Earth Sciences New Zealand

Kōura movement ecology & passage requirements

A rapid literature synthesis

Prepared for Bathurst Resources Ltd.

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Prepared by:
Paul Franklin
Rachel Crawford

For any information regarding this report please contact:

Paul Franklin
Freshwater Ecologist
Freshwater Ecology
[redacted]

New Zealand Institute for Earth Science Limited
[redacted]
Hamilton [redacted]

[redacted]

[redacted]

[redacted]		
[redacted]		
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4 August 2026 5.30 pm

Contents

Tables

Figures

Executive summary

Bathurst Resources Limited (including its subsidiary companies BT Mining Ltd, Bathurst Coal Ltd, and Buller Coal Ltd) (Bathurst) is seeking approvals under the Fast-Track Approvals Act 2024 for the Buller Plateaux Continuation Project (BPCP, or the Project), [redacted] Under the Freshwater Fisheries Regulation 1983, the National Environmental Standards for Freshwater 2020, and the National Policy Statement for Freshwater Management 2020, culverts must be designed to maintain fish passage unless specific dispensation is granted. For the purposes of these provisions, the New Zealand freshwater crayfish kōura (*Paranephrops planifrons* and *P. zealandicus*) are legally considered fish and their passage requirements must be addressed in the Project application.

Earth Sciences New Zealand (ESNZ) was commissioned to review the available literature on the movement ecology and passage requirements of freshwater crayfish to support Bathurst's application. We found limited research on the movement ecology and passage efficiency of kōura in New Zealand. Available evidence suggests that kōura generally spend long periods within stream reaches, but can make both upstream and downstream movements over larger distances. International studies indicate that crayfish typically move only tens of metres per day, though movements of several hundred metres or more have also been observed.

Much of the international literature on crayfish passage focuses on restricting the spread of invasive species. Studies show that high water velocities (>30 cm s^{-1}), slopes greater than 25°, vertical drops or overhangs, and smooth substrates all act as barriers to crayfish passage.

To maintain passage for kōura, culvert designs should include:

- Using roughened substrates to provide grip for walking.
- Ensuring water velocities remain below 30 cm s^{-1}.
- Limiting slopes to less than 25°.
- Avoiding vertical drops or overhangs at outlets.

There is a clear need for New Zealand-specific research on kōura movement ecology and passage efficiency, including telemetry studies and population genetics. Without this, culvert and instream structure designs should follow international best practice by avoiding steep slopes, high water velocities, vertical drops, and smooth surfaces, while incorporating roughened substrates and ramped outlets to support connectivity.

1 Introduction

Bathurst Resources Limited (including its subsidiary companies BT Mining Ltd, Bathurst Coal Ltd, and Buller Coal Ltd) (Bathurst) is seeking approvals through the Fast-track Approvals Act (FTAA) 2024 for the Buller Plateaux Continuation Project (BPCP, or the Project). [redacted]) [redacted]. Many new culverts (~ 50) over streams, and the replacement of some existing culverts, [redacted].

Under the Freshwater Fisheries Regulations 1983 culverts must be installed and maintained such that they do not impede the movement of fish unless dispensation is provided by the Department of Conservation (s42). Furthermore, the National Environmental Standards for Freshwater 2020 (NES-F) sets out minimum design standards for new culverts that must be met to achieve permitted activity status (s70). Where these design standards are not met, consent is required to install a new culvert (s71). The National Policy Statement for Freshwater Management 2020 (NPS-FM) requires that when considering an application for a consent relating to an instream structure, councils must have regard for the extent to which it provides for the compulsory objective to maintain or improve fish passage (s3.26(4)).

The FTAA legislation requires that as part of its application Bathurst seek approvals (among other things) for:

- 42(4)(a) a resource consent that would otherwise be applied for under the Resource Management Act 1991.
- 42(4)(j) an approval or a dispensation that would otherwise be applied for under regulation 42 or 43 of the Freshwater Fisheries Regulations 1983 in respect of a complex freshwater fisheries activity.

