Technical note supporting the River Murray: Fish Passage Trend and Condition Report Card

DEW Technical note 2018/18

Government of South Australia
Department for Environment and Water

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GPO Box 1047, Adelaide SA 5001

Telephone National (08) 8463 6946

International +61 8 8463 6946

Fax National (08) 8463 6999

International +61 8 8463 6999

Website www.environment.sa.gov.au

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Summary

The fish community of the River Murray has been severely impacted since the development of the River as a resource. Current estimates are that native fish populations are at approximately 10% of the pre-European settlement population levels. Since 2000 there has been a considerable push to improve populations of native fish in the River. The Native Fish Strategy was a key Australian Government plan to improve fish populations to 60% of pre-European levels. This plan identified 13 key issues that needed to be addressed for the recovery of native fish populations. One of the key issues was fish passage in the river. The Sea to Lake Hume Program was instigated to add fishways to all of the major barriers to fish passage along the River from the barrages to Lake Hume. Since the completion of this program in 2013, more localised projects and programs operating under either the Basin Plan or state government initiatives have sought to improve the ability of fish to move through and around the River and its wetlands and floodplains.

This report assesses the ability of fish to move through the South Australian River Murray. Barriers to fish passage have been identified across the region. This information was used to identify the area that is available for fish to use, as a percentage of the total available area. The assessment focused on the permanently inundated portions of the River as a basis to focus on the longitudinal connection along the River. The lateral connection to floodplains and wetlands is also a critical component of improving fish populations and is a focus of major developments in the South Australian River Murray such as The Living Murray Program and South Australian Riverland Integrated Infrastructure Program.

The results from the analysis showed that the current state of fish passage in the South Australian River Murray is **very good**. Over 98% of the permanently inundated areas of the river are passable to fish. The trend was identified as **getting better** over the last 15 years as the ability of fish to traverse the River Murray has gone from being limited to reaches between the main weirs to complete passage from the Southern Ocean to Lake Hume. The last 2% still to be achieved represents areas of wetlands currently blocked or areas intentionally blocked off to protect wetland vegetation from the impacts of common Carp.

Future improvements to the fish passage will focus on the ability of fish to access the floodplains and wetlands.

1 Introduction

The *Natural Resources Management Act (2004)* has a requirement ''to keep the state and condition of the natural resources of the State under review." In order to consolidate the data collected around the state in to a simple, easy to interpret information source, the Department for Environment and Water (DEW) produces report cards for the state's natural resources. Previous rounds of report cards have reported against the targets in the South Australian Natural Resources Management Plan (Government of South Australia, 2012). However, for the next round of reporting, the report cards will not only seek to report on the state of the natural resources of South Australia, but will also form the main source of data for the State of the Environment Report.

The State of the Environment Report (SOER) is a legislated requirement under the *Environment Protection Act (1993)*. The SOER has several key assessments that need to be undertaken including:

- Include an assessment of the condition of the major environmental resources of South Australia 112(3(a))
- Include a specific assessment of the state of the River Murray, especially taking into account the Objectives for a Healthy River Murray under the *River Murray Act 2003* 112(3(ab))
- Identify significant trends in environmental quality based on an analysis of indicators of environmental quality 112(3(b))

The River Murray has previously been part of the reporting process as it is a focal point of the state's natural resources. See the 2014 River Murray report cards here. However, the way that the river health has been assessed has continuously been adapted to reflect the needs of the reporting within the constraints of the available data and information. For the 2018 report cards, the River Murray report cards will be adapted to reflect the requirements of the SOER.

The *Environment Protection Act 1993* specifically refers to the *River Murray Act 2003* for the assessment of the health of the River Murray. Under the River Murray Act 2003 there is a series of objectives known as the Objectives for a Healthy River Murray (*River Murray Act 2003* 7(1-5)). These objectives cover a range of issues including:

- River health
- Environmental flows
- Water quality
- Human dimensions.

The suite of River Murray report cards for 2018 was developed with specific line of sight to the objectives for a healthy River Murray to facilitate both adequate reporting on the condition of the state's natural resources as well as the requirements of the SOER.

