



SURFACE WATER SCIENCE

The diets of native fish in NSW

Literature Review

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Cover image: Gunther Schmida - Murray Cod (*Maccullochella peelii*)

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Acknowledgment of Country

The Department of Planning and Environment acknowledges the Traditional Owners and Custodians of the land on which we live and work and pays respect to Elders past, present and future.

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Summary

Background

Freshwater fish consume a range of food resources including, but not limited to aquatic macroinvertebrates, organic detritus, benthic diatoms, filamentous algae, macrophytes, crustaceans, fish and terrestrial insects (Lintermans, 2009). Macroinvertebrates are considered a crucial trophic link between primary producers (e.g. algae) and higher order consumers (e.g. fish) and provide energy, proteins, lipids or fats and other essential micronutrients that are required for fish growth (Tran et al., 2015). Micronutrient composition varies among different taxonomic groups of insects and changes to their community composition could alter the nutritional landscape available to consumers (Dwyer et al., 2017). Identifying which insect taxa are consumed by specific fish species is an important step in predicting how changes in macroinvertebrate composition might influence native fish.

Most fish found within freshwater habitats of New South Wales (NSW) are considered opportunistic omnivores; they do not have a specialist diet (Balcombe et al., 2005). Omnivores can consume a wider range of foods, including insects, zooplankton, plants and algae. However, macroinvertebrates are still a major component of the diet of most omnivorous fish (Balcombe et al., 2005; Pusey et al., 2010). Fish with specialist diets, such as obligate insectivores, may be at greater risk from the impacts of drought and climate change compared to omnivorous fish, due to their ability to consume a greater range of material when other food sources are scarce (Chessman, 2013). Many iconic and important freshwater species are insectivores, including the Darling Hardy Head and Southern Pygmy Perch (Chessman, 2013). Improved understanding of which macroinvertebrate groups are most important within the diets of individual fish species could prove useful in the assessment of altered flow regimes and the protection of native fish populations (Rolls et al., 2012). Unfortunately, a lack of dietary data has been noted for some taxa, especially smaller species such as the galaxiids (Chessman, 2013; Moy et al., 2018).

Purpose of this review

The aim of this review is to investigate and summarise the important components of native fish diets in rivers and streams of NSW, Australia with an emphasis on macroinvertebrate taxa. This information will improve our understanding of the consequence of macroinvertebrate community changes on the food resources available for native fish within NSW.

An overview of the dietary composition of various fish diets are presented in Table 1 and 2 and a detailed breakdown of the macroinvertebrate taxa consumed by each fish species is presented in the Appendix (Table A1). This literature review focused on wild caught fish studies and where none were available included studies of captive reared, farmed and stocked dam studies. Laboratory studies were excluded due to the limited offering of prey species which would not reflect the range of prey choices available in natural rivers. Studies from New South Wales were preferred, however studies from the lower Murray Darling Basin (Victoria and SA), as well as studies from Queensland, Tasmania and New Zealand were included for fish species with limited information available (see Table 1).

Main findings

Most freshwater fish species include macroinvertebrates as a part of their diets (Table 1). Macroinvertebrates are not just consumed by insectivores but are also consumed by omnivorous fish species. The most preyed upon insect groups are the mayflies, beetles and weevils, true flies and caddisflies. Macroinvertebrates, especially Chironomid larvae, are important in the diets of the larval and juvenile stages of several freshwater fish species, including the iconic Murray Cod.

The mayflies (Ephemeroptera), beetles and weevils (Coleoptera), true flies (Diptera) and caddisflies (Trichoptera) are the most frequently consumed insects (Table 1 & 2). At least 24 fish species were found to include Chironomid larvae (Diptera) in their diets, making them the most widely consumed prey item eaten. Diptera were consumed by fish ranging from large bodied species (eg. Murray Cod) to very small species with restricted home ranges (eg. Mountain Galaxias) (Closs, 1994) (Table 2).

Many smaller fish species were insectivorous, feeding predominantly on macroinvertebrates (Table 1). These included the Cox's Gudgeon (Gregory et al., 2007), Australian Smelt (Rolls et al., 2012), Purple-spotted Gudgeon, Agassizii's Glassfish (Pusey et al., 2010) and Mountain Galaxias (Closs, 1994). These fish species include several insect orders in their diets including: Ephemeroptera, Diptera, Trichoptera, Coleoptera and also Odonata and Hemiptera.



Figure 1 Purple spotted Gudgeon (*Mogurnda adspersa*) feeds mostly on macroinvertebrates. (Image credit: Gunther Schmida)

Larger carnivore species such as Murray Cod are generally considered apex-predators, consuming mostly smaller fish and decapods (Ebner, 2006). However the larval life stage of the Murray Cod consumes mostly macroinvertebrates and zooplankton (Kaminskas and Humphries, 2009). Chironomid larvae (Diptera) are an important food source for young Murray Cod, as are cladocerans, cyclopoid copepods, mayflies and caddisflies (Kaminskas and Humphries, 2009) (Table 1 & Appendix).

Macroinvertebrates were also important in the diets of other large bodied omnivorous species such as the Silver Perch (Clunie and Koehn, 2001), Spangled Perch (Balcombe et al., 2005) and Macquarie Perch (Cadwallader and Douglas, 1986). The diet of these fish varied between species and studies, and included macroinvertebrates, terrestrial insects, decapods and algae (Table 1). There are limited studies of large omnivorous species, such as the Trout Cod, in natural environments and the contribution of macroinvertebrates to their diets has not been well recognized (Baumgartner, 2007).

What this means for water management

Native fish are critical components of freshwater ecosystems and hold special cultural, social and economic significance to the state of NSW. They have also been important drivers of significant legislative and policy changes. This was highlighted during the change to the Barwon-Darling Water Sharing Plan following the fish kills in 2018-19 (Vertessy et al., 2019). The Murray-Darling Basin Plan (MDBA, 2012) also targets specific outcomes for native fish, this includes both targeted environmental water delivery and also protection of planned environmental water within Water Sharing Plans.

