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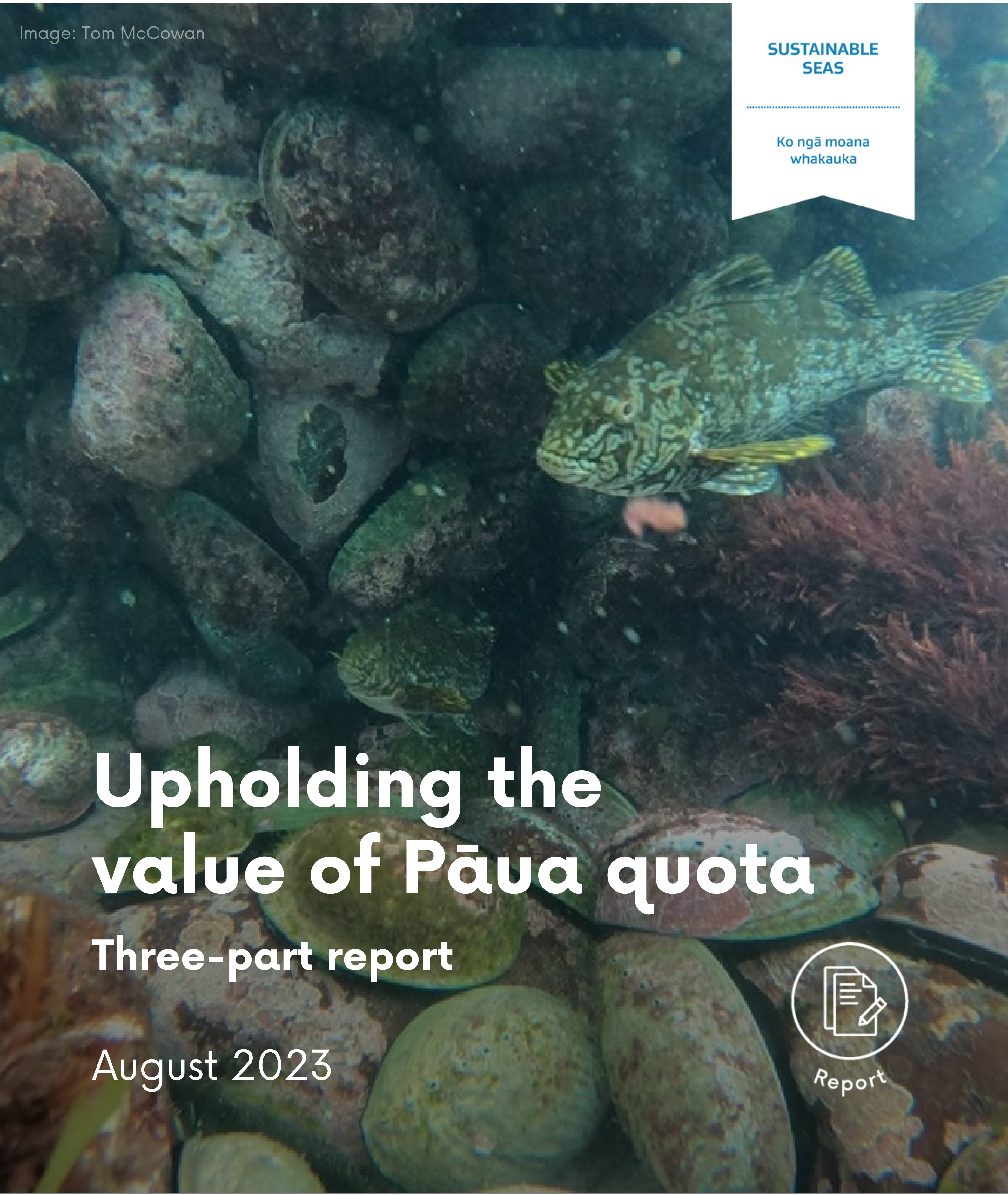

Image: Tom McCowan

SUSTAINABLE SEAS

Ko ngā moana whakauka

Upholding the value of Pāua quota

Three-part report

August 2023

Report

For more information on this project, visit: Upholding the value of Pāua quota

About the Sustainable Seas National Science Challenge

Our vision is for Aotearoa New Zealand to have healthy marine ecosystems that provide value for all New Zealanders. We have 75 research projects that bring together around 250 scientists, social scientists, economists, and experts in mātauranga Māori and policy from across Aotearoa New Zealand. We are one of 11 National Science Challenges, funded by the Ministry of Business, Innovation & Employment.

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Cover image: Abundant pāua (Haliotis iris), within the Pāua 2 (PAU2) commercial fishing zone. Photo credit: Tom McCowan

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The Project Advisory Group

Toa Pomare, Chair, PAU2; Nigel Bradley, Chief Executive Officer, Envirostrat; Clifford Baird (Cliff) Senior Fisheries Analyst, Inshore Fisheries Central and then Duncan Petrie Manager Inshore Fisheries Central, Fisheries New Zealand; Mark Ngata, General Manager Inshore and Tonis Focas, Harvest Team Leader, Moana New Zealand; Rawinia Lewis, Business Manager Ngāti Kahungunu; Ken Houkamau, Chief Executive Officer, Ngāti Porou Fisheries; Tom McClurg Toroa Strategy; Volker Kuntzsch, Chief Executive Officer, Cawthron Institute; Nick Lewis, Associate Professor, Auckland University; Maru Samuels, Chief Executive Officer, Iwi Collective Partnership.

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Outputs

Six outputs have been produced to summarise the findings of the project *Upholding the Value of Pāua Quota* including:

Part 1: Environmental Risks Facing Pāua including Summarised Natural Hazard Risks to Pāua Operations

Part 2: Pāua Fisheries, Management and Legal Considerations

Part 3: Model Description, Financial Perspectives and Pāua Quota Value Risks

Part 4: Summary - Upholding the Value of Pāua Quota

Part 5: The Model (and excel file)

Part 6: Appendices

Acronyms

ACE	Annual Catch Entitlement
AFL	Aotearoa Fisheries Limited
ANZ	ANZ Bank New Zealand Limited
AoG	All of Government
AOP	Annual Operating Plan
AUT	Auckland University of Technology
CARIM	Coastal Acidification: Rates, impacts and management
CBD	Convention on Biodiversity
CCA	Crustose Coralline Algae
CCAA	Climate Change Adaptation Act
CEO	Chief Executive Officer
CPUE	Catch Per Unit Effort
CRD	Climate Related Disclosure
CRE	Climate Reporting Entities
CRIF	Customary, recreational, and illegal fishing
DOC	Department of Conservation
EBM	Ecosystem Based Management
ER	Electronic Reporting
ESG	Environment and Social Governance
ETS	Emissions Trading Scheme
EU	European Union
FMA	Fisheries Management Area
FNZ	Fisheries New Zealand
FTA	Free Trade Agreement
GDP	Growth Domestic Product
GHG	Greenhouse Gas
GPR	Geospatial Positional Reporting
HCR	Harvest Control Rules
HPSFM	Habitats of Particular Significance for Fisheries Management
IQF	Individual Quick-Frozen
ITP	Industry Transformation Plan
LINZ	Land Information New Zealand
MBIE	Ministry of Business, Innovation and Employment
MCR	Māori Crown Relations
MFE	Ministry for the environment
MHS	Minimum Harvest Size
MHW	Marine Heatwave
MLS	Minimum Legal Size
MNZ	Moana New Zealand
MPI	Ministry for Primary Industries
MT	Metric Tonnes
NBEA	Natural and Built Environment Act
NES-PF	National Environmental Standards for Plantation Forestry
NIWA	National Institute of Water and Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
NPS	National Policy Statement
NPV	Net Present Value
NSC	National Science Challenge
NZ	New Zealand
NZBA	Net Zero Banking Alliance
NZCPS	The New Zealand Coastal Policy Statement
NZX	New Zealand Exchange
OECD	Organisation for Economic Co-operation and Development
PAU	Pāua Management Area
PĀUA MAC	Pāua Management Advisory Committees
PIC	Pāua Industry Council
QMA	Quota Management Area
QMS	Quota Management System
QSO	Quota Share Owners
RBNZ	Reserve Bank of New Zealand
RIB	Rigid Inflatable Boat
RMA	Resource Management Act
ROI	Return on Investment
SL	Shell Length
SPA	Strategic Planning Act
SST	Sea Surface Temperature
TAC	Total Allowable Catch
TACC	Total Allowable Commercial Catch
TCFD	Task Force on Climate-Related Financial Disclosures
TFND	Taskforce on Nature-Related Financial Disclosures
TML	Terra Moana Limited
TMOTT	Te Mana o te Taiao
UBA	Underwater Breathing Apparatus
XRB	External Reporting Board

Contents

Part 1: Environmental risks facing pāua and summarised natural hazard risks to pāua operations

McCowan T[1], Cummings V[2], Hewitt J[3], Short K[4], and Craig T[4]

Executive summary

Meeting human seafood security needs is increasingly at risk from environmental change, including climate change. Neither fisheries management, fishing sectors (whether commercial, customary, and recreational), nor seafood business investors and lenders, currently systematically account for environmental change, either as risks or opportunities. The shift to ecosystem-based management of fisheries requires improving understanding of environmental variability and change and of the associated risks and opportunities, so that fishery sectors can account for these, evolve where required, and collaboratively invest in appropriate response strategies.

Pāua is a taonga species and is culturally significant to Māori and many other people. Since the Māori Fisheries Settlement in 1992 Māori have gained ownership of 51% of the commercial pāua fishery quota nationally with Moana New Zealand (MNZ) holding 31.5% of the total on behalf of all iwi. This report aims to document some of the real world commercial pāua sector challenges related to environmental change, by working in place. The report is focused on the east coast North Island Pāua Fishery (known as PAU2). The region has experienced recent marine heatwave events and water temperatures mean that pāua growth rates and size are smaller in its northern regions than in more southerly latitudes. In the PAU2 fishery Māori collectively own 71.9% with MNZ holding 53.9% of that total and the area encompasses various iwi rohe moana (tribal marine areas). It is also an important customary fishery to Māori as well as a popular recreational fishery for many people.

This report is one of three from the Sustainable Seas Science Challenge Risk and Uncertainty Project 3.3: Upholding the value of Pāua Quota. The project has explored how to better understand, assess, and factor in the key environmental risks of climate change and sediments (exacerbated by climate change) to the fishery and subsequent pāua quota values to inform fisheries management, fishery investors and financiers, and the development of response strategies by all.

This Part 1 report summarises the environmental risks to pāua, and to the land-based infrastructure that supports the fishery. The environmental risks facing pāua, both now and in the future, include ocean warming and ocean acidification related to climate change, and sedimentation which, when combined with varying food quantity and quality, can affect pāua survivorship, growth and reproduction, and disease susceptibility. Warming seas and sediment inputs (settled and in suspension) can also negatively impact survival of the major pāua food sources and settlement surfaces, macroalgae (e.g., through altering nutrient availability). The magnitude of the impacts will vary with pāua life stage, time of year, and location around Aotearoa New Zealand, adding complexity to the challenge of predicting and modelling future pāua population success. Risks to infrastructure mainly come from sea level rise and increased frequency of intense rainfall and wind events impacting on roads. Again, these impacts are highly localised.

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[4] Partner, Terra Moana Ltd

Introduction

Uncertainty is the only certainty especially in the case of highly dynamic marine environments that are subject to multiple environmental stressors (Hunsicker, 2016). The marine environment is facing increasing environmental change including heat waves, pollution (including from microplastics), sedimentation, ocean acidification, sea level rise, and other climate change caused perturbations (Gerrard, 2021; Ministry for the Environment & Stats NZ, 2019). Uncertainty in the response of a system to stress, and potentially unknown synergistic or antagonistic effects, therefore, increases risk to its inhabitants and to the whole system. There is an increasing awareness of the many complex cumulative effects that occur between multiple stressors, influencing the ways we manage marine ecosystems and the species therein (Rullens *et al*., 2022). These cumulative effects pose risks to seafood businesses, and uncertainty arises in the when, where, and severity of impacts, and in any interaction outcomes (Taylor *et al*., 2015).

Pāua biology

Pāua are sedentary marine gastropods that inhabit rocky reefs around New Zealand's coast from the shallow sub-tidal zone out to 20 meters depth, most commonly in 1-5 meters (Poore, 1972a; Schiel & Breen, 1991). In a fisheries context, being sedentary means that they cannot move far. This characteristic can make them more susceptible to changing environmental stressors (and especially localised events) than species that are able to move large distances (e.g., some finfish species that move seasonally in response to water temperature), thus their state can reflect the impacts of climate change on a low-tolerance marine species.

Life cycle

Pāua are broadcast spawners, meaning gametes from both sexes are released synchronously into the water column where fertilisation occurs (Hooker & Creese, 1995). This 'sweepstake' reproductive strategy relies on the release of millions of gametes with the potential return of only a few surviving recruits. The timing and magnitude of spawning events are not well understood, but spawning is thought to be initiated by storm events or changes in temperature (Poore, 1972b). Spawning is anecdotally observed in Spring in the Marlborough Sounds and has been observed in Autumn in Kaikoura (Sainsbury, 1982; Wilson & Schiel, 1995). Presumably this variability and uncertainty in timing extends to other areas.

Figure 1: Tagged Pāua for growth information. Source: Tom McCowan

Pāua are mature at approximately 70-80 mm shell length (SL) depending on the region, with reproductive output (number of eggs) increasing significantly with length (McShane & Naylor, 1995; Naylor *et al.*, 2006). Length at maturity (as well as growth information (Figure 1)) is therefore a relevant consideration in the assessment of minimum legal size (MLS) or minimum harvest size (MHS). During spawning, the likelihood of successful fertilisation increases with proximity of mature adults of the opposite sex (Babcock & Keesing, 1999). Pāua are thought to form characteristic 'spawning aggregations' to enhance their reproductive potential. After fertilization (Figure), free swimming larvae persist in the water column for 10-14 days, a period which allows for a reasonable degree of larval dispersal (Stephens *et al.*, 2006). After this, they develop into veliger larvae which are then able to settle on appropriate substrates, of which crustose coralline algae (CCA) is preferred (Tong

& Moss, 1992). It is generally thought that larvae settle close to their parent population, exhibiting local-scale recruitment.

After settlement, veliger larvae develop into juvenile pāua that graze on microalgae films in cobble and boulder habitats in the shallow subtidal (Kawamura *et al.*, 1998). Pāua remain in these cryptic habitats until approximately 80-100 mm SL which roughly corresponds with the length at maturity. At this size they emerge into more open boulder and crevice habitats (McShane & Naylor, 1992). Adult pāua are 'drift feeders' meaning they feed primarily on drifting seaweed fragments (as opposed to attached or living seaweeds) (Allen *et al.*, 2006).

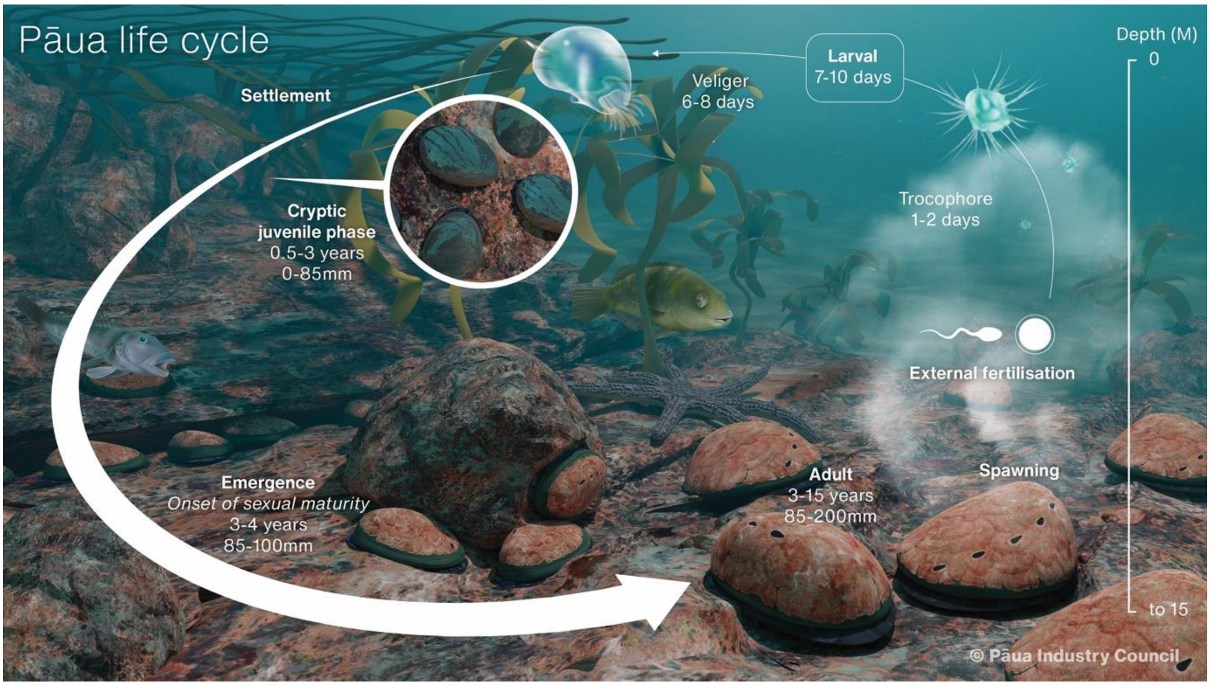

Figure 2: Pāua Life Cycle. Pāua Industry Council Ltd.

Growth

Pāua, like other abalone species, are known to exhibit significant variability in growth rates across small spatial scales. Sea temperature (or latitude) is the primary influence on growth rate (Naylor *et al.*, 2006) with pāua growing faster and getting to larger sizes in the cooler waters of the south compared to the warmer waters of the north. However, other factors such as wave exposure, food availability and habitat type can also influence growth, meaning that fast and slow growing populations can be observed in proximity or within the same locality (e.g., on an exposed headland versus a sheltered bay) (McShane & Naylor, 1995). Slow-growing populations in otherwise fast-growing areas are often referred to as 'stunted' pāua, and these individuals seldom reach the MLS. As introduced above regarding length at maturity, growth rates are also an important consideration in the setting of MLS and MHS (discussed in more detail below under Pāua Fishery).

Environmental risks

Being a relatively sedentary coastal rocky shore species, pāua is subject to disturbance from issues associated with poor land-use practices. Key amongst these are increased sediment inputs that settle out and smother pāua kelp habitat, food sources and settlement surfaces, or remain in suspension (elevating suspended sediment concentrations/turbidity) inhibiting kelp photosynthesis as well as pāua respiration and feeding. Ocean warming and acidification also affect pāua and their associated ecosystems and thus there is heightened risk from the cumulative effects of all such stressors (Cummings *et al.*, 2021; Rullens *et al.*, 2022).

Examples of the environmental factors causing such disturbance are provided below and while some factors appear to be direct threats to pāua today (e.g., sediments, pollution), others are directly associated with climate change and are expected to intensify in future (e.g., Cummings *et al*., 2021; Ministry for the Environment & Stats NZ, 2019). The most concerning of these factors for pāua are sediments (either as seafloor deposits or suspended in the water column), warming sea temperatures, marine heat waves and ocean acidification. In addition other risks that are also likely to pose threats to pāua and their habitats are the increased frequency and intensity of extreme weather events (leading to higher rates of coastal erosion), which can also be combined with sea level rise and coastal 'squeeze' (where sea level rise shifts intertidal habitats shoreward), as well as rocky areas potentially being reduced as the intertidal platforms disappear under water leaving cliffs (Kettles & Bell, 2015),

Coastal erosion and sediment inputs to coastal ecosystems

New Zealand is already experiencing changes in the frequency and severity of rainfall and storm events and more frequent input of freshwater and sediments to coastal regions are anticipated (Cummings et al., 2021), the latter due to increased coastal erosion or flood events. The east coasts of both the North and South islands have higher sensitivities to climate driven coastal erosion than their west coasts, because of their different geographies, geologies, and coastal environmental conditions.

Sediments affect coastal ecosystems in two main ways: increased sedimentation and increased concentrations of fine suspended sediments which can both directly and indirectly impact coastal ecosystems (Thrush *et al.*, 2004) including important pāua habitats (Figure 3). Land use practices (e.g., agriculture, forestry) are an important contributing factor to coastal sediment inputs (Thrush *et al.*, 2004).

Figure 3: Effects of sediment and sand movement of Pāua.

Sediments in New Zealand have been identified as a potential threat to pāua and pāua habitats. These stressors affect different parts of the pāua life cycle, as well as their preferred crustose coralline (CCA) and macroalgae habitats (e.g., *Macrocystis pyrifera*), and food sources.

Pāua larval settlement can be disrupted when sediments cover CCA habitat which is the preferred settlement substrate for pāua by preventing adherence and disrupting settlement cues (Philips & Shima, 2006). Newly settled recruits can also become smothered by sediments (Philips & Shima, 2006) and elevated suspended sediment concentrations can increase mortality of larval pāua in the water column (Chew *et al.*, 2013).

Juvenile righting behaviour (Pirker & Schiel, 1993) can be disrupted by sediments deposited on the seafloor, making it more difficult for pāua to reattach to rocks after they have been dislodged (Chew *et al.*, 2013). Sediment deposition in cryptic juvenile cobble/boulder habitat can smother pāua (Tony Craig and Pāua Industry Council (PIC), *pers. Comm*.), or cause them to emerge from their refuges, making them more susceptible to predation (Chew *et al.*, 2013). Sediment deposits can also smother adult pāua, and sediment covered rocks make it difficult for adults to remain attached to rocks (Pāua Industry Council (PIC), *pers. Comm*.).

Catchment-derived sediments can also have contaminants associated with them (e.g., bacteria, heavy metals). The impacts of these on pāua is currently unknown.

Macroalgae are a key pāua food source and a major component of some pāua ecosystems. Kelp (e.g., *Macrocystis pyrifera*) grows to a huge biomass in the summer months and in winter it is torn by storms, becoming an important food source for pāua. Kelp has a wave buffering effect and can also be a habitat for larval/juvenile pāua which can settle on the fronds. Elevated sedimentation can smother *Macrocystis* (and other seaweeds) and any associated new pāua recruits. Sediments can also smother macroalgae settlement substrates (Devinney & Volse, 1978) and abrade and weaken algae fronds (Geange *et al.*, 2004). Fine sediments settling on fronds also restrict nutrient and respiratory exchange (Pirker *et al*., 2002).

Increased concentrations of suspended fine sediments (turbidity) can limit water column light levels, affecting macroalgae photosynthesis and growth (Phillips & Shima, 2006). Negative effects on macroalgae have already been observed from suspended sediments in the USA and in Australia, especially in combination with warming sea temperatures (e.g., Rogers-Bennett, 2007; Rogers-Bennett *et al.*, 2010).

Storm events

As well as the coastal erosion and sediment inputs discussed above, storms can temporarily 'freshen' the seawater as well as cause direct physical disturbance to the seafloor via large swells. High rainfall associated with storms increases freshwater inputs into the marine environment, especially via discharge from swollen river and stream mouths (e.g., Steichen *et al.*, 2020). This creates low salinity pulses that can persist in the coastal zone for a short time (as the freshwater 'floats' on the surface of the seawater), and negatively impact species such as pāua (e.g., Davis *et al*., 2022).

Large sea swells driven by the storm events can also physically disturb the seafloor, moving sediments, cobbles, and rocks around, thereby disturbing pāua habitats and dislodgement. In boulder-silt habitats, burial by localised shifts in sand during storms can be a major cause of death of adult pāua (Sainsbury, 1982).

Ocean warming

Over the past 40 years the oceans around New Zealand have warmed by 0.016^{o}C per year on average, or 0.2-0.3^{o}C per decade. The magnitude of warming varies with location. There are significant warming trends around the South Island and on the East Coast of the North Island, including the Wairarapa coast where PAU2 operates (Figure 4).

Sea surface temperature warming of 2.5-3.0°C is projected by 2100 for the ocean around most of New Zealand, with the largest warming anomalies (>3°C) in the Tasman Sea and Subantarctic water south of the Chatham Rise (Law *et al.*, 2018a). This has implications for ecosystems beyond pāua, and especially for kelp which prefer cooler water. Furthermore, disease may be exacerbated both by warmer waters spreading and increasing diseases (e.g., Burge *et al*., 2013) and through weakening the ability of pāua to fight disease. Such warm water events also affect overall ecosystem productivity.

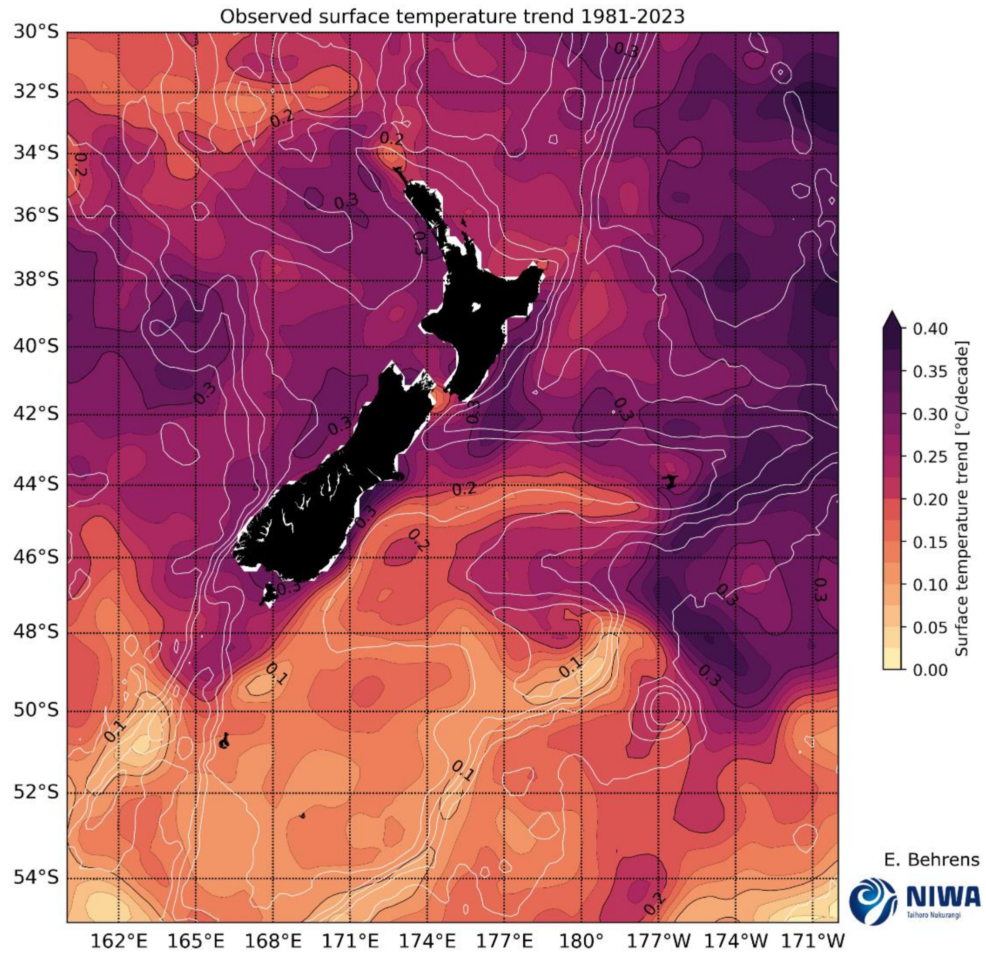

Figure 4: The linear trend in Sea Surface Temperature (SST) from 1981 to 2023, calculated from the NOAA OI SST V2 High Resolution Dataset (Banzon et al. 2016; Reynolds et al. 2007), by Erik Behrens (NIWA). Contour intervals are 0.05°C/decade.

Marine heatwaves

A marine heatwave (MHW) is defined as a prolonged anomalously warm water event, where temperatures exceed a seasonally varying threshold (usually the 90th percentile) for at least five consecutive days (Hobday *et al.*, 2016). MHWs are a growing threat and concern to marine ecosystems and species and are anticipated to increase in frequency (especially around the North Island) and in intensity (especially around the South Island) (Erik Behrens, *pers. Comm*.), and will potentially impact pāua populations. A MWH in Tasmanian brought with it the introduction and persistence of the sea urchin *Centrostephanus coronatus,* which have been shown to negatively impact resident abalone populations through competition for food and habitat (e.g., Strain *et al.*, 2013).

PAU2 has experienced recent marine heatwave events (ocean modelling of the Wairarapa coast from the Moana Project (Figure 5).

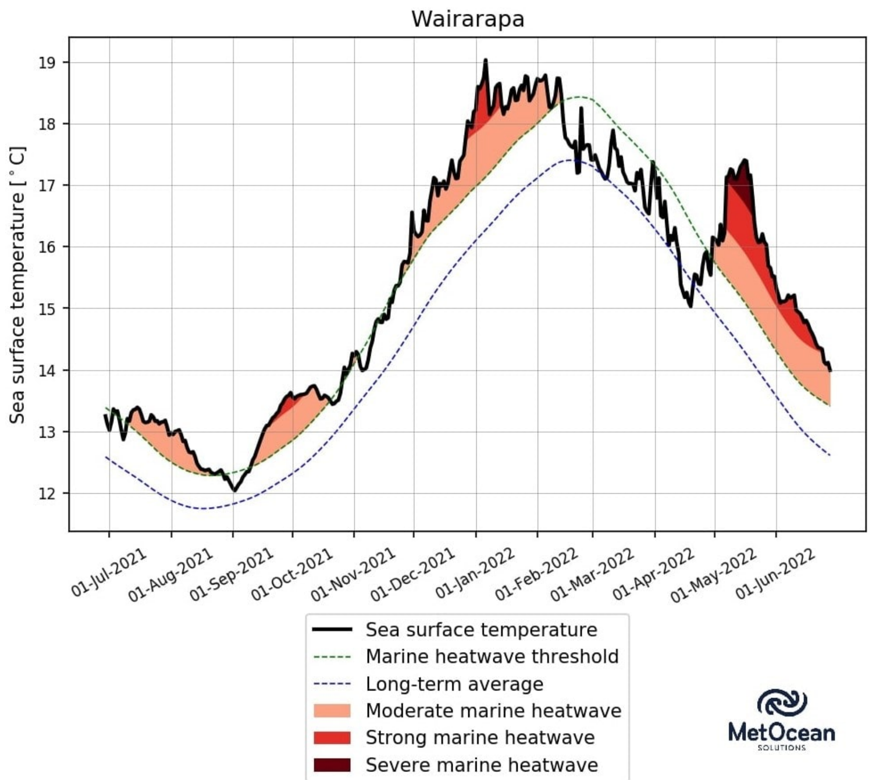

Figure 5: Sea surface temperatures in Wairarapa from July 2021 until June 2022: The dark red colour represents severe marine heatwaves; red is strong heatwaves and light red moderate

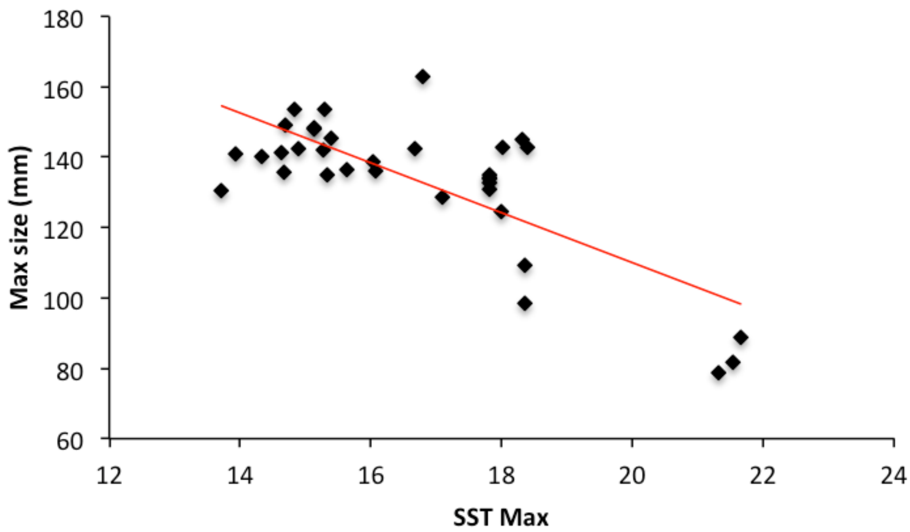

Figure 6: Relationship between maximum sea surface temperature (SST Max) and maximum Pāua size (data taken from Naylor et al 2006).