As such, Bathurst will be required to seek approvals required for culverts under both the Resource Management Act (RMA) and Freshwater Fisheries Regulations (FFR) as part of its application for the Project.

While fish are typically absent from waterways on the Buller Plateaux, the culturally important kōura (freshwater crayfish, *Paranephrops planifrons*) are widespread (Hogsden et al., 2020; Watson et al., 2024a, 2024b). Under the Fisheries Act 1996 (and hence the FFR and RMA), 'fish' are defined as including both finfish and shellfish. The definition of shellfish includes "all species of the class Crustacea". As such, for the purpose of Bathurst's application for the Project, kōura must be considered 'fish' and the fish passage provisions of the FFR, NES-F and NPS-FM apply.

Section 4(1) of the FTAA identifies that the construction of a culvert that permanently blocks fish passage is classified as a complex freshwater fisheries activity. An application for a complex freshwater fisheries activity approval must include the following information (as specified in Schedule 9(3)):

"(a) in relation to the structure and any fish facility:

(i) a description of the type of structure or fish facility:

(ii) the dimensions of the structure or fish facility:

(iii) the design of the structure or fish facility:

(iv) the placement of the structure or fish facility:

(v) the water flows:

(vi) the operating regime:

(b) the freshwater species and values present (with particular focus on threatened, data-deficient, and at-risk species as defined in the New Zealand Threat Classification System):

(c) the water quality and quantity in the surrounding habitat (at the proposed structure location, upstream and downstream):

(d) how the passage of fish will be provided for or impeded."

Bathurst have requested that Earth Sciences New Zealand (ESNZ) undertake a review of information available on the movement behaviours, and passage requirements of freshwater crayfish to support their application and fulfil the information requirements outlined above. The focus of the review will be two-fold:

1. to establish an understanding of the frequency, timing and spatial extent of movements undertaken by freshwater crayfish, and
2. determine the factors that enable or impede the movements of freshwater crayfish at instream structures.

The scope of the review will include relevant literature from both New Zealand and overseas, but excludes evaluation of specific culvert designs for their suitability to provide passage for kōura.

2 Methodology

We used a range of search terms including Boolean operators to help discover literature relevant to this review. Key search terms included:

- "kōura" OR "crayfish"
- "freshwater"
- "movement" OR "migration" OR “home range”
- “culvert” OR “weir” OR “barrier” OR “passage”

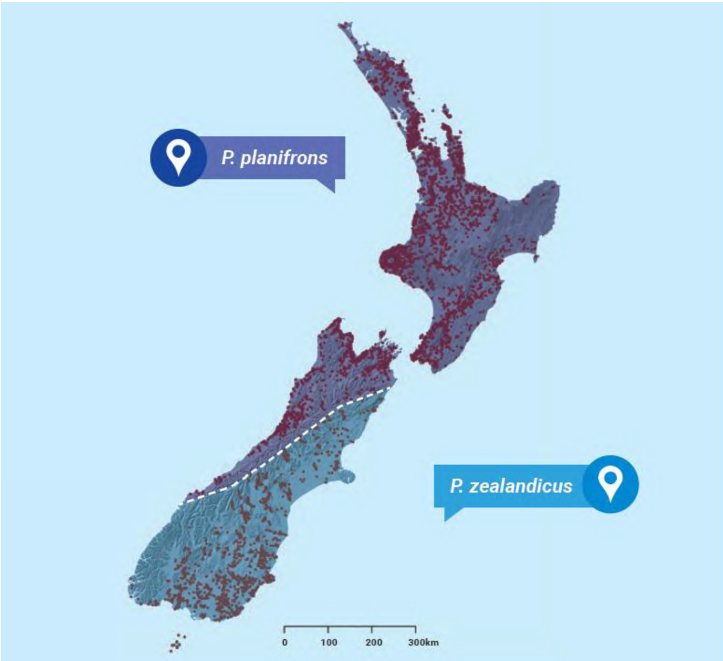
We searched both Google Scholar and the Web of Science. Web of Science is focused on the primary research literature, i.e., published peer-reviewed articles and books. Google Scholar additionally captures ‘grey’ literature sources including theses and published reports.