To ensure native fish populations are protected requires a range of environmental parameters to be considered, including adequate food resources. This review highlights that macroinvertebrates are a crucial part of the diet for many freshwater fish. Therefore, water management decisions that support macroinvertebrate communities play an important role in supporting food resources for fish species in NSW. Specifically, preventing cease to flow conditions and protecting baseflows within flowing habitats such as riffles, runs and rivulets will help maintain macroinvertebrate diversity and abundance to ensure that a range of prey items are available to sustain native fish (Coleman and Brooks, 2020).

Results

Table 1. Summary of the diet of selected fish species (* = Insectivore)

| Fish species | Reference and Location | Diet |
|---|---|--|
| Marbled eel <i>Anguilla reinhardtii</i> | (Pusey et al., 2010) Burdekin River, QLD | Mostly macroinvertebrates (Ephemeroptera, Trichoptera, Diptera [Chironomidae, Simuliidae, Tipulidae], Odonata, Coleoptera, Oligochaeta). Shrimp, gastropods, fish, terrestrial invertebrates, terrestrial plants. |
| Bony Herring <i>Nematalosa erebi</i> | (Sternberg et al., 2008) Moonie River, QLD | Predominantly benthic algae, filamentous algae, detritus. |
| | (Balcombe et al., 2005) Cooper Creek, QLD | Detritus, algae, plants, zooplankton (Rotifera, Calanoida, Cladocera, Cyclopoida, Ostracoda), macroinvertebrates (Chironomidae and Coleoptera), terrestrial insects and Acarina. |
| | (Pusey et al., 2010) Burdekin River, QLD | Mostly detritus (including diatoms), macroinvertebrates (Chironomidae and Simuliidae), bivalves, filamentous algae and surface invertebrates (Mesovellidae and Gerridae). |
| Eel-Tailed freshwater catfish <i>Tandanus tandanus</i> | (Davis, 1977) Gwydir River, NSW | Decapods (<i>Macrobrachium australiense</i> and <i>Chevax neopunctatus</i>), fish (<i>Hypseleotris klunzingeri</i>), macroinvertebrates (mainly Diptera (Chironomidae, Simuliidae, Stratiomyidae), also: Ephemeroptera, Trichoptera, Odonata, Coleoptera and Hemiptera), zooplankton (mostly Cladocera, also: Copepoda and Ostracoda), shrimps, gastropods. |
| Australian smelt * <i>Retropinna semoni</i> | (Rolls et al., 2012) Hunter River tributary, NSW | Primarily macroinvertebrates: Ephemeroptera (<i>Edmundsiops</i> , <i>Austrophlebioides</i> , <i>Atalophlebia</i>) and Trichoptera (<i>Cheumatopsyche</i> , <i>Chimarra</i> , <i>Asmicridia</i>). Also: Coleoptera (e.g. <i>Sclerocyphon</i>), Diptera (e.g. Simuliidae; <i>Austrosimulium</i> , Chironimidae), Lepidoptera (Pyralidae) and Mollusca (<i>Physa acuta</i>) and terrestrial insects. |
| | (Balcombe et al., 2005) Cooper Creek, QLD | Zooplankton (Calanoida, Cladocera, Cyclopoida), macroinvertebrates (Chironomidae and Diptera pupae), terrestrial insects and Acarina. |

| Fish species | Reference and Location | Diet |
|--|--|--|
| Climbing galaxias * <i>Galaxias brevipinnis</i> | (Glova and Sagar, 1989) NZ (Kusabs and Swales, 1991) NZ | Predominantly aquatic invertebrates. Ephemeroptera, Trichoptera, Diptera, Plecoptera, Megaloptera and Coleoptera. Also, fish, fish eggs and terrestrial organisms. |
| Mountain Galaxias * <i>Galaxias olidus</i> | (Closs, 1994) Cotter River catchment, ACT | Macroinvertebrates: Diptera (Chironomidae), Trichoptera, Plecoptera, Ephemeroptera, Coleoptera. Crustacea, Gastropoda, fish eggs and terrestrial invertebrates. |
| | (Cadwallader et al., 1980) Seven Creeks River system, VIC | Macroinvertebrates: Diptera and Trichoptera larvae and adults, Coleoptera adults and larvae, Ephemeroptera nymphs and adults, Hemiptera, Chironimidae adults and terrestrial insects. Zooplankton: Copepoda, Cladocera, Ostracoda, Decapoda. Occasionally; Gastropoda, Annelida, Arachnida, algae and terrestrial plants. |
| Common Jollytail <i>Galaxias maculatus</i> | (Pollard, 1973) Lake Modewarre, VIC | Copepoda (<i>Boeckella triarticulata</i> , <i>Microcyclops australis</i>), Amphipoda (<i>Austrochiltonia subtenuis</i>), Cladocera (<i>Daphnia carinata</i>), Ostracoda (<i>Cylocypris</i> sp., <i>Mytilocypris henricae</i>), Chironomid larvae (<i>Chironomus australis</i>), Trichoptera larvae (Leptoceridae), Zygoptera larvae (<i>Argiolestes</i> sp. and <i>Austrolestes</i> sp.), Hemiptera (Corixidae), Coleoptera (Hydrophilidae and Dytiscidae), Hymenoptera (mainly ants) and Lepidoptera larvae. |
| Darling River Hardyhead * <i>Craterocephalus amniculus</i> | (Moy et al., 2018) Macintyre River, NSW | Predominantly Chironomid larvae and detritus. Also: Macroinvertebrates (Ephemeroptera [nymphs and adults], Chironomid [pupae and adult], Corixidae, Coleoptera [adult], Plecoptera [nymphs], Trichoptera [nymphs and adults]), zooplankton (Ostracoda, Cladocera), arthropods, decapods, nematodes, bivalves and algae. |
| Flyspecked Hardyhead * <i>Craterocephalus stercusmuscarum</i> | (Pusey et al., 2010) Burdekin River, QLD | Mostly macroinvertebrates (Ephemeroptera, Trichoptera, Diptera (Chironomidae, Simuliidae, Tipulidae), Coleoptera, Oligochaeta), zooplankton (Copepoda, Cladocera, Hydracarina, Ostracods), bivalves, gastropods, water surface invertebrates (Mesovellidae and Gerridae), filamentous algae and plants. |
| Murray Hardyhead * <i>Craterocephalus fluviatilis</i> | (Wedderburn et al., 2013) SA | Zooplankton (Harpacticoids [<i>Mesochra</i> spp.], Copepods and copepod eggs, Rotifers and rotifer eggs [<i>Brachionus plicatilis</i>]) and macroinvertebrates (Corixidae) and ostracods. |