The influence of sea temperature on pāua biology

Pāua growth and reproduction are influenced by sea temperatures. In particular, pāua attain larger maximum size in the cooler water regions of New Zealand (Figure 6).

There have been several field surveys and laboratory studies that have investigated the effect of temperature on pāua. At warmer temperatures, larvae develop faster, and juveniles grow more rapidly (Tong *et al.*, 1980, 1982, 1992). For larger juveniles, the optimal temperature for maximum growth rate varies with age/size (Searle *et al.*, 2006). For 10- and 30-mm SL pāua, the optimal temperature was 22°C, but this reduced to 18°C for 60 mm pāua. This study also showed a decline in thermal tolerance in juveniles with size (Searle *et al.*, 2006). For adults, size at maturity is smaller with increasing temperature, and in areas where the maximum SST is > ~17°C (Naylor *et al.*, 2006). Adults grow fastest in areas with lower average monthly max SST, and slower in areas with high average monthly max SST (Naylor *et al.*, 2006). Furthermore, warming seas can negatively impact survival of the major pāua macroalgae food source (e.g., through altering nutrient availability, see Ignacio Vilchis *et al.*, 2005).

The PAU2 QMA is a region with water temperatures ranging from warmer waters in the north to colder in the south. These limit pāua growth rates and size whereby they are smaller in its northern regions than at more southerly latitudes (Naylor *et al.*, 2006).

Ocean acidification

The NIWA led CARIM (Coastal acidification: rates, impacts, and management) project conducted several relevant studies (Law *et al.*, 2018b). The CARIM experiments explored predicted pH concentrations for 2050 and at the end of the century and found that larval survival and development was severely affected under reduced seawater pH (Cummings *et al.*, unpublished. Data). Other studies on the *Haliotis* genus have reported similar effects of ocean acidification on larval survival and development (Byrne *et al.*, 2011; Crim *et al.*, 2011). Survival of larvae settling on CCA was reduced (Espinel-Velasco *et al.*, 2020).

For juvenile pāua, survival was sometimes affected (Cunningham *et al*., 2016; Cummings *et al*., 2019), and their growth was reduced in summer, but not winter, temperatures (Cunningham *et al.*, 2016). Dissolution of the juvenile shell surface was evident (Cunningham *et al.*, 2016; Cummings *et al.*, 2019), and newly developed shell was thinner (Cummings *et al.*, 2019). Survival of adults exposed to low pH for 16 months was not affected, but spawning success was low (Cummings *pers. comm.*).

Regional quota management areas and potential environmental risks

Figure 7: East Coast South Island river mouth after a storm. Photo credit Tony Craig.

In this section we briefly describe the pāua management areas and the potential environmental risks they face. Table 1 summarises catch and industry management initiatives implemented in each QMA as well as potential environmental stressors (Figure 7). The following provides some examples of recently suspected and observed environmental events that have had apparent effects on Pāua fisheries across the QMAs (PIC, *pers. obs*.).

Kaikōura earthquake and resulting sedimentation – PAU3:

Aside from the severe impacts of the earthquake uplift itself, the Kaikōura earthquake caused slips and landslides resulting in increased marine sedimentation. When combined with coastal uplift this resulted in a shift in local hydrodynamic regimes and high sediment deposition that was observed in some bays with high pāua abundance. This caused pāua in some areas to move from their habitats into exposed areas to avoid being smothered.

Marine heatwave events – PAU4:

In 2018 there was a marine heatwave event recorded in the Chatham Islands which was anecdotally linked to the loss of macroalgae as well as poor pāua health. This catalysed a joint project between PIC and Auckland University of Technology (AUT) to monitor physiology from different populations in response to potential environmental stressors.

Unexplained pāua mortalities – PAU7:

Periodically unexplained pāua mortalities are observed by PAU7 harvesters. Samples are usually collected and tested for disease and heavy metal concentrations; however, nothing significant has been detected. It has been loosely hypothesised that these events may be triggered by sudden changes in water temperature.

Table 1: Characterising New Zealand Commercial Pāua Fisheries (Developed by the Pāua Industry Council)

QMA	PAU2 (Wairarapa)	PAU3A (Kaikoura)	PAU3B (Canterbury)	PAU4 (Chatham Islands)	PAU5A (Fiordland)	PAU5B (Stewart Island)	PAU5D (Otago)	PAU7 (Marlborough)
TACC **Recreational** **Customary**[5]	121t 83t 1-10t	23t 5t 7.5t	46t 9t 15t	326.5 t (195t) 3t 3t	148t (105t) Unknown Unknown	90t 6t 6t	89t (56t) 22t 3t	93t (82t) 15t 15t
Industry Management	• Variable MHS • Catch spreading	• Fisheries plan • Variable MHS • Catch spreading • Reseeding	• Fisheries plan • Variable MHS • Catch spreading	• Fisheries plan • Variable MHS • Catch spreading • Shelving • Translocation	• Fisheries plan • Variable MHS • Shelving • Translocation • Harvest control rule	• Fisheries plan • Variable MHS • Translocation • Harvest control rule	• Fisheries plan • Variable MHS • Shelving • Harvest control rule	• Fisheries plan • Variable MHS • Shelving • Translocation • Reseeding • Harvest control rule
Potential environmental stressors[6]	• Water temperature • Marine heatwaves • Sedimentation • Storm events	• 2016 earthquake • Sedimentation • Water temperature?	• Sedimentation • Water temperature?	• Water temperature • Marine heatwaves • Sedimentation • Storm events • Macroalgae loss	• Water temperature • Marine heatwaves	• Water temperature • Marine heatwaves	• Water temperature • Marine heatwaves • Sedimentation • Storm events	• Water temperature • Marine heatwaves • Sedimentation • Storm events • Macroalgal loss

[5] The recreational and customary figures are 'allowances', except for PAU2 which is an estimate.
[6] Anecdotally reported or suspected.

D'Urville and Northern Faces pāua stock status – PAU7:

For several years there has been concern about the status of pāua stock around D'Urville Island and the Northern Faces in PAU7. There is a reported decrease in abundance in areas that were of historic importance to the fishery and a suspected decrease in growth rates. It is hypothesised that this is linked to increasing warm water events with changing weather patterns. There are also some anecdotal reports of decreases in macroalgal and pāua abundance in proximate regions within the Marlborough Sounds, which could conceivably be linked to changes in temperature as well as sedimentation.

Storm induced mortalities – PAU3 and PAU5D:

Occasionally there are reports of large numbers of pāua washed up on beaches following large storm swells. In recent years this has occurred at Maungamanu (PAU3) and Kaka Point (PAU5D). This could be due to a combination of factors including decreased salinity, sediment deposition affecting adherence, and also to loss of adherence after persistent swells.

The Wairarapa Case Study - Pāua Fishery (PAU2)

Although the wider PAU2 fishery is from Taranaki to East Cape, the commercial fishery is only from Turakirae Head (Western side of Palliser Bay) to Castle Point (the Wairarapa area) (Figure). PAU2 has been chosen for this study given:

- The TACC has remained unchanged since 1986 at 121.88MT per annum, i.e., the fishery is stable.
- There are large parts of the QMA that are closed to commercial fishing therefore providing good comparative opportunities of fish versus unfished areas.
- The East Coast/Poverty Bay and Taranaki Region's pāua are well known for smaller size at maturity with the assumption being that this is because of the warmer temperatures in these areas.
- The Poverty Bay/East Coast to Wairarapa has experienced extreme storm and marine heatwave events.
- The PAU2 Association is progressive and has good relationships with iwi in the area.
- The temperature gradient reflects the latitudinal gradient.

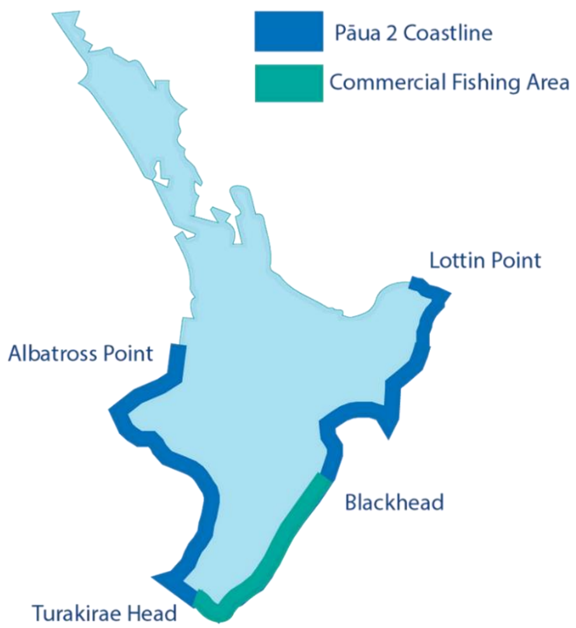

Figure 8: The PAU2 Fishery Area. Source: Terra Moana

That the PAU2 TACC has been stable at 121MT since the fishery was introduced into the QMS in 1986 is unique amongst other pāua fisheries that have had many management measures. This is largely a result of:

i. the TACC was initially set correctly, and
ii. the catch per unit effort (CPUE), the most powerful indicator of fishery performance, has remained stable since 1986.

Due to the influence of water temperature on pāua growth and the latitudinal positioning of the PAU2 fishery, there is great demographic variability across the PAU2 pāua populations. For example, an MHS of 128 mm is implemented from approximately the Honeycomb Rocks to Cape Palliser.

The PAU2 geographic location means it may be subject to the effects of warming water. There is also evidence from the marine heatwaves forecasting component of the Moana Project that the PAU2 fishery has been subject to recent marine heatwaves (the 2021/22 MHW). Much of the PAU2 coastline is proximate to land uses (e.g., plantation forestry and dryland farming) that potentially promote higher rates of sedimentation (Ministry for the Environment and Stats NZ, 2019).

Pāua climate change vulnerability assessment

Vonda Cummings (NIWA)

A Fisheries New Zealand (FNZ) project examined the potential implications of climate change for New Zealand fisheries. This study assessed what has changed and what might be expected to change in New Zealand's coastal and oceanic waters, and our understanding of what the responses of fisheries species may be, including pāua.

For pāua, it provided the opportunity to assess their vulnerability to climate change and other environmental challenges. It also allowed an initial exploration of adaptation strategies and management options to mitigate the effects of projected environmental changes.

For the vulnerability review, the PIC, other scientists, and fisheries managers were involved in a complex evaluation process. Proven methodology, in the form of a comprehensively scored questionnaire that had been designed and used by NOAA and EcoAdapt Ltd (Hare *et al.*, 2016; Hansen *et al*., 2017), was used. This method enables species understanding to be related to their climate change vulnerability, the conditions that are expected, impacts on species and their likelihood to be able to adapt to those changes. The (un)certainly of this knowledge was also incorporated in the resulting vulnerability score.

Pāua are considered to be very vulnerable to climate change and environmental stressors (Cummings et al. 2021, Figure 9 and Appendix 1.)

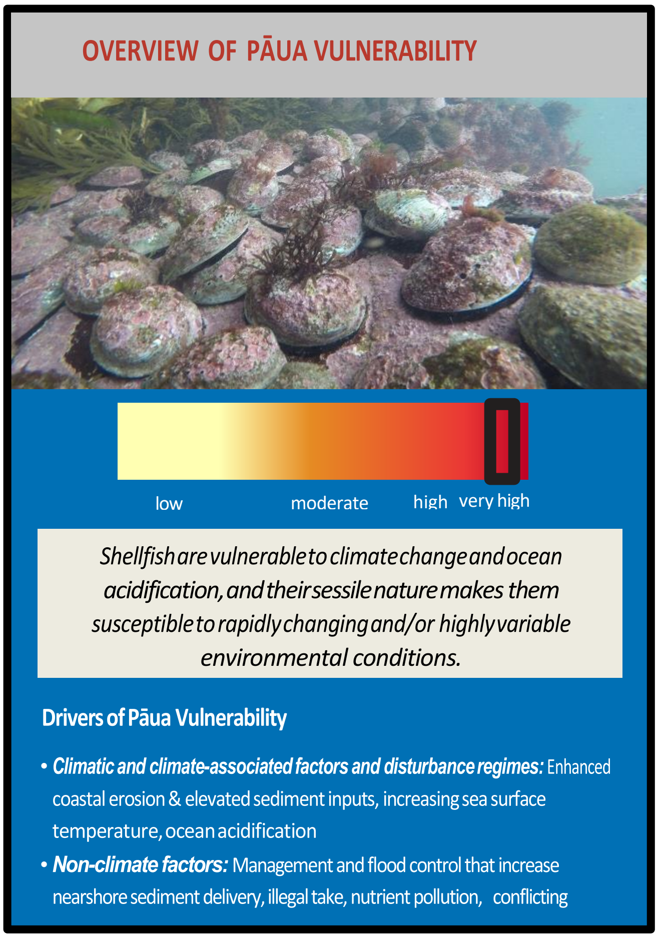

Figure 9. Summary Overview of Pāua Vulnerability excerpted from Appendix 1.

Impacts of natural hazards on key infrastructure in the PAU2 fishery

Terra Moana Limited

Pāua harvest areas along with some seafood holding and processing facilities are predominantly located in regional coastal New Zealand and therefore depend on rural infrastructure for access.

This infrastructure includes roads, boat ramps, wharves and bridges that are all at-risk from climate related hazard events including sea-level rise, increasingly severe and frequent storms, and associated flooding, as well as earthquakes. Furthermore, roads, electricity and gas, railways, fuel and water supply, wastewater and stormwater, broadband cabling, and ports and airports, are also infrastructure and referred to as lifelines[7] in the emergency management arena.

This section of the project sought to investigate the question of accessibility to the pāua fishery resource in relation to harvesting and transporting pāua, and specifically sought to understand the risks faced by the PAU2 fishery in using coastal sector infrastructure.

Three approaches were used to understand these risks:
1. A desktop review of natural hazards in the Wairarapa – history, trends, and current occurrences.
2. A survey of the PAU2 divers and dive managers seeking their anecdotal observations of climate events and their effects on pāua operations.
3. The Current Pāua Fisheries Legal and Policy Context reviews key legislation with respect to environmental hazards.

Natural hazards to lifelines

The Wairarapa has a lifelines association (Wairarapa Engineering Lifelines Association (WELA) which was formed in 1996 following a public meeting to discuss the risks to engineering lifelines from natural hazards, the likely impact on the local community and what was being achieved by other study groups in New Zealand. Key lifeline infrastructure relevant to pāua divers for harvesting include:

- road and rail
- petrol and diesel
- telecommunications

This section summarises material (online research and review reports, media, and public scientific information databases), about natural hazard and climate events that have occurred in the Wairarapa (see Figure 10). Fishers' observations are given in the next section.

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[7] Lifeline utilities is a term used in the Civil Defence and Emergency Management Act 2002 to describe organisations that provide essential infrastructure to the community. The Act says that lifeline utilities must "function at the fullest possible extent, even though this may be at a reduced level, during and after an emergency".

Figure 10: Natural hazards affecting the Wairarapa

With respect to earthquakes, the Wairarapa has some of the most highly exposed areas to tsunami in New Zealand, due to proximity to a significant local earthquake source, the Hikurangi subduction zone (Figure). This is potentially the largest source of earthquake and tsunami hazard in New Zealand[8].

The Wairarapa could potentially be cut off from the rest of New Zealand "for a number of weeks" after a major storm or earthquake[9].

When cyclone Gabrielle struck in Feb 2023, villages in the eastern Wairarapa were cut off with major arterial routes damaged by slips and flooding (Figure).[10]

Much of the eastern and coastal Wairarapa hill country is prone to slumps and shallow soil slips. Every four to twelve years the area suffers a storm severe enough to cause widespread landslides, with smaller slips evident regularly[11].

[8] https://www.gns.cri.nz/our-science/land-and-marine-geoscience/our-plate-boundary/hikurangi-subduction-zone/
[9] https://www.stuff.co.nz/environment/129325264/large-parts-of-wairarapa-would-be-cut-off-in-a-major-natural-event
[10] https://www.stuff.co.nz/national/131232054/villages-in-wairarapa-still-cut-off-as-cyclone-gabrielle-moves-away
[11] http://archive.gw.govt.nz/assets/importedpdfs/2511_MeasuringUpCh8lo_s4732.pdf

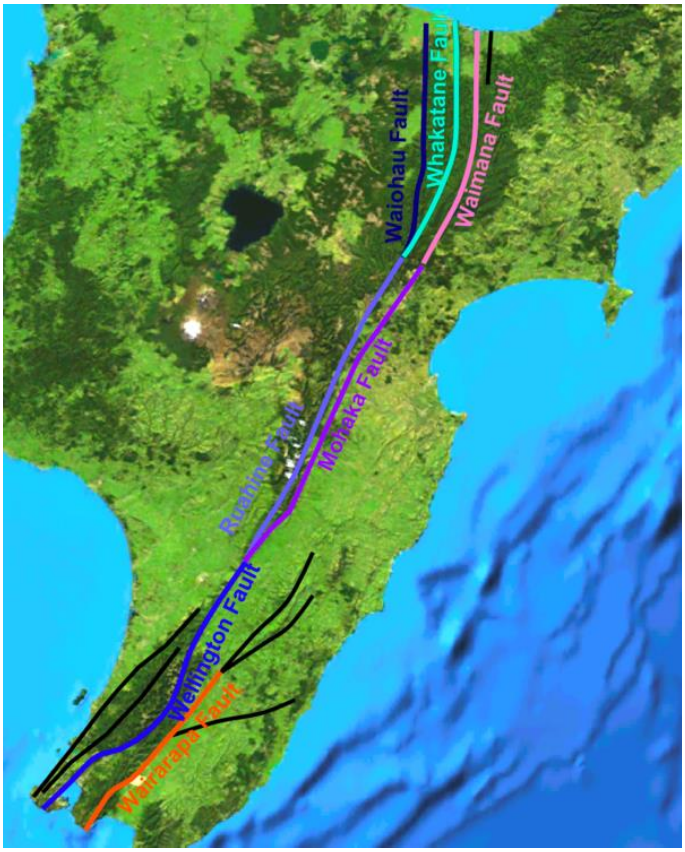

Figure 11: Faultlines North Island New Zealand. Source: https://en.wikipedia.org/wiki/Wairarapa_Fault

Figure 12: Turners Bay Cape Palliser. Source: Nat Davey (Pāua diver)

With respect to coastal sinking the PAU2 area is predicted to be the most severely impacted in New Zealand with sea level rise is expected at Cape Palliser and along the Tora coastline. The two coastal settlements within the PAU2 area (Masterton District) of Castlepoint and Riversdale are among those where rapid sea level rise is being documented. The New Zealand SeaRise website (Figure) shows that Castlepoint sea level rise is 3.77mm a year, while Riversdale is at 4.67mm.[12]

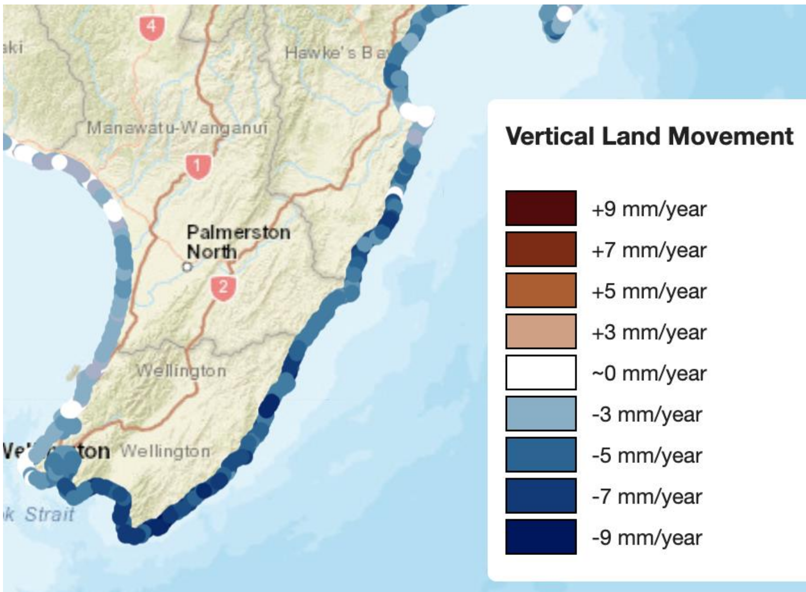

Figure 13: Sea level rises in the Wairarapa. source: https://searise.takiwa.co/map/6233f47872b8190018373db9/embed

Our review revealed an area susceptible to extreme weather events that can impact the accessibility of the PAU2 fishery. Notable events that can jeopardise key lifeline infrastructure are tsunami, flooding, slips and landslides, sea-level rise, earthquakes, and fires. Overall, the Wairarapa Coastline is somewhat unique in New Zealand as it is suffering from three key factors simultaneously:

1. It is sinking quicker than anywhere else in NZ because it is situated directly above the moving tectonic plates,
2. Sea level rise is evident due to climate change, and,
3. It has an expected highest level of potential earthquake magnitude likely in a major earthquake event.

Diver observations of the natural hazards and their impacts

The survey

A survey was developed by Terra Moana Ltd and reviewed by Dr Karen Fisher, Sustainable Seas Science. With the help of the PAU2 Executive, pāua divers operating in the PAU2 Management Area were encouraged to participate in the survey. PAU2 quota owners were also contacted to encourage their divers to participate. An online survey was sent out via email on the 21st Oct with a 7th Nov closing date. With only one response received the survey was extended to the 5th Dec 2022.

As the surveyor was well known to the divers, divers were also offered a telephone interview if preferred. Eight online (all) responses were received from across the 11 dive teams and 32 divers

[12] https://www.stuff.co.nz/environment/130796442/how-wairarapa-is-preparing-for-sinking-shorelines-and-rising-seas

in the fishery (25%). Most participants have more than 20 years' experience in the fishery and there was a mix of divers and dive team managers, who also dive.

Fishery context

As noted in Table 2 there are 10 fishery entry points used, and these are accessed via 8 major roads (Table 3) that are reported by the divers as being in poor to good condition.

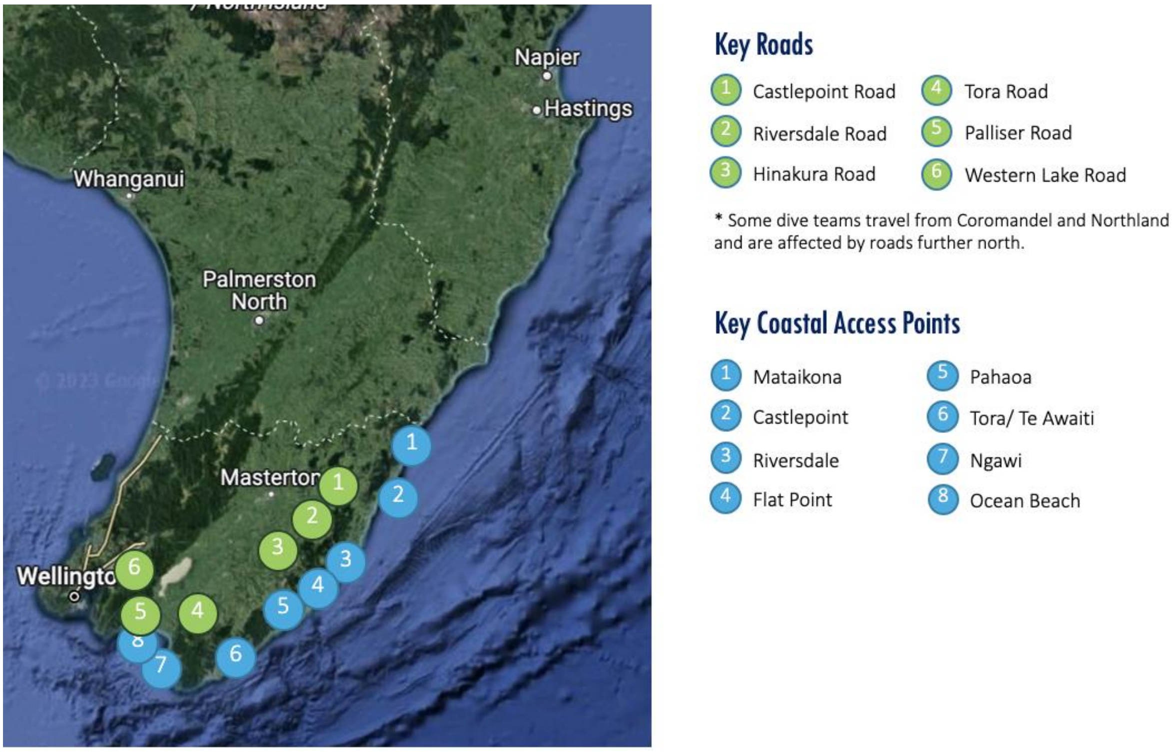

Figure 14: List of key roads and coastal access points in the PAU2 fishery

Table 2: Individual diver's identified PAU2 fishery coastal entry points

PAU2 Fishery Coastal Entry Points	**Usage Frequency**	**Fishing Method**
Pahahoa, Ngawi, Mataikona	Monthly	Boat Launch
Point Howard Wharf, Ocean Beach, Ngawi, Tora, Castlepoint, Mataikona	Yearly	Boat Launch
Ocean beach/Ngawi/Pahaoa/Riversdale/Mataikona	Weekly	Boat Launch
Tora beach	Weekly	Boat Launch
Mataikona, Riversdale, Flat Point, Te Awaite/Tora and Ngawi.	Weekly	Boat Launch
Tora	Yearly	Boat Launch
Castlepoint	Monthly	Boat Launch
Tora	Monthly	Boat Launch
Ngawi	Monthly	Boat Launch
Ocean beach	Monthly	Boat Launch

Table 3: Individual diver's identified PAU2 fishery access roads

PAU2 Fishery Access Roads	Usage Frequency	Road condition
Hinakura Rd, Cape Palliser, Rd Castlepoint Rd	Monthly	Poor
Palliser Rd	Yearly	Average
Tora Rd	Yearly	Average
Ocean beach	Yearly	Good
Western Lake Rd, Cape Palliser Rd, Hinekura/Hinakura[13] Rd, Riversdale Rd, Castlepoint Rd	Weekly	Poor
Tora Farm Rd	Weekly	Poor
Castlepoint Rd, Riversdale Rd, Tora/Te Awaiti Rd, Cape Palliser Rd	Weekly	Average
Tora Rd	Yearly	Average
Castlepoint Rd	Monthly	Good
Tora Settlement Rd	Monthly	Poor
Cape Palliser Road	Monthly	Poor
Western Lake Rd	Monthly	Good

Diver personal observations

Weather plays an important role in diver accessibility in this fishery with large parts of the coastline exposed to Easterly weather patterns (onshore) that restrict fishing versus Northwesterly patterns (offshore) that enhance diving opportunity.

In the last five years, divers reported that they have observed increased Easterly weather while Northwesterlies are being seen later than usual and over shorter time periods. The combination of these changes results in less favourable outcomes for the divers such as less days fishing and less catch. Divers also observed more frequent and severely changing weather patterns (Figure).

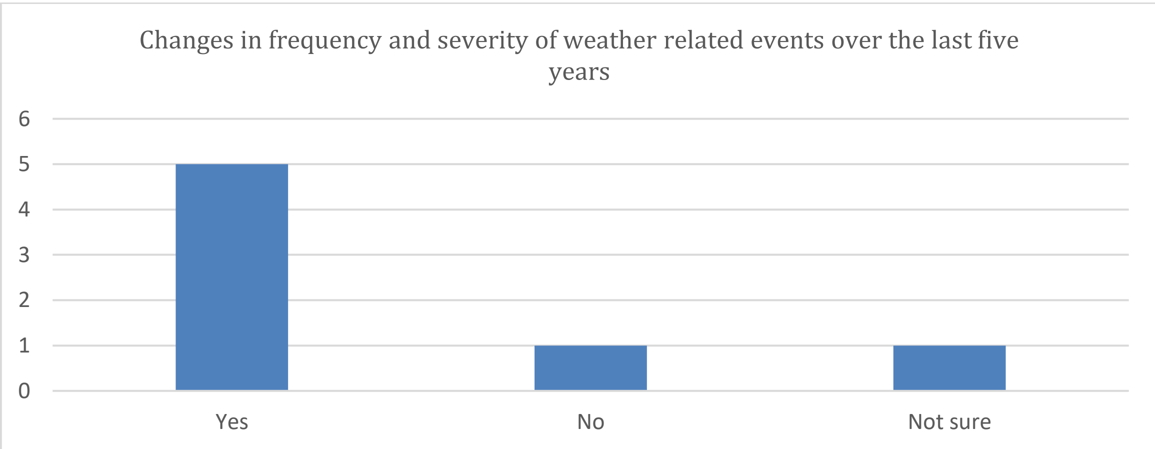

Figure 15: Divers answers on frequency and severity of weather in last five years

[13] Referred to as both Hinekura or Hinakura Road.

Natural hazards most affecting divers were landslides and flooding which causes road washouts which obviously impacts key lifeline infrastructure such as roads and their ability to access coastal points to launch vessels and go diving.

A full anonymized diver commentary of their observations is included in Appendix 2. Divers highlighted global warming, sedimentation, landslides as environmental challenges facing the fishery going forward.

Two examples

Hinekura/Hinakura Road

A landslide was reported by a diver as having severely damaged Hinekura Rd in July 2022[14] (Figure 16), and which closed pāua fishery launch access. A diver reported this as having added an extra hours' driving to get to the coast. The diver noted that a farmer has kindly put in a track over his farm for fishery access and use until the road is repaired.

Figure 16: Large parts of Wairarapa would be cut off in a major natural event. Source: Stuff News.

[14] https://times-age.co.nz/cracks-in-road-network-revealed/

Tora using the Te Awaiti Road

If the journey from Masterton to Tora using the Te Awaiti (also called Te Whiti) Road were cut off by a slip or washout, as occurred during Cyclone Gabrielle, access to fishery Statistical Areas 223 and 224 would be affected (Figures 17 and 18). Historically, the total average combined pāua taken from these two areas is 14.5MT. At an average port price of $24/kg, this would result in an estimated loss of $348,000. The Hinekura Road example described above is part of a potential alternative route that could be taken to access this coastal area.

Whilst the fishery may still be accessed from points further afield and fishing may still occur, however this would result in greater at sea time to steam to fishery sites incurring greater fuel, diver time, potentially diver fatigue, and wear and tear on vehicles and vessels incurring higher maintenance costs. Lastly, the small and open nature of the craft in this fishery means that the risks from sudden weather changes can be exacerbated.

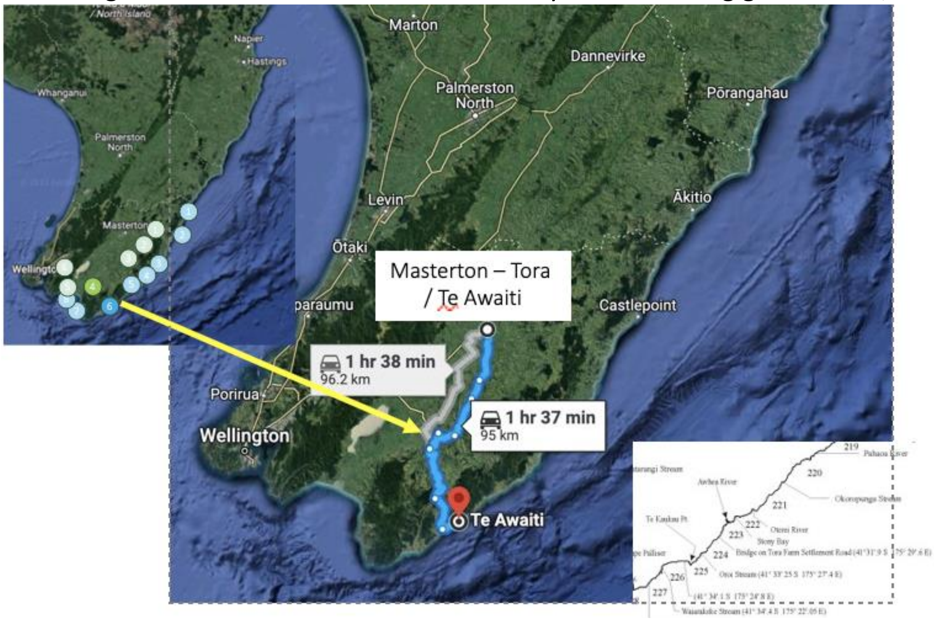

Figure 17: Tora / Te Awaiti Pāua harvest area

Figure 18: A flooded car on Te Whiti Rd between Gladstone and Masterton in Wairarapa. Source: Stuff News.