Search results were scanned and potentially relevant sources identified based on review of their title and abstract. We subsequently reviewed the full text of collated sources with the objective of extracting any quantitative or qualitative information on the movement ecology of kōura (or crayfish) or features of instream structures that either enable or restrict kōura (or crayfish) movements. The results are summarised in the following section.

3 Results & discussion

3.1 General ecology of kōura

There are two species of freshwater crayfish present in New Zealand: *Paranephrops zealandicus* – distributed along the eastern side of the South Island and on Stewart Island, and *P. planifrons* – located in the North Island and northwest of the South Island, including the West Coast[redacted]



The dots on the map show the places where kōura have been found. The dashed line shows the boundary between both species locations (NZFFD 2019).

[redacted]

Collectively known as kōura, these species are endemic to New Zealand and play a vital role in freshwater ecosystems. These species inhabit a range of aquatic environments including streams, lakes, and wetlands, with preferences for habitats offering structural complexity such as cobble substrates, woody debris, and undercut banks (Parkyn et al., 2009). Such features provide refuge from predation and hydrological disturbance, contributing to population stability.

Kōura are omnivorous detritivores, consuming a varied diet of leaf litter, algae, aquatic invertebrates, and occasionally small fish. Their feeding behaviour influences nutrient cycling and energy flow within stream ecosystems (Parkyn et al., 2001; Usio and Townsend, 2001). As ecosystem engineers, kōura also modify benthic habitats through bioturbation, affecting sediment dynamics and the composition of macroinvertebrate communities (Parkyn et al., 1997).

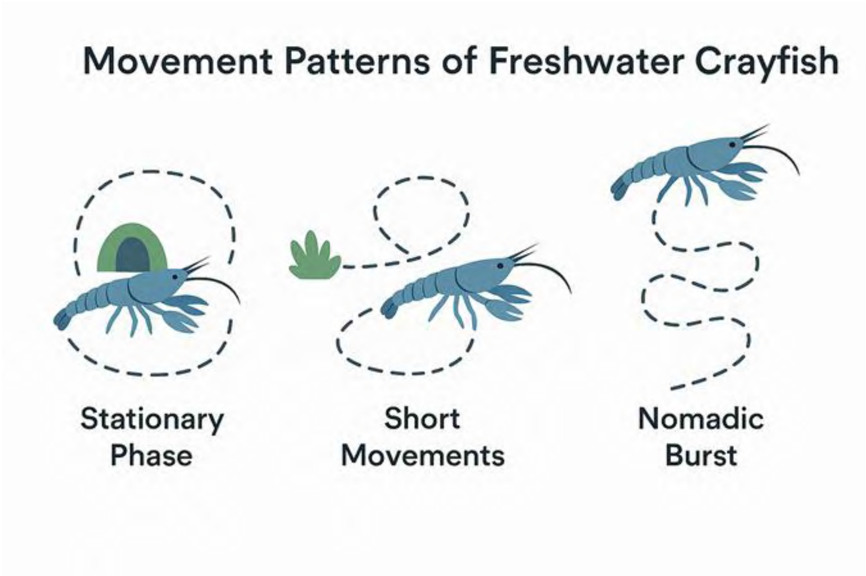
Kōura populations are vulnerable to a range of anthropogenic stressors. Sedimentation, nutrient enrichment, and chemical pollutants from agricultural and urban land use degrade habitat quality and reduce survival rates. Additionally, introduced predatory fish such as trout (*Salmo trutta*) and catfish (*Ameiurus nebulosus*) exert significant predation pressure, particularly on juvenile kōura (Usio and Townsend, 2000). Land-use intensification and riparian vegetation loss have also been linked to declines in kōura abundance and distribution (Parkyn et al., 2002).

Beyond their ecological role, kōura hold cultural significance for Māori as a traditional mahinga kai species. Their conservation is, therefore, important not only for biodiversity but also for the protection of indigenous knowledge and practices.