| Fish species | Reference and Location | Diet |
|---|---|--|
| Murray River Rainbowfish <i>Melanotaenia fluviatilis</i> | (King, 2005) Broken River, VIC | Terrestrial invertebrates, algae, chironomid pupae and larvae, Ephemeroptera, Cladocera (Macrothricidae), Hemiptera (Corixidae). Juveniles ate mainly chironomid larvae and corixids. |
| Agassizii's Glassfish * <i>Ambassis agassizii</i> | (Pusey et al., 2010) Burdekin River, QLD | Mostly macroinvertebrates (Ephemeroptera, Trichoptera, Diptera [Chironomidae, Simuliidae, Tipulidae], Odonata, Coleoptera, Oligochaeta) and zooplankton (Copepoda, Cladocera, Hydracarina, Ostracods). Also bivalves, water surface invertebrates (Mesovellidae and Gerridae), terrestrial invertebrates (insects and spiders), plants and filamentous algae. |
| Purple spotted Gudgeon * <i>Mogurnda adspersa</i> | (Pusey et al., 2010) Burdekin River, QLD | Mostly macroinvertebrates (Ephemeroptera, Trichoptera, Diptera [Chironomidae, Simuliidae, Tipulidae], Odonata, Coleoptera, Oligochaeta). Zooplankton (Copepoda, Cladocera, Hydracarina, Ostracoda), prawns and shrimp. Also bivalves, gastropods, fish, water surface invertebrates (Mesovellidae and Gerridae), terrestrial invertebrates, plants and filamentous algae. |
| Cox's Gudgeon * <i>Gobiomorphus coxii</i> | (Gregory et al., 2007) Macquarie Rivulet, NSW | Primarily macroinvertebrates: Ephemeroptera and Trichoptera (<i>Ecnomus</i> sp.). |
| | (Rolls et al., 2012) Hunter River catchment, NSW | Primarily aquatic macroinvertebrates: Ephemeroptera; Baetidae (<i>Edmundsiops</i>), Leptophlebiidae (<i>Austrophlebioides</i> , <i>Atalophlebia</i>), Caenidae (<i>Irpacaenis</i>) and Trichoptera; (<i>Cheumatopsyche</i> , <i>Chimarra</i> , <i>Asmicridia</i> , <i>Coenoria</i> , <i>Oecetis</i>). Also: Coleoptera (e.g. <i>Sclerocyphon</i> , <i>Kingolus</i>), Diptera (e.g. Simuliidae [<i>Austrosimulium</i>], Chironomidae), Lepidoptera (Pyralidae), Odonata (<i>Nannophlebia</i>), Plecoptera (<i>Illiesoperla</i>) and Mollusca (<i>Physa acuta</i>). |
| Carp Gudgeon * <i>Hypseleotris</i> sp. | (Mazumder et al., 2012) Yanga National Park, NSW | Insects, zooplankton (Copepoda, Rotifera, Cladocera, Ostracoda) and plants. |
| <i>Hypseleotris klunzingeri</i> | (Balcombe et al., 2005) Cooper Creek, QLD | Macroinvertebrates (Chironomidae and Diptera pupae) and Zooplankton (Cladocera, Calanoida, Cyclopoida and Rotifera). Terrestrial insects. |

| Fish species | Reference and Location | Diet |
|--|---|--|
| | (Pusey et al., 2010) Burdekin River, QLD | Mostly macroinvertebrates (Ephemeroptera, Trichoptera, Diptera (Chironomidae, Simuliidae, Tipulidae) Coleoptera, Oligochaeta), zooplankton (Copepoda, Cladocera, Hydracarina, Ostracods), bivalves, gastropods, water surface invertebrates (Mesovellidae and Gerridae) and filamentous algae. |
| Silver Perch <i>Bidyanus bidyanus</i> | (Barlow et al., 1987) Farm ponds, NSW | Chironomid larvae, Cladocera, Ostracods, Trichoptera larvae, Hemiptera (Notonectidae). |
| | (Clunie and Koehn, 2001) Review | Insect larvae, small macroinvertebrates, zooplankton, molluscs, earthworms, shrimps, green algae, filamentous algae, plant material. |
| | (Warburton et al., 1998) QLD (aquaculture) | Chironomid larvae, calanoid copepods (<i>Boeckella</i> sp.), Cladocerans (<i>Daphnia</i> , <i>Moina</i> sp.), corixids, ostracods, cyclopoid copepods (<i>Mesocyclops</i> sp.), Chironomid pupae, Ephemeroptera (Baetidae), Trichoptera (Leptoceridae), Coleoptera (Dytiscidae). |
| Golden Perch <i>Macquaria ambigua</i> | (Sternberg et al., 2008) Moonie River, QLD | Predominantly aquatic macroinvertebrates. Also: fish, crustaceans, terrestrial insects. |
| | (Balcombe et al., 2005) Cooper Creek, QLD | Crustaceans, detritus, algae, zooplankton (Calanoida, Ostracoda), macroinvertebrates (Chironomidae, Coleoptera, Diptera pupae and larvae, Hemiptera), bivalves (Conchostraca) and terrestrial insects. |
| | (Wedderburn et al., 2014) SA | Atyid shrimp and fish (bony herring, redfin perch, flathead gudgeon, Australian smelt, smallmouth hardyhead, common carp) |
| Spangled perch <i>Leiopotherapon unicolor</i> | (Balcombe et al., 2005) Cooper Creek, QLD | Fish, crustaceans, gastropods, zooplankton (Calanoida, Cladocera), bivalves (Conchostraca), macroinvertebrates (Chironomidae, Culicinae, Coleoptera, Diptera larvae and Hemiptera). Terrestrial insects and Acarina. |

