Freshwater and estuarine fisheries provide an important food source for Pacific Island people.

CHAPTER 5

Implications of climate change for freshwater and estuarine fisheries in the Pacific Islands region

Authors

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Introduction

Fishing for finfish, crustaceans and molluscs has been an important part of the cultural identity of many Pacific Island communities for over 3,000 years[1,2], and freshwater and estuarine fisheries themselves provide an important food source for these people (Basel et al. 2025, Chapter 8 this volume).

Catch estimates for freshwater and estuarine fisheries across the region increased by 25% between 2007 and 2021, with most of the increase coming from Papua New Guinea (PNG) and Solomon Islands. Catches in other Pacific Island countries and territories (PICTs) have remained steady, or have increased by smaller amounts over the same period[3].

Freshwater and estuarine fisheries are strongly influenced by the: 1) amount of available habitat, 2) condition of habitats, and 3) adequacy of flow to support ecosystem processes and provide access to habitats[2,4]. River flow is the main process shaping freshwater habitats and the productivity of the fisheries they support[5], and is a key driver of estuarine productivity[6,7]. Any change in climate that alters rainfall has the potential to modify river flows, with subsequent effects on fisheries[8]. Earlier climate projections for the Pacific Islands region suggest that increasing rainfall would lead to modest increases in fisheries production from freshwater and estuarine habitats[4].

The potential gains in fisheries production resulting from climate change, however, are subject to changes in catchment land use and resulting changes in water quality and quantity. Activities such as agriculture, forestry, mining, water resource development, power generation and urbanisation have altered hydrology and water quality to the detriment of aquatic species in the Pacific Islands region[9–16], thus limiting fisheries production (Figure 5.1). Efforts to reduce the vulnerability of fisheries to climate change, therefore, need to be considered alongside the impacts of catchment disturbance.

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Maintaining sustainable freshwater and estuarine fisheries in the context of natural environmental variability, climate change, and impacts of economic development poses complex challenges for fisheries management. Many of the processes that affect freshwater fisheries production are outside the jurisdiction of fisheries agencies and traditional management structures[17] (Figure 5.1). These pressures require effective governance strategies that involve cooperation among other agencies to ensure the resilience of freshwater and estuarine fisheries for the future[18].

Since the previous vulnerability assessment for freshwater and estuarine fisheries[2,4], scientific understanding of climate change[19] (see Webb et al. 2025, Chapter 2 this volume), its effects on aquatic ecosystems[20–22] and dependent fisheries[8,23,24], and interactions with catchment processes[25,26] have advanced considerably. Many PICTs have implemented policies and legislation promoting integrated catchment management to improve the sustainability of economic activities, but it is too soon to determine whether these actions have been effective. It is, therefore, timely to reassess the vulnerability of freshwater and estuarine fisheries in the Pacific Islands region to climate change, noting that uncertainties and knowledge gaps remain (see Appendix 1).

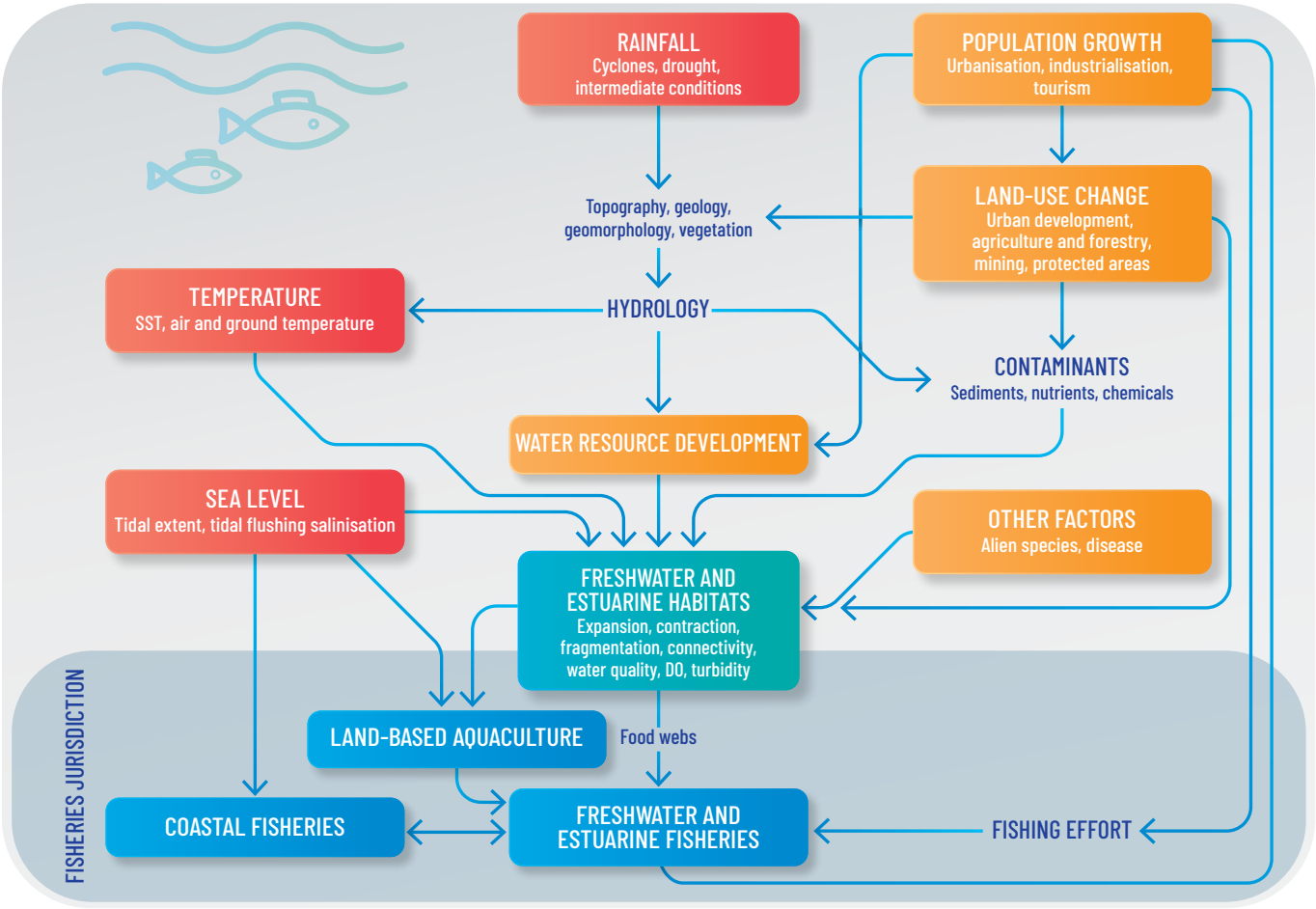

Figure 5.1 *Freshwater and estuarine fisheries are influenced by many factors, including the effects of climate change and human activities that alter the availability and condition of fisheries habitats. These factors include natural processes influenced by climate change (red), processes driven directly by humans and economic development (yellow), and activities controlled by fisheries agencies (blue). An ecosystem-based approach to managing freshwater and estuarine fisheries in the face of climate change seeks to identify the greatest threats to fishery-dependent communities, and opportunities to achieve desired fishery outcomes. DO = dissolved oxygen, SST = sea surface temperature.*

Nature and status of freshwater and estuarine fisheries

Changes in catch and economic value

Catch data for freshwater and estuarine fisheries are limited for much of the Pacific Islands region, with the most recent comparative estimates based on crude assumptions[3] (Table 5.1). More specific estimates are available for some fisheries, but the reliability of the data is low.

Total catch has increased by 25%, from 23,838 tonnes (t) in 2007 to 29,723 t in 2021. There is a large disparity in catches among PICTs, with PNG dominating production ahead of Fiji and Solomon Islands (Figure 5.2). The greatest increase in catches occurred in Melanesia, in contrast to the much smaller fisheries of Micronesia and Polynesia, which maintained steady production or experienced slight declines. Most of the catch is taken for subsistence, with freshwater clams (*Batissa violacea*) in Fiji representing the most substantial commercial fishery. The economic value of freshwater and estuarine fisheries catches doubled from USD 23,115,025 in 2007 to USD 46,533,490 in 2014, mostly from PNG, before declining to USD 45,136,465 in 2021.

Artisanal freshwater fisheries are poorly documented, with most products sold through roadside stalls and local markets. Local PNG estimates for the intensive fisheries in the Sepik-Ramu floodplain, the Fly, Purari, Kikori and smaller river systems, lakes and reservoirs, in addition to the available estimated catch and value data for the remaining PICTs (Table 5.1), put artisanal catches for the Pacific Islands region at 30,000 t annually. Subsistence catches, including those from the same systems in PNG, are estimated at around 10,000 t annually.

Large, undocumented harvests of freshwater clams from New Caledonia, PNG, Solomon Islands and Vanuatu add significantly to total catch estimates. The fishery in PNG appears to be larger than in Fiji, where recent harvests are estimated at between 4,000 t and 7,000 t per year[29], which is significantly more than the previous estimate of 2,526 t in 2004[3]. Estimates from PNG, based on the size of the industry, suggest harvests may exceed 10,000 t annually, with a projected value of more than USD 16 million in 2024. Unreported freshwater clam harvests from New Caledonia, Solomon Islands and Vanuatu may further increase total production, potentially raising the economic value from freshwater and estuarine fisheries for all PICTs to more than USD 70 million.

Since 2014, a new fishery has developed in remote parts of PNG, targeting species such as barramundi (*Lates calcarifer*), jewfish (*Protonibea diacanthus*), Papuan black bass (*Lutjanus goldiei*), fork-tailed catfishes (Ariidae), king threadfin (*Polydactylus macrochir*) and other large species for their swim bladders[30]. The swim bladders (maw) are dried and exported for use in Chinese medicine, and can fetch prices as high as USD 21,000/kg. Due to a lack of access to ice or refrigeration, the fish carcasses are discarded. The fishery uses large-mesh gill nets, which catch up to 80% bycatch, including sharks, sawfish and dolphins[31]. Estimates of total catch, waste, and economic value of this fishery are currently unavailable.

Main species and their uses

The wide variety of freshwater and estuarine habitats in the Pacific Islands region supports a high diversity of fish and invertebrate species (see Appendix 2). Target species range in size from large finfish, such as barramundi, king threadfin, and fork-tailed catfish (*Hemiarius dioctes*) that may exceed 100 cm in length and weigh more than 20 kg, to much smaller species such as larval gobies (e.g. *Sicyopterus* spp.) caught as whitebait, weighing less than 1 g. The greatest diversity and abundance of species occur on the high islands of Melanesia[9,10,16,32–34]. However, information on the fisheries biology of most freshwater and estuarine species in the tropical Pacific remains limited. The most well-studied species is barramundi, which was previously fished commercially in southern PNG[35].

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One ecological challenge that has drawn scientific attention is how freshwater species establish populations on islands surrounded by ocean. Amphidromous gobies and prawns have evolved complex oceanic migrations during their larval stage to maintain populations in freshwater habitats across the Pacific Islands region[36–39].

In New Caledonia, subsistence freshwater catches were recently estimated at 480 t for the Northern Province[34,40]. Given that the Northern Province accounts for 39% of the land area, the total freshwater catch for all of New Caledonia may be much larger, and certainly many times greater than the estimate of 10 t for New Caledonia shown in Table 5.1[3]. The main species caught are eels (Anguillidae), tilapia (*Oreochromis* spp.) and freshwater prawns (*Macrobrachium* spp.).