Summary and recommendations

There is a reasonable body of research detailing the potential effects of a variety of stressors on the different life stages of pāua, sufficient for Fisheries New Zealand to have undertaken a pāua climate change vulnerability assessment. However, this research has generally focussed on small-scale, short-term studies of single stressors. Therefore, there is uncertainty about the response of pāua populations to cumulative stressors (i.e., increased temperature plus increased sedimentation), especially at larger fishery scales under forecasted climate change projections. While pāua responses to cumulative stressors are likely to be greater than the addition of the response to the individual stressors, and longer, the longer the duration of stress, the stronger the response is most likely to be, at the population scale, some alleviation may occur. Any such alleviation could be assessed using a population dynamic model, as long as the model incorporated larval and juvenile survival and growth, and preferably some estimates of effects on reproduction. Field monitoring of pāua and stressors, together with mātauranga, Māori could also help improve overall ability to determine how generally applicable the present information is. In the meantime, a conservative estimate of effects could be obtained from the available research.

Furthermore, risks created by environmental events are not confined to Pāua themselves. Our review revealed the PAU2 management area and the adjoining land are susceptible to extreme weather events that can impact the accessibility of the PAU2 fishery. While earthquakes, fires, tsunami, and sea-level rise are all likely events in the area, the hazards that currently most affect the pāua industry operations are landslides and flooding which cause road washouts and affect vessel launch point access. However, divers also highlighted global warming and sedimentation as environmental challenges facing the fishery going forward.

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Part 2: Pāua fisheries, management and legal considerations

Craig T[15], FitzHerbert S[16], McCowan T[17], Short, K[1], and Stanley S[18]

Executive summary

This report is one of three from the Sustainable Seas Science Challenge Risk and Uncertainty Project 3.3: Upholding the value of Pāua Quota. The project has explored how to better understand, assess, and factor in the key environmental risks of climate change and sediments (exacerbated by climate change) to the fishery and subsequent pāua quota values to inform fisheries management, fishery investors and financiers, and the development of response strategies by all.

In this Part 2 report, the pāua fishery is described along with the resource and fisheries management laws and policy it operates under. Providing this context guides how the commercial wild harvest could be better managed to be resilient to the challenges of the changing environment.

Pāua is a valuable export product worth on average $50-60 million annually. It is commercially significant to Māori and has a strong customary and recreational usage. The fishery is managed under the New Zealand Quota Management System (QMS) with 8 management areas. Under the QMS Total Allowable Catch (TAC) is set for each area and includes the Total Allowable Commercial Catch (TACC), and an estimated recreational and customary take. Alongside the TACC, the minimum legal size (MLS) is the other main regulatory pāua fishery management control. The MLS is set at 125 mm around New Zealand except for the Taranaki region where it is 85 mm in recognition of smaller length at maturity, slower growth and generally reduced adult size in this region.

However, there are other legislative and public-private strategy processes connected to Māori rights, climate, land-use, waste treatment, sediment control/erosion and freshwater that influence pāua wellbeing, as well as the operational aspects associated with the pāua industry (i.e., freight, corporate climate change disclosures, location of infrastructure). Many reviews have noted the considerable (25+) pieces of legislation relevant to marine management.

The New Zealand pāua industry operates on a simple bottom-up structure with five regional associations known as Pāua Management Advisory Committees (PāuaMACs) which are collectives of quota owners, ACE holders, and divers. The Pāua Industry Council (PIC) is the national umbrella organisation that provides support to individual PāuaMACs and advocates for the industry nationally.

The New Zealand pāua industry deploys several fisheries management strategies and tools that operate inside the national TACCs and within the framework of the 1996 Fisheries Act. These strategies aim to achieve the fine scale management required to properly manage pāua fisheries

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that reflect the population structure and biological characteristics of the species, which is not achievable using the QMA scale management tools available under the Act.

While much has been achieved, the conclusions of this report, considering also the findings of the assessment of environmental risk to pāua biology, and discussions with the project team and advisory group, are:

1. As sediment affects pāua in multiple ways (for example, settlement, growth rates, attachability, movement, food quality, McCowan *et al.*, 2023), there needs to be better connection between management of the land and the sea. For example, including terrestrial stressors in management responses to protect Habitats of Significance for Fisheries Management (Section 9(c) of the Fisheries Act 1996) is essential.
2. Discussions within the project team and with the advisory group highlighted the need to consider seasonal and annual changes to the environment when assessing risks (McCowan *et al.*, 2023). Therefore fisheries management responsiveness needs to be able to occur at least annually and be based on the most real time data possible (e.g., harvest control rules).
3. Similarly, discussions within the project team and with the advisory group demonstrated that further research is needed to specifically understand the effects of changing environmental stressors on pāua fisheries (individuals and population levels) at fisher management relevant scales and under forecasted climate change projections to fully support quota owners, fishers, and government to work together to respond to environmental risks including:
    a. continued collection of biological data,
    b. improved collection of environmental data, and
    c. medium-term (5-10 years) laboratory experiments that parallel environmental conditions to challenge better understand pāua physiological responses to environmental stressors.

Introduction

By 2027, the global market for seafood is projected to reach $199bn[19] – up from $159bn in 2019 (Topping, 2022). In New Zealand the seafood sector is estimated to contribute around $2 billion in export earnings (Seafood New Zealand, 2022). The recently signed New Zealand United Kingdom Free Trade Agreement (FTA) includes preferential access for New Zealand seafood and removes the 16% tariff on hoki and mussels immediately and includes consideration of the mauri of marine ecosystems (Article 22.9)[20]. The NZ-European Union (EU) FTA due to enter into force in 2024 also provides access, along with requirements for corporate sustainability governance, including for imported products (European Commission, 2022) that New Zealand seafood exporters will need to meet.

Pāua is a valuable export product worth on average $50-60 million annually (Pāua Industry Council (PIC) *pers. comm*.). Pāua is commercially significant (Leach & Boocock, 1993) to Māori. Since the Māori Fisheries Settlement in 1992, Māori have gained ownership of 51% of the commercial pāua fishery quota nationally with Moana New Zealand holding 31.5% of the total on behalf of all iwi. An important customary fishery exists, as well as being fished recreationally. Illegal take can also be high and in the early to mid-2000s, illegal fishing was around 50-100% of the commercial catch, although this has now declined to ~20%. Most illegal catch occurs in areas where commercial fishing is not being done, for example, although the Wellington South Coast which has never been commercially fished but is heavily illegally fished.

This report sets out basic information about the fishery itself and the legal and policy context within which management occurs. It concludes with a section on guidance for commercial strategic responses to environmental risk and uncertainty.

[19] https://www.digitaljournal.com/pr/seafood-market-to-reach-us-198854-86-million-globally-by-2027-at-2-9-cagr-the-insight-partners
[20] https://www.mfat.govt.nz/assets/Trade-agreements/UK-NZ-FTA/NZ-UK-Free-Trade-Agreement.pdf

The pāua fishery

Under the New Zealand Quota Management System (QMS), Total Allowable Catch (TAC) by Quota Management Area (QMA) includes the Total Allowable Commercial Catch (TACC), and which also allows for estimated recreational and customary take. With an absence and at times unavailability of detailed recreational and customary catch levels, TAC decisions are driven by commercial fishery catch per unit effort (CPUE) trends, although in most cases a time lag exists between catch information entering the management system and TAC setting. Nationally, the pāua Total Allowable Commercial Catch (TACC) is slightly above 900 metric tonnes (MT) across eight main Quota Management Areas (QMAs) (Figure 2) with approximately 705 MT harvested annually.

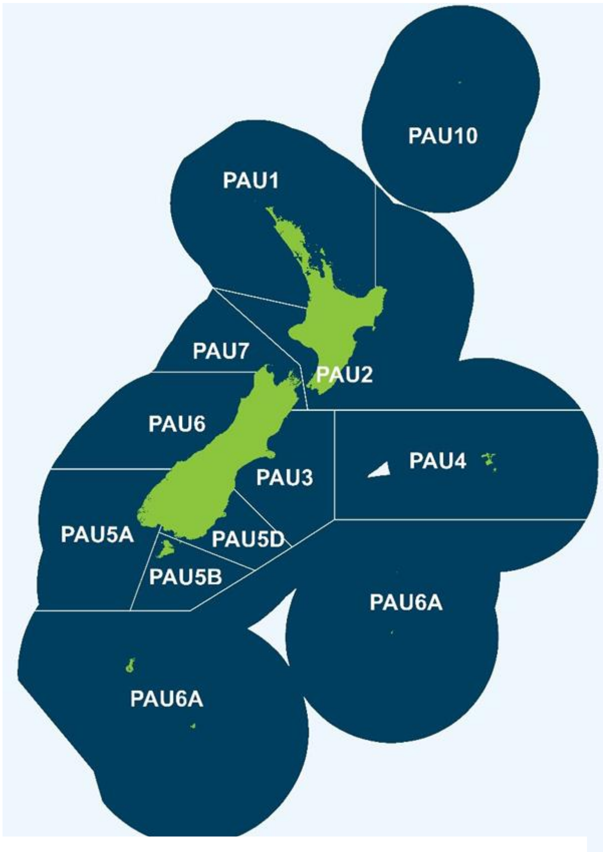

Figure 2: Quota Management Areas for Paua

There are eight QMAs (Figure 2) that are commercially fished for pāua: QMAs 2, 3A, 3B, 4, 5A, 5B, 5D & 7. The status of pāua stocks in each QMA is addressed by periodic stock assessments in each QMA (approximately every three years) with the outcomes of these informing management settings. The commercial fishing season runs from 1 October to 30 September. The most significant pāua target market is for Chinese Lunar New Year banquets that occur late January to end February in Chinese communities globally.

The recreational bag limit for pāua is 10 per person per day around most of the country, except for in PAU3B and PAU7 where it is five per person per day and PAU3A where it is three per person per day (and two per person per day within the Oaro-Haumuri Taiāpure). Unlike the commercial fishery, there is little monitoring and no reporting of recreational catch. This can introduce uncertainty to the stock assessment process.

Pāua are harvested by freediving, apart from in the PAU4 fishery (the Chatham Islands) where underwater breathing apparatus (UBA) is approved to reduce the risk of great white shark incidents. Harvesters abide by recommended best industry practices for harvesting and handling pāua to reduce the risk of incidental mortality[21], these practices are outlined in the annual operating plan (AOP) for each pāua fishery.

Alongside the TACC, the minimum legal size (MLS) is the other main regulatory pāua fishery management control. The MLS is set at 125 mm around New Zealand except for the Taranaki region where it is 85 mm in recognition of smaller length at maturity, slower growth and generally reduced adult size in this region. MLS is set to allow mature pāua time to spawn for

[21] Pāua are heamophiliacs so must be harvested with care so that any undersized individuals returned are better able to survive.

several seasons before they can be harvested to ensure sufficient recruitment to sustain the fishery. Length at maturity and growth rates are two important considerations for the setting of MLS (Naylor & Andrew, 2000), with these parameters varying in response to water temperature (Naylor *et al.*, 2006). This variability of growth in response to water temperature means that the range of the commercial fishery is restricted to areas where pāua regularly grow past the MLS of 125 mm.

Pāua quota share ownership

The New Zealand Quota Management System includes two legal instruments that form the basis of harvest rights. The first is "quota", or more correctly quota shares. In any QMA the right to harvest pāua is expressed as a shareholding in the 100,000,000 shares which are issued in each QMA. So, a person who owns quota owns a set percentage of the harvest rights in that fishery. These shares are tradeable and can have mortgages registered against them. They are a form of private property right. Quota shares are normally expressed as a tonnage. So, if there is a TACC set for a QMA of 100 MT, a QSO with one metric tonne of quota, has the right to harvest one metric tonne of pāua in any single-year (1% of 100 million (M) shares). The number of shares issued, 100M, remains the same regardless of movements in the TACC.

There are 238 listed quota share owners in New Zealand[22]. Pāua quota ownership is dispersed widely both geographically as well as in multiple small and large parcels. There is a high level of Māori ownership both from the Māori Fisheries Settlement (1992) and through post settlement purchases by iwi, rūnanga and hapū. There is also significant participation directly in the business of harvesting pāua by Māori QSOs, ACE holders, divers, and support crew. Many rūnanga have their own quota managers and dive crews. It is considered highly likely that more than half of the pāua quota shares in New Zealand are owned by Māori, rūnanga, hapū, individually, and through the 1992 Māori Fisheries Settlement by Te Ohu Kaimoana, and Moana New Zealand. The ownership of quota shares is geographically spread, with owners often living in coastal and rural communities, for example in PAU3A and 3B where 70% of QSOs and dive crews are based in the Kaikōura region.

Every year the Quota Share Holding generates an Annual Catch Entitlement (ACE). This is expressed in kilograms and is the amount the quota share owner can legally take. The ACE entitlement is also tradeable. So, one can own quota, but lease the right to that years' catch as ACE, to another entity.

Commercial pāua fishery value

Table 1 below shows the average values from the commercial fishery – the values are in ranges given the commercial sensitivity. Pāua achieves NZD$40-60 M in annual export earnings (Stats NZ), depending on market conditions. There is also a minor, but increasing, domestic market.

This regional Gross Domestic Product (GDP) enhancement has been calculated as a multiplier of 2.6 times the beach price paid to QSOs (BERL 2015) (i.e., multiplying national catch (approx. 735 MT) by average beach price of $35,000 then the direct economic benefit to the combined QSOs is NZ$26m). Using this multiplier, the additional economic value generated by the commercial pāua sector should be in the order of NZ$67m ($26m x 2.6).

[22] Foreign ownership is prohibited.

Table 1: Pāua sector average values. Source: Pāua Industry Council

Total annual export earning	$40-60m (+minor domestic market)
Capital value of pāua quota shares	$400,000 – 500,000 per metric tonne
Earnings to QSO/ACE price	$30,000 – 35,000 per metric tonne
Harvest crew	$9000 -14,000 per metric tonne
Contract diver	$2000 per metric tonne
Regional communities	Economic multiplier is approximately 2.6 X beach price (source: BERL/Stats NZ

The quota market value can be a function of many factors including beach price, political situation, the perceived health of a fishery, and market quota availability. However, sales of quota shares currently tend to be in the $400,000-500,000 per tonne range, or more depending on QMA. Individual quota parcels might sell for less or more depending on the situation. Smaller parcels of quota shares from the Stewart Island Pāua fishery (PAU5B) may be above $600,000 per tonne, for example, as it is likely to have a TACC increase. The annual quota share owner earnings from leasing of ACE currently averages $30,000-35,000 per metric tonne.

The overall capital value of the fishery is difficult to establish with precision. However, there are three ways to estimate values. Firstly, using quota trading data from the official Government quota trading register managed by FishServe[23] multiplied by the tonnage held. Secondly, through the capitalisation of annual ACE trading prices also collected through the official register are used in quota and fishery valuation. The register does not require exact trading price information to be provided with the result being that both registers provide low average and high price points for quota trades and ACE trades. Thirdly, values can be tracked through anecdotal information passing through interested parties, i.e., the chat on the street.

Furthermore, pāua shell can be quite a valuable part of the catch, though this depends on whether the catch is sold whole or canned. If whole, for example in the Individual Quick-Frozen (IQF) format or live, the whole fish is exported, so shell is unavailable to the domestic shell market. If the catch is canned, only the foot (meat) is used so the shell is available as a byproduct for the domestic market and further value adding. Live export means that the shell is not available for sale separately[24].

A harvest crew can make $9,000-14,000 per metric tonne for contract harvesting of the catch. The canned market is still the major export market, with prices which tend to be less than for the live market. Live and whole (IQF) normally achieve higher export prices. It should be noted that live and whole IQF have higher catch costs due to handling and live storage requirements

[23] FRED is an online tool that allows reports to be run using live up-to-date-data from the Quota Share and ACE Registers via the internet. It gives access to aggregated ACE and Quota transfer prices and aggregated Catch figures (the old Blue Book data).

[24] Note: Included in exports are raw and value-added shell, processed by-products, health supplements and nutraceuticals. Today, everything is value added and nothing is wasted.

and shipment orders tend to be smaller. Contract divers working in the harvest team will earn $2,000-$4,000 per metric tonne landed. An average daily boat catch is probably in the 0.5 metric tonne range, but this can vary a lot between QMAs.

As with most primary industries the value to the country is more than simply direct export earnings. As mentioned, the activity of pāua fishing and processing generates downstream economic benefits, for example in increased employment, transport, service industries, processing and so on.

Industry structure

The New Zealand pāua industry operates on a simple bottom-up structure with five regional associations, the Pāua Management Advisory Committees (PāuaMACs) which are collectives of quota owners, ACE holders, and divers. Their task is to ensure that the interests of members are represented and, importantly, that their fishery remains healthy.

The Pāua Industry Council (PIC) is the national umbrella organisation that provides support to individual PāuaMACs and advocates for the industry nationally. PIC is a limited liability company, and the PāuaMACs are Incorporated Societies. The PāuaMACs each provide a director to the PIC Board to ensure regional representation. Funding is by way of a levy on quota shares set under the Commodity Levies Act. The authority for this levy is held by PIC and is renewed every 6 years.

The New Zealand pāua industry deploys several fisheries management strategies and tools that operate inside the national TACCs and within the framework of the 1996 Fisheries Act. These strategies aim to achieve the fine scale management required to properly manage Pāua fisheries that reflect the population structure and biological characteristics of the species, which is not achievable using the QMA scale management tools available under the Act.

Fleet structure

The fleet is small and modern with harvest vessels upgraded frequently. Most of the fleet are 5-7m trailer-based vessels. These smaller size classes of fishing vessel have become more efficient over time, with reduced carbon footprints. As an example, there has been a marked change from the use of two-stroke motors to the more fuel efficient four-stroke motor. Larger vessels tend to be working in the remote areas of Fiordland, Stewart Island, and the Marlborough Sounds. These are harvest vessels in the 12-20m range which act as mother ships for multi-day trips. They have live holding tanks and carry small, fast, rigid inflatable boats (RIBs) to service dive crews doing the harvesting.

The trend in most QMAs is for harvest operation consolidation through natural attrition leading to fewer, more professional crews. For example, the Marlborough-Nelson fishery has reduced from 45 crews and vessels in total in the early nineties, to about eight harvest crews currently. PIC estimates that there are about 100 vessels nationally although some fish for multiple species including pāua, rock lobster and blue cod. As mentioned earlier, a feature of pāua fisheries is that pāua quota ownership is dispersed with many small holdings that have strong regional fidelity and which are consequently often family and/or whanau owned. Thus, the economic value tends to stay within the regions and is well distributed along the value chain from harvest to exporters.

Electronic reporting

When the QMS was introduced in 1986, a paper-based system was used to report daily catch, with a monthly summary by divers. This did not provide the real-time information that the industry considered was needed. In the mid-2000s the pāua industry embarked on a programme to develop an electronic reporting system that included vessel and diver-based data collectors. The system was widely used in the industry some years before the Fisheries New Zealand Electronic Reporting and Geopositional Reporting (ER/GPR) System was introduced. However, regulatory requirements meant that the industry data collection systems had to be abandoned in favour of the Ministry requirements, although the pāua industry regarded their previous system as superior. The previous system included location, depth, temperature and catch, whilst the new system only requires location and catch reporting. (*Tony Craig, pers. comm*.). The recently introduced ER/GPR system includes a geopositional reporting system for vessels, and electronic recording and reporting of catch data. The industry has adapted to the new system and set up daily data feeds into a real-time dashboard system populated by catch information. Management decisions by the industry are informed significantly by these data streams. These can be overlaid with growth rates and other fishery independent data to inform catch-spreading and size limit increases. Overall, it is a reasonably well understood fishery from a commercial harvest perspective. There is very good information on commercial harvest and an agile decision-making framework that is actively used for management by industry, although overall Ministry responses are much slower (see section on Guidance and prioritised commercial wild harvest sector strategic responses to address environmental risk and uncertainty).

Pāua fisheries legal and policy context

Dr Stephen FitzHerbert (NIWA)

Introduction

This section reviews the associated legislation relatable to pāua, their habitats and associated infrastructure. It focuses on the legislation and strategies across customary and commercial domains related to pāua. Particularly on those environmental risks associated with changes which may be mitigated domestically through legislative mechanisms: land-use practices and infrastructure adjacent to pāua habitats. These include the legislative and public-private strategy processes connected to Māori rights, climate, land-use, waste treatment, sediment control/erosion and freshwater that influence pāua wellbeing, as well as the operational aspects associated with the pāua industry (i.e., freight, corporate climate change disclosures, location of infrastructure).

Māori entities have significant customary and economic rights in the management of pāua to generate economic value and ensure its protection. Commercial and customary rights are different, albeit they interconnect and may be of mutual benefit in the ability to exercise rights to protect and manage pāua resources. Changes to pāua means changes to livelihoods. Under Te Tiriti and subsequent settlement Acts, Māori have rangatiratanga over their cultural and economic resources. Climate-induced and land-based activities are having significant impact on pāua and their habitats, whereby Māori interests in expressing cultural and economic rights are being challenged. For this reason, the relevant legislation and or policy overviewed in this section is classified customary and or commercial.

Key documents

The sustainable management of pāua populations, their ecosystems, and the interconnected domains that contribute to the state of the environment for pāua (i.e., land-based activities) all require an interconnected legislative ecosystem. Many reviews, including Severinsen *et al*. (2021) and Office of the Prime Minister's Chief Science Adviser (Gerard 2021), have noted the considerable (25+) pieces of legislation relevant to marine management (**Error! Reference s ource not found.**).

Table 2: List of current legislation relevant to paua and their habitats.

Title	**Agency**	**Status**	**Relevance to Pāua**
Treaty of Waitangi (Te Tiriti o Waitangi)	AoG (MCR)	Legislation	Customary and commercial: Taonga species, protection of customs, knowledge & taonga, protection of taonga environments
Treaty of Waitangi (Fisheries Claims) Settlement Act	AoG	Legislation	Commercial and customary
WAI262	AoG	Negotiation	Customary and commercial
Marine and Coastal Area Te Takutai Moana Act	MCR	Legislation	Customary
Ngā Rohe Moana o Ngā Hapū o Ngāti Porou Act 2019	MCR	Legislation	Customary

Māori Fisheries Amendment Bill	MCR	Submissions	Commercial
New Zealand National Adaption Plan (2022)	MFE	National Plan	Customary and commercial
Resource Management Act 1991	MFE	Being repealed	Customary and commercial
Strategic (Spatial) Planning Act	MFE	Introduced 2023	Customary and commercial
Natural and Built Environments Act	MFE	Introduced 2023	Customary and commercial
Climate (Change) Adaptation Act	MFE	Introduced 2023	Customary and commercial
Taskforce on Climate-related Financial Disclosures (TCFD)	The Reserve Bank	Coming into effect 2024	Commercial
National Coastal Policy Statement	DOC	Compulsory Policy Statement	Customary and commercial
Fisheries Act 1996	MPI	Legislation	Commercial and customary
Environmental Reporting Act	MFE	Under revision	Commercial and customary
Te Mana o te Taiao – Biodiversity Strategy 2020-2050	DOC	Strategy	Customary and commercial
National Environmental Standards for Plantation Forestry	MPI (MFE)	Under revision	Customary and commercial
Seafood Sector Adaptation Strategy	Aotearoa Circle	Plan	Commercial
Fisheries Industry Transformation Plan	MPI	Plan	Commercial

Te Tiriti o Waitangi (1840): Article 2 of Te Tiriti guarantees the protection of iwi and hapū rangatiratanga over their taonga. Te Tiriti and the associated rights of Māori are becoming increasingly embedded in recent amendments and or drafting of bills as well as in cross sector strategies. The expression and delivery of Māori rights in the protection and management of both environments and taonga species, as per customary and commercial interests, is likely to increase with the maturation of the Crown's responsibility under te Tiriti in legislation. It is foreseeable that such transitions can provide better mechanisms to safeguard customary and commercial pāua interests.

Treaty of Waitangi (Fisheries Claims) Settlement Act (1992): The Act has three purposes: to give effect to the settlement of claims relating to Māori fishing rights, to make better provision for Māori non-commercial fishing rights and interests, and to make better provision for Māori participation in the management and conservation of New Zealand's fisheries.

WAI262[25]: Is yet to be settled, albeit the Crown is currently working through its response in the work programme, Te Pae Tawhiti[26]. At the heart of this claim is the assertion that Māori be able

[25] The Wai 262 Claim
[26] Te Pae Tawhiti: Wai 262 (tpk.govt.nz)

to control things Māori and in which tino rangatiratanga is restored over taonga. Should this longstanding claim be settled, the foreseen outcomes include greater customary influence over the protection of taonga species (i.e., pāua), which may include better resourcing the ability to protect taonga species and their habitats and the related practices and mātauranga associated with taonga. Additional Te Pai Tawhiti programmes include the exploration of biodiversity incentives to support the Aotearoa Biodiversity Strategy (2020), as well as the integration of work into Resource Management Act (RMA) reform, aquaculture strategies and the National Policy Statement (NPS) for Freshwater Management.

Marine and Coastal Area Te Takutai Moana Act (Customary) (2011): Provides for recognition of the customary interests of iwi, hapu and whanau in the common marine and coastal area of Aotearoa New Zealand and its offshore islands. It ensures customary title and access to mana moana. However, the interlink between this Act and the expression of mana moana to advance interests in the management of matters that create adverse effects in customary areas and or prevent customary practice, is not explicit. Likewise, the consequences for activities that impair mana moana as well as when such activities are responded to where necessary to ensure healthy habitats, is not clear.

Ngā Rohe Moana o Ngā Hapū o Ngāti Porou Act 2019 (Customary): Provides the legal expression, protection, and recognition of the continued exercise of mana by Ngā Hapū o Ngāti Porou in relation to ngā rohe moana o Ngā Hapū o Ngāti Porou. Ngāti Porou is a significant pāua quota owner. It is unclear how this can be exercised to protect customary activity (including activities that may derive commercial gain for hapu) in marine habitats affected by adverse land-based activities and which may contribute to increased sedimentation and or changes to coastal water quality. Similarly, it is unclear how this can be exercised in consenting processes in which an activity is adjunct to or directly affecting a customary marine title area. Although Ngāti Porou has a commercial fishing company and other commercial marine interests, this Act can only be exercised for customary matters, it cannot be exercised by any commercial Māori fishing right or other commercial interest.

Māori Fisheries Amendment Bill: Currently underway, the aim of this amendment is to give iwi a greater degree of rangatiratanga over their commercial kaimoana assets and more influential relationships with the Crown to assert Māori rights. The changes pertain to the governance and operations of Māori entities, allocation of Māori quota, and the redistribution of revenue. The Submissions are currently being considered. The Amendment does not afford iwi with new influence regarding protecting kaimoana assets from external threats.

National Adaptation Plan[27]: The *National Adaptation Plan* was published in August 2022 and is proposed as an all of government strategy to drive climate related transitional actions in policy and institutional frameworks to deliver sustainable adaptation to climate change in Aotearoa New Zealand. The key sections related to pāua-related livelihoods include, *Enabling better risk-informed decisions*, *Economy and financial systems*, and *Providing for Te Tiriti and protecting Māori rights and interests*.

> *Enabling better risk-informed decisions.* The objective is to provide people and businesses with access to better information to be able to better assess current and future climate risks to support informed decision making related to livelihoods. One of the targeted action areas is the development of a platform for Māori climate action that will enable and resource Māori to actively participate in policy design and tangata Māori climate actions

[27] https://environment.govt.nz/assets/publications/climate-change/MFE-AoG-20664-GF-National-Adaptation-Plan-2022-WEB.pdf

that support the development of action plans and strategies for adaptation and mitigation of climate change effects.

Economy and financial systems. The objective of this section of the National Adaptation Plan is to strengthen the fisheries management system – the risks to fisheries are counted as those related to characteristics, productivity, and spatial distribution of resources due to changes in ocean temperature and acidification. However, the interplay between land and inshore activities is not explicit, nor is the responsibility of land-based activities in events which may have a detrimental effect on inshore fisheries resources. Ongoing reform to the Fisheries Act (MPI) is also stated, in which new rules may better allow adjustment to catch limits in response to change in abundance. The new changes are aimed at making the fisheries system more responsive to the effects of climate change; yet not to the effects of poor land-based practices that boost the effects of severe weather events. Also, progress is intended for the implementation of the Government's response to the Prime Minister's Chief Science Advisor's report of commercial fishing[28], including actions that progress an ecosystem approach to fisheries management and that protect habitats of significance to fisheries management. Within this strand is also a commitment to developing a *Freight and Supply Chain Strategy* to reduce the risks of disruption. While the fisheries sector may become better resourced to identify risks and act, it is unclear how action can be exercised when sector activity is adversely affected by the operations of another sector.

Providing for Te Tiriti and protecting Māori rights and interests. Rural and remote Māori communities (particularly in the PAU2 area) are highly exposed to climate change from adverse weather events, damage to infrastructure (i.e., transport, housing, boat ramps), damage to and contamination of mahinga kai sites (esp. inshore coastal habitats), loss of taonga species (i.e., pāua) and loss of mātauranga associated to managing those environments and protecting species, and loss of forms of manaakitanga associated to those species (i.e., providing pāua to manuhiri). The effects of climate change have been highlighted in submissions by numerous Māori entities. The government has committed to working with Māori to support adaptation options for Māori, led by Māori. What is unclear is how the government proposes to (i) support Māori when adaptation options may be adversely impacted by other policy decisions, and/or (ii) enable Māori to have a say on the activities that further stress climate change effects on Māori environments and taonga species. Examples include:

- Principles that support abundance and inter-connectedness.
- Where adaptation is unduly forced upon customary and commercial interest due to the commercial and or legislative actions of others that exacerbate the effects of climate change and directly impact areas of Māori interest.
- How matters that unduly effect Māori customary identities and Māori commercial identities can be compensated.

Resource Management Act 1991 (RMA): Administered by the Ministry for the Environment, the RMA is the main legislation that governs how people interact with natural resources. The RMA manages air, soil, freshwater and the coastal marine areas, as well as regulation of land use and infrastructure so as to not have detrimental effect on the natural environment. This Act is currently being repealed and replaced by three new Acts – the Natural and Built Environment Act, the Strategic (Spatial) Planning Act and the Climate Change Adaptation Act. These three

[28] https://www.pmcsa.ac.nz/topics/fish/

replacement acts are at varying stages of development before accension into legislation. An overview of each proposed act follows below.

Strategic (Spatial) Planning Act (SPA) (2023): (Customary and Commercial): Otherwise known as the Spatial Planning Act,. The Act is under final development and expected to be introduced to Parliament in 2023. This Act is proposed to integrate with other legislation relevant to development and requires the development of long-term regional spatial strategies. This will include the identification of hazard zones and will guide development to occur in more suitable locations with lower risk and less potential to be detrimental to the environment.

Natural and Built Environment Act (NBEA) (2022):[29] (Customary and Commercial): The NBEA is the primary replacement of the Resource Management Act (1992). The NBEA provides for an integrated framework for regulating both environmental management and land use planning. It is proposed to provide a new foundation for decisions to reduce climate risk to development and existing operations. The key objective is to better prepare for adapting to climate change and risks from natural hazards. For example, this may impact existing and future land-use activities that contribute to sedimentation and/or contamination of inshore environments and habitats. There is currently a working group in Tairawhiti due to the multiple severe weather events in 2022 and 2023 that caused weather-related effects and sedimentation hazards, whose activities may feed into the shaping of this new legislation.

Climate (Change) Adaptation Act (CCAA) (2023): (Customary and Commercial): While the legislation is still in development, it is focused on addressing the key issues related to managed retreat, and funding and financing adaptation. The Act will work directly with the NBEA and SPA to deliver effective managed retreat. The Act may inform the guidance and support for the consequences of managed retreat, especially where Māori could experience a disconnection from coastal taonga and kaimoana and or the effects on key infrastructure associated to the pāua industry.

Taskforce on Climate-related Financial Disclosures: (Commercial) This is a new requirement from 1 January 2024 for Climate Reporting Entities 'CRE' including:

- Large NZX listed issuers of quoted equity or debt securities (i.e., a market capitalisation or nominal amount exceeding $60 million)
- Large, registered banks, licensed insurers, credit unions and building societies (with total assets exceeding $1 billion or for licensed insurers, where premium income exceeds $250m per annum)
- Large, licensed managers of registered managed investment schemes (with total assets in registered schemes exceeding $1 billion)

Additionally, other companies are adopting this reporting voluntarily and/or are being asked to declare their climate risks to their insurers and/or investors.