| Fish species | Reference and Location | Diet |
|--|--|---|
| | (Pusey et al., 2010) Burdekin River, QLD | Mostly macroinvertebrates (Ephemeroptera, Trichoptera, Diptera (Chironomidae, Simuliidae, Tipulidae), Odonata, Coleoptera, Oligochaeta,). Prawns and shrimp, Zooplankton (Copepoda, Cladocera, Hydracarina, Ostracods). Also bivalves, gastropods, fish, frogs and tadpoles, water surface invertebrates (Mesovellidae and Gerridae), terrestrial invertebrates, ants, plants and filamentous algae. |
| Macquarie Perch <i>Macquaria australasica</i> | (McKeown, 1934) Goodradigbee River, NSW | Coleoptera (Dryopidae), Hemiptera (Gerridae, Pentatomidae, Jassidae), Trichoptera, Hymenoptera (Formicidae), Lepidoptera, Odonata, Neuroptera, Ephemeroptera, Orthoptera (Acridiidae), Vermes. |
| | (Cadwallader and Douglas, 1986) Mitta Mitta River & Dart River, VIC | Ephemeroptera (Baetidae, Siphonuridae [<i>Coloburiscoides</i> spp.] and Leptophlebiidae [<i>Atalophlebioides</i> sp., <i>Jappa</i> sp.]), Odonata (Aeshnidae, Corduliidae, Libellulidae and Coenagrionidae), Plecoptera (Gryopterygidae, Eustheniidae [<i>Stenoperla</i> sp.]), Hemiptera (Corixidae, Notonectidae, Naucoridae and Mesoveliidae), Coleoptera (Dytiscidae, Gyrinidae and Psephenidae), Diptera (Culicidae [Chaoborinae], Chironomidae, Syrphidae, Tabanidae and Tipulidae), Trichoptera (Calamoceratidae, Hydropsychidae, Philopotamidae, Philorheithridae and Stenopsychidae, Calamoceratidea), Decapoda (<i>Paratya</i> sp.), Cladocera (Daphniidae), and terrestrial insects and decapods (<i>Engaeus</i> sp). |
| | (Cadwallader and Eden, 1979) Mitta Mitta River, VIC | Mainly macroinvertebrates: Coleoptera (Hydrophilidae [<i>Berosus</i>], Dytiscidae [<i>Sternopriscus</i>]), Diptera (Chironomidae [<i>Chironomus</i> , <i>Crictopus</i> , <i>Reitha</i>], Tipulidae), Ephemeroptera (Baetidae [<i>Baetis</i> , <i>Centroptilum</i>], Caenidae [<i>Tasmanocoenis</i>]), Trichoptera (Leptoceridae, Polycentropodidae [<i>Ecnomus</i>], Hydropsychidae), Megaloptera (Corydalidae). Also: Crustacea, Hemiptera (Corixidae [<i>Micronecta</i>]), Odonata and Mollusca. |
| Murray Cod <i>Maccullochella peelii</i> | (Ebner, 2006) Murray River, NSW & VIC | Mainly fish (mostly <i>Cyprinus carpio</i>), decapods (<i>Macrobrachium</i> and <i>Cherax</i>), gastropods. |
| | (Kaminskas and Humphries, 2009) Broken River, VIC | Diet of the Murray Cod larvae is predominantly macroinvertebrates (Chironomid larvae, Trichoptera [Hydropsychidae] and Ephemeroptera [Leptophlebiidae]) and zooplankton (Cladocera [Macrotrichidae, Daphniidae, Chydoridae], Copepoda [Cyclopoida, Harpacticoida]). To a lesser extent Ostracoda and Rotifera. |

| Fish species | Reference and Location | Diet |
|---|---|---|
| Trout Cod <i>Maccullochella macquariensis</i> | (Baumgartner, 2007) Murrumbidgee River, NSW | Macrocrustaceans, macroinvertebrates and fish. |
| Australian Bass <i>Macquaria novemaculeata</i> | (Harris, 1985) Hawksbury River, Georges River, NSW | Mainly fish: <i>Gobiomorphus</i> , <i>Hypseleotris</i> , <i>Philypnodon grandiceps</i> , <i>Gambusia affinis</i> , <i>Retropinna semoni</i> , <i>Potamalosa richmondia</i> and <i>Mugil</i> . Shrimp (<i>Paratya australiensis</i>), prawns (<i>Macrobrachium intermedium</i>). Macroinvertebrates: Coleoptera (Dytiscidae, Hygrobiidae, Haliplidae, Noteridae). Diptera - Chironomidae (Orthoclaadiinae), Culicidae (Chaoborinae), Simuliidae. Hemiptera - Naucoridae (<i>Naucoris</i> sp.), Gerridae, Notonectidae, Corixidae (<i>Micronecta</i> sp.), Pleidae. Odonata - Corduliidae and Lestidae. Trichoptera - Helicopsychidae, Odontoceridae, Philorheithridae and Calamoceratidae. Ephemeroptera and Plecoptera. Zooplankton: Copepods (<i>Gladioferens pectinatus</i> , <i>Sulcanus conflictus</i>), Cladocera (<i>Daphnia</i> sp.), Isopoda (<i>Cymodetta</i> sp.) Terrestrial invertebrates: Cicadidae, Tebanidae, <i>Musca vetustissima</i> . Nematomorpha. Acarina. |
| Two-spined Blackfish * <i>Gadopsis bispinosus</i> | (Rees et al., 2019) Buffalo Creek, VIC | Mostly macroinvertebrates (Trichoptera [<i>Notalina</i> , <i>Hydrobiosella</i>], Ephemeroptera [<i>Nousia</i> , <i>Austrophlebioides</i>], Odonata, Diptera [<i>Cricotopus</i> , <i>Chiromonidae</i>], Coleoptera, Plecoptera [<i>Acruroperla</i> , <i>Dinotoperla</i> , <i>Riekoperla</i>], Annelida [<i>Lumbricus</i>], Megaloptera [<i>Archicauliodes</i>]), terrestrial invertebrates (Lepidoptera [<i>Proteuxoa</i> , <i>Geometridae</i>], Hymenoptera [<i>Formicidae</i>]) and Acarina. |
| River Blackfish * <i>Gadopsis marmoratus</i> | (Rees et al., 2019) Buffalo Creek, VIC | Macroinvertebrates (Trichoptera [<i>Notalina</i> , <i>Ecnomina</i> , <i>Triaenodes</i> , <i>Tripletides</i>], Ephemeroptera [<i>Nousia</i>], Odonata [<i>Austroargiolestes</i>], Diptera [<i>Cricotopus</i>], Coleoptera, Plecoptera [<i>Riekoperla</i>], Annelida [<i>Lumbricus</i>]). |
| Southern Pygmy Perch * <i>Nannoperca australis</i> | (Humphries, 1995) Macquarie River, TAS | Predominantly amphipods and ostracods. Leptophlebiidae larvae (<i>Atalophlebia australis</i>), Copepoda (Harpacticoida), Cladocera (Daphniidae), Gastropoda (<i>Physastra gibbosa</i>), Chironomid larvae, Caenidea larvae (<i>Tasmanocoenis</i> sp.), Ephemeroptera (Baetidae), Trichoptera (<i>Ecnomus</i> sp.), Hemiptera, Isopoda. |

