Conceptual Model Case Study Series

Fitzroy coastal floodplain wetlands

The delta of the Fitzroy River in Central Queensland has extensive wetlands clustered around its large and intricate estuary system. These coastal and subcoastal wetlands comprise a network of semi-permanent pools of various types and sizes. They include estuarine, riverine, palustrine (swamp) and lacustrine (lake) wetlands.

The Fitzroy wetlands fulfill important ecological functions. They provide major food and habitat resources for fish, birds and invertebrates, as well as being nursery grounds for marine fish such as barramundi and for invertebrates, including prawns. They function as links between land-based (terrestrial) and marine ecosystems and provide pathways for the movement of nutrients (and pollutants) from the terrestrial to the marine environment.

The physical nature of the Fitzroy coastal floodplain wetlands is governed by the patterns of rainfall and flooding, and by the length and type of any connecting channels. Other important factors are whether the pools connect directly to marine waters during regular tide cycles and the effects of tidal anomalies. These anomalies can interfere with expected tide heights, sometimes bringing about connections that are not predicted or failing to produce predicted connections.

The vast and intricate estuary system around the Fitzroy River delta includes many wetland pools that provide nursery grounds for marine fish such as barramundi.

Image courtesy of Earth Sciences and Image Analysis Laboratory, NASA Johnson Space Center (STS051-78-64.JPG).

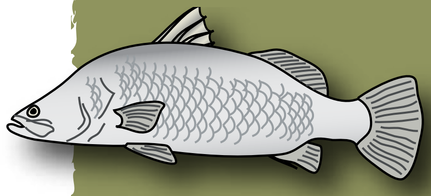
Image: NASA

Important factors in Fitzroy wetland ecology

Factors that determine the physical and biological nature of the various types of wetlands are:

- connection to nearby aquatic ecosystems
- salinity and changes to salinity
- persistence.

Connection to nearby aquatic ecosystems can occur through tides, stream flow, local rainfall or major floods. Salinity varies with proximity to marine waters, frequency and timing of connection to marine or fresh water and evaporation. Persistence – how long the pool lasts before drying out – is strongly related to pool depth.



Barramundi
(*Lates calcarifer*)

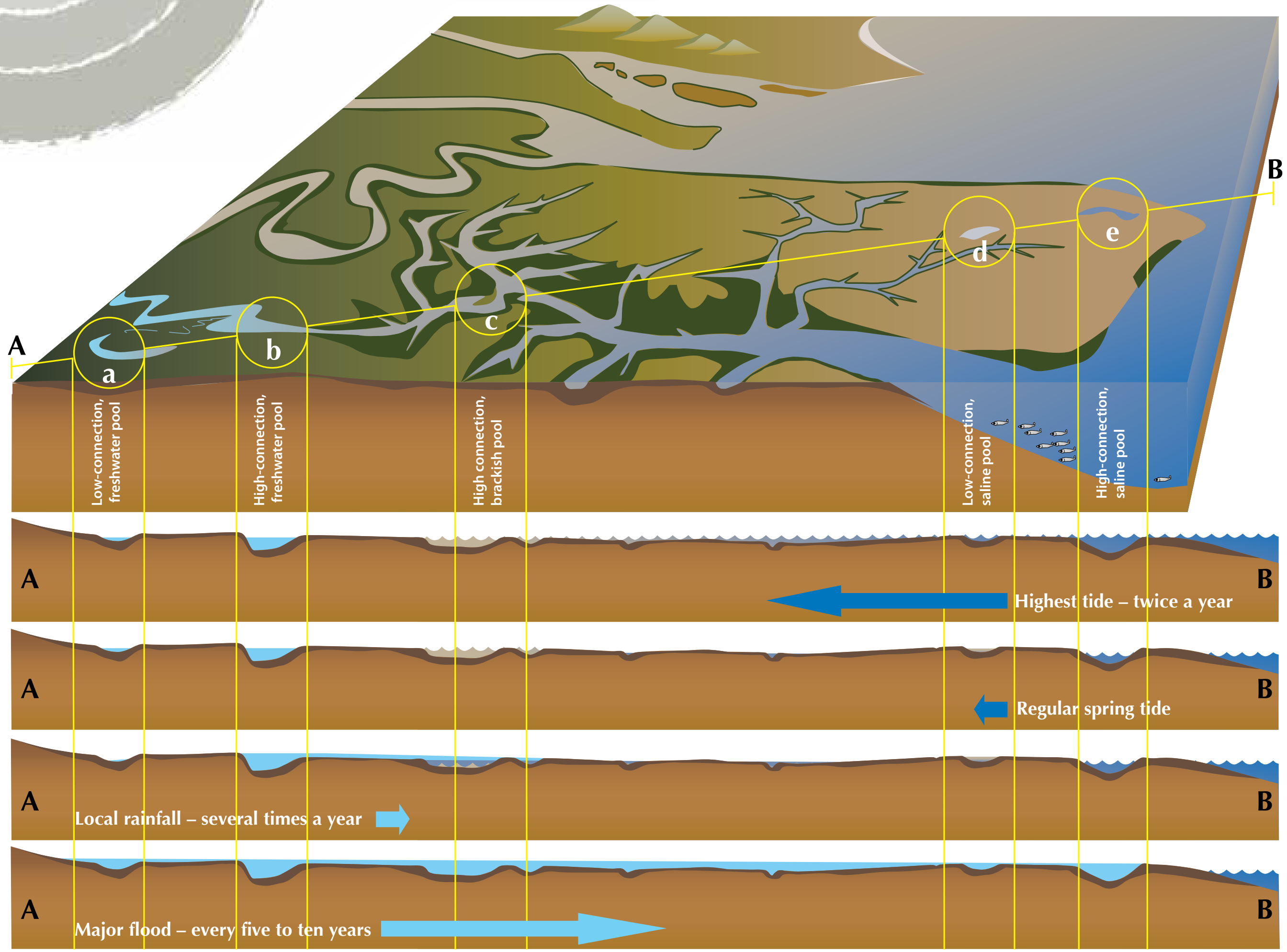
About this case study:

This case study was created by the Department of Environment and Resource Management Aquatic Ecosystem Health Science Integration and Capacity Building Team as part of the Queensland Wetlands Program. The purpose of this conceptual modelling case study is to synthesise and present information on the values of the Fitzroy estuarine floodplain wetland pools. In particular, the study examines how physical and biological connectivity across the Fitzroy delta landscape drives the ecological functioning of the wetland pools.

Fitzroy estuary delta – streams and pools

The landscape of the Fitzroy estuary delta is essentially flat, however, small differences in elevation are important in determining which of its many wetland pools will be 'topped up' by fresh or salt water and when these connections will occur.

Fitzroy wetland pools and streams can be described on the basis of how connected they are with water sources and on their salinity levels. The following are well represented among the Fitzroy coastal floodplain wetlands:



Typical landscape around the Fitzroy delta is shown at the top. Below are four diagonal cross-sections of the landscape from A to B showing some cyclic events that can connect wetland pools to other fresh or salt water sources. Illustrated are (from top to bottom) connections brought about by highest tides, regular spring tides, local rainfall and major floods (diagram not to scale).

Low-connection freshwater pools (a)

Some pools are connected to each other and to the main estuary system only during major floods, which occur at intervals of years to decades. In addition, these pools are not connected via groundwater. For such pools, size is the critical factor in their ability to maintain productive aquatic ecosystems (persistence). If they are too small, these pools will dry out. Then the aquatic ecosystem will collapse and any juvenile fish in the pools will not live to be adults. Rather, most of them will be eaten by birds.

High-connection instream pools (b and c)

Another group of pools are connected a number of times each year by local rainfall. These pools are components of creek systems and their regular connections allow aquatic animals to move both up and down stream. Such pools provide for marine spawning species, such as barramundi, moving upstream into nursery or feeding habitats. They also allow freshwater species, such as bony bream, to recolonise brackish pools, where they may live in abundance though not reproduce.

Low-connection saline pools (d)

These pools are shallow, isolated from stream systems and only connected to the marine environment during the very highest tides of the year. The seawater in these pools evaporates quickly, but long before they dry out completely, the concentration of the salt in the water becomes too high (hypersaline) to support aquatic life.

High-connection saline pools (e)

A final group of pools is never threatened with drying out because they are reasonably deep and have regular connections to the marine environment on high spring tides. These pools are dominated by marine species.