The New Zealand Coastal Policy Statement (NZCPS) (2010) (Customary and Commercial): The NZCPS is the only compulsory national policy statement (NPS) under the RMA. The RMA requires a NZCPS, albeit the NZCPS has not been updated since 2012. An update review may be forthcoming once the new Acts that replace the RMA are enshrined. The last review of the NZCPS was done by DOC (2017)[30]. Review participants (representing environmental groups)

[29] Natural and Built Environment Bill 186-1 (2022), Government Bill – New Zealand Legislation

[30] https://www.doc.govt.nz/about-us/science-publications/conservation-publications/marine-and-coastal/new-zealand-coastal-policy-statement/

identified excess sedimentation and restoration of natural character as an emerging major issue and recommended that these key issues needed to be addressed in the NZCPS.

In reference to coastal marine habitats, the current degradation, and pressures, alongside ocean acidification and climate change impacts, include:

- Excess sedimentation
- Marine pests
- Excess nutrients (carried down waterways)

Excess sedimentation is addressed in Policy 22 of the NZCPS; however, the effectiveness of this policy requires evaluation. Additionally, in DOC's review, participants called for mechanisms that deliver integrated management across the coastal and freshwater NPSs, as sediment-laden freshwater flows contribute to the degradation of near-shore environments. Similarly, with regard to Policy 21 Enhancement of Water Quality, participants considered that the current NPS thresholds were too low for what are considered 'significant adverse effects'. The effects of sedimentation have been significant between 2021 and 2023 due to land-use practices and the occurrence of extreme weather events. Extreme weather events are expected to occur more frequently with a changing climate. Without changes to land-use and or the enforcement of sediment controls, the risk of sedimentation and damage to pāua, their habitats, and access routes remains high.

Fisheries Act 1996 (Commercial & Customary): The Fisheries Act 1996 is a complex piece of legislation. Its foundation being the Quota Management Systems and its operation/application but following the Māori Fisheries Settlement 1992 has been adjusted to reflect the Settlement and provides for both commercial through the QMS and customary where the Minister makes allowances for customary interests when setting TACs. Customary interests are then supported through the regulatory framework. There is currently no direction on the Pāua industries' request for statutory support for the various management plans that the industry have established to enable greater "within TACC" management decision that can further enhance or protect pāua, and at this point voluntary reductions for such purposes cannot be enforced. If management plans are not supported by regulatory mechanisms, industry and community effort and the state of pāua populations are subject to misrepresentation and may subsequently lead to misinformed TACC adjustments. More responsive fisheries management that recognise local knowledge should be embedded in legislation in an effort to minimise undesirable outcomes.

Furthermore, the disconnect between local and central government, the Fisheries Act and The RMA means the ability to support the development of best practices to reduce sedimentation, dredging and debris in near-shore ecosystems is missing. The authority and information necessary to better advocate and be involved in consenting processes to mitigate adverse effects on near-shore habitats is sadly missing. Ongoing poor consideration of Section 11(a) regarding regional councils and their implementing statutory requirement to integrate a mountains-to-sea form of management is also missing. Thereby certain activities on land are being permitted, which have adverse effects on near shore habitats; which are likely to increase with climate change and the increased frequency of extreme events.

Environmental Reporting Act (date)[31]: The Act is being amended to enhance the quality and availability of environmental data as well as to expressly provide for te ao Māori and mātauranga Māori. Many of the Māori submitters to the amendments commended the shift, albeit with concerns as it was not clear how the new Act would provide for te Tiriti partnership or the

[31] Improving-Aotearoa-New-Zealands-environmental-reporting-system-Summary-of-submissions.pdf

intellectual property protection of mātauranga Māori. Furthermore, additional indicators of environmental performance were suggested, including Mahinga Kai (i.e., does the environment support sustainable harvest?). The amended Act may provide better environmental information to commercial and customary interests as well as how environments are measured and reported (e.g., greater quantification of stressors to pāua and their habitats).

Te Mana o te Taiao – Biodiversity Strategy (TMOTT) (2020-2050)[32]: The aim of this strategy is for the protection, restoration and sustainable use of biodiversity, particularly indigenous biodiversity, in Aotearoa New Zealand. One of the tasks is to clarify the roles and actions of local government to protect biodiversity. A key matter raised is the need to better manage land use that accelerates erosion, sedimentation, and eutrophication, which undermine water quality and the species (e.g., pāua) which depend on these habitats. The initial Implementation Plan (2021-22) set in place systems needed to deliver the strategy, with a second implementation plan developed for 2023-2025. Implementation planning will run on a 5-year cycle from 2025 onwards for the life of the strategy, with review of progress over the previous 5-years informing the development of each new plan.

National Environmental Standards for Plantation Forestry (2017) (NES-PF):[33] (Commercial and customary) This sets the standards for regulation of the management of forestry activities to maintain or improve environmental effects. The NES-PF was revised in 2022 with proposals which give local councils greater control over where forests are planted as well as the ability to be more stringent in their responsibility associated with the National Policy Statement for Freshwater Management (e.g., the responsibility to minimise any detrimental effects to waterways and adjacent environments). The occurrence of multiple extreme weather events in the PAU2 zone during 2022 and 2023 resulted in severe damage to infrastructure and near-shore habitats, and the transport of sediment into the near shore coastal environment. The contribution of forestry to excessive sediment and debris loads called into question the social license of operators. This led to a *Ministerial Inquiry into Land Use (2023)*[34] and a review of the activities of forestry operations. The review makes no mention of the impacts that forestry activity caused to coastal ecosystems and the related livelihoods associated to pāua and other kaimoana. The review recommends restricting large-scale clear-felling of plantation forests in the region to minimise sediment risk as well as strengthening infrastructure, whereby if actioned this could enhance and better safeguard the access to and from coastal areas. There is also a prospective driver of change from carbon credit providers, in which such plantations may be more closely audited by investors to ensure carbon offset investments do not create negative environmental and social effects.

There are also non-legislative initiatives that are relevant to pāua and pāua habitats. These include the Aotearoa Circle Seafood Sector Adaptation Strategy and the Fisheries Industry Transformation Plan. These initiatives represented multiple stakeholders, whose work may be able to influence policy and or research investment directives to support pāua and pāua habitats.

Seafood Sector Adaptation Strategy (2021-2030)[35]: This is a voluntary and non-binding strategy developed across the commercial seafood sector and with government agencies in a process facilitated by The Aotearoa Circle (Marine Domain). The strategy focuses on safeguarding the cultural, ecological, social, and economic fabric of the seafood sector in a changing climate, in

[32] Aotearoa New Zealand Biodiversity Strategy: Biodiversity (doc.govt.nz)
[33] National environmental standards for plantation forestry | Ministry for the Environment
[34] Ministerial Inquiry into Land Use | Ministry for the Environment
[35] Seafood Sector Adaptation Strategy — The Aotearoa Circle

which climate related risks and opportunities are identified. The strategy sets out the participating members' strategic goals to respond to climate change. The current stage of development is the implementation of group commitments as expressed in the strategy. A series of workshops were held in May 2023 to examine climate change risks and opportunities for selected fisheries.

Fisheries Industry Transformation Plan (ITP) (2023): The objective of this plan is to advance the recommendations of the Prime Minister's Chief Science Advisor's report, *The Future of Commercial Fishing in Aotearoa New Zealand*. Pāua featured prominently in that report and the PIC and Quota holders were championed as providing management options that safeguard the resource, albeit current legislative processes may enforce contradictory outcomes for the industry. The report supports the resolution of contradictions and suggests the Pāua management model could be extended to other fishery resources. Submissions to the ITP closed on the 11th of June (significant pāua quota owners Moana New Zealand, were amongst the submitters).

Summary

It is speculative as to how the customary rights holders and the pāua industry can exercise their interests in the development and or revision of policy. A resource barrier exists that makes it difficult for stakeholders to be involved in all the matters that shape positive outcomes for pāua and their habitats. In terms of pāua and ecosystem health, it may be a combination of exercising interests from customary and commercial angles where there are adverse risks created by activities adjacent to habitats. There is a relative disconnect between land-based and inshore legislation which creates a challenge to influencing better environmental outcomes for protecting pāua. A ki uta ki tai (from the mountains to the sea) approach has been advocated for (e.g., Davies *et al*., 2017; PCE, 2020; and in the NPS-FM and NZCPS) and identified as a more holistic approach to bringing together different legislation, but considerable work and coordination are required to move this beyond aspirational (e.g., PCE, 2020).

Guidance and prioritised commercial wild harvest sector strategic responses to address environmental risk and uncertainty.

Dr Tom McCowan and Storm Stanley (Pāua Industry Council)

This section details management tools and policy strategies that are available at both the government (Fisheries New Zealand) and Industry (PāuaMAC) level and discusses their utility in addressing environmental risk and uncertainty in pāua fisheries.

Management responses to environmental risk and uncertainty in pāua fisheries

Fisheries New Zealand management and some relevant legislated tools:

- ***Stock Assessment and TACC Setting*** – The primary tools for fisheries management available to Fisheries New Zealand are the setting of the total allowable catch (TAC), and more specifically for commercial fisheries, total allowable commercial catch (TACC). Fisheries stocks are evaluated periodically through stock assessments, approximately every three years. The primary output of stock assessment is the estimated biomass relative to virgin biomass (%B_0), and the target for most fisheries species including pāua is 40% B_0. Management decisions (i.e., adjusting TACC) are made to ensure that this target is being reached or at least trended towards.

  Pāua stock assessments do not specifically account for changing environmental variables, however, if environmental stressors had a significant impact on any of the input parameters (e.g., recruitment), it could be detected in outputs and potentially influence management decisions. The infrequency of stock assessments means this is not a very responsive process for managing fisheries given changing environmental stressors.

- ***Minimum Legal Size (MLS)*** – The MLS for pāua is 125mm around most of the fishery with a few regional exceptions e.g., 85mm in the Taranaki region. The purpose of MLS is to protect the spawning biomass for sufficient time to allow for adequate spawning contributions to sustain populations. Length at maturity and growth rates post-maturity are two critical biological parameters relevant for MLS setting. However, the regional variability in both these parameters means that the MLS of 125mm around most of the country is largely inappropriate. This is addressed in the commercial sector by fishing at larger minimum harvest sizes (MHS) (see below).

  The (in)appropriateness of the MLS may differ with changing environmental stressors such as increasing sea surface temperatures which can affect both length at maturity and growth rates. Changing MLS requires sufficient data and regulatory change which is a burdensome process. MLS as it is currently set and applied is therefore not a very appropriate or responsive tool given changing environmental stressors.

- ***Habitats of Particular Significance for Fisheries Management (HPSFM)*** –Section 9(c)I of the Fisheries Act (1996) outlines environmental principles that must be taken into account by those with powers under the Act and requires that HPSFM should be protected. HPSFM is not defined in the Act. Fisheries New Zealand is developing guidelines for its interpretation, the wider fishing industry has developed policy for its implementation, and the Pāua Industry has developed a framework for how this could be applied in practice for the management of pāua fisheries. The Pāua Industry position is that HPSFM 'protection' should extend to also ensuring their protection from environmental stressors (McCowan and Gibbs (2021). While this framework is yet to be tested, it is a potentially powerful tool to affect government decision making and improve the management of pāua fisheries that are potentially susceptible to environmental stressors.

- ***Section 11A of the Fisheries Act*** - *Fisheries Plans* – Fisheries Plans are Ministerially approved plans that outline industry management strategies and actions. Plans detail industry management tools and are operationalised in the Annual Operating Plan (AOP, see below) for respective PāuaMACs. Fisheries Plans have been approved in all the major paua Quota Management Areas (QMA), except for PAU2. Fisheries Plans and the strategies and tools within them must be considered by the Minister when making sustainability decisions in relation to that fishery. Importantly, they must also be considered in any decision making under the Resource Management Act making them a potentially powerful instrument for management in the context of environmental stressors (e.g., for mitigation of sedimentation)

Industry:

Annual Operating Plans (AOP) – AOPs are written and agreed upon each year by respective PāuaMACs. The AOP outlines industry management strategies and tools that are to be abided by harvesters for the coming fishing year. In PāuaMACs with approved Fisheries Plans (described above), AOPs are formally recognised, and the tools used must be considered by the Minister when making sustainability decisions. The management tools typically contained within a PāuaMAC AOP are detailed below. They can be adjusted on an annual basis (or more frequently by agreement), making management more responsive to potential environmental effects on pāua fisheries than the government tools detailed above.

- ***Catch-spreading*** – this is used to limit the amount of catch (as a proportion of the TACC) that comes out of a specific statistical area or defined zone. It is used to mitigate the risk of serial depletion of pāua populations, and to spread effort into areas that are less productive or more challenging to fish and therefore which might not be as favoured by harvesters. Catch spreading is a useful tool to manage fisheries susceptible to environmental stressors as commercial closures or caps can be implemented at fine scales in a responsive manner (e.g., in response to a flooding or storm event)

- ***Minimum Harvest Size (MHS)*** – MHS is applied to harvest pāua at sizes (above the MLS) that better reflect the fine-scale variation in biological characteristics of pāua populations (specifically growth and length at maturity). MHS is implemented in all the major pāua QMAs, for example, five different MHS are in place in PAU7 up to a maximum of 145mm. MHS can remain an effective tool given environmental changes. More specifically, if increasing sea surface temperatures reduce growth rates post-maturity, they can be adjusted on an annual basis. However, they cannot be lower than MLS, adjustment of MLS below 125mm raises the challenges outlined in the Minimum Legal Size section.

- ***Fine-scale data collection*** – Fisheries data is collected to inform government stock assessments and to guide industry management decisions. Catch per unit effort (CPUE) data is now collected electronically and can be visualised in real time to guide catch spreading tools. Commercial catch length frequency data is routinely collected from across the fishery, as well as growth and length-at-maturity data. Ongoing data collection is essential to enable responsive management with environmental stressors. For example, a decrease in localised CPUE after marine heatwave could indicate a mortality event that might require catch spreading away from the location to allow recovery.

- ***Enhancement*** – there are several ways that the fishery can be directly enhanced including:

    - *Translocation:* This involves moving pāua from slow-growing habitats to faster-growing, locally depleted habitats to increase the growth of translocated pāua into the fishery and to enhance the spawning biomass in receiving locations. Translocation has been trialled around most of the country's pāua fisheries under special permit and is likely to be adopted as a larger scale management tool. Translocation is a promising tool to manage fisheries with environmental changes to utilise slow(er) growing populations which may no longer reach MLS to sustain faster growing areas, especially in the context of a rigid MLS of 125mm which may exclude certain parts of the fishery in the future.

    - *Reseeding (Figure 2):* Involves releasing hatchery raised juvenile pāua into the wild to augment natural recruitment or to restore populations in areas where recruitment limitation has occurred (either from recruitment overfishing or due to environmental stressors). The utility of reseeding in the context of enhancing pāua fisheries subject to environmental stressors, must be carefully considered, as high mortality of vulnerable juvenile life stages (e.g., caused by sedimentation) may make reseeding unviable.

Figure 3: Juvenile reseeded pāua. Photo credit: Pāua Industry Council

Annual Catch Entitlement (ACE) Shelving – this is the voluntary reduction of catch (under the TACC) by Quota Share Owners to reduce pressure on the fishery when there are concerns about its status. It is a useful tool in the context of environmental stressors, as catch can be reduced more responsively (on an annual basis) compared to formal TACC adjustments which can only be made every three years or so.

- ***Harvest Control Rules (HCR)*** – these are pre-set decision rules that determine the level of catch from a QMA (or part of a QMA) based on an agreed performance index (usually standardised CPUE). They have been effectively trialled in the southern pāua QMAs (PAU5A, 5B and 5D) where results have been used to drive small changes in catch in some instances. At present they only have utility in reducing commercial catch apart from in QMAs where industry shelving is in place allowing catch to increase. HCRs are another potentially useful tool to manage fisheries with changing environmental stressors as catch can be adjusted annually (or within a year) basis based on real time fisheries data. The utility of HCR will improve significantly with the ongoing collection of fisheries data to inform models that estimate the performance index.

Summary

There is a suite of tools available for the management of pāua fisheries at both government and industry levels. Generally, those conducted at the industry level (i.e., PāuaMAC) can be implemented in short time frames and at finer scales than the central government level, potentially giving a greater scope for adaptive business risk management. To make the best use of this more fine-scaled management ongoing collection of fine scale fisheries data is required, as is formal affirmation of industry-level management techniques in Fisheries Plans.

Conclusions

The improving marine climate science in Aotearoa is providing guidance on the scales and rates of marine environmental change. But we cannot wait until there is 'perfect' information because there will never be enough information in a highly dynamic, changing world. In New Zealand we have insufficient marine environmental information of all types to provide highly accurate information for management. Fisheries management is also neither sufficiently agile nor responsive to the evident environmental change already occurring. Responsiveness needs to be increased and based on the most real time data possible (e.g., harvest control rules).

This situation is not helped by the complexity of and disconnect between land-based and inshore legislation and management jurisdictions which create challenges in influencing better environmental outcomes for pāua. At the very least, including terrestrial stressors in management responses to protect Habitats of Significance for Fisheries Management (Section 9(c) of the Fisheries Act 1996) seems necessary (McCowan *et al* 2023).

Moreover, although existing data, scientific knowledge and expert opinion can all be used to highlight probable impacts, it is presently difficult for customary rights holders and the pāua industry to exercise their interests in the development and or revision of policy.

As the companion reports make clear, further research is needed to specifically understand the effects of changing environmental stressors on pāua fisheries at both the fine-scale and larger fishery scales. For PAU2 it is particularly important that these are understood under forecasted climate change projections as this area is already suffering from temperature induced low growth rates. Because of this it is also critical to develop an understanding of how changing environmental stressors potentially influence outputs in the stock assessment process, as this is currently the driving mechanism for broad scale management responses. Such improved knowledge and data are also essential to inform industry and fishers use of relevant scenarios in the risk model (see the section titled "Model Use" in Short *et al* 2023).

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Part 3: Model description, financial perspectives, and pāua quota value risks

Short K[36], Craig T[37], Smith C[38], and Spicer D[39]

Executive summary

This report is one of three from the Sustainable Seas Science Challenge Risk and Uncertainty Project 3.3: Upholding the value of Pāua Quota. The project has explored how to better understand, assess, and factor in the key environmental risks of climate change and sediments (exacerbated by climate change) to the fishery and subsequent pāua quota values to inform fisheries management, fishery investors and financiers, and the development of response strategies by all.

At its heart, embedding climate change into business decision making requires new approaches to risk modelling. What were once considered externalities in so far as being external to the business and therefore not captured or reported on, are now often referred to as non-financial risks. Businesses are not only having to internalise these impacts but are also having to measure and report on them. Increasingly, advocacy groups and the wider society are expecting it, legal frameworks are requiring it, corporate governance organisations are recommending it, and premium markets are specifying for it. However, neither fisheries management, fishing sectors (whether commercial, customary, or recreational), nor seafood business financiers, investors, and insurers, systematically account for any "value change" that may be related to environmental change, either as risks and or opportunities for current portfolios.

This Part 3 report builds on the previous two reports:

Part 1. Environmental Risks Facing Pāua and Summarised Natural Hazard Risks to Pāua Operations.

Part 2. Pāua Fisheries Management and Legal Considerations.

It complements and extends them by describing the various elements required by the corporate governance, legal, finance and banking sector to identify and address the risks they identify. These are used to inform the newly developed Pāua Quota Valuation Bio-Economic Model (the Model).

Bioeconomic models are analytical tools that integrate biophysical and economic models. These models allow for analysis of the biological and economic changes caused by human activities. The biophysical and economic components of these models are developed based on historical observations or theoretical relationships. The models are often developed at farm, country, and global scales, and are used in various fields, including agriculture, fisheries, forestry, and environmental

The Model is designed to enable financiers, investors, and fishery managers to consider the implications of a range of possible scenarios where climate stressors may affect mortality, growth, and recruitment rates and which impact the available biomass above the 124 mm (legal pāua shell size) that currently supports the PAU2 commercial fishery. A Model Manual describes its operation and is provided in a separate appendix. This report concludes by synthesising key

[36] Partner, Terra Moana Ltd
[37] Partner, Terra Moana Ltd
[38] Ex-Securitisation, ANZ Bank New Zealand Limited
[39] Sustainable Finance, ANZ Bank New Zealand Limited

themes from across all three reports to make recommendations for future work that can build on the key insights and learnings gained through the research.

Climate science is improving such that we now have projections of warming water moving south which is important as pāua growth slows in warmer waters, with a trigger point around 21°C. Pāua physiology is also negatively affected by sediment, however, we do not know the quantities and or concentrations sufficiently to include them as predictive triggers in the Model. Thus, the Model includes 16 scenarios of how pāua populations could potentially be impacted.

The model we have built is intended to provide technical assistance for assessing the impact that climate change will have on fishery productivity and therefore quota values under various modelled scenarios. It is innovative in translating the fishery biomass stock assessment model, used for fishery management, into a financial value scenarios model, and is readily available in a standard spreadsheet format. By using simplified methodology that is well described for future operation, we hope we have provided a means of making a complex subject area more accessible, easily understood, and adaptable both as information improves for pāua, and for other fishery types.

Introduction

Uncertainty is the only certainty especially in the case of highly dynamic marine environments that are subject to multiple environmental stressors (Hunsicker, 2016). The marine environment is facing increasing environmental change including heat waves, pollution (including from microplastics), sedimentation, ocean acidification, sea level rise, and other climate change caused perturbations (Gerrard, 2021; Ministry for the Environment & Stats NZ, 2019). Uncertainty in the response of a system to stress, and potentially unknown cumulative effects of multiple stressors increases risk to its inhabitants and to the whole system. These cumulative effects pose risks to seafood businesses, and uncertainty arises in the when, where, and severity of impacts, and in any interaction outcomes (Taylor *et al*., 2015).

By 2027, the global market for seafood is projected to reach $199bn[40] – up from $159bn in 2019 (Topping, 2022). In New Zealand the seafood sector is estimated to contribute around $2 billion in export earnings (Seafood New Zealand, 2022). The recent New Zealand United Kingdom Free (UK) Trade Agreement (FTA) includes preferential access for New Zealand seafood including immediate 16% tariff removal on New Zealand hoki and green lipped mussels entering the UK. The NZ-European Union (EU) FTA is due to enter into force in 2024 and provides access, along with requirements for corporate sustainability governance, including for imported products (European Commission, 2022) that New Zealand seafood exporters will need to meet.

In recent years leading New Zealand seafood companies notably Moana New Zealand (MNZ) and Sanford have begun sustainability journeys to respond to the evolving context and have also found opportunities for operational business improvement in doing so. However, challenges remain in understanding the exact types and levels of environmental and climate related risk, their factoring in business analysis and management, and in fishery and associated catchment management, and therefore how to prioritise and invest in types and levels of response to address those risks. Furthermore, addressing some risks may support good public and private outcomes and therefore require consideration in terms of how they are funded, including through blended financing of a mix of public, private, philanthropic, and community investment to mitigate challenges e.g., replanting coastal margins to address issues such as sedimentation

[40] https://www.digitaljournal.com/pr/seafood-market-to-reach-us-198854-86-million-globally-by-2027-at-2-9-cagr-the-insight-partners

and collaborative marine environmental monitoring including mātauranga and citizen science.

While most of this report discusses risks general to the New Zealand seafood industry, the overarching project focusses specifically on pāua, particularly the east coast North Island, South Wairarapa pāua fishery known as PAU2. The report is structured to provide information on how quota values are determined, how financial institutions are requiring climate and nature-related risk disclosures and, finally, the development of a Pāua Quota Valuation Bio-Economic Model. This model is designed to enable fishery financiers, investors, and managers to consider the implications of environmental stressors that may impact the available pāua biomass (above the 124 m legal pāua shell size) and thus the values of the fishery in productivity and quota terms.

Pāua quota values and risks

Tony Craig (Terra Moana Ltd)

Pāua is a taonga species to Māori and is culturally and commercially significant (Leach & Boocock, 1993). Since the Māori Fisheries Settlement in 1992, Māori have gained ownership of 51% of the commercial Pāua fishery quota nationally with Moana New Zealand (MNZ) holding 31.5% of the total on behalf of all Iwi. Pāua is a valuable export product worth on average $50-60 million annually (Pāua Industry Council (PIC) *pers. comm*.). With respect to the project focus of PAU2, this fishery is unique in that large tracts of the total Quota Management Area (QMA) coastline are not fished commercially. For the commercial component of the PAU2 fishery, Māori collectively own 71.9% with MNZ holding 53.9% of that total. The area encompasses various iwi rohe moana (tribal marine areas) currently being applied for under the Marine Area Coastal Act (Takutai Moana, 2021). While being an important customary fishery to Māori, pāua is a popular recreational fishery for many people. The PAU2 QMA is a region with water temperatures ranging from warmer in the north to colder in the south. These limit pāua growth rates and size whereby they are smaller in its northern regions than at more southerly latitudes (Naylor *et al.*, 2006). PAU2 has also experienced recent marine heatwave events and sedimentation events (e.g., Cyclone Gabrielle), both of which are expected to affect pāua biology (McCowan et al 2023).

General risk factors for quota values

Specific information about pāua quota ownership and valuation is given in Short et al (2023). Here we simply add that from a demand perspective pāua has always attracted a high market premium because of its product attributes and due to its relative scarcity. Globally, poor management understanding, external influences (i.e., climate change) and illegal fishing for the black market, have had critical impacts over time on other abalone (pāua) fisheries around the world. While abalone farming has grown dramatically (particularly in China) the demand for wild caught abalone has remained high. Supply volumes in this instance are aligned to the stability of the fishery where rights to access the resource are held, and the supporting management framework that determines volume and other input controls.

What makes fisheries quota a unique asset?

Quota values are in essence driven by the fundamental attributes of security. These are tenure and access and demand and supply. With security and tenure, it can be argued that the quota management system (QMS), quota rights and their in-perpetuity nature provide the framework for greater right security and therefore tenure. However as is outlined below this is not always the case.

For instance, quota rights - in this case for pāua - are unique and while they hold many of the recognised attributes of other well-known rights/assets (i.e., land, buildings etc.) they fundamentally differ for the following reasons:

a) Fishing quota owner inability to diversify within their fishing operation i.e., as a farmer can in changing land use.
b) Access to the raw material is shared, including with non-quota owners.
c) Allocation decisions, production volume and management decisions are largely out of quota owner control, instead they are delivered by the associated Government Minister and agencies; and,
d) Quota owners have no power to avoid freeloaders reaping the benefit of internalised management decisions agreed by most quota owners that are designed to deliver increased fishery health and resilience.

It is useful to understand the evolution of quota by comparing it against other asset types, i.e., property (known as fee simple or freehold title). Quota was established through the QMS in New Zealand fisheries in 1986 (Fisheries Act 1983). The QMS was established in response to a previously weak regulatory regime where government tried to protect stocks by restricting fishing gear, closing fishing areas, shortening fishing seasons, and many other input controls.

As the 1991 Pearse Report to the Minister of Fisheries noted:

"*In New Zealand, as elsewhere, the weaknesses of this regulatory approach to managing fisheries became increasingly evident. Fishing fleets expanded well beyond the capacity needed to harvest the available catch, efforts to constrain fishing pressure failed to protect stocks from depletion, fishermen's incomes often declined, conflicts among fishing groups intensified, and governmental managers often found themselves on a treadmill of regulatory design and enforcement.*" (Pearse, 1991).

The QMS fundamentally changed New Zealand fisheries management to become a system based upon output controls (restricting the volume of fish that could be caught) rather than input controls (how, when, and where it might be caught).

Pearse's review, five years on from the introduction of the QMS and prior to the Māori Fisheries Act (1992), highlighted four key observations.

1. The quota system is a better way of managing fisheries and should be retained.

"*Virtually everyone I consulted - not only those who hold quota rights but also recreational, Māori, and environmental representatives, as well as governmental officials - agreed that the quota management system has proven to be a progressive innovation in fisheries policy.*"

2. Changes are urgently needed.

"*In my own opinion, too, substantial changes are needed. If the quota management system is to be retained and built upon, and if its potential contribution to fisheries management is to be realised, major improvements must be made to the quota system itself, and to the regulatory framework within which it is embedded.*"

3. Those who hold rights to fish should have more responsibility for managing them.

"*I found significant convergence of opinion in favour of assigning greater responsibility for managing fisheries and fishing activity to those who hold the rights to use the resources. The concomitants of this view are that users should bear the costs of management and be* *accountable for actions that impinge on other interests. This observation is, in effect, an endorsement of the idea that a system based on property rights, and the economic incentives that accompany them, can be an effective alternative to increasing governmental regulation. It also implies that the new approach has been adopted only partially, leaving scope for further development and improvement.*"

4. Environmental concerns are not well handled.

"*While the quota system facilitates the management of fishing, it depends on other processes to identify and protect public interests that are sometimes adversely affected by fishing. Such impacts take many forms, such as detrimental effects of fishing some stocks on the food supply of other stocks, mortality of seabirds and mammals caught up in fishing gear, damage to ocean habitats and impairment of aesthetic values. These concerns often call for sensitive weighing of non-commercial values against commercial values in determining allowable catch levels and the rules of fishing. The present, uncertain arrangements lack the confidence of both environmental groups and the fishing industry*".

Management responsibility

Scott (1988) provided early insight into how optimal fisheries management outcomes could only be achieved once each owner shared a stake in the management decisions.

"*An Individual Transferable Quota (ITQ) harvesting regime, requiring continued regulation, is best seen as only a brief stage in the development of management. Its evolution can be expected to continue until each owner has a share in the management decisions regarding the catch, and, further still, until he has an owner's share in the management of the biomass and its environment.*"

For many the transfer of responsibility for management was seen as an anathema as it was believed to be akin to allowing the "*fox into the hen house*". In trying to avoid this, a complex regulatory environment was developed and has remained in place. Adding to this, two other key changes in legislation occurred in the early years:

1) In 1990 the government decided to transfer the environmental risk in TACC setting to quota owners by removing compensation for quota reductions and by redefining ITQs as a portion of TACCs. In other words, quota ownership interests, as a % of the TACC, would remain the same through increases or decreases and only the kilos attached to such ownership would change.

2) Cost Recovery was introduced in 1994. McClurg (2000) provided insights into the tensions that existed between government and industry at the time.

    "*Although the concept of cost recovery had been discussed widely between 1991 and 1994, the statutory provisions that introduced a cost recovery regime to collect levies were drafted hastily with little consultation. While debate about cost recovery was largely free of the fundamental philosophical disagreements that characterised arguments about resource rentals, there was strong industry opposition to the actual mechanisms selected by the government for determining the cost recovery charges to be levied. The government was able to determine the quantity and quality of fisheries management services to be purchased, the identity of the service provider, the price of those services and the industry share of payment towards any joint goods.*" McClurg (2000).

These changes were significant in that government shifted the risk for TACC decisions directly to quota owners, but not the management responsibility nor the determination of the nature of research services that would underpin decisions. Furthermore, they would recover the research costs from industry even where industry questioned the relevance and efficiency of delivery of research and management respectively.

In the ensuing years the fishing industry has invested in its own research initiatives (many times in parallel to government funded research) to arm themselves with information from which to participate in the TACC setting processes contained within the Fisheries Act. In many instances industry research has proven to be of enhanced value to the process.

There are clear examples of this in the work undertaken by PIC and the PāuaMACs. They have undertaken a myriad of research programmes and management initiatives to improve understanding of the nature and extent of pāua stocks across Fisheries Management Areas (FMAs). This has significantly improved the information available at fine scale levels and in real time which has fundamentally changed the approach and nature of pāua fishery management. This reflects the situation envisaged by Scott in 1988.

Sadly, there is no regulatory support for these measures that would stop the "*freeloader effect*", whereby any management measures and or enhancement initiatives proposed by the PāuaMACs or PIC executives cannot be enforced on all quota owners. Thereby, freeloaders are enabled to benefit without contributing or committing to such measures.

Environmental concerns in a climate changing world

While the legislative changes of the 1990s focused on shifting environmental risk to quota owners for the setting of TACCs, "environmental risk" was not considered as explicitly then as the effects of climate change are requiring today.