The seven report cards for the River Murray are:

- River Murray: floodplain trees (Tree condition index) Trend and Condition Report Card
- River Murray: Coorong and Lower Lakes vegetation (Vegetation target success) Trend and Condition Report Card
- River Murray: high value wetlands (Achievement of ecological targets) Trend and Condition Report Card
- River Murray: Murray Mouth (Days open) Trend and Condition Report Card

- River Murray: fish passage (Permanently wet area accessible) Trend and Condition Report Card
- River Murray: flow regime (Achievement of environmental water requirements) Trend and Condition Report Card

River Murray: water (quantity and quality) Trend and Condition Report Card

This report provides the background information, methodology and results that will underpin the 2017 River Murray Fish Passage Report Card. There are a total of 46 native fish species in the Murray-Darling Basin - including freshwater, estuarine, marine and migratory fish. These species of fish range in size, from small species of gudgeon through to the large Murray Cod, and also life history strategy, habitat preference and behavior (Lintermans 2007). Of the 46 species, 26 species are considered as either rare or threatened under state or federal listings. The fish of the Murray-Darling Basin play an important role in the riverine ecosystem, filling roles including apex predators and, prey as well as being part of the nutrient cycling process. Many native fish also form important parts of Indigenous Australian culture and histories. In addition, recreational and commercial fishing is an important social industry estimated to generate over $1 billion annually.

The barriers to passage of fish through the Murray–Darling Basin has long been recognised as a major issue affecting the health of the fish communities in the Basin. Native fish species move along the length of the River Murray for a variety of reasons including recruitment, locating critical habitat and protection from threats (Lintermans 2007). In 2001, the Murray-Darling Basin Commission instigated a program to improve the health of native fish populations in the Murray-Darling Basin (MDB). The Native Fish Strategy for the Murray-Darling Basin 2003-2013 (MDBC, 2003) identified that current native fish levels may be as low as 10% of pre-European levels and that barriers to dispersal are one of eight key threats to native fish populations in the MDB. The Native Fish Strategy has set the target of restoring native fish numbers to 60% of pre-European numbers through a series of management actions that include habitat restoration, improved flow management and improved fish passage (MDBC 2003).

The Murray-Darling Commission Native Fish Strategy was further developed as part of this process to guide and adaptively manage the implementation of fish passage in the River Murray. The Sea to Hume Dam program aimed to improve the longitudinal connection within the River Murray (MDBC, 2007). This program focused on making the 15 existing weirs and tidal barrages along the main channel of the River Murray between the Murray Mouth and Lake Hume passable for native fish.

Further to the Basin Plan objectives, and Basin-wide environmental watering strategy outcomes for native fish in the Murray Darling Basin, South Australia has specific objectives relating to the ability of fauna to move within the River Murray (Section 7(2)d). Subsequently, all additional infrastructure programs that have been undertaken in the River Murray in South Australia have considered the health of native fish populations and taken steps to improve the ability of native fish to access critical habitat such as flowing anabranches, wetlands and floodplains. Infrastructure programs for key wetlands in South Australia have had a strong focus on fish passage. The Living Murray Icon site at Chowilla has fish passage through all of its large regulators. Similarly, the proposed regulating structures at Pike and Katarapko will all allow for the passage of native fish. It is also important to note that in some cases fish have been deliberately excluded from wetlands or floodplains with the aim of protecting water quality or aquatic vegetation from the impacts of common carp.

Fish movement in the River Murray can be described as either longitudinal, moving along the length of the main river channel, or lateral, moving between the main channel and the wetlands, floodplains and anabranches. These two different types of movement are important for different species of fish at different life stages. For obvious reasons, the longitudinal movement of diadromous species of fish is important as they need to access the ocean to complete their life cycle. However, freshwater fish also move great distances along the river seeking optimal habitat. The lateral connection is somewhat more complex with species moving into different habitats for different reasons including breeding, feeding and protection. It is important to consider how the fish community is impacted by different barriers, and what type of movement they restrict. This report card will focus assessing trend and condition of longitudinal connectivity in the permanently inundated areas, with comment on the lateral connectivity.

2 Methods

2.1 Condition assessment

The assessment of condition of fish passage in the South Australian River Murray (SARM) is dependent on a multitude of factors and could be viewed as very different for different species. There are two main types of life history for fish in the SARM, fish that move between the marine and freshwater environment (diadromous) and fish that move solely within the freshwater environment (potadromous). Habitat connectivity requirements vary between both types of life histories, however, there is evidence that both travel large distances along the river (MDBC 2008).