Table 5.1 *Trends in annual catches (tonnes) of freshwater and estuarine fisheries in Pacific Island countries and territories (PICTs) and the estimated combined value (in reported year) (USD) of subsistence, artisanal and commercial catches in 2007, 2014 and 2021. Zero indicates no reported catch.*

PICT	Catch (tonnes)			Value (USD)		
	2007	2014	2021	2007	2014	2021
Melanesia						
Fiji	4,126	3,731	4,000	4,287,500	3,741,414	3,301,887
New Caledonia	10	10	10	45,885	48,334	51,220
Papua New Guinea	17,500	20,000	23,000	16,554,054	38,132,296	36,752,137
Solomon Islands	2,000	2,300	2,500	1,464,052	3,800,786	4,223,602
Vanuatu	80	80	88	173,077	232,875	294,508
Micronesia						
Federated States of Micronesia	1	1	1	8,000	8,000	8,000
Guam	3	3	3	10,000	11,000	12,000
Kiribati	0	0	0	-	-	-
Marshall Islands	0	0	0	-	-	-
Nauru	0	0	0	-	-	-
Northern Mariana Islands	0	0	0	-	-	-
Palau	1	1	1	8,000	10,000	10,000
Polynesia						
American Samoa	1	1	1	4,000	4,000	4,900
Cook Islands	5	5	5	36,765	29,297	27,891
French Polynesia	100	100	100	488,506	487,920	415,678
Niue	0	0	0	-	-	-
Pitcairn Islands	0	0	0	-	-	-
Samoa	10	10	10	33,206	22,703	28,378
Tonga	1	1	1	1,980	3,226	2,917
Tokelau	0	0	0	-	-	-
Tuvalu	0	2	2	-	1,639	1,449
Wallis and Futuna	0	0	1	-	-	1,898
Total	**23,838**	**26,245**	**29,723**	**23,115,025**	**46,533,490**	**45,136,465**
Adjusted value 2021				**30,367,595**	**52,117,509**	**45,136,465**

Source: Gillett 2009[27], Gillett 2016[28], Gillett and Fong 2023[3]. These sources recognise catches from streams and lakes, and do not distinguish between freshwater and estuarine habitats.

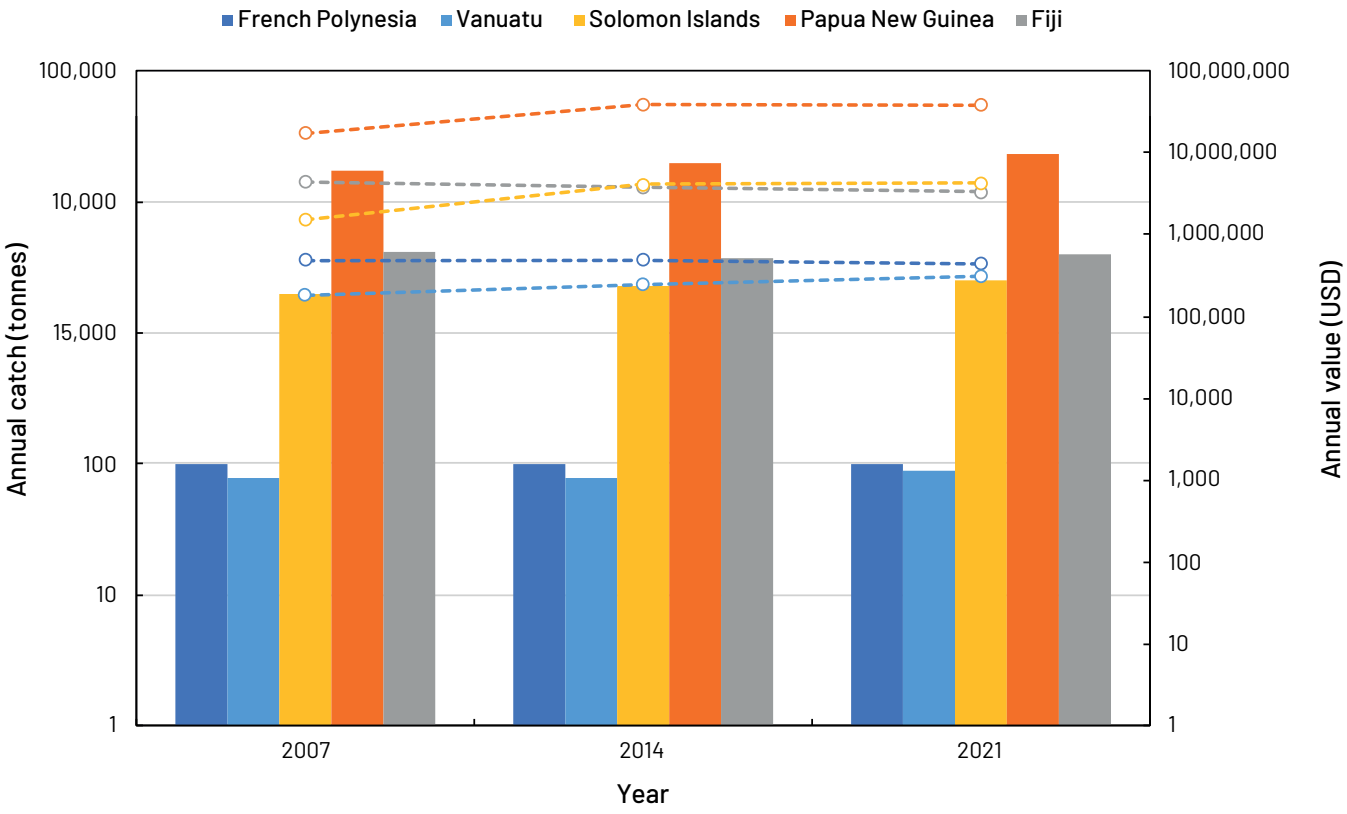

Figure 5.2 *Estimated annual freshwater catch (bars) and value (dashed lines) for the five largest producing PICTs. Catches are dominated by Papua New Guinea, with much smaller harvests in Fiji and Solomon Islands. By comparison, catches from French Polynesia and Vanuatu are very small.*

In addition to native species, approximately 25 non-native freshwater fish species have been introduced in the Pacific to supplement local catches. Among these, tilapia and common carp (*Cyprinus carpio*) are the most widespread introduced species and have become highly valued as food[41,42,43]. In PNG, a much broader range of introduced species has become established[12,44–47] including Java carp (*Barbonymus goniotus*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), snow trout (*Schizothorax richardsoni*), pacu (*Piaractus brachyponus*), redbreast tilapia (*Coptodon rendalli*), mahseer (*Tor putitora*), climbing perch (*Anabas testudineus*) and walking catfish (*Clarias batrachus*). In locations where carp and tilapia species have been stocked, such as the Yonki Reservoir and parts of the Sepik River in PNG, as well as Lake Tegano in Solomon Islands, these species now dominate local catches[48,49].

Other species, including bull sharks (*Carcharhinus leucas*), oxeye herring (*Megalops cyprinoides*), grunters (Haemulidae), trevallies (Carangidae), silver biddies (Gerreidae), silver moon-fish (Monodactylidae), scats (Scatophagidae), eels, mullets (Mugilidae) and larger species of gudgeons (Eleotridae) and gobies (Gobiidae) are harvested opportunistically for subsistence use and occasional sale in local markets[3,42]. However, data on their catches or economic value remain limited.

Freshwater clams constitute the largest portion of regional catches due to their wide distribution throughout the Indo-West Pacific, including Fiji, New Caledonia, PNG, Solomon Islands and Vanuatu[50,51]. Known by various names, including *kina* in PNG, and *kai* in Fiji, the combined commercial, artisanal and subsistence catch of freshwater clams is estimated to exceed 17,000 t. Clams reach densities of 2 kg/m^2 in sandy and muddy sediments in the freshwater reaches of rivers[52], where women collect them by wading or diving in shallow water. In Fiji, *kai* are mostly sold fresh at markets or kept by households and eaten raw or cooked. The value chain for *kai* includes harvesters, intermediary

traders who buy *kai* from harvesters and then resell them at local markets, and processors who clean, boil, shuck, package and freeze the clams before sale to supermarkets, hotels and restaurants, or for export[29]. Men are involved in more physically demanding aspects of the fishery, such as loading 80 kg sacks of clams for transport. In PNG, *kina* are harvested primarily by women for subsistence and artisanal purposes. *Kina* are transported to local markets for sale, and sold whole in lots, or the meat is extracted and either cooked in coconut cream or dried and smoked on skewers. The shells are burned to convert calcium carbonate ($CaCO_3$) into lime powder (calcium oxide CaO), which is widely traded and used throughout PNG for betel nut chewing[53]. The harvesting of freshwater clams is also widespread in New Caledonia, Solomon Islands and Vanuatu [54,55], although these fisheries remain largely undescribed.

In parts of PNG and elsewhere, there is growing interest in catch-and-release recreational fisheries for species such as Papuan black bass, spot-tail bass (*Lutjanus fuscescens*), and barramundi. While these small recreational fisheries do not focus on food production, they create local jobs and contribute to the economy of local communities by providing services to anglers[56]. Occasionally, small quantities of fish are retained and donated to local villages.

Harvest levels and confidence in catch data

Trends in freshwater and estuarine fisheries catches are somewhat more reliable than absolute estimates, suggesting that harvests have increased since 2007, especially in Melanesia[3]. Therefore, catch data in Table 5.1 should be viewed as indicative of the volumes of fish and shellfish caught in PICTs, while actual catches may be much larger.

Threats to freshwater and estuarine fisheries

In addition to threats from climate change, freshwater and estuarine fisheries also face threats from land-use changes, water resource development and power generation, modification of rivers and lakes, fishing pressure, and disease (Figure 5.3). The cumulative effects of these threats, along with the capacity to mitigate them through effective management, influences the ecological health of aquatic communities and the resilience of fisheries to climate change.

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Land-use change, driven by activities such as mining, forestry, clearing of vegetation for agriculture, and urbanisation presents an ongoing threat to fisheries (see Box 5.1). In PNG, operations at the Ok Tedi mine have been linked to a 57–87% decline in fish biomass and a 6–80% decline in the number of fish species in the Fly River between 1983 and 2006[12]. Other changes include increased aquatic algal growth[57] and contaminated sediments[58]. Sediment buildup downstream of the mine also has contributed to changes in water quality that exacerbate fish kills during El Niño events[14]. On the Fijian island of Viti Levu, land clearing for agriculture and urban development reduced forest cover by 5% and shrub vegetation by 35% between 2000 and 2020, with further losses of 5% and 11%, respectively, projected by 2040[59]. In cleared catchments on Vanua Levu (Fiji), river temperatures were higher and dissolved oxygen levels lower, resulting in reduced fish species richness and abundance compared to forested catchments[60].