Interestingly while elements of what is now known as ecosystem-based management (EBM) were considerations in the development of the original property rights framework, it has taken some thirty plus years for the debate to shift from managing fish stocks to seeking to better understand the ecosystems that support them. The emergence of EBM as a requirement for more holistic fisheries management is an important, positive step in the right direction.

Rights comparison

The law describing the nature of the right hopefully underpins the characteristics of the right, i.e.:

- Exclusivity
- Permanence
- Enforceability
- Tradeability
- Divisibility
- Clarity

In the case of fisheries quota rights, exclusivity and enforceability are weaker attributes. Both are weakened by the nature of fish stock access, production, and allocation through TAC setting. Decisions around access and resource allocation are heavily susceptible to influence, where the ultimate decision rests with the Minister of the Government in power at the time. There can be little "value" in owning a right where one cannot access its opportunities/benefits.

Furthermore, quota owners cannot easily diversify their income streams. Their production depends on the ecosystem that supports that species and the management framework that determines production volume, access opportunity, and utilisation.

For most fisheries, the problems outlined previously have not been significant in impacting quota values. Continuing challenges include the time lags in the current management framework, access and allocation decision making processes, the apparent rapid acceleration of climate change, and its wider impacts which are all serious threats to fisheries.

Establishing quota value

The value of any asset is aligned to nature of annual free cash flows derived from its ownership/usage. Free cash flows are derived from revenue less all associated costs. Once identified it is then possible to capitalise those free cash flows based on an expected rate of return (ROI) that include normal business influences and any specialist risks associated with assets ownership.

However, a review of the QMS by Batstone and Sharp (1999) suggests that the price of quota likely reflects current and future biological and economic conditions in the fishery.

"*The price that attaches to quota is determined endogenously. Thus, active firms buy and sell quota as long as the additional value to the firm is greater than (less than) the market price. Two important results follow. First the total quota will be caught by the most efficient firms. Second, the market value of quota provides summary information about the current and future conditions – biological and economic – in the fishery*."

It is uncertain however, whether climate change was a major factor in their considerations and, if it was not, an equilibrium status may have been assumed. If so, one might assume that the Batstone and Sharp (1999) conclusion of future conditions might be extended to include future "environmental, biological and economic" conditions.

In 2004 the Aotearoa Fisheries Limited (AFL) Quota Trading Team sought to establish a valuation methodology to transfer assets from Te Ohu Kaimoana to AFL (now Moana New Zealand) under the Māori Fisheries Act (2004). At the time it was extremely difficult to identify quota trading values in the official FishServe Register – this continues to be the case. This was because of:

a) the drop in registered quota trading volume over the years,

b) considerable distortion in the values of the trades due to intercompany transfer pricing; and,

c) people simply not logging actual values (legally not required).

Deloitte was commissioned in 2004 to develop a Weighted Average Cost of Capital (WACC) Model to guide establishing the transfer value described above and what AFL Moana should look for as a return on investment (ROI) when determining quota price for future quota purchases. Deloitte advised that the ACE register provided much more comprehensive trading data and because of the increased ACE trading volumes the values were more likely to reflect more robust market pricing.

The method to determine WACC asks the question: *what the acceptable rate of return should be from the ownership of the asset commensurate with normal business risk and any associated risk peculiar to the assets ownership*? While complicated, it starts with the official government bond rate to which a range of factors aligned with normal business risk are applied. A BETA factor is then added for a particular risk to the asset class. In the case of pāua the BETA factor equals government intervention, shared fishery issues etc.

ACE in this case is treated similarly to that of rent for a property and is deemed to be the "free cash flow" one gets from the ownership of the asset (less costs which for pāua would be MPI and PāuaMAC levies). The ACE price assumes it is a price that a fisher would pay to have dive access knowing a) what the chances of catching all the ACE were (strength of the fishery); and b) how much they are prepared to be paid to catch it. In other words, ACE + Diver Price = Port price.

The AFL Deloitte exercise established an ROI rate of 8.05% (2004). This is ironic given this is close to where things currently stand. To establish quota value this ROI requires applying a Net Present Value (NPV) multiplier of 12.42 times the ACE price (1 being infinity / .085 ROI =12.42 x ACE price). This would then equate if the following existed: Ace Price Average $21.30 Mt x 12.42 $263,818 per Mt quota value.

If the risk is higher the WACC rate will be higher and quota values would be lower (i.e., 10% ROI = NPV multiplier of 10 = Quota Value $212,414 per Mt **or** ROI 3.5% = NPV multiplier of 28.57= Quota Value $606,989 per Mt). In today's climate, this is where many quota owners are anxious having paid for quota when interest rates were low and have now risen significantly. This situation is possibly creating challenges for debt servicing, as is evident now in the housing market.

Having determined the average free cash flows and then applying a WACC rate (NPV multiplier) one can then:

1. Identify the possible average quota price per MT that may have been paid throughout each year (as outlined above).
2. Establish the possible value of the total fishery per year by then multiply the annual average quota value "1" above by the TACC.

For the purposes of the comparison this research did not look at individual Ministry for Primary Industries (MPI) / PāuaMAC levies for each year. Instead, last years' MPI levies across the previous years were applied. One might question why use the TACC when in PAU7 the catch was a lot lower at times; however, as stated it assumes the ACE price would and should reflect uncertainty.

Two New Zealand pāua fishery value comparisons

From a commercial perspective it is evident there are varying levels of performance and success across pāua fisheries in New Zealand. Perhaps none more so than the comparison between PAU2 (Central Hawkes Bay/Wairarapa) and PAU7 (top of the South Island) highlighted in Figure 1).

The graphs below compare the two fisheries and highlight:

- PAU2 (Figure 1a): Constant at 121MT TACC during the period; b) catch has nearly always matched the TACC allowances provided; c) much less volatile value per MT quota estimate increasing in later years as information and certainty improved; and d) estimated per MT quota value 2019/20 $400,000.

- PAU7 (Figure 1b): By contrast a) the TACC has reduced from 260MT to 89MT during the period; b) There have been many occasions where the catches have not reached the allowances on offer; c) the estimated price per MT has fluctuated considerably; d) the price per MT has been gradually dropping; and e) estimated per MT quota value 2019/20 $325,000.

- Because of the continuing reduction in the volume of quota sales, for the purposes of the exercise, average ACE trading prices have been used over the period from the official government register administered by FishServe NZ. As mentioned above, these prices provide more comprehensive trading data sets than quota trade information. As noted above this was an important piece of advice provided to Aotearoa Fisheries Ltd by Deloitte.

Note: The graphs below (Figure 1a and 1b) have been designed to illustrate the comparative difference in supply certainty and the contribution that supply certainty makes to maintaining value. Interestingly it is worth noting the lift in quota price values per MT in PAU7 following Quota Cuts post 1999-2003 and again in 2016-17. This could be interpreted as a response to scarcity and/or confidence in the state of the fishery going forward.

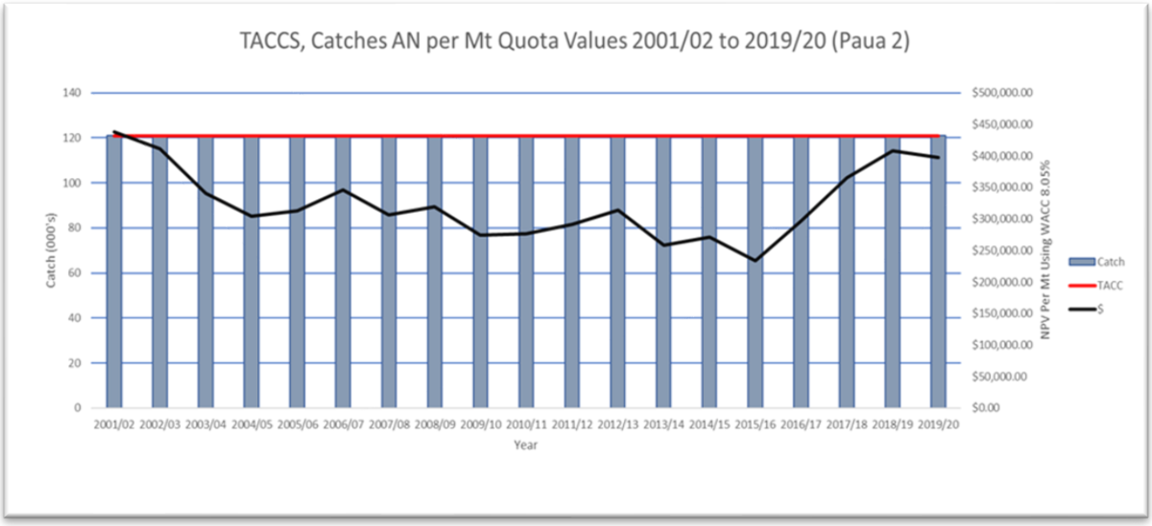

Figure 1a: PAU2 Catch versus TACC and estimated quota prices per MT 2001- 2020. Note the different scales on the Y-axes.

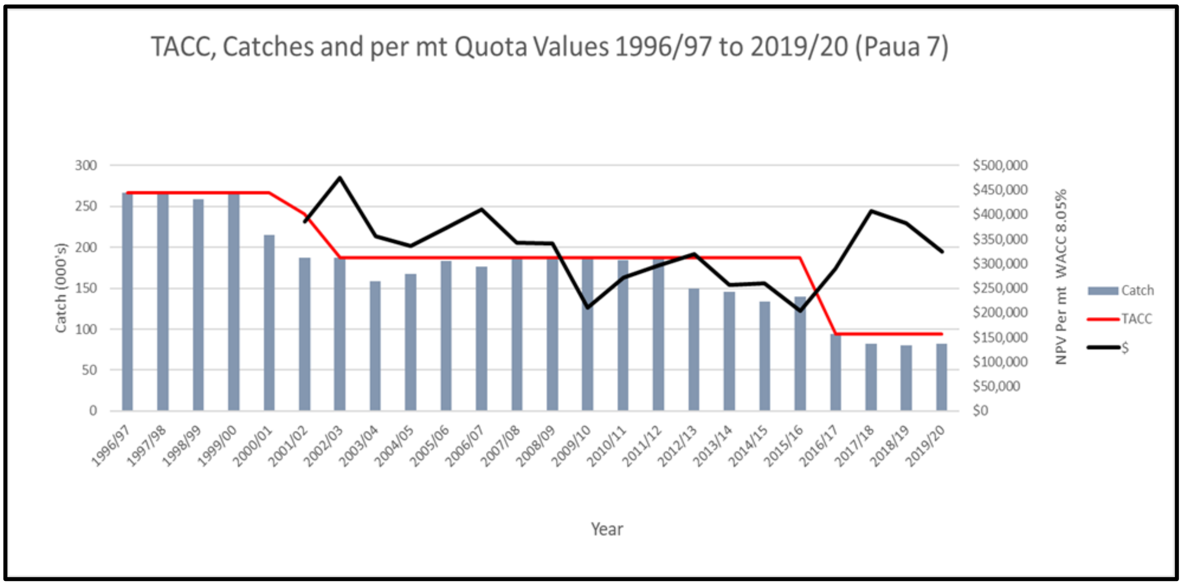

Figure 1b: PAU7 Catch versus TACC and estimated quota prices per MT 1996 -2020 Note the different scales on the Y-axes.

Figures 1a and 1b highlight the difference in estimated balance sheet values of quota in the respective fisheries. PAU2 fluctuated between NZ$30M - $50M, while PAU7 dropped from a high of NZ$118M to just under NZ$30M. The total value estimates are driven through a simple capitalisation of average ACE (lease) prices for each year in question (Figures 2 and 3).

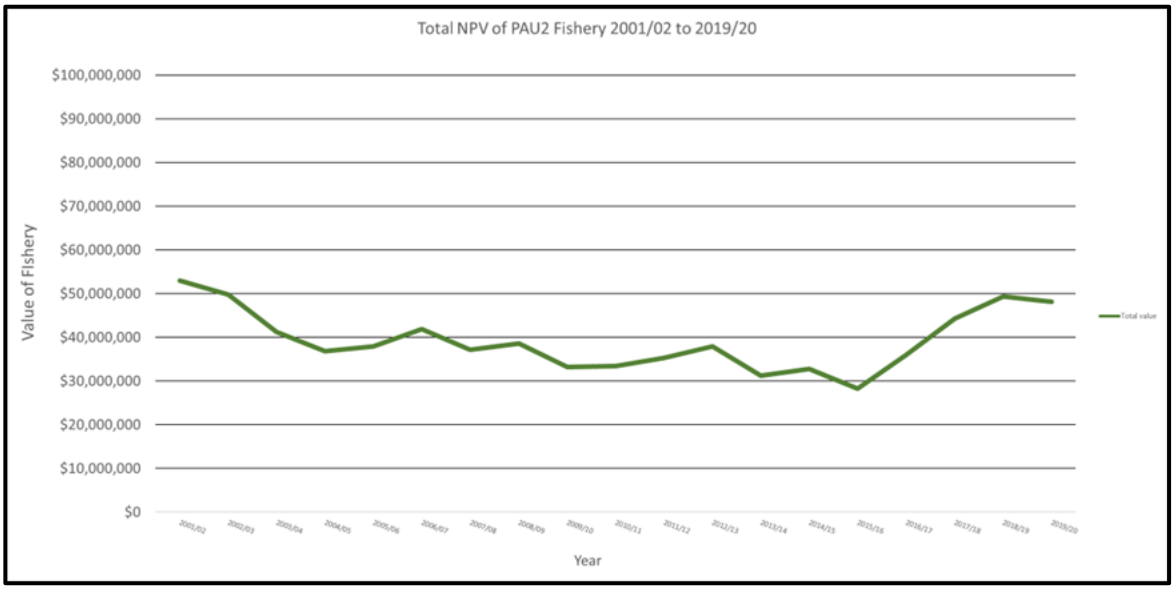

Figure 2: PAU2 Estimated Total Fishery Value 2001 – 2020

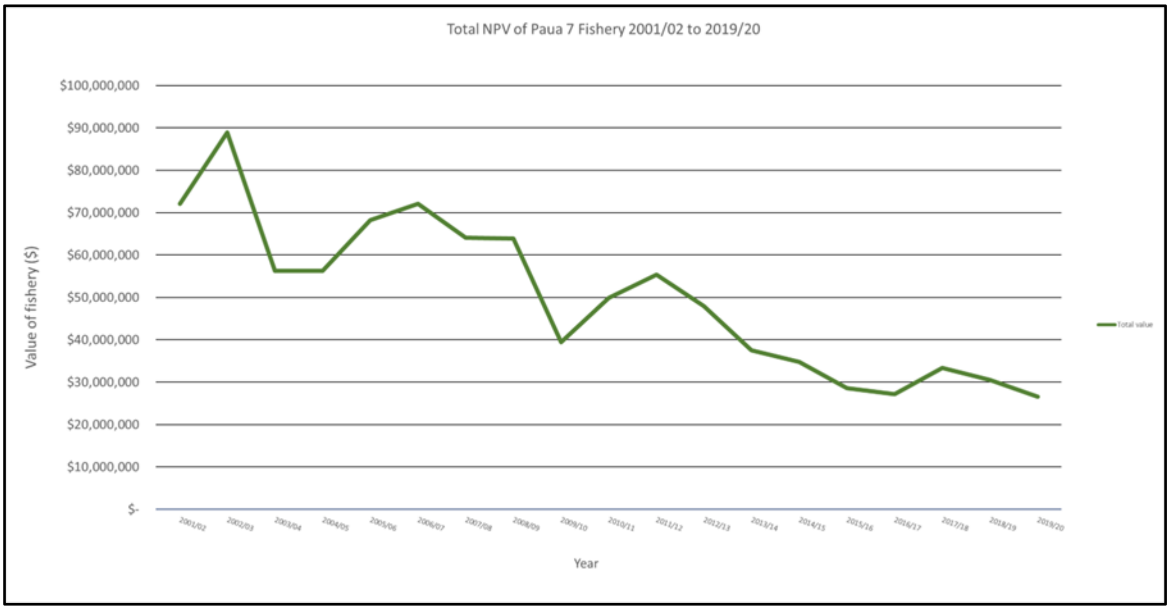

Figure 3: PAU7 Estimated Total Fishery Value 1996 – 2020

Risk factors for pāua quota ownership

Whilst this research project reviews risks that pāua quota owners face from climate change (McCowan et al 2023), there are other risks that impact on quota values. A simplified catalogue of the known risk factors that could impact valuing pāua quota are presented in Tables 1 and 2 and in McCowan et al (2023).

Table 1: Climate change risks within scope of this project

Environmental Factor (in Scope)		**Potential Impact**
Warming	Pāua	Susceptibility of juvenile and adult pāua to short term heat waves is unknown. Impact of prolonged heat waves on reproductive cycles is unknown.
Warming	Growth rate	Understood that growth above 80mm slows once water temperature passes an estimated 21.5°C (Moana Project).
Warming/MHW	Food sources impacted	Seaweeds are negatively impacted at higher temperatures
Sediments	Pāua	Assumed impacts on pāua energy consumption as they physiologically cope with sedimentation (respiration etc). Uncertainty about impacts of prolonged suspended sediment events. Impact of suspended sediments on reproductive cycles unknown.
Sediments	Pāua	Weakens the animal's substrate adherence capabilities. Juveniles and adults can be smothered by large-scale sedimentation events. Reduced availability of settlement sites
Sediments	Food sources and juvenile settlement sites	Seaweeds are negatively impacted by elevated suspended sediments and sediment deposition
Salinity	Pāua	Instances of significant washups assumed to be caused by prolonged exposure to reduced salinity seawater, resulting from elevated river flows and freshwater held against coastlines during storms.
Sea level rise	Pāua	Limited knowledge of how stressors impact pāua across their depth range
Acidification	Pāua	Known to have significant impact on larval development, with higher proportions of abnormally developed larvae at pH 7.8 and below.
Storms	Habitat Impacts	Potential for large storms to impact habitat structures (boulder movement, submerged logs), and habitat disturbance (lost weed) as evidenced in Cyclone Gabrielle.
Storms	Infrastructure	Increasingly severe and frequent storms are disrupting normal operational road access for divers to the fishery in the form of slips, washouts, and other damage.
Storms	Operational	The increasingly severity and frequency of storms reduce diver days in the water given storms increase turbidity and higher wave action is dangerous for diving.

Table 2: Other risks not within scope of this project.

Risk Factor (External)	Impact
Political implications	Management and allocation decisions controlled by Government Minister, and which is exposed to political pressure.
Management decision making	PāuaMACs not able to impose additional localised management decisions on all quota owners that can enhance QMS outcomes (i.e., the freeloader problem still exists).
Social considerations	Common access available and shared fishery with customary, recreational interests influencing allocation decisions. Lack of catch data to inform decisions accurately particularly for the recreational sector. Others can directly benefit from PĀUAMAC decisions (furthering the freeloader issue).
Customary considerations	For Māori it is regarded as taonga and critical for manaakitanga and for many for their sustenance needs, particularly rural. Expectation through the Māori Fisheries Settlement that these needs have priority and are respected and enforced.
QMS inflexibility	Still operating on historical fisheries management approaches and ecosystem-based management (EBM) is slow to be implemented. Inflexible and insufficiently responsive to current and emerging management and operational challenges i.e., climate change impacts.
Data collection and analysis	Insufficiently fine scale nor captured across the necessary geographical range, or information spectrum to understand impact trends from differing stressors. Disaggregated datasets. Expensive to collect in the marine environment and lack of coordination, cooperation, and collaboration. Investment required all round to address these issues.
Research responsiveness	Largely focused on research to manage the fishery not the ecosystem that supports it. Underfunded despite its wider significance and value to NZ.
Policy responsiveness	Difficulty in aligning to the new world order of ecosystem-based management demanding more inclusive, flexible, and responsive management frameworks.

Where are we now?

It appears that progress has been slow to address the following points highlighted in the Pearse (1991) report.

- The Quota Management System - The fundamental premise of removing the race for fish that occurred under the previous regulatory regime remains sound, although QMS review calls persist.
- Management Changes - Unfortunately the complex regulatory framework referred to by Pearse (1991) still exists with around 4,500 current fisheries regulations still in existence, let alone the multiple regulations affecting the environment (see Craig et al 2023).

- Responsibility for management – Perhaps the most contentious component of the Pearse report remains the most mis-understood component of reform suggested in the review.
- Environmental Factors – Whilst the fishery-environmental change research base is gradually improving, fish stock management responses are still complex, cumbersome, time consuming and not well-adapted to a rapidly, environmentally changing world. Precise information about fishery and species responses to environmental stressors is lacking and there is no marine environmental monitoring system in place to quantify change and impacts.

Scoping the intersection of environmental risks with emergent climate change corporate disclosure requirements

Dean Spicer (ANZ Bank New Zealand Limited) and Katherine Short (Terra Moana Ltd)

"Climate change mitigation efforts and the physical impacts of climate change itself will fundamentally change economies the world over, having significant impacts on economic and social conditions. In this setting, organisations that are not adapting strategy to take climate change into account are planning for a world which doesn't exist." Zoe Whitton and Wendy Mackay, Pollination Group.

Business sustainability and transparency of disclosures

Access to capital and the costs of capital are linked to the sustainability of the business and transparency of disclosures.

Global investors who fund the financial system expect the banks that they invest in to have developed clear sustainability strategies and to report transparently on their progress through regular disclosure statements aligned with market practice. The New Zealand mandatory Climate Disclosure reporting requirements, due to come into effect from 2024, align with investor expectations.

A growing number of banks, accounting for 40% of global banking assets so far, have committed to the Net Zero Banking Alliance (NZBA), including Australasian banks. Under the alliance, signatories will work to align their lending and investment portfolios with net zero emissions by 2050.

For New Zealand, a country with a unique emissions profile that is unlike many other OECD countries, work to support decarbonisation pathways will require unique solutions. For example, if New Zealand is to meet its international emissions reduction commitments, bank engagement and support for clients in material sectors is critical to support innovation, partnerships and research that can help drive transition, particularly in difficult to abate sectors such as agriculture.

The NZBA commitment is complementary to the work New Zealand banks are doing to understand climate impacts across material sectors in New Zealand under the Climate Disclosure reporting requirements. A local approach is required to first identify material sectors, then to set Paris-aligned decarbonisation targets for these sectors. Banks must then engage with their lending clients to support them in their transition plans if the banks' financed emissions are to meet their commitments. There is a clear alignment of stakeholder expectations for improved sustainability practices of businesses they engage with. To retain market access to our key export markets, the integrity of the supply chain will be paramount as food and fibre traceability becomes increasingly important.

Responsible investors are aligned with these expectations. A 2022 survey of New Zealand Kiwisaver investors highlighted that:

- ~50% of Kiwis consider it important that their fund provider sets targets to reduce emissions, commits to reducing GHG emissions of the companies within the fund, and or pledges to a net zero emissions target by 2050.

- 73% of Kiwis expect their investments to be ethical and or responsible and 56% would switch funds if their current manager invests in companies not aligned to their values.

Financial institutions face the same stakeholder expectation as any other business. As highlighted above, their customers, capital providers, staff and the wider community are all key stakeholders in the financial system, as are the regulators.

The Reserve Bank of New Zealand - Te Pūtea Matua (RBNZ) has released draft guidance for the financial sector on managing climate-related risks (the Guidance). Feedback on the Guidance was due by 7 June 2023, accompanied by a Consultation Paper for managing climate-related risks.

The Guidance seeks to support the regulated entities ("entities") the RBNZ regulates, broadly representing the banking and insurance sectors, and covers five sections:

1. **Climate-related risks** – describes how these risks impact upon entities and identifies the need to give climate-related risk specific analytical consideration.
2. **Governance** – emphasises that with climate related risks, like other risks, the responsibility for effective management lies with the board of directors. Our earlier sections have covered the importance of strong governance in managing climate risks and opportunities. The RBNZ views good governance as essential and highlights the XRB's Climate Standard CS1, requiring Climate Reporting Entities to explain the role that the board plays in overseeing climate related risks and opportunities. Such governance oversight should apply across all businesses.
3. **Risk management** – describes how climate risk manifests through conventional risks and should be embedded within the risk management framework. We will look at this in our next section.
4. **Scenario analysis** – provides the RBNZ's latest thinking on how entities should develop scenarios analysis capability. Acknowledged as an evolving area, entities should be starting to develop this capability now. This is also considered in the following section.
5. **Disclosure** - references the new mandatory climate-related disclosure regime in New Zealand.

The XRB has provided the Climate-related Disclosures standards for New Zealand reporting entities. These have been informed by the globally recognised Task Force on Climate Related Financial Disclosures (TCFD). TCFD have provided examples of climate-related financial information aligned with requirements under the framework. The banking sector financed emissions are a significant area of focus and this is where they can have the largest impact: i.e., by engaging with their borrowers to support them to establish or strengthen transition plans.

Also relevant is the Taskforce on Nature Disclosures (TFND) which encourages companies to produce integrated climate-nature disclosures and to develop appropriate risk management processes. In New Zealand it is likely there will be many opportunities to integrate and better reflect Te Ao Māori in TNFD, including through WAI262.

WWF estimates $44trn of value generation, representing more than 50% of global GDP, is moderately or highly dependent on nature, biodiversity, and the services it supports. In December 2022 Aotearoa New Zealand joined 200 parties in adopting the Kunming Montreal Global Biodiversity Framework at the Convention on Biodiversity (CBD) Conference of the Parties (COP15) meeting.

This framework, agreed by CBD parties, commits countries to the 30 by 30 initiative to protect 30% of land and oceans globally by 2030. Importantly, the framework also reflects an understanding that climate change and biodiversity loss are inextricably linked and must be addressed together.

The Ministry for the Environment and Department of Conservation are exploring a biodiversity credit system that could '*incentivise the protection and restoration of native wildlife in Aotearoa New Zealand*." They are seeking feedback (due 3 November 2023)[41] on the need for and design of the system and the different roles of government and Māori in implementing such credit systems.

Data is essential

Notwithstanding that one cannot manage what is not measured, to report against any of these frameworks, data is essential. In the marine arena data is expensive to collect and what has been collected is disaggregated. Research within the Sustainable Seas Blue Economy programme notes the importance of collaborative approaches to marine environmental monitoring to share the costs of collecting and storing the data. This is the case for factors such as temperature, turbidity, and other environmental status indicators, as well as cultural health and mātauranga, where Māori data sovereignty and governance must be addressed.

Figure 4 describes the relationship between improving environmental monitoring, blue economy businesses, their corporate disclosure domestically, and how these feed into the international environmental disclosure frameworks. Having evidence-based response strategies reduces risk and the evidence for both the state of the marine environment, and the efficacy of response strategies that come from having appropriate data and information. There are a range of new technologies emerging that can enable this including measurement instruments designed for the harsh conditions in the marine environment, which can be placed on marine infrastructure including vessels. Remote sensing is also emerging as an important mechanism.

For blue economy businesses, having strategic goals, policies, objectives, and analysis about the state of the marine environment underpins brand, enables compliance, can improve social licence and shareholder confidence, and can also lower the cost of capital. Furthermore, the better the response strategies to address the environmental risks, the lower the company risk profile. Because of the fluid nature of the marine environment, environmental monitoring, and response strategies need to be multi-stakeholder and collaborative.

[41] Helping nature and people thrive – Exploring a biodiversity credit system for Aotearoa New Zealand - Ministry for the Environment - Citizen Space

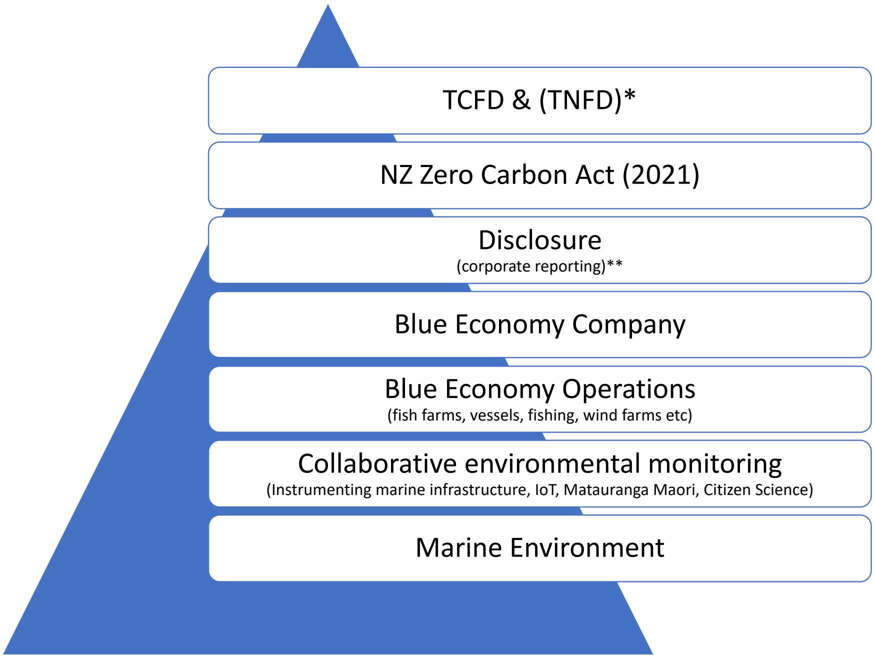

*Figure 4: Risk Reduction Pyramid. Source: Terra Moana Ltd. *TCFD = the Taskforce on Climate-related Financial Disclosures. New Zealand's mandatory climate related disclosure 'CRD' regime is aligned with the TCFD framework. The CRD regime applies to reporting periods starting 1 January 2024.; TNFD = Taskforce on Nature Disclosures. This is further documented in the Sustainable Seas Report Sustainability Disclosures in the Blue Economy.*

Frameworks to inform strategy development in the seafood sector

The importance of an aligned strategic focus has been highlighted in several papers, including those referenced below – they each call for a sector-led response that is embraced by all stakeholders.

Some key frameworks of note that we believe our modelling efforts align to include:

The Mana Kai Initiative - The Purpose and Values of Aotearoa New Zealand's food system

The Mana Kai Framework takes a Te Ao Māori worldview:

"The most significant implication of taking this approach, and the greatest departure from conventional food systems work, has been the placing of the protection and regeneration of the environment as the first priority in the framework. We believe that only in ensuring the strength and resilience of te taiao, will we ever be able to create a food system that can deliver the abundance we seek to meet both our domestic needs and to create the economic prosperity that underpins the functioning of our society."

The Aotearoa Circle - Seafood Sector Adaptation Strategy

The Aotearoa Circle provides strategic goals and specific objectives that tie into a new Seafood Sector roadmap for implementation. Relevant to scenario modelling and data capture are:

Objective 2.1 – business models which focus on long term resilience and purpose-led adaptation.

Objective 3.–3 - transparent communication of how data and information are used to make adaptation decisions.

Objective 3.–4 - insights into the evolution of risk and opportunity in the seafood sector are captured and lessons learnt from adaptation are gathered to inform decision making.

Sustainable Seas National Science Challenge – Blue Economy Principles

The Blue Economy Principles for Aotearoa New Zealand are a new proposed framework for marine industries (Figure 5). These were developed based on international blue economy principles while taking account of the unique Te Tiriti-based context of Aotearoa New Zealand.

Figure 5: Source: Sustainable Seas Science Challenge Blue Economy Principles 2023. This is further documented in the Sustainable Seas Report Blue Economy Principles.

*Chapter Zero New Zealand **Board Tool Kit***

The tool kit provides a practical framework for board members to use to ‘ensure the climate challenge is being effectively addressed at the board table’.

The tool kit covers five steps to ensure the board is prepared:

1: Ensure the right board oversight
2: Establish the need for change
3: Set direction and plan the change
4: Embed and sustain the change
5: Monitor and optimise

'Achieving the right board oversight requires the right knowledge, whole value chain transparency, and a shift from seeing climate action as compliance to seeing it as a fundamental strategic imperative.' Chapter Zero.

We have highlighted the Banking case study from the Chapter Zero tool kit below. It shows 'Climate related considerations across the value chain'.

How is the financial system approaching climate risk?

Stakeholder expectations on businesses are rapidly changing with a shift from shareholder primacy, where the purpose of the firm was to maximise shareholder returns, to one of stakeholder primacy, where businesses need to consider wider stakeholder values. Successful firms will ensure that they deliver satisfactory financial (and environmental and social) impact returns.