Possible barriers to fish movement within the SARM have been identified along the River Murray Channel in South Australia. These barriers were classed as either allowing or blocking fish passage.. This was based on two aspects, firstly, the physical form of the barrier and secondly, if the barrier had any form of fish specific modifications. Fish specific modifications were either in the form of fishways, modifications that are specifically designed to allow for fish passage (such as baffles installed on structures to disrupt laminar flow), or fish screens, modifications designed to prevent fish from moving through a structure.

These infrastructure points were used to break the permanently inundated portions of the SARM including the permanently inundated and connected anabranches and wetlands into smaller areas that could be attributed as either free for fish passage, blocked from fish passage or partially blocked. The River Murray spatial layer used represents the permanently inundated sections of the Murray River permanently inundated and connected wetlands, anabranches and other waterbodies. The use of this layer means that some of the more temporary wetlands and floodplains will not be captured as part of this assessment. In the future, once the longitudinal connectivity has been reported and captured, these additional areas should be incorporated into the assessment. For more details on the spatial analysis, see Appendix.

If infrastructure has been installed to allow for fish passage, the implementation date was also attributed to provide the ability to assess changes in fish passage through time. This assessment does not take into account the variability of the habitat available for fish through variable water levels (natural or managed) or the habitat requirements of specific fish, rather provides a general picture of available aquatic habitat for fish outside of any 'events' when river level deviates from normal pool level.

The overall area of river channel, wetland and floodplain habitat that was identified as permanently inundated and connected together and ultimately, to the ocean, was assessed to provide a picture of the available habitat for all species of fish. The condition was assessed based on the percentage of area that was considered passable for fish compared for the available space using the WATER.RiverMurray layer as the baseline. Condition levels (Table 1) were developed for this report card and are based on objectives in both the Basin Plan and the *River Murray Act 2003* as well as the report card definitions for condition as set out in as part of the report carding process (Table 1).

Areas that were partially open were considered to be open for the condition assessment. The assessment used spatial analysis to calculate the spatial area of water available for fish as a percentage of the total inundated area as defined by the WATER.RiverMurray spatial layer. This was assessed overall as well as for the various sections of the River Murray.

Table 1: Condition assessment criteria for the 2017 River Murray Fish Passage Report Card

Condition assessment	Report card definition	Percentage of available area
Very good	The natural resource is in a state that **meets all** environmental, economic and social expectations, based on this indicator. Thus, desirable function **can be expected for all** processes/services expected of this resource, now and into the future, even during times of stress (e.g. prolonged drought)	98-100
Good	The natural resource is in a state that **meets most** environmental, economic and social expectations, based on this indicator. Thus, desirable function **can be expected for only some** processes/services expected of this resource, now and into the future, even during times of stress (e.g. prolonged drought)	90-97
Fair	The natural resource is in a state that **does not meet some** environmental, economic and social expectations, based on this indicator. Thus, desirable function **cannot be expected from many** processes/services expected of this resource, now and into the future, particularly during times of stress (e.g. prolonged drought)	65-89
Poor	The natural resource is in a state that **does not meet most** environmental, economic and social expectations, based on this indicator. Thus, desirable function **cannot be expected from most** processes/services expected of this resource, now and into the future, particularly during times of stress (e.g. prolonged drought)	<65

2.2 Trend assessment

The trend assessment was undertaken by considering how the amount of spatial area available for fish has changed over the last 15 years. Given the dramatic changes that have occurred, the assessment was taken based on overall changes and was not modelled.

2.3 Reliability

The reliability of the data was scored using the scoring system developed for the 2017 Report Cards. This scoring system uses four scores to assess different aspects of the data used to underpin the report card. Scores for all four are then averaged to determine the final score. The four scores categories are:

- Information currency
- Information applicability
- Spatial representation
- Information accuracy

Scoring was undertaken according to Table 2.

Table 2: Scoring system for the reliability of the information used to underpin the analysis for the River Murray Fish Passage Report Card.

