered river-garfish	Native	LC	0	5355	7680	22130	8815	757	0	0	685	1595
	Actinopteri	Blenniiformes	Blenniidae	*Omobranchus*		Genus of combtooth blennies			0	0	0	0	904	0	0	0	0	0
	Actinopteri	Carangiformes	Carangidae	*Caranx*		Genus of trevally and kingfish			388	0	0	0	0	0	0	0	0	0
	Actinopteri	Centrarchiformes	Kuhliidae	*Kuhlia*		Genus of flagtails			460	0	101	5868	0	0	0	0	111	729
	Actinopteri	Centrarchiformes	Kuhliidae	*Kuhlia*	*Kuhlia mugil*	Barred Flagtail	Native	LC	2433	46	33	1289	0	0	2531	3516	0	600
	Actinopteri	Centrarchiformes	Terapontidae	*Terapon*	*Terapon jarbua*	Jarbua terapon	Native	LC	0	0	326	0	7847	0	0	3420	0	0
	Actinopteri	Chaetodontiformes	Leiognathidae			Family of ponyfishes and slimies			0	0	0	391	0	1606	2886	0	0	0
	Actinopteri	Cichliformes	Cichlidae	*Oreochromis*		Genus of oreochromine cichlids	Introduced		43437	36988	69035	2473	7981	3157	0	0	0	0
	Actinopteri	Clupeiformes	Clupeidae			Family of herrings and sprats	Introduced		1576	2891	938	0	7221	0	0	0	124	0
	Actinopteri	Clupeiformes	Engraulidae	*Encrasicholina*	*Encrasicholina heteroloba*	Shorthead anchovy	Native	LC	0	0	0	1102	606	3174	0	0	0	0
	Actinopteri	Clupeiformes	Engraulidae	*Stolephorus*		Genus of schooling fish			0	0	0	1218	0	1093	0	0	0	0
	Actinopteri	Clupeiformes	Engraulidae	*Thryssa*	*Thryssa baelama*	Baelama anchovy	Native	LC	292	0	80	0	3902	0	3438	0	0	0
	Actinopteri	Cypriniformes	Cyprinidae	*Carassius*	*Carassius auratus*	Goldfish	Introduced		0	0	0	12066	0	0	0	0	55	0
	Actinopteri	Cypriniformes	Cyprinidae	*Cyprinus*	*Cyprinus carpio*	Common carp	Introduced		0	0	0	0	0	7805	0	6892	0	0
	Actinopteri	Cyprinodontiformes	Poeciliidae	*Poecilia*		Genus of mollies and guppies			28	0	0	0	0	0	0	0	0	74
	Actinopteri	Cyprinodontiformes	Poeciliidae	*Poecilia*	*Poecilia mexicana*	Shortfin molly	Introduced		545	545	0	0	0	0	0	0	42	0
	Actinopteri	Elopiformes	Megalopidae	*Megalops*	*Megalops cyprinoides*	Indo-Pacific tarpon	Native	DD large distribution young inhabit river mouths	0	2328	1171	1172	0	0	0	0	0	0
	Actinopteri	Gobiiformes	Eleotridae			Family of sleeper gobies			0	45	0	0	61	0	260	110	0	403
	Actinopteri	Gobiiformes	Eleotridae	*Butis*		Genus of sleeper gobies			0	27	205	0	880	2781	0	0	0	0
	Actinopteri	Gobiiformes	Eleotridae	*Eleotris*		Genus of sleepers			0	431	0	630	2086	0	3981	1718	184	1492
	Actinopteri	Gobiiformes	Eleotridae	*Eleotris*	*Eleotris fusca*	Dusky sleeper	Native	LC	0	0	23	0	0	0	0	343	0	372
	Actinopteri	Gobiiformes	Eleotridae	*Eleotris*	*Eleotris melanosoma*	Broadhead sleeper	Native	LC	0	742	0	0	0	0	0	2435	78	1022
	Actinopteri	Gobiiformes	Eleotridae	*Giuris*		Genus of gobies and gudgeons			605	0	373	0	1313	0	1783	1211	78	2287
	Actinopteri	Gobiiformes	Eleotridae	*Hypseleotris*		Genus of carp gudgeons			0	0	0	0	0	0	14874	19993	3808	16270
	Actinopteri	Gobiiformes	Eleotridae	*NA*	*Ophieleotris OR Giuris OR Eleotris sp.*			Potentially Not evaluated: *Hypseleotris guentheri*. Large distribution	1740	0	0	0	0	0	0	6110	453	1259
	Actinopteri	Gobiiformes	Gobiidae			Family of gobies			0	0	28	0	0	3035	0	2310	56	604