This shift may seem to create a conflict with the profit maximisation mantra; however, firms that embrace the need to align purpose and profits with the expectations of their stakeholders will ultimately maximise stakeholder outcomes.

Global environmental, social and governance (ESG) drivers are affecting all businesses (Figure 6) and are also relevant to the New Zealand financial system. New Zealand's dependence on international funding is high for a developed economy, with offshore bank funding equating to around two thirds of New Zealand's net external liabilities, according to RBNZ data from May 2022.

Deloitte (in their report 'Asia Pacific's turning point') estimate that climate inaction will cost the region US$96 trillion by 2070, including US$2 trillion for Australia and New Zealand.

Conversely, gains from decarbonisation are estimated at US$47 trillion over the same period, including US$860 billion to Australia and New Zealand.

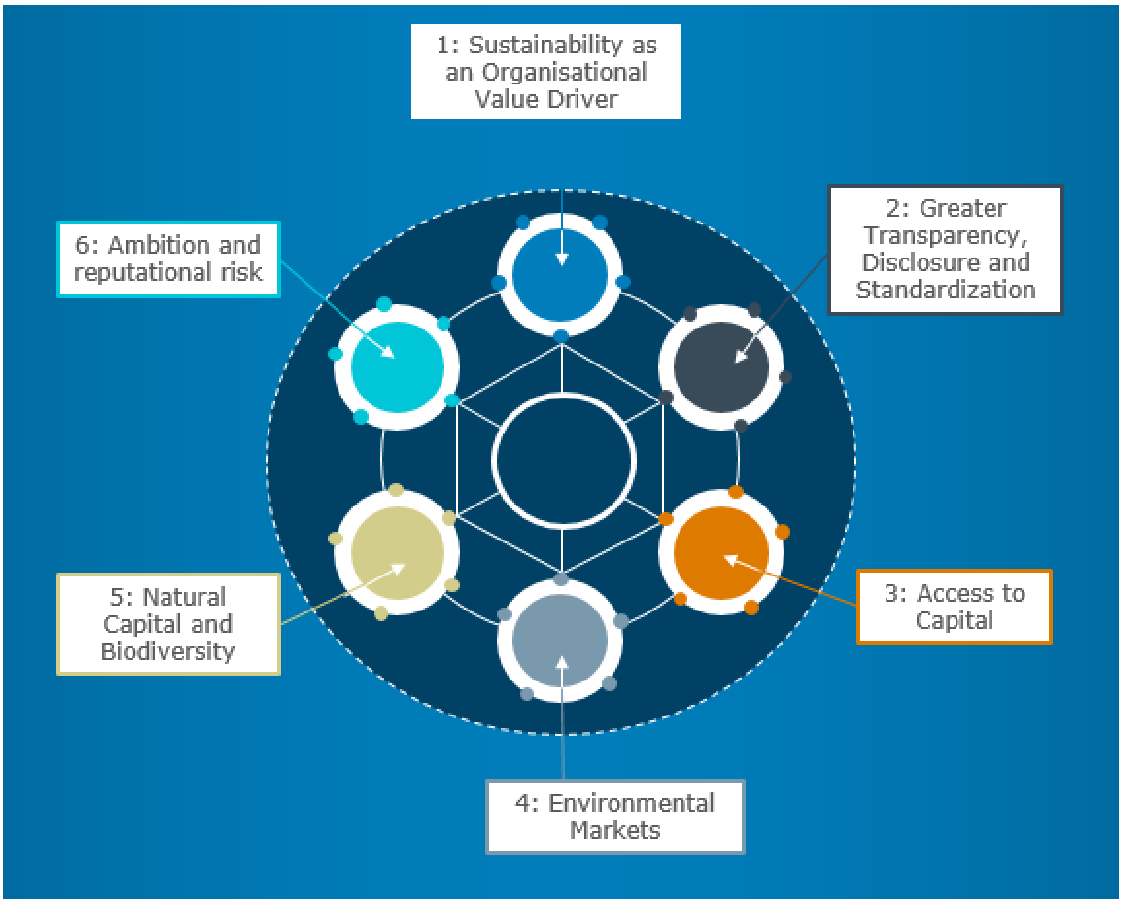

Figure 6: Global ESG Trends Increasing Focus. ANZ NZ.

Case study: ANZ customer engagement on sustainability and decarbonisation

ANZ Bank New Zealand Limited (ANZ) engages across their customer base through proactive conversations, products and services that support decarbonisation and sustainable business practices.

For large institutional customers, ANZ proactively engages on transition plans, emissions reductions, and ESG targets in the following ways:

1. Proactive discussions as part of regular customer engagement with large clients on three key elements of the transition plan: governance, targets, and disclosures.
2. Engagement on ESG and climate strategy and targets as part of how the bank structures sustainable finance deals, such as Sustainably Linked Loans, which provide advantageous financing for clients that meet set agreed sustainability targets.

ANZ also engages with Business, Corporate and Personal customers through products and services, for example through customer insights and education, and by providing lending products with advantageous rates to support customers moving to more sustainable and energy efficient practices.

For example, the ANZ Green Business Loan can be used for financing or refinancing for:

- renewable energy,
- energy efficiency,
- green buildings,

- sustainable land use,
- sustainable water and wastewater,
- clean transportation, and
- pollution prevention and control.

Customer conversations on their transition strategy and progress are a key enabler of uptake of these products. Relationship Managers often discuss a customers' business strategy for months before a customer chooses to adopt a specific lending product to support their decarbonisation plans.

Risk modelling

Risk modelling attempts to estimate the probability of an event occurring and the impact of the event should it occur. For example, insurance costs are derived from complex risk modelling that attempts to price the risk event by charging premiums that adequately compensate for the occurrence of future losses that the insurance company will pay out on.

In a business setting the more uncertain future revenue streams are, the lower the value ascribed to them. The value of an asset reflects the sum of the expected cashflows adjusted for the expected inherent risk.

Risk models can help us understand the change in value of an asset, for example quota values, under different scenarios. These scenarios can be adjusted to reflect potential 'what-if' scenarios that can be helpful in business planning and strategy development.

Embedding climate change into organisational strategy

At its heart, embedding climate change into business decision making requires new approaches to risk modelling. What were once considered externalities in so far as being external to the business and therefore not captured or reported on, are now often referred to as non-financial risks. Businesses are having to internalise these impacts and measure and report on them. Increasingly, advocacy groups and the wider society are expecting it, legal frameworks are requiring it, corporate governance organisations are recommending it, and premium markets are specifying for it.

The potential for climate change impacts needs to be factored into organisational strategy and considered in the company's value offering. Non-financial risks are quickly becoming core business financial risks and need to be captured in financial modelling.

The Pollination Group paper, Climate change and organisational strategy highlights two major roles that climate scenario analysis can play:

1. **Technical** – assisting in risk identification and supporting climate risk disclosures by quantifying value at risk for finance providers. This aids in the pricing of impacts of the risks on balance sheets and portfolio values.
2. **Insight** - supporting leadership teams to build an understanding, awareness and 'strategic intuition on climate change'.

The Pollination Group paper highlights the value in workshopping major scenarios with leaders, stress testing different scenarios, and utilising financing impacts and adaptation cost analysis in ongoing strategic decision making, planning and management.

This approach supports strong governance oversight of climate related risks and opportunities. It also provides organisations (private and public) with insights to describe the risks they face and *demonstrate the risk mitigation and resilience strategies that can underpin good environmental and social governance, organisational responsibility, stakeholder value and brand credibility.*

The value of scenario testing

The RBNZ Guidance highlights the value of climate-related scenario testing to provide stakeholders with an understanding of the 'resilience of its business model and strategy in both the short and long term'.

In relation to the financial sector, the RBNZ defines stress testing as '*a tool that subjects financial institutions to severe but plausible scenarios (and sensitivities) that are deliberately chosen for their potential to threaten the viability of their business model*'.

Pāua fisheries and, for that matter, many of the inshore fisheries in New Zealand, have significant customary and recreational fishing interests that increase risks related to political allocation decisions of the resource across sectors.

Section 21 Fisheries Act 1996

Matters to be taken into account in setting or varying any total allowable commercial catch:

(1) In setting or varying any total allowable commercial catch for any quota management stock, the Minister shall have regard to the total allowable catch for that stock and shall allow for—

(a) the following non-commercial fishing interests in that stock, namely—

(i) Maori customary non-commercial fishing interests; and

(ii) recreational interests; and;

(b) all other mortality to that stock caused by fishing.

The ambiguity associated with "allow for" has been repeatedly shown to open the door to potentially subjective and politically influenced decisions overriding sound research-based stock assessment. For Pāua fishery quota owners, this may feel daunting and outside the capabilities of the business and potentially futile if management interventions are constrained and or the rewards of risk analysis, resilience and mitigation cannot be fully captured.

Guidance to the financial institution highlights the use of scenario testing proportionate to an entity's size, business mix and complexity. For smaller firms, simplified scenarios may be appropriate. The guidance also acknowledges that climate risk scenario testing is:

- A developing area that is likely to evolve and become more sophisticated over time,
- An important starting point in assessing climate related risks.

Where there is a lack of data, appropriate qualitative assessments can be beneficial in providing insights into the operations risk exposure that can help inform business planning, strategy, and risk management practices.

Also relevant to the Pāua fisheries sector is the observation that smaller firms may be highly concentrated in a particular market, sector or geographical location that is exposed to material climate related risks. This is true for some Pāua quota owners and there may be value in a coordinated, catchment-wide approach to development of climate risk assessments, transition planning and, importantly, action plans related to execution of transition plans.

We hope that the model developed in this research project will help as a starting point in this process, but we acknowledge the inherent limitations of our model given the lack of detailed data: i.e., location/time based, on factors of climate change that may affect the Pāua fishery and the ecosystem that supports it, along with the challenges in modelling climate-related risks relative to traditional risk modelling highlighted in the RBNZ Guidance[42]. These challenges include:

- The non-linear nature of climate-related risks and the potential for '*irreversible changes in climate, leading to impacts that are not easily mitigated or reversed*'[43]
- The ability for climate-related risks to impact upon multiple lines of business at the same time, with the potential for financial stability impacts,
- Uncertainty in the time frames in which climate-related risks will materialise,
- The unprecedented nature of climate-change meaning that traditional risk assessment models that rely on historical data have the potential to systematically underestimate the impacts of climate change.

The level of complexity involved and the change that lies ahead for risk modellers is covered in a report from Mckinsey & Company: '*Climate models create significant risk and complexity. Model risk managers need a tailored approach to ensure they are fit for purpose*.

Climate change creates physical and transition risks that are complex, uncertain, and playing out in real time. To gauge the potential impacts on clients and portfolios, as well as the effects of mitigation measures, banks require new models, new documentation, and new model risk management (MRM) capabilities. With few precedents in hand, none of this is easy. And given the need for sector-specific methodologies, the finance industry is facing a significant talent deficit.

There are opportunities and challenges ahead. The challenges we have highlighted for modelling potential paths should not be seen as insurmountable or daunting. Embraced, they provide a framework for better stakeholder outcomes, to create a better future.

Developing an environmental-related risk model for PAU2

ANZ has partnered with Terra Moana Ltd and the project working group, believing an initiative like *Upholding the value of pāua quota* as part of the Sustainable Seas National Science Challenge will help advance our understanding in identifying and assessing the risks of climate change and other environmental stressors on the pāua industry.

Our aim was to create a *PAU2 climate-related risk bioeconomic model* to show stakeholders, including quota owners, investors, and financers, the potential implications of climate associated risks. The model we have built is intended to provide technical assistance for assessing the impact climate change will have under various modelled scenarios. The model is described in the section titled *The pāua quota valuation bio-economic model*.

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[42] 2022.03.02 Guidance - Climate-related risks (rbnz.govt.nz)

[43] Draft CPG 229 Climate Change Financial Risks (apra.gov.au)

The pāua quota valuation bio-economic model

Christine Smith (retired, ex-ANZ), Dean Spicer (ANZ) and Tony Craig (Terra Moana Ltd)

Background

The RBNZ Guidance[44] (detailed in the previous section pg20) for financial institutions highlights the use of scenario testing proportionate to an entity's size, business mix and complexity. For smaller firms, simplified scenarios may be appropriate. The guidance also acknowledges that climate risk scenario testing is:

- A developing area that is likely to evolve and become more sophisticated over time,
- An important starting point in assessing climate related risks.

The level of complexity involved and the change that lies ahead for risk modellers is covered in a report from McKinsey & Company: '*Using model risk management to address climate analytics: It's a process not a task, Climate models create significant risk and complexity. Model risk managers need a tailored approach to ensure they are fit for purpose*".

Where there is a lack of data, appropriate qualitative assessments can be beneficial in providing insights into the operations risk exposure that can help inform business planning, strategy and risk management practices.

There are challenges in modelling climate-related risks relative to traditional risk modelling highlighted in the RBNZ Guidance. These challenges include:

- The non-linear nature of climate-related risks and '*the potential for irreversible changes in climate, leading to impacts that are not easily mitigated or reversed*'[45],
- The ability for climate-related risks to impact upon multiple lines of business at the same time, with the potential for financial stability impacts,
- Uncertainty in the time frames in which climate-related risks will materialise,
- The unprecedented nature of climate-change meaning that traditional risk assessment models that rely on historical data have the potential to systematically underestimate the impacts of climate change.

The McKinsey report notes: "Climate change creates physical and transition risks. that are complex, uncertain, and playing out in real time. To gauge the potential impacts on clients and portfolios, as well as the effects of mitigation measures, banks require new models, new documentation, and new model risk management (MRM) capabilities. With few precedents in hand, none of this is easy. And given the need for sector-specific methodologies, the finance industry is facing a significant talent deficit".

[44] 2022.03.02 Guidance - Climate-related risks (rbnz.govt.nz)
[45] Ibid

Our model

Our model is simple, transparent and uses standard business spreadsheet software that can be run by non-subject matter experts. With the assistance of Phillip Neubauer at Dragonfly Data Science we developed a much-simplified version of some of the methodology in the pāua stock assessment model to derive an initial population for PAU2 and then model it over a 20-year period with various scenarios which impacted on recruitment success, growth transition, natural mortality ("instantaneous mortality") and fishing mortality.

The model was built in Excel and consists of thirty-nine worksheets. Two of the worksheets can be input by users to create and select scenarios and sub-zones. The remainder of the worksheets perform calculations, aggregate and graph results, or contain information as illustrated in the structure diagram below (Figure 7)

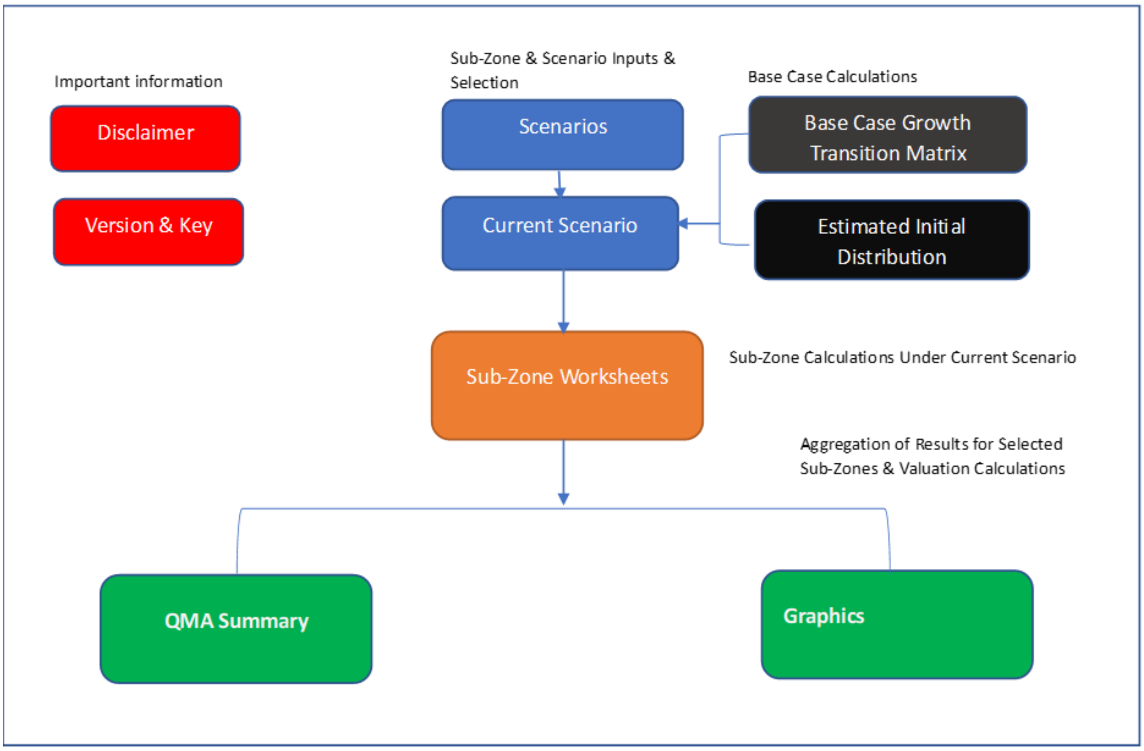

Figure 7: Model Structure

Model development

Model development was undertaken in three stages.

1. Firstly, workshops on pāua biology and lifecycle, the industry and the environmental risks were held. These established baseline knowledge for the team about the Wairarapa Coast PAU2 fishery. These workshops highlighted that pāua recruitment success and growth and mortality rates can be impacted by environmental stressors including those arising from climate change and sedimentation, but that effects are known to differ in different areas. It was proposed the model would be able to run scenarios for smaller regions with similar characteristics and biomass within the PAU2 fishery area rather than attempting to model the biomass for PAU2 as a whole. Caution

was expressed about the lack of any exact knowledge about levels of temperature or sedimentation that cause specific physiological responses in pāua.

2. The second stage of model development involved seeking an appropriate methodology for modelling the biomass and calculating the value of quota. We developed a much-simplified version of some of the methodology in the pāua stock assessment model to derive an initial population for PAU2 and then model it over a 20-year period with various scenarios which impacted on recruitment success, growth transition, natural mortality ("instantaneous mortality") and fishing mortality. In relation to quota valuation, traditional methodology was used but with the annual commercial catch projected by the model used as the annual catch entitlement. The main difference between our model and traditional methodology is the added transparency in calculating projected harvestable biomass within the allocated TAC and adjustments to the discount rate[46] in relation to other climate risks.

3. In stage three, a draft model was built to represent the base case (current situation in PAU2) and presented to the Shellfish Working Group and Project Advisory Group for feedback. Input was sought on the environmental stress scenarios and consequential impacts to model. These groups felt that there was no clear evidence of the long-term impacts of environmental stressors on pāua or the time horizon over which they could be expected to occur, except for the relationship between temperature and pāua maximum size attained where it is known that pāua grow larger in waters below 21.5^{o} Celsius. For this reason, we decided to base scenarios on several different hypotheses and allow them to be easily amended or supplemented in the future, if and when data becomes available which supports the actual impact occurring.

Model operation

The Model has been built in Microsoft Excel and can be found on the Sustainable Seas website.

The operation of the model is summarised in the following points. A more detailed explanation of the model is set out in the manual in Appendix 1.

- The model allows for up to 31 different PAU2 fishery sub-zones.
- The initial distribution of pāua by length (separated into length buckets i.e., shell length category from 70 mm to 170 mm in 2 mm increments) has been derived. These length-buckets are hard-coded into the model. The user determines the percentage of the population contained in each sub-zone.
- Potential impacts of climate change are modelled by allowing the user to create their own scenarios in relation to recruitment success, instantaneous mortality, growth transition (i.e., the movement of pāua between length buckets as they grow), fishing mortality and valuation factors over time. Users then select the scenario which is being run and the sub-zones to which it applies.

[46] The discount rate is the rate of return, which an investor expects to earn on an investment, taking its risks into account.

- Each sub-zone has its own calculation sheet which calculates annual recruitment success, growth, distribution by length buckets, pāua weight, recreational, customary, and illegal catch by numbers and tonnage, commercial catch by numbers and tonnage, instantaneous mortality and opening and closing balance numbers of pāua each year under the current scenario.
- The results for the sub-zones selected by the user are aggregated in a valuation worksheet. The net present value of the discounted cash flows and capitalised value of the annual available catch entitlement are calculated based on the valuation assumptions in the current scenario.
- The model graphs the results.

Model limitations and transferability

The methodology used in our model is a much-simplified version of the extensive New Zealand pāua stock assessment model which is presently used by MPI in management. We understand that it is currently under further development to factor climate change stressor impacts upon the pāua populations. Our model is designed as a first effort to establish a ***financial valuation tool***. The complementary use, if not ultimately merging, of these two tools in future could well provide a far more compelling information base and story line for enhancing management investment by both industry and government that truly reflects the needs of the changing marine environment.

Our model is not designed to provide truly accurate projections of future stock numbers. However, it does provide a methodology to run scenarios on fishery value. Nevertheless, the model provides a tool for testing hypotheses in relation to climate and other environmental change impacts. While the stock assessment model itself could be used to run scenarios, it is a scientific model which requires expert scientific input and management, which precludes public access and general use by quota owners, seafood business executives and non-experts. In addition, and importantly, the stock assessment model does not capture valuation data and or perform valuations.

For pāua, we currently lack comprehensive data on thresholds of responses to different environmental variables and are unable to explicitly model scenarios to assess the implications of climate and other environmental change. In the meantime, however, the model is a tool which could be helpful in projecting future stock *trends* based on known data, assisting with more active management of the fishery, understanding of factors which mitigate or exacerbate climate impacts, and guiding investment in response strategies.

It can also be used in its current form for assessing risk to pāua quota in other areas as it is built around the generic pāua stock assessment model. For other species, a simplified version of that species' stock assessment model could be used as a basis to structure a similar value scenarios model for that species. The length categories hard coded into the model would need to be changed.

Given the inherent variability and interactions in organism responses, the natural environment, and the magnitude and impact of environmental stressors, the model should be reviewed periodically to ensure that the methodology remains appropriate.

Model scenarios

Following is a list of the scenarios that we ran to test the model.

Scenario Name	Description
Base Case	The base case using some parameters from the stock assessment model. Used to calculate the opening biomass for PAU2.
Scenario 1	Mortality rate increases by 1% per annum (such as could occur with events such as heatwaves or sedimentation, or elevated fishing pressure). No change to other base case parameters.
Scenario 2	Mortality rate increases by 2% per annum. No change to other base case parameters.
Scenario 3	Mortality rate increases by 5% per annum. No change to other base case parameters.
Scenario 4	Base case growth transition for 5 years and then matrix 1 applies thereafter (no further growth greater than 160mm and proportional increase in proportions in length buckets between 70mm and 158mm). No change to other base case parameters.
Scenario 5	Base case growth transition for 5 years and then matrix 2 applies thereafter (no further growth greater than 140mm and proportional increase in proportions in length buckets between 70mm and 138mm). No change to other base case parameters.
Scenario 6	Base case growth transition for 5 years and then matrix 3 applies thereafter (no further growth greater than 120mm and proportional increase in proportions in length buckets between 70mm and 118mm). No change to other base case parameters.
Scenario 7	Recruitment success rate reduces by 1% per annum (such as could occur with a coastal acidification or sedimentation event). No change to other base case parameters.
Scenario 8	Recruitment success rate reduces by 2% per annum. No change to other base case parameters.
Scenario 9	Scenarios 1 and 4 aggregated.
Scenario 10	Scenarios 2 and 5 aggregated.
Scenario 11	Scenarios 1, 4 and 7 aggregated
Scenario 12	Scenarios 2, 5 and 8 aggregated
Scenario 13	200% increase in the mortality rate and 20% reduction in recruitment success, vis a vis the base case, in year 2 (such as may result from a sedimentation and freshwater event caused by for example, Cyclone Gabriel, or an extreme heatwave event). In other years and for other parameters base case assumptions apply.
Scenario 14	200% increase in the mortality rate and 20% reduction in recruitment success, vis a vis the base case, in years 2 and 4. In other years and for other parameters base case assumptions apply.
Scenario 15	200% increase in the mortality rate and 20% reduction in recruitment success, vis a vis the base case, in years 2, 3 and 4. In other years and for other parameters base case assumptions apply.
Scenario 16	200% increase in the mortality rate and 20% reduction in recruitment success, vis a vis the base case, in years 2, 5, 9 and 13. In other years and for other parameters base case assumptions apply.

To illustrate the model outputs, we have used an example scenario (Scenario 13). Under Scenario 13, the mortality rate increases by 200 per cent and the recruitment rate reduces by

20 per cent in year two in the selected sub-zones. This scenario mimics a hypothetical impact of instantaneous mortality and recruitment success from environmental stressors such as marine heatwaves, severe storms, increased sedimentation and/or a combination of multiple stressors. We are not predicting that such events will occur at within that time or that mortality increases, and recruitment success reductions, of those magnitudes will occur. The results of the scenario are shown in the tables and graphs below. For presentation purposes, we only show every second year. The aggregate results of this scenario for the selected sub-zones can be viewed on the QMA Summary sheet (Table 3) or viewed in graphic form on the Graphics worksheet in the Model.

Table 3 shows, in the top part of the table, the impact on pāua numbers. The bottom part of table 3 shows the weight of pāua caught both for customary, recreational, illegal fishing (CRIF) and commercial fishing and compares those with the expected CRIF tonnage and the TACC.

Recruitment numbers are lower and natural mortalities are higher in the impacted years. As no other changes have been made in the model in relation to the TACC, it is assumed that the maximum weight of pāua continues to be caught if it is available for fishing and sufficient pāua remain after CRIF to allow that.

Table 4 shows the impact of the scenario on the valuation of pāua quota. For the purposes of the valuations, the projected commercial catch is assumed to be the annual catch entitlement. The top part of Table 4 shows the projected internal rate of return (ROR) for an investment in pāua quota over a 10-year period under the valuation assumptions in the scenario – this is described as the traditional valuation method. The bottom part of table 4 shows the capitalised value over a 20-year period, that is the value of the investment each year at the current year's annual catch entitlement, taking into account the quota owner's weighted average cost of capital and any further adjustment which is made to reflect climate risks, e.g., increased costs as a result of more severe weather events.

As there is no reduction in the projected commercial catch vis a vis the TACC, there is no impact on the value of pāua quota under the scenario. Please note, we are not predicting that such an outcome would occur. This simply illustrates the impact of the scenario on the valuation using the assumptions in the scenario.

Table 3: Impact on pāua numbers under Scenario 13 whereby the mortality rate increases by 200 per cent and the recruitment rate reduces by 20 per cent in year two in the selected sub-zones.

Scenario Description	200% increase in the mortality rate and 20% reduction in recruitment success, vis a vis the base case, in year 2. In other years and for other parameters base case assumptions apply.

This table summarises the total paua numbers for the selected Sub-Zones

Paua Numbers Selected Sub-Zones	**Month**	**0**	**24**	**48**	**72**	**96**	**120**	**144**	**168**	**192**	**216**	**240**
	Date	**Mar-23**	**Mar-25**	**Mar-27**	**Mar-29**	**Mar-31**	**Mar-33**	**Mar-35**	**Mar-37**	**Mar-39**	**Mar-41**	**Mar-43**
Total Paua Numbers Opening Balance (excluding New Recuits)		11,393,070	8,281,261	8,571,192	8,792,123	8,962,124	9,091,861	9,191,584	9,269,524	9,331,610	9,381,906	9,423,169
Total New Recruit Numbers		1,586,207	1,586,207	1,586,207	1,586,207	1,586,207	1,586,207	1,586,207	1,586,207	1,586,207	1,586,207	1,586,207
Total Customary, Recreational & Illegal Fishing (CRIF) Catch Numbers		71,601	72,082	73,130	73,792	74,466	74,941	75,187	75,262	75,233	75,155	75,059
Total Commercial Catch Number		377,277	379,808	385,334	388,817	392,369	394,872	396,170	396,563	396,415	396,002	395,498
Total Instantaneous Mortality Numbers		1,305,240	980,782	1,010,298	1,032,880	1,050,148	1,063,352	1,073,579	1,081,649	1,088,134	1,093,425	1,097,785
Total Closing Balance Numbers		11,225,158	8,434,796	8,688,637	8,882,842	9,031,349	9,144,904	9,232,856	9,302,258	9,358,035	9,403,532	9,441,034
Weighted Average Length of Biomass (mm)		108.90	109.48	108.57	108.30	108.29	108.39	108.53	108.67	108.80	108.91	109.01
Number of Pāua Reaching Minimum Legal Size		3,728,349.73	2,716,520.57	2,493,458.89	2,388,025.96	2,370,161.49	2,402,694.51	2,457,292.65	2,516,326.88	2,571,188.60	2,618,934.31	2,659,355.58
Proportion of Pāua >= Minimum Legal Size		32.72%	32.80%	29.09%	27.16%	26.45%	26.43%	26.73%	27.15%	27.55%	27.91%	28.22%

This table summarises the weight of paua fished for the selected Sub-Zones

Paua Weight Selected Sub-Zones	**Month**	**0**	**24**	**48**	**72**	**96**	**120**	**144**	**168**	**192**	**216**	**240**
	Date	**Mar-23**	**Mar-25**	**Mar-27**	**Mar-29**	**Mar-31**	**Mar-33**	**Mar-35**	**Mar-37**	**Mar-39**	**Mar-41**	**Mar-43**
Total Expected CRIF Weight (kgs) Selected Sub-Zones		23,000	23,000	23,000	23,000	23,000	23,000	23,000	23,000	23,000	23,000	23,000
Actual CRIF Weight (kgs)		23,000	23,000	23,000	23,000	23,000	23,000	23,000	23,000	23,000	23,000	23,000
Actual CRIF Weight as % of Expected CRIF Weight		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Total Allowable Commercial Catch TACC (kgs)		121,190	121,190	121,190	121,190	121,190	121,190	121,190	121,190	121,190	121,190	121,190
Actual Commercial Catch (kgs)		121,190	121,190	121,190	121,190	121,190	121,190	121,190	121,190	121,190	121,190	121,190
Actual Commercial Catch as % of TACC		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Weighted Average Length Commercially Fished Paua (mm)		133.94	133.69	133.10	132.74	132.39	132.14	132.02	131.99	132.00	132.05	132.10

Table 4: The impact on the valuation of pāua quota under Scenario 13 whereby the mortality rate increases by 200 per cent and the recruitment rate reduces by 20 per cent in year two in the selected sub-zones. For the purposes of the valuations, the projected commercial catch is assumed to be the annual catch entitlement. The traditional valuation method is the internal rate of return (ROR) for an investment in pāua quota over a 10-year period.

