# BRUNSWICK RIVER REPORT

## 2022

POSITIVE CHANGE FOR MARINE LIFE

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# INTRODUCTION

## About the Bruns

The Brunswick River is located in the Northern Rivers region of New South Wales (NSW). It meets the ocean at the picturesque coastal town of Brunswick Heads, forming an open, mature, wave-dominated estuary (NSW Government DPIE, 2022). From the headwaters of the main river, its waters flow past several settlements and agricultural areas with Main Arm, Mullumbimby and Brunswick Heads the major towns en-route to the ocean. From its highest reaches to the ocean, the River ranges 34km in length and drains an area of 225km² (Digital Atlas of Australia, 2022). For the people, land, and wildlife within its basin it plays host to a vast range of critical ecosystem services. Supporting a diversity of habitats and species, providing water for agriculture, and exceptional natural space for recreation and nature-based experiences - the value of such a waterway is difficult to overstate. For those fortunate to live within its reach, it is an integral part of life in the Brunswick Valley - especially given its significant environmental, social and economic importance to the region.

## First Stage

Our early River Warriors program gave us first-hand experience concerning the issue of marine debris and pollution in waterways in four key estuaries along Australia's east coast. Supported by a growing understanding that waterways are responsible for significant inputs of marine debris into the ocean (Schmidt et al. 2017), our projects aimed to address the issue at its source. ***During the early stages of River Warriors we conducted kayak-based surveys to collect, categorise and properly dispose of marine debris, and to develop clear recommendations based on source-based management solutions.***

While this phase of River Warriors on the Brunswick River in NSW highlighted the threat that marine debris posed to the catchment, we soon recognised the need to address broader human impacts including water quality, riparian zone degradation, as well as biodiversity and habitat loss - all vital to the river's long-term health. While some of these impacts are being proactively addressed, this often occurs in isolation and with limited coordination between the wide range of river users, who are vital stakeholders and need to be included in decision making. Our new approach therefore, was to support an integrated, ecosystem-focused catchment management program, to achieve tangible and long-lasting rejuvenation of the River.

> **"THE STORYMAP PROVIDES AN INNOVATIVE PLATFORM, WHICH SERVES TO HIGHLIGHT THE KEY THREATS TO THE RIVER, MAP THEIR SEVERITY ACROSS THE ESTUARY, AND PROVIDE PRACTICAL WAYS TO BETTER MANAGE THIS INVALUABLE RESOURCE.**

## Second Stage

The second stage of *River Warriors* has seen our team further develop and activate this ecological approach, ***focused on identifying, monitoring and mapping a range of environmental threats, analysing information gaps, bringing stakeholders together to share knowledge and resources, and prioritising cost-effective restoration projects to enhance, restore and protect the Brunswick River.***

During this stage we worked with project partners to fill existing data gaps and share information and knowledge to assist us in developing an interactive and comprehensive picture of the threats facing the river through the creation of an online ArcGIS Story Map. The StoryMap provides an innovative platform, which serves to highlight the key threats to the river, map their severity across the estuary, and provide practical ways to better manage this invaluable resource. It does this by displaying a wide range of ecological information in an interactive, clear, spatial format, sharing the story of the river and the factors that impact it. It also helps bring together the many different stakeholders, groups and management authorities actively working on ecosystem health across the catchment.

Over the past year we have carried out five working group meetings, seven kayak based surveys (covering more than fifteen kilometres of riverbanks), four community engagement clean-up events, two collaborative boat based surveys and collected more than seven hundred and fifty data points in the field - including georeferenced imagery. Through the map, we identify and explore several focus areas that require further management intervention, these are further explained in the section below.

"THE (BRUNSWICK) RIVER HOLDS **IMMENSE CULTURAL AND HERITAGE VALUE,** WHILE SUPPORTING A WIDE RANGE OF COMMERCIAL AND RECREATIONAL ACTIVITIES."

# FOCUS AREAS AND METHODOLOGY

Rivers are innately complex systems. Through vast drainage networks they collect run-off from rainfall events, and in doing so connect numerous ecosystems and land-use types. The Brunswick River forms in the upper reaches of Mount Jerusalem National Park in the Byron Bay hinterland, eventually weaving its way through the towns of Mullumbimby and Brunswick Heads to meet the ocean in the protected waters of the Cape Byron Marine Park. Throughout its journey, the river supports remaining native terrestrial ecosystems including the "Big Scrub" rainforest, while bordering agricultural, recreational, residential, urban and commercial land. It supports an enormous diversity of natural processes, hosts numerous endangered plant and animal species and provides critical nursery grounds for many marine species. The Big Scrub was the largest area of subtropical lowland rainforest in eastern Australia, however following intensive clearing for agriculture and logging in the 19th century, less than 1% remains (Parkes et al 2012). In addition, the river holds immense cultural and heritage value, while supporting a wide range of commercial and recreational activities; including eco-tourism, kayaking, boating, swimming, fishing, aquaculture, and recreational parks and trails.

Since European settlement, the majority of natural landscapes in the Brunswick Valley have been extensively modified. Vast tracts of land were cleared following selective logging for primary production and agriculture, especially for grazing (Australian Bureau of Statistics, 2010; Gale et al, 2004). The catchment has also seen significant residential development, centred mostly around the towns of Mullumbimby and Brunswick Heads, but also bordering the river and extending into its upper reaches and tributaries. While this vast river network is influenced by numerous natural and human impacts, our River Warriors project identified several that require urgent action in order to protect the long-term health of the River. During our river surveys, and with the input and consultation of key partners and stakeholders, we identified five focus areas for the project:

- Erosion;
- Water quality;
- Riparian habitat; native and invasive vegetation;
- Marine debris, and;
- Blue carbon.



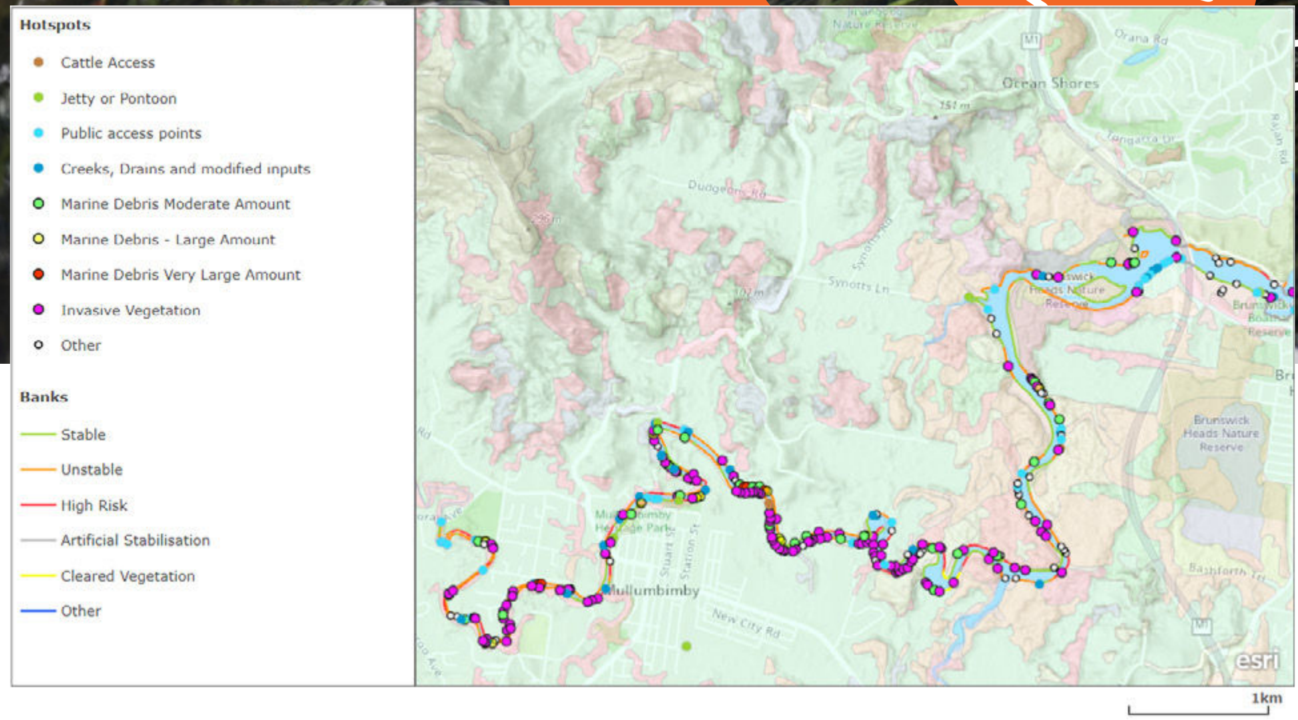



*Figure 1. An overview of some of the spatial data collected during kayak-based riverbank surveys in the field.*

To better understand these focus areas and how they are distributed along the length of the river, we mapped a range of indicators from the mouth of the Brunswick River upstream to the town of Mullumbimby. Data collection was conducted through kayak-based surveys using GPS enabled electronic tablets. To ensure consistent water quality measurements (collected in a narrow window of time and across comparable conditions), we were supported by NSW Department of Planning, Industry and Environment (DPIE), Cape Byron Marine Parks staff and watercraft. For all on-river surveys, data was collected using ESRI Collector and Explorer apps for ArcGIS. Data was then collated and mapped in ArcGIS Pro.

Existing data was also added to some sections of our mapping in order to support and provide context to our results. The data was either publicly available through state and departmental data portals (NSW Government SEED - Sharing and Enabling Environmental Data in NSW), or requested directly from state, local council and non-governmental organisations. Data was imported in georeferenced, spatially ready formats, directly into ArcGIS Pro.