3.2 Freshwater crayfish movement ecology

Relatively little is known about the detailed movement ecology of New Zealand kōura (*Paranephrops spp*.) when compared to international freshwater crayfish species. Existing research suggests relatively long residence times in forested streams, with many individuals remaining in the same stream reach (6-8 m reach lengths) for up to twelve months (Parkyn, 2000). In modified, pastoral stream reaches, kōura tend to exhibit shorter residence times, typically ranging from three to six months, and overall exhibit more upstream and downstream movements than individuals in forested streams (Parkyn, 2000). The New Zealand Macroinvertebrate Trait Database (Phillips and Smith, 2018), which is based on published and unpublished data, personal observations, and expert opinion, indicates that *Paranephrops spp*. are unlikely to disperse less than 10 m, but may move distances of 1 km or more. Furthermore, it records that kōura are capable of swimming but are more likely to crawl. However, we found no published information on the size of kōura home ranges or typical movement distances/rates. Recovery following disturbance events, such as major flooding, can take up to three years in pasture systems (Parkyn and Collier, 2004), highlighting the importance of recolonization and dispersal movements (and hence connectivity) for sustaining populations.

Based on the international literature, freshwater crayfish movement is generally characterised by long sedentary phases interspersed with exploratory or nomadic bursts (Gherardi et al., 1998; Robinson et al., 2000). Most individuals occupy relatively restricted ranges, often remaining within tens of metres of a "home" refuge, while a smaller proportion disperse over hundreds of metres or more (Bubb et al., 2008; Loughman et al., 2013; Makiguchi et al., 2024; Moorhouse and Macdonald, 2011). Long-term tracking studies show that median daily movements typically span less than 1 m day^{-1} in some species (Bubb et al., 2008; O'Hea Miller et al., 2024) and up to around 30 m day^{-1} in others (Hudina et al., 2011) (see Table 3-1). In cases of short daily movements, individuals usually return to the same refuge. By contrast, long-distance dispersal events (>100 m day^{-1}) have been reported (Loughman et al., 2013) and may have disproportionate consequences for population spread. Once individuals vacate a refuge after such a dispersal event, they typically do not return but instead establish new home refuges (Figure 3-2).



[redacted]

Movement patterns of freshwater crayfish are strongly seasonal, with higher activity during warmer months and reduced movement during colder periods or moulting events (Bubb et al., 2004; Hudina et al., 2011; Makiguchi et al., 2024). This is consistent with observations for kōura in New Zealand (e.g., Parkyn 2000). Reproductive status also plays a role, where female crayfish may travel further following hatching, and egg-bearing females may be less active (Hudina et al., 2011). In some populations, females and larger individuals tend to travel greater distances than males or smaller conspecifics, although these patterns are not always observed across all populations (Bubb et al., 2008; Hudina et al., 2011).

Compared to native species, invasive species consistently demonstrate enhanced dispersal capacity across populations (Bubb et al., 2006; O'Hea Miller et al., 2024). In European rivers, the invasive signal crayfish (*Pacifastacus leniusculus*) typically move farther per day than the native white-clawed crayfish (*Austropotamobius pallipes*), with median daily movements of around 5 to 7 m compared to around 2 m for the native species (Bubb et al., 2006). Signal crayfish populations may be able to move downstream at rates of up to 1.5 km per year (Bubb et al., 2004). Invasive red swamp crayfish (*Procambarus clarkii*) combine nomadic bursts with strong exploratory tendencies, enabling rapid colonisation of new habitats (Gherardi et al., 1998). Behavioural traits such as boldness and greater plasticity in refuge or habitat use further enhance invasive success, supporting colonisation of patchy environments (Bubb et al., 2006; Galib et al., 2022; Johnson et al., 2019). In some cases, invasive crayfish can even bypass in-stream barriers through overland movements (Thomas et al., 2019).

Across crayfish species and freshwater systems, several patterns emerge:

- Most crayfish exhibit a mix of sedentary behaviour interspersed with occasional nomadic dispersal.
- Daily ranges are generally small, with mean movements typically less than 50 m day^{-1}.