| Fish species | Reference and Location | Diet |
|---|---|--|
| Introduced species: | | |
| Common Carp <i>Cyprinus carpio</i> | (Mazumder et al., 2012) Yanga National Park, NSW | Plants, algae, diatoms, insects, zooplankton (Copepoda, Rotifera, Cladocera, Ostracoda, Protozoa, Nematoda), unidentified animals. |
| Brown Trout <i>Salmo trutta</i> | (McKeown, 1934) Tuross River, NSW | Coleoptera (Gyrinidae, Curculionidae, Scarabaeidae), Diptera (Stratiomyidae, Tipulidae), Hemiptera (Neonectidae, Gerridae, Corixidae, Psyllidae, Jassidae), Trichoptera, Hymenoptera, Lepidoptera, Odonata (Anisoptera, Zygoptera), Orthoptera, Crustacea (Paratya sp.), Annelida, Mollusca, Vermes. |
| Mosquitofish <i>Gambusia holbrooki</i> | (Balcombe et al., 2005) Cooper Creek, QLD | Predominantly Gastropods and Zooplankton (Cladocera). Also Macroinvertebrates (Chironomidae and Diptera pupae), terrestrial insects and Acarina. |
| | (Pusey et al., 2010) Burdekin River, QLD | Mostly filamentous algae, terrestrial invertebrates, water surface invertebrates (Mesovellidae and Gerridae), macroinvertebrates (Chironomidae, Simuliidae, Coleoptera, Oligochaeta, Tipulidae) and Zooplankton (Ostracods). |
| Redfin Perch <i>Perca fluviatilis</i> | (Wedderburn et al., 2014) SA | Mostly fish (Lagoon goby, bony herring, redfin perch, tamar river goby, flathead gudgeon, smallmouth hardyhead, common carp), shrimp. |

Table 2. Aquatic invertebrate groups consumed by freshwater fish

| Fish species | Insects | | | | | | | | | Crustaceans | | | | | Others | | | |
|-------------------------------|-------------------------|---------|---------------|-----------|-------------|-------------|---------|------------|-------------|-------------|-----------|----------|----------|-----------|----------|------------|-------------|-----------|
| | Coleoptera | Diptera | Ephemeroptera | Hemiptera | Lepidoptera | Megaloptera | Odonata | Plecoptera | Trichoptera | Amphipoda | Cladocera | Copepoda | Decapoda | Ostracoda | Rotifera | Gastropoda | Oligochaeta | Arachnida |
| Marbled eel | x | x | x | | | | x | | x | | | | x | | | x | x | |
| Bony Herring | x | x | | x | | | | | | | x | x | | x | x | | | |
| Eel-Tailed freshwater catfish | x | x | x | x | | | x | | x | | x | x | x | x | | x | | |
| Australian smelt | x | x | x | | x | | | | x | | x | x | | | | | | |
| Galaxiids | Climbing galaxias | x | x | x | | | | x | x | | | | | | | | | |
| | Mountain Galaxias | x | x | x | x | | | | x | | x | x | x | x | | x | | |
| Common Jollytail | x | x | x | x | x | | | | x | x | x | | | x | | | | |
| Hardyheads | Darling River Hardyhead | x | x | x | x | | | | | | x | | | x | | | | |
| | Flyspecked Hardyhead | x | x | x | x | | | | | | x | x | | x | | x | x | x |
| | Murray Hardyhead | | | | | | | | | | | x | | x | x | | | |
| Murray River Rainbowfish | x | x | x | x | | | | | | | | | | | | | | |
| Agassizii's Glassfish | x | x | x | x | | | | | | | x | x | | x | | | x | x |
| Gudgeons | Purple Spotted Gudgeon | x | x | x | x | | | | | | | | x | x | | x | x | x |
| | Cox's Gudgeon | x | x | x | | x | | | | | x | x | | | | | | |
| | Carp Gudgeon | x | x | x | x | | | | | | | x | | x | x | x | x | x |