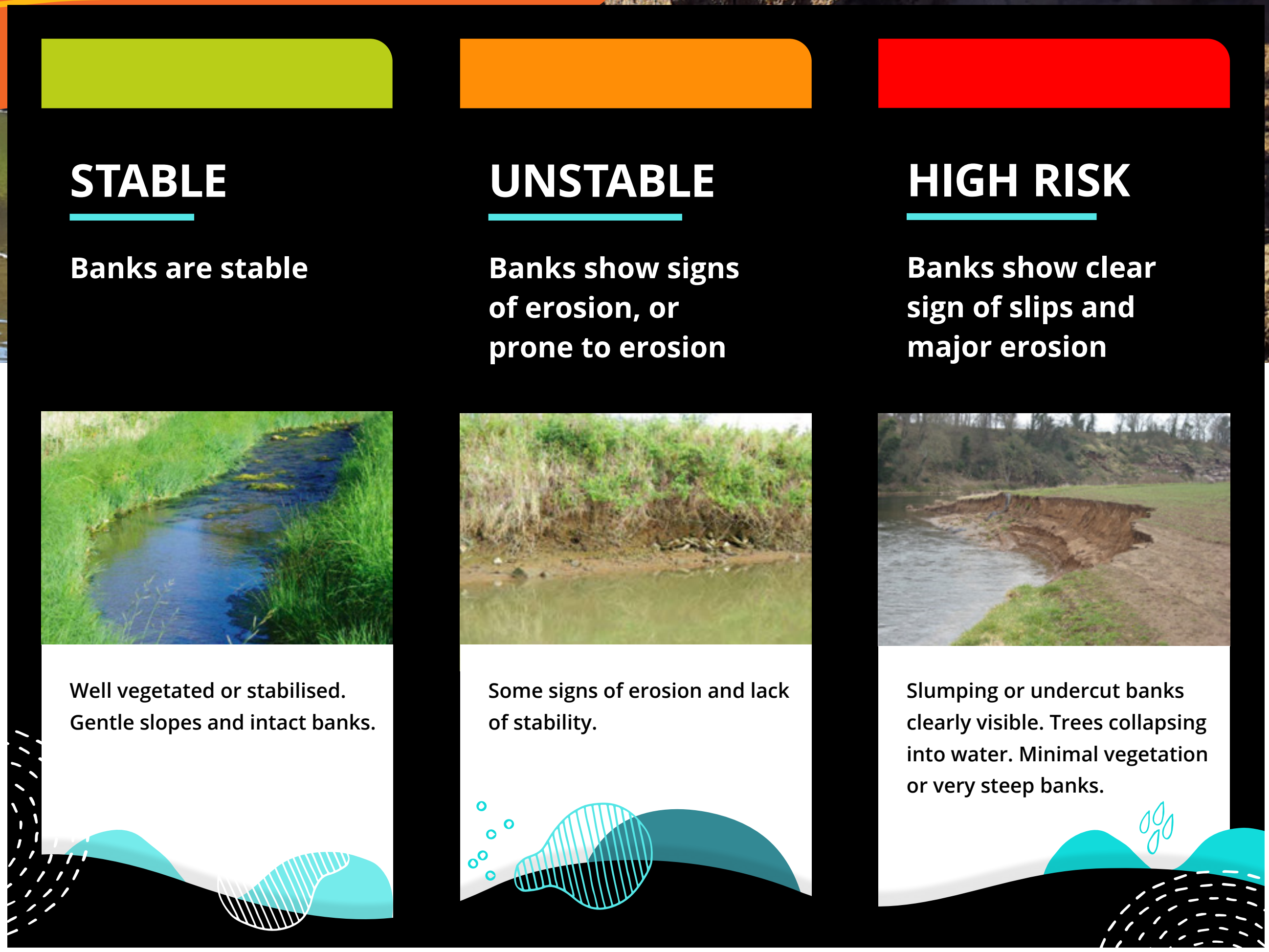



*Figure 2. Reference cards for bank stability categories identified from the mouth of the Brunswick River upstream to the town of Mullumbimby.*

"...(OUR MAPPING) ENABLED US TO PROVIDE A CLEAR VISUAL OVERVIEW OF THE SEVERITY OF BANK EROSION.

## Erosion

Early working group meetings, stakeholder consultation and surveys identified that of the many challenges facing the Brunswick River, bank erosion poses one of the most significant threats to its riparian habitats and ecosystem function. Erosion is a natural component of every river - they are dynamic systems, with alternate banks eroding and accreting in the lower reaches and shifting over time (Ro Charlton, 2007). However, due to clearing for extensive development and agricultural use, vegetation is often completely removed or confined to a thin strip fringing the river, providing a significantly reduced buffer between the waterway and the land. This leads to unstable banks, increased surface run-off and flow and the natural process of erosion, which usually occurs gradually and imperceptibly over time, is dramatically accelerated in this highly modified landscape.

To clarify how erosion differed across the river, we mapped the integrity of riverbanks. Kayak-based surveys were carried out along both banks and each distinct section was assigned one of three categories of bank stability *(Figure 2).*

These categories enabled us to provide a clear visual overview of the severity of bank erosion across the survey area. Sections where vegetation had been cleared, or where riverbanks had been artificially stabilised, were also included in the mapping. We extensively photographed stretches of the bank to include georeferenced images in our final ArcGIS interactive StoryMap, produced as a core component of this research project.



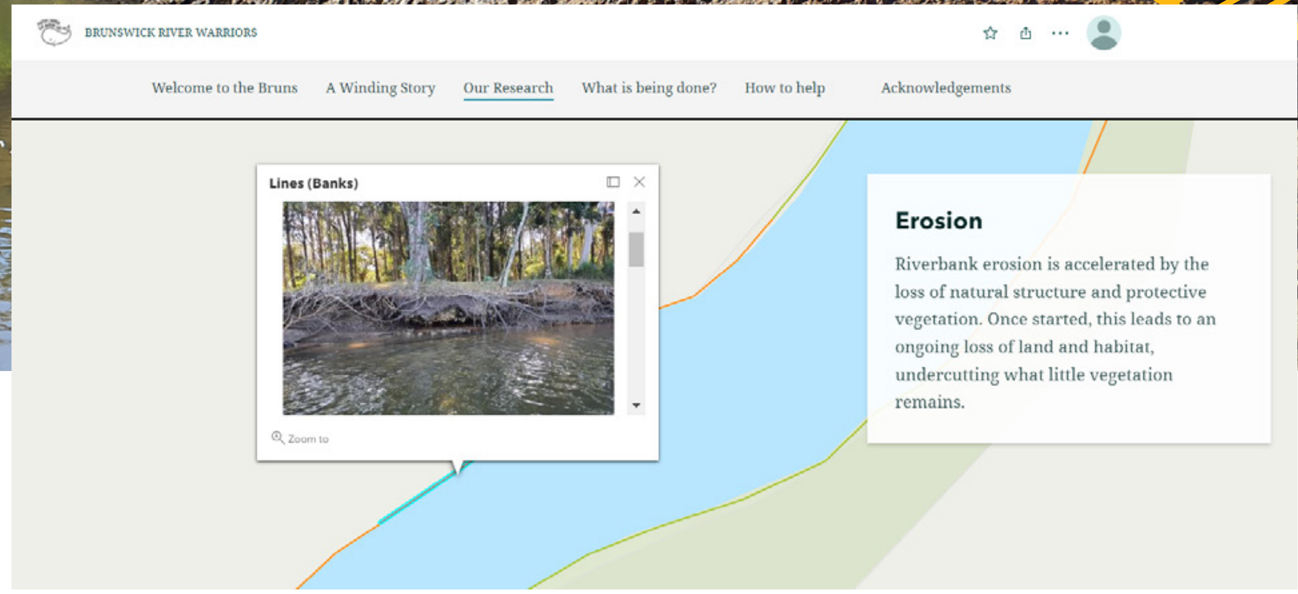



*Figure 3. Extensive georeferenced imagery was captured during all riverbank surveys, enabling users to easily view the bank condition or point of concern at any given time - effectively supporting decision making and site assessments for future work.*

## Riverbank access and clearing

Access points along the riverbank, whether for recreational use, cattle access or otherwise, invariably lead to a loss of structure and vegetation - unless very carefully managed. The resulting degraded riparian habitat weakens the riverbank and leads to increased erosion. During kayak-based riverbank surveys, we mapped all access points (footpath, vehicle, campsites, and cattle access), jetties and pontoons, as well as creeks and inlets to the river (in the study area). This provided a clear overview of all of the access points on this stretch of the river, visualised with georeferenced images referencing site-specific characteristics and threats.

## Water quality

Human impacts and poor land management practises directly influence water quality in rivers and streams. Runoff and erosion often carry excess nutrients, both soluble in surface run-off, and in silt and soil. Agricultural practices also lead to increased nutrient loads; through waste products from livestock, clearing and subsequent runoff from artificial fertiliser and additives (Costanzo et al. 2003).

We measured several factors affecting water quality, including dissolved oxygen (DO), salinity (S), total dissolved solids (TDS) and hydrogen (H). With support from NSW DPIE we collected water samples every 100m at a depth of 1m on an outgoing tide, and during comparable flow regimes. DO readings were taken on the river immediately following sample collection, using a FLIR Systems Extech DO610 ExStick II multi-probe. The remaining variables (H, TDS, S) were measured within 48 hours of sample collection following gentle agitation, using the Extech EC600 conductivity meter. All data was georeferenced and imported into ArcGIS Pro using the ESRI Collector Field app and ArcGIS Pro.