- Some individuals undertake long-distance movements exceeding 100 m, though usually less than 1 km.
- Movement is seasonal, with greater activity in warmer months and reduced movement in winter.
- Sex- and size-related effects appear in some populations, with females and larger individuals often travelling farther.
- Invasive species generally display greater dispersal capacity and behavioural plasticity than native species.

Although international research has identified these broad patterns, they require validation for New Zealand kōura. The absence of fish predators on the Denniston Plateau, along with species-specific behaviours and physiology, may result in movement patterns that differ from those reported for international species.

Table 3-1 provides a summary of key movement behaviours and distances for freshwater crayfish determined from the available literature.

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4 August 2026 5.30 pm

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3.3 Freshwater crayfish passage

Freshwater crayfish are capable of both short-range and long-distance movements, but instream structures such as weirs and culverts can create barriers to dispersal. For New Zealand kōura, we found no studies that have directly tested passage requirements. International literature is often focused on preventing the spread of invasive crayfish and, therefore, creating barriers to crayfish passage; however, it does provide some details of structural features that are most likely to impede crayfish movements.

Across species and populations, several structural features have been shown to reduce crayfish passage at instream barriers. Water velocity is one of the most influential factors, where passage success has been found to decline at water velocities greater than 30 cm s^{-1}, which corresponds with the critical swimming capacity of many crayfish species (Foster and Keller, 2011). At these speeds, crayfish moving through culverts were frequently observed slipping, further reducing their ability to pass. Additional higher water velocities (those above 60–70 cm s^{-1}) have been found to completely block crayfish passage (Ikeda et al., 2019). Other physical characteristics, including slopes steeper than 25°, vertical drops, overhangs, and smooth substrates, also hinder or prevent movement (Frings et al., 2013; Louca et al., 2014; Rosewarne et al., 2013). Surface or substrate type within structures is particularly important, where smooth concrete or steel surfaces prevent crayfish from gaining purchase to travel overground, whereas roughened substrates or wetted margins with lower flows provide footholds that can facilitate successful passage (Louca et al., 2014). Virile crayfish (*Orconectes virilis*) were observed moving upstream through an eel ladder with slopes of 30–50° (Welsh and Loughman, 2015).Researchers suggested this was possible because of the internal peg-board substrate, highlighting the importance of substrate type or internal structures in enabling crayfish to overcome otherwise challenging obstacles such as steep slopes or high water velocities (Welsh and Loughman, 2015).

Crayfish behaviour also plays a role in determining whether barriers are passable. Many species use both walking and swimming to negotiate instream obstacles, switching between modes depending on flow conditions and slope. Walking dominates in shallower or moderate flows, whereas swimming is relied upon at steeper slopes or when flows exceed walking capacity (Rosewarne et al., 2013). Behavioural traits such as boldness, persistence, and climbing ability also increase passage success, with bolder individuals more likely to move upstream (Galib et al., 2022; Rosewarne et al., 2013). Invasive species in particular show behavioural plasticity, including the ability to bypass instream structures through overland movement (Krieg and Zenker, 2020), raising the possibility that kōura may also exploit alternative pathways when suitable habitats are available.

Several interventions have been trialled to facilitate crayfish passage, although most have targeted native species overseas. Roughened surfaces, such as crayfish tiles, studded mats, or bristle arrays installed on low-head weirs, have been shown to improve passage for native crayfish but not for invasives, suggesting scope for selective design (Kerr et al., 2021). These structures provide decreased flows through the structure as well as providing refugia for crayfish to rest.

Based on international literature, the features more likely to prevent crayfish passage and, therefore, need to be accounted for in a New Zealand context include:

- Water velocities should not exceed 30 cm s^{-1}.
- Slope should not be great than 25°.
- Vertical drops and overhangs should be minimized so crayfish can still crawl into the mouth of the structure.
- Culvert substrate should be roughened to improve crayfish purchase and climbing ability.

