Department of **Employment, Economic Development and Innovation**

Addressing Threats Posed by Invasive Aquatic Animals on Shoalwater & Corio Bay Ramsar Wetlands

Matthew Moore & Tim Marsden



CARING FOR OUR COUNTRY

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Queensland Government

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Matthew Moore & Tim Marsden

For further information contact:
Tim Marsden
Fisheries Biologist
Fisheries Queensland
Ph: (07) 49670724

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Cover Figure: Top: 'Mellis Swamp' located in Dismal Swamp. Bottom, left to right: the vulnerable native honey-blue eye (*Pseudomugil mellis*), sampling with a backpack electrofisher & native saw-shelled turtle (*Wollumbinia latisternum).*

Contents

Abbreviations and Acronyms

DEEDI	-	Department of Employment, Economic Development & Innovation
FQ	-	Fisheries Queensland
ADF	-	Australian Defence Force
FBA	-	Fitzroy Basin Association
SWBTA	-	Shoalwater Bay Training Area
QP&WS	-	Queensland Parks & Wildlife Service
Byfield NP	-	Byfield National Park
Byfield SF	-	Byfield State Forest
GBRMP	-	Great Barrier Reef Marine Park

Glossary of Terms

Diadromous - Diadromous fishes are truly migratory species whose distinctive characteristics include that they (i) migrate between freshwaters and the sea; (ii) the movement is usually obligatory; and (iii) migration takes place at fixed seasons or life stages. There are three distinctions within the diadromous category, catadromous, amphidromous and anadromous.

Catadromous - Diadromous fishes which spend most of their lives in fresh water, and which migrate to sea to breed.

Amphidromous - Diadromous fishes in which migration between freshwater and the sea is not for the purpose of breeding, but occurs at some other stage of the life cycle.
Anadromous - Diadromous fishes which spend most of their lives at sea, and which migrate to freshwater to breed.

Potamodromous - fish species whose migrations occur wholly within freshwater for breeding and other purposes.

Executive Summary

The introduction and continued spread of pest fish into waterways throughout Queensland has the potential to detrimentally affect native fish populations. The impacts of most introduced species on native fish populations are generally poorly known; however, in pest species that have been studied impacts can include competition for food resources and habitats, predation on eggs and fry, and habitat degradation. Established populations of exotic pest fish including mosquitofish (*Gambusia holbrooki*), guppy (*Poecilia reticulata*) and goldfish (*Carassius auratus*) currently inhabit waterways surrounding Shoalwater and Corio Bay (SCB). The threat and potentially immanent spread of these pest fish into SCB's pristine wilderness areas would be detrimental to the unique, threatened and endangered fish species that inhabit the area.

To investigate the status of pest fish in SCB's unique Ramsar wetlands, 'Iwasaki' wetlands of national significance and adjacent waterways, aquatic invasive identification surveys were carried out. Sampling was undertaken at 56 sites across five catchments over a two year period. Electrofishing was chosen as the preferred sampling method due to its effectiveness in sampling a wide variety of habitat types and longitudinal zones. Important habitat type's sampled included perennial sandy substrate streams, ephemeral clay substrate streams, perched dune lakes, farm dams, coastal wetlands and swamps.

A total of 10,335 native freshwater fish comprising 26 species representing 17 families were recorded. Significantly, no invasive pest fish or other invasive aquatic animals were sampled, making the Shoalwater Bay region significant on a national scale. Importantly, intensive aquatic surveys have provided a greater understanding of the health of the regions aquatic eco-systems and contributed valuable information used to produce 'Shoalwater Bay Training Area Pest Fish Management Strategy'.

Shoalwater Bay's geographic position in a climatic overlap zone has resulted in the mixing of tropical and subtropical fauna and flora species. This combination has resulted in a diverse array of unique fish species and habitats. The complexity of habitats created by this overlap zone in SCB has contributed to the occurrence of four fish species exhibiting their northern most range distribution; ornate rainbowfish (*Rhadinocentrus ornatus),* firetail gudgeon *(Hypseleotris galii*), short-headed lamprey *(Mordacia mordax)* and honey blue-eye (*Pseudomugil mellis*). The occurrence of a healthy population of endangered honey-blue is significant. Southern honey blue-eye populations and habitats are currently under pressure from urban encroachment and invasive pest species. Therefore, the discovery of a healthy honey blue-eye population safely protected from adverse surrounding land use practices and currently free of invasive pest fish species is good news for the conservation of this species.

SCB's aquatic habitats were found to be in excellent condition. Generally, habitats comprised significant areas of un-disturbed aquatic eco-systems and diverse and healthy fish assemblages, many of which remain unchanged from their natural state. The excellent condition of the regions aquatic habitats and associated fish communities is largely due to their location inside Shoalwater Bay Training Area (SWBTA), Byfield National Park (Byfield NP) and Byfield State Forest (Byfield SF). Environmental management plans and limited access provisions implemented by SWBTA, Byfield NP and Byfield SF have assisted in preventing pest fish incursions. These measures have also significantly reduced anthropogenic impacts which have devastated many other key coastal habitats along the east coast of Australia, providing a large pristine wilderness area probably unmatched anywhere along the Queensland coast south of Cape Melville.

Introduction

The current project 'Addressing the Threats Posed by Invasive Aquatic Animals on Shoalwater and Corio Bay Ramsar Wetlands' is the first comprehensive invasive aquatic animal identification project undertaken in Central Queensland. It is a joint collaboration between Fitzroy Basin Association (FBA) and Fisheries Queensland (FQ) in partnership with the Australian Defence Force (ADF), Queensland National Parks and Wildlife Service (QP&WS) and private land manager Iwasaki Sangyo Co, (Aust) Pty. Ltd. The project is funded by the Fitzroy Basin Association (FBA) through the Australian Governments 'Caring for our Country' natural resource management initiative.

The project aims to:

- Determine whether invasive aquatic animals have infiltrated the unique and relatively undisturbed aquatic eco-systems of Shoalwater and Corio Bay (SCB) Ramsar wetlands, 'Iwasaki' wetlands of national significance and adjacent waterways.
- Investigate and determine the key vectors and threatening processes which have the potential to facilitate the proliferation of pest fish into SCB aquatic habitats.
- Collate this information to produce a 'Pest Fish Management Strategy' for Shoalwater Bay Army Training Area and Iwasaki wetlands of national significance.
- Construct two fishways to provide connectivity between important aquatic habitats and assist in the management of pest fish through augmentation of native fish.
- Implement on-ground pest fish eradication programs (if pest fish are identified).
- Provide the first baseline condition assessment of SCB fish communities and their associated aquatic habitats.

The SCB region is located on the central Queensland coast approximately 50km north-east of Rockhampton. The region contains significant areas of internationally important Ramsar listed wetlands which provide valuable habitat for many rare and endangered species. SCB's geographic position has it placed in a climatic overlap zone which has resulted in a mixture of tropical, temperate and sub-tropical fauna and flora species. This large ecotonal area with its ancient parabolic dune systems and pristine groundwater fed streams has provided the right conditions for the development of many unique aquatic eco-systems. The complexity of aquatic habitats has in-turn have provided ideal conditions for many unique and restricted fish species.

SCB's aquatic habitats provide critical refuge for the northern most population of the endangered honey blue-eye (*Pseudomugil mellis)*, several fish species exhibiting their northern most range distributions and no exotic pest fish species. The absence of pest fish over such a large and diverse region is extremely rare, making this wilderness area significant on a national scale. Unfortunately, in recent times established populations of exotic pest fish including mosquitofish (*Gambusia holbrooki*), guppy (*Poecilia reticulata*) and goldfish (*Carassius auratus*) have been recorded from rivers and streams to the north and south of SCB. The establishment of exotic pest fish populations in nearby catchments and the lack of recent studies in the region have greatly increased the threat of pest fish impacting SCB's Ramsar listed wetlands.

The introduction and spread of exotic pest fish is a major threat to the biodiversity of native fish populations and the ecological sustainability of their aquatic habitats. The spread of exotic pest fish into the Ramsar listed wetlands of SCB would be detrimental to the regions freshwater fish communities. Unfortunately, the isolated population of endangered honey blue-eye may be one of the most at risk species. SCB's biological diversity, large size and unique undisturbed habitats, make this wilderness area a benchmark for scientific research. The introduction and spread of pest

fish into SCB's aquatic habitats would greatly diminish its integrity and vicarious nature to the detriment of Australia's national heritage.

To investigate whether pest fish or any other associated invasive animal has spread into these important aquatic habitats, the extent of incursion and to assess the current status of the regions fish assemblages, intensive aquatic animal surveys were undertaken. The surveys were carried out at 56 sites over a two year period. Electrofishing was chosen as the preferred sampling method due to its effectiveness in sampling a wide variety of habitat types and longitudinal zones. The results of these intensive surveys are detailed in this report.

Site Information

The current project's area of interest includes SCB Ramsar listed wetlands and 'Iwasaki' wetlands of national significance. However, many freshwater fish species of central Queensland are highly migratory and undertake extensive lateral and longitudinal migrations during different stages of their life-cycle. Due to this, adjacent waterbodies and waterbodies that flow into and out of the areas of interest were also investigated to effectively determine the threats posed by invasive aquatic animals in the region.

The vast majority of sampling sites occur within Shoalwater Bay Training Area (SWBTA), which comprises all Ramsar listed freshwater wetlands (Figure 1). The remaining sampling sites were located in adjacent catchments, including; upper Fitzroy Basin catchment, Broadsound catchment, Shoalwater Bay catchment, Great Barrier Reef Marine Park (GBRMP) catchment and the Waterpark Creek catchment.

Of particular interest were the areas dominated by human settlement, as humans have historically been primary vectors in the translocation of pest fish. Fortunately, the SCB region is largely devoid of human settlement due to the establishment of Byfield NP, Byfield SF, SWBTA and the privately owned 'Iwasaki' wetlands taking up approximately 95% of all inhabitable land in the study area. This has resulted in only one small peri-urban settlement occurring in the region, the township of Byfield (Figure 2). Farm dams located around Byfield are part of the Waterpark Creek catchment and have the potential to possess pest fish as a result of humane induced stocking. To comprehensively determine that pest fish are absent from the study area a proportion of farm dams in Byfield were also selected as sites for further investigation.

Shoalwater & Corio Bay Ramsar Wetlands

SCB Ramsar listed wetlands are located on the Central Queensland coast (Figure 1) and cover an area of approximately 239 100 ha. The southern boundary of the wetlands is approximately 50 kms north east of Rockhampton. The listing of SCB's aquatic habitats as wetlands of international significance (Ramsar wetlands) was formalised in 1996, creating the largest Ramsar listed wetlands on the east coast of Australia. The majority of the Ramsar wetlands fall within SWBTA, and includes the intertidal areas, adjacent lands and marine waters up to highest astronomical water mark from Broome Head in the north to the southern boundary of SWBTA and the intertidal areas of Corio Bay in the South (ramsar.wetlands.org 1995).

The Shoalwater and Corio Bay region is acknowledged both nationally (National and Commonwealth Heritage listing) and internationally (World Heritage & Ramsar listed wetlands) as an area containing outstanding natural heritage values worthy of protection and promotion. The area's terrestrial, marine and five major estuarine environments represent the largest relatively undisturbed area in central east Queensland containing representative coastal and aquatic landscapes with areas containing significant floral and faunal assemblages including rare and threatened species (ramsar.wetlands.org 1995).

The area occurs in an ecotone between tropical and subtropical faunas, containing many diverse aquatic habitat types unequalled in its biogeographic region. Habitats include; freshwater lagoons, swamps, perched lakes, sinkholes, peat swamps, perennial groundwater fed and intermittent streams. Its geographic location in the transitional zone combined with its unique and minimally impacted aquatic habitat types has led to a high diversity of freshwater fish fauna, with 26 recorded species. The absence of exotic pest fish, high diversity and unique aquatic habitats make this biodiverse region significant on a national scale.

Shoalwater Bay Training Area (SWBTA)

SWBTA is one of Australia's most important military training areas, integrating blue water naval forces and air and land assets to effectively undertake large scale exercises with other alliance countries such as the United States and Singapore (Sommer *et al.,* 2008). All Ramsar listed freshwater wetlands fall within SWBTA. Rainfall and aquatic habitat types vary immensely within the SWBTA, with an average annual rainfall of about 1, 700mm in the east to about 800 mm near the western boundary (O'Neill & Stock, 2008). The majority of rainfall in SWBTA occurs during the 'wet season' with more than half the annual rainfall falling between December and March. Four separate water catchments occur in the SWBTA, with the south west draining into the Fitzroy Basin, western sections draining into Broadsound, north north-east sections flowing directly into the GBRMP catchment and the south eastern section flowing into the Waterpark Creek catchment.

Generally streams in the northern and western parts of SWBTA are ephemeral, flowing during the wet season before contracting back to a series of isolated waterholes. The eastern parts of SWBTA are characterised by perennial groundwater fed streams emanating out of springs located in the parabolic dunes of Manifold Hills. While most of streams draining the Coast Range in the south of SWBTA are generally ephemeral, but may become perennial in years of above average rainfall.

Iwasaki Wetlands of National Significance

Iwasaki wetlands are located approximately 10 kms north of Yeppoon and form the southern boundary of the Waterpark Creek catchment. Inflow into the wetlands is provided by Station Creek which drains the low hills in the south west of the catchment. Overflow from the wetlands discharges into the Ramsar listed wetlands of Corio Bay. The Iwasaki wetlands have been placed on the directory of important wetlands in Australia due to their significance on a national scale. The wetlands cover an area of approximately 646 ha and are potentially the largest privately owned wetlands in Australia (Ford, 1995). The wetlands have been created through the construction of bund walls which form the boundary between the Ramsar listed wetlands of Corio Bay and the Iwasaki wetlands of national significance. The bund walls which prevent saltwater intrusion have formed artificial wetlands creating significant amounts of productive wetland habitat. Unfortunately, the bund walls have created barriers to fish passage, preventing some diadromous fish species from migrating into these critical lowland habitats.

Sampling Area's & Habitat Characteristics

For the purposes of this report waterways within the study area have been divided into eight 'sampling areas' (Table 1). Sampling areas were determined based on aquatic habitat characteristics. Generally sampling areas contain catchments with similar habitat and flow characteristics i.e. Broadsound & Shoalwater Bay catchments. The many varied habitat types and flow characteristics experienced in the Waterpark Creek catchment has resulted in the creation of six different sampling areas in this catchment alone. The eight sampling areas are:

Table 1. 'Sampling areas', showing their catchment and associated flow/habitat characteristics

Catchment	Flow/Habitat Characteristics
Broadsound / Shoalwater Bay catchments	Ephemeral streams
Fitzroy River catchment	Ephemeral streams
Waterpark Creek / GBRMP catchments	Perennial sandy substrate streams
Waterpark Creek catchment	Ephemeral clay substrate streams
Waterpark Creek catchment	Ephemeral rocky substrate streams
Waterpark Creek catchment	Dismal Swamp
Waterpark Creek catchment	Iwasaki Wetlands
Waterpark Creek catchment	Byfield Farm Dams

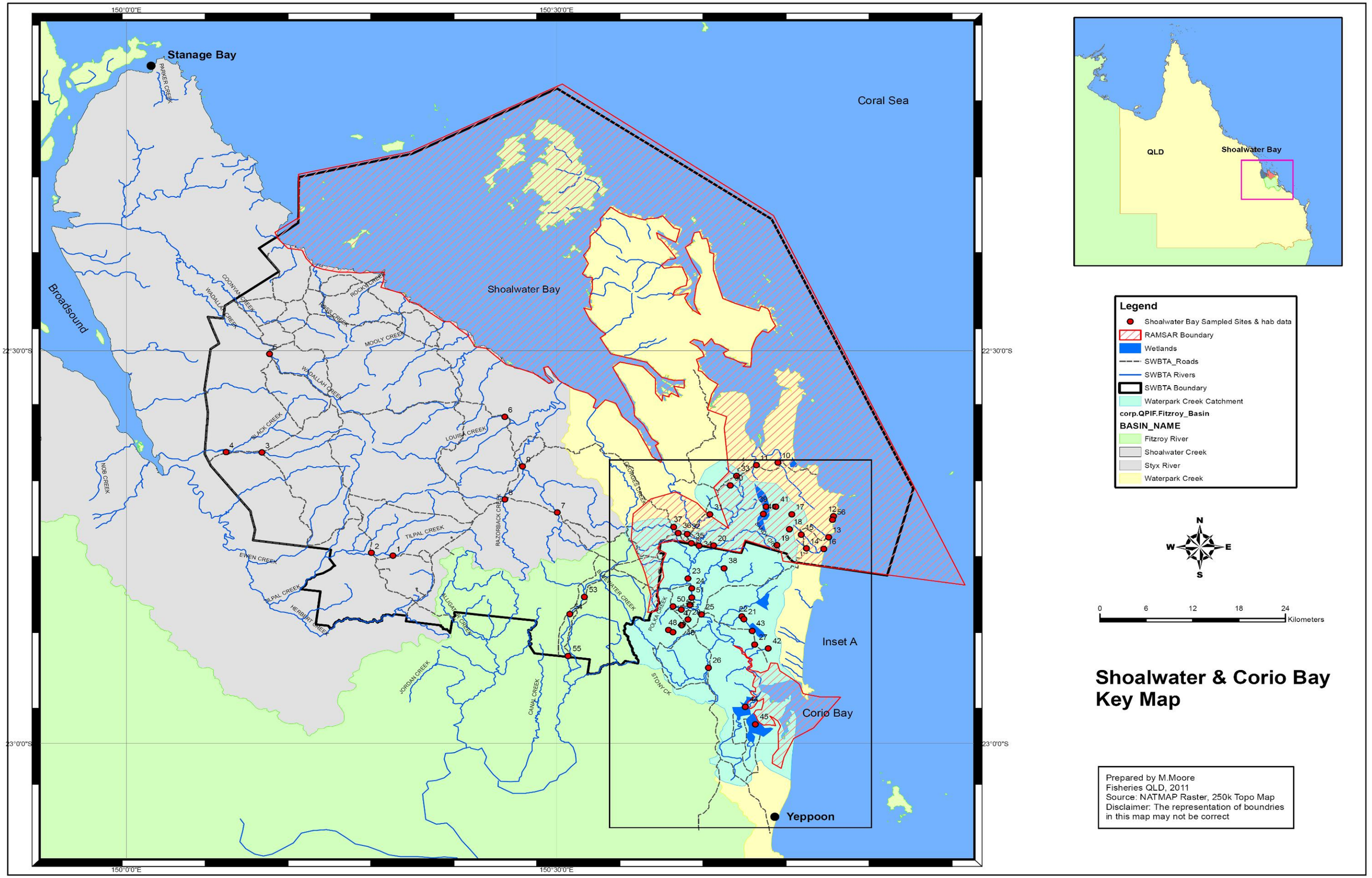

Figure 1. The greater Shoalwater and Corio Bay region, showing all sampling sites. ***Note:*** *Each sampled site contains its own unique identification number. This number and its corresponding site it represents can be found in the results section of this report i.e. Shoalwater Creek - Lower (9).*

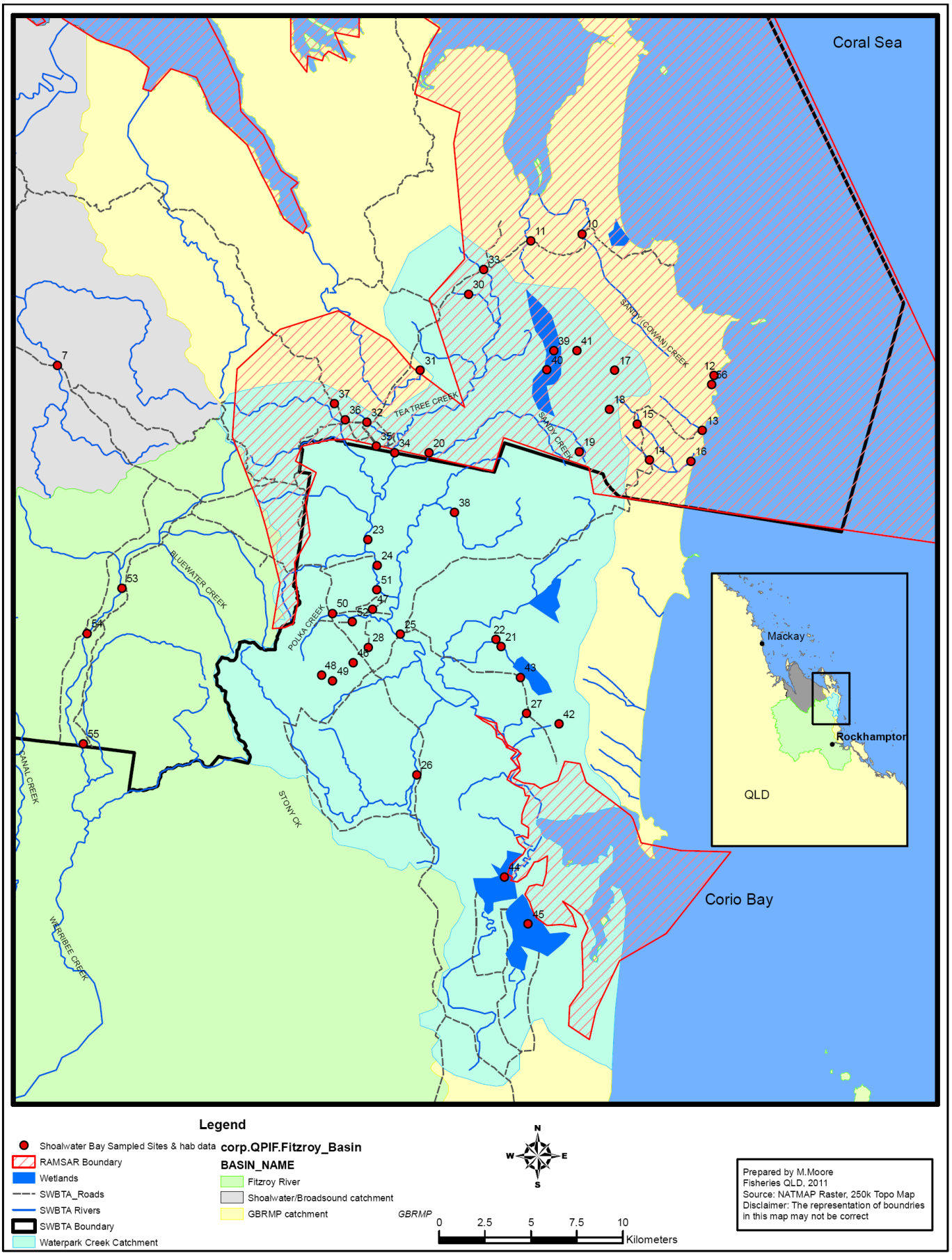

Figure 2. Inset A from Figure 1, showing a close up of sampling sites around the Waterpark Creek catchment.

Broadsound / Shoalwater Bay Catchments

Broadsound Catchment

Ephemeral Streams

Waterways draining the Broadsound catchment originate in the hills and mountains of the western side of the Normanby Range in the western sections of SWBTA, before flowing through quaternary alluvial and cainozoic loamy and sandy plains of the Brigalow Belt (O'Neill & Stock, 2008). Streams in this part of SWBTA are ephemeral, flowing during the wet season before contracting back to a series of isolated waterholes (Figure 3). Broadsound streams flow directly to the sea via a complex estuarine system, contain no barriers to fish passage and are generally in good condition with healthy riparian areas dominated by eucalyptus, melaleuca and casuarina species. Broadsound streams contain abundant in-stream woody debris, rocky/muddy substrate and abundant submergent and emergent native macropyhtes. The woodlands and open forest which surround these streams have resulted in large areas of open over-story cover, while the alluvial plains have increased levels of sedimentation, reducing water clarity. Major waterways in the Broadsound region include; Tilpal, Halfway and Wadallah creeks.