Quota Valuation Selected Sub-Zones Valuation in in two formats: the traditional approach and capitalised value

	Month	0	24	48	72	96	120	144	168	192	216	240
Traditional Valuation Approach	**Date**	**Mar-23**	**Mar-25**	**Mar-27**	**Mar-29**	**Mar-31**	**Mar-33**	**Mar-35**	**Mar-37**	**Mar-39**	**Mar-41**	**Mar-43**
Volume (kgs)	121,190											
Price ($/kg)	$ 480											
Total Investment	$ 58,171,200											
CPI		6.10%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
Capital Growth	2.00%											
Annual Catch Entitlment		121,190	121,190	121,190	121,190	121,190	121,190					
Price ($/kg)		$ 24.50	$ 27.05	$ 28.14	$ 29.28	$ 30.46	$ 31.69					
Quota Levies ($/kg)		$ 0.50	$ 0.55	$ 0.57	$ 0.60	$ 0.62	$ 0.65					
Net ACE Income ($/kg)		$ 24.00	$ 26.50	$ 27.57	$ 28.68	$ 29.84	$ 31.04					
ACE Earnings		$ 2,908,560.00	$ 3,210,964.44	$ 3,340,687.40	$ 3,475,651.17	$ 3,616,067.48	$ 3,762,156.61					
ACE Yield		5.00%	5.52%	5.74%	5.97%	6.22%	6.47%					
Terminal Value ($)							$ 70,910,368.20					
($/kg)							$ 585.12					
Unlevered Cash Flows	-$ 58,171,200.00	$ 2,908,560	$ 3,210,964	$ 3,340,687	$ 3,475,651	$ 3,616,067	$ 74,672,524.81					
Unlevered IRR	7.11%											

	Month	0	24	48	72	96	120	144	168	192	216	240
Capitalised Value	**Date**	**Mar-23**	**Mar-25**	**Mar-27**	**Mar-29**	**Mar-31**	**Mar-33**	**Mar-35**	**Mar-37**	**Mar-39**	**Mar-41**	**Mar-43**
Annual Catch Entitlment		121,190	121,190	121,190	121,190	121,190	121,190	121,190	121,190	121,190	121,190	121,190
CPI		6.10%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
Price ($/kg)		$ 24.50	$ 27.05	$ 28.14	$ 29.28	$ 30.46	$ 31.69	$ 32.97	$ 34.30	$ 35.69	$ 37.13	$ 38.63
Quota Levies ($/kg)		$ 0.50	$ 0.55	$ 0.57	$ 0.60	$ 0.62	$ 0.65	$ 0.67	$ 0.70	$ 0.73	$ 0.76	$ 0.79
Free Cashflow ($/kg)		$ 24.00	$ 26.50	$ 27.57	$ 28.68	$ 29.84	$ 31.04	$ 32.30	$ 33.60	$ 34.96	$ 36.37	$ 37.84
Weighted Average Cost of Capital	8.05%											
Adjustment to the Discount Rate for Other Climate-Linked Risks	0.50%											
Aggregate Discount Rate	8.55%											
WACC Multiplier		11.69590643	11.69590643	11.69590643	11.69590643	11.69590643	11.69590643	11.69590643	11.69590643	11.69590643	11.69590643	11.69590643
Capitalised Value		$ 34,018,245.61	$ 37,555,139.62	$ 39,072,367.26	$ 40,650,890.90	$ 42,293,186.89	$ 44,001,831.64	$ 45,779,505.64	$ 47,628,997.67	$ 49,553,209.17	$ 51,555,158.82	$ 53,637,987.24

The Model contains a set of 4 graphs, which provide a visual representation of key outputs as follows:

Figure 8 compares the TACC with the estimated commercial catch under the scenario for the selected sub-zones,

Figure 9 plots the capitalised value and the estimated commercial catch each year in kilograms for the selected sub-zones,

Figure 10 plots the aggregate closing number of pāua each year for the selected sub-zones and compares that number with the number of pāua available for fishing each year under the scenario. It also plots the weighted average length of all pāua in the selected sub-zones under the scenario, which is useful for illustrating the impact of scenarios which result in slower growth and declining maximum lengths; and,

Figure 11 plots the weight of pāua available for fishing remaining after assumed CRIF under the scenario and compares that with the estimated commercial catch. This is also plotted in percentage terms along with the estimated percentage of aggregate pāua which have reached the minimum legal size for fishing each year under the scenario for the selected sub-zones.

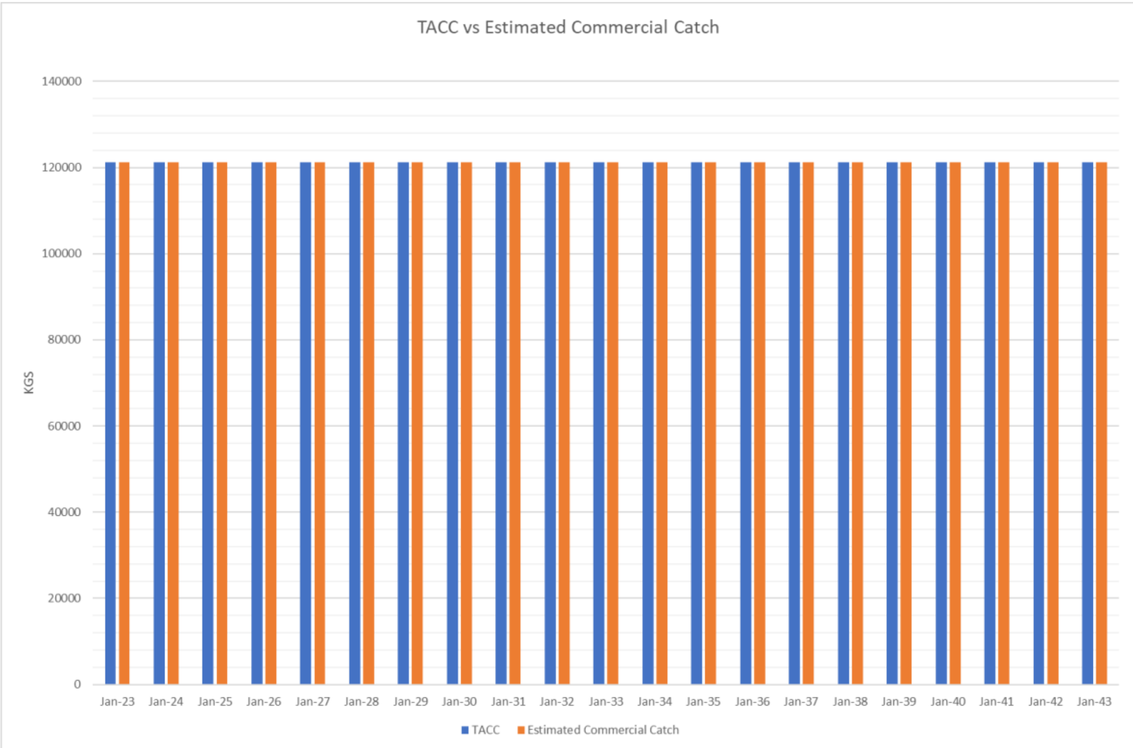

Figure 8: Comparison of TACC vs Estimated Commercial Catch

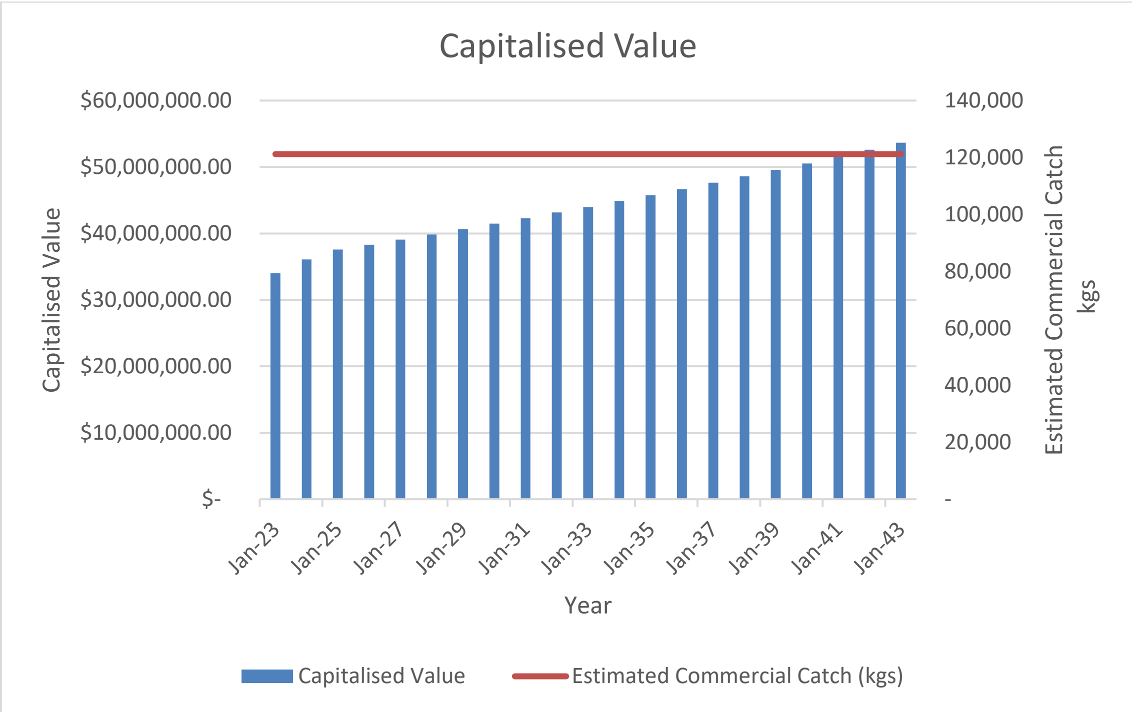

Figure 9: Capitalised value and estimated commercial catch (kgs)

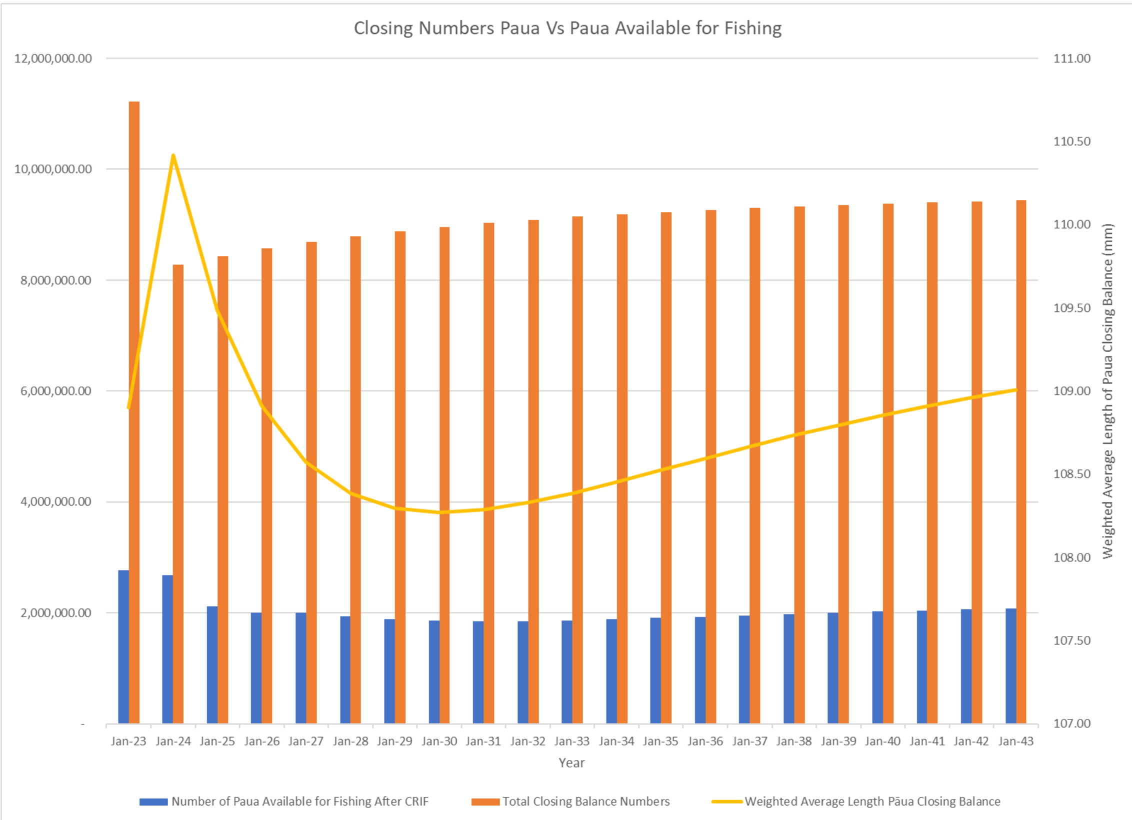

Figure 10: Closing Numbers of Paua versus Paua Available for Fishing

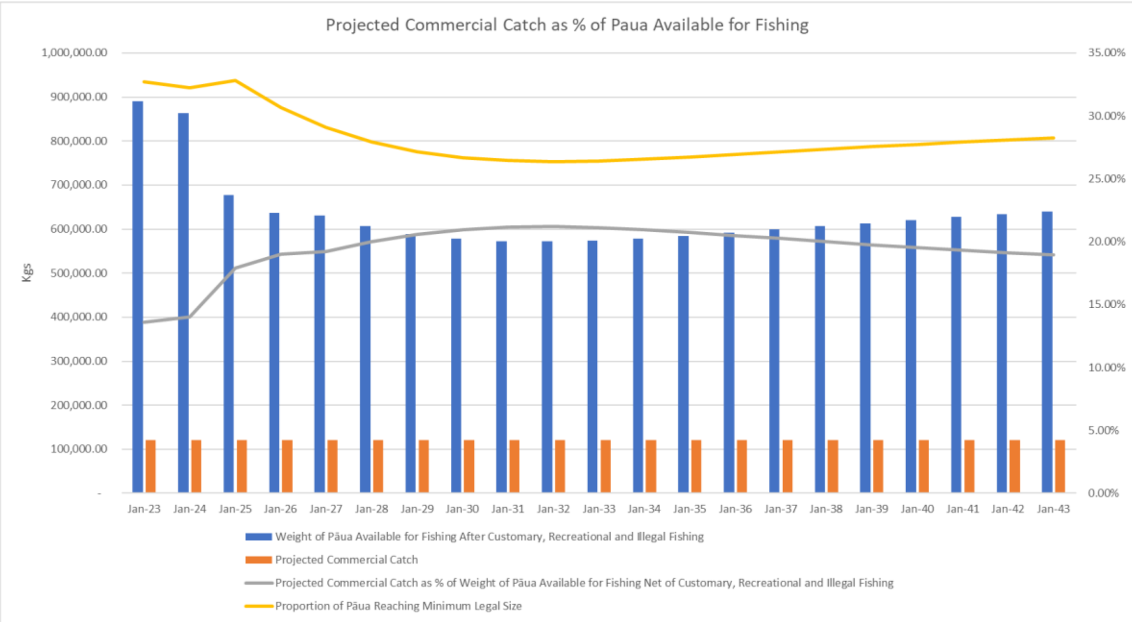

Figure 11: Projected Commercial Catch as % of Paua Available for Fishing

Model use

As the research to date suggests pāua stocks are unlikely to benefit from climate change. This therefore drives the need for careful risk analysis and targeted mitigation strategies. The model has been built to enable such risk analysis across sixteen climate and environmental change driven scenarios to the best extent possible at this point. Indicative value change is provided in relation to combinations of climate driven risks at various scales, and in the absence of more exact information about pāua individual, fishery, and coastal ecosystem responses to environmental change.

New research is essential to provide this information which would improve the ability to model scenarios and understand more detailed responses in terms of the timing of environmental changes. Fisheries New Zealand is currently researching climate change risks to commercial fisheries at the broader scale, but pāua specific physiological and ecological research is needed.

In the meantime however, the model can provide value to the following users:

Pāua quota owners

Pāua quota owners need to begin to assess the potential downstream impacts of differing climate change scenarios on the resource. This is both the right thing to do to inform business investment and management and is becoming increasingly important for the finance sector and for future sustainable financing opportunities. The ability to model likely change in abundance, size ranges, productivity and harvestability, as well as overlaying the infrastructure and accessibility challenges informs strategic policy setting, fisheries management and operational business decision making. The increasingly volatile, uncertain, complex and ambiguous world quota owners must operate in under climate change increasingly demands a more hands on approach to understand the ongoing dynamics of the fishery, the ecosystem that supports it and pāua needs in order to uphold value. Moreover, model scenarios could be used to determine changes in recruitment, growth and mortality that would have high impacts on business risk and be used to design experiments and data collection.

Pāua divers

Pāua divers will benefit from using the model to better understand what is happening in and across the fishery, year on year, in some cases “in year”, and over the long term. For example, during or post a year’s catch, a scenario could be run using that year’s observed recruitment running for future years. Being modelled across a range of potential scenarios enables better planning, at the area/paddock level, of more efficient harvest operations. As knowledge improves the model will likely identify the most likely scenarios that will produce optimal operational models. These will likely need to be mobile, agile and responsive to short term setbacks (weather events), and long-term change, as climate change unfolds.

For an investor

Investors will benefit in using the model through significantly improving their understanding of the potential impacts of climate and environmental change, and thus reduced uncertainty about such risks in their financing of pāua commercial fisheries. Where previously the finance sector largely relied on the information from and understanding of the borrower (Quota Owner or Diver), to know about long-term fishery outlook, this tool will allow the finance sector to engage at an analytical level not possible previously.

Investors (both providers of debt and equity) could use this new tool to test their own assumptions in relation to the potential impact of climate change on their exposure to the sector through investment in the sector and other parties which rely on the sector. While currently the value of the tool is limited, because users have to come up with their own assumptions, it could be more valuable in the future if data were to become available on the actual impact of climate and environmental change and consequent risks.

Currently, investors, using their own assumptions, could use the model in the following ways, as examples:

- Running different scenarios in relation a specific business (or all their impacted businesses) to model the impact of climate or environmental change on a company’s pāua related assets or income. For example, an investor could model some of the assumed impacts of higher sea surface temperatures resulting in slower and stunted growth in order to project future commercial catch for that borrower and quantify the impact on a borrower’s assets and/or financial strength, if any.
- Running different scenarios in relation to value to quantify the potential impact of climate scenarios on the assets and income of a fishery or seafood business. For example, an investor might wish to model the impact of a scenario which showed smaller commercial catch due to climate or environmental change but higher price due to scarcity, if considered likely, to assess the impact on borrower's assets and/or income.
- Modelling the impact of a severe weather event which may impact a region. For example, an investor may wish to assess the potential loss of income from lower commercial catch to one region by modelling higher mortality rates for affected areas in that region; and/or,
- Assessing risks in relation to aggregate exposure to the sector, by modelling the impact of different scenarios in different regions.

In future the model could acquire more detailed supporting information that includes not only commercial viability but the environmental, managerial and policy implications that would underpin such viability. Potentially, such conversations could lead to designing innovative response strategies such as building coastal ecosystem resilience and may support the development of environmental markets like a biodiversity credit scheme or blue carbon opportunities.

Furthermore, for all these direct users of the model, even in the absence of exact cause and effect data, the modelled scenarios show the increasing risk of cumulative environmental stressors on pāua and the coastal ecosystems upon which they rely. Through bringing the financial implications into sharper focus use of the model could underpin dialogue with landowners, regional councils, and inform engagement in consenting processes and improve climate change mitigation and adaptation approaches. Making financial analysis information more visible, the model therefore enables a sharper focus on the financial risks to the fishery, conversations between interested parties, and potentially a stronger coalition of the willing to address the climate change challenges facing the fishery and affecting value.

Summary and recommendations

Quota rights, in this case pāua, are unique and while they hold many of the commonly recognised attributes of other well understood rights such as property, they fundamentally differ. There is the inability to diversify, the access to raw materials is shared, and the management decisions are largely out of quota owner control. Quota owners also have no power over freeloaders reaping the benefits of internalised management decisions agreed by most quota owners, which have been designed to deliver increased fishery health and resilience.

Even without climate and environmental change, the factors outlined above mean that risks are naturally higher than conventional primary sector businesses. While it may be assumed that such factors would or should be factored into the current value of quota it is unlikely that values today consider downstream climate change impacts.

It is critical to analyse and model likely changes that climate and environmental change may cause to fish stocks. This requires undertaking the most appropriate and likely timebound research projects and defining and collecting the data necessary to assess the assumed and predicted changes. Such work needs to be prioritised to explore the necessary policy and management changes to respond to findings, ensure fishery resilience, and in turn uphold quota values.

Our aim was to create a ‘PAU2 climate and environmental related risk’ bioeconomic model to show stakeholders, including quota owners, investors, and financers, the potential implications of such risks. The model we have built is intended to provide technical assistance for assessing the impact climate and environmental change will have under various modelled scenarios. It is a tool which could be helpful in projecting future stock trends based on known data, and assisting with more active management of the fishery as well as the understanding of factors which mitigate or exacerbate climate impacts. By making the model readily available in a standard spreadsheet format, using simplified methodology, we hope we have provided a means of making a complex subject area more accessible, easily understood, and able to be readily adapted, applied, and developed in future.

A benefit of our modelling is likely to be increasing understanding of the potential impacts of the environmental risks that pāua fisheries, and therefore pāua quota holders are increasingly exposed to. We suggest that this could help drive changes at the strategic, organisational, and operational management levels, and importantly, contribute to better informed business strategies.

Whilst the model is innovative in translating the fishery biomass stock assessment model, used for fishery management, into a financial value model, it has limitations due to the lack of robust impact data available on how multiple environmental stressors affect pāua recruitment success, instantaneous mortality, and growth, individually and when combined. This is a key finding of the project; that is, we need better information about the levels of environmental stressors and change that affect pāua, at both the individual physiological and fishery scales.

These data gaps need to be filled. In addition, systematic data capture infrastructure investment is needed if impact measurement and modelling are to be developed to provide reliable and robust environmental impact, risk analysis and resilience/mitigation business management analysis that can be presented in succinct information dashboards. Such an approach, if implemented quickly, should ensure climate change impact assessment becomes the norm, and provide confidence to the financial sector to support ongoing investment, to uphold the value of quota.

The following are recommendations arising from the research:

Pāua

1. Invest in further research to increase certainty around the effects of changing environmental stressors on pāua fisheries.
2. Develop an understanding of how changing environmental stressors potentially influence outputs in the stock assessment process, as this is currently the driving mechanism for broad scale management responses.
3. Consider using a pāua fishery as an exemplar for building resilience and the demonstration of ecosystem-based management as outlined below.

The national enabling environment

Although not the subject of direct research in the project, given the users of this research are largely pāua quota owners and fishery financiers, project discussion included considerations of how to respond to these challenges including by fishery management. Discussion also included the transferability of the model and the findings of the project to other fisheries and marine businesses. This section relates to these discussions.

4. Develop credible and well-functioning environmental markets to enable timely and informative signals to be sent to businesses.
5. Build capability throughout those involved with the blue economy to understand how science, research and improving marine environmental data underpins improving management and corporate disclosure, de-risks investments and enables enduring financing.
6. Promote financing for marine management and improving data, information, and knowledge, including mātauranga. The pāua findings 1-3 above generated discussion within the project team and advisory group about how they could be funded. At present <10% of environment funding is spent on the marine environment (Parliamentary Commissioner for the Environment 2022). Internationally models for blue financing roundtables are being used to bring a range of interested parties together to contribute to marine management e.g., The Organisation for Economic Cooperation and Development (OECD), the Asian Development Bank and the United Kingdom.

PAU2 as a resilience exemplar

Through the project discussions the Project Advisory Group considered how PAU2 could become an exemplar of a resilient fishery and a model for demonstrating kaitiakitanga and ecosystem-based management, where risks are fully assessed and factored into management. This is partly because of the stability of the fishery as the opportunity exists to act before the fishery is in trouble. To do so the following steps should be considered. Note that not all of these steps are directly related to the project and these are steps are italicised.

- *Finalise the PAU2 Wairarapa Fisheries Plan (Draft December 2022) out for consultation:*
    - Note: this does not include improving the marine environmental information base, nor improving information about the relationships between environmental conditions and pāua physiology.
- Improve the information base about the marine environment including climate change and sedimentation, and their relationship with pāua population:
    - Collaboratively finance marine environmental monitoring.
    - Establish citizen science and Mātauranga Māori marine environment and cultural health programmes.
    - Monitor habitat condition and change.
- Disaster Preparedness:
    - The need for this was highlighted during the project, as Cyclones' Hale and Gabrielle affected both the ability of fishers to reach launch sites and, potentially, pāua recruitment, growth and mortality through large amounts of sediment entering the marine environment.
    - Establish response preparedness plans for the fishery, and marine environment.
    - Enable post-event monitoring and analysis, and fishery operations and management adjustment as required.
- Innovate:
    - *Take up the learnings, new knowledge, science, and research from the Sustainable Seas Science Challenge into the management of the fishery.*
    - Improve the Model through including better environmental monitoring and climate impact information, as mentioned above.

- Improve the PAU2 Stock Assessment Model to strengthen it's understanding of the relationships between pāua population dynamics and environmental conditions.

Figure 12. Excerpt from the full proposed draft resilience plan for the PAU2 Fishery which maps this out more fully is available. This was developed by Terra Moana Ltd and presented to the PAU2 Executive by Tony Craig.

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Appendix 1: Pāua Climate Vulnerability Assessment

Pāua (Abalone)

Climate Change Vulnerability, Adaptation Strategies, and Identified Management Options for New Zealand Waters

Fisheries New Zealand

NIWA

SPECIES DISTRIBUTION

Pāua (*Haliotis iris, H. australis*) are endemic New Zealand abalone, occupying a narrow coastal ribbon of intertidal rocky shorelines and nearshore reefs to depths of ~15 m. They are long-lived, annual broadcast spawners (1-3 week larval stage) and feed primarily on drift algae as adults. Temperature and related factors (food) are the primary drivers of adult size. Pāua have been virtually unchanged for 65 million years, making them one of the least evolved abalone species. Pāua support important commercial (export value ~NZ$55M), customary, and recreational fisheries.

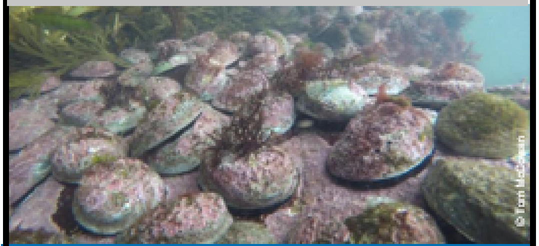
VULNERABILITY TO CLIMATE CHANGE

Pāua growth and development are influenced by water temperature, wave exposure, and food availability. Pāua are vulnerable to smothering during sedimentation events. Pāua are also affected by decreasing pH both directly and indirectly (e.g., declines in coralline algae as a food source and settlement cue), and changes in suitable substrate availability due to coastal sedimentation. Terrestrial land use changes and management practices can exacerbate climate impacts due to increases in sedimentation and reduced water quality.

Fishery implications:

- Increasing temperatures and diminishing food may reduce the number of individuals that are of harvestable size
- Altered availability of food and suitable settlement substrate may reduce stock numbers (particularly in combination with elevated sediment inputs) and animal condition
- Sedimentation reduces recruitment surface availability, increases larval mortality

OVERVIEW OF PĀUA VULNERABILITY



Shellfish are vulnerable to climate change and ocean acidification, and their sessile nature makes them susceptible to rapidly changing and/or highly variable environmental conditions.

Drivers of Pāua Vulnerability

- ***Climatic and climate-associated factors and disturbance regimes:*** Enhanced coastal erosion & elevated sediment inputs, increasing sea surface temperature, ocean acidification
- ***Non-climate factors:*** Management and flood control that increase nearshore sediment delivery, illegal take, nutrient pollution, conflicting management

SUMMARY OF VULNERABILITY

PROJECTED FUTURE CHANGES (EXPOSURE)	POTENTIAL EFFECTS ON PĀUA (SENSITIVITY)	FACTORS THAT INFLUENCE ABILITY TO RESPOND TO CHANGE (ADAPTIVE CAPACITY)
Increasing ocean temperature • *+0.55-3.3°C by 2100, depending on emissions scenario* • *Largest increases likely in the Tasman Sea and south of Chatham Rise* • *Increasing marine heatwaves*	• Increased rate of larval development NZ • Reduced size at maturity and maximum adult size NZ • Altered distribution and survival of macroalgal food source NZ • Mortality events (Global data)	**Ecological factors that enhance adaptive capacity:** • Wide distribution around mainland New Zealand and offshore islands • Broad diet, long-lived (20-30 years) • High levels of genetic variation may provide opportunities for adaptation • Association with kelp beds may alleviate local acidification effects • Ability to raise larvae in hatcheries increases management potential (i.e., can avoid adverse conditions, selection of resilient strains)
Ocean acidification • *Oceanic pH declines of 0.13-0.33 units by 2100, depending on emissions scenario* • *Lowest pH levels will occur in the south*	• Reduced juvenile growth rates NZ • Greater prevalence of abnormalities in larvae NZ • Enhanced shell surface dissolution in juveniles NZ • Reduced suitable recruitment habitat and/or food availability for juveniles due to pH-related declines in coralline algae (More information needed)	**Societal factors that enhance adaptive capacity:** • High economic, societal, and cultural value (taonga species) increase support for management • Fishery employs free diving for harvest
Increasing frequency and severity of storms and extreme precipitation events • *Contributes to sudden decreases in salinity and increased sedimentation* • *Rubble abrasion of populations*	• Disrupted harvest pressure as storm events increase • Mortality from large or sudden decreases in salinity (Global data) • Mortality from habitat storm disturbance *** Also see sedimentation impacts*	**Factors that reduce adaptive capacity:** • Adults are essentially sessile, increasing vulnerability to changing conditions • Extremely localised recruitment (failures reported when adult aggregation falls below 1.5 m to nearest neighbour) • Shallow habitat is more vulnerable to stressors
Increasing coastal sedimentation • *Deposits layers of sediment and/or elevates suspended sediment concentrations*	• Increased larval mortality due to elevated suspended sediment levels NZ • Settled sediments reduce availability of suitable larval settlement habitat, limiting recruitment and abundance NZ • Macroalgal food sources damaged by reduced light and smothering NZ	**Data source symbol key** (globe) Global data NZ Regional data (?) More information needed

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POTENTIAL ADAPTATION STRATEGIES FOR PĀUA

Note: Strategies evaluated for E (effectiveness) and F (feasibility)

Projected Change	Vulnerability of Fishery	Potential Adaptation Strategy & Management Options
Increasing ocean temperature	Reduced adult size resulting in fewer individuals that reach harvestable size each year	• Incorporate consideration of projected environmental change into plans for industry and NZ fisheries management *(High E/High F)* • Adjust catch size (where maturing smaller, recalculate sustainable harvest, if population has reset to smaller size) *(High E/Mod F)* • Change collection and harvest regulations *(High E/Mod F)* • Enhance pāua resilience to increasing ocean temperatures by reducing other stressors that are detrimental to growth (e.g., water quality) via effective catchment management *(High E/Low F)* • Continue investigation of pāua ability to acclimate or adapt to rising temperatures (growth, time to and length at maturity, mortality rates, variability by region), and incorporate knowledge into management plans *(High E/Mod F)* • Use traditional aquaculture, although cooling costs may limit economic feasibility *(High E/Mod F)* • Translocate individuals from slow-growing/depleted sites to fast-growing sites to achieve greater biomass *(High E/High F)*

	Reduced survival, especially when combined with other stressors	• Manage sediment input and other stressors where necessary *(High E/Low F)*
		  • *Create fisheries plans (Section IIA plans) for inclusion in regional plans*
		  • *Address land use and flood management*
		  • *Enforce the Resource Management Act across the whole catchment*
		• Seasonal closures of fishery or sites (determine most effective timing for closures) *(Low E/High F)*

	Reduced survival of algal food source	• Habitat enhancement to support algae *(Low E/Low F)* • Manage environment health to sustain preferred algae (reduce other stressors that are detrimental to survival) *(Mod E/Low F)*
	Potential impacts on spawning and larvae	• Increase understanding of vulnerability to marine heat waves/extreme events through existing research and translation to scale *(Mod E/Mod F)* • Research and select broodstock that is naturally more resilient to changes in temperature, pH, and disease, and incorporate these into breeding programmes *(Mod E/Mod F)*
Ocean acidification (OA)	Shells eroded, settlement habitat may be diminished	• Continue to investigate the ability of pāua to acclimate or adapt to ocean acidification *(High E/Mod F)* • Test management actions to increase OA resilience (e.g., return crushed shells to sites *unknown E/Mod F*, identify resilient families *High E/High F*) • Ocean ranching (movement to suitable habitat at each lifestage) *(High E/High F)*
	Fewer individuals that reach harvestable size each year	• Incorporate consideration of projected environmental change into plans for industry and NZ fisheries *(High E/High F)* • Change collection and harvest regulations *(High E/Mod F)* • Identify/map suitable locations for juvenile planting and managed area designation *(Mod E/Mod F)* • Hatchery-based farming, managed brood stock, spawning, and rearing through vulnerable life stages *(High E/Mod F)* • Ocean ranching (movement to suitable habitat at each lifestage) *(High E/High F)* • Use traditional aquaculture *(High E/Mod F)* • Marine aquaculture hybrid (build facility out of buffering substrate) *(Unknown E/Unknown F)*
Enhanced coastal sedimentation and erosion	Reduced availability of suitable substrate, limiting recruitment and abundance	• Develop best management practices for different land uses to reduce nearshore sedimentation *(High E/Mod F)*
Decreased O_2	Range shifts, decreased growth rates, decreased survival	• Global issue of potential importance to New Zealand. Research specific to pāua needed *(unknown E/High F)* • Identify and protect higher O_2 refugia (places of disturbance) *(unknown E/unknown F)*

Comparison of Potential Adaptation Strategy & Management Options by Effectiveness and Feasibility

EFFECTIVENESS (Likelihood of reducing vulnerabilities) by FEASIBILITY (Ease of action/implementation)

Effectiveness \ Feasibility	Low	Moderate	High
High	**High E/Low F** • Improve water quality via effective catchment management • Manage sediment inputs and other stressors	• Use traditional aquaculture • Adjust catch size & collection/harvest regs • Hatchery-based farming in vuln. stages • Develop BMPs to reduce sedimentation • Research pH, O_2 & temperature responses	**High F/High E** • Translocation • Ocean ranching • Identify resilient families • Consider projected change in industry and fisheries plans
Moderate	• Manage environment health to sustain preferred algae	**Mod E/Mod F** • Outplant to maximize juvenile survival • Select resilient broodstocks • Identify/map suitable locations for juvenile planting and managed areas • Research response to extreme events	
Low	• Habitat enhancement to support algae **Low E/Low F**		• Seasonal closures **Low E/High F**

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Citations can be found in products available online at CAKE.