Photo: R. Johnston

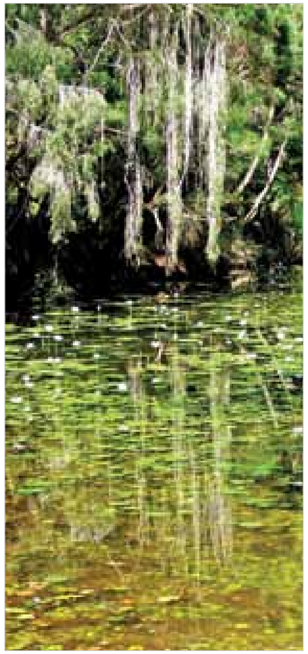


Photo: R. Johnston

Woolwash Lagoon (far left), is a low-connection freshwater pool. This photo shows the lagoon when it has become too shallow to support its aquatic ecosystem. Dying fish can be seen on the near shore, while those fish that remain will soon be taken by the pelicans on the far shore.

This pool on Manduran Creek (left) is a highly connected freshwater pool with a diverse and thriving aquatic ecosystem.

Wetland pools on Gonong Creek (below) are well connected to both fresh and salt water sources. The pools receive water from both local rainfall and stream flow and are regularly connected to the sea on spring tides.

German Jacks Lagoon (bottom) is not well connected to saline or freshwater sources. It receives salt water at higher spring tides, about four times a year, and some local rainfall but no stream flow. It is shallow and susceptible to hypersalinity.

Photo: R. Johnston

Photo: R. Johnston

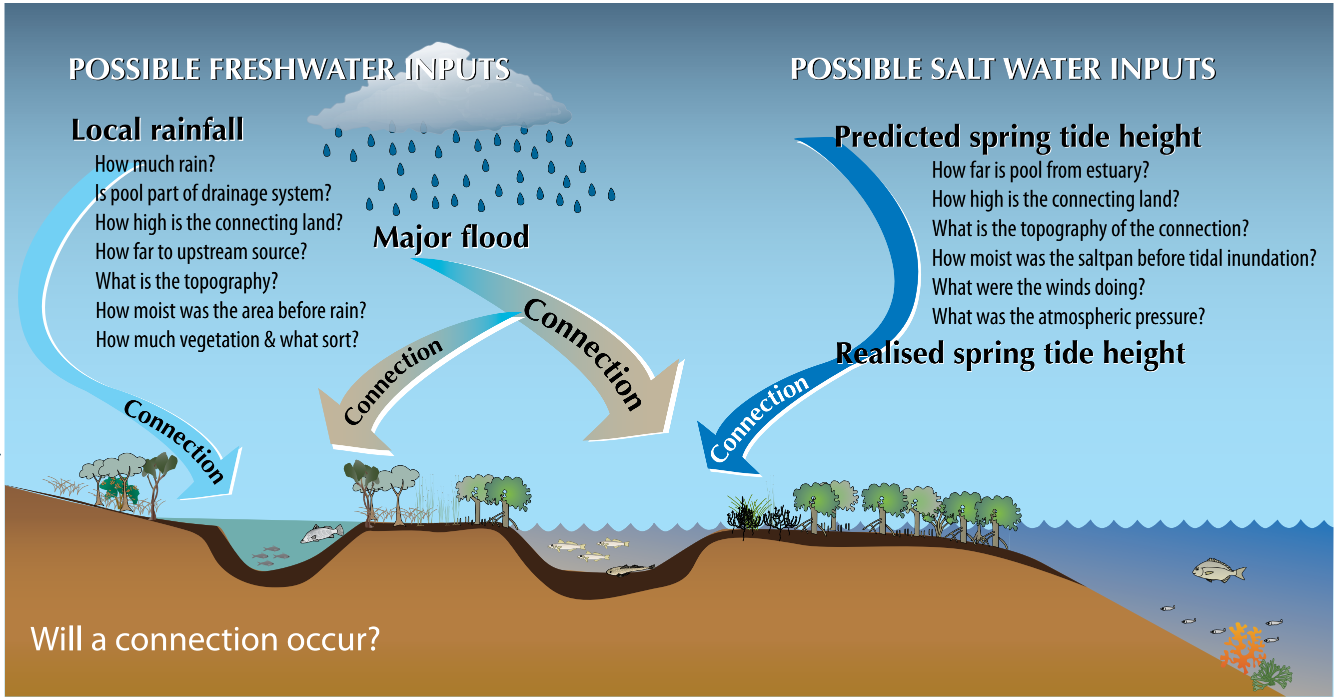


Illustration based on a model by M. Sheaves

The importance of time

In addition to connectivity, salinity and persistence, time is another important dimension to consider in the ecology of the Fitzroy wetland pools:

- The timing of flood connections is important – this must match the abundance of fish or invertebrate larvae if the pools' nursery function is to be fulfilled.
- The amount of time between floods is also critical to pool ecology.

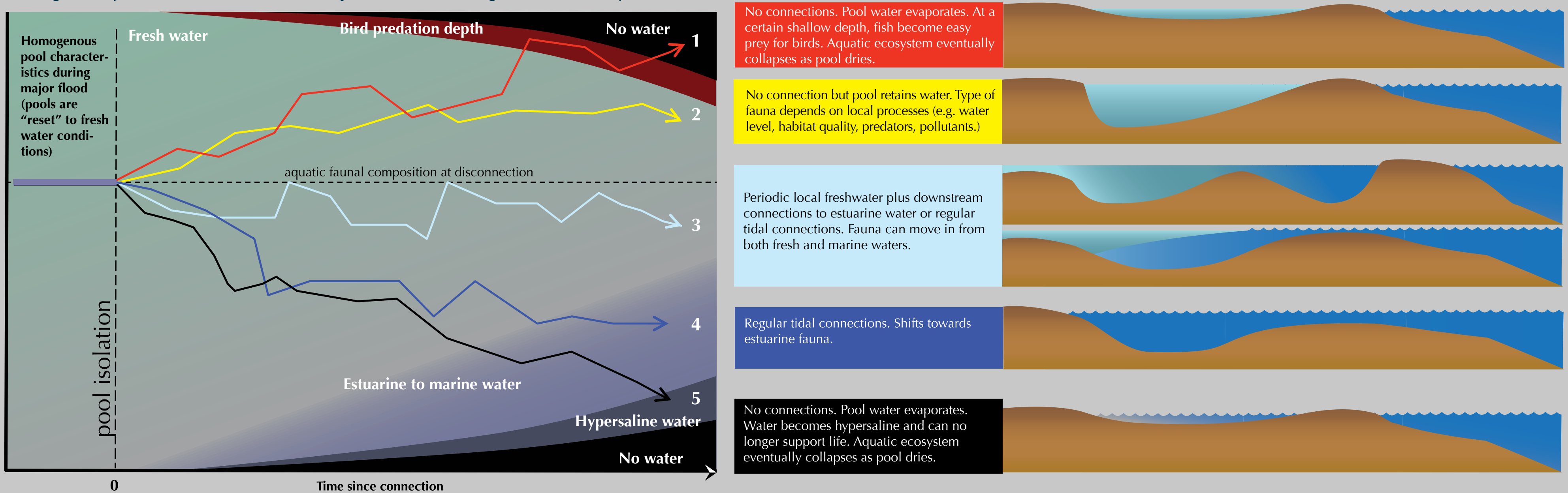
The timing of flood connections is crucial for the successful use of the pools as nurseries for marine fish. Marine fish generally spawn at particular times of the year. Their larvae live and grow in the upper levels of estuarine and coastal waters for just a few weeks. Then they must move to appropriate juvenile habitats (a process termed *recruitment*). Consequently, they are available to enter pools only for part of the year, so if physical connections do not occur at these times of the year, no biological connection can occur for fish.

Birds, on the other hand, provide a continual biological connection between the wetlands pools of all types, flying among them to partake of available food and habitat resources. For birds, the timing of *disconnection* is important:

- As different pools become isolated and move towards collapse of the aquatic ecosystem, a critical point is reached when their fish population is highly available for bird predation.
- Because different pools reach this stage at different times across the landscape of the Fitzroy wetlands, the availability of fish to birds is eked out across time.
- For birds, roosting habitat is important as well as places to feed.
- When there are no fish in the pools, birds may still roost there and eat food other than fish, such as arthropods, amphibians and reptiles, or they may eat fish from other pools.
- Birds are responsible for very broad biological connectivity across Australian (and international) landscapes.