Shoalwater Bay Catchment

Ephemeral Streams

The Shoalwater Bay catchment consists of waterways that drain directly to Shoalwater Bay. They originate in the hills and mountains on the north eastern side of the Normanby and Coast Ranges in the north west of SWBTA, before flowing east through quaternary alluvial plains and lowlands on metamorphosed sedimentary rocks (O'Neill & Stock, 2008). Streams in this area are ephemeral, flowing during the wet season before contracting back to a series of isolated waterholes (Figure 4). Shoalwater Bay catchment streams flow directly to the sea via a complex estuarine system of mangroves, tidal flats and beaches. Waterways in this part of SWBTA are generally in good condition, containing both open and closed river reaches, a healthy riparian strip, predominantly rocky substrate and minimal barriers to fish passage. Riparian areas consist mainly of eucalyptus, melaleuca and callistemon species which provide abundant in-stream woody debris. Streams contain abundant submergent and emergent macropyhtes and good water clarity. Major waterways flowing into Shoalwater Bay include; Shoalwater, Louise, Georges and Mooly creeks.

Fitzroy River Catchment

Ephemeral Streams

Fitzroy River catchment draining streams originate in the hills of the Coast Range in the west of SWBTA. These streams make up a very small component of the Fitzroy River catchment, contributing 0.002% of the total drainage area. Generally these streams are ephemeral in nature, flowing during the wet season before constricting back to a series of isolated waterholes (Figure 5). These waterholes are characterised by sandy/muddy substrate and consist of both open and closed canopy reaches which provide enough light for the growth of some emergent and submergent macropyhtes. Riparian zones are intact and healthy providing an abundance of in-stream woody debris. No barriers to fish passage occur on any of the Fitzroy Basin draining streams inside SWBTA, but many occur further downstream outside SWBTA, potentially affecting fish migration. Major waterways of the Fitzroy River catchment draining the SWBTA include; Werribee, Alligator and Sardine creeks.

Figures 3-5. Typical ephemeral waterhole habitat of Halfway Creek in the Broadsound Catchment (top), Louisa Creek in the Shoalwater Bay Catchment (middle) and lower Werribee Creek in the Fitzroy River Catchment (bottom).

GBRMP Catchment

Perennial sandy substrate streams

Perennial sandy substrate streams of the GBRMP flow east out of Manifold Hills directly to the sea. They are generally short steep streams less than 8kms in length, many of which are less than 1km (Figure 6). These oligotrophic streams rise quickly from the ocean to their headwaters in the Manifold Hills and generally contain steep gradients and waterfalls which prevent most migratory species from accessing upstream habitat. These streams contain excellent riparian vegetation, in-stream habitats and no artificial barriers to fish passage and are generally in excellent condition (Figure 7). The major perennial sandy substrate waterways draining the GBRMP catchment are; The Three Rivers, Cowan and Solitude creeks.

Waterpark Creek Catchment

Perennial sandy substrate streams

Perennial sandy substrate streams of the Waterpark Creek catchment originate from groundwater reserves below the large parabolic dunes of Manifold Hills in the eastern section of SWBTA. These groundwater reserves have the single greatest influence on the diversity of aquatic habitat types and associated fish fauna experienced in SWBTA. The large parabolic dune and beach ridge system that acts as a groundwater reservoir drains to springs within and on the perimeter of the sandmass (O'Neill, 1998). This provides a year round supply of water to permanent swamps in SWBTA (Dismal and Freshwater swamps), as well as to perennial streams (Cowan and Sandy creeks). The perennial groundwater fed Sandy Creek flows west into Waterpark Creek then east into Corio Bay.

These perennial streams are characterised by a lush riparian zone which generally encloses the stream allowing very little light penetration and few submergent macropyhtes (Figure 8). The edges of the streams contain abundant emergent macropyhtes providing good in-stream cover. The streams are generally small, clear and shallow averaging 0.5m deep and 1.5m wide and contain abundant in-stream woody debris. These streams are characterised as being oligotrophic as the sandy substrates provide very little nutrients and organic matter. Most of these streams are in pristine condition, with only a few areas of some streams impacted by feral pigs and invasive weeds. The major perennial sandy substrate waterways draining the Waterpark Creek catchment are; Sandy, Apple Tree and Waterpark creeks.

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Figures 6-8. Steep gradient of an unnamed creek flowing onto the beach in the GBRMP catchment (top). Lower Cowan Creek in the GBRMP catchment (middle). Typical perennial sandy substrate stream habitat at lower Sandy Creek in the Waterpark Creek catchment (bottom).

Waterpark Creek catchment

Ephemeral rocky substrate streams

Ephemeral rocky substrate streams of the Waterpark Creek catchment originate in the Coast Range in the south of SWBTA near the town of Byfield and to the north of Corio Bay in Byfield National Park. Some of these streams are outside SWBTA and flow through Byfield State Forest and Byfield National Park before flowing into Waterpark Creek. During years of above average rainfall these streams become perennial in nature with a peak flows occurring during the wet season. These short coastal streams are characterised by healthy riparian zones consisting of lush vegetation which provide a closed canopy cover (Figure 9). Riparian areas provide an abundance of in-stream habitat in the form of woody debris, but also prevent light penetration restricting the growth of aquatic macropyhtes. The oligotrophic waters and minimal light penetration has had a significant effect on the fish communities of these streams, generally reducing fish abundance. There are barriers to fish passage located on Stony Creek, two of which now have rock ramp fishways. Generally these streams are small and clear averaging 2-3 m wide and 1.0 m deep and are in good condition. The two major ephemeral rocky substrate streams of the Waterpark Creek catchment are Stony and Norton creeks.

Ephemeral clay substrate streams

Ephemeral clay substrate streams originate in the north north-west headwaters of the Waterpark Creek catchment in southern sections of SWBTA close to Samuel Hill. These streams are generally small and deprived of groundwater inflows so rely on rainfall events to replenish flows. Therefore these streams usually only flow during the wet season before constricting back to a series of isolated waterholes (Figure 10). Open forest woodlands consisting of melaleuca and eucalyptus species dominate the riparian zones of these streams providing a combination of open and enclosed canopy cover and an abundance of in-stream woody debris. Open canopy reaches have provided suitable conditions for the proliferation of aquatic submergent and emergent macropyhtes which have provided excellent in-stream cover. Bottom substrates are characterised by a clay/loamy substrate with a thick layer of detritus. These streams generally carry high levels of suspended sediments which reduce water clarity and light penetration. On average streams are 2 m wide and up to 1.5 m deep. The two major ephemeral sandy/clay substrate streams draining the Waterpark Creek catchment are Tea Tree and Valentine creeks.

Dismal Swamps

Dismal Swamp, located in the headwaters of the Waterpark Creek catchment, is a peat sedge swamp perched 50-60m above sea level and characterised by dark tannin stained oligotrophic waters and surrounded by patterned fens, of which their occurrence in tropical conditions is of great significance (Jaensch, 2008). Dismal Swamp is characterised by a series of small permanent interconnecting palustrine waterbodies. The largest perched waterbody is located in the middle of the swamp and is approximately 40m long by 2m wide and consists of an open canopy (Figure 11). Seepages draining out from this swamp flow very slowly through depressions that are totally enclosed by canopy cover consisting of sedge species and *Banksia robur*. These interconnecting seepages predominantly remain enclosed, but occasionally they feed into small open water palustrine habitats. The edges of these small open water habitats are dominated by dense emergent macropyhtes which provide abundant in-stream cover for the endangered honey-blue eye *(Pseudomugil mellis)*. Water depth varies but may be up to 1.5 m deep. Water slowly drains out of these palustrine habitats into Sandy Creek and then into Waterpark Creek before flowing out into the ocean. Overall the wetlands are in excellent condition.

Figures 9-11. Typical ephemeral rocky substrate stream habitat at Norton Creek in the Waterpark Creek Catchment (top), ephemeral clay stream habitat of Tea Tree Creek in the Waterpark Creek Catchment (middle) and open water habitat of Central Dismal Swamp (South Mellis Swamp) (bottom).

Byfield Farm Dams

Generally farm dams within the small peri urban township of Byfield overflow directly into the Waterpark Creek Catchment. Only farm dams within the Waterpark Creek catchment were surveyed. Most farm dams were small, comprising less than 1 ha of open water habitat with an average depth of 1.5-2 m. They contained abundant submergent and emergent aquatic macropyhtes and minimal in-stream woody debris. Most farm dams were permanent and surrounded by a small riparian zone.

Iwasaki Wetlands of National Significance

Iwasaki's shallow lacustrine wetlands and palustrine marshes are permanent during most average and above average rainfall years, only drying out completely during severe drought conditions. The Iwasaki wetland complex consists of two major open water lacustrine habitats, north (Figure 12 and south Iwasaki (Figure 13). Both north and south Iwasaki contain abundant in-stream habitat in the form of emergent and submergent macropyhtes. Riparian habitat is generally poor, with vast areas of bund walls and cleared agricultural areas deficient of riparian vegetation. Small areas of remnant melaleuca stands (figure?) remain, providing some areas of shade in an otherwise large open water habitat. North Iwaski wetland is characterised by an abundance of water lily's and less open water habitat than south Iwaski. South Iwaski is characterised by a mixture of open water habitat interspersed by emergent sedge species. Prior to the aquatic survey of north Iwaski, the wetland had experienced a large scale chemical spray in an attempt to eradicate large swathes of the aquatic weed species Hymenachne. While this weed programme had successfully eradicated most of the Hymenachne, some still remains. Overall the wetland habitats of Iwasaki are in poor to good condition.

Figures 12 & 13. Melaleuca and lily habitat of north Iwaski (top) and sedge habitat of south Iwaski (bottom).

Methods

Aquatic invasive sampling was undertaken over a two year period, between September 2009 and July 2011. Electrofishing was chosen as the preferred sampling method due to its effectiveness in sampling a wide variety of habitat types and longitudinal zones in a time efficient manner. Where possible, electrofishing was conducted on the 3.7m vessel (Hypnos II) which operated a Smith-Root 2.55 GPP electrofisher unit, two boom arms with 4 dropper anode arrays and hull cathode. An operator and single dip-netter were employed during sampling activities on Hypnos II. Two sites (Iwasaki wetlands) were sampled with a 4.7m electrofishing vessel (Discopyge II) which operated a Smith-Root 7.55 GPP electrofisher unit, two boom arms with 16 dropper anode arrays and hull cathode. An operator and two dip-netters were employed during sampling on Discopyge II. Where vessel access was prevented, a backpack electrofishing unit was employed. The unit utilised was a Smith-Root Model-12B-POW Backpack Electrofisher operating a 500-volt Pulsed-DC current and a standard pulse setting (1 ms). An operator and single dip-netter were utilised during all backpack sampling activities.

Sampling was conducted in shallow water to 5 m depth and encompassed all habitat types for optimum catch results and species representation. Sampling was conducted during daylight hours and was standardised by fishing time and area.

The electrofishing sampling method used in this study consisted of 300 second ‘shots’. A ‘shot’ conducted by a vessel mounted unit utilized a 50 m section of pool and included two 50 m runs mid stream parallel to the bank, which consisted of multiples of 12 seconds power-on followed by 12 seconds power-off. Further to this there were ten runs into the bank at 5 m intervals along the same 50 m stretch. A run into the bank consisted of a total of 24 seconds power-on including, 10 seconds motoring into the bank, hold for 4 seconds at the bank then 10 seconds reversing from the bank. In areas where a 50 m stretch of bank was not available or the stream had insufficient width a ‘shot’ consisted of multiples of power-on, power-off electrofishing for a total of 300 seconds of power-on using all the stream area available. These techniques allow the thorough sampling of an area whilst preventing fish herding effects of boat electrofishing.

A ‘shot’ conducted by a backpack electrofisher unit consisted of the operator walking in a straight line across the width of the stream from one bank to the other using a side to side sweeping motion covering an area of 4 m. The dip-netter is located slightly behind the operator on the downstream side at all times. Power on is applied from one side of the stream bank to the other. Once the operator has reached the far bank he then works his way back across the width of the stream, 2 m upstream and parallel to the area just electrofished. This method is repeated for a total of 300 seconds of power-on.

All fish captured during electrofishing were identified to species level, counted and measured to the nearest millimetre (fork length for forked-tailed species, total length for all other species). Fish were then released into the area from which they were captured. When more than 50 individuals of a single species were captured in any single ‘shot’, randomised sub-samples of 50 fish were measured and the remainder counted. Fish observed as affected by the electric field and positively identified, but not netted, were recorded and have been included in any abundance analyses in this report.

Results

A total of 10,335 native freshwater fish comprising 26 species representing 17 families were recorded during sampling of SCB. Significantly no pest fish species were recorded. A total of 56 sites were sampled during the survey with an overall catch rate of 18.26 fish/ min.

The Waterpark Creek catchment contained the highest species diversity with 21 species. The Broadsound/Shoalwater Bay catchment recorded the second highest species diversity with 17 species followed by the Fitzroy River catchment and GBRMP catchment with 11 and 8 species respectively (Table 1). The Waterpark Creek catchment also recorded the highest fish abundance of all catchments with a catch rate 32.97 fish/min. Broadsound/Shoalwater Bay catchment recorded the second highest fish abundance with 20.24 fish/min, followed by the Fitzroy River and GBRMP catchments with 18.03 and 7.71 fish/min respectively.

Melanotaenia splendida was the most abundant fish species recorded during sampling with 2,860 individuals at a catch rate of 5.1 fish/min, closely followed by *Mogurnda adspersa* with 2,495 individuals at a catch rate of 4.4 fish/min and *Hypseleotris compressa* with 1,175 individuals at a catch rate 2.1 fish/min (Figure 14). All these three species are potamodromous. *Anguilla reinhardtii* was the most abundant diadromous species recorded during the survey with 181 individuals at a catch rate of 0.3 fish/min followed by *Lates calcarifer* with 81 individuals at a catch rate of 0.14 fish/min.

Hypseleotris compressa was the most widespread species recorded during the survey occurring at 17 of the 19 sub-catchments and all catchments accept the Fitzroy River catchment. *Anguilla reinhardtii* was the next most widespread species recorded at 16 sub-catchments and all four catchments, followed by *Mogurnda adspersa* which was recorded at 14 sub-catchments and all catchments accept the GBRMP catchment (Table 1). *Melanotaenia splendida* was the only other species recorded from all four catchments during the survey.

Philypnodon grandiceps and *Glossogobius giuris* were the least abundant species with just 1 individual recorded for each species. This was followed by *Porochilus rendahli, Notesthes robusta, Pseudomugil mellis* and *Mordacia mordax* with 2, 4, 13 and 14 individuals respectively. *Pseudomugil mellis, Philypnodon grandiceps*, *Glossogobius giuris, Mugil cephalus* and *Mordacia mordax* were the most restricted species recorded during the survey, each occurring at just one site.

Waterpark Creek in the Waterpark catchment recorded the highest species diversity with 13 species, including 3 diadromous and 10 diadromous species (Table 1). Halfway Creek in the Broadsound catchment recorded the second highest species diversity with 12 species, including 3 diadromous and 9 potamodromous species. Werribee Creek in the Fitzroy River catchment and Tilpal Creek in the Broadsound catchment recorded the equal third highest species diversity with 11 species respectively. Shoalwater, 3 Rivers and Stony creeks each contained the highest diversity of diadromous fish with 4 recorded species. While the Waterpark Creek and Broadsound/Shoalwater Bay catchment each contained the highest diversity of diadromous freshwater fish with 5 recorded species.

Note: *Each site name in the following results section is accompanied by a unique site number in brackets i.e. Shoalwater Creek - Lower (9). This unique identification number is the same number used to identify the correct geographic site location for each site in figures 1 and 2 in the 'Site Information' chapter.*

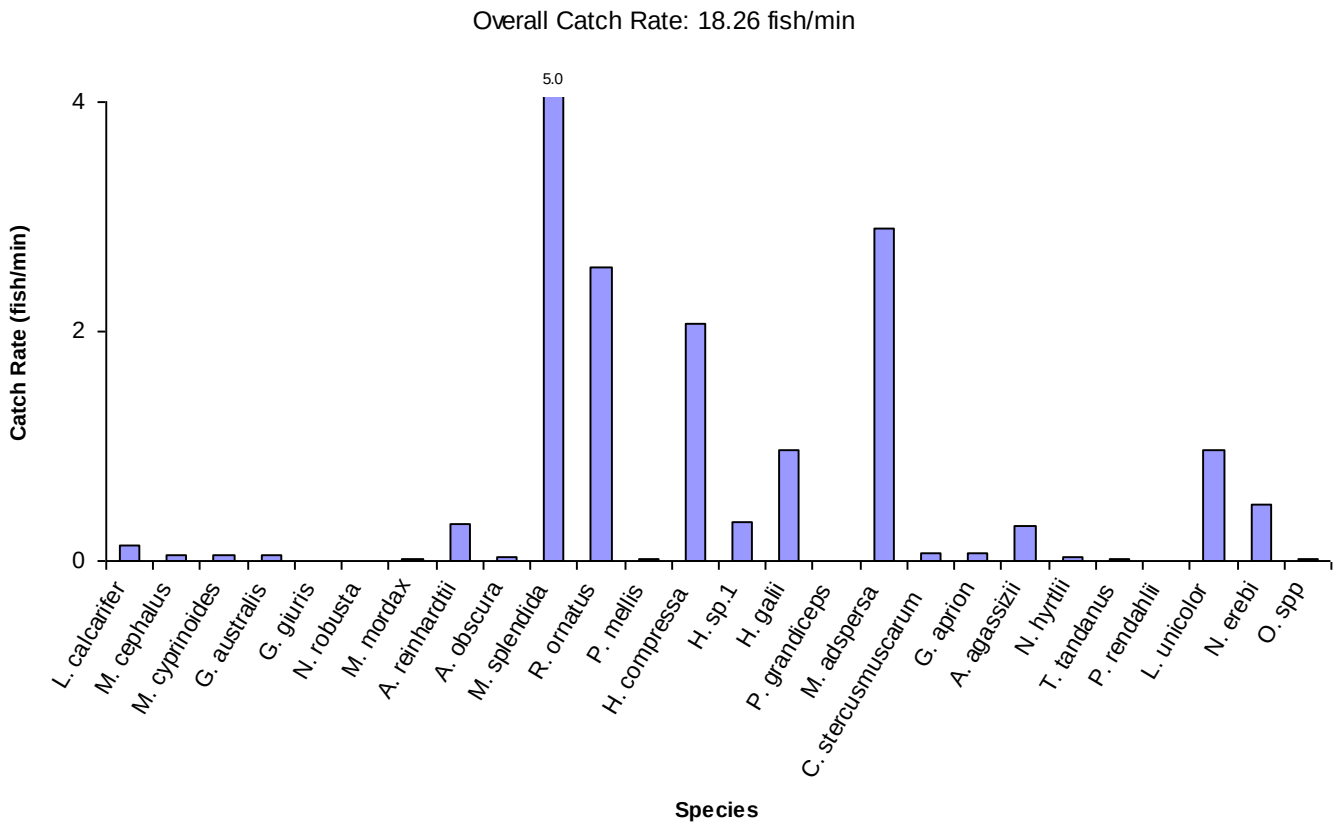


Figure 14. Overall catch rates (fish/min) of all fish species recorded at all sampling sites in the Shoalwater Bay region.

Figure 15. Access into Dismal Swamp to undertake sampling was often difficult and hard going.

Table 1. Summary of freshwater fish species recorded at each sub catchment.

Catchment		Broadsound/Shoalwater					GBRMP			Waterpark Creek											Fitzroy
Sub-catchments		Tilpal Ck	Halfway Ck	Wadella Ck	Shoalwater Ck	Louisa Ck	Cowan Ck	Solitude Ck	3 Rivers & Beach Sites	Nth Dismal Swamp	Sth Dismal Swamp	Tea Tree Ck	Waterpark Ck	Apple Tree Ck	Sandy Ck	Norton Ck	Stony Ck	Iwasaki Wetlands	Farm Dams	Weribee Ck
Migration Classification and Common Name	**Diadromous**																			
	Mordacia mordax														✓					
	Megalops cyprinoides		✓		✓															
	Anguilla reinhardtii	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓		✓	✓	✓	✓
	Anguilla obscura					✓	✓		✓			✓								
	Notesthes robusta												✓				✓			
	Lates calcarifer		✓		✓	✓			✓										✓	
	Mugil cephalus				✓															
	Glossogobius giuris																✓			
	Gobiomorphus australis						✓	✓	✓				✓	✓	✓		✓			
	Potamodromous																			
	Nematalosa erebi	✓	✓																	
	Porochilus rendahli		✓										✓							
	Tandanus tandanus												✓		✓		✓			✓
	Neosilurus hyrtlii	✓	✓										✓							✓
	Craterocephalus ster.	✓																		✓
	Rhadinocentrus ornatus						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
	Melanotaenia splendida	✓	✓	✓	✓	✓		✓				✓	✓			✓	✓	✓	✓	✓
	Pseudomugil mellis									✓										
	Ophisternon spp.		✓				✓		✓	✓					✓		✓		✓	
	Ambassis agassizii	✓	✓		✓							✓						✓		✓
	Leiopotherapon unicolor	✓	✓	✓	✓								✓				✓		✓	✓
	Glossamia aprion	✓											✓							✓
	Hypseleotris galii									✓	✓	✓		✓		✓			✓	
	Hypseleotris sp.1	✓	✓	✓	✓	✓							✓							✓
	Hypseleotris compressa	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Mogurnda adspersa	✓		✓	✓	✓				✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
	Philypnodon grandiceps																			✓
Total Species: Sub-catchment		**11**	**12**	**5**	**10**	**7**	**6**	**5**	**7**	**7**	**4**	**8**	**13**	**4**	**8**	**5**	**10**	**5**	**8**	**11**
Total Species: Catchment		**17**					**8**			**21**										**11**

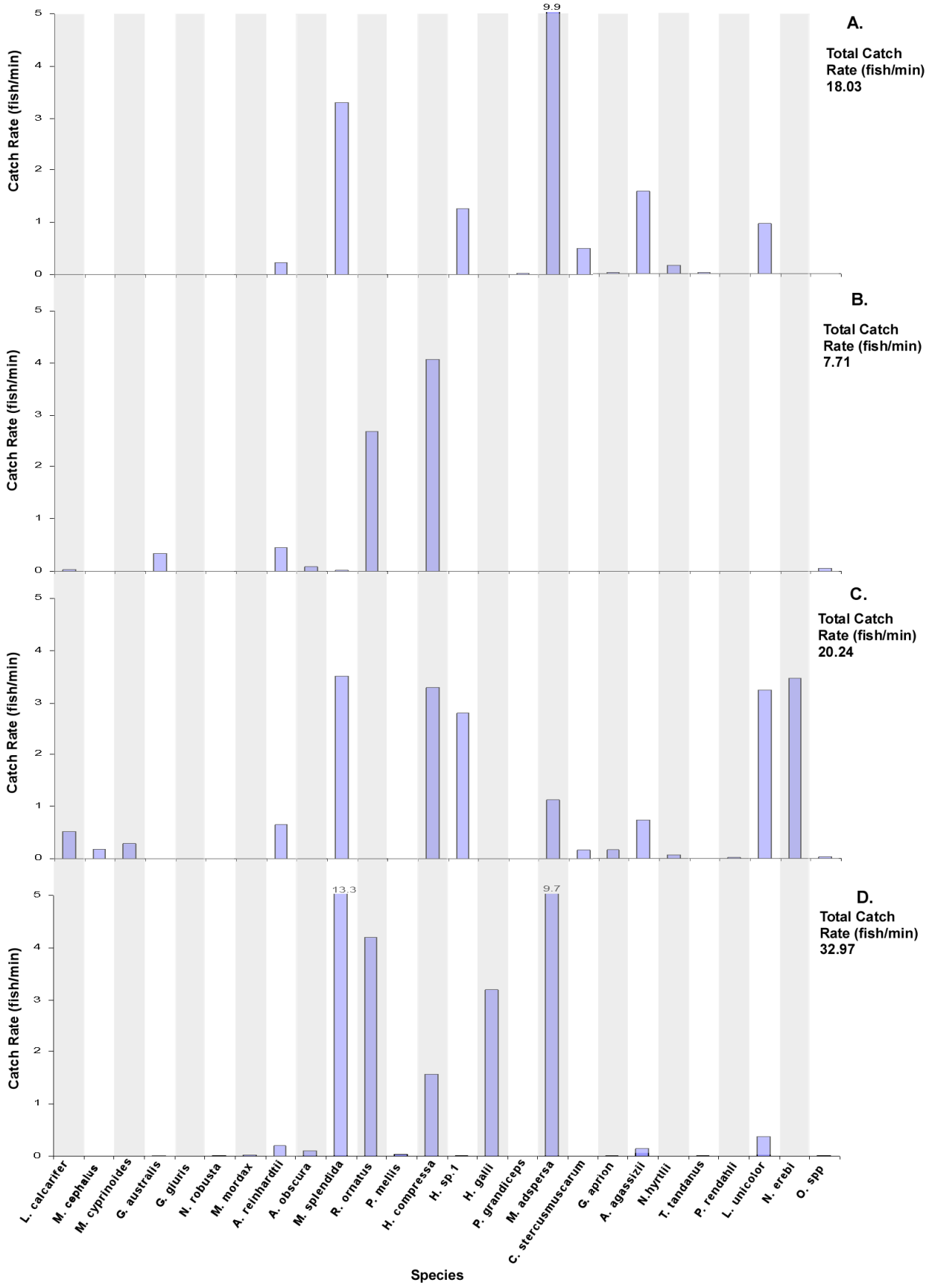


Figure 16. . Fish species abundance (catch rate - fish/min) of fish species per catchment. Fitzroy River catchment (A), GBRMP catchment (B), Broadsound/Shoalwater Bay catchment (C) and the Waterpark Creek catchment (D).