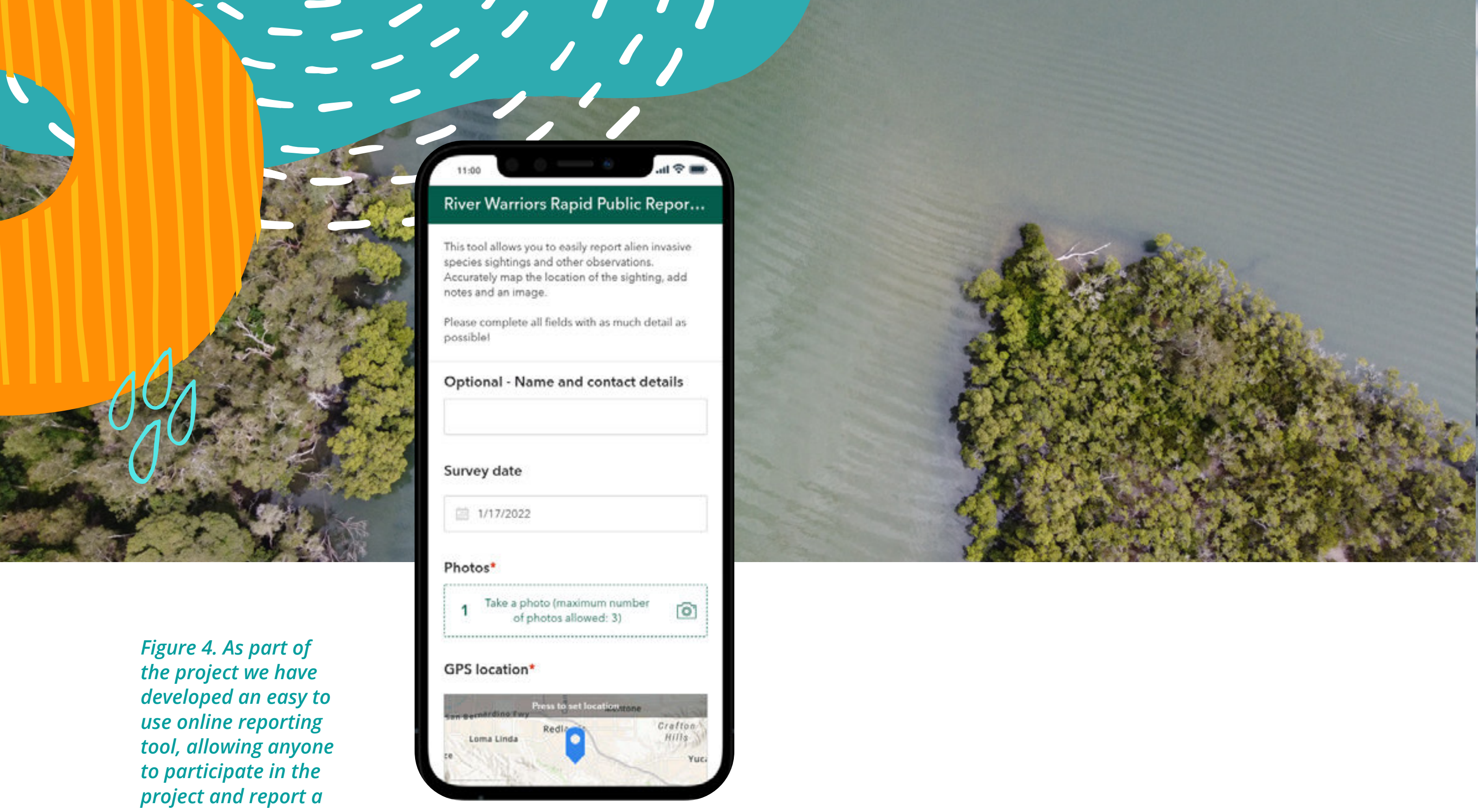



*Figure 4. As part of the project we have developed an easy to use online reporting tool, allowing anyone to participate in the project and report a sighting of interest straight from their phone - uploading location, a photograph and comments. This could be an exotic invasive species, a cluster of marine debris on the river, or anything in line with the project's focus.*

## Riparian habitat; native and invasive vegetation

Invasive species pose a major threat to native ecosystems. Introduced from foreign ecosystems, and free from the pests and predators which control them in their own native range, they outcompete native species and modify habitats.

To begin our data collection, program partners Brunswick Valley Landcare (BVL) provided a list of the ten exotic invasive species of highest concern on the Brunswick River. From this, a reference card was produced and during our surveys project members recorded any incidental sightings of these exotic species (figure 4), accompanied by georeferenced imagery.

To better understand the extent of invasive vegetation along the River, we developed a citizen science platform enabling community members and partners to report on and map invasive plant species (or any relevant threat or observation on the waterway). Simply by clicking a link on your phone, tablet or computer and taking a photograph, a record is submitted to our mapping project for confirmation and then added to the data set.

## Marine debris

Previous River Warriors projects focused primarily on surveying and collecting marine debris, providing a wealth of contextual information. This included detailed results on the breakdown and composition of litter from various sources. Prior findings, including the most prevalent types of debris along various stretches of the river, key sources and opportunities for mitigation, have helped to inform this new program, which continues to monitor debris hotspots along the River.

Hotspots are divided into three broad categories and their locations mapped with georeferenced imagery.

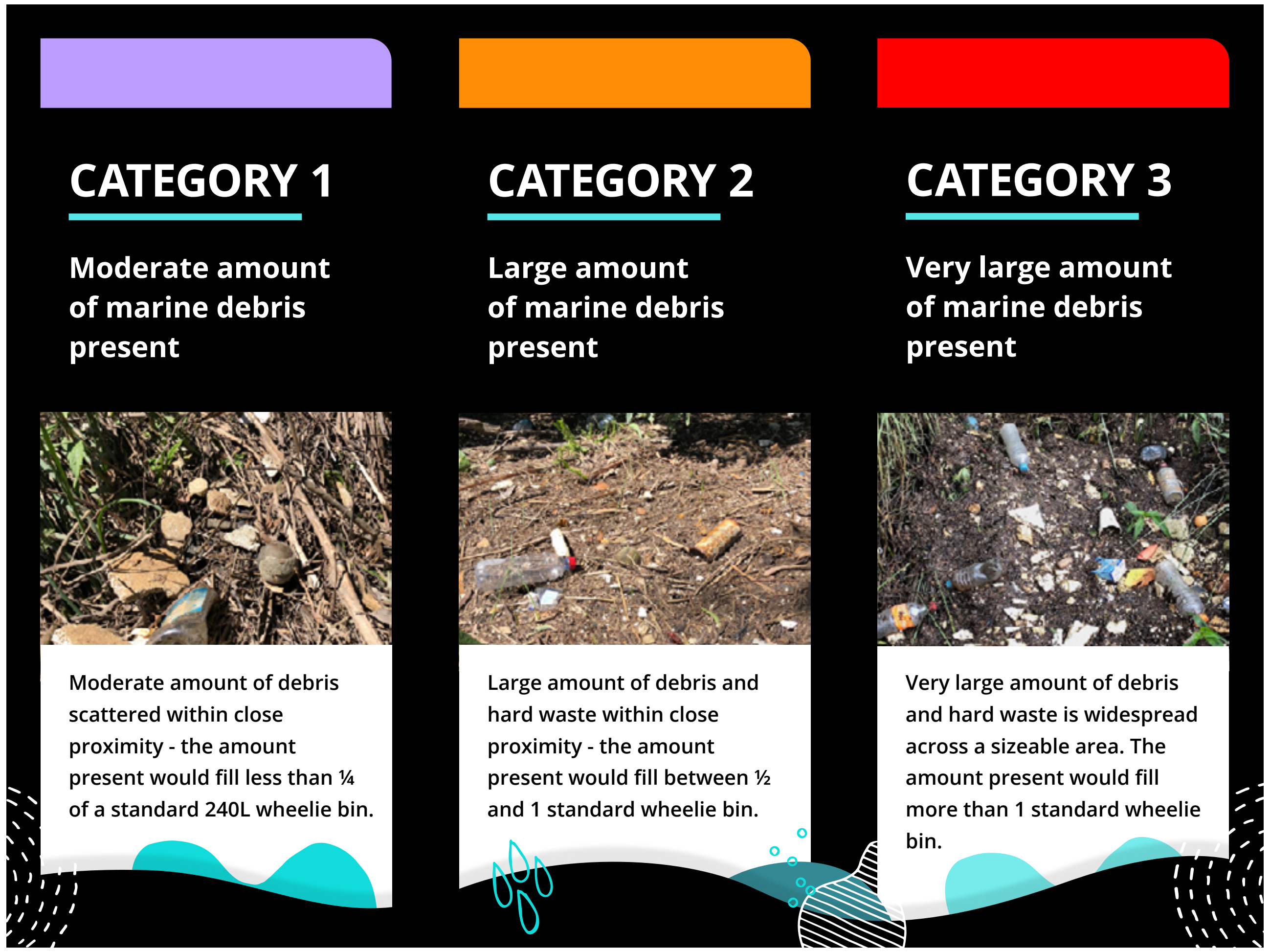



*Figure 5. Reference cards for marine debris hotspot categories identified from the mouth of the Brunswick River upstream to the town of Mullumbimby.*

## Blue carbon

In light of the growing threat of global climate change, focus has grown on better understanding the flows and stores of carbon both in the atmosphere and below ground. It is increasingly recognised that climate change must be taken into consideration not only in conservation and natural resource management fields, but also as a core component of good governance at all levels of government (NSW Government, AdaptNSW 2022).

> "MANGROVES AND SALT MARSHES **REMOVE CARBON FROM THE ATMOSPHERE** AT A RATE OF UP TO TEN TIMES GREATER THAN THAT OF TROPICAL FORESTS...

Blue carbon is the carbon that is stored in coastal and marine ecosystems (most notably; mangroves, salt marshes and seagrasses) and is of particular importance in estuarine stretches of rivers which support them. These ecosystems sequester and store large quantities of blue carbon in both the plants and the sediment below. Mangroves and salt marshes remove carbon from the atmosphere at a rate of up to ten times greater than that of tropical forests, and are able to store up to five times as much carbon per area (NOAA, 2022).