Another important aspect of the time dimension is the way pools develop *through* time. After a major flood event, the pools eventually become isolated once more. Then the development of their individual ecosystems diverges in interesting ways. The degree of connection, whether water sources are fresh or salt, and pool depth, are the main factors driving these divergent trajectories.

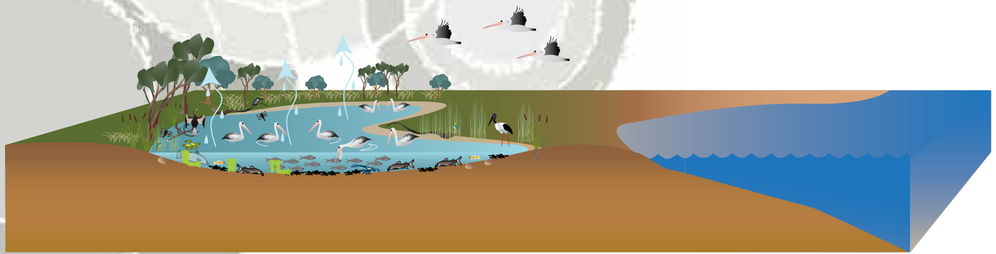
Divergent trajectories of coastal wetland pools when no longer connected by flood waters



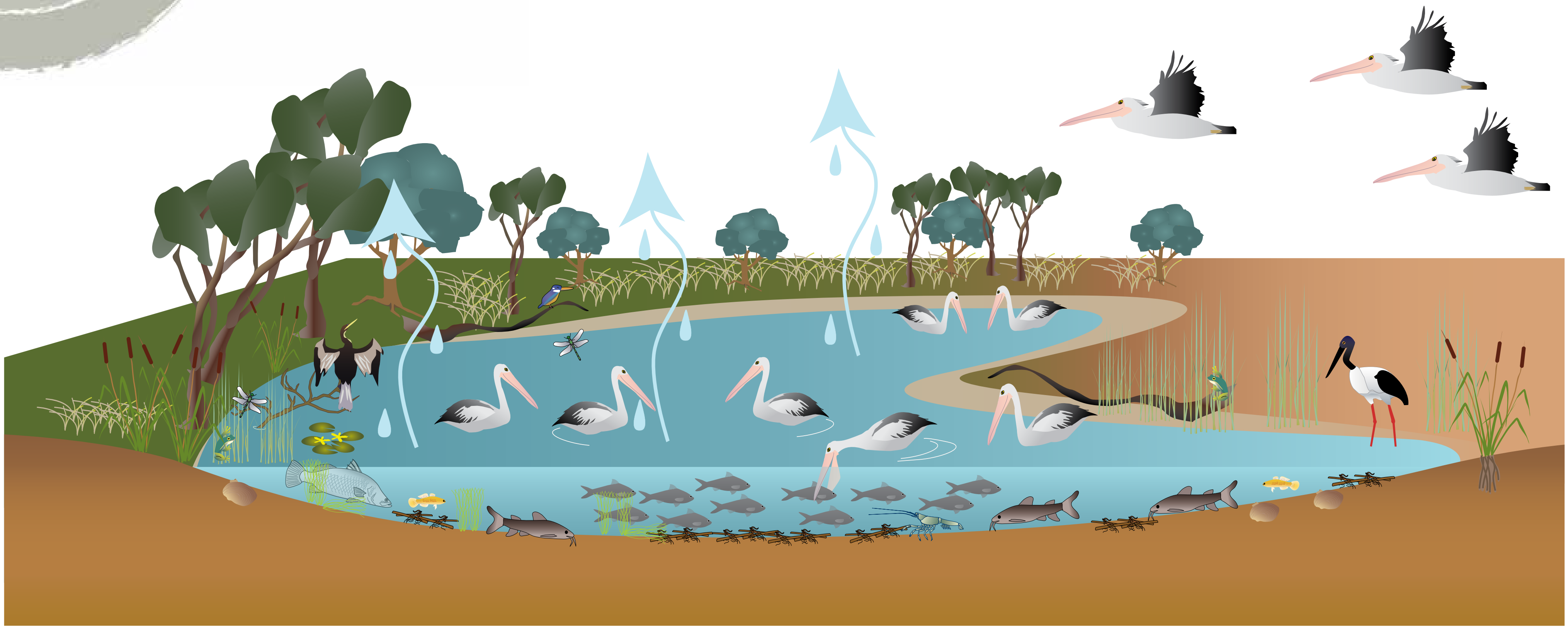
Major floods fill all the wetland pools with fresh water. Once the floods recede and the pools are again isolated, the faunal composition of each wetland pool follows an erratic trajectory, depending on local inputs of fresh or saline water; however, the overarching factors of connectivity, salinity and persistence determine whether an aquatic ecosystem will be viable in the long term and what sort of ecosystem that will be.

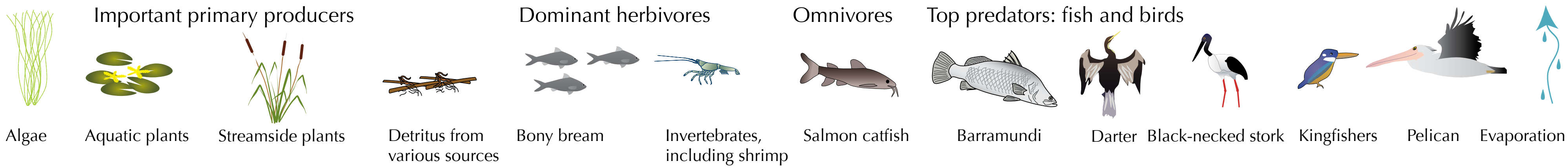
Illustration based on a model by M. Sheaves

1 Shallow, low-connection freshwater pool



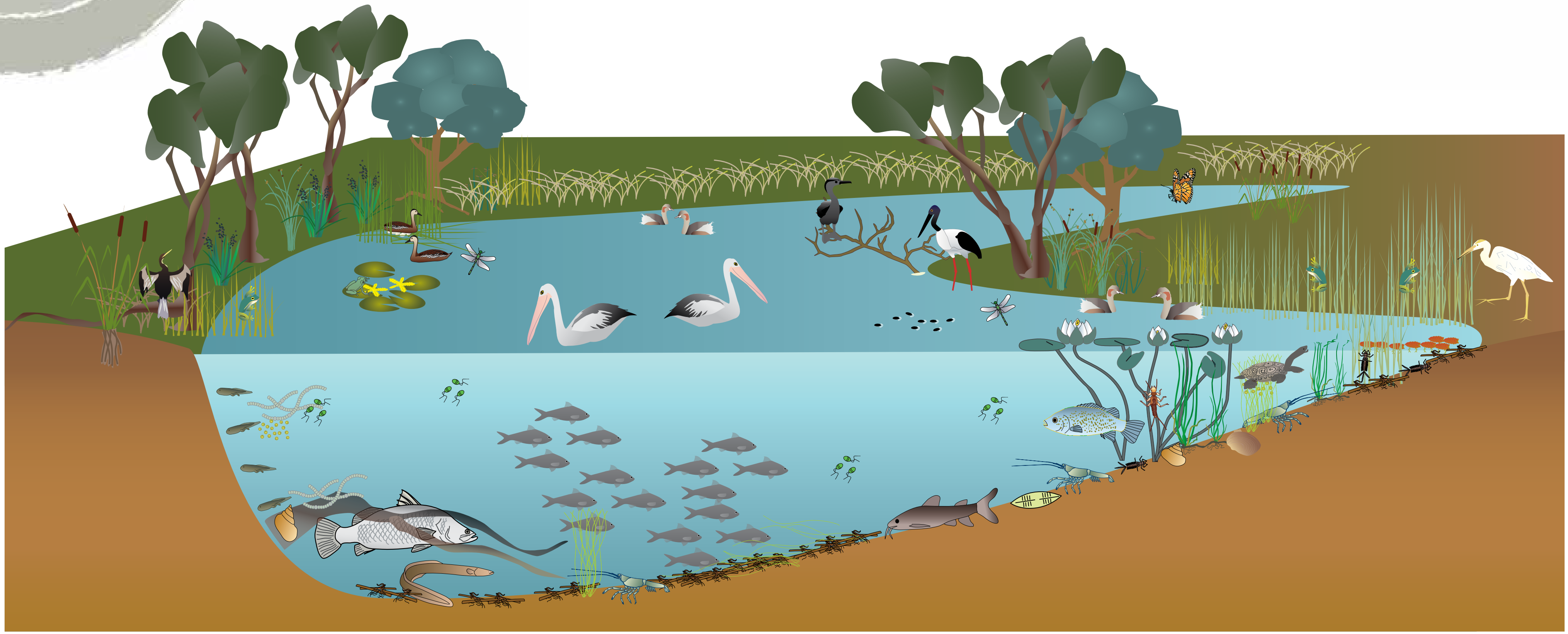
This shallow freshwater pool has been isolated since the last major flood and has reached the depth where pelicans can easily catch fish, so the pool has become a major exporter of energy (via well-fed birds). The bony bream tend to stay in the deeper areas but the water has reached such a low level that they are no longer safe anywhere in the pool. Many bony bream (*Nematolosa erebi*) have already been eaten and salmon catfish (*Arius graeffei*) are becoming more common. These omnivores will eventually be the most common fish species in the pool. If the pool does not soon connect with a source of water, the aquatic ecosystem will collapse.