Score given	Information currency	Information applicability	Spatial representation	Information accuracy
5	Information >10 years old	Data are based on expert opinion of the measure	From an area that represents less than 5% the spatial distribution of the asset within the region/state or spatial representation unknown	Better than could be expected by chance
4	Information up to 10 years old	All data based on indirect indicators of the measure	From an area that represents less than 25% the spatial distribution of the asset within the region/state	> 60% better than could be expected by chance
3	Information up to 7 years old	Most data based on indirect indicators of the measure	From an area that represents less than half the spatial distribution of the asset within the region/state	> 70 % better than could be expected by chance
2	Information up to 5 years old	Most data based on direct indicators of the measure	From across the whole region/state (or whole distribution of asset within the region/state) using a sampling design that is not stratified	> 80 % better than could be expected by chance
1	Information up to 3 years old	All data based on direct indicators of the measure	From across the whole region/state (or whole distribution of asset within the region/state) using a stratified sampling design	> 90 % better than could be expected by chance

3 Results

3.1 Trend

The trend in fish passage is classed as getting better. This is due to the dramatic increase in longitudinal connection through the South Australian River Murray. The installation of fishways on the main weirs over the last 10 years has meant that the connectivity has gone from having connectivity solely within each section of the river through to having connection from the Southern Ocean through to the border. This represents essentially complete longitudinal connection.

3.2 Condition

The condition results show that currently the available habitat area available to fish linked to the Murray Mouth is 98.5%, or approximately 124,276 km^2. This gives a current condition of very good. When each of the different sections of the river are considered the percentage of available habitat ranges from 83.9% (Lock 2 to Lock 3) through to 99.7% (Barrages to Wellington) (Table 3). The condition assessment for each of the reaches is shown in Figure 1 and Figure 2.

Table 3: Results from the spatial analysis of the permanently inundated area of the South Australian River Murray and the areas that are connected through to other reaches and the Southern Ocean.

Reach	Inundated area	Connected area	Percent connected	Condition
Wellington to Barrages	104754.90	104439.21	99.7	Very Good
Lock 1 to Wellington	7406.62	6679.18	90.2	Good
Lock 2 to Lock 1	2423.15	2143.80	88.5	Fair
Lock 3 to Lock 2	1652.72	1387.17	83.9	Fair
Lock 4 to Lock 3	5164.34	5016.87	97.1	Good
Lock 5 to Lock 4	2396.42	2306.24	96.2	Good
Lock 6 to Lock 5	1612.35	1585.66	98.3	Very Good
Border to Lock 6	732.63	718.44	98.1	Very Good
Overall	126143.16	124276.61	98.5	Very Good

Figure 1: Condition assessment of the fish passage of the reaches of the River Murray in South Australia based on the condition assessments provided in Table 1

This figure was modified for the report card, see report card contents below.

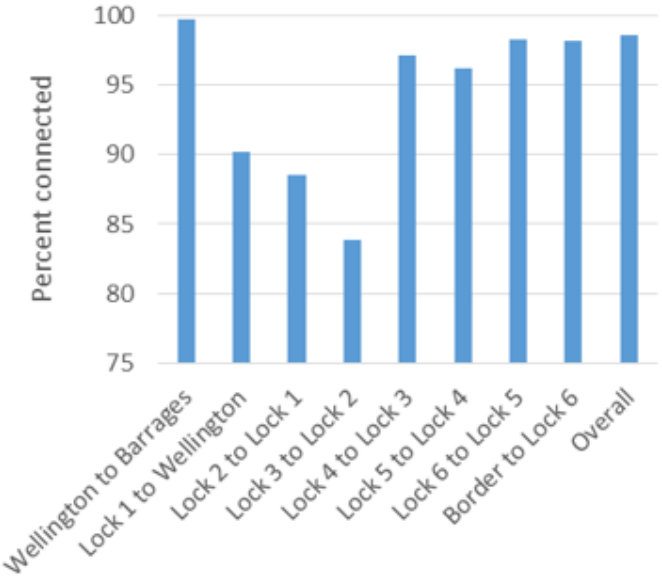

Figure 2: Percentage of permanently inundated area that is connected to the main channel, produced for the report card.

3.3 Reliability

The scores for each of the four guides along with justification is provided in Table 2.