Table 2. Continued

| Fish species | | Insects | | | | | | | | Crustaceans | | | | | Others | | | | |
|--------------|----------------------|------------|---------|---------------|-----------|-------------|-------------|---------|------------|-------------|-----------|-----------|----------|----------|-----------|----------|------------|-------------|-----------|
| | | Coleoptera | Diptera | Ephemeroptera | Hemiptera | Lepidoptera | Megaloptera | Odonata | Plecoptera | Trichoptera | Amphipoda | Cladocera | Copepoda | Decapoda | Ostracoda | Rotifera | Gastropoda | Oligochaeta | Arachnida |
| Perches | Australian Bass | x | x | x | x | | | x | x | x | | x | x | x | | | | | |
| | Macquarie Perch | x | x | x | x | x | x | | x | x | | x | | x | | | | | |
| | Golden Perch | x | x | | | | | | | | | | x | x | x | | | | |
| | Spangled perch | x | x | x | x | | | | x | | | x | x | x | x | | x | x | x |
| | Silver Perch | x | x | x | x | | | | | x | | x | x | x | x | | | | |
| | Murray Cod | | x | x | | | | | | x | | x | x | x | x | x | | | |
| Blackfish | Two-spined Blackfish | x | x | x | | | x | x | x | | | | | | | | | | |
| | River Blackfish | x | x | x | | | | x | x | | | | | | | | | | |
| | Southern Pygmy Perch | | x | x | x | | | | x | | x | x | | x | | x | | | |
| Introduced | Common Carp | | | | | | | | | | | x | x | | x | | | | |
| | Brown Trout | x | | | x | x | | | x | | | | | | | | | | |
| | Mosquitofish | | x | | x | | | | | | | | | x | | x | x | | |
| | Redfin Perch | | | | | | | | | | | | x | | | | | | |
| | Total | 21 | 24 | 21 | 18 | 5 | 3 | 13 | 7 | 21 | 2 | 17 | 16 | 11 | 17 | 5 | 10 | 7 | 5 |

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APPENDIX

Table A1. Prey items of freshwater fish

| Macroinvertebrate taxon | Fish species | Notes |
|-------------------------|-------------------------------|---|
| Diptera | | |
| Blephariceridae | Macquarie Perch | |
| Chironomidae | Marbled Eel | |
| | Bony Herring | |
| | Eel-Tailed Freshwater Catfish | |
| | Australian Smelt | |
| | Mountain Galaxias | |
| | Climbing galaxias | |
| | Common Jollytail | <i>Chironomus australis</i> |
| | Darling River Hardyhead | |
| | Flyspecked Hardyhead | |
| | Agassizii's Glassfish | |
| | Carp Gudgeon | |
| | Cox's Gudgeon | |
| | Purple spotted Gudgeon | |
| | Murray River Rainbowfish | |
| | Macquarie perch | <i>Chironomus, Crictopus, Reitha, Paracladopelma, Stenochironomus, Tanytarsus, Rheotanytarsus</i> |
| | Golden Perch | |
| | Silver Perch | |
| | Spangled Perch | |
| | Southern Pigmy Perch | |
| | Australian Bass | <i>Orthoclaadiinae</i> |
| | Two-spined Blackfish | <i>Cricotopus</i> |
| | River Blackfish | <i>Cricotopus</i> |
| Murray Cod | | |
| Mosquitofish | | |
| Ceratopogonidae | Macquarie Perch | |
| Chaoboridae | Australian Bass | |
| | Macquarie Perch | |
| Culicidae | Spangled perch | |
| | Macquarie Perch | |

| | | |
|---------------|-------------------------------|-----------------------|
| | Southern Pygmy Perch | |
| Empididae | Macquarie Perch | |
| Rhagionidae | Macquarie Perch | |
| Simuliidae | Marbled Eel | |
| | Bony Herring | |
| | Eel-Tailed freshwater catfish | |
| | Australian smelt | |
| | Flyspecked Hardyhead | |
| | Agassizii's Glassfish | |
| | Climbing Galaxias | <i>Austrosimulium</i> |
| | Purple spotted Gudgeon | |
| | Cox's gudgeon | <i>Austrosimulium</i> |
| | Carp gudgeon | |
| | Spangled perch | |
| | Australian Bass | |
| | Mosquitofish | |
| | Macquarie Perch | |
| Syrphidae | Macquarie Perch | |
| Tipulidae | Marbled Eel | |
| | Flyspecked Hardyhead | |
| | Agassizii's Glassfish | |
| | Climbing Galaxias | |
| | Purple spotted Gudgeon | |
| | Carp gudgeon | |
| | Spangled perch | |
| | Macquarie Perch | |
| | Mosquitofish | |
| Tabanidae | Macquarie Perch | |
| Ephemeroptera | Australian Bass | |
| | Marbled Eel | |
| | Eel-Tailed freshwater catfish | |
| | Darling River Hardyhead | |
| | Flyspecked Hardyhead | |
| | Murray River Rainbowfish | |

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|-----------------|-------------------------------|--|
| | Climbing galaxias | NZ taxa: Deleatidium spp., Coloburiscus humeralis |
| | Mountain galaxias | |
| | Carp Gudgeon | |
| | Spangled perch | |
| Baetidae | Cox's Gudgeon | <i>Edmundsiops</i> |
| | Australian smelt | <i>Edmundsiops</i> |
| | Silver Perch | |
| | Macquarie Perch | <i>Baetis, Centropilum, Mirawara, Coloburiscoides</i> |
| | Southern Pygmy Perch | |
| Leptophlebiidae | Murray Cod | |
| | Southern Pygmy Perch | <i>Atalophlebia australis</i> |
| | Cox's Gudgeon | <i>Austrophlebioides, Atalophlebia</i> |
| | Australian smelt | <i>Austrophlebioides, Atalophlebia</i> |
| | Two-spined Blackfish | <i>Nousia, Austrophlebioides</i> |
| | River Blackfish | <i>Nousia</i> |
| | Macquarie perch | <i>Austrophlebioides, Atalophlebia, Jappa</i> |
| Caenidae | Cox's Gudgeon | <i>Irpacaenis</i> |
| | Macquarie Perch | <i>Tasmanocoenis</i> |
| | Southern Pygmy Perch | <i>Tasmanocoenis</i> |
| Trichoptera | Mountain galaxias | |
| | Australian smelt | |
| | Marbled Eel | |
| | Carp Gudgeon | |
| | Darling River Hardyhead | |
| | Flyspecked Hardyhead | |
| | Eel-Tailed freshwater catfish | |
| | Climbing galaxias | NZ taxa: Hydrobiosis frater, Hydrobiosis umbripennis, Hydropsychidae, Oxyethira albiceps, Olinga feredayi, Pycnocentrodus spp. |
| Ecnomidae | Cox's Gudgeon | <i>Ecnomus</i> |
| | Macquarie perch | <i>Ecnomus</i> |
| | River Blackfish | <i>Ecnomina</i> |
| | Southern Pygmy Perch | <i>Ecnomus</i> |
| Calamoceratidae | Australian Bass | |
| | Macquarie perch | <i>Anisocentropus</i> |
| Glossosomatinae | Macquarie perch | <i>Agapetus</i> |