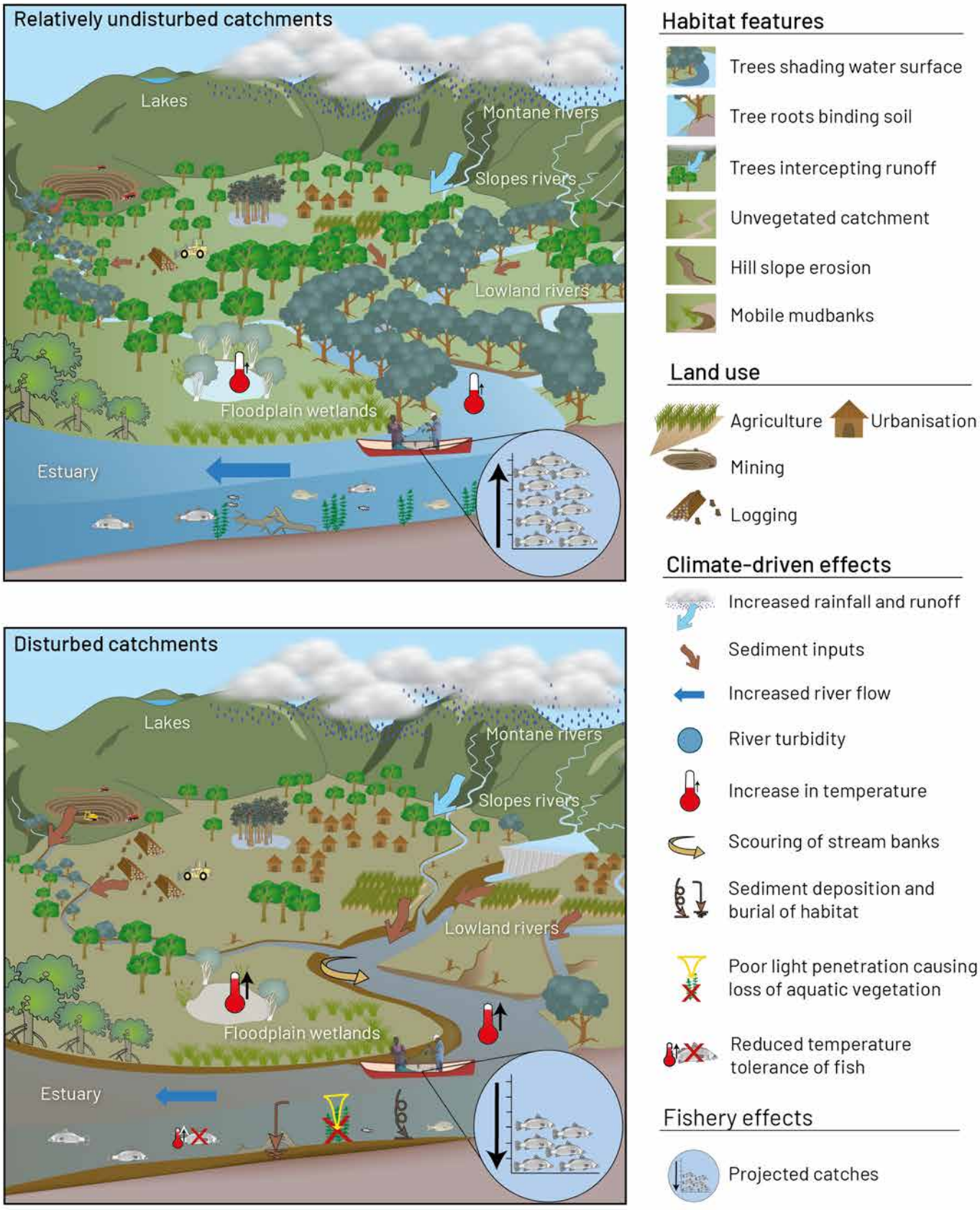

Figure 5.3 *Main effects of climate change on freshwater and estuarine fisheries in: a) relatively undisturbed catchments, and b) disturbed catchments. In well-managed, relatively undisturbed catchments the increase in habitat availability due to climate change is expected to result in increased fisheries catches. In poorly-managed, disturbed catchments, where vegetation cover has been reduced, the exposure of species to warming and habitat loss will be greater, leading to reductions in catches. Modified from Gehrke et al. 2011b*[4].

Box 5.1: Impacts of land use change on freshwater fisheries

The Fly and Ba rivers are examples of how climate change can lead to both positive and negative outcomes in freshwater and estuarine habitats and fisheries. In catchments where activities can be managed to avoid habitat degradation, increased rainfall is expected to support an increase in fish and shellfish populations (Figure 5.3). But in degraded catchments, fisheries are likely to decline due to ongoing habitat degradation, despite the projected benefits of a wetter climate.

Fly River, PNG

The Fly River system in Western Province of PNG covers a catchment area of 7,600 km^2, with a discharge of 6,000 m^3/second, making it one of the world's great rivers. The Fly floodplain supports more than 45,000 km^2 of wetlands, the largest wetland system in the South Pacific region, including Australia and Indonesia[61]. This floodplain supports a diversity of habitats, including oxbow lakes, blocked valley lakes, and grassed floodplain lakes[14].

The Fly River system faces significant pressure from the Ok Tedi gold and copper mine, which has been discharging 80,000 t of waste rock and mine tailings annually into the Ok Tedi River, a major tributary, since 1984[62]. This practice has altered the river's geomorphology by increasing sediment load, causing forest dieback due to hydrological changes, contaminating water quality with metals and other mining chemicals, and disrupting the food web from primary producers to top predators[14]. These changes will persist over decades as river flow continues to transport mine sediments downstream.

The Fly River fisheries for barramundi, Papuan black bass, river herring and other species are located downstream of the Ok Tedi mine. River herring, the dominant fish species in floodplain habitats, feed on plant material and detritus[14], and account for 38% of fish biomass[12]. Preliminary investigations suggest the river herring fishery could potentially yield over 5,000 t annually[14]. Other abundant species include fork-tailed catfishes and eel-tailed catfishes.

Changes in land use resulting in habitat degradation are closely linked to declining ecosystems and fishery health[14]. Habitat degradation has affected the food supply, diet, reproduction, and population structure of fish in the Fly River, triggering a cascade of ecological shifts that will affect fishery production and local food security for decades[14]. Abundant species such as river herring are keystone species that serve as indicators of river ecosystem health. The Fly River demonstrates that ecosystems exposed to multiple environmental stressors may lose their resilience to other disturbances such as low flows during El Niño events and become more vulnerable to climate change[14].

Ba River, Fiji

The Ba River catchment on Viti Levu covers an area of 957 km^2. Between 1992 and 2007, agricultural land use expanded by 16.53%, causing a reduction in forest cover (–9.03%) and shrub land (–8.95%)[63]. Broader trends on Viti Levu predict a 59% increase in agricultural land between 2000 and 2040, along with a 262% increase in urban areas over the same period, driving further declines in forest area (–10%) and shrub lands (–42%)[59].

The Ba River supports a commercial fishery for freshwater clams (*kai*) in its lower freshwater reaches, as well as subsistence fisheries for eels and tilapia upstream, and shark species in the estuary[64]. However, the freshwater clam population in the Ba River has declined, with biomass decreasing from 11–2,017 g/m^2 in 1996, to 0–1,496 g/m^2 in 2019[52]. This decline has been attributed to dredging for flood mitigation and overfishing, particularly of juvenile clams. Sedimentation of the lower reaches of the river has been exacerbated by vegetation clearing and plantation forestry in the Ba catchment[15], which in turn has increased surface runoff and erosion[63].

In 2012, during a La Niña episode, heavy rain caused multiple slope failures leading to more than 150 debris flows, which transported significant sediment loads to the river. Most of the debris (93%) originated within shallow-rooted plantation areas[15].

Agricultural runoff, urban runoff from Ba Town, and waste discharge from a local sugar mill have contributed to increasing acidification and other contaminant loads. During the sugarcane crushing season, mean pH in the vicinity of the mill declined by 3.06 pH units, with a minimum pH of 5.32 compared with mean pH values of 8.16 and 8.20 before the crushing season[64]. During the early crushing season when river flows are low, the river has limited capacity to dilute acidic discharge. However, the wet season increases runoff from agricultural land and forest plantations, which are typically acidic, and river flow, which helps disperse the acid plume from the mill.

Climate change projections indicate an increase in rainfall of up to 10% (median 3.4–4.0%) for Fiji, which is expected to increase river flows during both the wet and dry seasons, potentially improving the capacity to dilute and disperse contaminants. However, these projected changes in rainfall are relatively small compared with natural variability. As a result, the predicted expansion of agricultural land and plantation forests is likely to have a more substantial impact on water quality deterioration and, consequently, on the kai fishery than any benefits from increased river flow due to climate change.

Water resource development, such as dams, weirs, and water extraction from rivers, has impacted freshwater, estuarine and coastal fisheries worldwide[5–7]. Changes in river flow have wide-ranging effects, such as impeding species migrations, disrupting reproduction, reducing habitat quality and accessibility, altering food webs, and degrading water quality; examples include the intrusion of saline water upstream, and the release of cold, hypoxic water downstream[5,6]. Projects such as the Tina River Hydropower Dam in Solomon Islands[65] and proposed flood mitigation dams in Fiji[66] offer benefits for people including a secure water supply, clean energy, reduced flood damage, and potential economic gains from agriculture. However, these benefits must be weighed against the loss of freshwater and estuarine fisheries production and the associated loss of food and cultural identity[67].

Modification of rivers and lakes may take many forms. In Fiji, dredging river beds to reduce flooding and supply sand and gravel for construction is a common practice[66,68,69], but there is increasing evidence of its negative impacts on stream morphology, water quality and aquatic life[52,70]. While dredging is readily accepted as a flood mitigation strategy, ecosystem-based approaches to slow the passage of water through catchments – such as planting riparian buffers, re-forestation and floodplain vegetation – tend to be more cost-effective than engineered infrastructure solutions[69]. Other modifications, such as causeways, road culverts and levee banks pose additional threats to fisheries by fragmenting freshwater and estuarine habitats, disrupting connectivity, and impacting fish life histories and ecosystem health.

Fishing pressure is an increasing concern as growing populations rely on fisheries for food. Heavy fishing pressure can deplete fish populations to the point where fisheries must be closed to allow recovery (e.g. Fly River commercial barramundi fishery[71]). Improved access to fishing gear, such as monofilament gill nets, aluminium boats, and outboard engines, enables fishers to cover greater areas and intensify their targeting of species, thereby increasing the risk of overfishing. Many freshwater and estuarine habitats in the Pacific Islands region are small, and highly susceptible to overfishing[2,72], especially through destructive practices such as *Derris* poisoning. This method involves crushing *Derris* roots and applying them to tidal pools, where rotenone is released into the water. Rotenone – a respiratory poison found within the roots of *Derris* plants – indiscriminately kills fish and invertebrates. This practice has depleted fish and invertebrate populations in parts of Fiji[74]. Although *Derris* poisoning is prohibited under fisheries regulations in Fiji and other PICTs, the practice continues. Freshwater clam populations are declining under heavy fishing pressure, with reductions in both abundance and shell size observed at heavily fished locations[50,52]. Due to their limited salt tolerance and the absence of a salt-tolerant migratory stage, depleted freshwater clam populations must rely on local recruitment for replenishment as they cannot be supported by populations from nearby rivers[50,52].

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Introduced species such as tilapia in Fijian rivers have led to a decline in the number of native fish species, notably eleotrid and gobiid taxa, in affected rivers[13]. Introduced species have also contributed to a reduction of native fish populations in PNG[47,75]. However, in some cases, the presence of introduced species has had less detrimental effects. For example, after Nile tilapia (*Oreochromis niloticus*) became established in Lake Kutubu in PNG in 2010, local villagers began targeting the productive tilapia, easing fishing pressure on overfished endemic species[43,76]. The spread of genetically improved farmed tilapia (GIFT or *O. niloticus*), bred for aquaculture, from PNG to Saibai Island in Torres Strait, Australia, highlights the challenges of balancing the promotion of cultured fish to support food security and managing their impacts on ecosystems and native species[77]. Additionally, invasive species from Indonesia, such as walking catfish (*Clarias batrachus*) and snakehead (Channidae), have been illegally introduced into PNG and have spread across a wide geographic range, threatening endemic fish populations through predation, competition and disease[78,79].

Fish disease outbreaks occur occasionally but are reported inconsistently. In 2013, Lake Kutubu in PNG experienced a fish kill that was attributed to epizootic ulcerative syndrome[80]. Following the outbreak, fish catches and the number of people fishing declined to 31% and 30% of previous levels, respectively[80]. Prior to the outbreak, freshwater catches were dominated by hardyheads (*Craterocephalus papuanus*) and gudgeons *(Oxyeleotris* spp., *Mogurnda* spp.). Two years later, the dominant species caught was GIFT tilapia. Epizootic ulcerative infections have also been recorded in the Fly[81] and Sepik[82] river systems. In 2023, fish mortalities from suspected epizootic ulcerative syndrome were reported in

the Sepik River to the PNG National Fisheries Authority and other PNG government agencies. Environmental stress is commonly associated with fish disease outbreaks, suggesting that even small environmental changes under future climate scenarios could increase the incidence of disease and subsequent effects on local fisheries[80].

Managing threats to fisheries

Collectively, land-use change, water resource development, and the modification of rivers and lakes tend to be coordinated by multiple government agencies, including those responsible for infrastructure and economic development, agriculture, planning, mining, water, environment, forestry, soil conservation, disaster and emergency services, health, energy, transport, and finance. This makes it difficult for fisheries agencies to manage threats that originate outside their jurisdiction. While other threats, such as from increased fishing pressure, introduced species, and fish diseases, fall within the jurisdiction of fisheries agencies, resource constraints often limit their ability to address these threats effectively[17].

In the face of these multiple threats, ensuring sustainable fisheries for people requires aquatic ecological communities to continually adapt to both individual and cumulative pressures. This is the concept of resilience of coupled natural environmental and human social systems[83]. A resilience approach to fisheries management considers three key aspects: 1) the capacity of both natural and human elements of the fishery to absorb pressure from individual and cumulative threats; 2) the capacity to adapt to change when the absorptive capacity is exceeded, yet the system still provides goods and services that support food and livelihoods; and 3) the capacity to transform into new fishery systems in the face of continued pressures or threats[83].