Catchments

Fitzroy River Catchment (Figure 16 - A)

Mogurnda adspersa was the most abundant species recorded in the Fitzroy River catchment with a catch rate of 9.90 fish/min. *Melanotaenia splendida* and *Ambassis agassizii* were the next most abundant species with catch rates of 3.30 and 1.6 (fish/min) respectively.

GBRMP (Figure 16 - B)

Hypseleotris compressa was the most abundant species recorded in the GBRMP catchment with a catch rate of 4.67 fish/min. *Rhadinocentrus ornatus* and *Anguilla reinhardtii* and were the next most abundant species with catch rates of 2.69 and 0.44 (fish/min) respectively.

Broadsound/Shoalwater Bay Catchments (Figure 16 - C)

Melanotaenia splendida was the most abundant species recorded in the Broadsound and Shoalwater Bay catchment sampling area with a catch rate of 3.47 fish/min. *Nematalosa erebi* and *Hypseleotris compressa* were the next most abundant species with catch rates of 3.47 and 3.30 (fish/min) respectively.

Waterpark Creek Catchment (Figure 16 - D)

Ephemeral rocky substrate streams within the Waterpark Creek catchment recorded the highest catch rate of all sampling area's in that catchment with 46.78 fish/min. Perennial sandy substrate streams recorded the second highest catch rate with 39.78 (fish/min). Both sandy and clay substrate streams recorded the highest species diversity with 15 species respectively.

Perennial Sandy Substrate Streams (Figure 17 - E)

Rhadinocentrus ornatus was the most abundant species recorded in perennial sandy substrate streams with a catch rate of 7.25 fish/min. *Hypseleotris compressa* and *Melanotaenia splendida* were the next most abundant species with catch rates of 1.47 and 0.45 (fish/min) respectively.

Ephemeral Clay Substrate Streams (Figure 17 - F)

Mogurnda adspersa was the most abundant species recorded in ephemeral clay substrate streams with a catch rate of 23.09 fish/min. *Hypseleotris galii and Melanotaenia splendida* were the next most abundant species with catch rates of 9.60 and 4.29 (fish/min) respectively.

Ephemeral Rocky Substrate Streams (Figure 17 - G)

Melanotaenia splendida was the most abundant species recorded in ephemeral rocky substrate streams with a catch rate of 34.55 fish/min. *Mogurnda adspersa* and *Rhadinocentrus ornatus* were the next most abundant species with catch rates of 5.95 and 2.92 (fish/min) respectively.

Dismal Swamp (Figure 17 - H)

Rhadinocentrus ornatus was the most abundant species recorded in Dismal Swamp with a catch rate of 9.86 fish/min. *Hypseleotris compressa* and *Hypseleotris galii* were the next most abundant species with catch rates of 0.71 and 0.30 (fish/min) respectively.

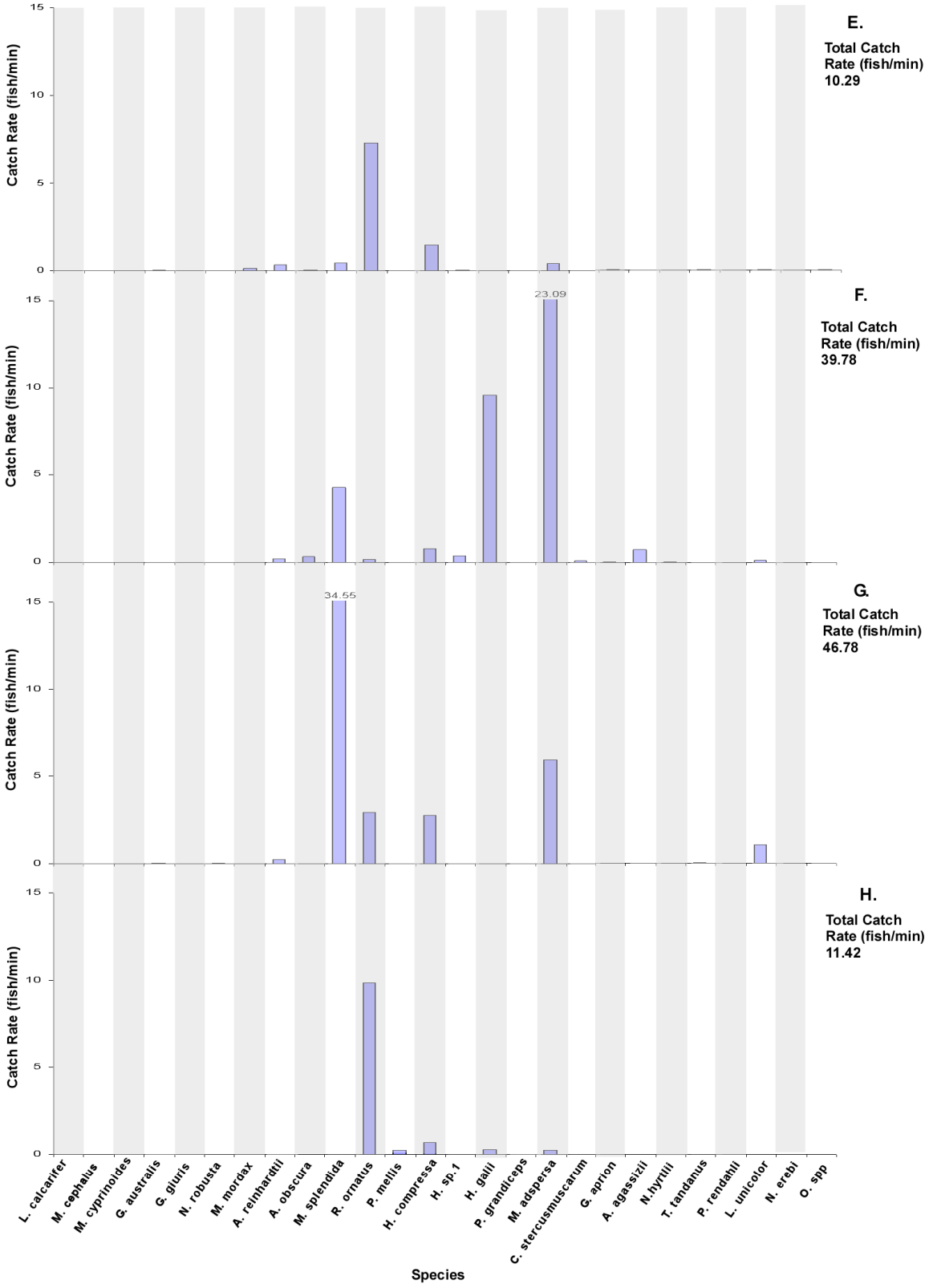

E.
Total Catch Rate (fish/min) 10.29
F.
Total Catch Rate (fish/min) 39.78
23.09
G.
Total Catch Rate (fish/min) 46.78
34.55
H.
Total Catch Rate (fish/min) 11.42
Catch Rate (fish/min)
0
5
10
15
L. calcarifer
M. cephalus
M. cyprinoides
G. australis
G. giuris
N. robusta
M. mordax
A. reinhardtii
A. obscura
M. splendida
R. ornatus
P. melis
H. compressa
H. sp.1
H. galii
P. grandiceps
M. adspersa
C. stercusmuscarum
G. aprion
A. agassizii
N.hyrtlii
T. tandanus
P. rendahli
L. unicolor
N. erebi
O. spp
Species

Figure 17. Fish species abundance (catch rate - fish/min) of fish species recorded in each Waterpark Creek sub-catchment. Perennial sandy substrate streams (E), ephemeral clay substrate streams (F), ephemeral rocky substrate streams (G) and Dismal Swamp (H).

Broadsound/ Shoalwater Bay Catchment

Tilpal Creek

Upper - Watering Point (1)

Sampling at upper Tilpal Creek watering point yielded 544 individuals comprising 10 species at a catch rate of 26.6 fish/min. *Melanotaenia splendida was* the most abundant species representing 39.5% of the total catch at a rate of 10.51 fish/min (Figure 18 - (1)). *Nematalosa erebi* were the next most abundant species contributing 26.1%, followed by *Leiopotherapon unicolor* with 20.4%. The remaining 13.5% consisted of *Glossamia aprion, Craterocephalus stercusmuscarum, Anguilla reinhardtii, Neosilurus hyrtlii, Hypseleotris sp.1, Mogurnda adspersa* and *Ambassis agassizii.*

Middle - Road Crossing (2)

A total of 198 individuals comprising 10 species at a catch rate of 39.6 fish/min were recorded from middle Tilpal Creek road crossing. *Nematalosa erebi* was the most abundant species representing 56.6% of the total catch at a rate of 22.4 fish/min (Figure 18 - (2)). *Leiopotherapon unicolor* were the next most abundant species contributing 15.2%, followed by *Melanotaenia splendida* and *Ambassis agassizii* with 8.6% and 7.6% respectively. The remaining 12% consisted of *Anguilla reinhardtii, Mogurnda adspersa, Craterocephalus stercusmuscarum, Hypseleotris compressa, Neosilurus hyrtlii* and *Glossamia aprion.*

Halfway Creek

Middle (3)

Sampling at middle Halfway Creek yielded 52 individuals comprising 8 species at a catch rate of 10.4 fish/min. *Leiopotherapon unicolor* was the most abundant species representing 32.7% of the total catch at a rate of 3.4 fish/min (Figure 18 - (3)). *Hypseleotris compressa* were the next most abundant species contributing 23.1%, followed by *Melanotaenia splendida* and *Lates calcarifer* with 13.5% and 11.5% respectively. The remaining 19.2% consisted of *Ambassis agassizii, Megalops cyprinoides* (Figure 22), *Nematalosa* erebi*, Anguilla reinhardtii.*

Lower (4)

Sampling at lower Halfway Creek yielded 165 individuals comprising 12 species at a catch rate of 11.0 fish/min. *Ambassis agassizii* was the most abundant species representing 21.2% of the total catch at a rate of 2.33 fish/min (Figure 18 - (4)). *Nematalosa* erebi were the next most abundant species contributing 15.2%, followed by *Melanotaenia splendida* and *Leiopotherapon unicolor* with 14.5% and 12.7% respectively. The remaining 36.4% consisted of *Hypseleotris compressa, Megalops cyprinoides, Lates calcarifer, Hypseleotris sp.1, Anguilla reinhardtii, Ophisternon spp., Neosilurus hyrtlii* and *Porochilus rendahli.*

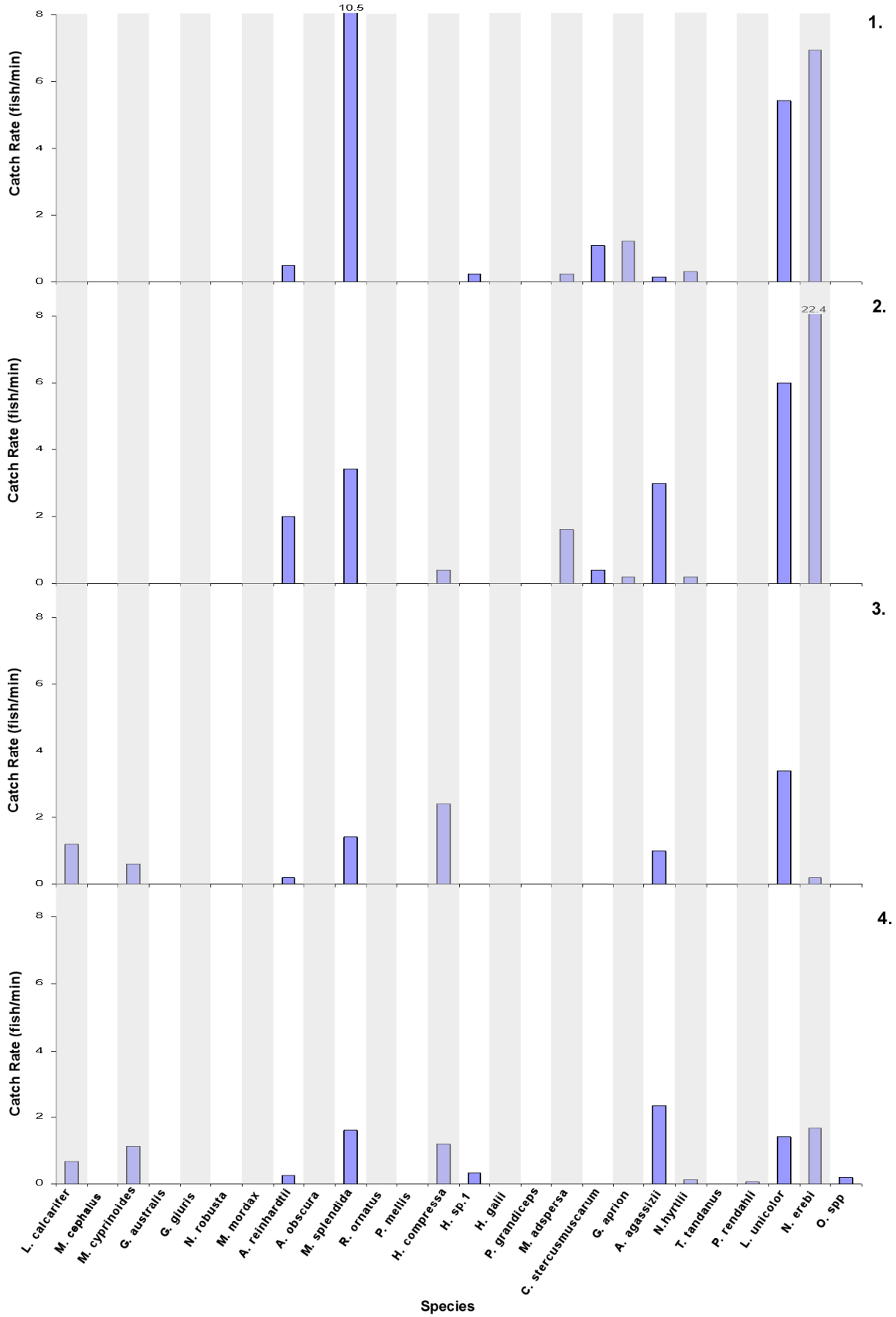


Figure 18. Fish species abundance (catch rate - fish/min) of all fish species recorded at Tilpal Creek upper (1) and middle (2) and Halfway Creek middle (3) and lower (4).

Wadallah Creek

Watering Point (5)

A total of 254 individuals comprising 5 species at a catch rate of 16.93 fish/min were recorded from Wadallah Creek watering point (Figure 19). *Leiopotherapon unicolor* was the most abundant species representing 43.7% of the total catch at a rate of 7.4 fish/min (Figure 21 - (5)). *Melanotaenia splendida* were the next most abundant species contributing 39.8%, followed by *Mogurnda adspersa* and *Hypseleotris sp.1 and Anguilla reinhardtii* with 13.8% and 2.4% and 0.4% respectively.

Louisa Creek

Lower - Road Crossing (6)

A total of 72 individuals comprising 7 species at a catch rate of 3.60 fish/min were recorded from Louisa Creek (Figure 20). *Hypseleotris compressa* was the most abundant species representing 44.4% of the total catch at a rate of 1.60 fish/min (Figure 21 - (6)). *Melanotaenia splendida* was the next most abundant species contributing 18.1%, followed by *Mogurnda adspersa* and *Anguilla reinhardtii* with 12.5% and 11.1% respectively. The remaining 13.9% consisted of *Hypseleotris sp.1, Lates calcarifer and Anguilla obscura* with 8.3% and 4.2% and 1.4% respectively.

Figures 19 & 20. Wadallah Creek watering point (top) and Louisa Creek (bottom).

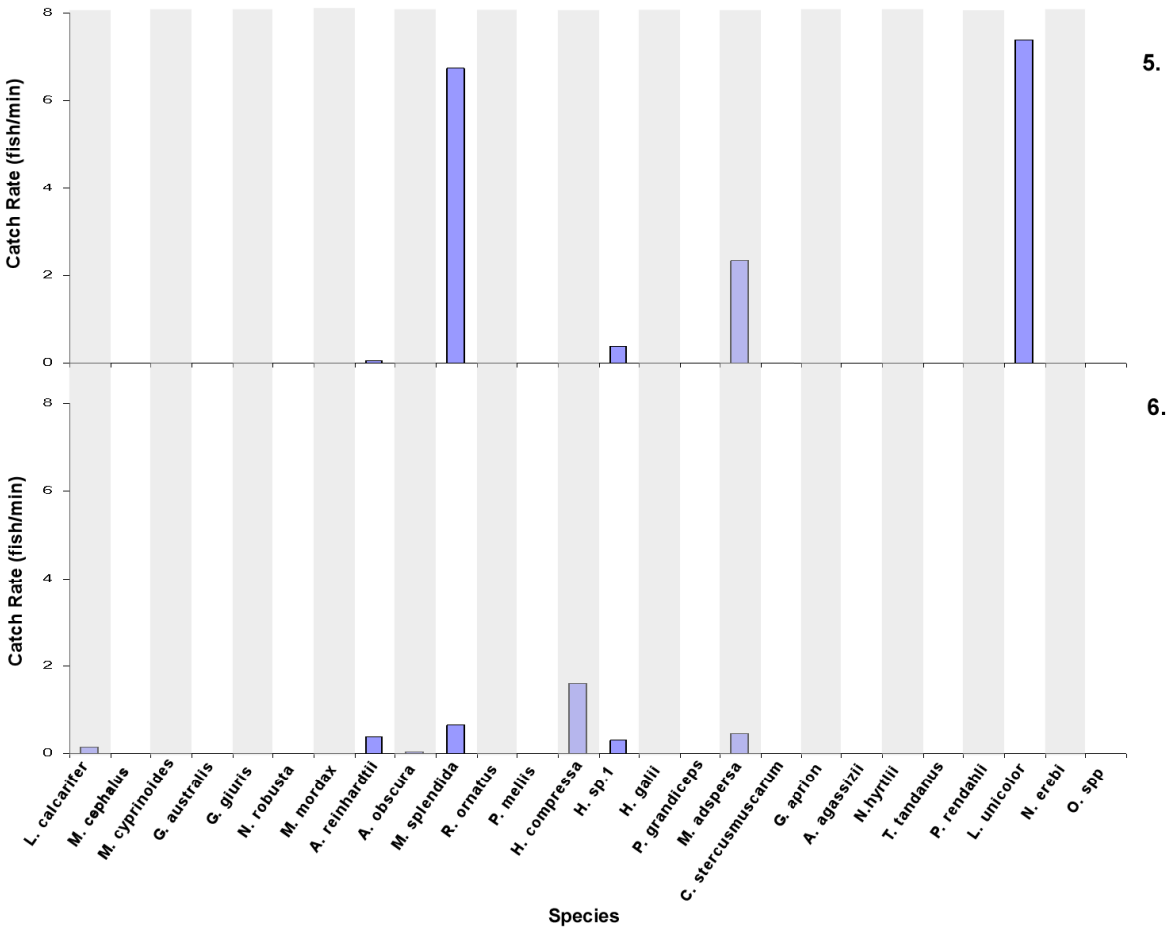


Figure 21. Fish species abundance (catch rate - fish/min) of all fish species recorded at Wadallah Creek watering point (5) and Louisa Creek (6).

Figure 22 Sub-adult barramundi (bottom) and tarpon (top) sampled at lower Halfway Creek in the Broadsound Catchment.

Mt Hummock Creek (upper Shoalwater Creek) (7)

Sampling at Mt Hummock Creek yielded 239 individuals comprising 8 species at a catch rate of 25.16 fish/min. *Hypseleotris compressa* was the most abundant species representing 49.4% of the total catch at a rate of 12.42 fish/min (Figure 24 - (7)). *Leiopotherapon unicolor* were the next most abundant species contributing 22.2%, followed by *Mogurnda adspersa* and *Anguilla reinhardtii* with 11.7% and 7.5% respectively. The remaining 9.2% consisted *Melanotaenia splendida* (Figure 25), *Hypseleotris sp.1, Lates calcarifer and Ambassis agassizii.*

Razorback Creek (upper Shoalwater Creek) (8)

A total of 235 individuals comprising 7 species at a catch rate of 47.0 fish/min were recorded from Razorback Creek. *Hypseleotris sp.1* was the most abundant species representing 50.2% of the total catch at a rate of 23.6 fish/min (Figure 24 - (8)). *Hypseleotris compressa* were the next most abundant species contributing 22.6%, followed by *Melanotaenia splendida* and *Leiopotherapon unicolor* with 11.9% and 7.7% respectively. The remaining 6.6% consisted of *Mogurnda adspersa, Megalops cyprinoides and Anguilla reinhardtii* with 5.5%, 1.7% and 0.4% respectively.