Table 4: Results of the reliability assessment of the DTR data

Guide	Score	Justification
Currency	5	Data available up to date
Applicability	4	Data is a not a direct measure of fish passage. While there are programs that collect this data, they are not reported here. The measure used, that area of accessible habitat is a surrogate and makes assumptions about the level of use and effectiveness of fish passage structures. It also does not include an assessment of lateral connectivity to temporary habitats.
Spatial representation	5	Data covers the whole of the SARM
Accuracy	4	Spatial data may be an approximation of the locations and therefore the surface area calculated may not be exact. Variations in the water level will also affect fish passage, especially during high flow events where all infrastructure is inconsequential. It is also important to note that the base spatial layers are not complete and there are some areas of habitat that are not assessed as part of this assessment.

The overall reliability of the data is considered to be five out of a possible five. The accuracy of the data is limited by the spatial accuracy of the information contained in the spatial databases. The extrapolation of point data to polygon shapes is not exact and while care was taken to ensure no errors were made, there are over 500 individual pieces of infrastructure listed in the database, not including the Locks and the Barrages and error checking each individual point was prohibitive.

4 Discussion

4.1 Trend

The overarching trend across the record of data is upwards. The principal driver of this increase has been the installation of fishways at the barrages and weir between the Murray Mouth and the border. These structures represented the most significant barriers to fish passage as they fragmented the river into segments and stopped movement to the Murray Mouth.

It is clear that the Sea to Hume program has facilitated the longitudinal connection of the River Murray for fish. This connection is the likely reason for the increased numbers of diadromous fish species being found in the river, specifically Common Galaxias and Congolli (MDBA, 2017). This will also have been a factor in the increase in other larger-bodied native fish in the river as well by allowing them to disperse to new, potentially more favorable areas.

The lateral connections have become more of a focus since the last of the 15 major barriers were overcome. In South Australia there are several major areas of habitat that have been the focus of major planning and investment, including fish passage. Chowilla, The Living Murray icon site, has had extensive regulating structures installed to allow for the variation of water levels within the wetland and floodplain system for ecological benefit. As part of this, the regulators were fitted with fish ladders and rock ramps to ensure fish could access these habitats, especially during operation. Similar structures are proposed, or under construction at other key habitat sites along the South Australian River Murray including Pike and Katarapko under the South Australian Riverland Floodplains Integrated Infrastructure Program (SARFIIP).

There are other programs that are also focused on the lateral connectivity component of the fish passage story. The Riverine Recovery Project is a South Australian Government program that, in conjunction with the MDBA, is seeking to improve connectivity to many of the smaller wetland systems across the River Murray. Also, and importantly for this assessment, this program is also intentionally blocking off some smaller wetlands through the use of carp screens to facilitate localised wetland benefits. These areas were not accounted for in the analysis and it is important to acknowledge that achievement of 100% connected area is not desirable.

Lateral connections are not well evaluated as part of this assessment. This is due to nature of lateral connections and the habitat that is connected through these processes. The base layer used for this assessment is the permanently inundated areas of the River. Lateral connections to these permanent areas are important, however, there is no representation of the temporary habitats that are made accessible during times of higher flow/managed inundations. This is not to say they are any less important. It is also important to note that during inundations, managed or natural, these laterally connected areas will become significantly larger and this highlights the need for fish passage to allow fish to access these temporary habitat areas, and to be able to exit the areas once the water begins to recede. Given that the longitudinal connectivity is essentially as good as it will get, future assessments should focus on the lateral connectivity.

The trend from this point is set to continue to improve with the current investment in the South Australian River Murray. The longitudinal connection through the state is likely as good as it will get without major changes to infrastructure (removal of weirs etc.), however, the lateral connections should continue to improve through programs such as Riverine Recovery and SARFIIP.

4.2 Condition

The current condition of fish passage in the SARM is considered to be in a very good condition. As previously mentioned, it is important to note that this is based on an overall area of available aquatic habitat and makes no assumptions about the value of that habitat, i.e. all areas are considered equal. It is acknowledged that there are

some areas that are more important than others. These areas are likely represented by the smaller spatial gains that have been made since the implementation of the fishways on the locks and barrages.