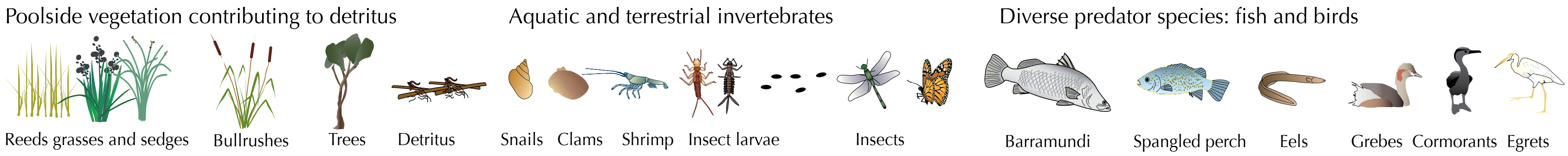




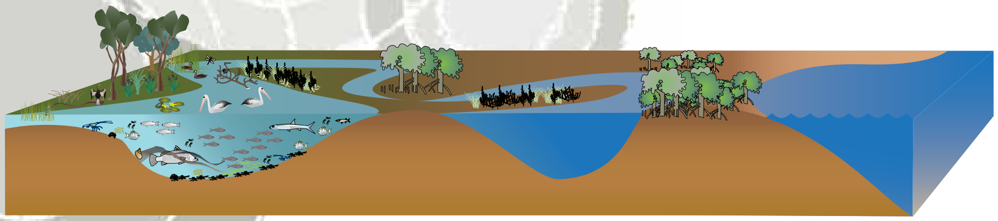
2 Deep, low-connection freshwater pool

This freshwater pool is also isolated, however, it is relatively deep and supports a thriving freshwater ecosystem. Terrestrial and aquatic plants, and algae, are the main primary producers. Bony bream are the dominant herbivore fish. They are prey to larger fish such as the spangled perch and the barramundi (the dominant predator fish). Fish-eating birds in this ecosystem include pelicans, grebes, darter, black cormorants, stork and egret. Egrets also prey on frogs, which are abundant. Ducks are breeding in the reeds. Aquatic and terrestrial invertebrates are also abundant and play an important role in the freshwater food web.