Shoalwater Creek - Lower (9)

Sampling at lower Shoalwater Creek yielded 109 individuals comprising 6 species at a catch rate of 5.45 fish/min. *Lates calcarifer* was the most abundant species representing 40.4% of the total catch at a rate of 2.2 fish/min (Figure 24 - (9)). *Mugil cephalus* (Figure 23) was the next most abundant species contributing 28.4%, followed by *Hypseleotris compressa, Anguilla reinhardtii Melanotaenia splendida* and *Megalops cyprinoides* with 19.3%, 5.5%, 5.5% and 0.9% respectively.

Figure 23. Adult sea mullet (550mm) sampled at lower Shoalwater Creek.

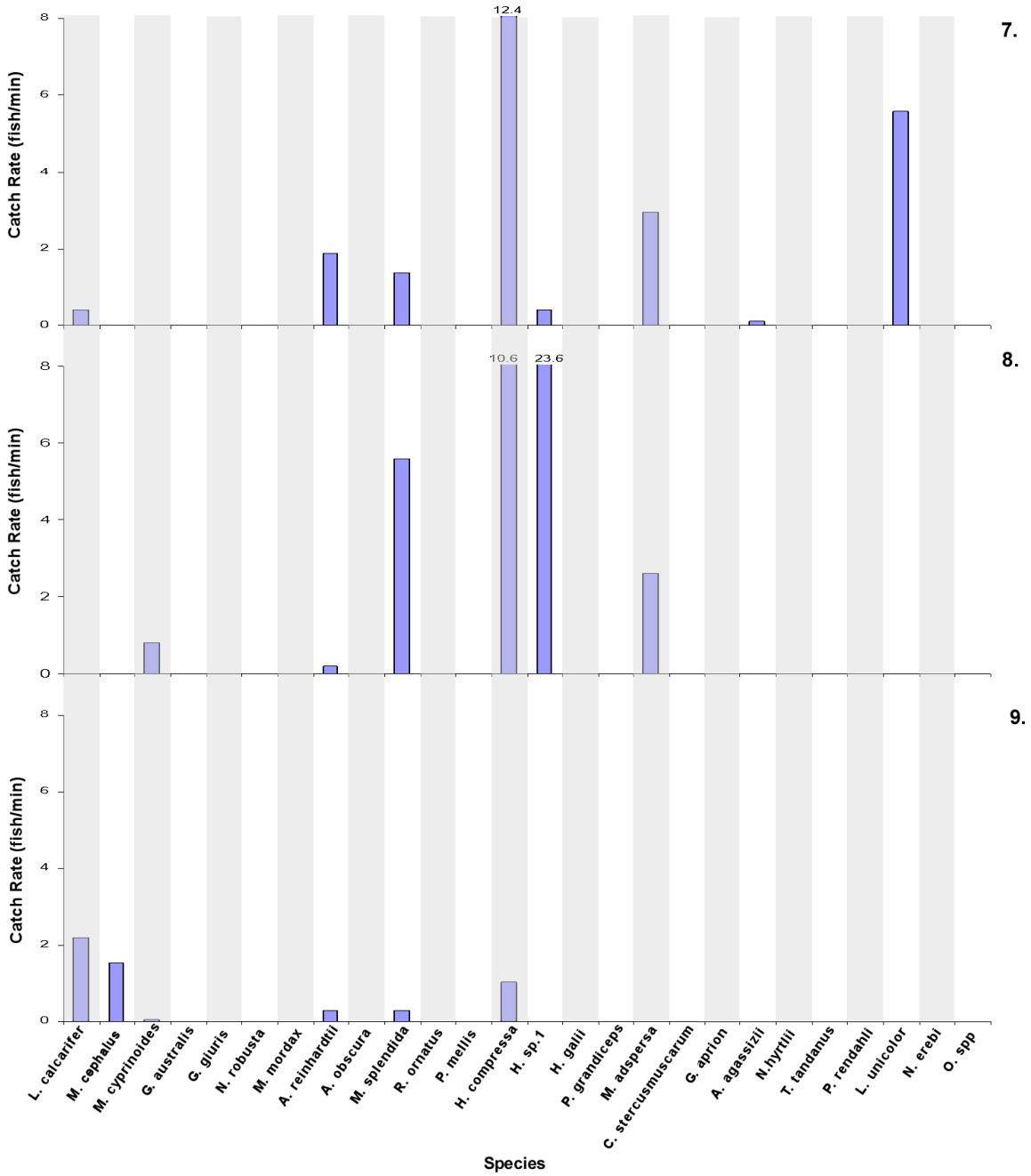


Figure 24. Fish species abundance (catch rate - fish/min) of all fish species sampled at Mt Hummock, Creek (upper reaches of Shoalwater Creek) (7), Razorback Creek (upper reaches of Shoalwater Creek (8) and lower Shoalwater Creek (9).

Figure 25. Eastern Rainbowfish (*Melanotaenia splendida) sampled* from Mt Hummock Creek.

GBRMP Catchment

Perennial Groundwater Fed Sandy Substrate Streams

Cowan Creek

Lower Cowan Creek - Road Crossing (10)

Sampling at Cowan Creek (Figure 26) yielded 135 individuals comprising 6 species at a catch rate of 9.0 fish/min. *Rhadinocentrus ornatus* was the most abundant species representing 46.7% of the total catch at a rate of 4.2 fish/min (Figure 27 - (10)). *Hypseleotris compressa* were the next most abundant species contributing 37%, followed by *Anguilla reinhardtii* and *Gobiomorphus australis* with 7.4% and 5.2% respectively. The remaining 3.7% consisted of *Ophisternon spp. and Anguilla obscura with 2.2% and 1.5%* respectively.

Solitude Creek

Lower Solitude Creek - Road Crossing (11)

A total of 183 individuals comprising 5 species at a catch rate of 18.3 fish/min were recorded from Solitude Creek. *Rhadinocentrus ornatus* was the most abundant species representing 56.3% of the total catch at a rate of 10.3 fish/min (Figure 27 - (11)). *Hypseleotris compressa* were the next most abundant species contributing 41.5% of the total catch at a rate of 7.6 fish/min. The remaining catch consisted of *Gobiomorphus australis, Anguilla reinhardtii* and *Melanotaenia splendida* representing 1.1%, 0.5% and 0.5% respectively.

Figure 26. Measuring fish sampled at lower Cowan Creek in the GBRMP Catchment.

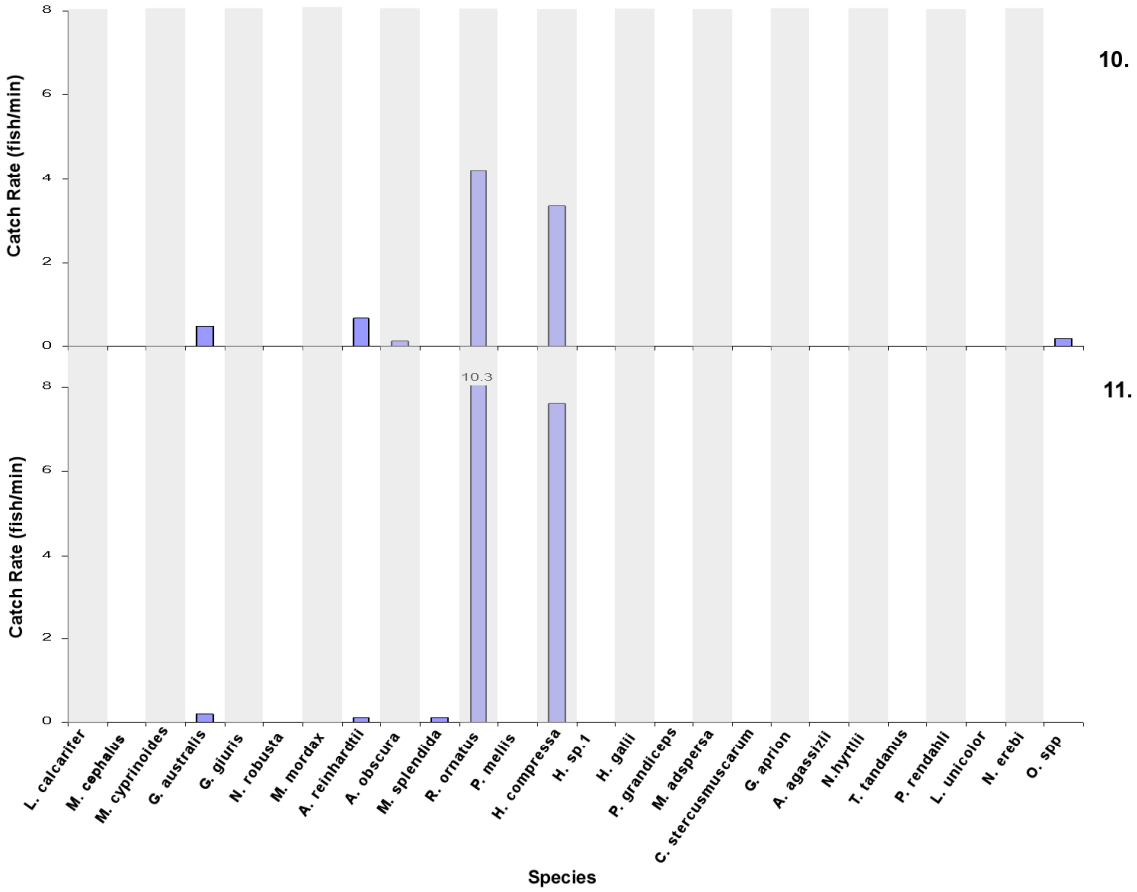


Figure 27. Fish species abundance (catch rate - fish/min) of all fish species recorded at lower Cowan (10) and Solitude (11) Creeks in the GBRMP Catchment.

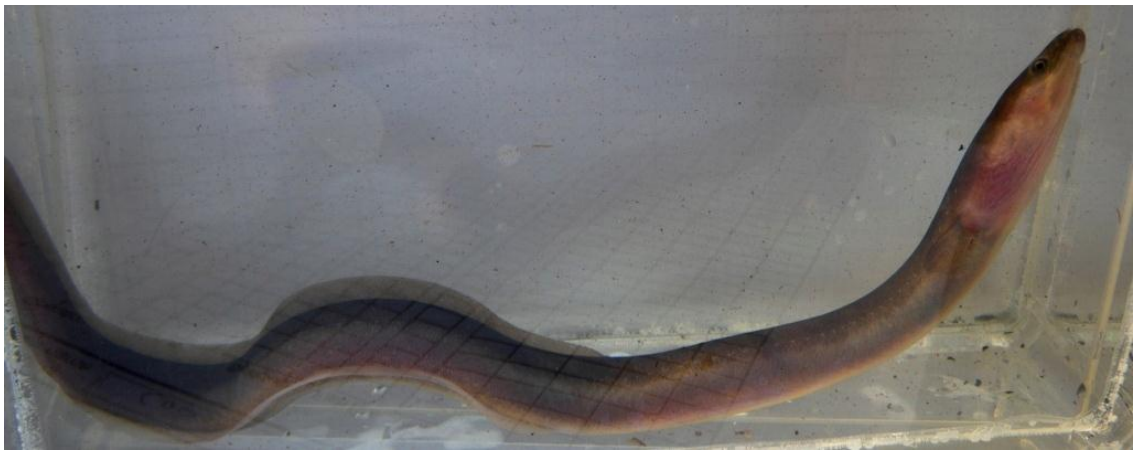


Figure 28. Pacific short-fin eel sampled at lower Cowan Creek in the GBRMP Catchment.

Unnamed Creek 1

Chopper Beach - North (12)

Sampling at Unnamed Creek 1 yielded 4 individuals comprising 3 species at a catch rate of 0.8 fish/min. *Hypseleotris compressa* was represented by two individuals while *Anguilla obscura* and *Anguilla reinhardtii* were both represented by 1 individual (Figure 30 - (12)).

Unnamed Creek 2

Chopper Beach - South (56)

No fish species were recorded from Unnamed Creek 2.

Waterfall Creek

Switzerland's Beach (13)

Anguilla reinhardtii was the only recorded species from Waterfall Creek on Switzerland's Beach with 1 individual at a catch rate of 0.4 fish/min (Figure 30 - (13)).

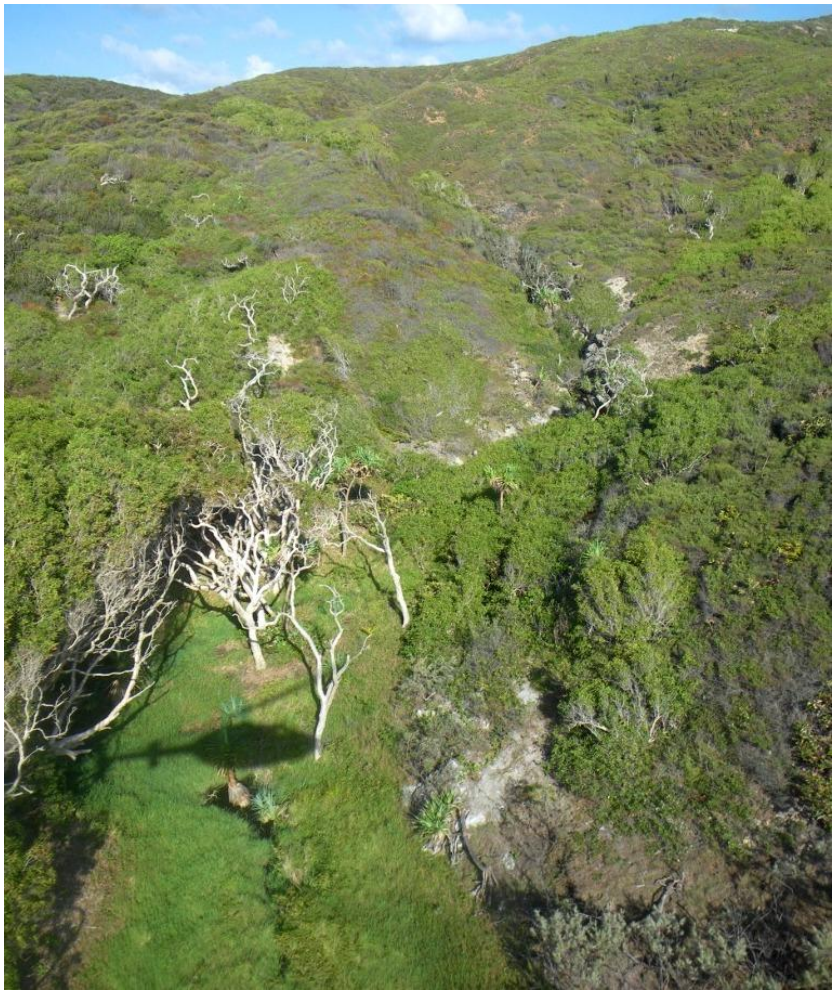


Figure 29. The lower reaches of Unnamed Creek 1, showing the steep gradient and habitat characteristics just before it reaches the beach in the GBRMP Catchment.

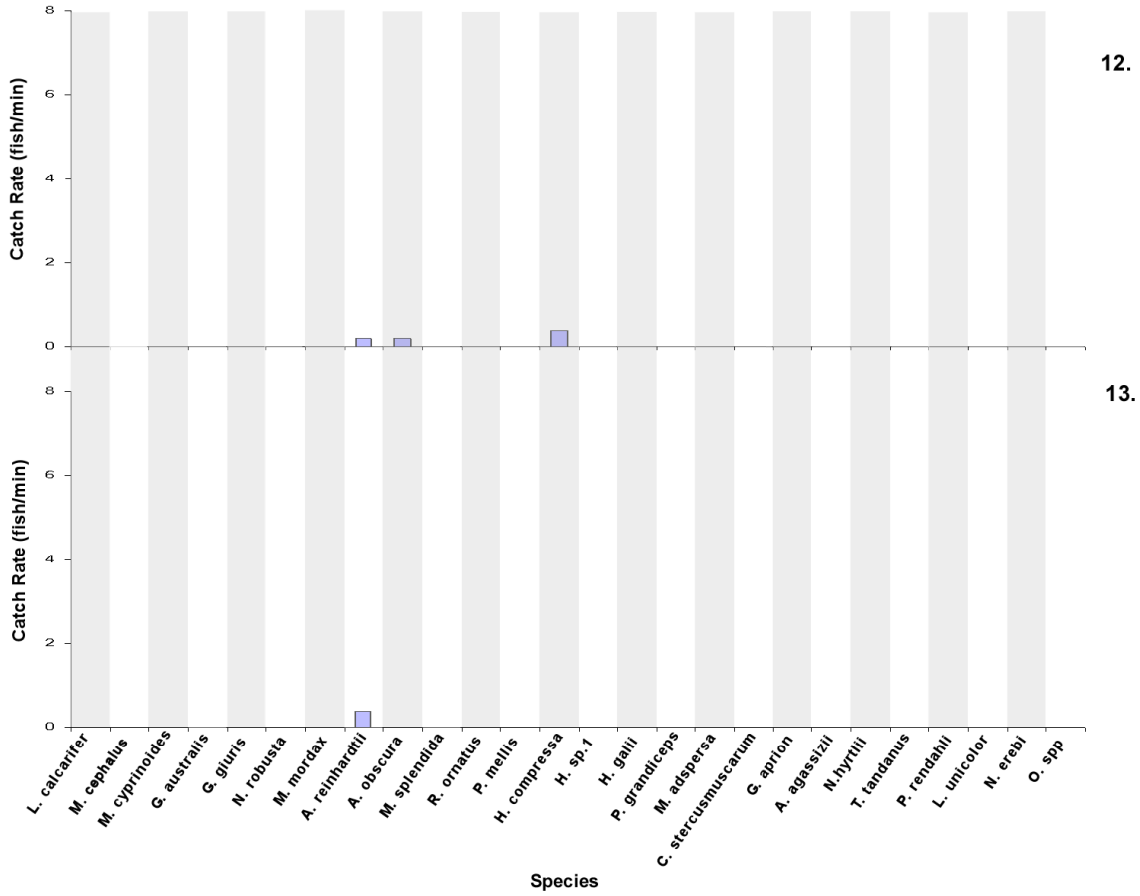


Figure 30. Fish species abundance (catch rate - fish/min) of all fish species recorded at Unnamed Creek 1 (12) and Waterfall Creek (13) in the GBRMP Catchment

Figure 31. Macrobrachium species sampled from Unnamed Creek 1

Three Rivers Creek

Upper Three Rivers Creek -Sinkhole (14)

Anguilla reinhardtii was the only recorded species from the Three Rivers sinkhole (Figure 32) with 1 individual at a catch rate of 0.4 fish/min (Figure 34 - (14)).

Upper Three Rivers Creek (15)

Rhadinocentrus ornatus was the only recorded species from middle Three Rivers Creek with 12 individuals at a catch rate of 2.4 fish/min (Figure 34 - (15)*).*

Lower Three Rivers Creek (16)

Sampling at lower Three Rivers Creek yielded 119 individuals comprising 7 species at a catch rate of 22.67 fish/min. *Hypseleotris compressa* was the most abundant species representing 75.6% of the total catch at a rate of 17.14 fish/min (Figure 34 - (16)). *Rhadinocentrus ornatus* and *Gobiomorphus australis* (Figure 33) were the next most abundant species contributing 8.4% and 7.6% respectively*.* The remaining 8.4% consisted of *Anguilla reinhardtii, Lates calcarifer, Ophisternon spp., and Anguilla obscura* with 5.9%, 0.8%, 0.8% and 0.8% respectively.

Figure 32 & 33. Typical upper 3 Rivers Creek habitat (top) and Striped Gudgeon (*Gobiomorphus australis*) (bottom) sampled from lower 3 Rivers Creek.

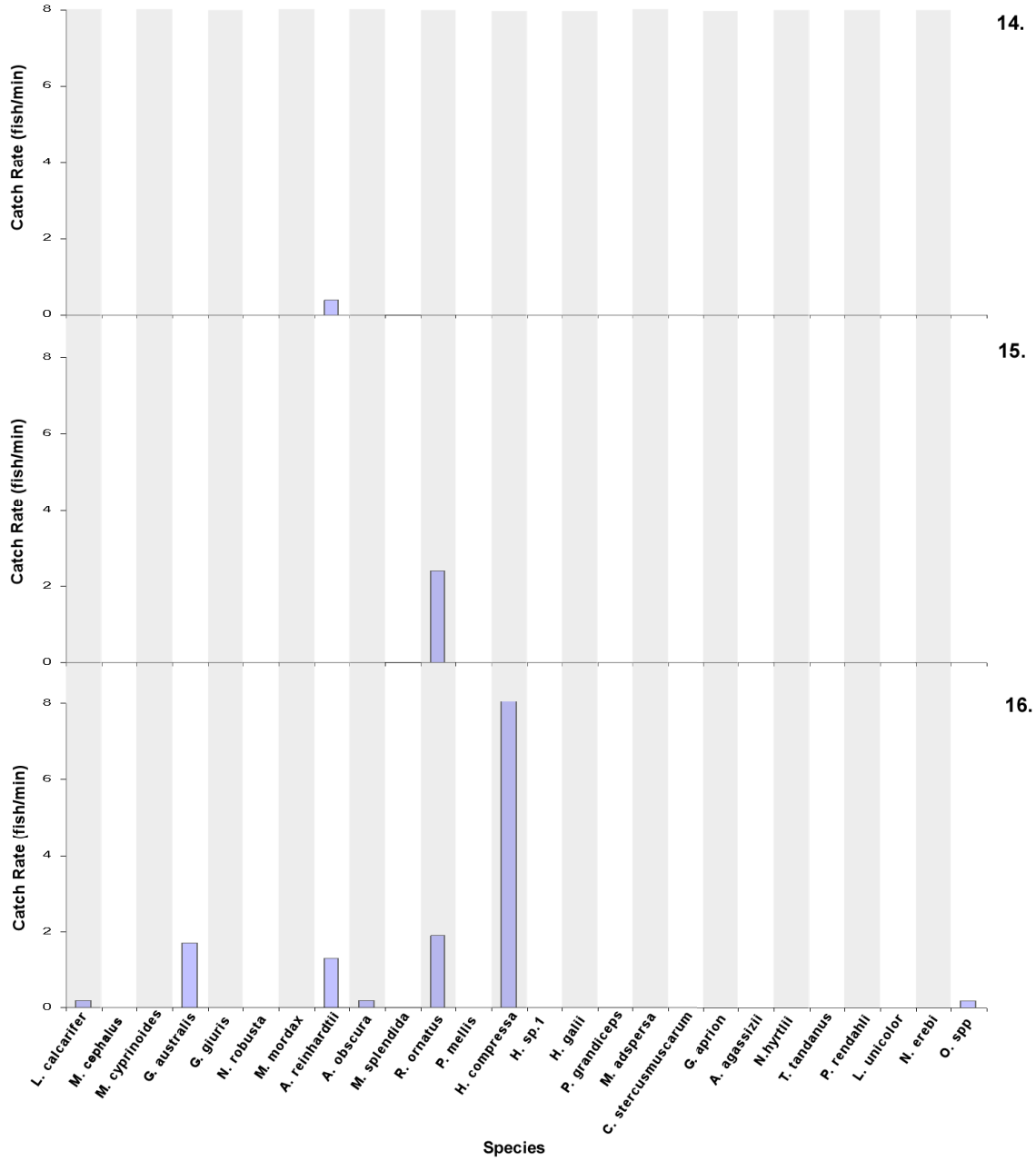


Figure 34. Fish species abundance (catch rate - fish/min) of all fish species recorded at 3 Rivers Creek upper sinkhole (14), upper (15) and lower (16) sampling sites.

Figure 35. The restricted Ornate rainbowfish (*Rhadinocentrus ornatus*) from Sandy Creek.