Given the capacity that mangroves have to stabilise banks, act as a buffer to wave-based erosion and their ability to sequester atmospheric carbon, they can play a valuable role in restoration (Stewart et al. 2008) if used in appropriate sites, and not at the cost of other valuable habitats (for example, saltmarsh, seagrass or mudflats). To better understand the opportunities that exist to prioritise blue carbon habitats, we obtained and mapped spatial data from NSW DPIE, mapping the extent of key blue carbon habitat (mangroves, seagrasses and saltmarshes) in the Brunswick Estuary.



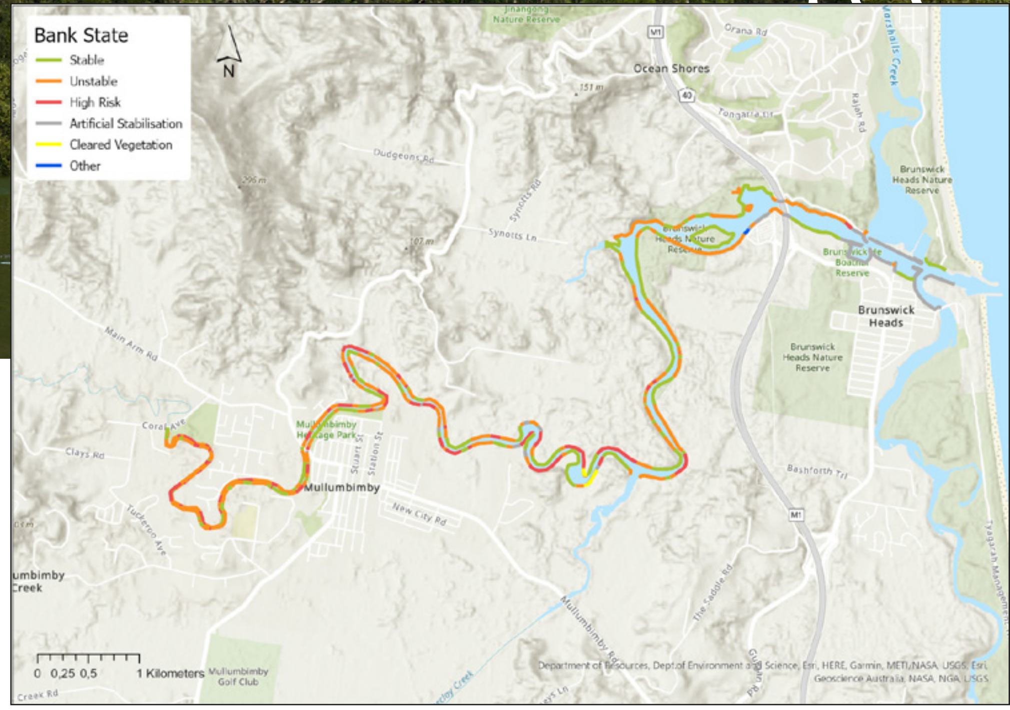



*Figure 6. Bank stability along the lower to middle reaches of the Brunswick River - mapped as a part of our ArcGIS interactive StoryMap.*

# RESULTS AND DISCUSSION

Collecting data spatially allowed us to interpret how the various human impacts we identified differed over the survey area. The severity and frequency was represented visually and interpreted based on surrounding influences and characteristics. Below we present our results, discuss our findings and considerations for future projects, as well as explore management interventions to address the myriad threats that currently face the river.

## Erosion

We found that much of the lower reaches of the river were characterised by longer, more gentle, alternating stretches of unstable or stable banks, with small sections at high risk. In several stretches in the lower reaches, this stability was provided by the nature of the underlying geology, with more erosion-resistant rocky banks and cliffs especially near the M1 overpass. The banks near the mouth of the Brunswick River were largely stabilised through artificial techniques and rock armouring. This included the harbour, as well as somewhat patchy stone toe protection across much of the estuary bay.

Although this rock armoring provided protection for much of the riverbank on either side of the river mouth - these works are starting to fail in places, exposing undercut banks to renewed ongoing erosion. This was particularly noticeable in places along the restored native bushland behind Torakina beach, shown here in Figure 7 (one of the georeferenced images from our riverbank stability map).

*Figure 7. Patchy failure of stone-armoured banks protecting the nature reserve behind Torakina beach is leading to renewed erosion and bank failure in parts, threatening native vegetation.*

From Kings Creek up into Mullumbimby bank erosion was more severe, with long stretches of bare bank, extensive bank failure, undercutting and slumping. Significant erosion was noted in several locations where rehabilitation had been carried out, and vegetation was being undercut and gradually lost due to erosion. This highlights that revegetation in itself is often inadequate in controlling erosion. Where the Brunswick River winds through Mullumbimby, there is even greater development pressure on the riparian zone, coupled with dense invasive vegetation, and more narrow incised channels. This gradual undercut erosion, visible across the length of the Brunswick River, is caused by the loss of the riverbank toe, the protective barrier between the riverbank and the water. We discuss the most likely factors and their additional impacts on erosion in the next section.

## Boat wash

*Figure 8. As motorised watercraft move through the river their hull displaces water, pushing a wave, or wake behind them. This wake breaks against the banks, with the force breaking down sediments - contributing to undercutting and instability.*

The Brunswick River is a popular destination for motorised boat users. A well-regarded fishing destination in itself, the river also provides launch access to the rich waters around the Cape Byron Marine Park and headland. On weekends the Brunswick Heads Harbour boat ramp is a hive of activity, highlighting the heavy boat presence from the boat harbour ramp, primarily down to the river mouth - but also up into the middle reaches.

Motorised boating represents an important recreational use on the waterway however, the wake formed by the passage of even small boats operating above a certain speed creates waves that will travel hundreds of metres until their energy is dissipated. These waves break against the banks of the shore, removing sediments and gradually breaking down the toe of the bank (Cox & McFarlane, 2019). Studies in New Zealand have shown that motorised vessels can generate waves up to eighty times larger, and with one hundred times more energy than background/natural wind-generated waves (Mcconchie et al. 2003). Particularly in narrow, shallow waterways (which describes much of the Brunswick River), boat wake has also been directly linked to erosion and increased turbidity (Bilkovic et al. 2019). Coupled with other erosive action, it can lead to slumping, bank failure and collapse - even in stretches with healthy riparian vegetation. In many stretches of the Brunswick, this is evidenced by rows of fallen trees, lying perpendicular to the banks.

Working with stakeholder groups and representative bodies to raise awareness and provide ongoing education campaigns is a key strategy to address this challenging issue. Other activities may include implementing no-wake zones in particularly sensitive stretches of



*Figure 9. Bank collapse and fallen trees along a stretch of the Brunswick River.*

the river, and clear signage and an enforcement presence to ensure compliance. A range of bank stabilisation techniques (specifically designed to mitigate the impact of boat wash and enhance the resilience of the bank toe to this form of erosion) can also be applied. These major interventions are best implemented in worst-affected stretches, in synergy with other restoration practices, as discussed later in this report.

*Figure 10. Log fillets, pictured here - are one of the riverbank restoration techniques specifically designed to protect the bank toe from boat wash, providing shelter for native vegetation (such as mangroves) to recover.*


*Figure 11. Flooding can cause rivers to overflow, damaging vegetation, increasing flow speed and further eroding banks where there is limited or no vegetation present to protect them.*

## Tidal and storm influences

Land which has been cleared less readily absorbs rainfall. While periods of heavy rainfall and infrequent flooding occur naturally, their impacts are greatly exacerbated in a modified landscape such as that surrounding the Brunswick River (where extensive vegetation has been cleared for agriculture and development). Instead of the ground soaking up the water and releasing it slowly, surface flow is more common (Reside el al. 2017). This water flows across fields, roads, and artificial surfaces and on into creeks, catchments and rivers. This often leads to abrupt, high rises in water level - with stronger, more turbulent waters rapidly eroding sensitive banks and often over-washing fringing vegetation and regrowth (Silberstein et al. 2004). This highlights a negative feedback loop that can occur in rivers with degraded banks. As riparian habitat is degraded or cleared, the river loses its capacity to absorb the impact of these high flow events, leading to even greater erosion and riverbank degradation. In essence, healthy rivers - with extensive buffers of native riparian vegetation, and well-vegetated catchments - are able to absorb and mitigate the impacts of large rainfall events. If these natural systems are cleared and degraded the buffer is reduced, leading to increased erosion, sedimentation and nutrification.

> **"IF THESE NATURAL SYSTEMS ARE CLEARED AND DEGRADED THE BUFFER IS REDUCED, LEADING TO INCREASED EROSION, SEDIMENTATION AND NUTRIFICATION**

*Figure 12. When riparian habitat is entirely cleared - it can have a disastrous impact on riverbank stability and erosion, especially when cattle have unrestricted access to the water.*

## Riverbank Access and clearing

Riverbank erosion is greatly accelerated by the loss of natural structure and protective vegetation. Healthy riparian vegetation acts as a buffer to many forms of erosion including during flooding and heavy rainfall. It also slows down water as it moves across the landscape, increasing infiltration and reducing the intensity of run-off. Roots bind and help reinforce the soil, whilst also capturing carbon and storing it in living biomass. Without this healthy vegetation and cover, bare banks are easily eroded and rivers are quickly laden with additional silt and soil (Abernethy et al. 1999).

In many places along the Brunswick River the root structure from old stands of large camphor *(Cinnamomum camphora)* trees is all that prevents further undercutting and complete bank collapse. However, this is a blessing and a curse as camphor is an invasive species and also one of the most prevalent established tree species along the middle reaches of the river. While in places it might be providing a useful stop-gap for erosion, it outcompetes native vegetation, supports less biodiversity than native species and can also increase the impacts of erosion through its fast growing and destructive root systems.

European settlement in New South Wales (NSW), Australia in the late 18th century resulted in extensive areas of floodplain and riparian vegetation cleared to allow farming on the rich alluvial soils with plentiful water supply (Skorulis, 2016). Ongoing land development to meet agricultural, commercial, and private residential development demands, has greatly reduced riparian vegetation and cover across the length of the Brunswick River. This leaves only small areas of vegetation for absorption and filtration of surface runoff. Furthermore, the riverbank itself is prone to trampling and clearing for access points to the waterway. Livestock access is a particularly damaging process on riverbanks, as their hooves break down bank and toe structure across a wide area, trample vegetation and increase siltation (Minchinton, 2019).