	Actinopteri	Gobiiformes	Gobiidae	*Awaous*		Genus of gobies		LC- all three potential species.	0	0	0	0	413	0	0	0	0	0
	Actinopteri	Gobiiformes	Gobiidae	*Glossogobius*		Genus of gobies			0	0	0	0	91	0	0	0	0	0
	Actinopteri	Gobiiformes	Gobiidae	*Glossogobius*	*Glossogobius celebius*	Celebes goby	Native	LC	0	38	302	0	0	0	0	0	0	0
	Actinopteri	Gobiiformes	Gobiidae	*Periophthalmus*		Genus of mudskippers		Lc	0	0	0	1113	0	0	0	0	0	0
	Actinopteri	Gobiiformes	Gobiidae	*Schismatogobius*		Genus of gobies		LC	281	220	91	0	0	0	0	0	0	0
	Actinopteri	Gonorynchiformes	Chanidae	*Chanos*	*Chanos chanos*	Milkfish	Native	LC	597	1031	259	505	0	0	0	0	0	0
	Actinopteri	Kurtiformes	Apogonidae			Family of cardinalfishes			0	0	0	0	0	4346	0	0	182	136
	Actinopteri	Kurtiformes	Apogonidae	*Fibramia*	*Fibramia lateralis*	Humpback cardinal	Native	LC	0	0	0	0	0	0	0	0	366	1452
	Actinopteri	Kurtiformes	Apogonidae	*Pristicon*		Genus of cardinalfishes			0	0	0	822	0	0	2267	0	0	0
	Actinopteri	Kurtiformes	Apogonidae	*Taeniamia*	*Taeniamia buruensis*	Buru cardinalfish	Native	LC	0	0	0	0	0	0	0	0	33	0
	Actinopteri	Kurtiformes	Apogonidae	*Zoramia*		Genus of cardinalfishes			0	0	0	0	0	0	0	0	593	5720
	Actinopteri	Lutjaniformes	Haemulidae	*Plectorhinchus*		Genus of sweetlips			0	0	0	0	1374	0	0	0	0	0
	Actinopteri	Lutjaniformes	Haemulidae	*Plectorhinchus*	*Plectorhinchus gibbosus*	Harry hotlips	Native	LC	0	0	0	3983	0	0	0	0	0	0
	Actinopteri	Lutjaniformes	Lutjanidae	*Lutjanus*		Genus of common snapper			0	0	0	0	0	0	0	3955	0	0
	Actinopteri	Lutjaniformes	Lutjanidae	*Lutjanus*	*Lutjanus argentimaculatus*	Mangrove red snapper	Native	LC	926	0	254	2769	1190	2713	0	0	0	0
	Actinopteri	Lutjaniformes	Lutjanidae	*Lutjanus*	*Lutjanus fulvus*	Blacktail snapper	Native	LC	0	1132	692	544	3995	0	0	0	46	125
	Actinopteri	Mugiliformes	Mugilidae			Family of mullet			0	0	0	472	0	0	0	0	0	0
	Actinopteri	Mugiliformes	Mugilidae	*Crenimugil*	*Crenimugil seheli*	Bluespot mullet	Native	LC	0	0	0	0	1094	0	0	0	0	0
	Actinopteri	Mugiliformes	Mugilidae	*Mugil*		Genus of mullet			1612	454	0	0	1196	0	0	0	0	0
	Actinopteri	Mugiliformes	Mugilidae	*Mugil*	*Mugil cephalus*	Flathead grey mullet	Native	LC	0	0	0	0	0	0	0	3288	0	0
	Actinopteri	Mugiliformes	Mugilidae	*Planiliza*		Genus of mullet			15889	35172	33984	33987	16885	17546	0	2229	0	587
	Actinopteri	NA	Ambassidae	*Ambassis*		Genus of glassfish			0	0	36	0	883	0	0	514	0	55
	Actinopteri	NA	Scatophagidae	*Scatophagus*	*Scatophagus argus*	Spotted scat	Native	LC	0	0	461	0	3221	0	0	315	0	0
	Actinopteri	Scombriformes	Scombridae			Family of mackerel and tuna			0	0	0	0	0	0	0	0	0	30
	Actinopteri	Scombriformes	Scombridae	*Katsuwonus*	*Katsuwonus pelamis*	Skipjack tuna	Native		0	0	0	0	0	0	0	0	308	11
	Actinopteri	Scombriformes	Scombridae	*Thunnus*		Genus of tuna			0	0	0	0	0	0	0	0	0	246
	Actinopteri	Spariformes	Lethrinidae	*Lethrinus*		Genus of emperors			0	0	0	545	0	0	0	0	0	0
TOTAL numbers of fish taxon per sample:									**18**	**20**	**23**	**20**	**24**	**12**	**9**	**18**	**20**	**23**