Waterpark Creek Catchment

Perennial Groundwater Fed Sandy Substrate Streams

Sandy Creek

Upper Sandy Creek - Perched Dune Lake Outlet (17)

Rhadinocentrus ornatus (Figure 35) was the only recorded species from the Perched Dune Lake Outlet on Sandy Creek with 20 individuals at a catch rate of 12.05 fish/min (Figure 36 - (17)).

Upper Sandy Creek - Sinkhole source (18)

Rhadinocentrus ornatus was the only recorded species from the sinkhole source on upper Sandy Creek sinkhole (Figure 36) with 19 individuals at a catch rate of 7.60 fish/min (Figure 36 - (18)).

Upper Lawyer Creek (19)

A total of 230 individuals comprising 7 species at a catch rate of 14.88 fish/min were recorded from Lawyer Creek, a headwater tributary of Sandy Creek. *Rhadinocentrus ornatus* was the most abundant species representing 87% of the total catch at a rate of 12.94 fish/min (Figure 36 - (19)). *Hypseleotris compressa* and *Mogurnda adspersa* were the next most abundant species contributing 4.8% and 4.3% respectively. The remaining 3.9% consisted of *Anguilla reinhardtii, Anguilla obscura, Ophisternon spp.* and *Gobiomorphus australis* representing 1.7%, 1.3%, 0.4% and 0.4% respectively.

Lower Sandy Creek - Sam Hill Pump Station (20)

Sampling at Samuel Hill Pump Station on Sandy Creek yielded 148 individuals comprising 8 species at a catch rate of 9.87 fish/min. *Rhadinocentrus ornatus* was the most abundant species representing 62.2% of the total catch at a rate of 6.13 fish/min (Figure 36 - (20)). *Anguilla reinhardtii* and *Mordacia mordax* were the next most abundant species contributing 14.2% and 9.5% respectively. The remaining 14.1% consisted of *Hypseleotris compressa, Mogurnda adspersa, Tandanus tandanus, Ophisternon spp.* and *Gobiomorphus australis* contributing 7.4%, 2.7%, 2.0%, 1.4% and 0.7% respectively.

Figure 36. Aerial view of upper Sandy Creek sinkhole source.

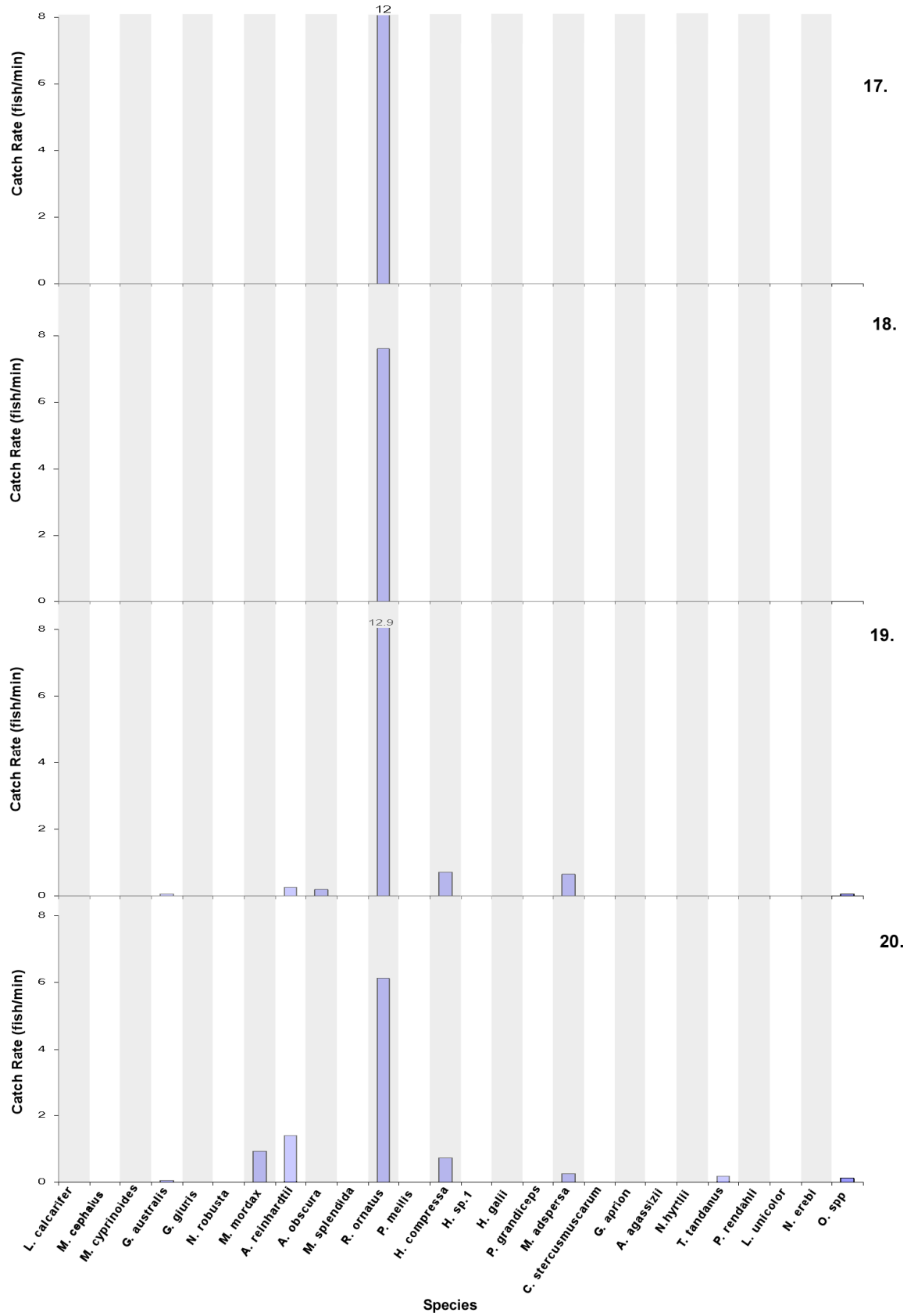


Figure 37. Fish species abundance (catch rate - fish/min) of all fish species recorded at upper Sandy Creek Dune lake Outlet (17), upper Sandy Creek Sinkhole Source (18), Upper Lawyer Creek (19) and Lower Sandy Creek at Sam Hill Pump Station (20).

Apple Tree Creek

Upper Apple Tree Creek - Road Crossing (21)

A total of 106 individuals comprising 3 species at a catch rate of 7.07 fish/min were recorded from upper Apple Tree Creek. *Rhadinocentrus ornatus* (Figure 38) was the most abundant species representing 59.4% of the total catch at a rate of 4.2 fish/min (Figure 40 - (21)). *Hypseleotris compressa* and *Hypseleotris galii* were the next most abundant species contributing 39.6% and 0.9% respectively.

Middle Apple Tree Creek (22)

Sampling (Figure 39) at middle Apple Tree Creek (Figure 41) yielded 388 individuals comprising 3 species at a catch rate of 25.87 fish/min. *Rhadinocentrus ornatus* was the most abundant species representing 79.9% of the total catch at a rate of 20.67 fish/min (Figure 40 - (22)). *Hypseleotris compressa* and *Gobiomorphus australis* were the next most abundant species contributing 19.8% and 0.3% respectively.

Figures 38 & 39. A different colour morph of the Ornate Rainbowfish (*Rhadinocentrus ornatus*) from Apple Tree Creek (top), and sampling with the backpack electrofisher at middle Apple Tree Creek, (bottom).

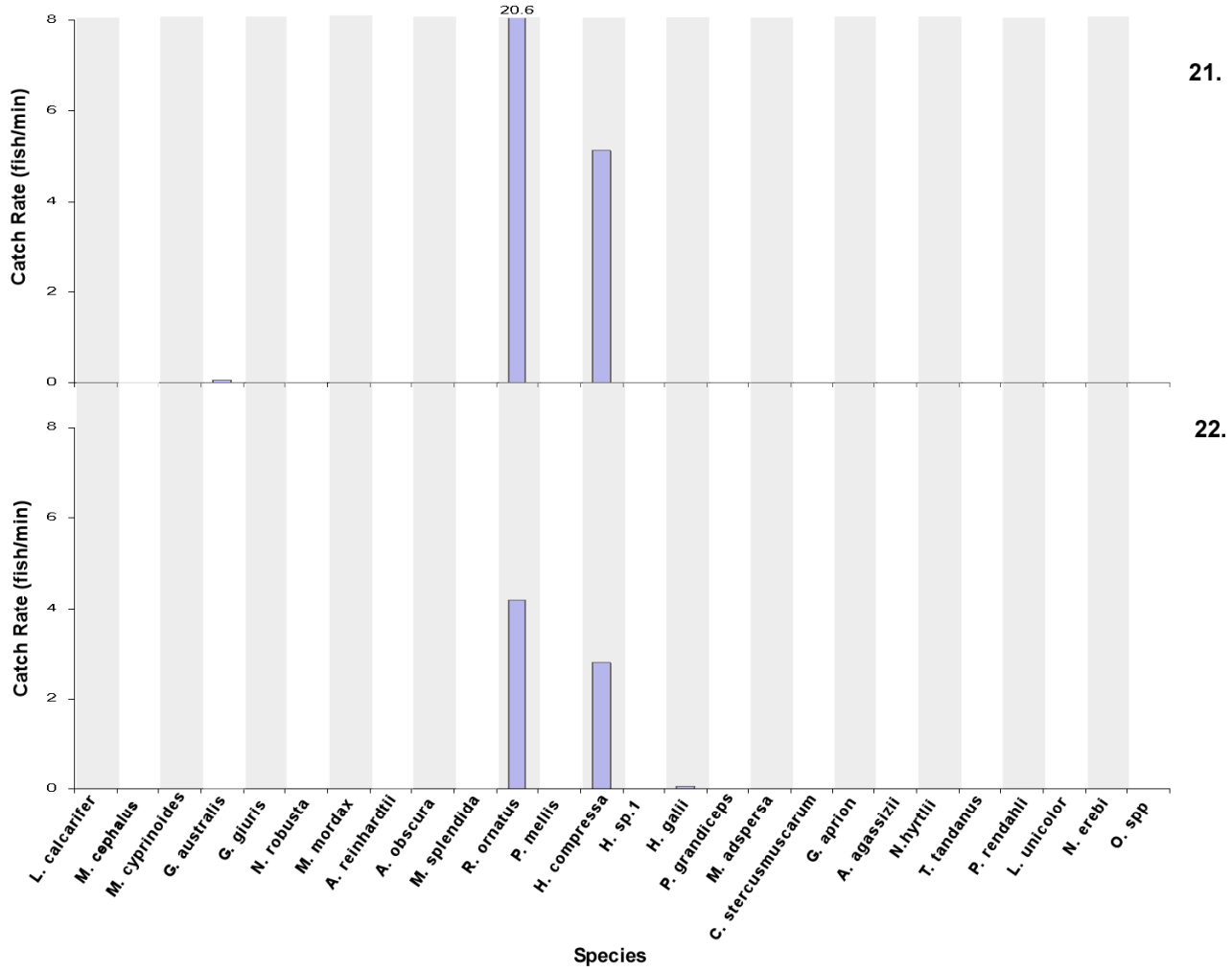


Figure 40. Fish species abundance (catch rate - fish/min) of all fish species recorded at Upper Apple Tree Creek (21) and Middle Apple Tree Creek (22) in the Waterpark Creek Catchment.

Figure 41 Typical Stream habitat at Middle Apple Tree Creek (22).

Waterpark Creek

Old bridge Site - Middle Creek Site (23)

A total of 101 individuals comprising 6 species at a catch rate of 5.05 fish/min were recorded from the old bridge site on Waterpark Creek. *Rhadinocentrus ornatus and Mogurnda adspersa* were the most abundant species representing 32.7% of the total catch at a rate of 1.65 fish/min (Figure 42 - (23)). *Hypseleotris compressa* and *Anguilla reinhardtii* were the next most abundant species contributing 20.8% and 11.9% respectively. The remaining 2% consisted of *Tandanus tandanus and* Gobiomorphus *australis.*

Upper Weir Pool (24)

Sampling the upper weir pool in Waterpark Creek yielded 166 individuals comprising 11 species at a catch rate of 5.53 fish/min. *Melanotaenia splendida* was the most abundant species representing 39.2% of the total catch at a rate of 2.17 fish/min (Figure 42 - (24)). *Hypseleotris compressa* and *Anguilla reinhardtii* were the next most abundant species contributing 30.7% and 9% respectively. The remaining 21.1% consisted of *Leiopotherapon unicolor, Hypseleotris sp.1, Mogurnda adspersa, Gobiomorphus australis, Notesthes robusta, Glossamia aprion, Neosilurus hyrtlii* and *Tandanus tandanus* contributing 7.8%, 5.4%, 4.2%, 1.2%, 0.6%, 0.6%, 0.6% and 0.6% respectively.

Lower Weir Pool (25)

A total of 140 individuals comprising 10 species at a catch rate of 4.67 fish/min were recorded from Waterpark Creek's lower weir pool (Figure 41). *Melanotaenia splendida* were the most abundant species representing 40% of the total catch at a rate of 1.87 fish/min (Figure 42 - (25)). *Hypseleotris compressa* and *Mogurnda adspersa* were the next most abundant species contributing 24.3% and 19.3% respectively. The remaining 16.4% consisted of *Glossamia aprion*, *Anguilla reinhardtii, Hypseleotris sp.1, Tandanus tandanus, Neosilurus hyrtlii, Porochilus rendahli* and *Leiopotherapon unicolor* contributing 5%, 3.6%, 3.6%, 2.1%, 0.7%, 0.7% and 0.7% respectively.

Figure 42. Waterpark Creek lower weir pool habitat.

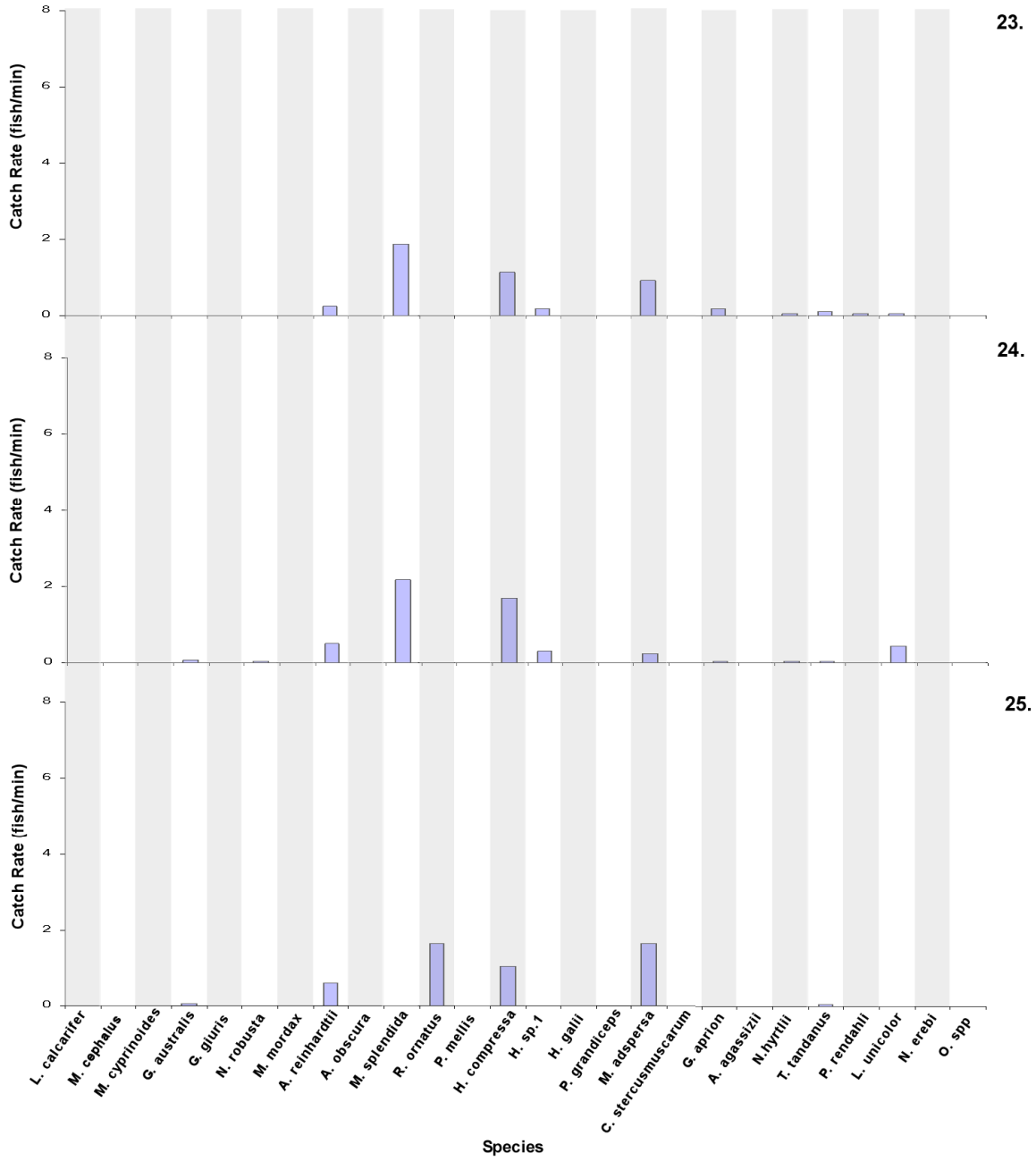


Figure 42 Fish species abundance (catch rate - fish/min) of all fish species recorded at Waterpark Creek middle creek site (23), upper weir pool (24) and lower weir pool (25).

Ephemeral Rocky Substrate Streams

Stony Creek

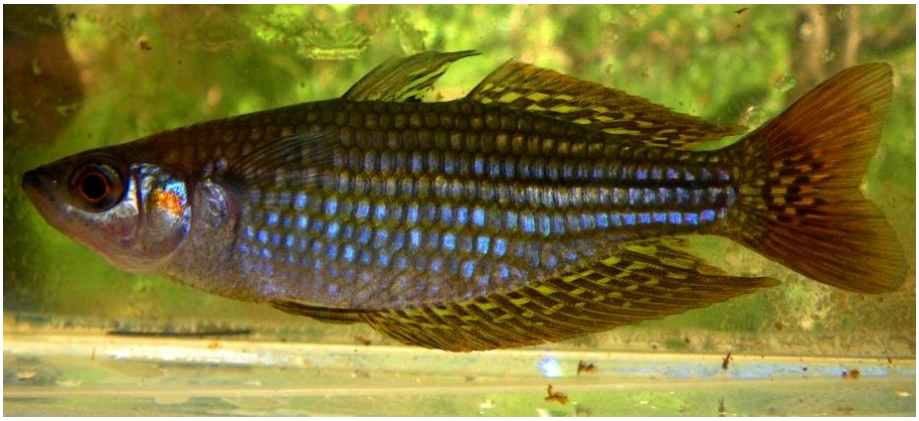
Lower Stony Creek (26)

A total of 254 individuals comprising 10 species at a catch rate of 16.93 fish/min were recorded from lower Stony Creek. *Melanotaenia splendida* was the most abundant species representing 45.7% of the total catch at a rate of 7.73 fish/min (Figure 45 - (26)). *Hypseleotris compressa* was the next most abundant species contributing 40.6% at a catch rate 6.87 fish/min. The remaining 13.7% consisted of *Anguilla reinhardtii, Mogurnda adspersa, Notesthes robusta, Tandanus tandanus, Gobiomorphus australis, Glossogobius giuris* (Figure 43), *Leiopotherapon unicolor* and *Ophisternon spp.* contributing 5.9%, 3.9%, 1.2%, 0.8%, 0.8%, 0.4%, 0.4% and 0.4% respectively.

Norton Creek

Norton Creek - Road Crossing (27)

A total of 240 individuals comprising 5 species at a catch rate of 16 fish/min were recorded downstream of Norton Creek road crossing. *Rhadinocentrus ornatus* was the most abundant species representing 69.2% of the total catch at a rate of 11.07 fish/min (Figure 45 - (27)). *Hypseleotris compressa* was the next most abundant species contributing 26.7% at a rate of 4.27 fish/min. The remaining 4.1% consisted of *Mogurnda adspersa, Melanotaenia splendida* (Figure 44), and *Hypseleotris galii* contributing 3.3%, 0.4% and 0.4% respectively.



Figures 43 & 44. Flathead goby sampled from Stony Creek (top), eastern rainbowfish sampled from Norton Creek (bottom).

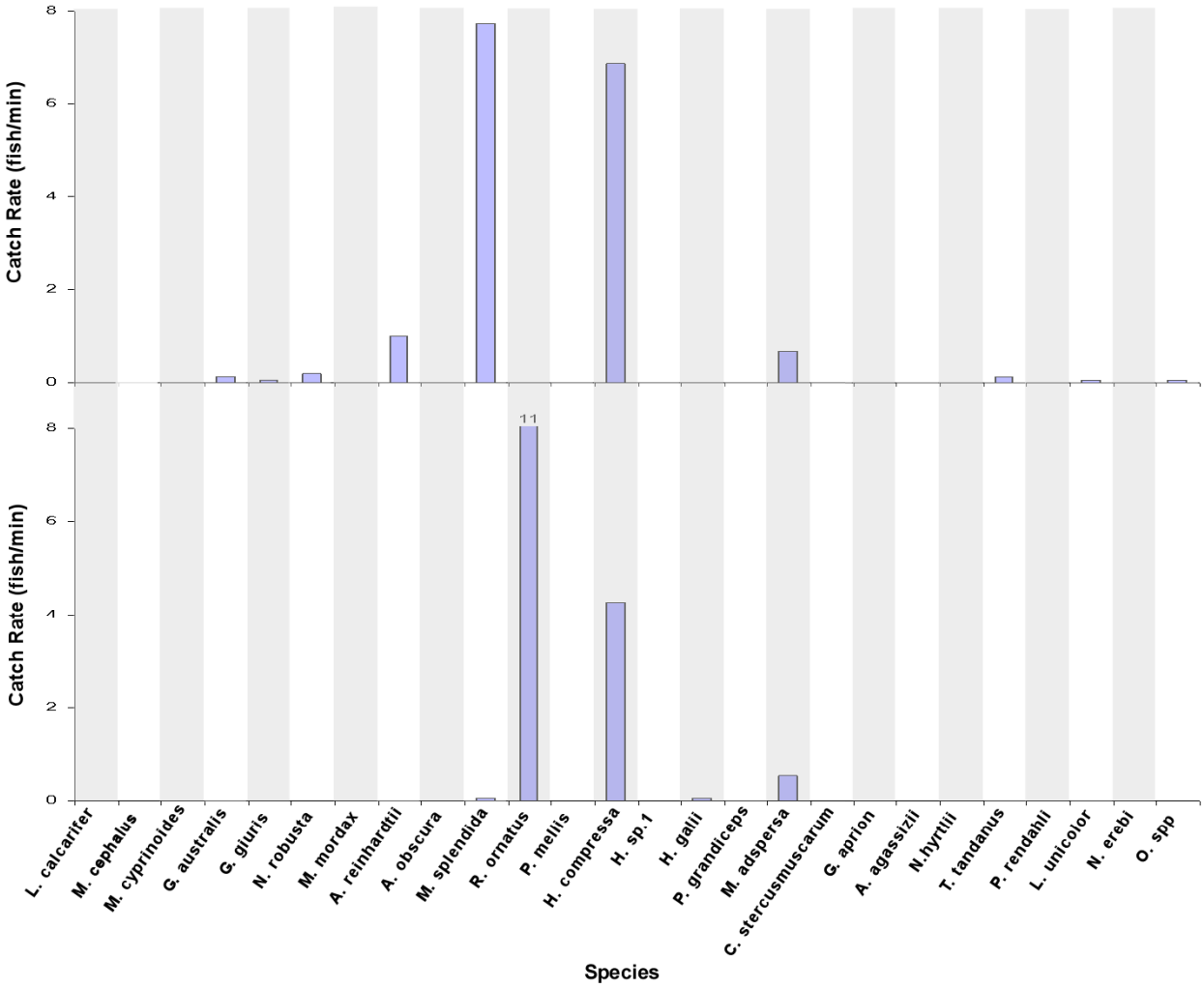


Figure 45. Fish species abundance (catch rate - fish/min) of all fish species recorded at Stony Creek (26) and Norton Creek (27).