The health of freshwater and estuarine habitats, along with fish communities are, therefore, critical to the resilience of fisheries to cumulative existing threats, in addition to those posed by climate change. For fisheries to successfully adapt to climate change, fisheries management and governance processes must simultaneously strengthen the resilience of both natural fisheries resources and the human dimensions of fisheries to all threats. This requires effectively strengthening knowledge, improving communication, and fostering collaboration with other sectors and jurisdictions beyond the traditional scope of fisheries management.

Stock status and sustainable yield

Stock status

Trends in the status of freshwater and estuarine fisheries in the Pacific Islands region are summarised in Table 5.2. There is growing concern about increasing fishing pressure on freshwater fish and shellfish stocks, particularly when considered in conjunction with other threats discussed in the previous section.

Estimated sustainable production

Existing data are not reliable enough to provide quantitative estimates of sustainable production. However, reported declines in some freshwater and estuarine fisheries suggest that fishing pressure has reached unsustainable levels, triggering the implementation of local regulations.

Fly River region, Papua New Guinea

The Fly River commercial barramundi fishery has been closed for over a decade[48]. Under the 2004 Barramundi Fishery Management Plan[71], the total allowable catch for the fishery was set at 260 t/year. A thriving unlicenced artisanal fishery

now operates in rivers draining into the Gulf of Papua, from the Fly River east to the Purari River; the combined catch of barramundi and black bass has been estimated at 600 t/year[3]. The impact of the unregulated maw (swim bladder) fishery has not yet been assessed.

Previous sustainable yield estimates for river herring (*Nematalosa papuensis*) in the Fly River ranged from 5,000 to 33,000 t/year[84,85]. These assessments included habitats inaccessible to fisheries, suggesting that 5,000 t/year may be more reasonable. Even so, this estimate is many times greater than recent catches of < 500 t/year. For all species combined, potential yields for the middle Fly River system have been estimated at 5,000 to 10,000 t/year[86,87]. Similarly, Lake Murray and other lakes produce a sustainable catch of 5,000 to 10,000 t/year[48].

Other PNG regions

Catches in the Sepik-Ramu region are dominated by introduced species, including Java carp (*Barbonymus gonionotus*), Emily's fish (*Prochilodus argenteus*), pacu (*Piaractus brachypomus*), and tilapia. Native ariid catfishes, such as eels (*Anguilla bicolour*, *A. marmorata*) and Papuan black bass, are frequently caught during peak migratory seasons. Freshwater prawns are also harvested, although in low volumes and for local markets only. Artisanal and subsistence catches in the Sepik-Ramu River system are not well documented, but estimates suggest an annual catch of around 10,000 t[48]. Current catches appear to be sustainable and exceed historical estimates of sustainable production for the Sepik-Ramu region, which ranged from 3,000 to 5,000 t/year[88] to over 8,000 t/year[46,89]. The higher estimates reflect the contribution of introduced species. Fishing is more intensive in the Sepik River system than elsewhere in PNG, with people setting gill nets daily. The fish introduction program is considered to have been successful in improving food security and income[90], although the benefits remain controversial[91].

Reservoir fisheries have evolved in recent years. Following the filling of Yonki Reservoir on the headwaters of the Ramu River, catches of carp, Mozambique tilapia and redbreast tilapia increased from 40 t in 1992 to 61 t in 1995[92]. Since 2005, heavy fishing pressure increased catches to 365–800 t/year, before declining around 2010 to current levels of 37 t/year. The catch now predominantly consists of Nile tilapia, with occasional carp and mahseer[48].

Fiji

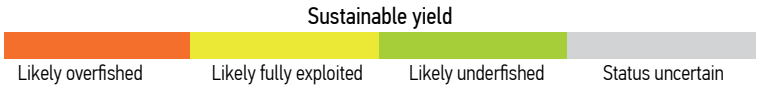
Fiji's once-abundant yearly mullet runs have declined due to overfishing and habitat loss[42]. From a peak of over 1,000 t in 1988, catches stabilised between 300 and 500 t, with a reported catch of 417 t in 2004[42]. As the mullet population declined, its market value increased, with average market prices rising from USD[i] 1.62–1.87 per kg in 2002–2004 to USD 3.16 in 2016[42]. Freshwater prawn production also registered a decline, from a peak of 72 t in 1991 to 53 t in 1992[42]. By 2004, total prawn catch was estimated at 420 t, and in 2017, the reported catch had increased to 634 t [42]. Catches of *kai* in Fiji vary, with reports indicating annual catches of 2,000 to 2,527 t in 2004[42]. Recent accounts suggest the catch may be higher, ranging between 4,000 to 7,000 t annually[29]. There is also growing interest in developing a high- value eel fishery in Fiji, focusing on collecting juvenile eels as they enter freshwater and growing them out to marketable size in aquaculture facilities[93].

i Based on 2024 conversion FJD 1.00 = USD 0.44

Table 5.2 *Estimated sustainable yield for fisheries for selected species groups, based on stock status, estimated catches, and known threats.*

Species	PICT	Stock status	Threats	Recent catches (tonnes)	Sustainable yield
Barramundi *Lates calcarifer*	PNG	Stock steady, commercial fishery closed	Overfishing, mining, drought	200–250	Likely fully exploited
River herring *Nematalosa papuensis*	PNG	Variable	Mining, drought	200	Likely underfished
Fork-tailed catfish Ariidae	PNG	Declining	Overfishing, introduced species	3,000	Likely overfished
Eels *A. obscura, A. marmorata*	Fiji, New Caledonia	Insufficient information	Dams, indiscriminate fishing (*Derris* poisoning)	Insufficient data	Likely underfished
Mullet Mugilidae	Fiji, PNG, Solomon Islands, Tonga, Vanuatu	Rebuilding in Fiji following local declines, steady elsewhere	Overfishing, mining	~300 Fiji, 2,000 PNG	Status uncertain
Whitebait *Sicyopterus lagocephalus, S. pugnans*	French Polynesia	Variable	Overfishing	61	Status uncertain
Tropical freshwater snappers *Lutjanus* spp.	PNG, Solomon Islands, Vanuatu	Papuan black bass declining in parts of PNG, other species common elsewhere	Mining, logging, agriculture	7,000 PNG (2,000 Sepik- Ramu; 3,000 Fly/ Purari/ Kikori; 2,000 elsewhere)	Likely fully exploited
Freshwater clams *Batissa violacea*	Fiji, New Caledonia, PNG, Solomon Islands, Vanuatu	Some declines in Fiji, e.g. 27% population decline 1996–2019 in Ba River; decreasing size in fished populations	Sea level rise and salinisation, water quality, water resource development, overfishing	4,000–7,000 Fiji, 10,000 PNG, no estimates elsewhere	Likely overfished in Fiji Likely fully exploited in PNG
Freshwater prawns *Macrobrachium* spp., *Palaemon* spp.	Fiji, PNG	Declining in places in Fiji	Overfishing, water quality	634 Fiji, 6 PNG, limited data elsewhere	Likely overfished in Fiji Likely underfished elsewhere
Tilapia* Cichlidae, mostly *Oreochromis niloticus*	Fiji, PNG, Solomon Islands	Mostly stable, some declines. Localised depletion in heavily fished parts of Sepik River in PNG	Overfishing, predation from other species	8,000 PNG, 10 Fiji, 16 Solomon Islands, limited data elsewhere	Status uncertain Likely overfished in some lakes
Carp* *Cyprinus carpio*	PNG	Decreasing size because of competition	Competition from other species	1,000	Likely underfished
Java carp* *Barbonymus goniotus*	PNG	Insufficient information	Overfishing, mining, drought	No data	Status uncertain

*Introduced species. Sources: FAO 2023[106], Lako et al. 2019[29], Lee et al. 2020[42], Oreihaka 2001[107], PNG National Fisheries Authority unpublished data 2024[48]



Climate change projections and effects on freshwater and estuarine fisheries

Current climate projections recognise five distinct climatic zones for the Pacific Islands region (see Figure 2.11 in Webb et al. 2025, Chapter 2 this volume), representing a significant enhancement in spatial resolution compared with the previous vulnerability assessment[4]. PICTs represented in each climatic zone are listed in Table A1 in Chapter 2, which also provides details on the climate projections used in this assessment. Medium (SSP2-4.5) and high (SSP5-8.5) greenhouse gas emissions scenarios were used in this assessment (see Johnson et al. 2025, Chapter 1 this volume for description of SSP scenarios).

Hydrological indicators are critical for accurately assessing climate change vulnerability of freshwater and estuarine fisheries because relying solely on climate variables can lead to overestimating impacts[23]. However, hydrological data are limited across the diversity of river types in the Pacific Islands region[2]. Accordingly, this assessment uses rainfall trends to infer trends in hydrology.

Climate change projections typically do not include estimates of water temperature in freshwater systems, partly because habitats vary widely with flow conditions, shading, elevation, size, wind exposure, and other factors that influence water temperature[8]. Modelling and empirical studies of energy transfer between air and water, based on rainfall, hydrology, and temperature in rivers and lakes[20–22,94] have shown that water temperature is strongly influenced by rainfall and river flow, and cannot be considered independently.

Sea level projections are used to estimate changes in the location of estuaries and estuarine salinity ranges. Many rivers in the Pacific Islands region have limited development of estuaries in the traditional sense. This is because of high rainfall, extensive freshwater flushing, steep terrain resulting in short estuaries, and small tidal ranges that limit saltwater exchange[73]. In contrast, the Fly River estuary in PNG has a tidal range of more than 5 m and extends over 1,000 km upriver.

Rainfall effects on river flow and water temperature

Rainfall does not affect aquatic species directly, but instead produces multiple indirect hydrological effects that influence the quality and accessibility of aquatic habitats for fish and invertebrates. In contrast, changes in water temperature directly affect species' physiology and behaviour.

River flow is closely linked to seasonal and annual changes in precipitation[20], meaning that an increase in rainfall magnitude and frequency is projected to increase river flows and inflow to lakes. In tropical catchments, increases in water temperature are expected to be moderate[20] due to several factors: increased evaporative cooling (latent heat flux), increased back radiation (blackbody radiation from the water surface), and higher mean annual river flow (thermal capacity). These processes combine so that the increase in water temperature from climate change in the Pacific Islands region will be less than the corresponding increase in air temperature. The cooling contribution of groundwater to river flow will also moderate water temperature[25,95]. Furthermore, projected changes in air temperature have been found to overestimate climate impacts on freshwater fish[96]. As a result, this assessment uses sea surface temperature as a proxy for expected changes in freshwater temperatures, acknowledging that temperature in individual habitats will exhibit greater variability.

The ecological roles of river flow in supporting freshwater and estuarine habitats and fisheries in the tropical Pacific Islands region have been synthesised previously[2,4]. River flow is critical for maintaining connectivity between habitats, transporting nutrients and food downstream, and providing behavioural cues for migration and reproduction. Increased rainfall boosts river flows and connectivity, allowing fish greater access to a range of habitats. Freshwater fish display a wide range of adaptations to take advantage of high river flows[97,98]. Conversely, low flows reduce connectivity, limiting species' access to habitats. As a result, catchments in the Pacific Islands region that experience an increase in rainfall are likely to see a rise in fish and shellfish populations[4], while lower rainfall and declining river flows are projected to cause declines in fisheries populations.