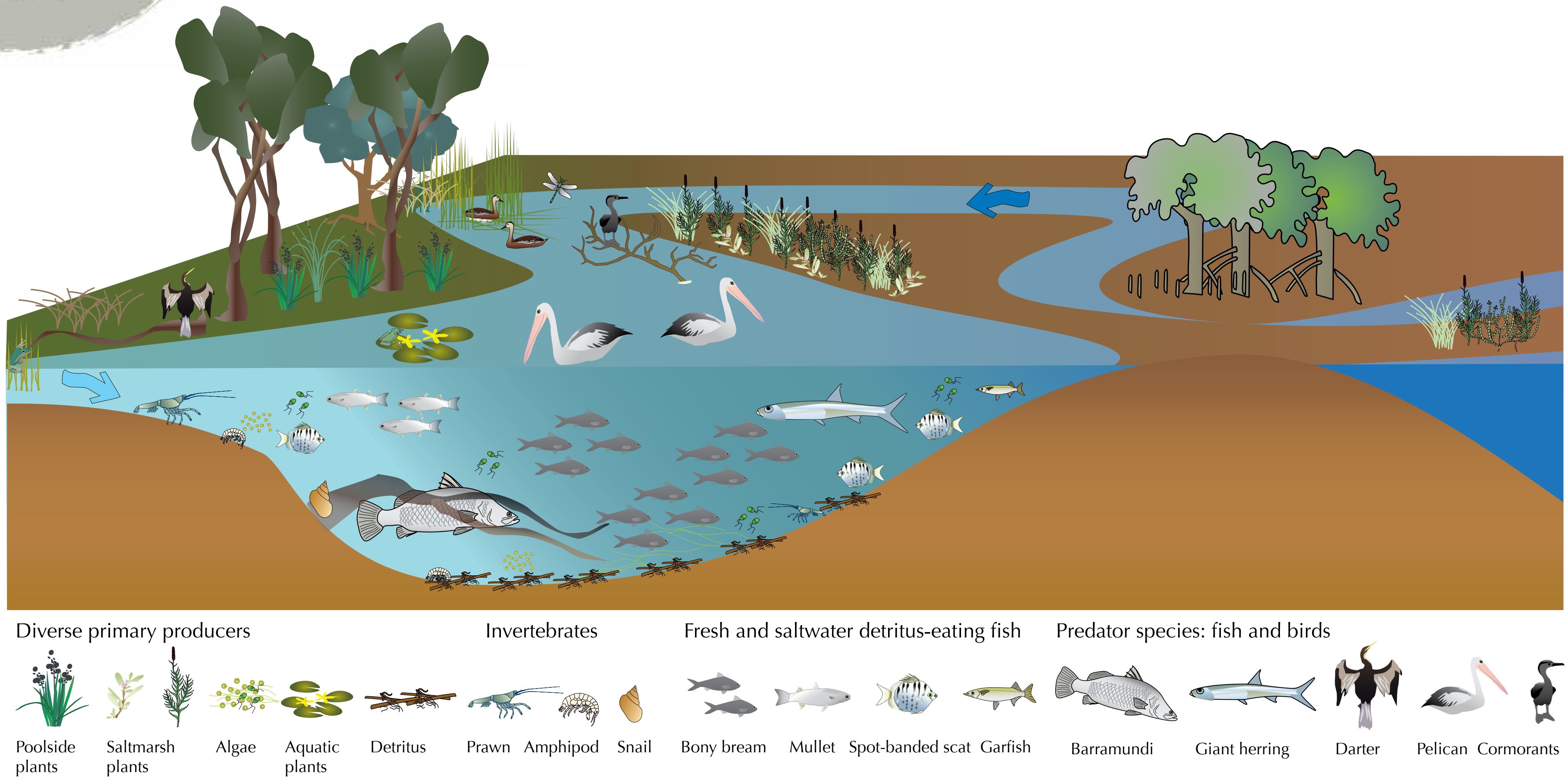




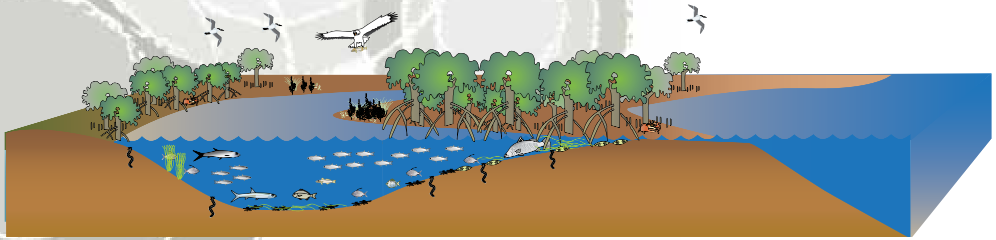
3 High-connection brackish pool



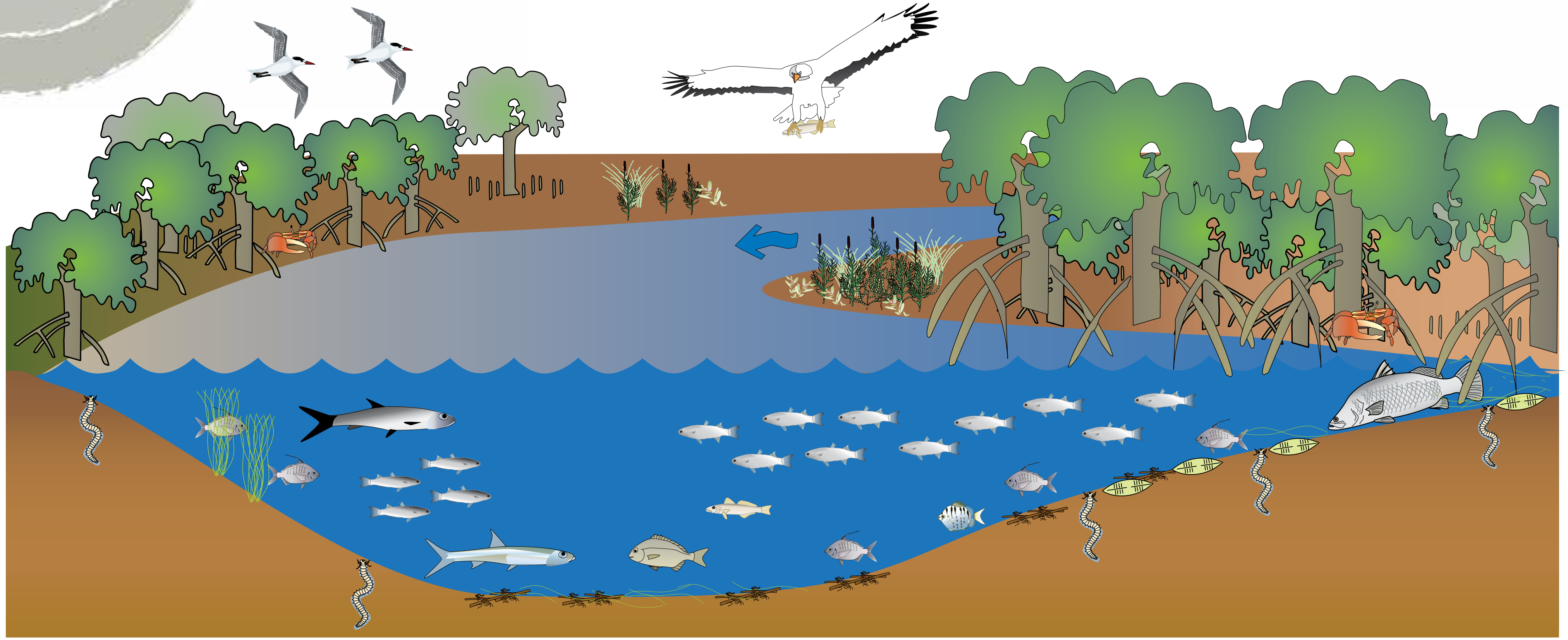
This pool is part of an estuarine wetland and is therefore highly connected to both fresh and saline water. Algae are important primary producers, as are saltmarsh plants such as salt couch (*Sporobolus virginicus)* and sea purslane (*Sesuvium portulacastrum)*. These, along with aquatic plants, make a significant contribution to the detritus eaten by herbivorous fish (detritus eaters). Bony bream are still the dominant herbivores, but the pool also supports a suite of marine and brackish species – mullet, garfish, spot-banded scat and giant herring (a marine predator fish). Barramudi are also present as are fish-eating birds – darters, pelicans and cormorants.

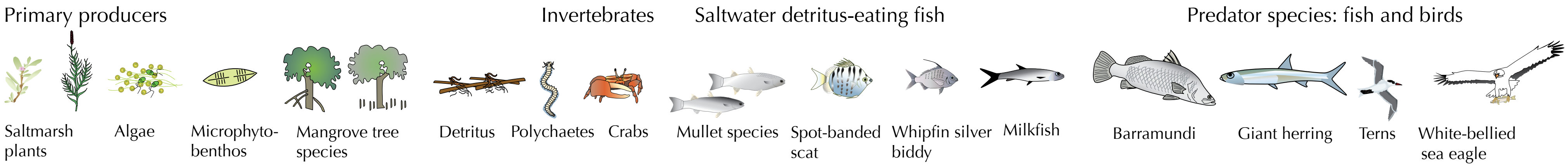


4 High-connection saline pool



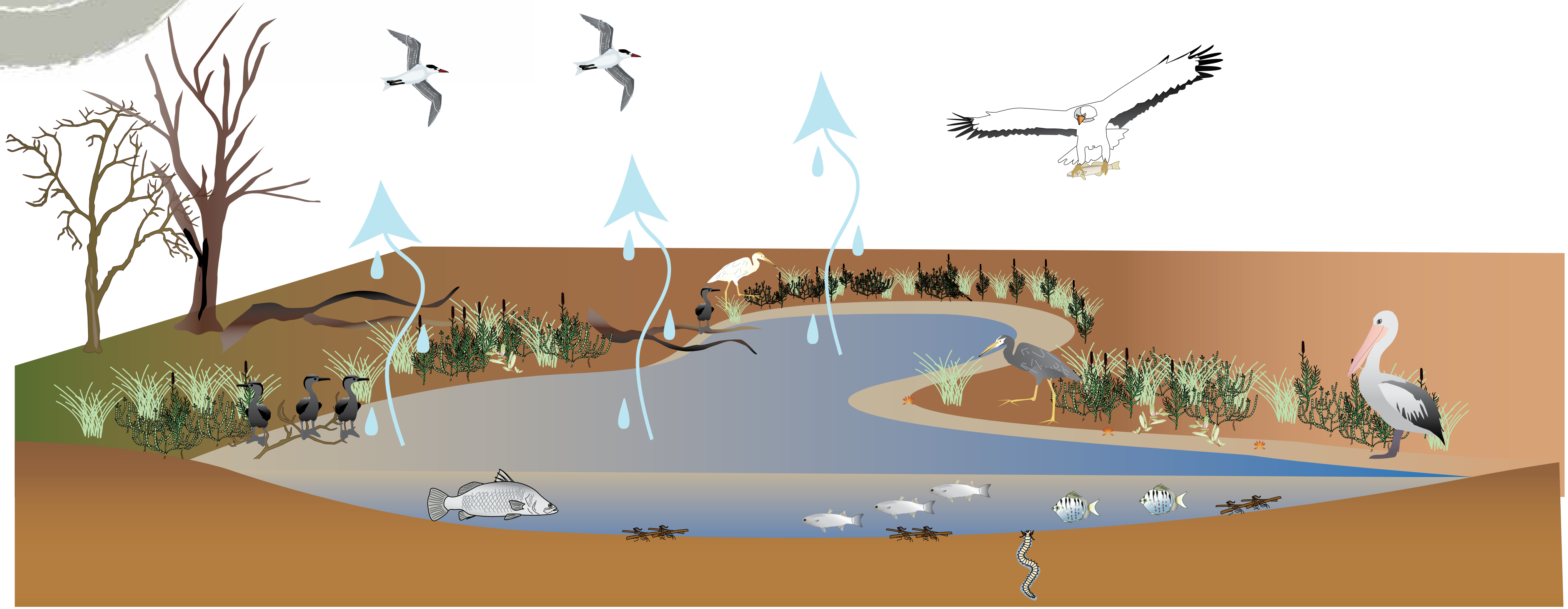
Saltmarsh plants and algae, including minute bottom-dwelling microphytobenthos are the main primary producers in saline pools. Detritus in these pools contains a large proportion of mangrove and saltmarsh plant material however, fish are not able to process the mangrove detritus, getting most of their nourishment from the saltmarsh fraction. Brackish and marine fish are abundant. Mullet, whipfin silver biddy and spot-banded scat are all detritus-eating herbivores. Barramundi and giant herring are predator fish. Among marine invertebrates, polychaete worms are dominant.

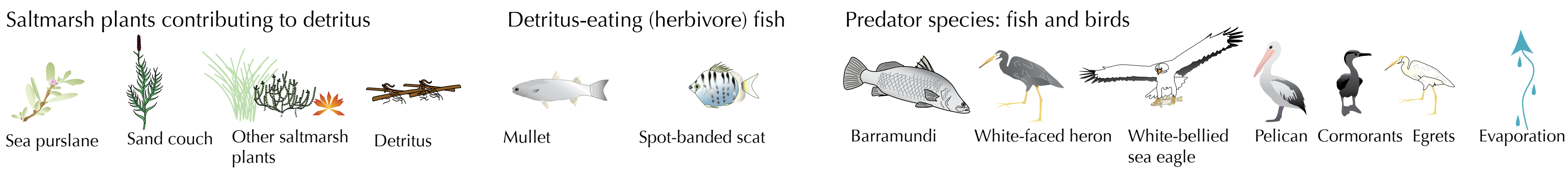




5 Shallow, low-connection saline pool

In this isolated saline pool, the water is evaporating rapidly and will soon become hypersaline. A diversity of predatory birds, including little black cormorants, pelicans, egrets, herons and terns, take advantage of the remaining fish. The aquatic ecosystem is heading for collapse. Even the barramundi in this pool will become bird food. Fish will not be able to recolonise the pool until it is again connected to salt water on an extreme high tide or if there is a major flood.