Figure 13. Here, cattle access has destroyed what little vegetation remained after clearing, with an almost entirely denuded mangrove tree and its trampled root system exposed.

By mapping jetties, and recreational and cattle access points on the waterway, we were able to identify high impact activities. Examining these in conjunction with stability maps further confirmed that the more tightly meandering stretches just south of Mullumbimby suffered from greater erosion and access issues than lower reaches. This information will be critical when considering potential restoration sites. It is worth noting that properly constructed jetties and pontoons can provide much better river access alternatives, restricting the footprint and damage to the riverbank and surrounding vegetation, however poorly managed they can become a hazard and also contribute plastic and polystyrene marine debris into the waterway, which can wash out into the Cape Byron Marine Park.

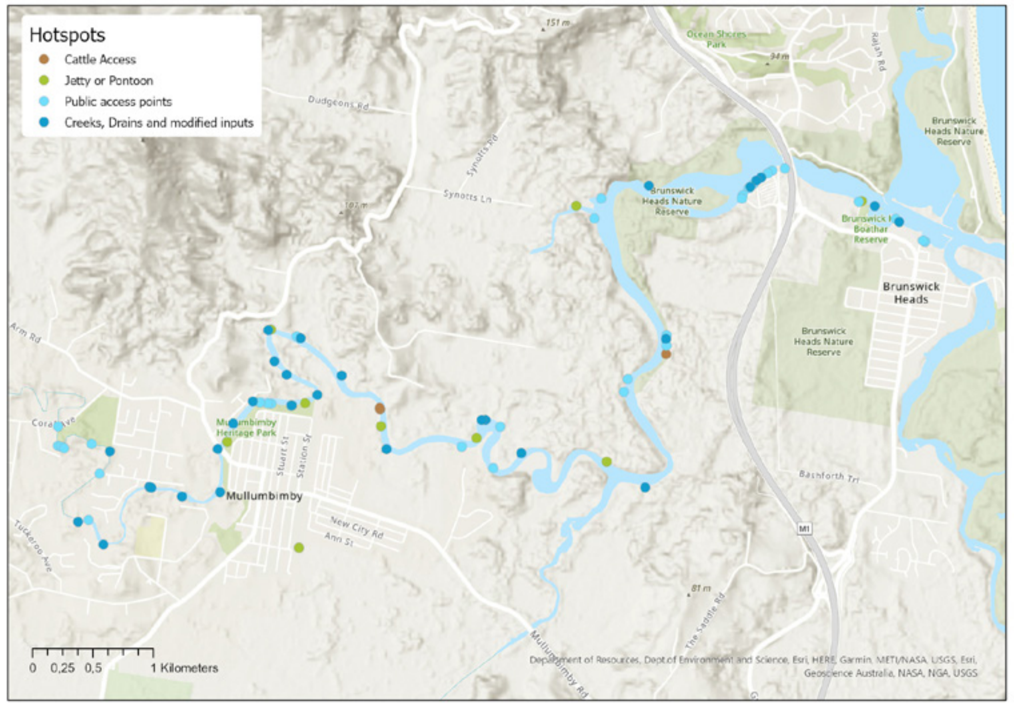



Figure 14. Human and cattle access points, jetties and pontoons, and various inlets along the lower to middle reaches of the Brunswick River.



Figure 15. Heavily eroded banks showing murky, turbid, sediment-laden water below.

"EROSION AND THE INCREASE IN SEDIMENTS AND NUTRIENTS THAT IT STIMULATES, IS COMMONLY RECOGNISED AS ONE OF THE MOST **SIGNIFICANT NEGATIVE INFLUENCES ON MODIFIED WATERWAYS.**

## Water quality

Although a range of impact inputs (including pollutants from nearby towns, developments and roadways) affect water quality, erosion and the increase in sediments and nutrients that it stimulates, is commonly recognised as one of the most significant negative influences on modified waterways. Greater erosion results in increased and fluctuating sediments, and available nutrients transported in the water column. Given adequate light, greater nutrients can rapidly increase growth of microalgae and bacteria (Nasir et al. 2014). The microalgae and bacteria then feed on the oxygen in the river, reducing availability for the many other species which constitute a healthy ecosystem; including fish, invertebrates, rays and molluscs.

Erosion can also lead to turbidity (cloudiness/opacity) of the water; due to increased sediment loads in the waterway, or the nutrients that they bring with them and potential for associated algal blooms (Prosser et al. 2001). Increased turbidity reduces the amount of light available and can smother aquatic habitats like eelgrass. These habitats are vital nursery grounds for a diverse range of fish and marine species.

Residential and commercial developments create polluted runoff from roads and the vehicles that use them, gardens and other commercial/industrial practices. A decommissioned sewage treatment plant sits in close proximity of our study area on the Brunswick River. Even with the careful use of retaining ponds and artificial wetlands for filtration - nutrient-rich waters are a common output from these sites for many years after their closure. Specific laboratory analyses for various nutrients and pollutants are required to understand these point sources and their influence on water quality. Specific, consistent monitoring of the decommissioned sewage facility was beyond the scope of this study.

Dissolved oxygen (DO) is an important component of water quality - as all living animals in the river require oxygen to survive. Typically, water is oxygenated by diffusion from the atmosphere, aeration of the water as it tumbles over falls and rapids, and through plants photosynthesizing. Areas of low dissolved oxygen may be caused by higher water temperatures (as warm water holds less dissolved gas, and also speeds up other reactions), but is more often due to excess nutrients that lead to a range of impacts - as aforementioned.

*Figure 16. Floating wetlands are just one possible hybrid engineered solution to help dramatically reduce in-stream pollutants and nutrients.*

We observed decreased oxygen levels from the oxygen-rich water flushed in from the ocean as we sampled upstream into Mullumbimby. The decrease is particularly noteworthy at the bend just northeast of Manns Road - directly downstream of the decommissioned Sewage Treatment Plant (STP). A suggested hypothesis is that this area is affected by increased nutrient run-off from the water treatment plant, leading to increased microbial and algal activity, reducing dissolved oxygen along this section. However, this warrants further investigation, specifically testing for nitrates and phosphates in the water column. Decreased dissolved oxygen in the more developed stretches of the river, near Mullumbimby, also warrant additional testing for nutrient levels and source. This further testing could determine whether engineering solutions (such as constructed wetlands) could serve as mechanisms to increase aeration, flow management and source reduction. Discussions with technical partners around exciting new techniques and developments such as artificial, floating wetlands have already begun in anticipation of our future restoration and mitigation projects.


*Figure 17. A snapshot of Dissolved Oxygen (DO) shows the shift from more oxygenated water from the ocean on a given tide, slowly decreasing upstream.*

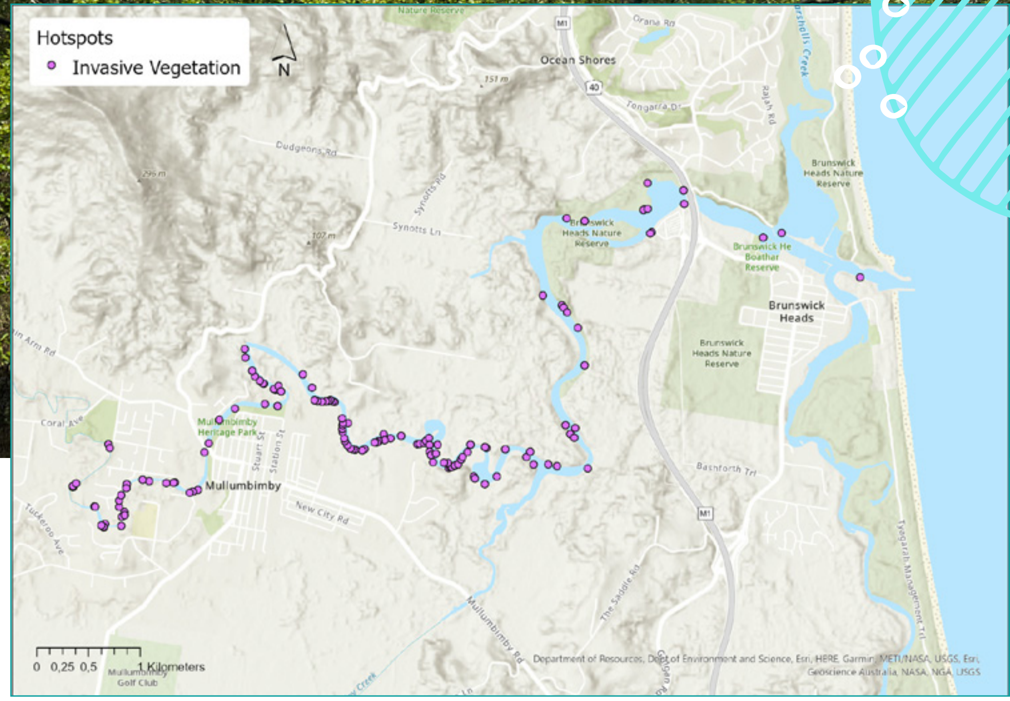



Figure 18. Initial surveys showing exotic invasive vegetation along the estuarine reaches of the Brunswick River.

## Riparian habitat; native and invasive vegetation

Exotic invasive vegetation presents one of the greatest threats to Australia's native vegetation, biodiversity, and primary productivity. The Australian Centre for Invasive Species Solutions places a conservative cost of damage caused by invasive species at $390 billion over the past six decades and around $25 billion a year and growing (Bradshaw et al 2021). More than 80% of nationally listed threatened native species are endangered by invasive species (Sheppard et al. 2021). Invasive species are widespread and persistent in virtually every ecosystem across Australia, and the Brunswick River is no exception.