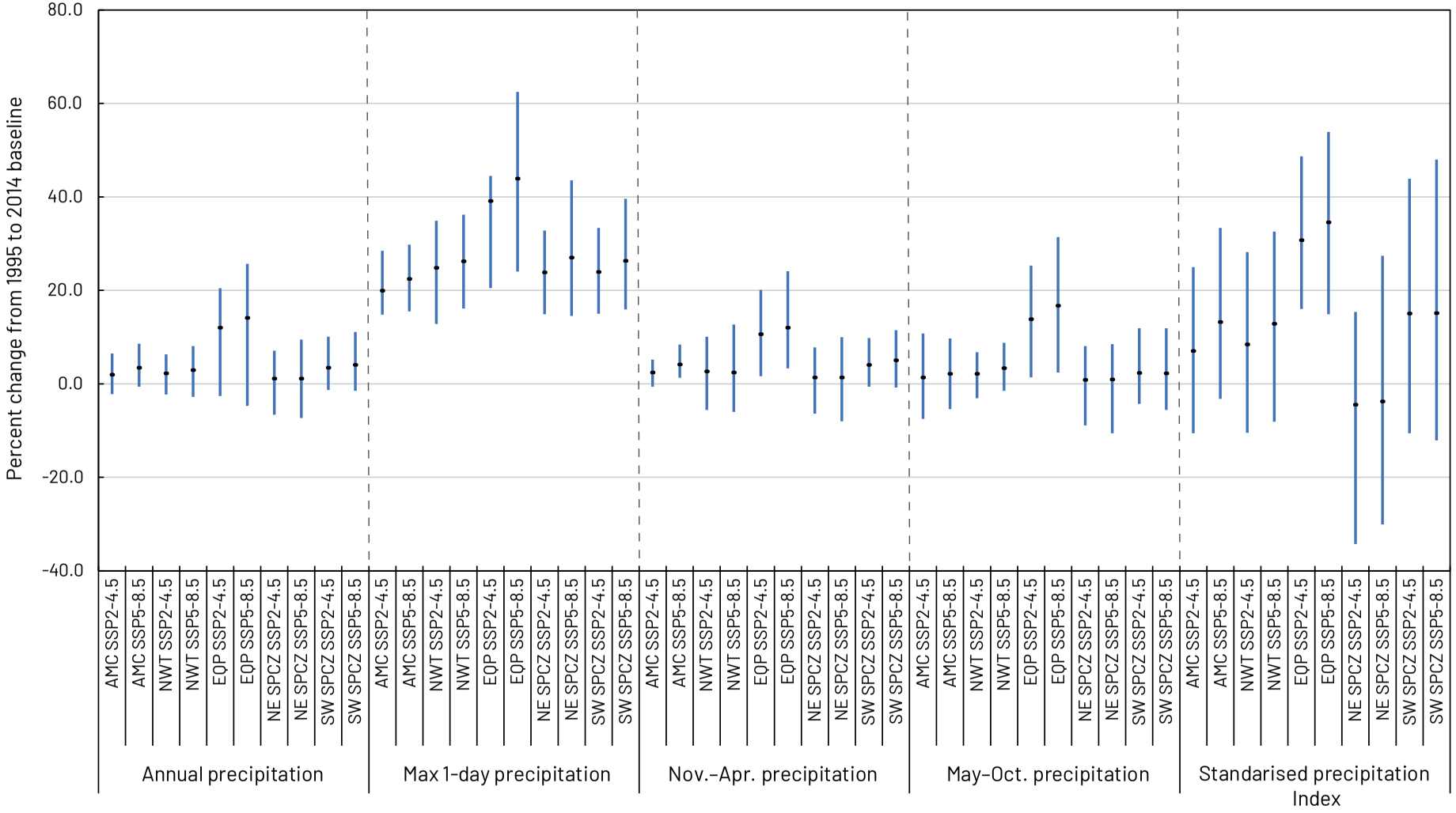


Figure 5.4 *Relative magnitude of projected changes in rainfall indicators that affect hydrology across the five climatic zones (AMC – Australian and Maritime Continent Monsoon; NWT – Northwest Tropical Pacific; EQP – Equatorial Pacific; NE SPCZ – Northeast South Pacific Convergence Zone; and SW SPCZ – Southwest South Pacific Convergence Zone) in the Pacific Islands region, for medium emissions SSP2-4.5 and high emissions SSP5-8.5 scenarios. Plotted values represent median, 10th and 90th percentile projections. Sources: Webb et al. 2025, Chapter 2 this volume; IPCC-WG1-Interactive-Atlas 2023*[19]

The largest projected changes in rainfall indicators by 2050 (Figure 5.4) are expected in the Equatorial Pacific zone (e.g. Kiribati and Nauru)[19] (see Webb et al. 2025, Chapter 2 this volume). However, these changes are of little consequence for fisheries because of the lack of freshwater and estuarine habitats on these atolls.

Annual precipitation is predominantly projected to increase by less than 10%, with a larger increase expected in the Equatorial Pacific zone. Increases under the high emissions scenario (SSP5-8.5) are slightly greater than under the medium emissions scenario (SSP2-4.5). However, projected increases in river flow of this magnitude are likely to be obscured by annual variability and may be imperceptible for practical purposes.

The influence of storms, represented by the maximum 1-day precipitation in the wet season, is projected to increase markedly in all climate zones. The storms will drive transient high river flows, which can cause both habitat damage and beneficial effects, such as transporting materials, connecting habitats, and facilitating fauna dispersal and migration. However, high river flows may also make it difficult or unsafe for people to fish, resulting in lost fishing days. The largest changes in maximum 1-day precipitation are expected in the Equatorial Pacific zone. For 2050, maximum 1-day precipitation and associated high river flows are projected to be slightly higher under the high emissions scenario (SSP5-8.5) than under the medium emissions scenario (SSP2-4.5), although the difference between scenarios is small.

Changes in total rainfall during both the wet and dry seasons are projected to mirror the small overall increases in annual rainfall across all climate zones, except the Equatorial Pacific. Both seasons are expected to be wetter on average, with some drier years. By 2050, these projected changes in seasonal rainfall will mostly result in small increases in river flow for high flow and low flow events. Rainfall and river flows will be slightly higher under the high emissions scenario than under the medium emissions scenario, although the difference between scenarios is small.

The Standardised Precipitation Index (SPI) is used as an indicator of prolonged dry conditions. Projected SPI values suggest that prolonged dry periods will be wetter and less severe than current conditions in most climate zones. However, the range of negative SPI values confirms that some drier periods will still occur. Low rainfall periods will be most pronounced in the Northeast South Pacific Convergence Zone (SPCZ), which produces only small catches of freshwater fish, except for the intermittent whitebait fishery in French Polynesia. There is no practical difference between SPI projections for medium and high emissions scenarios.

Water temperature

Seasonal increases in water temperature are most likely to adversely affect freshwater and estuarine ecosystems when three conditions occur simultaneously: 1) high water temperatures coincide with low flows; 2) low flows are reduced by more than 25%; and 3) increases in water temperature exceed 2°C[20,21]. However, these conditions are not projected to coincide in 2050 for the Pacific Islands region[20], resulting in low temperature-related risks to fisheries production. Exceptions may occur during El Niño events, when reduced rainfall may lead to contraction of floodplain waterbodies, combined with higher temperatures and declining water quality[14]. By 2090, water temperature is projected to increase 1.9–4.4°C under the high emissions scenario (SSP5-8.5) (Webb et al. 2025, Chapter 2 this volume).

Projected increases in median water temperature by 2050 are mostly less than 1°C under the medium emissions scenario, and less than 2°C under the high emissions scenario. These changes are unlikely to significantly impact most species in lakes and rivers. High elevation fish species, such as snow trout, that prefer colder water temperatures may move farther upstream to avoid increasing temperatures at their lower elevation limit[99]. However, studies on other species, like brown trout, suggest that range contractions may not occur[100], or may be offset by range expansions elsewhere, as seen with bull trout[101], resulting in no net habitat loss. Where extreme temperatures and low flows coincide, negative impacts may arise, such as when floodplain waterbodies recede, crowding fish and invertebrates into contracting habitats, and oxygen becomes depleted, causing respiratory stress. While projected changes in rainfall and temperature suggest these conditions are likely to become less frequent, they may still coincide occasionally, potentially leading to episodic fish kills[14].

Dissolved oxygen

The solubility of oxygen in water decreases as water temperature increases, but the projected temperature changes due to climate change will result in only small reductions in solubility. For example, at 25°C, freshwater at sea level elevation has an oxygen solubility of 8.26 mg/l, whereas a 2°C increase to 27°C reduces oxygen solubility to 7.97 mg/l. Such small changes are generally not a concern, except for conditions where oxygen is limiting, and further reductions in oxygen availability could restrict aquatic respiration[21,102,103].

Increased biological oxygen demand (BOD) – driven by the decomposition of organic matter during floods, prolonged low flows, or algal blooms – is a common cause of fish kills[14]. The effects of climate change on the frequency and magnitude of high flow and low flow events, and associated peaks in BOD, pose a greater risk to fisheries than the small reductions in oxygen availability associated with projected rises in water temperature.

Sea level

Rising sea levels will have a direct effect on freshwater and estuarine fisheries by driving saline water upstream into the lower freshwater reaches of rivers. By 2050, projected sea-level rise across all climatic zones and emissions scenarios ranges from 0.1 m to 0.4 m (Webb et al. 2025, Chapter 2 this volume). In macrotidal regions, such as the Fly River estuary in PNG, where the tidal range is 5–6 m, the projected increase in sea level represents less than 10% of the daily tidal oscillation. In contrast, microtidal regions such as Tahiti experience a tidal range of about 0.3 m during spring tides and less than 0.1 m during neap tides, meaning the projected increase in sea level is likely to be equal to, or even exceed, the natural tidal range. Consequently, the impacts of sea-level rise are likely to be proportionally greater in regions with smaller tidal ranges.

Species that have a low tolerance for salt water, such as freshwater clams, are likely to move progressively upstream. Species that migrate between saltwater and freshwater to complete their life cycle, such as barramundi and amphidromous gobies, may require little adjustment to their distributions, depending on the salinity tolerance of their freshwater life-history stages. Given the resilience of estuarine species to environmental fluctuations[73], it is likely that they are pre-adapted to the changes in estuarine habitats that are projected as a result of rising sea levels.

Vulnerability of freshwater and estuarine fish and invertebrates to climate change

Direct effects of temperature, river flows and sea level

Freshwater and estuarine fish and invertebrates in the Pacific Islands region are projected to exhibit low to moderate beneficial responses to climate change in well-managed catchments, with the greatest vulnerability in disturbed catchments and in the Northeast SPCZ[4] (see Table 5.3).

Direct vulnerability to warming is low, because the temperature changes up to 2050 are small and fall within the wide range of existing temperature variations and species' temperature tolerances. However, in catchments disturbed by vegetation clearing, soil disturbance, and water infrastructure, fish may be more vulnerable to the effects of warmer temperatures[26,104,105].

The life cycles of many species of freshwater and estuarine fish and crustaceans in the Pacific Islands region are closely linked to hydrology, with elevated flows supporting migration and recruitment[108,109]. Increases in annual rainfall and flow events from tropical storms promote recruitment, growth and survival, and ultimately contribute to improved fisheries production[110,111]. A comprehensive synthesis of cyclone impacts[112] found that freshwater ecosystems had the highest resilience to biogeochemical and hydrographic impacts. Estuarine ecosystems, particularly fish, showed positive responses to increased rainfall but were less resistant to strong winds. Overall, vulnerability of freshwater and estuarine fish and invertebrates to increased rainfall and river flows is low because increased flows are mostly beneficial.

The vulnerability of species to reduced river flows and the drying of small rivers and floodplain habitats is low, given projected increases in dry season rainfall. However, in the Northeast SPCZ, climate variability may still produce more severe droughts on occasion. Consequently, the vulnerability of fisheries to reduced rainfall and river flows is generally low.

Freshwater and estuarine fish and invertebrates in the Pacific Islands region are projected to exhibit low to moderate beneficial responses to climate change in well-managed catchments, with the greatest vulnerability in disturbed catchments and in the Northeast SPCZ.

The vulnerability of species groups to rising sea levels is mostly low due to the small magnitude of change and the tolerance of estuarine species to warmer water[73]. While infrastructure such as causeways and tidal barriers, or natural obstacles may prevent species from adapting by moving upstream in response to changing conditions[4], the combination of increased river flows and elevated sea levels may create additional opportunities for species to migrate above low-level barriers.

Tropical estuarine fish species, and freshwater species with marine life-history stages, tend to be resilient to extreme conditions because of the daily and seasonal fluctuations in their physical environment. For instance, a study of fish in salt concentrator ponds in tropical Western Australia[113] found species such as mangrove jack (*Lutjanus argentimaculatus*), golden trevally (*Gnathanodon speciosus*), estuary cod (*Epinephelus coioides* and *E. malabaricus*) and giant trevally (*Caranx ignobilis*) in salinities greater than 50 ppt. Mangrove jack, in particular, use the full range of salinities, from freshwater to hypersaline, as nursery habitats[114], with their ability to use marginal habitats constrained more by connectivity and drying conditions than by salinity[115].

Estuarine fish species also tend to have greater tolerances for hypoxic environments compared to coral reef specialists[116], which greatly enhances their ability to survive in habitats such as mangroves that exhibit fluctuating oxygen availability[117]. These adaptive traits may allow many common estuarine species to be highly resilient to climate change. In fact, their distribution and abundance are more likely more to be impacted by human responses to climate change (e.g. barrier construction) than by the direct effects of climate change.