Figure 46. Typical habitat of Norton Creek (27) in the Waterpark Creek Catchment.

Byfield Creek

Lower Byfield Creek (28)

Sampling lower Byfield Creek yielded 72 individuals comprising 4 species at a catch rate of 14.4 fish/min. *Melanotaenia splendida* was the most abundant species representing 72.2% of the total catch at a rate of 10.4 fish/min (Figure 48 - (28)). *Mogurnda adspersa* and *Rhadinocentrus ornatus* were the next most abundant species contributing 18.1% and 4.2% respectively. The remaining 1.4% consisted of *Leiopotherapon unicolor* contributing 1.4%.

Nob Creek

Upper Nob Creek (29)

A total of 360 individuals comprising 3 species at a catch rate of 144 fish/min were recorded from upper Nob Creek (Figure 47). *Melanotaenia splendida* was the most abundant species representing 83.3% of the total catch at a rate of 120 fish/min (Figure 48 - (29)). *Mogurnda adspersa* was the next most abundant species contributing 20% of the total catch at a rate of 13.9 fish/min. The remaining 2.8% consisted of *Leiopotherapon unicolor* making up 2.8% of the total catch.

Figure 47. Upper Nob Creek site in the Waterpark Cree Catchment.

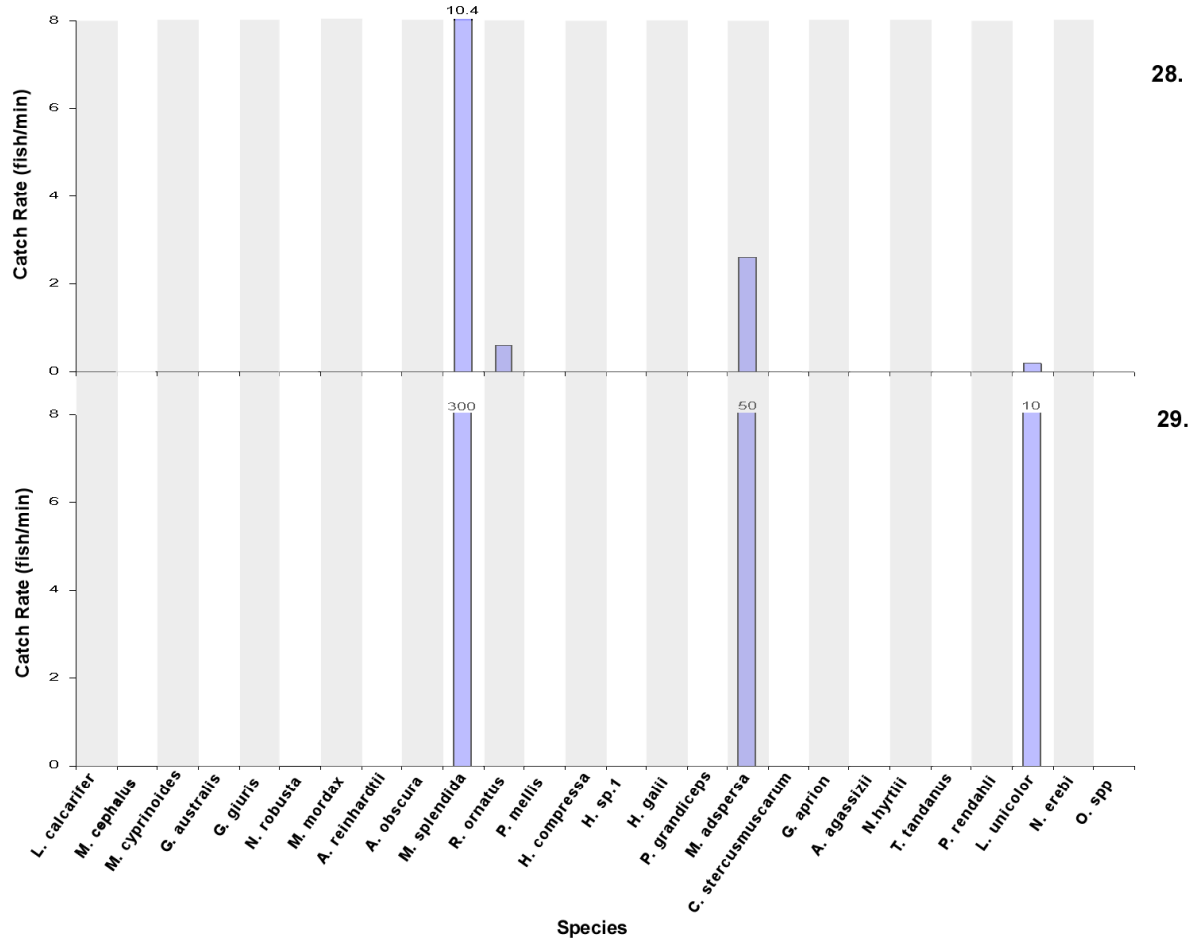


Figure 48. Fish species abundance (catch rate - fish/min) of all fish species recorded at Byfield (28) and Nob (29) Creeks.

Ephemeral Sandy/Clay substrate streams

Tea Tree Creek

Tea Tree Creek - Upper Tributary - Quads (30)

A total of 440 individuals comprising 6 species at a catch rate of 44 fish/min were recorded from an upper tributary of Tea Tree Creek. *Melanotaenia splendida* was the most abundant species representing 36.6% of the total catch at a rate of 16.10 fish/min (Figure 50 - (30)). *Hypseleotris galii* and *Mogurnda adspersa* (Figure 49) were the next most abundant species contributing 34.3% and 23.4% of the total catch at rates of 15.1 fish/min and 10.3 fish/min respectively. The remaining 5.7% consisted of *Ambassis agassizii*, *Anguilla reinhardtii* and *Hypseleotris compressa* contributing 2.7%, 2% and 0.9% respectively.

Tea Tree Creek - Upper Tributary - Rehab Road (31)

Sampling at 'Rehab Road', a tributary of Tea Tree Creek yielded 136 individuals comprising 5 species at a catch rate of 57.14 fish/min. *Hypseleotris galii* was the most abundant species representing 85.3% of the total catch at a rate of 48.74 fish/min (Figure 50 - (31)). *Mogurnda adspersa* and *Hypseleotris compressa* were the next most abundant species contributing 8.1% and 3.7% respectively. The remaining 2.9% consisted of Melanotaenia *splendida* and *Anguilla obscura* contributing *2.2%* and *0.7%* respectively.

Tea Tree Creek -Upper Tributary - Blue Route Road Crossing (32)

A total of 230 individuals comprising 7 species at a catch rate of 46 fish/min were recorded from 'Seahound Hard Road Crossing', a tributary of Tea Tree Creek. *Mogurnda adspersa* was the most abundant species representing 86.1% of the total catch at a rate of 39.6 fish/min (Figure 50 - (32)). *Hypseleotris galii* and *Melanotaenia splendida* were the next most abundant species contributing 6.1% and 3.5% respectively. The remaining 4.3% consisted of *Anguilla obscura, Hypseleotris compressa, Ambassis agassizii* and *Anguilla reinhardtii* contributing 2.6%, 0.9%, 0.4% and 0.4% respectively.

Figure 49. Purple-spotted gudgeon (*Mogurnda adspersa),* the most abundant fish species recorded from the Blue Route Road crossing site on upper Tea Tree Creek

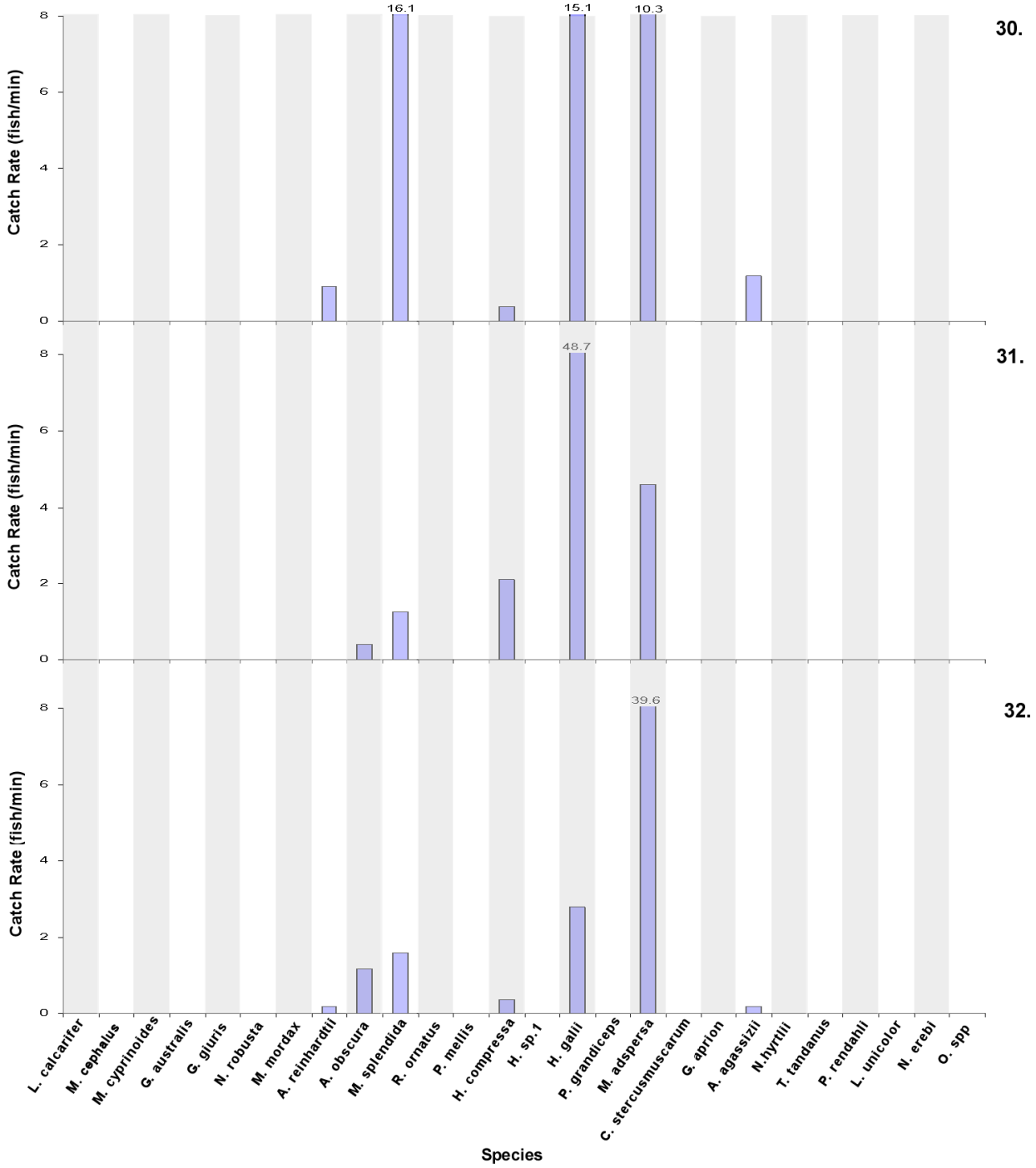


Figure 50. Fish species abundance (catch rate - fish/min) of all fish species recorded at 'Quads' an upper tributary of Tea Tree Creek (30), 'Rehab Road', upper tributary of Tea Tree Creek (31) and 'Blue Route Crossing, an upper tributary of Tea Tree Creek (32).

Upper Tea Tree Creek - Seahound Hard Road (33)

Sampling upper Tea Tree Creek yielded 325 individuals comprising 4 species at a catch rate of 65 fish/min. *Mogurnda adspersa* was the most abundant species representing 64.6% of the total catch at a rate of 42 fish/min (Figure 53 - (33)). *Hypseleotris galii,* Melanotaenia *splendida* and *Anguilla reinhardtii* were the next most abundant species contributing 21.8%, 13.2% and 0.3% respectively.

Lower Tea Tree Creek - SWBTA Boundary Fence (34)

A total of 77 individuals comprising 6 species at a catch rate of 7.7 fish/min were recorded from lower Tea Tree Creek (Figure 51). *Hypseleotris compressa* was the most abundant species representing 40.3% of the total catch at a rate of 3.1 fish/min (Figure 53 - (34)). *Hypseleotris galii* and *Mogurnda adspersa* were the next most abundant species contributing 22.1% and 20.8% respectively. The remaining 16.8% consisted of *Melanotaenia splendida*, *Rhadinocentrus ornatus* and *Anguilla obscura* contributing 9.1%, 5.2% and 2.6% respectively.

Tea Tree Creek Off-stream Lagoon - Airstrip (35)

Sampling at the 'Airstrip' off-stream lagoon (Figure 52) on Tea Tree Creek, yielded 35 individuals comprising 6 species at a catch rate of 3.5 fish/min. *Hypseleotris galii* was the most abundant species representing 45.7% of the total catch at a rate of 1.6 fish/min (Figure 53 - (35)). *Mogurnda adspersa* and Melanotaenia *splendida* were the next most abundant species contributing 17.1% and 17.1% respectively. The remaining 20.1% consisted of *Hypseleotris compressa, Ambassis agassizii* and *Anguilla obscura* contributing 8.6%, 8.6% and 2.9% respectively

Figures 51 & 52 Lower Tea Tree Creek habitat (top), Tea Tree Creek off-stream lagoon (bottom).

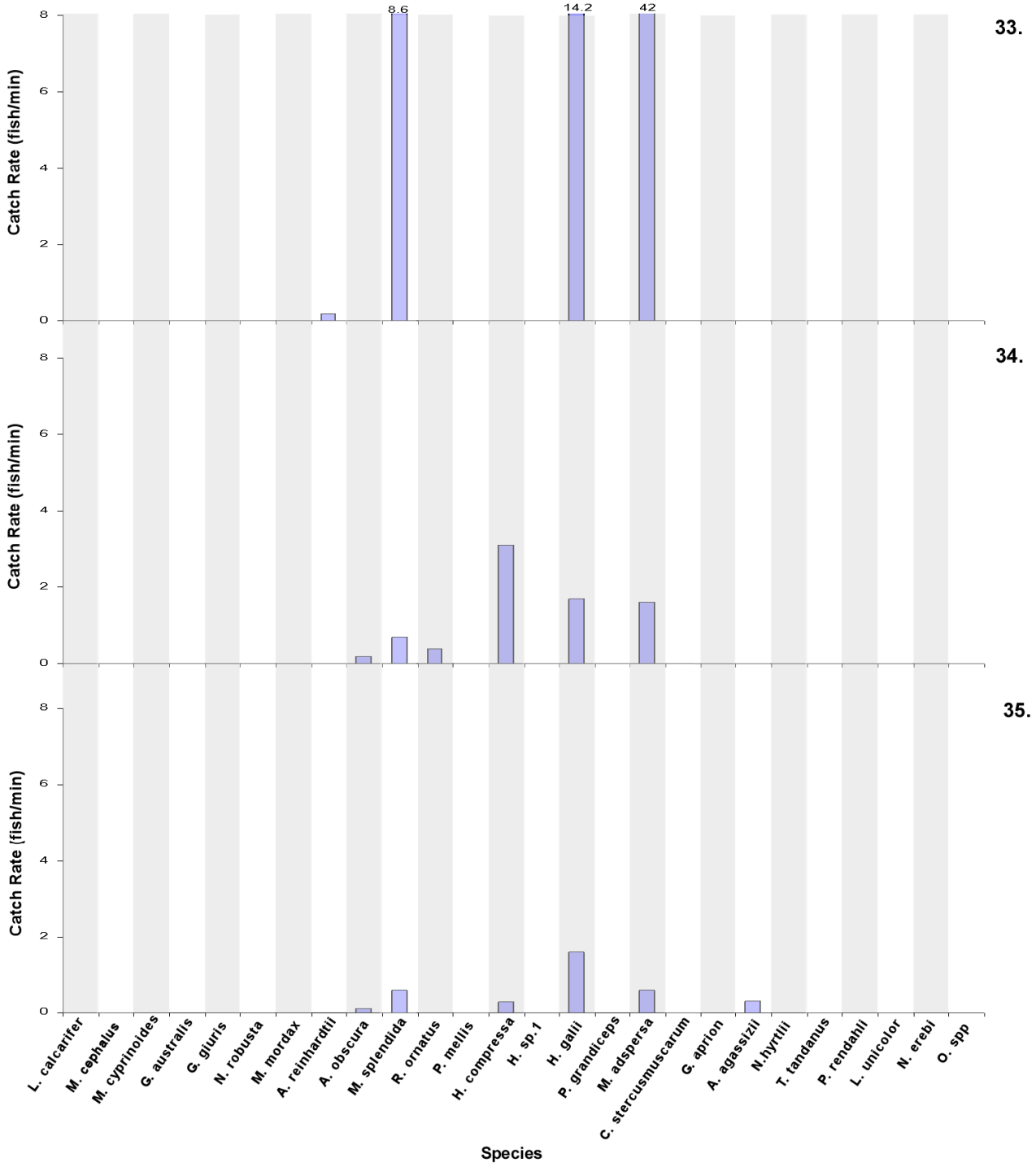


Figure 53. Fish species abundance (catch rate - fish/min) of all fish species recorded Upper Tea Tree Creek 'Seahound Hard Road' (33), Lower Tea Tree Creek 'SWBTA Boundary Fence (34) and Tea Tree Creek 'Off-stream Lagoon' (35).

Tea Tree Creek Off-stream Quarry Pit - Quarry (36)

A total of 42 individuals comprising 2 species at a catch rate of 8.4 fish/min were recorded from the 'Quarry', an off-stream quarry pit (Figure 54) draining into Tea Tree Creek. *Mogurnda adspersa* was the most abundant species representing 78.6% of the total catch at a rate of 6.6 fish/min, followed by *Hypseleotris galii* (Figure 55) with 21.4% at a rate of 1.8 fish/min (Figure 56 - (36)).

Tea Tree Creek Off-stream Dam - Sentry Post (37)

Sampling at the 'Sentry Post' an off-stream dam draining into Tea Tree Creek, yielded 420 individuals comprising 2 species at a catch rate of 100.96 fish/min. *Mogurnda adspersa* was the most abundant species representing 99.3% of the total catch at a rate of 100.24 fish/min (Figure 56 - (37)). While 3 individual *Anguilla obscura* at a catch rate of 0.7 fish/min were also recorded.

Valentine Creek

Upper Valentine Creek (38)

Sampling at upper Valentine Creek yielded 53 individuals comprising 8 species at a catch rate of 13.38 fish/min. *Mogurnda adspersa* was the most abundant species representing 37.7% of the total catch at a rate of 5.05 fish/min (Figure 56 - (38)). Melanotaenia *splendida* and *Hypseleotris galii* were the next most abundant species contributing 26.4% and 17% respectively. The remaining 18.9% consisted of *Rhadinocentrus ornatus, Hypseleotris compressa, Anguilla obscura, Anguilla reinhardtii* and *Glossamia aprion* contributing 7.5%, 5.7%, 1.9%, 1.9% and 1.9% respectively.

Figures 54 & 55. Tea Tree Creek 'Off-stream Quarry' (top), home of this male firetail gudgeon (bottom).

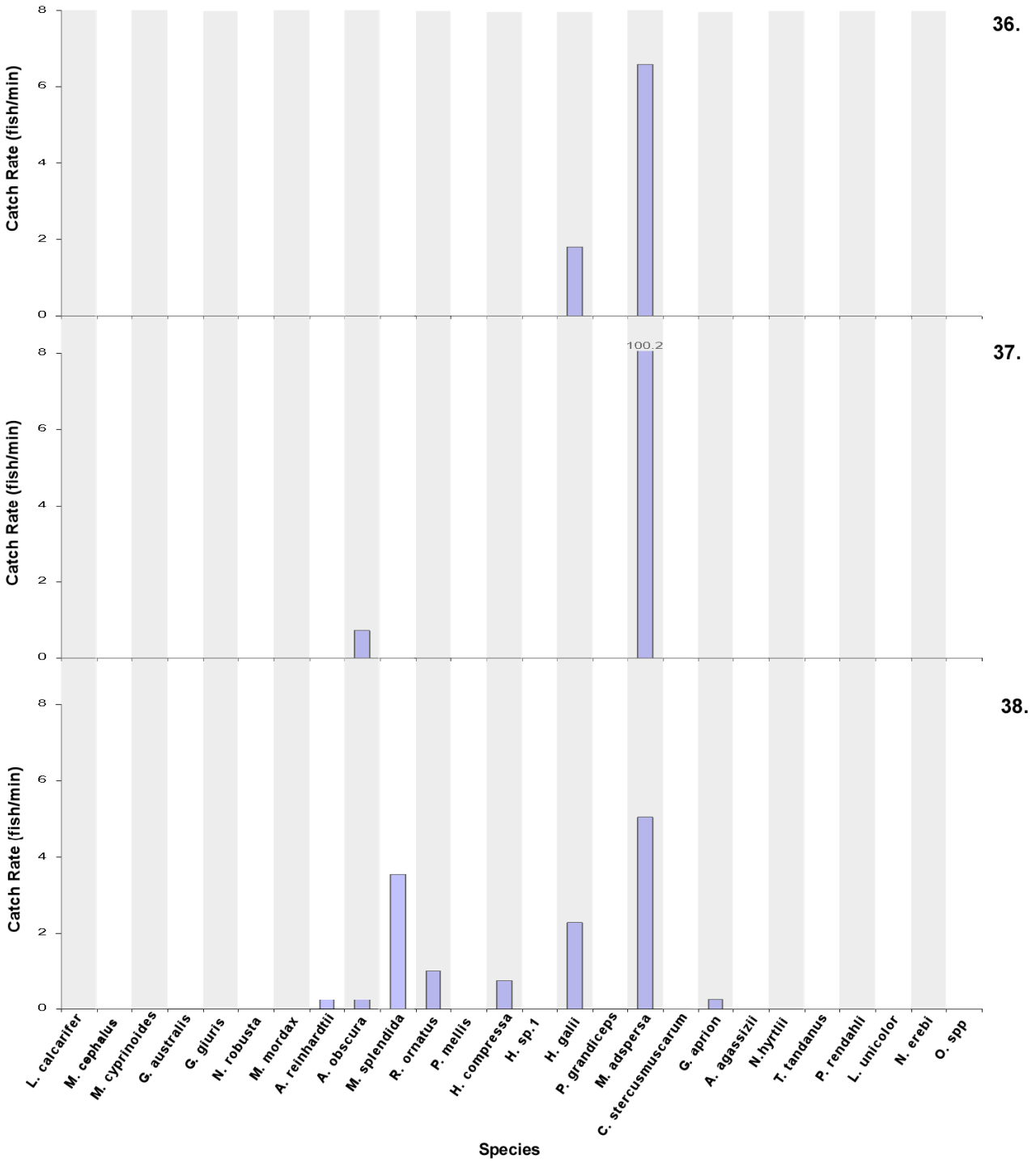


Figure 56 Fish species abundance (catch rate - fish/min) of all fish species recorded at Tea Tree Creek 'Off stream Quarry Pit' (36), 'Off stream Dam Sentry Post' (37) and Valentine Creek sites (38).