Food chains and webs

Food chains among the different types of pools are generally short with just three links – detritus to detritus-eating fish to carnivorous fish or birds. These short food chains in the Fitzroy wetland pools provide efficient energy transfer to top-level predators that take energy out of the system. Thus the pools are efficient exporters of nutrients and energy.

As with other characteristics, the pools' food web structures are related to differences in depth, salinity and connectivity. In saline and brackish pools, saltmarsh and algae are the main primary producers. The majority of plant material is converted to detritus and energy flows through detritus-eating fish or invertebrates before being exported at low but constant rates by birds and by fish leaving the pools during connection events.

In freshwater pools, poolside terrestrial plants, aquatic plants and algae are the main primary producers. Again, these are consumed by detritus-eating fish. Unless freshwater pools are connected to other waters, energy can be exported from these pools only via birds. Energy export can be slow and constant if the pools are deep, or rapid if the pools are shallow enough to reach the point where birds have access to all the available fish. Soon after this happens, the pool will dry up and the aquatic ecosystem will collapse.

Photo: Jonathan Harrod

When pool water levels fall below a certain depth, fish living in them become easy prey to birds such as this greater egret that has skewered a small fish.

Roles and importance of some fish species

Plant and detritus eaters (herbivores)

Bony bream (*Nematalosa erebi*) is the keystone species (critical to ecosystem functioning) in dry tropics wetlands with a saline influence, including the Fitzroy wetland pools. Important facets of this fish's role include:

- It is the only major plant or detritus-eating fish spawning in fresh water.
- In pools where it is found, it dramatically dominates the faunal biomass (the total weight of living animals).
- Its importance has been under-appreciated because it lives in the deeper water and is usually not found around the edges of pools where most sampling has been done. This may be a strategy to avoid predators (including biologists with nets).
- In floods, many bony bream are washed downstream. They cannot spawn in brackish water but they are a food source for barramundi and other predatory fish.
- There is no equivalently important species in salty pools. Here the herbivore/detritivore role is shared among several species (for example various mullet species).
- Invertebrates can also have a role as primary herbivores, for example long-armed prawns can fulfill this role in freshwater pools.

Predatory fish

- Barramundi (*Lates calcarifer*) is the dominant and most popular (for fishing) of the predator species.
- Other important predators in the Fitzroy saline pools are the giant herring (*Elops hawaiiensis*) and tarpon (*Megalops cyprinoides*).
- These predator fish may have mechanisms that let them tolerate low oxygen levels, for example the tarpon has an open swim bladder and can breathe air.

Unlike the herbivores, individual predators are not keystone species in these wetland ecosystems. One species can be replaced by another. Top-level predators can be fish or birds or mammals (e.g. people). On the other hand, plant and detritus eaters such as the bony bream, whose biomass dominates the herbivore level of the food chain, are very important. The impact of losing one species such as the bony bream can be indirect as well as direct, for example, predators will target other fish if they cannot get *N. erebi*, thus depleting the numbers of these other species as well.

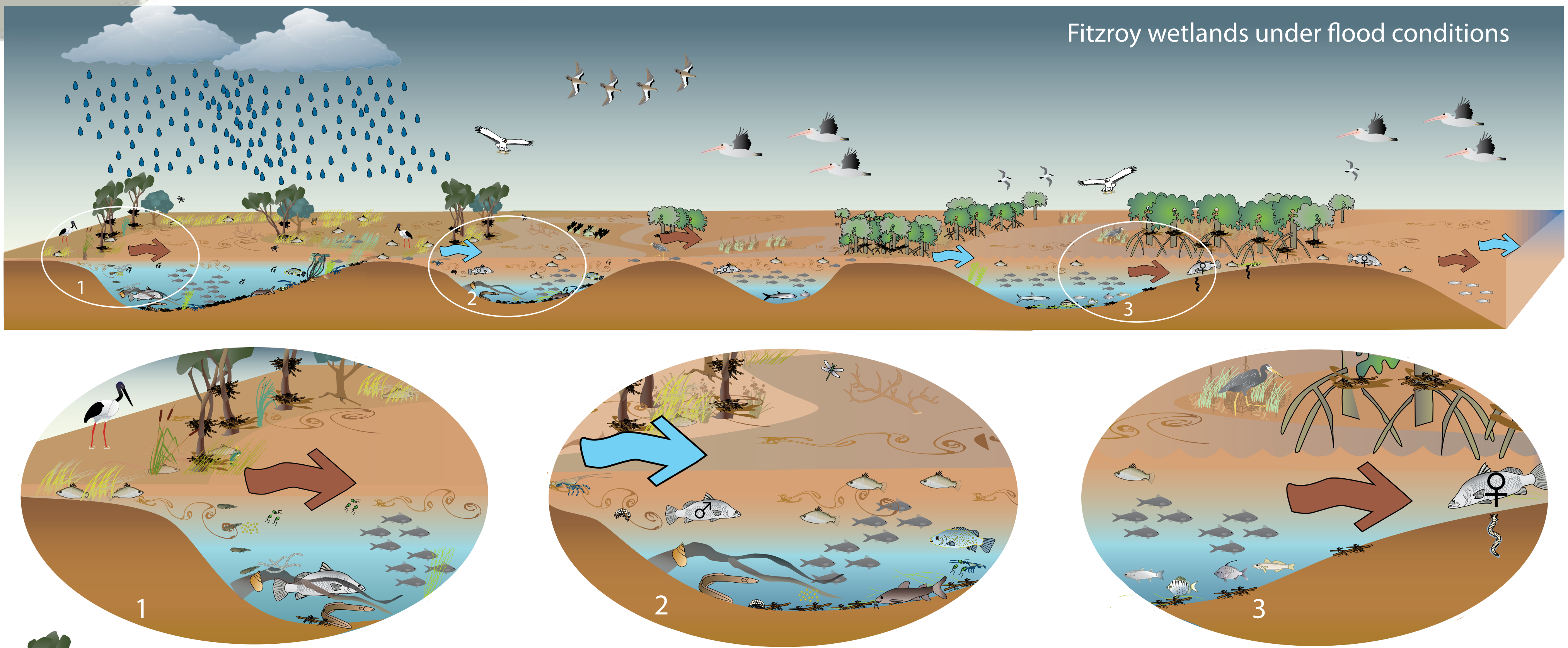
What happens to the Fitzroy wetland pools in major floods?

Parts of the floodplain that are wet *only* during major floods may hold the key to the high productivity of dry tropics coastal wetlands, including the Fitzroy coastal floodplain wetlands. These are places critical to wetland function but are not wet often enough to be classified as wetlands under current classification schemes.

When the paddocks and other vegetation on the Fitzroy coastal floodplain are flooded for more than two months, juvenile fish are abundant, widely dispersed and difficult for predators to find (in contrast to times when they are confined to pools). At this important time of their life cycle, they are in places not classified as wetlands.

While the highest production levels of species such as barramundi occur after major floods, it may be that the fish living in pools are a safeguard population for drier times.

In addition to stimulating high productivity in fish and invertebrates, floods are the major influencer of the salinity variations in the wetland pools. They play an important role in 'resetting' the pools back to freshwater conditions.



Trees with flood debris

Juvenile fish hide in flooded vegetation.

Sediment transport

Fresh water

In floods, all pools are repopulated by freshwater fish species.

Swirling muddy water

In major floods, mature male barramundi swim downstream while juveniles swim upstream.

Saltwater fish lurk at the bottoms of pools where the water may be stiller and/or saltier.

Female barramundi are ready to spawn at the estuary mouth.