Table 40. Decapod taxon by sample detection table with sequence reads.

	Family	Genus	Species	Common Name	SR 1	SR 2	SR 3	VC 1	VC 2	VC 3	LR 1	LR 2	SH 1	SH 2
DECAPODS	Atyidae	*Caridina*		Genus of freshwater shrimp	0	5545	2181	7017	12998	0	0	0	0	0
	Atyidae	*Caridina*	*Caridina serratirostris*	Ninja shrimp	0	3090	0	0	0	0	0	0	0	0
	Atyidae	*Caridina*	*Caridina typus*	Australian amano shrimp	0	0	0	2429	24	0	0	0	0	0
	Gecarcinidae	*Cardisoma*	*Cardisoma carnifex*	Brown land crab	0	699	0	0	0	0	0	0	0	0
	Ocypodidae	*Austruca*	*Austruca citrus*	Lemon fiddler crab	0	0	0	650	0	0	0	0	0	0
	Ocypodidae	*Ocypode*	*Ocypode ceratophthalmus*	Horned ghost crab	0	0	0	0	0	0	0	0	19	0
	Palaemonidae	*Macrobrachium*		Genus of freshwater prawn or shrimp	32668	0	2294	0	0	0	0	0	0	0
	Parastacidae			Family of freshwater crayfish	0	0	0	0	0	0	0	0	37	0
	Penaeidae	*Metapenaeus*		Genus of prawns	0	0	478	0	0	0	0	0	0	0
	Sesarmidae	*Parasesarma*	*Parasesarma lividum*	Shore crab, Bluish mangrove crab	0	0	0	0	0	1001	0	0	0	0
	Varunidae	*Varuna*	*Varuna litterata*	River swimming crab	1776	168	0	0	0	0	0	0	277	5603
TOTAL numbers of taxon per sample:					2	4	3	3	2	1	0	0	3	1

Table 41. Mollusc taxon by sample detection table with sequence reads.

	Class	Order	Family	Genus	Species	Common Name	Status	SR 1	SR 2	SR 3	VC 1	VC 2	VC 3	LR 1	LR 2	SH 1	SH 1
MOLLUSC								0	0	0	0	0	15	0	0	0	104
	Bivalvia	Cardiida	Psammobiidae					0	0	0	0	27	0	0	0	0	0
	Bivalvia	Myida	Dreissenidae	*Mytilopsis*				8068	82	1318	863	19299	407	0	0	0	0
	Bivalvia	Myida	Teredinidae	*Teredo*				0	0	0	126	0	0	0	0	0	0
	Bivalvia	Venerida	Cyrenidae					56	10	0	0	0	0	0	0	0	0
	Gastropoda							0	0	0	0	177	0	0	0	0	4461
	Gastropoda	NA	Cerithiidae	*Cerithium*				0	0	0	260	0	0	0	0	0	0
	Gastropoda	NA	Physidae	*Physella*				0	0	11	0	0	0	0	0	0	0
	Gastropoda	NA	Physidae	*Physella*	*Physella acuta*			0	15	0	0	0	0	0	0	0	0
	Gastropoda	NA	Thiaridae					4525	48530	156264	0	493	0	0	0	0	3012
	Gastropoda	NA	Thiaridae	*Sermyla*				299	46	0	0	2668	0	0	0	0	0
	Gastropoda	NA	Thiaridae	*Stenomelania*				244	261	201	0	0	0	0	0	0	0
	Gastropoda	NA	Thiaridae	*Stenomelania*	*Stenomelania aspirans*			97028	37564	125514	0	0	0	0	0	0	3203
	Gastropoda	NA	Thiaridae	*Thiara*				17122	146226	62	0	0	0	0	0	0	0
	Gastropoda	Cycloneritida	Neritidae					371	0	0	0	0	0	0	0	0	1352
	Gastropoda	Cycloneritida	Neritidae	*Neritina*				0	0	10	0	0	0	0	0	0	0
	Gastropoda	Cycloneritida	Neritiliidae	*Neritilia*				1109	99	0	0	0	44985	0	0	0	3151
	Gastropoda	Littorinimorph	Assimineidae					53	5591	33	0	0	0	0	0	0	0
	Gastropoda	Stylommatophora						0	0	0	0	0	0	0	0	0	1015
	Gastropoda	Stylommatop	Ariophantidae	*Macrochlamys*	*Macrochlamys tersa*			173	10	0	0	291	0	0	0	0	837
	Gastropoda	Stylommatop	Camaenidae	*Bradybaena*	*Bradybaena similaris*		Introduced	1882	89	0	0	0	0	0	0	0	0
	Gastropoda	Stylommatop	Dyakiidae	*Quantula*	*Quantula striata*		Introduced	1062	56	0	0	0	0	0	0	0	2868
	Gastropoda	Stylommatop	Helicarionidae	*Parmacochlea*	*Parmacochlea balios*			0	0	0	0	0	0	0	0	0	13676
	Gastropoda	Systellommat	Rathouisiidae					0	31	0	0	0	0	0	0	0	0
	Gastropoda	Systellommat	Veronicellidae	*Sarasinula*	*Sarasinula plebeia*		Introduced	3335	186	72	0	5054	0	0	0	0	13594
	Gastropoda	Systellommat	Veronicellidae	*Semperula*	*Semperula wallacei*		Introduced	0	0	17	0	0	0	0	0	0	1577
UNASSIGNED								24335	3418	1816	36457	50845	25723	0	0	0	75144
TOTAL numbers of taxon per sample:								15	16	11	4	8	4	0	0	0	13