Table 5.3 *Expected vulnerability (High, Moderate, Low), and direction of response (▲ beneficial, ▼ detrimental) of species groups of fish and invertebrates to the direct effects of climate change by 2050 in Pacific Island countries and territories. There is no distinction in vulnerability between the medium emissions scenario (SSP2-4.5) and high emissions scenario (SSP5-8.5). Separate estimates are provided for undisturbed and disturbed catchments to account for species in disturbed catchments experiencing increased exposure to certain climate change elements. Responses represent the median response across habitat types. SPCZ = South Pacific Convergence Zone. n.a. = not applicable*

Group	Water temperature	Annual river flow (annual rainfall)	Peak river flow (1-day max rainfall)	Low river flow (Standardised Precipitation Index)	Sea level rise
Catadromous species Barramundi, eels, flagtails, mullet, oxeye herring, milkfish	▲ Low ▼ Low in disturbed catchments	▲ Low	▲ Low – Moderate ▼ Low – Moderate in disturbed catchments	▲ Low – Moderate ▼ Low – Moderate in Northeast SPCZ	▼ Low
Amphidromous species Gobies, gudgeons, *Macrobrachium* spp.	▲ Low ▼ Low in disturbed catchments	▲ Low	▲ Low – Moderate ▼ Low – Moderate in disturbed catchments	▲ Low – Moderate ▼ Low – Moderate in Northeast SPCZ	▼ Low
Potamodromous species River herring, freshwater clams, carp	▲ Low ▼ Low in disturbed catchments	▲ Low	▲ Low – Moderate ▼ Low – Moderate in disturbed catchments	▲ Low – Moderate ▼ Low – Moderate in Northeast SPCZ	▼ Low
Marine visitors Snappers	▲ Low ▼ Low in disturbed catchments	▲ Low	▲ Low – Moderate ▼ Low – Moderate in disturbed catchments	▲ Low – Moderate ▼ Low – Moderate in Northeast SPCZ	▲ Low
Substrate spawners Eel-tailed catfish, large gudgeons	▲ Low ▼ Low in disturbed catchments	▲ Low	▲ Low – Moderate ▼ Low – Moderate in disturbed catchments	▲ Low – Moderate	▼ Low
Mouth brooders Fork-tailed catfish, saratoga	▲ Low ▼ Low in disturbed catchments	▲ Low	▲ Low – Moderate ▼ Low – Moderate in disturbed catchments	▲ Low – Moderate	▼ Low
Introduced species Tilapia	▲ Low ▼ Low in disturbed catchments	▲ Low	▲ Low – Moderate ▼ Low – Moderate in disturbed catchments	▲ Low – Moderate ▼ Low – Moderate in Northeast SPCZ	▼ Low
High elevation species Rainbow trout, snow trout	▼ Low	▲ Low	▲ Low – Moderate ▼ Low – Moderate in disturbed catchments	▲ Low – Moderate	n.a.

vulnerability

L	LM	M	MH	H
Low	Low – Moderate	Moderate	Moderate – High	High

The differences between climate projections to 2050 for the medium and high emissions scenarios are small, resulting in little practical difference in the vulnerability of freshwater and estuarine fish. While the potential benefits, such as improved river flows and increased connectivity between river and floodplain habitats, are slightly greater under the high emissions scenario, these differences are likely imperceptible when compared with natural variability.

Indirect effects of climate change

Indirect vulnerability of freshwater and estuarine species to climate change, through climatic interactions with their habitats, is generally low, with greater negative effects in disturbed catchments and in the drier Northeast SPCZ (Table 5.4). For example, montane rivers, lakes and reservoirs in PNG have been colonised by introduced species such as rainbow trout, tilapia, carp and to a lesser extent, golden mahseer, chocolate mahseer (*Neolissochilus hexagonolepis*), and snow

trout. Cold water species such as rainbow trout, snow trout and mahseer were expected to shift upstream to cooler water in response to warming temperatures[4], which would also allow species such as tilapia and carp to expand their range upstream. However, recent studies suggest that range shifts attributable to warming will be offset by increased rainfall[20,22], so that the net effect on species distributions in the Pacific Islands region is likely to be small[23,101]. In dams and lakes, episodic dry periods during El Niño events may lower water levels and reduce habitat availability, but these changes are expected to be offset in the long term by the overall increase in rainfall.

The vulnerability of freshwater and estuarine species and fisheries to climate change is shaped by interactions between temperature and rainfall patterns, and interactions among habitats, different climatic zones, and catchment condition (Table 5.4). These complex interactions are likely to result in some unanticipated outcomes.

Table 5.4 *Estimated vulnerability (High, Moderate, Low) among habitats, and direction of response (⬆ beneficial, ⬇ detrimental) of species groups to the combined effects of climate change by 2050 in Pacific Island countries and territories. There is no distinction in vulnerability between the medium (SSP2-4.5) and high (SSP5-8.5) emissions scenarios. Separate estimates are provided for undisturbed and disturbed catchments to account for species in disturbed catchments experiencing increased exposure to some climate change elements. Responses represent the median response across climatic zones. SPCZ = South Pacific Convergence Zone. n.a. = not applicable*

Group	Montane rivers	Slopes and lowland rivers	Lakes and floodplains	Estuaries
Catadromous species Barramundi, eels, flagtails, mullet, oxeye herring, milkfish	n.a.	⬆ Low ⬇ Low in disturbed catchments	⬆ Low – Moderate ⬇ Low – Moderate in disturbed catchments, Northeast SPCZ	⬆ Low ⬇ Low in Northeast SPCZ
Amphidromous species Gobies, gudgeons, *Macrobrachium* spp.	n.a.	⬆ Low ⬇ Low in disturbed catchments	⬆ Low – Moderate ⬇ Low – Moderate in disturbed catchments, Northeast SPCZ	⬆ Low ⬇ Low in Northeast SPCZ
Potamodromous species River herring, freshwater clams, carp	n.a.	⬆ Low ⬇ Low in disturbed catchments	⬆ Low – Moderate ⬇ Low – Moderate in disturbed catchments, Northeast SPCZ	⬆ Low ⬇ Low in Northeast SPCZ
Marine visitors Snappers	n.a.	⬆ Low ⬇ Low in disturbed catchments	n.a.	⬆ Low ⬇ Low in Northeast SPCZ
Substrate spawners Eel-tailed catfish, large gudgeons	n.a.	⬆ Low ⬇ Low in disturbed catchments	⬆ Low – Moderate ⬇ Low – Moderate in disturbed catchments, Northeast SPCZ	n.a.
Mouth brooders Fork-tailed catfish, saratoga	n.a.	⬆ Low ⬇ Low in disturbed catchments	⬆ Low – Moderate ⬇ Low – Moderate in disturbed catchments	n.a.
Introduced species Tilapia	n.a.	⬆ Low ⬇ Low in disturbed catchments	⬆ Low – Moderate ⬇ Low – Moderate in disturbed catchments	n.a.
High elevation species Rainbow trout, snow trout	⬇ Low	n.a.	n.a.	n.a.

vulnerability

L	LM	M	MH	H
Low	Low – Moderate	Moderate	Moderate – High	High

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Lower elevation rivers are projected to provide small increases in habitat due to increased river flows. Elevated flows are expected to improve opportunities for species to migrate within rivers, between rivers and floodplain habitats, and between freshwater and coastal habitats, as well as supporting enhanced recruitment of species that migrate to sea as part of their life cycle[118].

Species such as eels, flagtails (*Kuhlia* spp.), tilapia, carp, gudgeons, gobies, and crustaceans and freshwater clams, are expected to benefit from a projected expansion in habitat size and increased food availability in lowland rivers. For instance, in Fiji, glass eel stages of *Anguilla obscura* and *A. marmorata* recruit continuously in low numbers throughout the year, but species composition in catches is influenced by the timing of heavy rainfall and river flow[119]. *Anguilla obscura* was the most abundant species in a 2015 study, accounting for 55% of collected glass eels, with peak recruitment in the late wet season from February to April. In contrast, recruitment of *A. marmorata* (41%)

peaked in the late dry season from September–October. *Anguilla megastoma* comprised only 3.9% of the glass eels collected, with peak recruitment in April and October. Future changes in rainfall seasonality may produce subtle changes in the composition of freshwater fish catches.

Increased river flows to estuaries are projected to benefit most species that use estuarine habitats at some stage of their life cycle[6]. Variability in rainfall projections suggests that the Northeast SPCZ, in particular, may experience reduced flows to estuaries in some years.

Integrated vulnerability assessment for freshwater and estuarine fisheries

Climate change and interactions with human activities

The vulnerability of fisheries to climate change across all five climatic zones (Figure 5.5), under both medium (SSP2-4.5) and high (SSP5-8.5) emissions scenarios, is strongly influenced by human activities that disturb catchments. In well-managed catchments, climate change is expected to mainly result in greater freshwater and estuarine fisheries production.

However, these benefits may be nullified in catchments where habitats and water quality have been degraded[15,21]. Projected fisheries benefits from increased rainfall may not eventuate in impounded rivers. Dams create predictable changes in the hydrology and ecology of rivers and estuaries, leading to declines in local species and fisheries[120–123].

To ensure that economic development improves livelihoods without compromising food security and cultural heritage[3,50], robust planning and environmental impact assessments are necessary.

In most climate zones, the combined effects of climate change are projected to be marginally beneficial for freshwater and estuarine fisheries (Figure 5.5). Increased rainfall projections under the high emissions scenario (SSP5-8.5) are linked to slightly greater benefits by 2050 than under the medium emissions scenario (SSP2-4.5). However, vulnerability to adverse effects increases in disturbed catchments where aquatic species experience greater exposure to both the direct and indirect effects of climate change.

Fisheries in the Northeast SPCZ demonstrate the greatest vulnerability to increased frequency of low rainfall periods that are interspersed with wetter seasons. This variability will have intermittent effects on fisheries production, as PICTs in this zone have only small freshwater fisheries with occasional opportunistic catches[124].

Extending this analysis to 2090 (2081–2100) indicates that both temperature and rainfall extremes will become more pronounced under both the medium and high emissions scenarios, with differences between scenarios becoming more accentuated (Webb et al. 2025, Chapter 2 this volume). By 2090, it will become increasingly difficult to isolate the opposing effects of increased rainfall and river flow in both wet and dry seasons from more pronounced warming. Interactions between temperature, rainfall and habitats further add to the uncertainty in vulnerability projections (see Appendix 1). The projected temperature increase of 0.9–4.4°C by 2090 may be partly mitigated by increased river flows, which promote cooling. However, increased variability in rainfall may result in both increased beneficial flows as well as transient damaging flows. Rising sea levels, potentially ranging from 0.3–1.0 m, may have limited impact in macrotidal locations such as the Fly River in PNG, or substantial local-scale impacts in microtidal locations such as Tahiti in French Polynesia. Overall, the increased variability in climate projections to 2090 may lead to a broader range of vulnerabilities among freshwater and estuarine fisheries, potentially resulting in some unexpected outcomes.