There have been state-wide weed mapping projects conducted previously on the Brunswick River catchment. Although they are not current, they provide a useful starting point as many of these locations remain heavily affected. Given the extensive invasive vegetation along the length of the river and its propensity to spread rapidly, comprehensive mapping across the catchment is required to fully understand the problem and priority areas for management. Our riverbank surveys provide insight into the distribution of some of the most damaging invasive species across the estuarine extent of the waterway.

Volunteer, staff and community sightings and records, along with past local and state weed mapping projects, are included in our River Warriors StoryMap. Easily navigable maps and georeferenced imagery allow conservation planners and managers to assess areas where weed control is required, aiding site selection and supporting decision making. The easy to access, single-click citizen science portal also enables project partners and passionate community members to submit records of potential invasive species for review and addition to our ever-evolving map.

*Figure 19. During our surveys we identified large areas where Ground Asparagus (Asparagus aethiopicus) has heavily invaded banks, upstream from the M1 overpass.*

Whilst many sections of the river require invasive species control, we have identified three areas of particular concern. Across large tracts of riparian land in the lower estuarine reaches (particularly upstream of the M1 overpass) ground asparagus *(Asparagus aethiopicus)* has completely smothered native ground vegetation, outcompeting valuable saltmarsh habitat. Frequent presence of Coastal Morning Glory *(Ipomoea cairica)* and Lantana *(Lantana camara)* were noted in the middle reaches, and large numbers of Umbrella Trees *(Schefflera actinophylla)* were recorded on the banks to the south of Mullumbimby.

Camphor Laurel *(Cinnamomum camphora)* is common across all but the lower reaches of the river, making it one of the most entrenched invasive species in the catchment. Camphor can invade and grow vigorously to form dense thickets, excluding native vegetation from an area. It fruits heavily, and is rapidly spread by several bird species. Its dense, shallow roots and thick canopy cover tend to exclude ground cover through overshading and can further weaken riverbanks (Firth et al. 2014). Despite this, in some degraded stretches, very old camphor tree root structures act as the last form of bank toe protection, making their removal challenging. Because of this, it is important to incorporate rehabilitation strategies that take this into consideration, such as successional planting or bank stabilisation works.

> "...IN THE BRUNSWICK HEADS NATURE RESERVE ALONE, **FORTY-THREE THREATENED ANIMAL SPECIES** AND THIRTY-SIX THREATENED PLANT SPECIES HAVE BEEN RECORDED...

The loss of healthy riparian vegetation equals a loss of critical habitat for the species that call these unique environments home. In the Brunswick Heads Reserve alone (a small parcel of well-restored native riparian vegetation) forty-three threatened animal species and thirty-six threatened plant species have been recorded (NSW National parks, 2022). When selecting restoration sites, reducing fragmentation by connecting areas of regenerating vegetation with intact, healthy riparian habitat will be a key consideration.

Intact and well established native riparian vegetation is essential to healthy waterways. It provides a living link between water and land. For people, it provides a critical space for recreation, culture and well-being. Riparian vegetation also provides a host of ecosystem services including filtration, flow control and regulation, sediment trapping, biodiversity maintenance, as well as carbon sequestration.

It is our recommendation that invasive species control programs are assessed, strengthened and well-monitored to mitigate any unintended consequences of control measures. Regeneration of native species should complement these invasive mitigation measures and the existing alliance of local groups strengthened to increase community participation, while decreasing reliance on chemical inputs, which can further harm natural processes.



## Marine debris

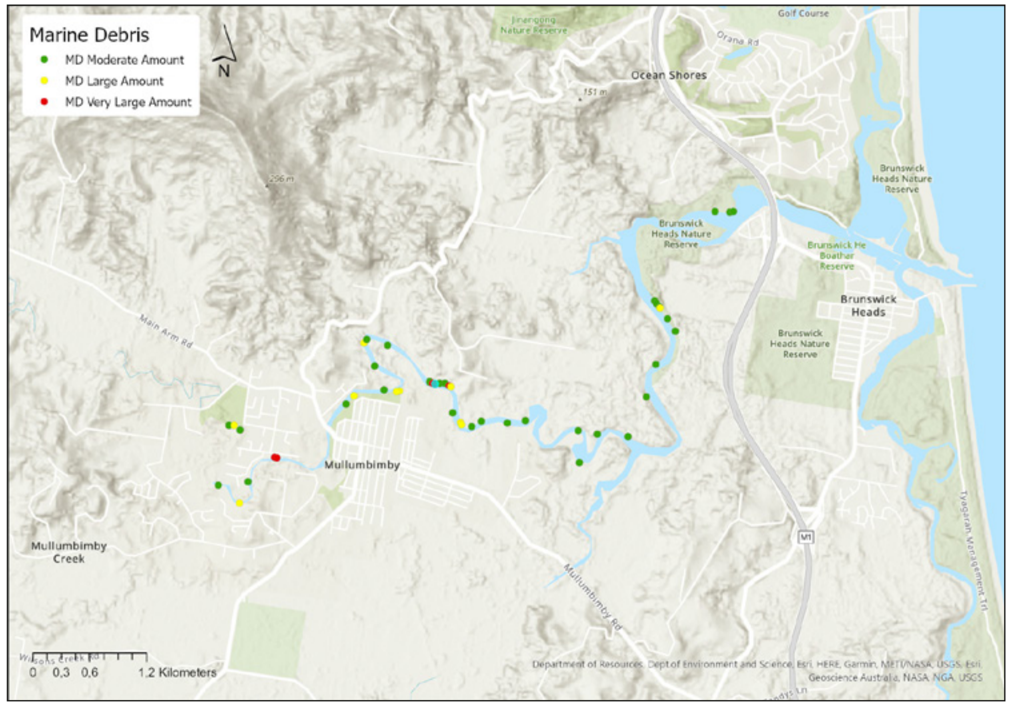
Solid waste (including plastic) commonly makes its way into rivers and creeks through drains, runoff, wind, extreme weather events and direct littering. Particularly buoyant plastic - most notably polystyrene - can also be pushed up-river from the ocean during peak tides and intense weather. Tides, heavy rain and floods wash debris onto banks and into vegetation where it is often trapped and accumulates over time. Both in the river and in the sea, man-made debris threatens countless species through ingestion and entanglement. It affects food safety, tourism, and even contributes to climate change (Ford, 2022). So great are its risks that it has been identified as a Key Threatening Process in Australia since 1999 (Commonwealth of Australia, 2018). Some studies suggest that plastic will outnumber fish (by weight) in our oceans by 2050 (World Economic Forum, 2016), and scientists estimate 90% of all seabirds alive today have ingested plastic of some kind (Wilcox et al. 2015).

The results of our mapping exercise suggest that the banks closest to the mouth of the Brunswick River show fewer, and less severe marine debris hotspots than the middle reaches leading up into Mullumbimby *(figure 20)*. This is supported by findings from past projects, when significantly more debris was collected from the middle reaches (66 pieces of debris collected per volunteer hour) vs lower reaches (19 pieces per volunteer hour).

The greater abundance of marine debris in the middle reaches is likely due to two factors - 1) the winding nature of the river in this stretch, coupled with thicker patches of riparian vegetation provides greater catch-points for marine debris to accumulate when making its way downriver (close enough to the estuary mouth/tidal range for large catchment flows, but not tidal enough for the greater pull closer to the mouth) and, 2) development pressure on the riverbanks increases further upstream towards Mullumbimby, resulting in a greater abundance of debris.

Some of the hotspots identified include old and derelict dumpsites that appear to have gradually been exposed over time. We know from our previous marine debris-focused projects that the main waste types found across similar transect areas near Mullumbimby included litter and debris from urban development, informal dumpsites, localised littering and overflow from properties, single-use food packaging, and buoyant foamed plastic transported via tides and river flow. Something to take into consideration is that the lower reaches of the river are armoured with rock fill. Although this does trap some marine debris, the steeper banks and more uniform structure is less likely to capture litter than mangroves or vegetated banks.


Figure 20. Map showing identified Marine Debris Hotspots on the Brunswick River.




During previous surveys, we found an average of 945 pieces of debris per kilometre on the Brunswick River, and scored the river an F+ on our Marine Debris Report card. This reflects the numerous sources of debris entering the river, the quantity found, as well as the disproportionately large amounts of plastic and foam. Mapping the key points of accumulation enables us to better consider how to address this ongoing issue. While the same mitigation efforts highlighted previously still largely apply, this spatial data will help to direct and implement these measures more effectively.