Dismal Swamp Complex

North Dismal Swamp (SWBTA)

North Mellis Closed Swamp (39)

Sampling at north Mellis Swamp yielded 110 individuals comprising 3 species at a catch rate of 26.4 fish/min. *Rhadinocentrus ornatus* was the most abundant species representing 96.4% of the total catch at a rate of 25.48 fish/min (Figure 59 - (39)). *Hypseleotris compressa and Pseudomugil mellis* were the next most abundant species contributing 2.7% and 0.9% respectively.

South Mellis Open Water Swamp (40)

A total of 170 individuals comprising 7 species at a catch rate of 11.33 fish/min were recorded from south Mellis Swamp (Figure 57) in the Dismal Swamp complex. *Rhadinocentrus ornatus* was the most abundant species representing 79.4% of the total catch at a rate of 9.0 fish/min (Figure 59 - 40). *Hypseleotris compressa and Pseudomugil mellis* (Figure (58)) were the next most abundant species contributing 8.2% and 7.1% respectively. The remaining 5.3% consisted of *Mogurnda adspersa, Hypseleotris galii, Ophisternon spp. and Anguilla reinhardtii* representing 2.4%, 1.8%, 0.6% and 0.6% respectively.

Perched Dune Lake (41)

No fish species were recorded from the Perched Dune Lake. There was a no open water habitat, and only a minimal amount of water at the base of reeds. It appears the dune lake dries out quite often.

Figures 57 & 58. Open water habitat of Central Dismal's South Mellis Swamp (top), critical habitat for the endangered honey blue-eye (Pseudomugil mellis) (bottom).

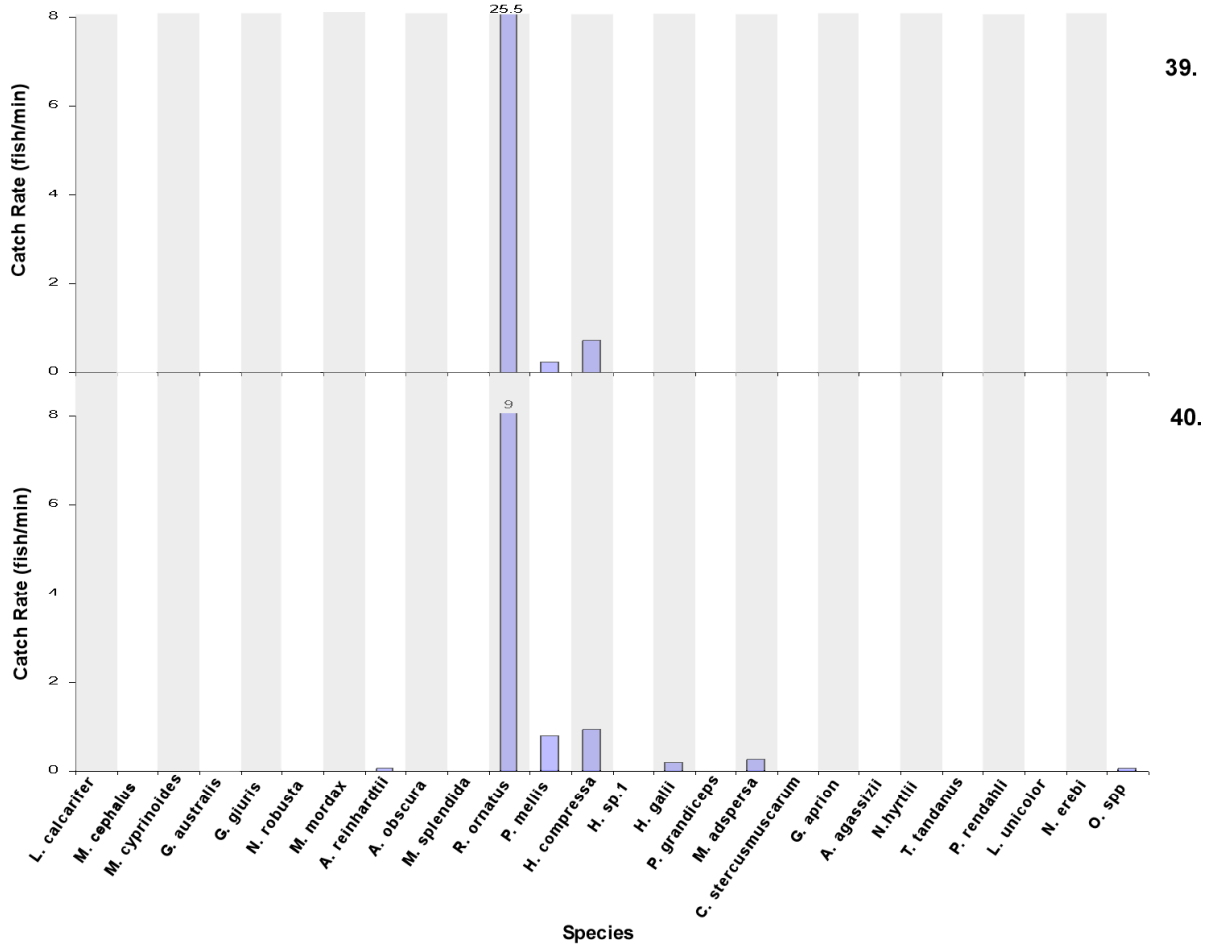


Figure 59. Fish species abundance (catch rate - fish/min) of all fish species recorded at North Dismal Swamp's 'North Mellis Closed Swamp' (39) and 'South Mellis Open Water Swamp' (40).

Figure 60. Sampling the closed water habitat in North Dismal Swamp (39)

South Dismal Swamp (Byfield)

National Park Watering Point Swamp (42)

A total of 25 individuals comprising 3 species at a catch rate of 4.62 fish/min were recorded from the National Park Watering Point (Figure 64) in South Dismal Swamp. *Rhadinocentrus ornatus* was the most abundant species representing 80% of the total catch at a rate of 3.70 fish/min (Figure 63 - (42)). *Mogurnda adspersa* and *Hypseleotris compressa* were the next most abundant species contributing 16% and 4% respectively.

Reed Swamp (43)

Sampling at Reed Swamp (Figure 61) yielded 113 individuals comprising 3 species at a catch rate of 22.6 fish/min. *Rhadinocentrus ornatus* (Figure 62) was the most abundant species representing 77% of the total catch at a rate of 17.4 fish/min (Figure 63 - (43)). *Hypseleotris compressa* and *Hypseleotris galii* were the next most abundant species contributing 22.1% and 0.9% respectively.

Figures 61 & 62. South Dismal Swamp's 'Reed Swamp' (43) (top) and ornate rainbowfish (*Rhadinocentrus ornatus)* sampled from 'Reed Swamp' (bottom).

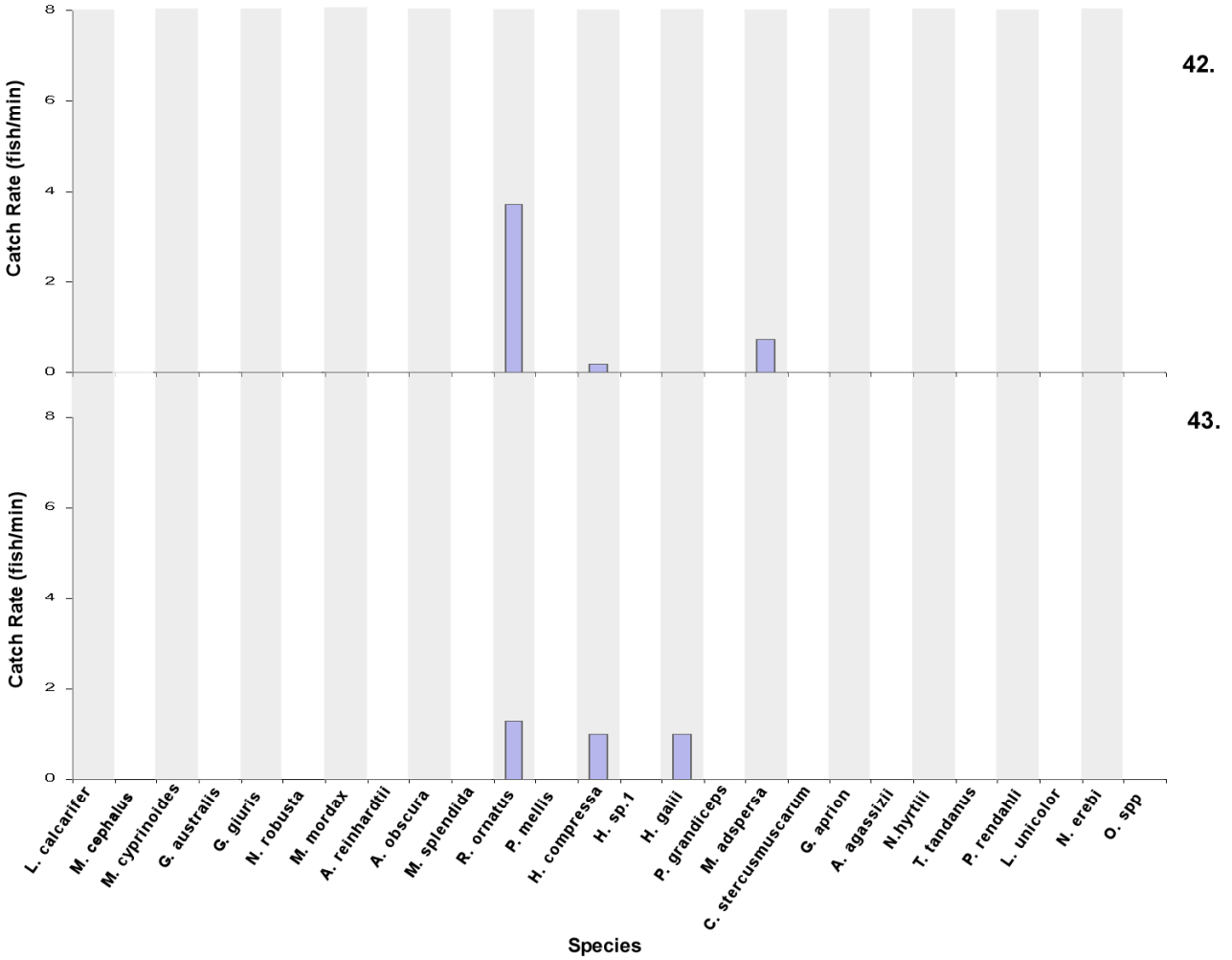


Figure 63. Fish species abundance (catch rate - fish/min) of all fish species recorded at South Dismal Swamp's 'National Park Watering Point Swamp' (42) and 'Reed Swamp' (43).

Figure 64 Typical habitat of South Dismal Swamp's 'National Park Watering Point Swamp' (42).

Iwasaki Wetlands

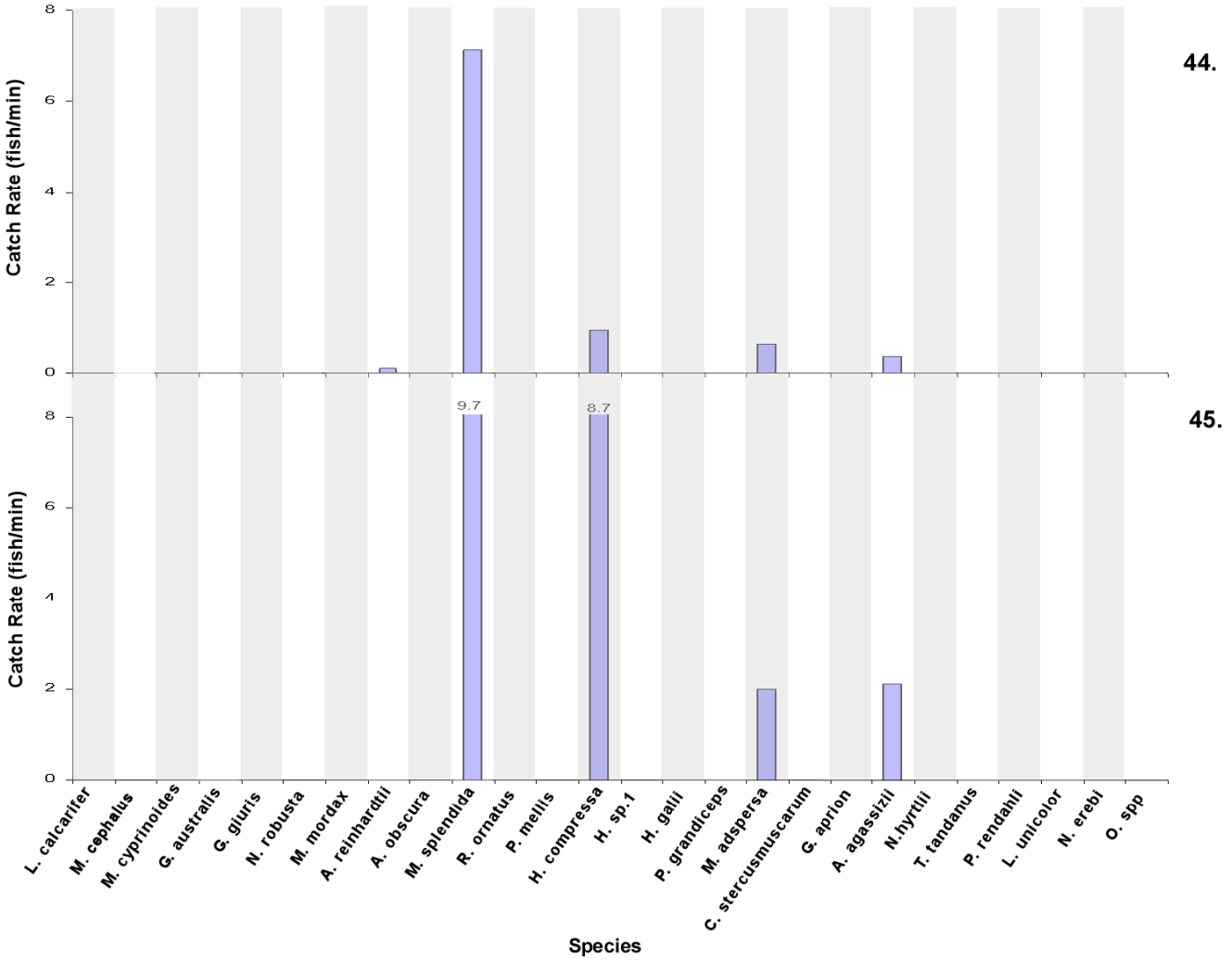
North Iwasaki Wetland (44)

Sampling at north Iwaski wetland yielded 368 individuals comprising 5 species at a catch rate of 9.2 fish/min. *Melanotaenia splendida* was the most abundant species representing 77.4% of the total catch at a rate of 7.1 fish/min (Figure 40). *Hypseleotris compressa* was the next most abundant species contributing 10.3% at a catch rate of 1 fish/min. The remaining 12.3% consisted of *Mogurnda adspersa, Ambassis agassizii* and *Anguilla reinhardtii* contributing 7.1%, 4.1% and 1.1% respectively (Figure 67 - (44)).

South Iwasaki Wetland (45)

A total of 341 individuals comprising 4 species at a catch rate of 22.7 fish/min were recorded from south Iwaski wetland. *Melanotaenia splendida* was the most abundant species representing 42.8% of the total catch at a rate of 9.7 fish/min (Figure 65). *Hypseleotris compressa* (Figure 66) was the next most abundant species contributing 39% at a catch rate of 8.87 fish/min. The remaining 18.2% consisted of *Ambassis agassizii and Mogurnda adspersa,* contributing 9.4% and 8.8% respectively (Figure 67 - (45)).

Figures 65 & 66. Bund wall at south Iwasaki wetland which has created a barrier to fish passage (top), and thousands of stranded adult empire gudgeon (bottom) that are unable to negotiate the bund wall barrier at north Iwasaki wetland.



Figures 67. Fish species abundance (catch rate - fish/min) of all fish species recorded at North Iwasaki Wetland (44) and South Iwasaki Wetland (45).

Figure 68. Typical wetland habitat of north Iwasaki wetland.

Byfield Farm Dams

Bloodwood Road - Marcus Farm Dam (46)

Sampling at Bloodwood Road farm dam (Figure 69) yielded 84 individuals comprising 3 species at a catch rate of 4.2 fish/min. *Hypseleotris galii* was the most abundant species representing 88.1% of the total catch at a rate of 3.7 fish/min (Figure 70 - (46)). *Mogurnda adspersa* was the next most abundant species contributing 10.7% at a catch rate of 0.45 fish/min. The remaining 1.2% consisted of a single *Anguilla reinhardtii.*

Ferns Hideaway (47)

A total of 72 individuals comprising 6 species at a catch rate of 14.4 fish/min were recorded from Ferns Hideaway farm dam. *Hypseleotris galii* was the most abundant species representing 55.6% of the total catch at a rate of 8 fish/min (Figure 70 - (47)). *Hypseleotris compressa* was the next most abundant species contributing 31.9% at a catch rate of 4.6 fish/min. The remaining 12.5% consisted of *Mogurnda adspersa, Melanotaenia splendida, Ophisternon spp.* and contributing 6.95, 2.8%, 1.4% and 1.4% respectively.

Nob Creek Pottery Neighbours Dam (48)

Sampling at the farm dam at site 48 yielded 104 individuals comprising 2 species at a catch rate of 10.4 fish/min. *Leiopotherapon unicolor was* the most abundant species representing 99% of the total catch at a rate of 103 fish/min (Figure 70 - (48)). *Mogurnda adspersa* was the next most abundant species contributing a single specimen.

Nob Creek Pottery Top Dam (49)

No fish were recorded from Nob Creek Pottery top dam.

Figure 69. Bloodwood Road farm dam.

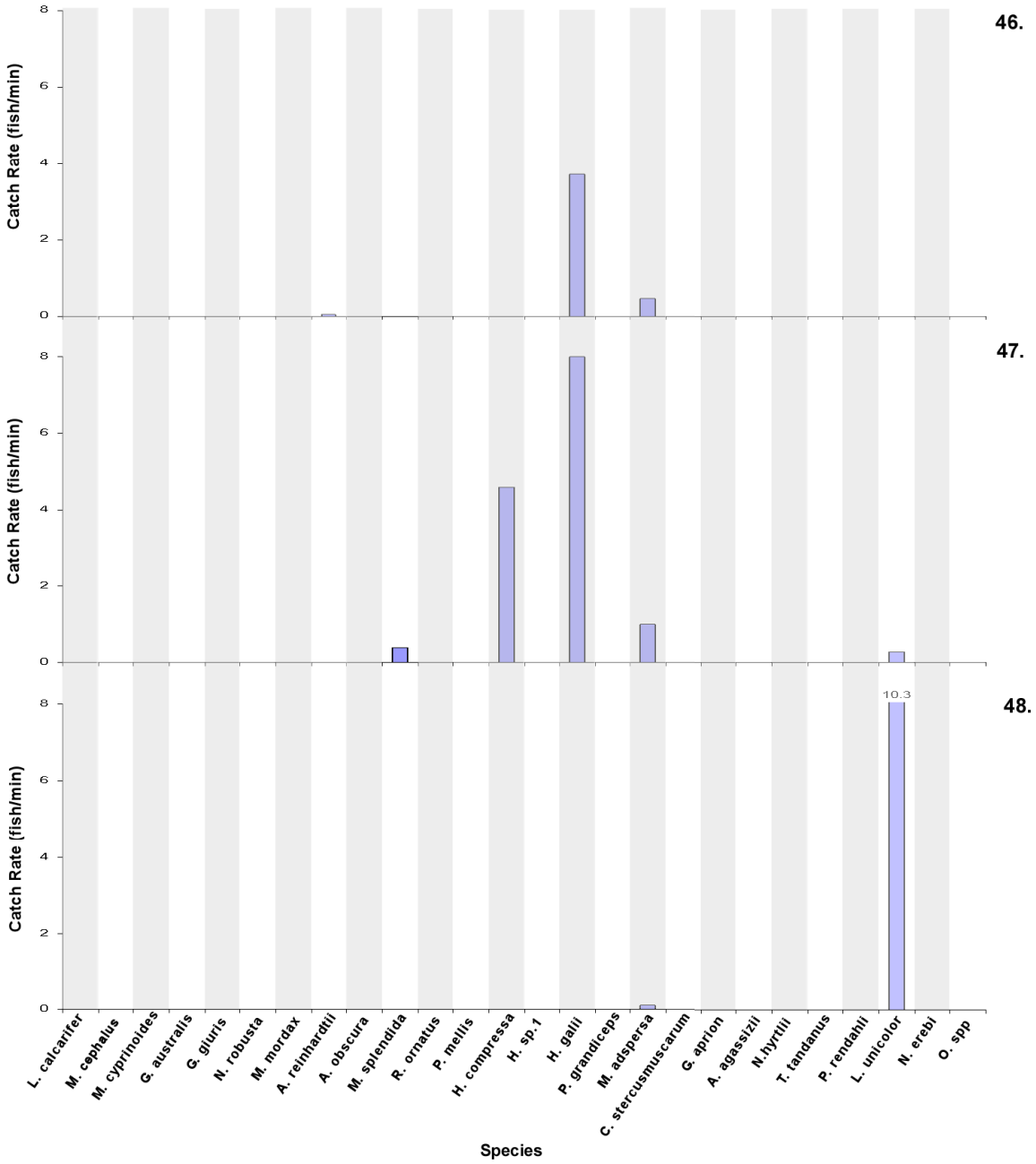


Figure 70. Fish species abundance (catch rate - fish/min) of all fish species recorded at Bloodwood Road farm dam (46), Ferns Hideaway farm dam (47) and Nob Creek Pottery neighbours farm dam (48).

Rainforest Ranch (50)

Sampling at Rainforest Ranch farm dam yielded 43 individuals comprising 3 species at a catch rate of 8.6 fish/min. *Leiopotherapon unicolor* was the most abundant species representing 58.1% of the total catch at a rate of 5 fish/min (Figure 71 - (50)). *Melanotaenia splendida* and *Mogurnda adspersa* were the next most abundant species contributing 23.3% and 18.6% respectively.

Waterpark Creek Cabins (51)

A total of 1037 individuals comprising 3 species at a catch rate of 103.7 fish/min was recorded from Waterpark Creek cabins. *Melanotaenia splendida* was the most abundant species representing 96.5% of the total catch at a rate of 100.1 fish/min (Figure 71 - (51)). *Hypseleotris galii* and *Lates calcarifer* were the next most abundant species contributing 2.2% and 1.3% respectively.

Broughton's Road Farm Dam (52)

Sampling at the Broughton's Road farm dam yielded 305 individuals comprising 5 species at a catch rate of 30.5 fish/min. *Hypseleotris galii* was the most abundant species representing 59.7% of the total catch at a rate of 18.1 fish/min (Figure 71 - (52)). *Mogurnda adspersa* was the next most abundant species contributing a 32.7% of the total catch at a rate of 9.9 fish/min. The remaining catch consisted of *Melanotaenia splendida, Hypseleotris compressa* and *Anguilla reinhardtii* contributing 2%, 0.7% and *0.1%* respectively.

Figure 71. Aerial view of the Ramsar listed wetlands of Corio Bay. All farm dams located in Byfield in the Waterpark Creek catchment flow into Corio Bay.