Barramundi in the Fitzroy coastal floodplain wetlands


Photo: R. Johnston

Barramundi ***(Lates calcarifer)***

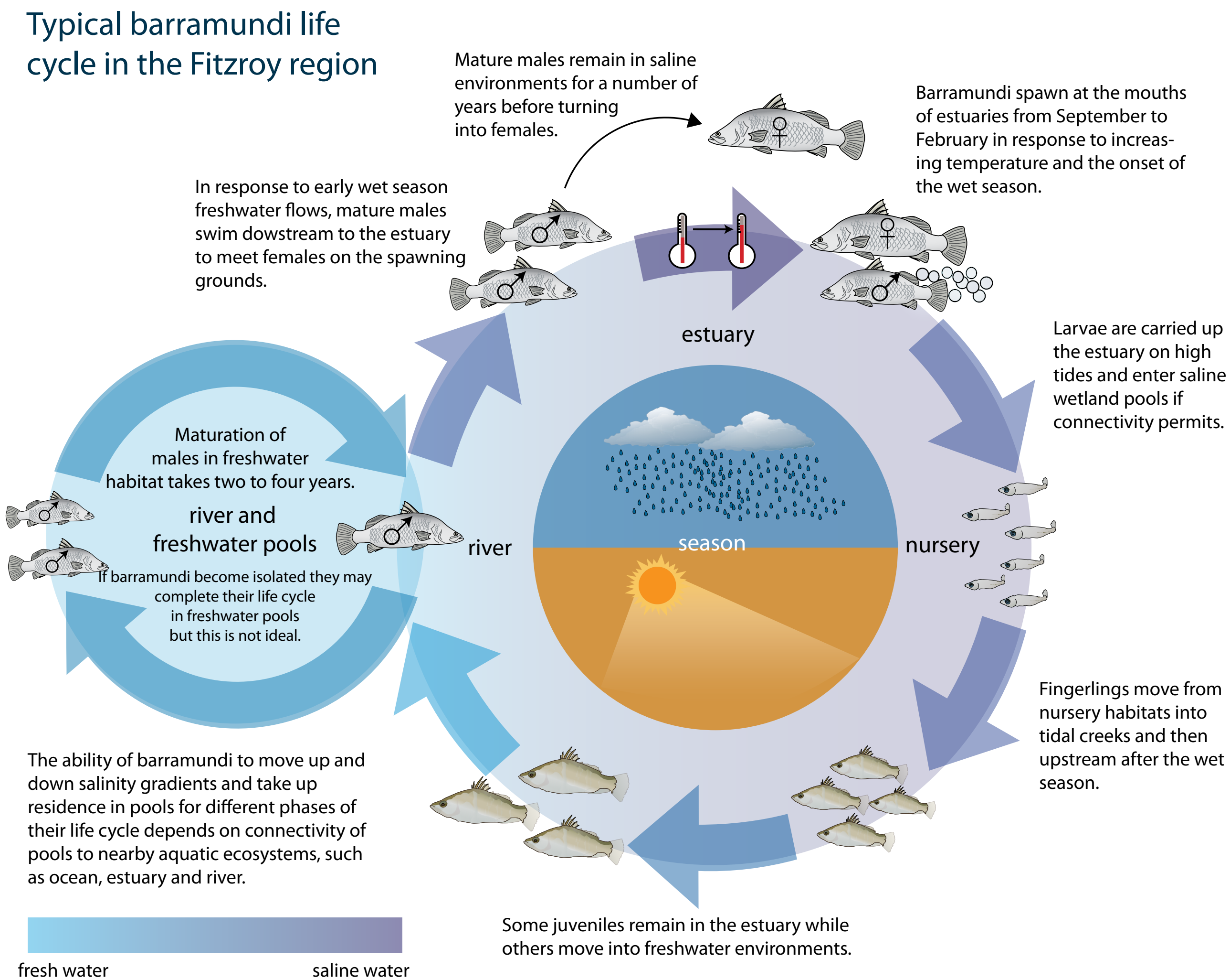
The barramundi or 'barra' is an important commercial and recreational predator fish living in estuaries and freshwater wetlands throughout southern and south-east Asia, Papua New Guinea and northern Australia. It is an iconic and much prized fish in the Fitzroy River system.

The barramundi is 'catadromous', that is, it tends to live in fresh water and migrate to saline water to breed. Studies of minerals in the ear bones (otoliths) of barramundi have shown that this species tolerates a wide range of salinity conditions. Some populations spend their entire life cycles in estuaries, without a freshwater phase. Others have predominantly freshwater life histories, as happens if they become stranded in isolated lagoons or river reaches. However, research suggests that the survival and growth rates of juvenile barramundi are higher in years when early juveniles from estuarine areas can access freshwater habitats.

The role of coastal floodplain wetlands in the life cycle of the barramundi is a topic of considerable scientific and community interest in the Fitzroy region and in other dry tropical parts of Queensland. Barramundi spawn in the mouths of estuaries. Subsequent tidal connections to saline wetland pools enable barramundi fry to access these pools as nursery habitat. Barramundi are known to time their spawning to coincide with the highest tides, thus maximising access to these nursery areas. On the other hand, freshwater connectivity maximises the available habitat for barramundi in later life-stages, when they prefer to be in fresh water.

Major floods in the Fitzroy estuary are strongly correlated with subsequent high catch rates of those barramundi that hatched in the year of the flood. In other words, in flood years, more baby barramundi survive, eventually to become catchable adults, than in non-flood years.

Typical barramundi life cycle in the Fitzroy region



Research suggests this is because prolonged inundation of the floodplain, along with high connectivity of freshwater wetlands, gives subadult and older juvenile barramundi better access to safe and productive freshwater habitats. Another possibility is that major flooding allows barramundi that have reached maturity in deep isolated freshwater pools the opportunity to migrate to the mouths of estuaries, where they may participate in spawning. This is supported by reports of two spawning peaks for barramundi in flood years. The second peak would represent spawning by landlocked fish released by floodwaters.

The following climatic events have been found to affect the barramundi fish catch:

- High sea surface temperature between January and March increases spawning rates.
- Winter rains, as well as high rainfall and river flows between January and March and high sea surface temperature between January and March increase survival of larvae.
- Winter rains, as well as high rainfall and river flows between January and March increase the survival of fingerlings and juvenile barramundi, while high annual evaporation rates decrease the survival of barramundi past this life-stage.
- An early start to the wet season with high flows between October and December, as well as persistent rainfall throughout the season, increases the number of mature male barramundi returning to estuary mouths to breed and entering the commercial fish population.

Many of these climatic factors are related to the major dimensions of connectivity, salinity and pool persistence that determine the ecology, not only of barramundi, but of all Fitzroy coastal floodplain wetlands plants and animals.

Waterbird habitat values of the Fitzroy floodplain wetlands

The Southern Fitzroy floodplain wetlands are listed in the National Directory of Important Wetlands in Australia. The wetlands provide important bird habitat consisting of:

- diverse mosaics of wetlands ranging from permanent deepwater habitats through to ephemeral swamps that support migratory shore birds listed under the Japan–Australia Migratory Bird Agreement (JAMBA) and the China–Australia Migratory Bird Agreement (CAMBA)
- regionally significant breeding populations of waterfowl including cotton pygmy geese, swans, black-necked storks, magpie geese and brolgas
- a seasonally dry environment but with a number of permanent freshwater lagoons and at least one perennial stream fed by groundwater
- habitat for a number of waterbird species listed as 'near threatened' under the Nature Conservation Act 1992 (Qld) including the radjah shelduck (***Tadorna radjah***), black-necked stork (***Ephippiorhynchus asiaticus***) and cotton pygmy goose (***Nettapus coromandelianus***).

Photo: R. Johnston

Photo: A. Chapman

Photo: M. Kibby

Fitzroy floodplain wetlands birds: magpie goose (***Anseranas semipalmata***) (top), plumed whistling-duck (***Dendrocygna eytoni***) (above) and sharp-tailed sandpiper (***Calidris acuminata***), a migratory wader bird from Siberia (left)

How environmental modification by humans has impacted the Fitzroy wetland pools

Key environmental threats to the Fitzroy coastal floodplain wetlands are:

- loss of connectivity between freshwater and marine habitats and among aquatic habitats more generally
- reduced (or poor) water quality due to soil erosion and inappropriate land use practices
- invasive and exotic weeds, especially exotic grass species used for ponded pastures
- fire regimes that damage native vegetation
- climate change.

The impacts of ponded pastures

The major land use adjacent to the Fitzroy wetland pools is cattle grazing. Development of the cattle industry has involved the modification of vast areas of land to create pondage systems for pasture development in low-lying areas, particularly coastal areas, to complement more extensive grazing practices.