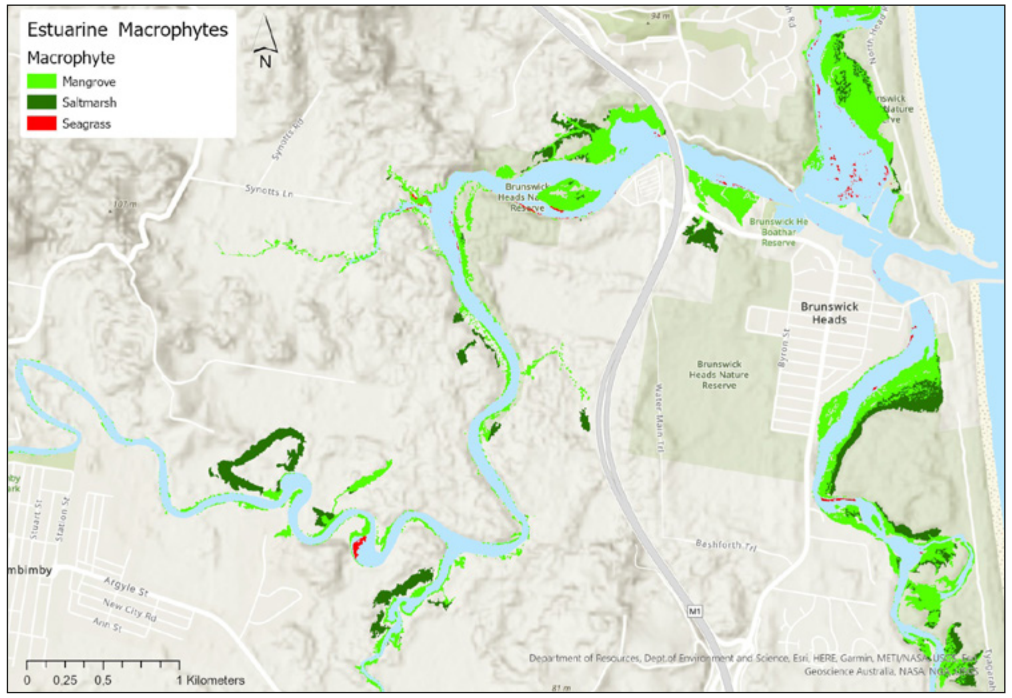
## Blue carbon

Blue carbon ecosystems are aquatic or estuarine vegetation types that have been recognised as capturing and storing disproportionately high amounts of carbon from the atmosphere. They include mangroves, seagrasses, saltmarshes, algae, macroalgae and other coastal plants, which occupy diverse niches from estuaries, to entirely submerged marine beds. Despite covering much smaller areas (globally) than tropical and temperate forests, blue carbon ecosystems are recognised to sequester carbon two to forty times faster than terrestrial forest ecosystems, and to store it for much longer (Mcleod et al. 2011, Murray et al. 2011) at depths of up to six metres below the surface (The Blue Carbon Initiative, 2022).



*Figure 22. Zostera eelgrass beds on a stretch of the Brunswick River near the mouth of Kings Creek.*

*Figure 21. Distribution and extent of remaining major blue carbon ecosystems on the Brunswick River and adjacent creeks.*

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**SEAGRASS BEDS AND MANGROVES IN PARTICULAR, ARE KNOWN NURSERY GROUNDS FOR A WIDE RANGE OF MARINE SPECIES... THEY ALSO FILTER WATER, REDUCE EROSION AND FULFIL A RANGE OF OTHER VITAL ECOSYSTEM SERVICES.**

On the Brunswick River, remnant blue carbon ecosystems are fragmented, with the largest intact stretches occupying the lowest estuarine reaches - especially in the form of mangroves and saltmarsh (*Figure 21).* Seagrass cover is minimal and restricted to 4km from the river mouth, apart from one shallow, sheltered bay upstream from Kings Creek where there remains a large seagrass (eelgrass) bed *(Figure 22).*

While carbon capture is an important attribute of blue carbon ecosystems, these unique areas also serve a broad range of equally important natural functions. Seagrass beds and mangroves in particular, are known nursery grounds for a wide range of marine species, including those of commercial importance (Nagelkerken et al. 2002; Laegdsgaard et al. 1995). They also filter water, reduce erosion and fulfil a range of other vital ecosystem services (as aforementioned throughout this report). There has been some restoration of blue carbon ecosystems on the Brunswick River to date, however there is scope for more extensive programs that will create broad and long-term positive impacts for the waterway and the people and other animals who rely on it.

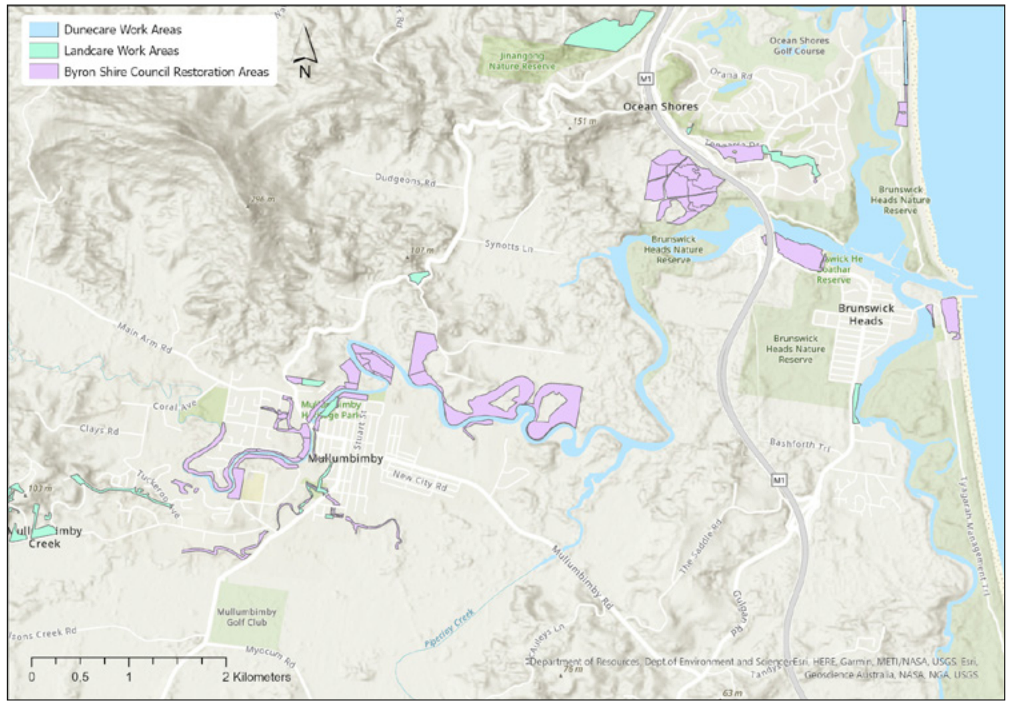
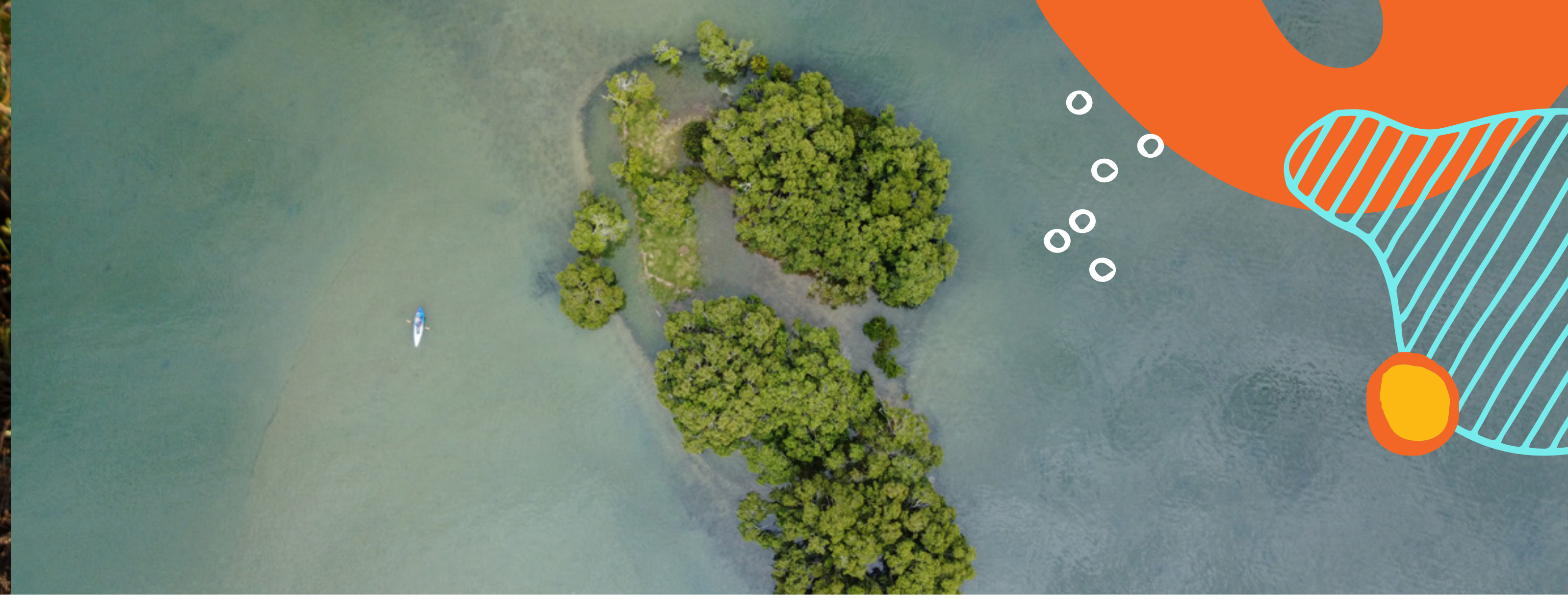



*Figure 23. Landcare, Dunecare and Byron Shire Council's existing habitat restoration sites on and around the Brunswick River.*

Byron Shire Council (BSC), Brunswick Valley Landcare (BVL) and the NSW National Parks and Wildlife Service (NPWS), among others, have been actively involved with habitat restoration, weed control and revegetation across a range of sites adjacent to the Brunswick River *(Figure 23).* This includes a significant project by Byron Shire Council as part of their *Bring Back the Bruns* campaign, targeting a stretch of the most severely degraded banks of the river. Despite this, there is still a lot of work to do, with much of the land fringing the river in a very poor state. This is reflected in the NSW EPA 2021 State of the Environment Report, which rated the river moderate-poor in terms of health.

Intact riparian corridors are a key component of a healthy waterway. A project to revegetate extensive corridors represents considerable potential and could incorporate a range of techniques, including bank stabilisation, flow regulation, habitat restoration and a blue carbon credit trading scheme to further incentivise stakeholder buy-in. This innovative, multi-faceted approach, has not been implemented on the river in the past.





# CONCLUSION AND NEXT STEPS

> "...WE AIM TO CHANGE THAT STORY, CREATING A NEW, SUSTAINABLE LEGACY FOR THE BRUNS.