There is no assessment made here of the effectiveness of the structures that have been installed to allow for fish passage. This is an active area of study with several studies showing that both native and non-native fish are using the fishways (e.g. Baumgartner et al., 2014). These studies identify that some species use the fishways more effectively than others. It is also important to note that the majority of fishways are designed for the larger bodied fish (Cod, Perch etc.). While they will allow for the passage smaller fish, there are different designs that better cater for small bodied fish such as those installed on the tidal barrages and trialled previously (Stuart et al., 2008). Improvements through time will allow for these structures to be optimised.

There is also a link to be made here to the reinstatement of environmental flows. Fish in the River Murray use flow as a cue for various behaviours including migration and breeding. One of the key outcomes of returning flows to the river is to ensure that these cues are met. This has a strong link to the ability of fish to move along the river and especially out into the floodplain and wetland habitats which form the spawning grounds for many native species. Therefore, there is a strong link with flow regime management and maximizing the effectiveness of infrastructure.

Overall, there is evidence that the native fish populations in the River Murray are improving. Key species such as the Macquarie Perch, Murray Cod and Trout Cod are showing signs of improvement across the length of the river and diadromous species such as Common Galaxias and Congolli are showing increasing numbers in the lower reaches of the river, specifically the Lower Lakes (MDBA, 2017). While this cannot be solely attributed to the increase in fish passage, the ability to move to optimal areas of habitat for breeding and growth are key for fish population recovery (MDBC, 2003).

5 References

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6 Appendix

Description of the methods used to calculate area of connected fish habitat

Purpose

The spatial analysis that is described in this appendix have been carried out to calculate the area of connected fish habitat along the River Murray and associated anabranches within South Australia. As part of this work fish habitat is described as areas of permanent water on the Murray River floodplain expected under normal flow conditions (WATER.RiverMurray).

Procedure

The spatial analysis methods described in this section was undertaken using ESRI ArcGIS Version 10.2. The processing has been compiled as a series of steps, implemented as custom tools developed using ESRI ModelBuilder. All tools were run from a custom ArcGIS Toolbox located in the following DEW network file share:

R:\DFW_CBD\Applications\GISData\Projects_Eco\NRM Region_MDB\RM_Report_Cards\tools\toolboxes

Toolbox name: 01_RM_ReportCard_ChannelConnectivity_00_Toolbox.tbx

Please Note: the aforementioned toolbox and compiled tools provide the most complete documentation of the spatial analysis methods followed for this work. The script tools have been developed in a way that they can be re-used if any of the input datasets are updated or improved in any way.

A series of ESRI file geo-databases for post-processing inputs / outputs were created (by the first tool) in the following DEW network share drive:

R:\DFW_CBD\Applications\GISData\Projects_Eco\NRM Region_MDB\RM_Report_Cards\spatial_data\gdb

All spatial datasets were processed to maintain the following spatial reference system:

Spatial reference: GDA_1994_South_Australia_Lambert

ESRI WKID: 3107 Authority: EPSG

A description of each tool is provided as steps below:

Step 001 – Create workspaces

This script tool creates three ESRI file geodatabases to compile input spatial layers for subsequent steps, as well as the workspace for all spatial layer and tabular outputs generated as part of this work.

Step 002 – Extract spatial raster data

This tool extracts the corporate spatial data layers required to undertake this work, including:

- River Murray main channel and anabranches (polygon features)
- River Murray wetland infrastructure locations (point features)
- River Murray lock reaches (polygon features); this layer was access from the South Australian Floodplain Information Package (February 2012) data compilation that was made available on DVD.

The tool also creates an empty line feature class to capture the blocking alignment for infrastructure locations depicted as point features:

River Murray wetland infrastructure blocking lines (line features)

Step 003 – Manual edits to infrastructure points

This step is not a geo-processing tool. The infrastructure point feature class was checked and edited, where required, to ensure the point features of mapped infrastructure corresponded with the most likely location using heads-up digitsing (HUD) techniques in ESRI ArcMap. The points were visually inspected against one of the following ortho-rectified high resolution aerial imagery datasets:

River Murray Lock 2-Border 29 Mar-6 Apr 2014 30cm (RGB)

River Murray 10-16 Mar 2008 50cm (RGB)

Step 004 – Manual edits to generate infrastructure blocking lines

This step is not a geo-processing tool. New line features were captured to represent the blocking alignment for infrastructure locations classified as 'blocked' for fish passage using heads-up digitsing (HUD) techniques in ArcMap. These features were created so that the line extended beyond the waterbody features the infrastructure was intended to block and passing through (snapped to) the blocking point location.