Photo: Graham Pritchard

The ponded pasture plant ***Hymenachne*** is now listed as a weed of national significance.

To create ponded pastures, earth banks (bunds) are constructed, impounding fresh water. Grass species adapted to growing in wet conditions are planted. While the use of ponded pastures greatly increases grazing productivity in coastal central Queensland, this land use contributes to the key environmental threats listed above:

- The creation of bunds in sensitive locations alters the habitat structure, interfering with connectivity and reducing the area under saline influence.
- The most popular exotic ponded pasture grasses – para grass, aleman grass and hymenachne – are now considered to be environmental weeds because they are fast growing and invasive and clog waterways and wetlands. *Hymenachne amplexicaulus* has been declared a pest plant under state legislation as well as being listed as one of 20 weeds of national significance (WONS).
- Para grass, now widely spread throughout Queensland's wetlands, burns much hotter than native vegetation. The resulting hot fires often kill native stream-bank (riparian) vegetation, an important component of wetland habitats.
- As the global climate continues, on average, to warm and the sea level rises, shoreline habitats will tend to retreat landwards. Existing ponded pasture bunds may disrupt the ability of habitats to adapt in this way, potentially leading to habitat loss. Saline intrusion will be a major issue for property holders as the sea level rises.

Ponded pasture systems are generally shallow and unshaded. Water quality in the ponds is periodically poor with high temperatures, low dissolved oxygen levels and pH levels well into the alkaline range. Typically the ponds empty completely during the sping dry season. As a consequence, juvenile fish, including barramundi, that enter pasture ponds in the wet season are trapped in hostile conditions as the weather dries.

Poorly planned and located pasture ponds disrupt natural freshwater drainage. Ponded pasture bunds built below the highest astronomical tide level disrupt the inflow of seawater. In such cases, they interfere with the connectivity of the coastal floodplain wetlands and limit the movement of fish, such as barramundi, that migrate through the wetland system during their life cycle.

The adverse impacts of ponded pastures in and adjacent to intertidal areas, across watercourses and in areas of high conservation or fish habitat value have been officially recognised with policies to restrict such development. Para grass, aleman grass and hymenachne are no longer recommended for use in ponded pastures.

The impacts of climate change

The Fitzroy floodplain wetlands pools provide a diversity of special and often unique habitats, with each pool supporting a fauna that reflects its connectivity and salinity conditions. Individual wetland pool habitats are fragile. Their characteristics are determined by small differences in height relative to tide levels and by specific climate patterns. Even small changes in these factors will change the nature of the pools.

The predicted impacts of climate change include:

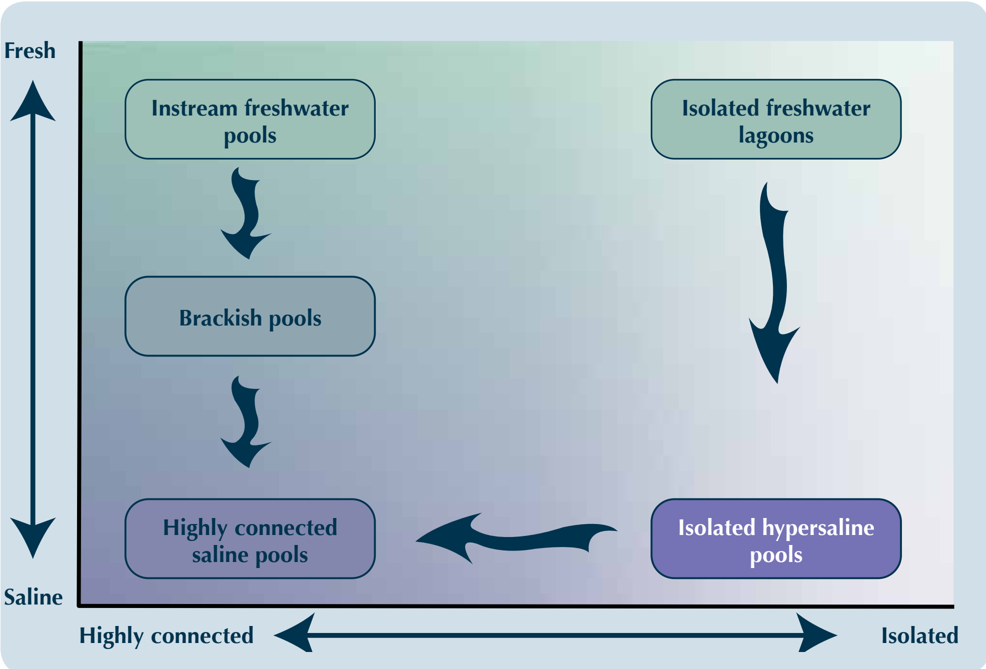
- increased climate variability with more extreme weather events

- higher temperature and higher evaporation rates
- changes to winds and atmospheric pressure which are important in determining the timing and height of tides
- sea level rise
- ocean acidification.

These changes are likely to have a profound influence on the total area of wetland pools available, the natures of individual pools and their quality as habitats. Climate change impacts on pools will not just affect the species using the pool habitats but also other coastal and off shore ecosystems linked to the wetlands by the movement of organisms and nutrients.

One likely impact of climate change is alteration of the distribution of pool types, along with the fauna and flora that characterise each type. Ecological communities will move to new areas as climate conditions shift.

For example, sea level rise will increase marine connectivity by making the connections deeper and more frequent, while also creating marine connections to freshwater pools that currently have none. The overall trend is towards greater marine connectivity and increased salinity. Brackish pools will become more saline and low lying freshwater pools will become brackish. Isolated pools that tend to become hypersaline will be connected more often and better able to resist drying out, while some isolated freshwater lagoons will move towards more saline conditions.



Connectivity and salinity interact to determine the nature of wetland pools. As the sea level rises due to climate change, pools will tend to become more saline and to be more connected by the sea. These trends are indicated by wavy arrows. (Adapted from Sheaves et al, 2006)

The extreme sensitivity of these environments to sea level rise of even a few millimetres offers the possibility of using changes in wetland pools to monitor sea level rise. For example, changes in fish assemblages in selected pools could indicate the rate ecological change due to sea level rise.

The greatest impacts of climate change are likely to result from the interaction between climate change and people's attempts to adapt to such change. For example, one possible response of coastal land managers is to build levee banks and weirs to prevent seawater from intruding. This will reduce wetland connectivity – already severely compromised in the Fitzroy coastal floodplain wetlands – componding the impacts of climate change themselves.

While individual pools are vulnerable, coastal habitats as a whole are resilient to climate change, provided they have the opportunity to retreat inland and provided connectivity can be maintained. Habitats need 'room to move' if they are to continue providing important services such as supporting fish throughout their life cycles. With so much development so close to the coast, finding this 'room to move' will be a challenge.

Common and scientific names of species

Bullrush	***Typha orientalis***
Salt couch	***Sporobolus vitginicus***
Sea purslane	***Sesuvium portulacastrum***
Para grass*	***Brachiaria mutica***
Aleman grass*	***Echinochloa polystachy***
Hymenachne*	***Hymenachne amplexicaulis***
Barramundi	***Lates calcarifer***
Bony bream	***Nematolosa erebi***
Salmon catfish	***Arius graeffei***
Spangled perch	***Leipotherapon unicolour***
Spot-banded scat	***Selenotoca multifasciata***
Whip-fin silver biddy	***Gerres filamentosus***
Giant herring	***Elops hawaiensis***
Milkfish	***Chanos chanos***
Tarpon	***Megalops cyprinoides***
Pelican	***Pelecanus conspicillatus***
Darter	***Anhinga anhinga***
Black-necked stork	***Ephippiorhynchus asiaticus***
Brolga	***Grus rubicunda***
White-faced heron	***Ardea novaehollandiae***
White-bellied sea eagle	***Haliaeetus leucogaster***
Magpie goose	***Anseranas semipalmata***
Cotton pygmy goose	***Nettapus coroamandelianus***
Plumed whistling duck	***Dendrocygna eytoni***
Radjah shelduck	***Tadorna radjah***
Black swan	***Cygnus atratus***
Sharp-tailed sandpiper	***Calidris acuminata***

*exotic species

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Photo: R. Johnston

German Jack's Lagoon, a Fitzroy floodplain wetland pool with infrequent marine and freshwater connections

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