Although most evidence comes from studies focused on restricting invasive crayfish, these findings highlight the structural and behavioural factors most relevant to supporting kōura passage through instream structures in New Zealand. As no studies have yet examined kōura passage directly, future research is needed to validate these patterns in a New Zealand context.

4 Conclusions & recommendations

Presently there is little published information available on the movement ecology nor passage requirements of New Zealand's kōura species. Evidence suggests that kōura are most mobile during summer months, but we lack information on the spatial extent of those movements. Available international literature on freshwater crayfish suggests that, on average, regular movements are in the region of tens to hundreds of metres. However, longer-term dispersal patterns are little studied other than for invasive species that have demonstrated an ability to colonise entire catchments over time. There is an urgent need to better understand the movement ecology of native kōura and to determine the potential impacts of instream barriers on their movement and population processes. This should include consideration of genetic structuring of populations.

The international literature identifies several distinct design features of instream structures that impede or block movements including vertical drops, high water velocities, and smooth substrates. As far as practicable, these should be avoided in new structures to minimise impacts on kōura dispersal and movements. Features that can be incorporated that will likely improve passage include the use of roughened substrates within culvert barrels and rock ramps at culvert outlets to eliminate vertical drops. The ability to disperse over land has been observed for some species but not others; in the absence of information on this trait in kōura, it is not recommended to rely on overland movements as a means of mitigating the impacts of instream barriers.

The above recommendations are based on current best available information. However, the absence of evidence specific to the New Zealand kōura species means that there is high uncertainty over the effectiveness of the above recommendations and the potential effects on kōura populations if movements are impeded by the Project.

Future research that would reduce uncertainty associated with the environmental effects of the Project on kōura include (in order of priority):

A. Testing if substrate roughness can facilitate dispersal through culverts.

B. Rock-ramp designs to enable kōura passage.

C. Biotelemetry studies of kōura movements around culverts with different characteristics.

D. Investigation of population genetics and association with instream structures.

Testing the effectiveness of substrate roughness for facilitating kōura passage (A) would have the greatest benefit for informing culvert design and reducing uncertainty over likely ecological outcomes of the Project. Such testing could be completed in a controlled laboratory setting and it is strongly recommended that this be undertaken prior to culvert designs for the Project being finalised.

Kōura have been observed by the authors passing standard lateral ridge rock-ramp fishway designs as set out in the New Zealand Fish Passage Guidelines (Franklin et al., 2024). However, it is unlikely that this rock-ramp design will be practicable within the environmental setting of many of the Project culverts (Bixley, 2025). We are unaware of any examples of crayfish-specific rock-ramp designs that could be transferred to this application. As such, there is a need for collaborative work to explore and test different rock-ramp designs (B) to ensure a fit-for-purpose solution is identified for the Project culverts where an outlet drop is unavoidable. We are not aware of experimental facilities in New Zealand that would be suitable for testing at a realistic scale. As such, in-situ field-based studies will likely be required. This could be undertaken as part of an adaptive management process within the Project.

Because of the absence of information on the movement ecology of New Zealand's kōura species, it will be important to monitor the effects of the Project on kōura movement. Biotelemetry (i.e. tagging studies) can be used to track the movement of individuals over time in reaches with and without culverts (C). It is recommended that this be incorporated as a monitoring requirement for the Project. Ideally, monitoring would follow a Before-After-Control-Impact sampling design (Baker et al., 2024) to maximise the ability to detect any effects of the Project on kōura movements. Consequently, we recommend that monitoring commence prior to construction so that the effects of the Project can be more clearly delineated.

River fragmentation can impair gene flow and drive genetic structuring in populations (Wilkes et al., 2018). If the kōura populations on the plateau have been geographically isolated for a sufficient period of time, they may be genetically differentiated from populations elsewhere within the species' range and, thus, of conservation importance. Where effective kōura passage is to be provided within the Project, understanding any genetic structuring of the populations on the plateau (D) will be of low priority. However, if the movement of kōura is to be impeded significantly by the culverts within the Project, then we recommend completing a population genetics analysis.

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