Step 005 – Import blocking lines and process waterbody polygons

This tool was developed to bring together the input spatial layers and create and output polygon feature class that represents the anabranches, back waters and any other waterbody connected to the River Murray main channel. To achieve this the following sub-steps were utilized:

a) The River Murray main channel and anabranches (polygon features) spatial layer was dissolved using the ArcGIS 'Dissolve' tool with the output layer having 'single parts' (polygons not connected to any other polygon feature generated as separate polygons).

b) The largest polygon from the dissolved River Murray main channel and anabranches spatial layer was selected using the ArcGIS 'Select' tool. The output polygon feature class in this layer was considered to represent all of the connected waterbodies possible along the River Murray, based on the input data layer, regardless of the presence of any blocking structures.

c) The River Murray wetland infrastructure blocking lines (line features) were buffered by 2.5 m using the ArcGIS 'Buffer' tool to generate a polygon feature to represent the alignment of the blocking structures that would not be passable by fish. These polygon features were then attributed with the same attributes as their corresponding blocking structure using the ArcGIS 'Spatial Join' tool.

d) The buffered River Murray wetland infrastructure blocking alignment polygon were then used to disconnect the corresponding waterbody sections (a 5 m wide slice) from the output of sub-step b (connected waterbodies possible along the River Murray) using the ArcGIS 'Erase' tool with an XY tolerance of 0.5 m. The output polygon feature class in this layer was considered to represent only the connected waterbodies along the River Murray, incorporating any disconnections imposed by blocking structures. This output feature class was the exploded into individual polygons for features using the ArcGIS 'Multi-part to Single-part' tool. The largest polygon from the 'single part' layer was selected using the ArcGIS 'Select' tool. The output polygon feature class in this layer was considered to represent only the connected waterbodies along the River Murray, incorporating any disconnections imposed by blocking structures.

e) The River Murray lock reaches (polygon features) layer was buffered by 25 m to generate an output polygon layer with a slightly larger extent footprint. This buffered layer was then spatially intersected with the layer output from sub-step d) [only the connected waterbodies along the River Murray, incorporating any disconnections imposed by blocking structures], using the ArcGIS 'Identity' tool. This was undertaken to provide additional attributes for the summarizing the length of the River Murray in South Australia into the weir pools imposed by the lock system and barrages.

f) The final area summary table was generated to incorporate the total areas of all permanent water on the Murray River floodplain expected under normal flow conditions (in hectares) as well as the area of only the permanent water determined to be connected (in hectares) and the percentage of the connected permanent water for each lock reach. This was compiled as a file geodatabase table using the ArcGIS 'Summary Statistics' tool and exported to Microsoft Excel using the ArcGIS 'Table to excel' tool.

Outputs

There were three main outputs from the spatial analysis component to identify connected fish habitat in the main channel and associated anabranches of the Murray River:

1. Infrastructure point feature class with the location of the structure checked against high resolution aerial imagery plus associated line feature class to depict blocking alignment across waterbody features for infrastructure classified as 'blocked' for fish passage.

2. River Murray main channel and anabranches polygon feature class (waterbody features) with a 2.5 m buffer (a total of 5 m wide) of the blocking alignment line feature class 'erased' to disconnect the polygon features at 'blocked' infrastructure locations.

3. A table (in both file geodatabase table and Excel format) that provides a summary for each of the lock reaches within South Australian section of the River Murray (state border to the barrages), including:

    a. Total area of permanent water (hectares)

    b. Area of connected permanent water (hectares)

    c. Percentage of connected fish habitat

Limitations

The spatial layers used for this work may have imposed limitations to the fish habitat area summary. It is assumed that the primary input layers (River Murray main channel and anabranches and the River Murray wetland infrastructure locations) accurately depict the connectivity of surface waterbodies associated with the River Murray floodplain in South Australia and any blocking structures that would provide a barrier the movement of fish species.