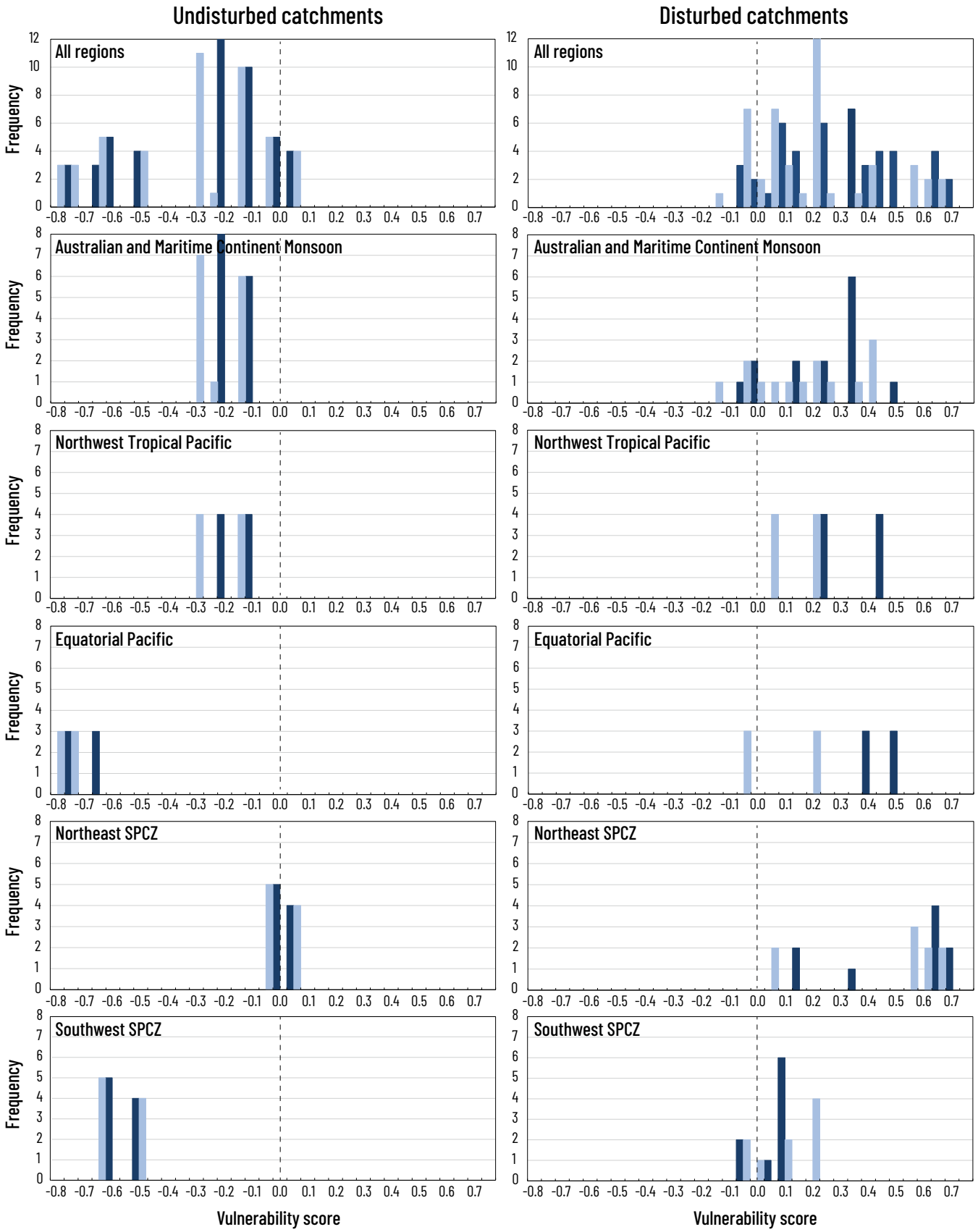

Figure 5.5 *Integrated vulnerability score for fish species groups, by climatic zone, in undisturbed and disturbed catchments. Negative vulnerability indicates potential beneficial outcomes, positive vulnerability indicates potential adverse impacts. Dashed line indicates neutral vulnerability. Dark bars show vulnerability under a medium emissions scenario (SSP2-4.5), light bars show vulnerability under a high emissions scenario (SSP5-8.5). Fish in the Northeast SPCZ are the most vulnerable to climate change. Fish in disturbed catchments experience greater exposure to climate change and are more vulnerable than similar species in undisturbed catchments.*

Projected changes in fisheries yields

Freshwater and estuarine fisheries yields are mostly projected to increase marginally, with larger decreases in disturbed catchments. The previous assessment in 2011[4] projected increased yields of 0–2.5% by 2035, and up to 0–12.5% by 2100. Based on the updated information available, we suggest that increases in fisheries yields by 2050 will be at the lower end of this range (Table 5.5). If fisheries production follows the same proportional changes projected for habitats, we estimate that, for most climatic zones, fisheries production under the medium emissions scenario will increase by 0.5–2.4%, with a decline of 3.0% in the Northeast SPCZ due to reduced dry season rainfall. Under the high emissions scenario, freshwater fisheries production is estimated to increase by 2.0–2.6%, with a 3.0% decline in the Northeast SPCZ.

Combining these projections across all PICTs provides an estimated increase in production of 287 t (1.0% increase) under the medium emissions scenario, and 760 t (2.6% increase) under the high emissions scenario. However, the variability and uncertainty in climate projections – combined with existing seasonal, annual, and longer term climate variability – suggest that changes in freshwater and estuarine fisheries production due to climate change are likely to be indistinguishable from existing natural fluctuations in catches. The unreported catches identified in this analysis may increase total catch by 35,000 t, emphasising the imperative for more accurate catch data.

While the projected changes in freshwater and estuarine fisheries production up to 2050 are likely to be small, two caveats require consideration. First, in disturbed catchments, adverse effects of climate change are likely to be amplified[21] and may lead to a decline in production. Of special note is the construction of dams for water storage, hydroelectricity generation and flood mitigation. It is paradoxical that dams designed to reduce the impacts of climate change may simultaneously cause a decline in freshwater fisheries that otherwise might benefit from climate change. Secondly, these projections carry a low level of confidence for longer-term changes in freshwater and estuarine fisheries to 2090. Over this longer time frame, differences between the medium emissions scenario and high emissions scenario become more pronounced, and both the beneficial and adverse effects of temperature, rainfall and sea level rise are expected to grow, thereby increasing the likelihood of interactions that could lead to unforeseen outcomes.

Management implications and recommendations

The overarching objective among PICTs for freshwater and estuarine fisheries management is to ensure the long-term management, conservation, development and sustainable use of fisheries resources for the benefit of people, with legislation explicitly excluding fishing for personal use or customary use[125]. In Fiji, management measures that benefit freshwater resources are generally considered favourable for freshwater fisheries as well[17]. Beyond this broad objective, there are no clearly stated goals for freshwater and estuarine fisheries among PICTs to guide climate change adaptation strategies. Accordingly, we have framed the following recommendations to sustain freshwater and estuarine fisheries in the face of the expected challenges from climate change to guide PICTs in establishing their own priorities.

The dominant effect of climate change on freshwater and estuarine fisheries in the Pacific Islands region is projected to be a small increase in catches by 2050, driven by increased rainfall and higher river flows. Consequently, the vulnerability of these fisheries to climate change is relatively low, although this change may be imperceptible against background variability in fisheries catches. The outcome for catches to 2090 is more uncertain.

To achieve this climate-mediated increase in catches, it is crucial for fisheries agencies to prevent overfishing, which presents compliance challenges, especially in remote locations. A greater challenge comes from threats to fisheries caused by activities outside of the jurisdiction of fisheries agencies, which could negate anticipated increases in catch. Moreover, it is likely that catchment disturbance will increase exposure to climate change, making fisheries more vulnerable than in well-managed catchments.

Table 5.5 *Projected percentage changes in annual freshwater and estuarine fisheries production (t) (increase; decrease) relative to estimated recent production[4], assessed from projected changes in habitat availability and quality due to climate change to 2050. Likelihood and confidence in projections are shown for each climatic zone. Unreported catches from New Caledonia, Papua New Guinea, Solomon Islands and Vanuatu, and potentially French Polynesia, may translate to actual production being much higher, with greater increases from climate change.*

Climatic zone	PICT	Recent production estimate (t)	Projected change (%) by 2050	
			SSP2-4.5	SSP5-8.5
Australian and Maritime Continent Monsoon	PNG	23,000	+0.6	+2.6
Likelihood and confidence			L M	L M
Northwest Tropical Pacific	Guam	3	+0.5	+2.0
	Marshall Islands	-	+0.5	+2.0
	Federated States of Micronesia	1	+0.5	+2.0
	Northern Mariana Islands	-	-	-
	Palau	1	+0.5	+2.0
Likelihood and confidence		-	L M	L M
Equatorial Pacific	Kiribati	-	-	-
	Nauru	-	-	-
Likelihood and confidence			-	-
Northeast SPCZ	Cook Islands (northern)	5*	-3.0	-3.0
	French Polynesia	100	-3.0	-3.0
	Pitcairn	-	-	-
	Tokelau	-	-	-
	Tuvalu	2	-3.0	-3.0
Likelihood and confidence			L M	L M
Southwest SPCZ	American Samoa	1	+2.4	+2.6
	Cook Islands (southern)	5*	+2.4	+2.6
	Fiji	4000	+2.4	+2.6
	New Caledonia	10	+2.4	+2.6
	Niue	-	-	-
	Samoa	10	+2.4	+2.6
	Solomon Islands	2500	+2.4	+2.6
	Tonga	1	+2.4	+2.6
	Vanuatu	88	+2.4	+2.6
	Wallis and Futuna		-	-
Likelihood and confidence			L M	L M

* Production estimates for Cook Islands (southern) and Cook Islands (northern) show the total for both island groups combined.

The following recommendations distinguish between two complementary adaptation pathways: actions within the remit of fisheries agencies, and actions that extend beyond fisheries agencies' jurisdictions and require cooperation with other agencies.

Adaptation Pathway 1: Recommendations within fisheries jurisdiction

Accuracy of catch data to understand opportunities, risks and economic value

The actual catches and economic value of freshwater and estuarine fisheries in the Pacific Islands region may be substantially higher than reported estimates. This means that even a small percentage of increase in catches due to climate change could translate into a much larger absolute gain than projections based on published estimates. Conversely, the economic losses from reduced production in disturbed catchments would also be much greater. Underestimating the economic value of freshwater and estuarine fisheries production could lead PICTs to assign lower priority and fewer resources to their management, thus increasing the risk of mismanagement. It is recommended that each PICT reassess their catch estimates for freshwater and estuarine fisheries to provide greater confidence in the potential benefits and costs associated with climate change. Specific recommendations include:

- *Assess the size of freshwater and estuarine catches*. Published estimates, particularly for Fiji, French Polynesia, New Caledonia, PNG, Solomon Islands and Vanuatu likely underestimate true catches by as much as 1–2 orders of magnitude. This means that both the risks and opportunities presented by climate change are grossly underestimated.
- *Assess the size of the freshwater clam fishery and socioeconomic importance* in New Caledonia, Palau, PNG, Solomon Islands and Vanuatu and reassess data for Fiji. This fishery is far more valuable than is currently recognised. The limited knowledge about the risks and opportunities presented by climate change poses a risk to the people who derive their livelihoods from freshwater clams. The lack of effective management of this resource further elevates the potential risks from threats to the fishery.

Threats to fisheries

- *Strategic investigation of the implications of dams* for freshwater and estuarine fisheries in the Pacific Islands region. Dams are currently being considered as climate change adaptations to mitigate carbon emissions and reduce flood risks in at least two PICTs. However, changes to riverine environments affected by dams will have profound effects on freshwater, estuarine and even coastal fisheries. For example, the environmental and social management plan for the Tina River Hydropower Project in Solomon Islands does not consider fisheries impacts beyond conservation measures for habitats and species[126]. There is an opportunity for fisheries agencies to develop a regional framework and legislative basis for assessing risks to fisheries from development of water resources. This framework could guide subsequent negotiations with external agencies and stakeholders to ensure fisheries are adequately considered in such projects.
- *Strategic investigation of the impacts of land-use change and habitat modification* on freshwater and estuarine fisheries in the Pacific Islands region. There is an opportunity for fisheries agencies to develop a regional framework and legislative basis for assessing risks to fisheries from land-use change and modification of aquatic habitats, to guide subsequent negotiations with external agencies and stakeholders.
- *Review safety of fishing operations during floods* to establish guidelines for fishers, and determine potential safety risks from more extreme rainfall and a wetter climate, as well as possible reductions in the number of fishing days because of rain and flooding.

- *Assess the catch, economic and nutritional value of introduced species* against impacts on native species, in the context of vulnerability to climate change. The objective of this assessment is to support a clear policy on introduced species regarding both food production and conservation of native species.
- *Assess the potential for overfishing to limit projected increases in catch* due to a wetter climate. Specific concerns include the sustainability of freshwater clam fisheries, accessibility of gill nets, species targeted for fish maw in PNG, and the illegal practice of *Derris* poisoning. Fisheries legislation may need to be amended to include fishing for personal consumption and customary use.

Opportunities for freshwater and estuarine fisheries

- *Identify opportunities to derive revenue from selected fisheries*, including eels and iconic recreational fishing species, to realise potential economic benefits from climate change.
- *Review the current fishery for river herring in PNG* to assess actual versus potential yields and explore opportunities for expanding the fishery, considering the impacts of climate change and mining.
- *Assess opportunities to develop specialty products from existing waste streams*, such as fish skin leathers and shell products, to generate additional income that could offset potential losses in production due to climate change in other fisheries.