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|-------------------|-------------------------------|---|
| Helicopsychidae | Australian Bass | |
| | Macquarie perch | |
| Helicophidae | Macquarie perch | |
| Hydropsychidae | Macquarie perch | <i>Cheumatopsyche, Asmicridea</i> |
| | Murray Cod | |
| Hydroptilidae | Macquarie perch | |
| Leptoceridae | Two-spined Blackfish | <i>Notalina</i> |
| | River Blackfish | <i>Notalina, Triaenodes, Triplectides</i> |
| | Common Jollytail | |
| | Silver perch | |
| | Macquarie perch | |
| | Southern Pygmy Perch | |
| Odontoceridae | Australian Bass | |
| | Macquarie perch | <i>Atriplectides dubian</i> |
| Polycentropodidae | Macquarie perch | |
| Philorheithridae | Macquarie perch | |
| | Australian Bass | |
| Philopotamidae | Macquarie perch | |
| | Two-spined Blackfish | <i>Hydrobiosella</i> |
| Psychomyiidae | Macquarie perch | |
| Rhyacophilidae | Macquarie perch | |
| Stenopsychidae | Macquarie perch | |
| Tasimiidae | Macquarie perch | |
| Coleoptera | Bony Herring | |
| | Marbled Eel | |
| | Australian Smelt | |
| | Mountain Galaxias | |
| | Climbing Galaxias | |
| | Agassizii's Glassfish | |
| | Flyspecked Hardyhead | |
| | Eel-tailed Freshwater Catfish | |
| | Darling River Hardyhead | |
| | Purple Spotted Gudgeon | |
| | Cox's Gudgeon | |
| | Carp Gudgeon | |

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|-----------------|--------------------------|--|
| | Two-spined Blackfish | |
| | Murray River Rainbowfish | |
| | River Blackfish | |
| | Golden Perch | |
| | Spangled Perch | |
| | Mosquitofish | |
| Dytiscidae | Silver Perch | |
| | Macquarie Perch | <i>Sternopriscus, Platynectus, Necterosoma, Macroporus, Copelatus, Bidessus, Antiporus</i> |
| | Australian Bass | |
| | Common Jollytail | |
| Dryopidae | Macquarie Perch | |
| Elminthidae | Macquarie Perch | |
| Gyrinidae | Macquarie Perch | |
| Psephenidae | Macquarie Perch | |
| Helodidae | Macquarie Perch | |
| Hydraenidae | Macquarie Perch | |
| Hydrochidae | Macquarie Perch | |
| Hydrophilidae | Macquarie Perch | <i>Berosus</i> |
| | Common Jollytail | |
| Hygrobiiidae, | Australian Bass | |
| Haliplidae, | Australian Bass | |
| | Macquarie Perch | |
| Noteridae | Australian Bass | |
| Lepidoptera | Common Jollytail | |
| | Macquarie Perch | |
| Pyralidae | Australian Smelt | |
| | Cox's Gudgeon | |
| Plecoptera | Darling River Hardyhead | |
| | Climbing Galaxias | NZ species: <i>Stenoperla prasina</i> |
| | Australian Bass | |
| | Two-spined Blackfish | <i>Acruroperla, Dinotoperla, Riekoperla</i> |
| | Cox's Gudgeon | <i>Illiesoperla</i> |
| Eustheniidae | Macquarie Perch | <i>Stenoperla</i> sp |
| Gripopterygidae | Macquarie Perch | |
| | River Blackfish | <i>Riekoperla</i> |

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|----------------------|-------------------------------|--|
| Nemouridae | Macquarie Perch | |
| Megaloptera | Climbing Galaxias | NZ species: <i>Archichauliodes diversus</i> |
| Corydalidae | Macquarie Perch | |
| | Two-spined Blackfish | <i>Archichauliodes</i> |
| Odonata | Marbled Eel | |
| | Mountain galaxias | |
| | Eel-Tailed freshwater catfish | |
| | Two-spined Blackfish | |
| | Agassizii's Glassfish | |
| | Purple Spotted Gudgeon | |
| | Spangled Perch | |
| Zygoptera (suborder) | Common Jollytail | <i>Argiolestes</i> sp. and <i>Austrolestes</i> sp. |
| | River Blackfish | <i>Austroargiolestes</i> |
| | Southern Pygmy Perch | |
| | Macquarie Perch | |
| Aeshnidae | Macquarie Perch | |
| Coenagrionidae | Macquarie Perch | |
| Corduliidae | Macquarie Perch | |
| | Australian Bass | |
| Gomphidae | Macquarie Perch | |
| Libellulidae | Macquarie Perch | |
| | Cox's Gudgeon | <i>Nannophlebia</i> |
| Lestidae | Australian Bass | |
| Synthemidae | Macquarie Perch | |
| Hemiptera | Eel-Tailed freshwater catfish | |
| | Mountain Galaxias | |
| | Southern Pygmy Perch | |
| Corixidae | Common Jollytail | |
| | Darling River Hardyhead | |
| | Murray River Hardyhead | |
| | Murray River Rainbowfish | |
| | Silver Perch | |
| | Macquarie Perch | <i>Micronecta</i> , |
| | Australian Bass | <i>Micronecta</i> |
| Gerridae | Bony Herring | |