This report outlines the findings of our 12-month research program on the Brunswick River. Our results have been incorporated into an effective spatial database, which highlights the key focal areas for addressing the health of the waterway, how they differ across the estuary and what influences them. The StoryMap not only presents this information in an intuitive and captivating way, it also enables stakeholders to contribute directly to the data itself. In doing so, it simultaneously works as a Citizen Science platform, which fosters greater community collaboration to *Bring Back the Bruns*.

The current state of the Brunswick River is legacy to intensive land management for primary industry, as well as maladaptive practices on and around the river. We aim to change that story, creating a new, sustainable legacy for the Bruns. In order to do this, a multi-faceted approach is required. One that involves mitigating current threats, including accelerated erosion, degraded riparian habitat, reduced water quality, invasive species and marine debris, while simultaneously working to reverse existing damage through a range of projects focusing on collaborative habitat restoration, education and the potential for carbon sequestration programs in priority area, which also mitigates increasing climate impacts at a local level.

From the StoryMap platform, we aim to unite our partners and the broader community to effectively communicate, plan, strategise and act towards a healthier Bruns. This lays a foundation for the following actions in the next stage of the project:

- The creation of additional informative and engaging content through our StoryMap platform, as well as through online and printed toolkits to support a diverse group of River Warriors (from landowners to farmers, fishers and Traditional Owners).
- A pilot blue carbon habitat restoration program across at least two identified sites on the Brunswick River.
- Additional ecological monitoring, including threatened species assessments, boat wash monitoring, and new, innovative remote sensing techniques.
- New partnerships with academic organisations and specialist groups to create tangible links between the private sector, blue carbon market and habitat restoration.

> THE BRUNSWICK RIVER WARRIORS **STORYMAP IS AN INNOVATIVE AND ENGAGING PLATFORM** THAT WILL DRIVE COMMUNITY AND STAKEHOLDER UNDERSTANDING, PARTICIPATION AND COLLABORATION FOR THE RESTORATION AND ONGOING PROTECTION OF THE BRUNSWICK RIVER

- A community organising program that builds self-managed local groups and supports them in planning restoration, accessing grants and having a collective, politically powerful voice on issues facing their waterways, land and industries.

Utilising the StoryMap (as well as the more extensive findings outlined in this report) as a foundation to actively improve river health, we will identify potential restoration sites along the estuarine reaches of the river. These sites will be determined by a number of factors, including maximising habitat connectivity (prioritising key habitat), linking existing restoration sites, improving river flows, as well as increasing landowner participation and stewardship of their banks. In addition, the restoration sites will be chosen based on their potential for a pilot blue carbon sequestration program. With funding secured for at least one site on the river, we aim to launch a unique, multi-faceted, community-centred conservation program that incorporates state-of-the-art GIS and remote monitoring technology, alongside grassroots community organising to *Bring Back the Bruns.*

Self-organised groups of individual landowners and managers are also able to have a significant collective effort by working together to better manage their properties. By replanting native species, minimising run-off and erosion, and working to restore degraded land, they can help rebuild healthy and resilient landscapes. To help ensure the broader success of River Warriors and drive community stewardship in the catchment, a parallel community engagement and education program will run in conjunction with our ongoing monitoring and restoration work. Extensive community consultation and participant surveys will ensure that we are connected with a diverse and multi-faceted group of stakeholders who depend upon the river, while also assisting us to develop new links with those who may not yet be actively engaged.

The Brunswick River Warriors StoryMap is an innovative and engaging platform that will drive community and stakeholder understanding, participation and collaboration for the restoration and ongoing protection of the Brunswick River. By mobilising all stakeholders; Bundjalung people, farmers, fishers, landholders, local and state governments, business owners and recreational users we can help to coordinate collective efforts to better manage this important catchment - the beating heart of the Byron Shire.



## ACKNOWLEDGEMENTS

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Compiled by Marx, D., and Goodsell, K. On behalf of Positive Change for Marine Life.

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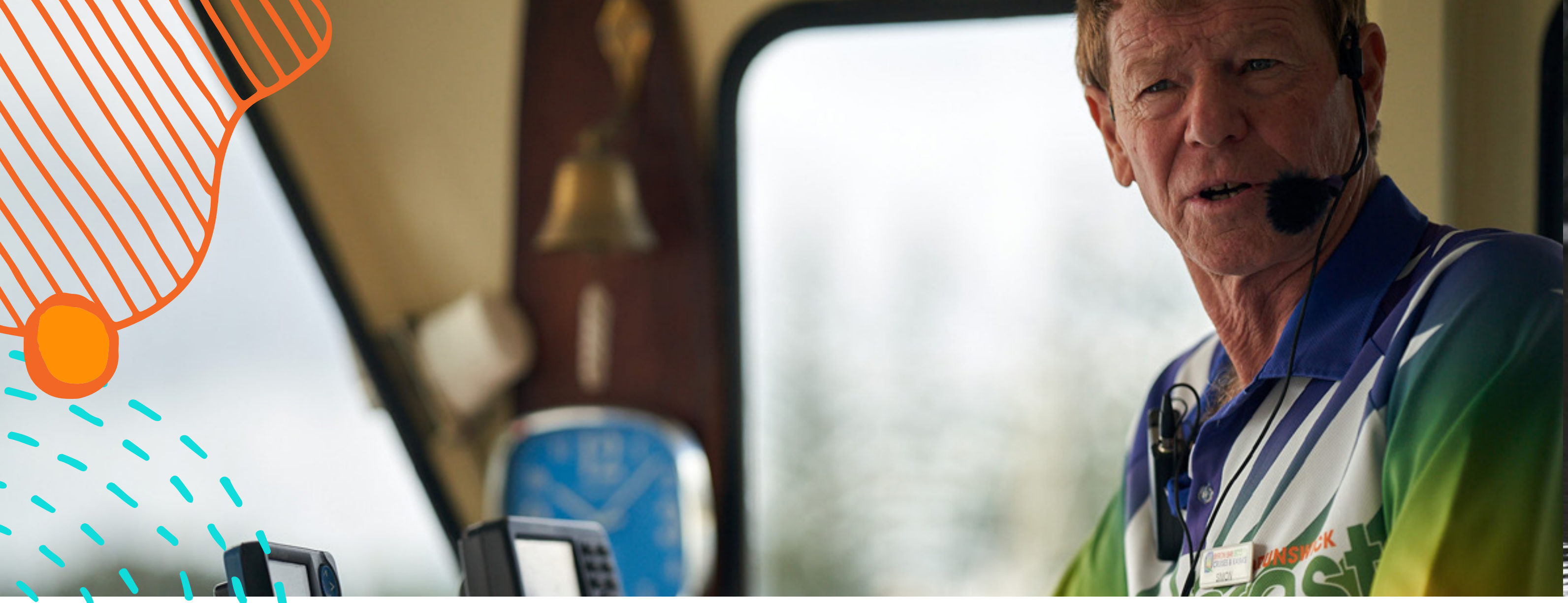

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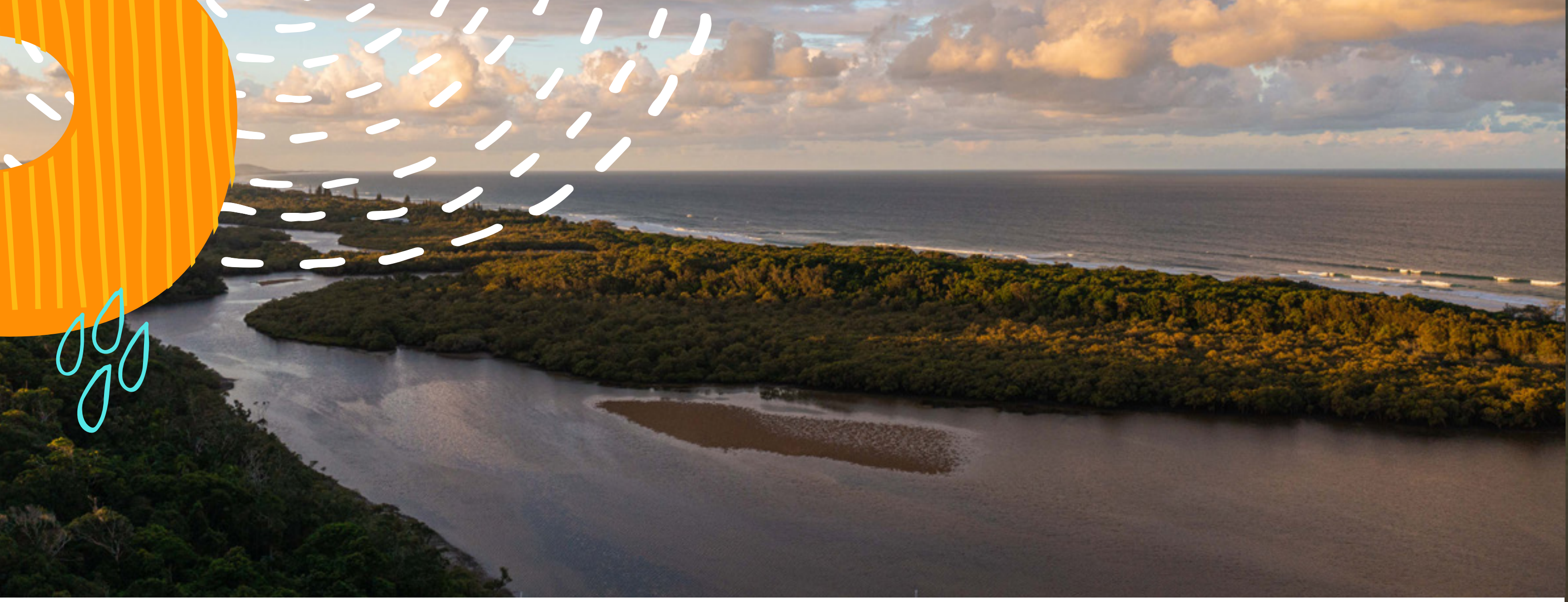


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- Figure 10: NSW Local Land Services, North Coast.
- Figure 11: Australian Government Department of Health.

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