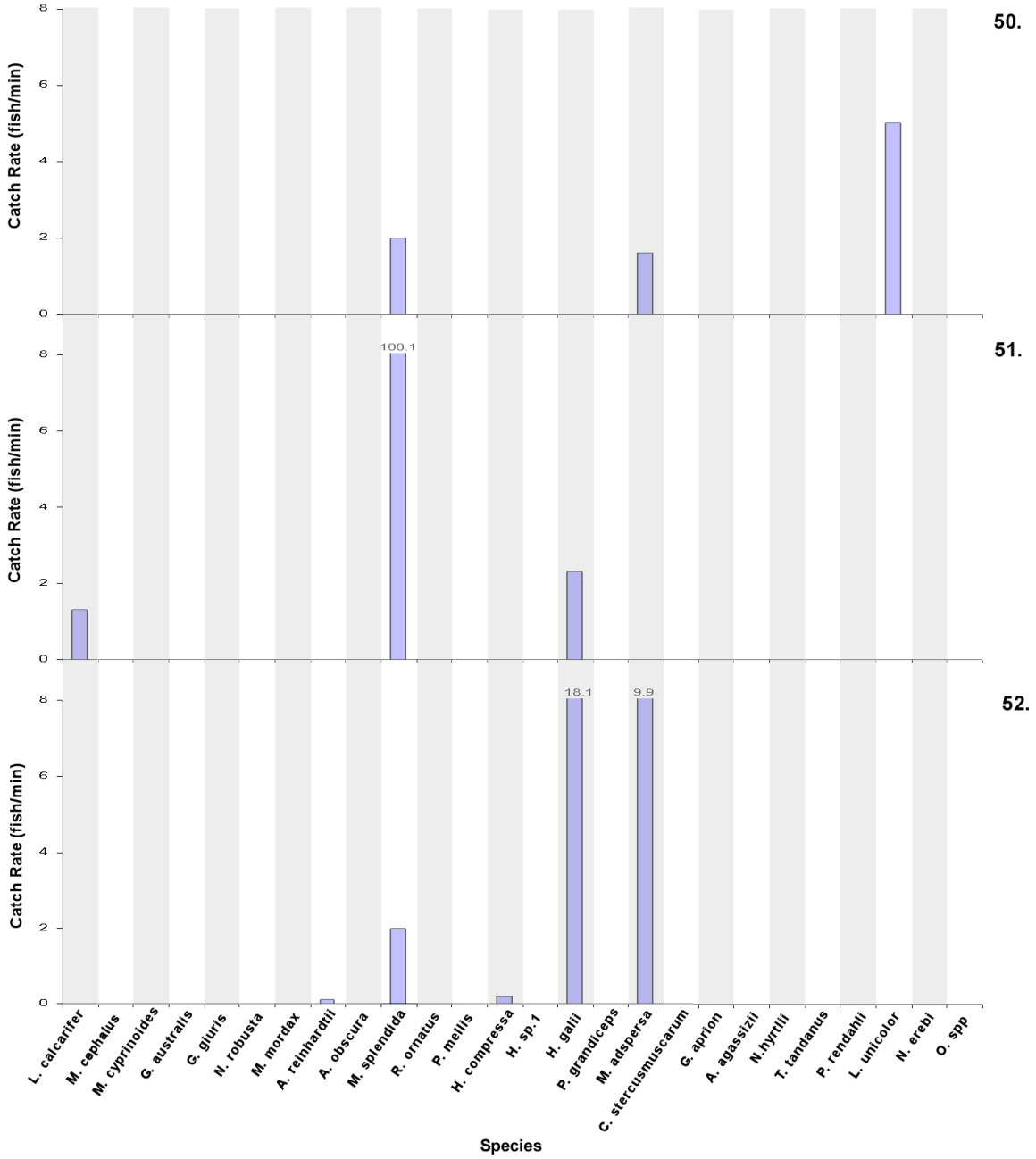


Figure 72. Fish species abundance (catch rate - fish/min) of all fish species recorded at Rainforest Ranch (50), Waterpark Creek Cabins (51) and Broughton's Road farm dam (52).

Fitzroy Drainage Basin

Werribee Creek

Upper Werribee Creek (53)

Sampling at upper Werribee Creek yielded 134 individuals comprising 2 species at a catch rate of 26.80 fish/min. *Mogurnda adspersa* was the most abundant species representing 91.8% of the total catch at a rate of 24.60 fish/min (Figure 74 - (53)). Melanotaenia *splendida* were the next most abundant species contributing 8.2% at a catch rate of 2.2 fish/min.

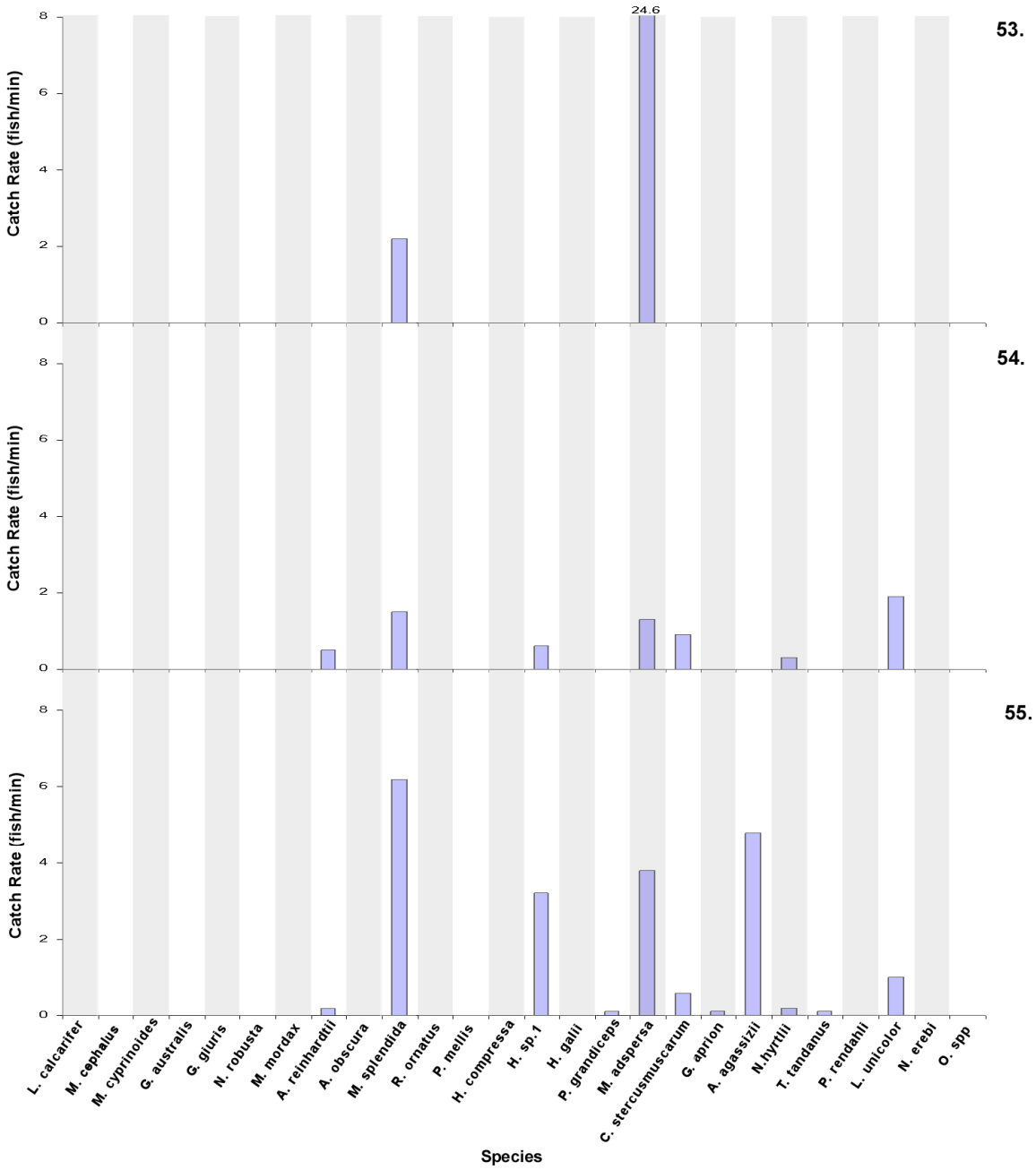
Middle Werribee Creek - Watering Point (54)

A total of 70 individuals comprising 7 species at a catch rate of 7 fish/min were recorded from middle Werribee Creek. *Leiopotherapon unicolor* was the most abundant species representing 27.1% of the total catch at a rate of 1.9 fish/min (Figure 74 - (54)). *Melanotaenia splendida* and *Mogurnda adspersa* were the next most abundant species contributing 21.4% and 18.6% respectively. The remaining 32.9% consisted of *Craterocephalus stercusmuscarum, Hypseleotris sp.1, Anguilla reinhardtii* and *Neosilurus hyrtlii* contributing 12.9%, 8.6%, 7.1% and 4.3% respectively.

Lower Werribee Creek - SWBTA Boundary (55)

Sampling at lower Werribee Creek yielded 203 individuals comprising 11 species at a catch rate of 20.30 fish/min. Melanotaenia *splendida* was the most abundant species representing 30.5% of the total catch at a rate of 6.2 fish/min (Figure 74 - (55)). *Ambassis agassizii* and *Mogurnda adspersa* were the next most abundant species contributing 23.6% and 18.7% respectively. The remaining 27.2% consisted of *Hypseleotris sp.1, Leiopotherapon unicolor, Craterocephalus stercusmuscarum, Anguilla reinhardtii, Neosilurus hyrtlii, Tandanus tandanus, Philypnodon grandiceps* (Figure 73) and *Glossamia aprion* contributing 15.8%, 4.9%, 3%, 1%, 1%, 0.5%, 0.5% and 0.5% respectively.

Figure 73. Flathead gudgeon (*Philypnodon grandiceps)* recorded from lower Werribee Creek.



Figures 74. Fish species abundance (catch rate - fish/min) of all fish species recorded at upper (53), middle (54) and lower (55) Werribee Creek sites.

Figure 75. Midgley's carp gudgeon (*Hypseleotris sp.1*) from lower Werribee Creek.

Discussion

The findings of the current study have provided a greater understanding of SCB's aquatic habitats and associated fish communities. It was found that aquatic eco-systems are in excellent condition, with large areas of un-disturbed habitats displaying diverse and healthy fish communities, many of which remain unchanged from their natural state. Significantly, no pest fish were recorded at any sites within the Ramsar listed wetlands or adjacent waterbodies within the SCB. The absence of pest fish over such a large biogeographic area encompassing many unique and varied habitats is significant on a national scale.

The SCB region boasts a high diversity of fish fauna with 26 recorded species, including an isolated population of endangered honey blue-eye (*Pseudomugil mellis*). The high diversity of fish species is largely due to SCB's geographic position in a climatic overlap zone, which has resulted in the mixing of tropical and subtropical fauna and flora species. The high diversity of fish species can also be attributed to the complexity of aquatic habitats found to occur in the region. These include; perched dune lakes, palustrine and lacustrine wetland habitats, groundwater fed perennial sandy substrate streams and ephemeral rocky and clay substrate streams.

Perennial freshwater reserves draining out of the large parabolic dunes in the eastern section of SWBTA have contributed the regions unique fish communities and diverse aquatic habitats. This large parabolic dune and beach ridge system acts as a reservoir collecting rainfall before discharging it from springs and sinkholes within and on the perimeter of the sandmass. This provides a year round supply of freshwater into Dismal Swamp, creating a series of diverse aquatic habitats. These reserves also sustain base flow into Cowan, Solitude, Sandy and Waterpark Creeks, creating conditions suitable for a wide range of unique fish fauna.

Four fish species recorded in SCB exhibit their northern most range distribution; honey blue-eye (*Pseudomugil mellis*), ornate rainbowfish (*Rhadinocentrus ornatus),* firetail gudgeon *(Hypseleotris galii)* and short-headed lamprey *(Mordacia mordax).* Most notable of these four species is the occurrence of a small isolated population of endangered honey blue-eye (*Pseudomugil mellis).* This species occurs across a restricted and fragmented range in coastal lowland wallum swamps of central and south-east Queensland (Pusey *et al.,* 2004). The isolated population occurring in Dismal Swamp is approximately 400 km north of the next nearest population in Tin Can Bay. South-east Queensland populations of *P.mellis* are currently threatened by habitat fragmentation, urban encroachment, sedimentation, pollution, eutrophication and exotic pest fish (Pusey *et al.,* 2004). Fortunately the population of *P.mellis* in Dismal Swamp occurs within the eastern sector of SWBTA, protecting it from many of these key anthropogenic threats.

Prior to the commencement of this survey the current status of this endangered species in Dismal Swamp was unknown. A previous survey undertaken by the Australian Museum 20 years ago collected a single individual, and since then no surveys have taken place. The real and potentially immanent threat was that pest fish species mosquitofish (*Gambusia holbrooki*) may have infiltrated the critical wallum swamp habitats preferred by honey blue-eye, to the detriment of the population. However, the current survey established that the honey blue-eye population in Dismal Swamp is viable and healthy, with no indication of pest fish or any other serious anthropogenic threats. This is largely due to the sound management practices employed by Defence's environmental officers who have declared Dismal Swamp off limits to any adverse military exercises. The detrimental feeding habits of feral pigs remain the only potential threat to Dismal Swamp's critical aquatic habitats. Defence is well aware of this potential threat and currently address this on a yearly basis through systematic baiting exercises.

The perennial sandy substrate stream habitats of Sandy and Waterpark Creeks provide excellent habitat for the highly cryptic short-headed lamprey (*Mordacia mordax).* Allen *et al.,* 2004 suggests *M. mordax* is an anadromous species that migrates upstream from estuarine and near shore

marine environments as adults to spawn in freshwaters. The newly hatched ammocoetes take refuge in slow moving sandy substrate stream reaches before metamorphosing after 3-4 years and migrating downstream as young adults, becoming parasitic on other fishes (Allen *et al.*, 2002). The occurrence of *M. Mordax* in the tropical waters of Shoalwater Bay is unusual, and is the only record of this species occurring in the tropics anywhere in the world. The next nearest population of *M. mordax* occurs in the Noosa River, 500 kms to the south, and the next nearest population after Noosa is located in the Hawkesbury River a further 1,100 kms away (D Moffat 2010, pers. comm.).

The restricted ornate rainbowfish (*Rhadinocentrus ornatus*) is another species exhibiting its northern most range distribution in Shoalwater Bay. *R. ornatus* was found to prefer the oligotrophic groundwater fed sandy substrate heath habitats. These preferred habitat types generally occur on the coast, and as such are heavily impacted by anthropogenic activities. This has led to population declines in Southern Queensland and the placement of R*. ornatus* on the restricted species list. Fortunately, the isolated populations of *R. ornatus* in the greater Shoalwater Bay region are extremely healthy, and are often the most abundant species recorded in their preferred habitat types.

The remoteness and relatively undisturbed aquatic habitats found in this unique wilderness area have assisted in preventing invasive pest fish from establishing self-sustaining populations. The areas complex habitat types also support a high diversity of fish fauna. A large portion of the SCB Ramsar wetlands are located in SWBTA, and as such, experience minimal anthropogenic impacts. Defence rigorously controls access into SWBTA, imposing strict environmental standards to army personnel, contractors and other users wishing to enter. An environmental team undertakes a suite of duties aimed at protecting the environmental assets of the training area, including vegetation management, feral animal management, weed control and environmental monitoring. These management measures in-conjunction with the total protection of critical aquatic habitats such as Dismal Swamp, have largely contributed to the undisturbed nature of SWBTA's aquatic habitats, which in-turn have facilitated diverse and abundant fish communities.

Queensland Parks and Wildlife Service (QPWS) also manage a large area of the SCB Ramsar wetlands (Byfield National Park), and through the implementation of environmental management plans have greatly minimised anthropogenic impacts on the areas aquatic habitats and contributed to the pest free status of its waterbodies. Private land manager Iwasaki Sangyo Co Pty. Ltd. are the owner managers of the nationally significant Iwasaki wetland complex. A bund wall constructed at the base of the Iwasaki wetlands forms the boundary with the Ramsar listed wetlands of Shoalwater and Corio Bay (Figure 1). Iwasaki Sangyo Co Pty. Ltd. strictly control the access of visitors into the wetlands, and in-conjunction with its semi-isolated location has helped contribute to its pest fish free status.

Human settlement in SCB is limited, with the small peri-urban town of Byfield having the most residents. Generally, residents that live in and around Byfield are very environmentally conscious. Residents we spoke with understood the risks associated with stocking translocated species and introducing pest fish. Aquatic invasive sampling in dams and creeks around the town of Byfield identified healthy fish communities with no signs of pest fish species. However, as pest fish incursions are strongly correlated with human settlement, this is one area (lower Waterpark Creek) that should be surveyed regularly.

Fish communities of the Broadsound/Shoalwater Bay, GBRMP and Waterpark Creek catchments were found to be diverse and relatively abundant. All predicted species that should occur in the region were recorded. Excellent fish community and good in-stream habitat can be attributed to minimal anthropogenic activities and sound environmental management that has occurred in the region over the past 50 years. Both Defence and QP&WS have led the way as environmental custodians of SWBTA and Byfield NP respectively, employing best management practices to protect and conserve the regions unique and diverse flora and fauna species. The formation of

SWBTA and Byfield NP has effectively prevented the destructive land use practices associated with urban development that has detrimentally affected many other important coastal habitats along the east-coast of Australia.

In-stream and riparian habitats in SWBTA were found to be in good to excellent condition, with many sites such as those in Dismal Swamp and the headwaters of Waterpark Creek in pristine condition. Both these habitats are used as benchmark areas for scientific research. Minimal impacts that were identified were caused by the feeding habits of feral pigs, which have resulted in bank destabilisation and provided conditions suitable for the proliferation of noxious weeds. These impacts were rare, with only a small section of Solitude Creek adversely affected. The only other anthropogenic impacts in the Area included a significant barrier to fish migration located on Mt Hummock Creek on the East West Road.

The habitats and fish communities of the Iwasaki wetlands were found to be in poor to average condition. The fish communities comprised less than a third of the expected species that generally occur in lowland wetland habitats in the tropics. The lack of diadromous species in north Iwasaki wetland (4 long-fin eel) and total absence in south Iwasaki wetland is concerning. The depleted diversity and abundance of diadromous fish species in both wetlands can be attributed to the man-made bund walls that have been constructed to form the wetlands and prevent salt water intrusion. The bund walls form a 0.6 m high barrier to fish passage, preventing connectivity between the estuarine habitats downstream and the wetland habitats upstream. The bund walls create a water surface drop and velocity barrier that all but long-fin eel (*Anguilla reinhardtii*) appear to be able to negotiate in any great numbers.

While undertaking aquatic surveys at the Iwasaki wetlands, eastern rainbowfish *(Melanotaenia splendida*), red scat (*Scatophagus argus*) and tens of thousands of adult empire gudgeon (*Hypseleotris compress*) were observed downstream of the bund walls attempting to migrate upstream (Figure 66). Many of the fish that were observed had already died, either by exhaustion or by receding downstream water levels leaving them stranded. To prevent this from occurring in the future and to enable the upstream migration of diadromous and potamodromous fish species to reach important nursery habitats and feeding areas, the wetlands each require the construction of one rock-ramp fishway.

Conclusion

The findings of the current study found no invasive pest fish in the Ramsar wetlands of SCB, Iwasaki wetlands or adjacent waterways. The absence of pest fish over such a large wilderness area are significant on a national scale. These exceptional findings can largely be attributed to the formation of SWBTA and Byfield NP which contain and protect all Ramsar listed freshwater wetlands. Environmental land managers of SWBTA and Byfield NP have enforced strict access restrictions in-conjunction with the sensible implementation of environmental management plans to protect and enhance this unique wilderness area. It appears from this study, that the management plans and access restrictions enforced by these organisations have contributed to the areas pest fish free status.

The study found that fish assemblages of SCB are unique and diverse. Significantly, the isolated population of endangered honey blue-eye (*Pseudomugil mellis)* in Dismal Swamp was found to be viable and healthy, with no indications of pest fish or any other serious anthropogenic impacts currently threatening their existence. The presence of four fish species exhibiting their northern range distribution: ornate rainbowfish (*Rhadinocentrus ornatus),* firetail gudgeon *(Hypseleotris galii),* honey blue-eye *(Pseudomugil mellis*) and short-headed lamprey *(Mordacia mordax)* indicates the Shoalwater and Corio Bay region is an important refuge area that deserves continued protection from key anthropogenic threats. It was also found that fish communities of the region showed a strong affinity to particular habitat types. In-particular the oligotrophic perennial sandy substrate streams emanating out of the large parabolic sand dunes in the south eastern sections of SWBTA.

Fish communities of the Iwasaki wetlands were in poor condition. Both northern and southern wetlands were deficient of migratory (diadromous) fish species, a direct consequence of barriers to fish passage (bund walls) located on the wetland/estuarine interface. These barriers separate the upstream freshwater wetlands from the downstream marine Ramsar listed habitats. These barriers to fish passage prevent lateral fish migrations into important life-cycle dependant habitats for many diadromous fish species. The results showed that the wetlands comprised only one third of the expected fish species that occur in lowland wetlands in the region. Rock-ramp fishways are required to remediate these barriers and provide connectivity. Fishways will enable native fish species the opportunity to migrate into these important nursery habitats, increasing the resilience and biodiversity of the wetlands and enhancing the productivity of the regions fisheries resources.

In-stream and riparian habitats located in SWBTA and Byfield NP were found to be in excellent condition, with large areas of un-disturbed aquatic habitats. Waterways generally displayed diverse and healthy fish communities, many of which remain unchanged from their natural state. Shoalwater Bay's biological diversity, large size and unique un-disturbed habitats make this wilderness area a benchmark for scientific research. However, the introduction and spread of pest fish into Shoalwater Bay's aquatic habitats would be detrimental to the ecological sustainability of the regions freshwater fish communities, particularly the small isolated population of endangered honey blue-eye *(Pseudomugil mellis)*. The introduction of pest fish would also greatly diminish SCB's integrity and vicarious nature to the detriment of Australia's national heritage.

To successfully mitigate the threat of pest fish infiltrating aquatic habitats of SCB Ramsar wetlands, Iwasaki wetlands and adjacent waterways, it's recommended that the 'Shoalwater and Corio Bay Pest Fish Management Plan (2011)' is utilised and adhered too.

Recommendations

It needs to be recognised that the vicarious nature of SCB is extremely important to Australia's natural heritage. Large diverse and pristine wilderness areas like Shoalwater Bay are extremely rare on the east-coast of Australia and should therefore continue to be protected from key anthropogenic activities.

It is recommended that the following actions be undertaken to ensure the continued protection against possible invasive pest fish incursions:

1. Yearly on-going invasive aquatic surveys of ten representative sites inside and outside of the Ramsar listed wetlands:

    - Sites should be selected to cover representative habitats
    - Sites should be rotated so each site is sampled at least once every 3 years, allowing 30 sites to be visited over a 3 year period
    - Sites should focus on the most likely entry points that may facilitate access for pest fish into the Ramsar wetlands.

2. Triennial (every 3 years) invasive aquatic surveys of Dismal and Freshwater swamps (3 sites).

3. Implement and adhere to the 'Shoalwater and Corio Bay Pest Fish Management Plan (2011).

4. Maintain current access restrictions into SWBTA and Byfield NP.

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