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| | Flyspecked Hardyhead | |
| | Agassizii's Glassfish | |
| | Purple Spotted Gudgeon | |
| | Carp gudgeon | |
| | Spangled perch | |
| | Macquarie Perch | |
| | Australian Bass | |
| | Mosquitofish | |
| Mesoveliidae | Bony Herring | |
| | Flyspecked Hardyhead | |
| | Agassizii's Glassfish | |
| | Purple Spotted Gudgeon | |
| | Carp gudgeon | |
| | Spangled perch | |
| | Macquarie Perch | |
| | Mosquitofish | |
| Notonectidae | Silver Perch | |
| | Macquarie Perch | |
| | Australian Bass | |
| Naucoridae | Australian Bass | <i>Naucoris</i> |
| | Macquarie perch | |
| Pleidae | Australian Bass | |
| Pentatomidae | Macquarie perch | |
| Jassidae | Macquarie perch | |
| Veliidae | Macquarie perch | |
| Cladocera | Common Carp | |
| | Bony Herring | |
| | Australian Smelt | |
| | Mountain Galaxias | |
| | Agassizii's Glassfish | |
| | Flyspecked Hardyhead | |
| | Eel-tailed Freshwater Catfish | |
| | Darling River Hardyhead | |
| | Carp Gudgeon | |
| | Common Jollytail | |

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|----------------|-------------------------------|----------------------------------|
| | Spangled Perch | |
| | Mosquitofish | |
| Daphniidae | Silver Perch | <i>Daphnia</i> |
| | Macquarie Perch | |
| | Murray Cod | |
| | Australian Bass | <i>Daphnia</i> |
| | Southern Pygmy Perch | |
| Chydoridae | Murray Cod | |
| | Southern Pygmy Perch | |
| Moinidae | Silver Perch | <i>Moina</i> sp. |
| Macrotrichidae | Murray Cod | |
| Copepoda | Common Carp | |
| | Mountain Galaxias | |
| | Eel-tailed Freshwater Catfish | |
| | Agassizii's Glassfish | |
| | Flyspecked Hardyhead | |
| | Spangled Perch | |
| | Australian Bass | <i>Sulcanus conflicta</i> |
| Harpacticoida | Murray Hardyhead | <i>Mesochra</i> |
| | Murray Cod | |
| | Southern Pygmy Perch | |
| Cyclopoida | Silver Perch | <i>Mesocyclops</i> sp. |
| | Common Jollytail | <i>Microcyclops australis</i> |
| | Carp Gudgeon | |
| | Bony Herring | |
| | Australian Smelt | |
| | Murray Cod | |
| Calanoida | Silver Perch | <i>Boeckella</i> sp. |
| | Common Jollytail | <i>Boeckella triarticulata</i> |
| | Spangled Perch | |
| | Golden Perch | |
| | Bony Herring | |
| | Australian Smelt | |
| | Carp Gudgeon | |
| | Australian Bass | <i>Gladioferens pectinatus</i> . |

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|---------------------------|-------------------------------|------------------------------|
| Amphipoda | Common Jollytail | |
| | Southern Pygmy Perch | <i>Rivisessor gunnii</i> |
| Decapoda | Australian Bass | <i>Paratya australiensis</i> |
| | Marbled Eel | |
| | Eel-tailed Freshwater Catfish | |
| | Purple spotted Gudgeon | |
| | Redfin Perch | |
| | Macquarie Perch | <i>Paratya sp.</i> |
| | Mountain Galaxias | |
| | Silver Perch | |
| | Golden Perch | |
| | Spangled Perch | |
| | Murray Cod | |
| Hymenoptera (terrestrial) | | |
| Formicidae | Macquarie Perch | |
| | Two-spined Blackfish | |
| Isopoda | Australian Bass | <i>Cymodetta sp.</i> |
| | Southern Pygmy Perch | |
| Orthoptera | | |
| Acridiidae | Macquarie Perch | |
| Ostracoda | Bony Herring | |
| | Mountain Galaxias | |
| | Agassizii's Glassfish | |
| | Flyspecked Hardyhead | |
| | Eel-tailed Freshwater Catfish | |
| | Darling River Hardyhead | |
| | Murray Hardyhead | |
| | Purple Spotted Gudgeon | |
| | Carp Gudgeon | |
| | Common Jollytail | |
| | Silver Perch | |
| | Golden Perch | |
| | Spangled Perch | |
| | Southern Pygmy Perch | |
| Murray Cod | | |

| | | |
|-------------|-------------------------------|------------------------------|
| | Common Carp | |
| | Mosquitofish | |
| Rotifera | Bony Herring | |
| | Carp Gudgeon | |
| | Murray Hardyhead | <i>Brachionus plicatilis</i> |
| | Murray Cod | |
| | Common Carp | |
| Aracnida | Spangled Perch | |
| Hydracarina | Flyspecked Hardyhead | |
| | Agassizii's Glassfish | |
| | Carp gudgeon | |
| | Purple spotted Gudgeon | |
| Gastropoda | Southern Pygmy Perch | <i>Physastra gibbosa</i> |
| | Marbled Eel | |
| | Flyspecked Hardyhead | |
| | Eel-tailed Freshwater Catfish | |
| | Mountain Galaxias | |
| | Purple Spotted Gudgeon | |
| | Carp Gudgeon | |
| | Spangled Perch | |
| | Murray Cod | |
| | Mosquitofish | |
| Ogliochaeta | Spangled Perch | |
| | Marbled Eel | |
| | Flyspecked Hardyhead | |
| | Agassizii's Glassfish | |
| | Purple spotted Gudgeon | |
| | Carp Gudgeon | |
| | Mosquitofish | |