Table 42. Fish captured during surveys at the four bridge sites.

Bridge	Species	Scientific name	Number	Range	IUCN status
Madraukutu	Feathered river garfish	*Zenarchopterus dispar*	3	native	Least concern
	Barred flagtail	*Kuhlia mugil*	1		Least concern
	Short fin molly	*Poecilia mexicana*	2	introduced	
	Broadhead sleeper	*Eleotris melanosoma*	1	Large range	
	Humpback cardinal	*Fibramia lateralis*	2		
Sabato	Pacific Short finned eel	*Anguilla obscura*	2	Large range	Data deficient
	Barred flagtail	*Kuhlia mugil*	1		Least concern
	Indo-Pacific tarpon	*Megalops Cyprinoides*	1		Least concern
	Flat head grey mullet	*Mugil cephalus*	3		Least concern
	Mangrove red snapper	*Lutjanus argentimaculatus*	1		Least concern
	milk fish	*Chanos chanos*	1		Least concern
	celebes goby	*Glossogobius celebius*	1	Large range	Least concern
	Short fin molly	*Poecilia latipinna*	4		Introduced
Lami	Pacific Short finned eel	*Anguilla obscura*	1	Large range	Data deficient
	barred flagtail	*Kuhlia mugil*	1		Least concern
	flathead grey mullet	*Mugil cephalus*	1		Least concern
	Spotted scat	*Scatophagus argus*	3		Least concern
Viseisei	Mangrove red snapper	*Lutjanus argentimaculatus*	3		Least concern
	Feathered river garfish	*Zenarchopterus dispar*	3	native	Least concern
	Nile Tilapia	*Oreochromis niloticus*	2	introduced	Least concern
	Indo-Pacific tarpon	*Megalops Cyprinoides*	1	large distribution	data deficient
	Goldfish	*Carassius auratus*	1	introduced	

40.1 Environmental DNA (eDNA) for monitoring aquatic systems

Environmental DNA (eDNA) is revolutionizing the monitoring of aquatic systems by providing a non-invasive and highly sensitive method for detecting and identifying species present in a given water body. eDNA refers to the genetic material shed by organisms into their environment through skin cells, scales, feces, mucus, and other biological materials. By collecting water samples and analyzing the eDNA within them, scientists can determine the presence or absence of specific species without the need for physical capture or observation. This approach is particularly useful for monitoring rare, elusive, or invasive species, as it allows for the detection of organisms at very low population densities. Additionally, eDNA sampling is less labor-intensive and can cover larger spatial areas compared to traditional methods, making it a cost-effective tool for biodiversity assessments.

eDNA technology is especially valuable for monitoring migratory aquatic species and threatened species. For migratory species, eDNA can track their presence and movement across different habitats, providing critical information on migration patterns and timing. This can aid in identifying key habitats and ensuring they are protected. For threatened species, eDNA offers a way to detect and monitor populations without disturbing them, facilitating conservation efforts and helping to assess the effectiveness of protection measures. Furthermore, eDNA is a powerful tool for monitoring aquatic environments during development projects. By regularly collecting and analyzing eDNA samples, developers can detect changes in species composition and abundance, allowing for early identification of potential environmental impacts. This proactive approach can help mitigate harm to aquatic ecosystems and ensure compliance with environmental regulations, ultimately supporting more sustainable development practices.