Cultural heritage

- *Investigate the cultural values of freshwater and estuarine fisheries*, and the potential effects of climate change adaptation on the cultural heritage of fishing communities.

Adaptation Pathway 2: Recommendations beyond fisheries jurisdiction

Leadership in ecosystem-based management and environmental planning

- *PICTs are encouraged to adopt policies that drive improvements in environmental management* to strengthen the resilience of freshwater and estuarine fisheries to climate change, land-use changes, water resource development, and the modification of rivers and lakes. A co-creation, cross-jurisdictional approach to fisheries management is needed, requiring fisheries agencies (including at the executive level) to deepen their understanding of climate change and local ecosystems and fisheries, while also fostering collaboration with local communities.
- *Promote collaboration and leadership in ecosystem management across agencies*. Many PICT governments acknowledge the challenges of managing small, data-limited fisheries and recognise the importance of managing aquatic habitats and surrounding catchments. The increased vulnerability of fisheries in disturbed catchments to climate change underscores the need for fisheries voices to be heard in planning negotiations. Fisheries agencies have an opportunity to adopt stronger leadership in ecosystem management when collaborating with other agencies during planning for economic development. This would ensure that the combined effects of climate change, land-use changes, water resource development, and modification of rivers and lakes do not compromise the sustainability of fisheries that provide food and livelihoods for local communities.

Training in climate change, ecosystem-based management and environmental planning

- *Develop (or review) training modules* focused on ecosystem processes, climate change, fisheries, and traditional practices. These modules should empower fisheries representatives to negotiate effectively with other agencies during the planning of economic development and climate change adaptation initiatives.

Strategic climate change monitoring and data collection

- *Collaborate with other agencies to establish a climate data network* for monitoring freshwater and estuarine habitats, focusing particularly on hydrology and water temperature, to inform future assessments. The costs of establishing and maintaining such a monitoring network could be funded through approvals for development projects, with data from multiple activities stored in a central database. Regional agencies, such as the Pacific Community (SPC) and the Secretariat of the Pacific Regional Environment Programme (SPREP), could play a coordinating role in facilitating networks across multiple PICTs.

- *Establish a satellite mapping program to track changes in land use* across the region, using existing imagery, to support multi-jurisdictional approaches for managing environmental change in freshwater and estuarine fisheries. Such a programme would also support the evaluation of changes in vulnerability to climate change. Linking land-use data to climate data (see previous recommendation) would strengthen fisheries agencies' ability to negotiate during development planning and catchment remediation efforts. Regional agencies, such as SPC and SPREP, could play a coordinating role in facilitating networks across multiple PICTs.


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Appendix 1: Uncertainty, knowledge gaps and future research

Perhaps the most crucial knowledge gap regarding freshwater and estuarine fisheries is the size of catches, and trends and sustainability of the catch. A corollary to this deficiency is the low reliability of the economic value of the fishery[3,27,28]. But where local estimates are available – such as the *kai* fishery in Fiji, the Sepik and Fly region fisheries in Papua New Guinea (PNG), and the undescribed fisheries for *kina* in PNG and freshwater clams elsewhere – catch estimates are much greater than published estimates[3]. The catches, and social and economic values reported in regional assessments grossly underestimate the true catch and its value to people. The discrepancies and uncertainty in catches creates further uncertainty about the sustainability of the fisheries, and their vulnerability to climate change and other threats. Accordingly, the projected positive and negative effects on freshwater and estuarine fisheries are likely to be substantially understated. Targeted research to develop reliable estimates is required to better inform policy decisions on resource conservation, fishery management, food security, and planning for economic development. By undervaluing the catch, fisheries and associated socioeconomic issues cannot receive due consideration in planning for other economic development projects that may have adverse effects on the environment and habitats that support fisheries.

Numerous examples exist across the region of changes in land use that have had negative impacts on freshwater and estuarine fisheries production. With the notable exception of the Ok Tedi mine in PNG, these impacts are not well documented. This assessment has identified that climate change is likely to support small increases in production in freshwater and estuarine fisheries in the Pacific Islands region. However, the loss of ecological resilience in disturbed catchments, and the resulting decline in catches highlights a number of limitations regarding how to promote economic development to improve standards of living, while simultaneously sustaining the very environments and fisheries that provide livelihoods and nutrition for local people. Solutions require detailed research at a systems-level that integrates scientific knowledge with traditional cultural practices on climatic, environmental, social and economic issues. This research will drive a top-down framework to establish priorities for locally effective catchment management strategies to sustain freshwater and estuarine fisheries, management of other threats to fisheries, and biological understanding for production of individual species.

Limited knowledge of several fisheries is a significant impediment to managing them appropriately.

- The wide distribution of the freshwater clam *Batissa violacea* across the Pacific Islands region has led to this species supporting subsistence, artisanal and even commercial fisheries for food, as well as the production of lime. Yet these activities have only been documented for Fiji. As the most widely harvested freshwater species in the region, with the largest catch by weight, documentation of catches from each PICT and uses of the product is required, so that the environmental, social and economic aspects of the value chain can be optimised, including use of the shells as a byproduct.
- The emerging fish maw fishery in remote regions of PNG produces a high-value product, but wastes the fish flesh that could be used for food. A better understanding is required of the context and scale of this multi-species fishery, its potential impacts on individual species, climate change implications, and possible management approaches considering the remote locations where the maw fishery occurs.
- The emerging recreational fishery for Papuan black bass in the New Britain region of PNG is still developing its economic potential and supporting industries. A related research question is the extent to which other recreational fisheries can be developed to provide non-destructive fisheries to support local livelihoods in other PICTs to offset projected declines in other fisheries as a result of climate change.

A persistent dichotomy exists between the nutritional benefits of fisheries for introduced species and the ecological impacts on native species. Introduced fish species have become preferred food species in many PICTs, and are highly valued by people. Eradicating or even controlling populations of introduced species where they have become established in the wild is largely impractical and uneconomical. But research to better understand the threats posed by introduced species would benefit the fisheries agencies responsible for limiting any further spread of these species as well as future introductions.

The small scale of most freshwater and estuarine fisheries, combined with their remote locations in some cases, means that opportunities for active fishery management are typically limited. For this reason, several jurisdictions such as Fiji promote a philosophy of managing freshwater fisheries by promoting sound catchment and environmental management. Habitat management, and habitat improvement is well-established as a fisheries management approach in other regions where local ecology is relatively well-understood. However, recent evidence suggests that these approaches are not as effective as intended, and that greater consideration of the resilience of natural systems is required to successfully manage hydroclimatic, geomorphic, biological or social change, to sustain subsistence, recreational and commercial fisheries[18]. For the Pacific Islands region, targeted research into the resilience of freshwater and estuarine ecosystems to water resource development, land use change and changing climate, and the effectiveness of environmental management to sustain fisheries, is required to allow fisheries management by environmental proxy to be fine-tuned to local systems.

Appendix 2: Freshwater and estuarine fisheries of Pacific Island countries and territories

PICT	Principal species	Main habitats	Methods of capture	Nature of fishery (and use)
Melanesia				
Fiji	*Kai* (freshwater clams)	Lowland rivers and upper estuaries	Hand collection	Commercial, artisanal and subsistence, sold fresh, cooked, marinated, eaten raw
	Freshwater prawns (*Macrobrachium* and *Palaemon*)	Rivers and lakes	Push nets, hand collection, spears, traps	Artisanal, subsistence
	Eels	Lowland rivers and wetlands	Hook-and-line, spears	Limited subsistence
	Tilapia, carp, flagtails	Lowland rivers and lakes	Gill nets, hook-and-line, traps	Limited subsistence
	Gobies	Rivers and lakes	Whitebait traps	Limited subsistence
New Caledonia	Eels, small fish, *Macrobrachium*	Lowland rivers and lakes	Spears, traps, hook-and-line	Subsistence
	Tilapia, carp	Lowland rivers and lakes	Gill nets, hook-and-line, traps	Limited subsistence
	Freshwater clams	Lowland rivers and upper estuaries	Hand collection	Subsistence
PNG	Barramundi	Southern lowland rivers, floodplains, estuaries	Gill nets, traps, hook-and-line	Artisanal, subsistence, recreational
	Papuan black bass, tropical snappers	Southern rivers and estuaries	Hook-and-line	Subsistence, recreational
	Fork-tailed catfish	Lowland rivers, floodplains, estuaries	Gill nets, traps, hook-and-line, spears	Subsistence (dried and smoked)
	River herring	Southern lowland rivers, floodplains	Gill nets, traps, cast nests	Subsistence and commercial (exploratory cannery, fish meal)
	Saratoga	Western lowland rivers, lakes, floodplains	Gill nets, traps, hook-and-line	Illegal aquarium trade, subsistence
	Tilapia, carp	Sepik-Ramu River system, lakes, reservoirs, floodplains	Gill nets, traps, hook-and-line	Artisanal, subsistence (markets and roadside sales)
	Rainbow trout, other mountain species	High elevation rivers and lakes	Gill nets, traps, hook-and-line	Subsistence
	Macrobrachium	Lowland lakes and rivers	Traps, cast nets, seine nets, diving, spears	Commercial, artisanal, subsistence
	Kina (freshwater clams)	Lowland rivers and upper estuaries	Hand collection	Artisanal, subsistence (dried, smoked, powdered lime)

PICT	Principal species	Main habitats	Methods of capture	Nature of fishery (and use)
Solomon Islands	Mullet, flagtails, tropical snappers, eels, gobies and other fish	Lowland rivers and lakes	Gill nets, traps, hook-and-line	Subsistence, artisanal (local sale)
	Whitebait	Lowland rivers and lakes	Basket traps	Subsistence, artisanal (local sale)
	Tilapia	Lowland rivers and lakes	Hook-and-line, diving, gill nets	Subsistence, artisanal (local sale)
	Macrobrachium	Lowland lakes and rivers	Traps, spears	Subsistence, artisanal (local sale)
	Freshwater clams	Lowland rivers and upper estuaries	Hand collection	Subsistence
Vanuatu	Flagtails, grunters, tropical snappers, silver biddies, silver moonfish, scads, mullet, eels, carp, tilapia	Lowland lakes and rivers	Gill nets, traps, hook-and-line	Subsistence, small-scale commercial
	Macrobrachium	Lowland lakes and rivers	Traps, spears	Subsistence
	Freshwater clams	Lowland rivers and upper estuaries	Hand collection	Subsistence
Micronesia				
Federated States of Micronesia	Eels, tilapia, *Macrobrachium*	Rivers and lakes	Hook-and-line, traps, spears	Limited subsistence
Guam	Eels, tilapia, milkfish, *Macrobrachium*	Rivers and stocked lagoons	Hook-and-line, traps, gill nets, spears	Subsistence
Kiribati	Milkfish	Stocked brackish lagoons	Gill nets	Subsistence, commercial (live bait)
Nauru	Tilapia	Ponds	Nets	Subsistence aquaculture
Palau	*Macrobrachium*	Rivers	Traps, spears	Subsistence
Polynesia				
American Samoa	Eels, gobies, flagtails, *Macrobrachium*	Lowland rivers	Traps, nets	Subsistence
Cook Islands	Eels	Lowland rivers	Gaff, hook-and-line	Subsistence
	Tilapia	Brackish lagoons	Nets	Subsistence
	Milkfish	Stocked brackish lagoons	Nets	Subsistence
French Polynesia	Gobies (whitebait)	Lowland rivers and estuaries	Basket traps	Subsistence
	Flagtails, tilapia, eels, *Macrobrachium*	Lowland rivers and estuaries	Traps, hook-and-line	Subsistence
Samoa	Tilapia, eels, *Macrobrachium*	Rivers and lakes	Traps, nets, hand collection	Subsistence, artisanal (local sale)
Tonga	Tilapia, mullet, *Macrobrachium*	Stocked lakes	Traps, nets	Subsistence
Wallis and Futuna	*Macrobrachium*	Rivers	Hand collection	Subsistence

* Additional species that do not support fisheries are not listed.

Source: Gillett and Fong 2023[3]; Jellyman et al. 2016[47]

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