EcoAdapt

Appendix 2: Natural Hazards Summary

Pāua Diver Survey Full Results

With the help of the PĀUA2 Executive, Pāua Divers in the PĀUA2 Management Area were encouraged to participate in the survey. Quota owners were also contacted to encourage their divers to participate. The online survey was sent out via email on the 21st Oct with a closing date for 7th Nov (only one response was received in the first round) so the survey was extended to the 5th Dec 2022.

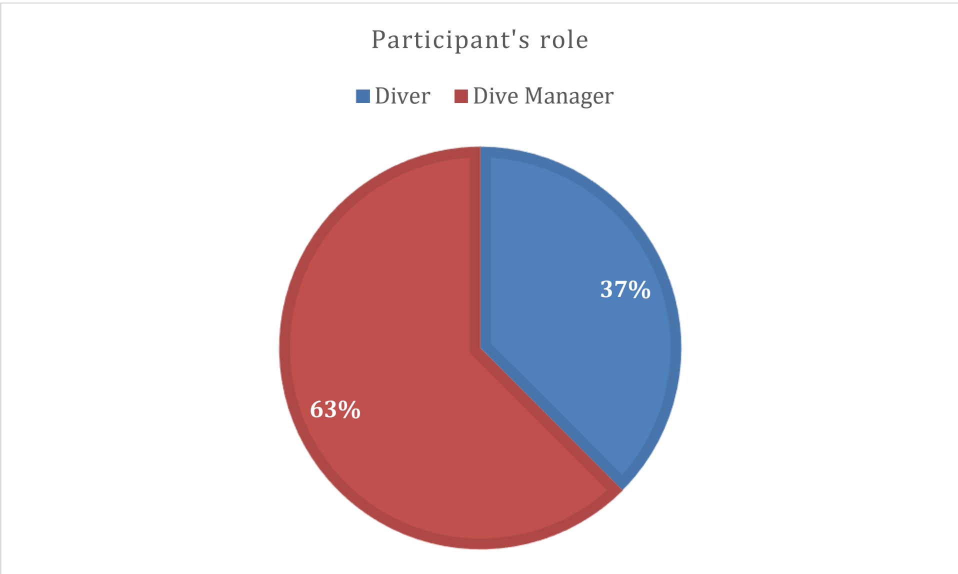
As the surveyor was well known to the divers, divers were also offered a telephone interview if preferred. In the end all responses were received online.

The PĀUA2 Executive and all participating divers will receive the anonymized report of the results.

There were 8 final responses received. There are 11 dive teams and 32 divers in the fishery.

Participant Profile

- 8 participants.
- Experience in the industry varied from newcomers (2 years) to experienced (45 years).
- Most participants have more than 20 years' experience.
- Mix of divers and team managers (who also dive).



Weather observations

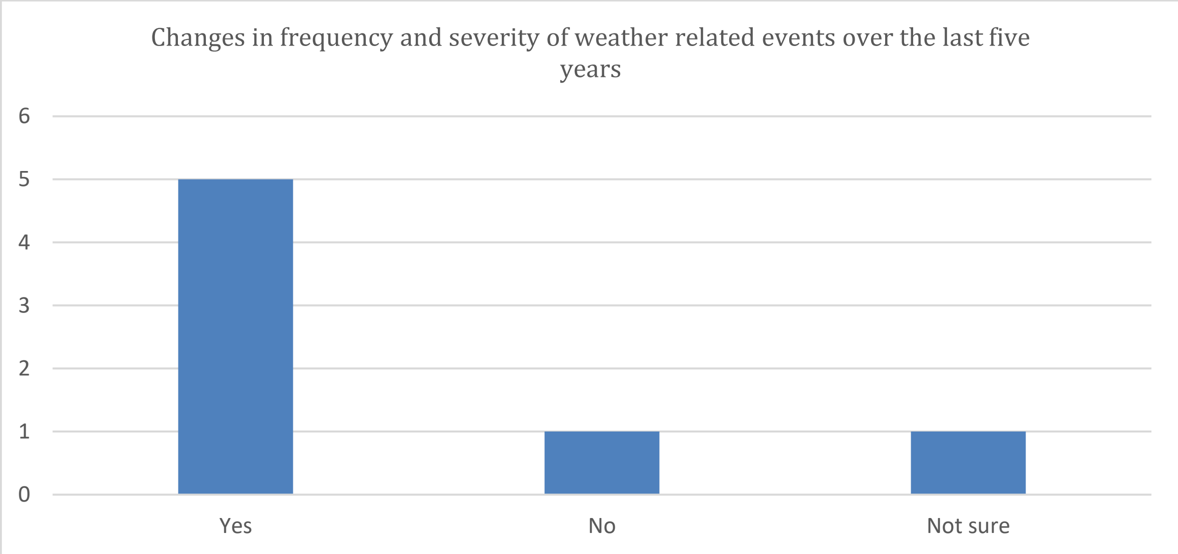
Weather naturally plays an important role in diver accessibility in this fishery with large parts of the coastline exposed to Easterly weather patterns (onshore) that restrict fishing versus Northwesterly patterns (offshore) that enhance diving opportunity.

While respondents were asked to consider weather pattern changes during their time in the industry versus the last 5 years, it was difficult for respondents to recall beyond the last 5 years.

Summary of responses:

- More Easterly weather patterns observed annually.
- North Westerlies that were occurring during Spring are now not happening for a longer periods (weeks). Only one or two days.
- Very changeable weather is rare now and there seems to be more sustained weather patterns.

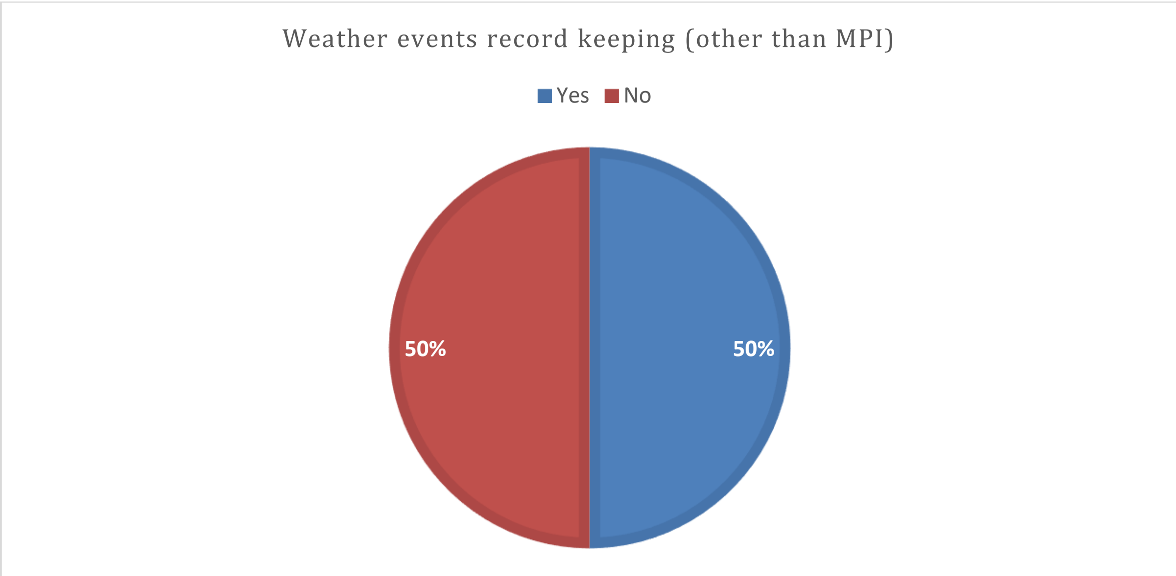
Has the Frequency and Severity of Weather Events Changed Over the Last 5 Years?

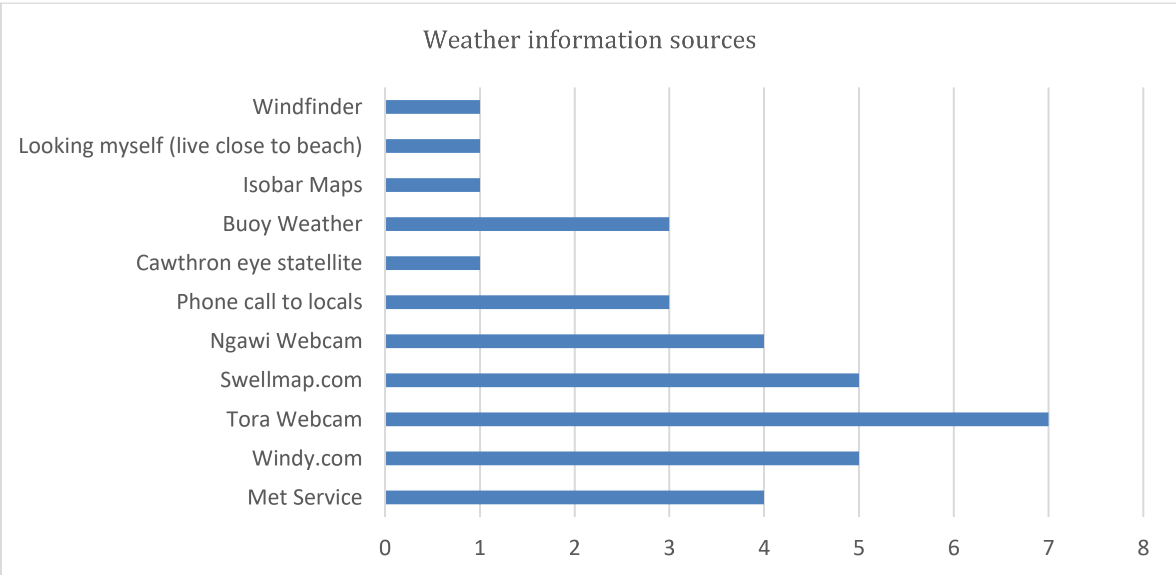


- Weather patterns are a month later than normal. NW gales (Sept/Oct) and cyclone (Feb/Mar)
- La nina effect – re more Easterlies.
- More weed loss in areas once lush.

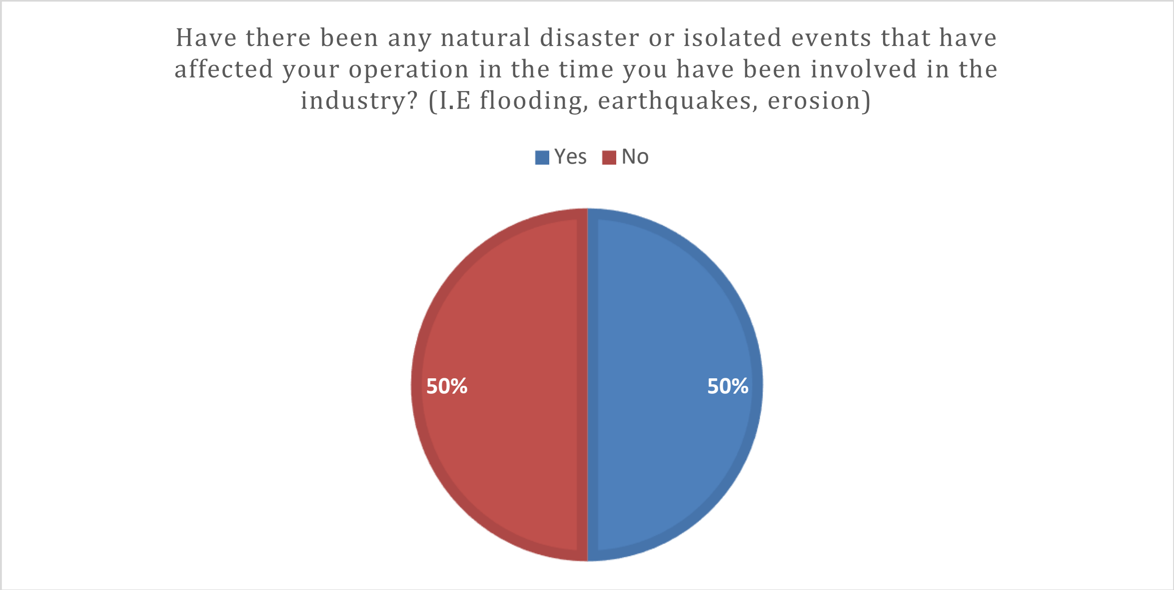
What of the following conditions restrict your diving or launching capabilities?

- Swell height 1-2m.
- Wind direction and swell direction varies.
- Wind levels 15knots (2 pax) 25 knots (1pax).
- Visibility limit 0.5-3m.
- 2-4 days for swell to clear up before being able to dive again.


Weather events record keeping (other than MPI)
Yes
No
50%
50%


Weather information sources
Windfinder
Looking myself (live close to beach)
Isobar Maps
Buoy Weather
Cawthron eye statellite
Phone call to locals
Ngawi Webcam
Swellmap.com
Tora Webcam
Windy.com
Met Service
0
1
2
3
4
5
6
7
8

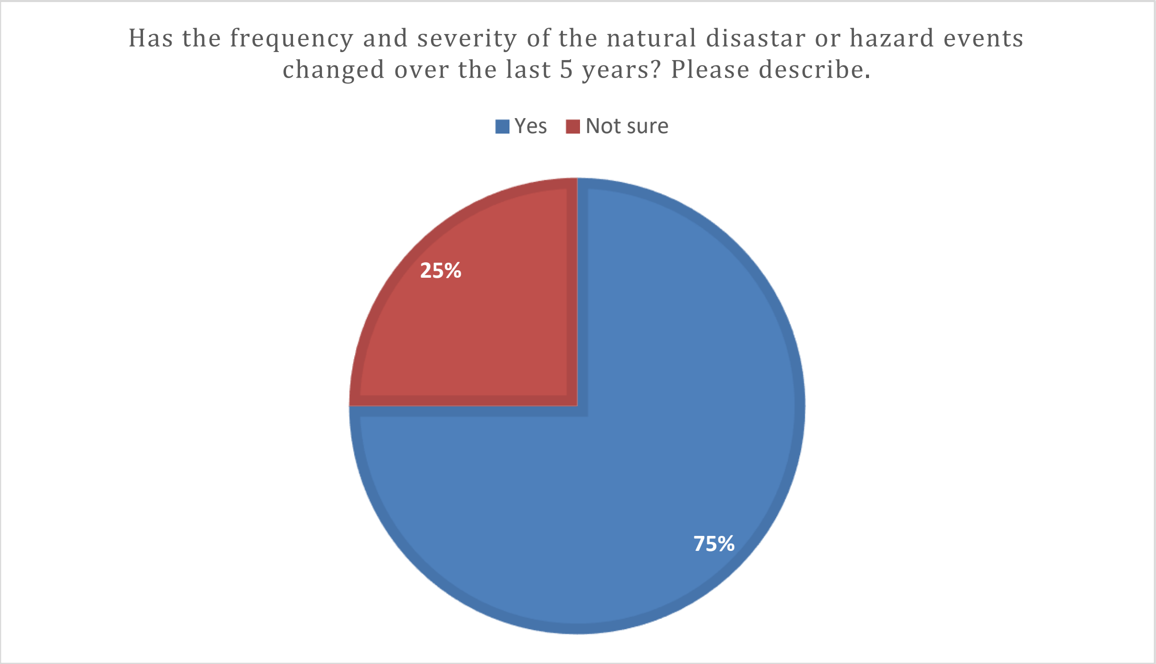
Natural Disasters

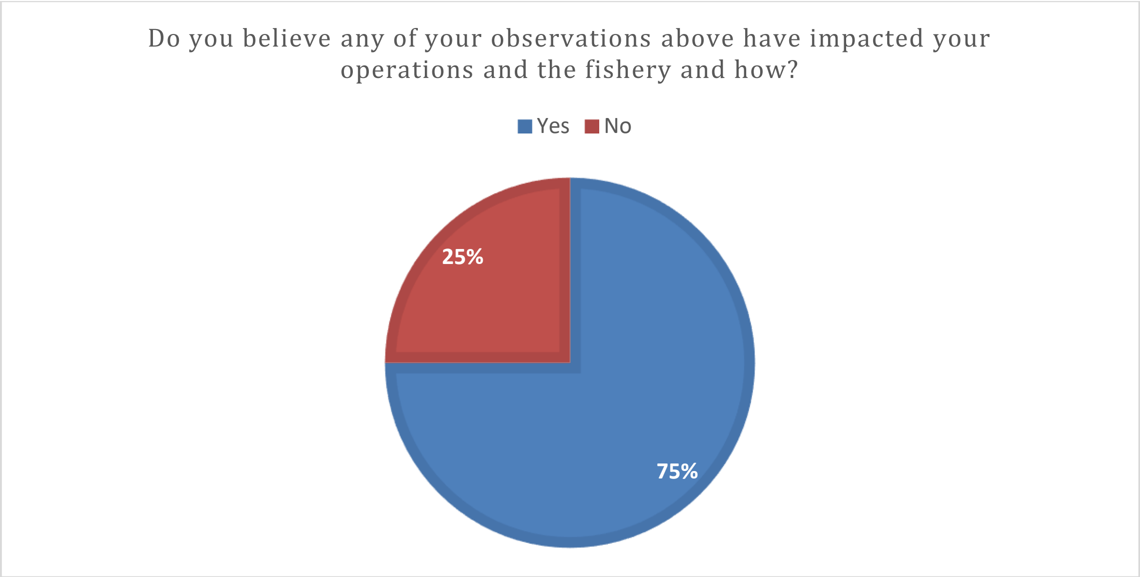


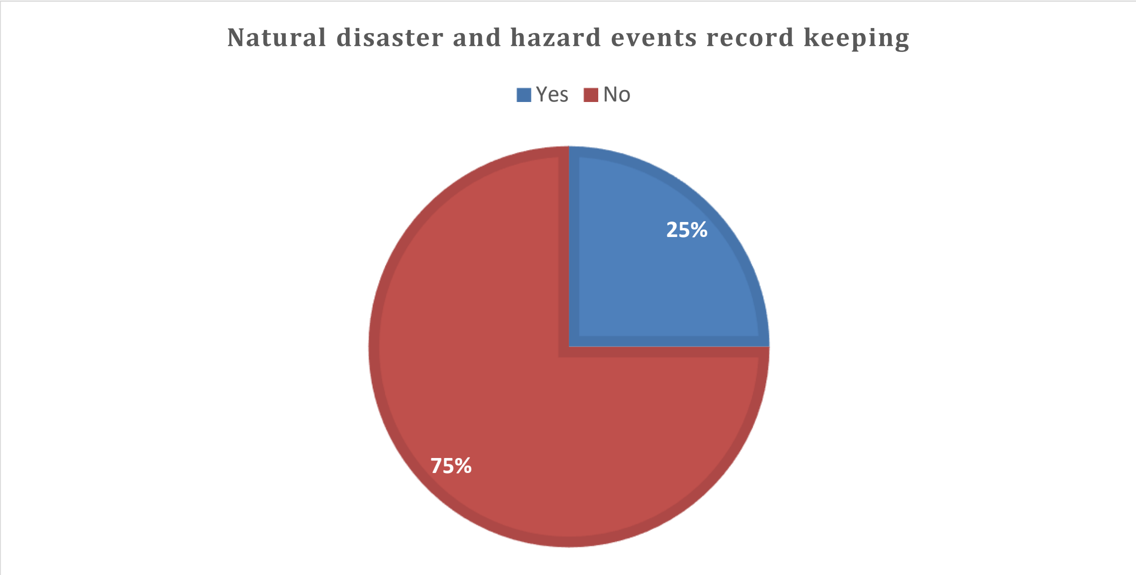
Result:

Landslides	4
Road washouts	4
Flooding	2

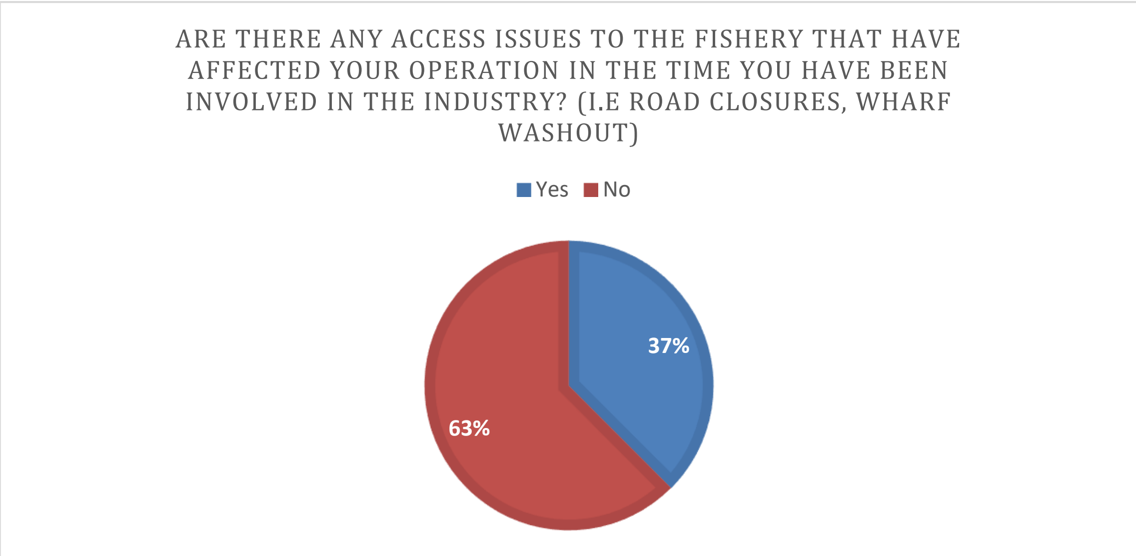
- Increased events of slips, landslides and flooding resulting in road washouts.
- Mostly affected by landslides and road washouts.
- Some found flooding to affect their operations too.
- Landslide had taken out a road (Hinakura Rd), which has closed the access to launch from the East Coast. Added an extra hour to work, currently a farmer has put a track to use until the road is fixed by council.


Has the frequency and severity of the natural disastar or hazard events changed over the last 5 years? Please describe.
Yes
Not sure
25%
75%


Do you believe any of your observations above have impacted your operations and the fishery and how?
Yes
No
25%
75%



Access



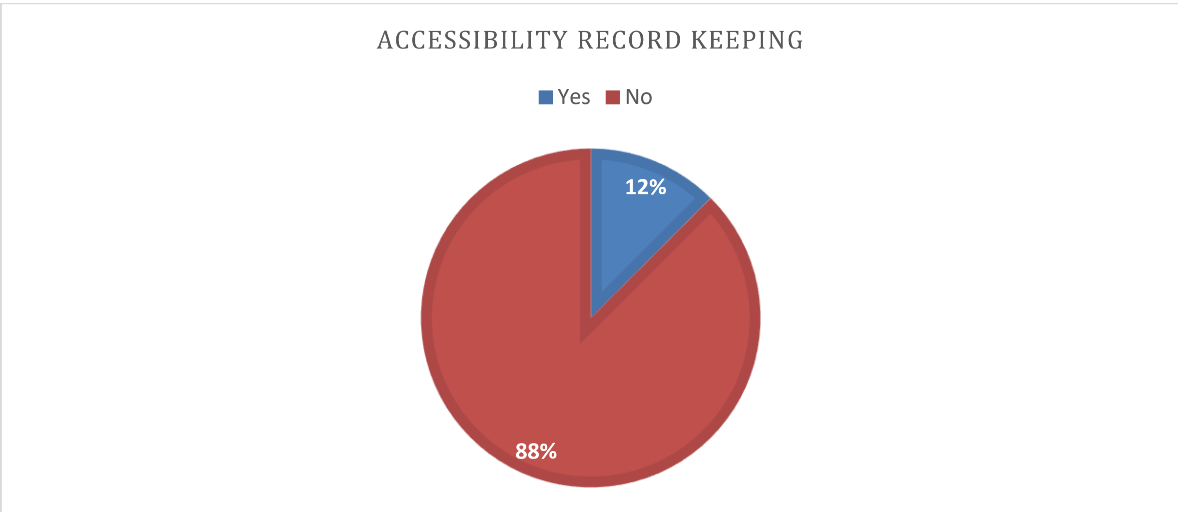
What are the coastal access points you use to fish?

1	Coastal Access Point	Usage Frequency	Fishing Method
2	Pahahoa Ngawi Mataikona	Monthly	Boat Launch
3	Point Howard wharf,ocean beach,ngawi,tora,castlpoint,matakona	Yearly	Boat Launch
4	Ocean beach/Ngawi/pahaoa/Riversdale/Mataikona	Weekly	Boat Launch
5	Tora beach	Weekly	Boat Launch
6	Matikona, Riversdale, Flat Point, Te Awaite/Tora and Ngawai.	Weekly	Boat Launch
7	Tora	Yearly	Boat Launch

8	Castle point	Monthly	Boat Launch
9	Tora	Monthly	Boat Launch
10	Ngawi	Monthly	Boat Launch
11	Ocean beach	Monthly	Boat Launch

What are the roads you use to get to the access points identified above?

1	Road Name	Usage Frequency	Road condition
2	Hinakura Rd Cape palliser Rd Csstlepoint rd	Monthly	Poor
3	Palliser rd	Yearly	Average
4	Tora rd	Yearly	Average
5	Ocean beach	Yearly	Good
6	Western lake rd/Cape Palliser rd/Hinekura rd/Riversdale rd/ Castle point rd	Weekly	Poor
7	Tora farm rd	Weekly	Poor
8	Castle Point Rd, Riversdale Rd, Tora/Te Awaite Rd, Cape Palliser Rd.	Weekly	Average
9	Tora	Yearly	Average
10	Castle point road	Monthly	Good
11	Tora settlement road	Monthly	Poor
12	Cape Palliser road	Monthly	Poor
13	Western lake road	Monthly	Good



Conclusion

Based on your observations, what are the environmental challenges for the fishery going forward?

- Global warming
- North Westerlies resulting in smaller fishing windows
- Sedimentation
- Landslides

- Changing weather patterns
- Run off from forestry blocks

Can you suggest ways to better prepare and mitigate any issues that may arise from environmental changes?

- Building new roads
- Artificial reefs seemed to be working to help with erosion from high swells
- Better forestry practices
- Allow for underwater breathing apparatus for diving

Event Logs of PAU 2 Diver Observations

Date	Notes
7/21/2016	The other day I read about the p ā ua problems in the upper South Island , I noted with interest that forestry was a problem with its downstream problems . > To add to this in the last few days I have heard that Lagoon Hills is to start logging again, possibly up to 30 trucks a day on the road, so the Oterie Stream around the corner from me will take the " run off " from this operation . > Also Whakapuni Station and Waipawa farm have started logging so the Awhea Stream will be the "run off" at the south end, plus today I have been told a big area in the Pahau area is to commence logging. > Been pretty rough here lately, spoke to one of the Cray Guys this morning and it's not good, heard from another at Ngawi and he told me his best day last week was 25 kg.
7/25/2016	Could be some major run off from these activities. Oterei river runs out into our launching bay, in the past we have had problems with trees etc running down into the bay due to there being no catchment gates further up the river. We have a heads up on the activities so might be timely to put something in place. As to the crays, we are in a downturn cycle which seems to happen every 8 to 10 years. This year looks to be the bottom of the trough. For reference, stat area 915 in the Northern cra4 zone experienced a major weather event approximately 12 or so years ago with large slips and run off occurring. That run off affected a very large area and so sedimentation from that wiped out Cray/ Pāua habitat and is only now showing signs of regenerating. It displaced around 30 or so tonnes of Cray that was pushed into other stat areas in Cray 4. Pāuawasn't so much talked about due to hardly any commercial diving done there. Obviously the forestry activities are to a far lesser extent but is worth noting.
10/15/2020	Turakirae – diving on border of Stat areas 236/235 there's a lot of dead shells, random sizes. Southern end was all right but on the northern side noticeable quite barren (near slip), lots of starfish and octopus.
15-Nov-17	Re the sediment, after the major sediment fan I observed off the Pahaoa river back in February this year, noting a lot of guts and holes on the seabed were full of a fine silt, with no crayfish to be seen in those areas. Fishing through this winter and spring, the sediment has dispersed and the crayfish are back where the silt was sitting. The question I would like to know the answer to is how do pāua deal with the fine silt buildups? Obviously crayfish can move in and out. Tom might be worth a call to answer this

Diver Survey Form

Paua 2 Resilience Project

We would like you to be part of a Sustainable Seas Project looking at what Pāua fishery investors (quota owners, divers, processors etc) need to know about the fishery and industry to maintain confidence to invest?

What are the implications (good or bad) around climate change, fishery performance, management responses and the relationship between risk and quota values? In these rapidly changing times, socially, economically and environmentally, it is essential to bring all the knowledge we can to better understand rural economies and the ecosystems they depend upon.

Uniquely this project brings together recent advances in marine science sedimentation and climate change knowledge with Pāua quota owners, divers, sustainable finance, and fishery management. Alongside the marine science it is taking an initial look at the risks to the Pāua fishery from climate related sea level rise and storms to rural infrastructure such as boat ramps, wharves and roading.

With respect to the focal Wairarapa Pāua fishery (PAU2), it is imperative to uphold its value to local communities, to quota owners and to the markets that prize it as a delicacy through: i) understanding the risk to the fishery from climate change and sedimentation and using that to influence investment decisions in better caring for the fishery, and rural communities, and ii) knowing that the right management is in place and working effectively at all scales.

With a focus on sedimentation and climate change the project is characterising the fishery, building quantitative and qualitative risk analysis tools, profiling these environmental risks as they pertain to the PAU2 Fishery, and documenting key response strategies that are essential to reduce that risk.

A key part of this work is understanding the risks you face as divers through access to the resource from weather (fishing days), roading (getting to the grounds) and launching (getting on the water)

Thank you for helping us with providing your valuable knowledge of these factors!

Name

First

Last

Email

Phone

What is your role? i.e (dive manager, diver, processor)

How many years have you been in the industry?

Weather

What changes have you noticed in the weather over the time that you have been involved in the industry?

i.e increased easterly weather patterns or prolonged lack of vis periods.

Describe the event	Years	Trend	Frequency	Severity
i.e easterly weather patterns	i.e 2015	select dropdown	select dropdown	Describe the extend

+ Add event

Has the frequency and severity of the weather events changed over the last 5 years? Please describe.

Do you believe any of your observations above have impacted your operations and the fishery and how?

What of the following conditions restrict your diving or launching capabilities?

Swell height (meters)

Wind direction

Swell direction

Wind levels (knots)

Visibility Limits (meters)

Days to clear up after a swell (number)

Other than MPI reporting requirements, do you keep any other record of weather observations? (i.e diary)

○ Yes ● No

What are your weather information sources?(Select all relevant)

- ☐ Metservice.com
- ☐ Swellmap.com
- ☐ Windy.com
- ☐ Other website or Apps
- ☐ Tora webcam
- ☐ Ngawi webcam
- ☐ Phone call to locals
- ☐ Other

Natural Disasters or Isolated Events

Have there been any natural disaster or isolated events that have affected your operation in the time you have been involved in the industry? (i.e flooding, earthquakes, erosion)

○ Yes ◉ No

Access

Are there any access issues to the fishery that have affected your operation in the time you have been involved in the industry? (i.e road closures, wharf washout)

○ Yes ◉ No

What are the coastal access points you use to fish?

Please note all points by adding items

Coastal Access Points	Frequency of use	Fishing Method
i.e Mataikona / Ngawi	select dropdown	

+ Add Item

What are the roads you use to get to the access points identified above?

Please note all points by adding items

Road Name	Frequency of use	What is the condition of the road?
i.e Cape Palliser Road	select dropdown	

+ Add Item

Do you keep a record of your observations of these issues? (i.e diary)

○ Yes ◉ No

Conclusion

Based on your observations, what are the environmental challenges for the fishery going forward?

Can you suggest ways to better prepare and mitigate any issues that may arise from environmental changes?

Submit