Stock Status Summary 2023

NSW Stock Status Summary – Murray cod (*Maccullochella peelii*)

Assessment Authors and Year

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Stock Status

Current stock status	On the basis of the evidence contained in this assessment, the NSW Murray cod fishery is classified as **depleted**.

Stock Structure & distribution

Murray cod *Maccullochella peelii* occurs throughout most of the Murray–Darling Basin (MDB), inhabiting a diverse range of river and lake systems. Murray cod is considered to be one biological stock, with one large genetically panmictic population throughout most of its distribution in the Murray–Darling Basin (Rourke et al. 2011). However, genetically distinct populations have been identified in the more isolated Lachlan, Macquarie and Gwydir catchments (Rourke et al. 2011). This separation appears to be the result of restricted gene flow due to the isolated nature of these catchments. Furthermore, the presence of barriers such as weirs and dams has resulted in fragmentation of some populations, with distinct populations likely operating within/ above impoundments and in the connected riverine environments below them.

The distribution and abundance of Murray cod is considered to be much-reduced compared to that of pre-European settlement levels in New South Wales (NSW) (Harris and Gehrke 1997, Kearney and Kildea 2001, Rowland 2005). Concerns about declining numbers date back to as early as 1880, primarily driven by decreasing catch rates within the commercial fishery (Rowland 1989). The initial decrease in their distribution predominantly took place in the upper reaches of rivers (Rowland 2005).

Biology

Murray cod is Australia's largest freshwater fish regularly reaching 1400 mm total length (TL) and a maximum recorded age of 48 years (Anderson et al. 1992, Rowland 2005). Murray cod become sexually mature at ~4 years of age depending on growth rates and environmental conditions. Sexual maturity in Murray cod is thought to be more dependent on age, not size. Females and a few males had matured by 3 years of age, but at 4 years of age, 77% of females (> 480 mm, 2.1 kg) and 72% of males (> 530 mm, 2.3 kg) were mature and at 5 years all females and most males were mature. All Murray cod larger than 590 mm and 3.9 kg in rivers were mature, but the smallest sexually-mature cod sampled from the impoundment, Lake Mulwala, was 610 mm and 5.0 kg (Rowland 2005). These data suggest that first maturity in Murray cod in most NSW waters is determined by age, not size. Therefore, roughly 70% of wild river Murray cod, with their slower growth rate, have reached sexual maturity by 500 mm in length. Spawning for Murray cod typically takes place during the warmer months, from late spring to early summer, when water temperatures rise. The exact timing can vary with latitudes and depending on local conditions, but it generally occurs when water temperatures reach around 15°C (Rowland 2005, Koehn et al. 2020, Butler et al. 2022). Absolute fecundity of Murray cod in rivers ranges from 6,800 (TL 480mm, weight 2.1kg) to 86,600 (1050mm, 22.7kg). Relative fecundity ranges from 3.2 to 7.6 eggs/g, and limited data

suggests it may decline with increasing size in fish over about 10 kg (Rowland 1985, 1998a, Roland 2005). Spawning occurs most years across a range of flow conditions, with post-larval survival largely influencing recruitment (Humphries et al. 1999, King et al. 2009, Koehn et al. 2020).

Male Murray cod are responsible for protecting and caring for the eggs spending a lot of time guarding and tending to the fertilised eggs by continually fanning the eggs to keep them oxygenated (Rowland 2005, Butler et al. 2022). This behaviour makes them vulnerable to fishing, as they are more aggressive and territorial during this period (Butler et al. 2022). In impoundments, there is evidence of spawning, however, hatching and recruitment failures within these systems means fish stocking is relied on to maintain the fishery (Forbes et al. 2015a).

Fish stocking and management

A number of management actions have been implemented to facilitate Murray cod recovery across New South Wales (Kearney and Kildea 2004, Lintermans 2004, Forbes et al. 2020). This has included restocking, with hatchery-reared fry and fingerlings, closed seasons, size and-bag regulations and habitat rehabilitation (Lintermans 2004, Rowland 2005, Forbes et al. 2020). Recreational fishing for Murray cod in NSW is subject to a closed season in most waters from September 1st until November 30th (with the exception of Blowering Dam and Copeton Dam which are open year round), with a harvest slot of 550-750 mm, a daily bag limit of 2 fish, and a possession limit of 4 fish per licence holder. Over 17 million Murray cod have been stocked in NSW waters since 1977 (Figure 1). The majority of Murray cod have been stocked into impoundments (11.7 million) for recreational fishing purposes with another 6.2 million stocked in riverine environments. While many riverine stockings are for recreational fishing purposes, some riverine stocking has been undertaken in rivers to aid in recovery after fish kills with mixed results (Thiem et al. 2017).

More than 50 lakes, dams and impoundments are regularly stocked with Murray cod in NSW. This includes a range of smaller urban lakes such as Lake Albert (Wagga Wagga), Rylstone Dam (Rylstone) and Lake Wyangan (Griffith) to a range of large impoundment fisheries such as Blowering Dam (Tumut River), Lake Burrinjuck (Murrumbidgee River), Wyangala Dam (Lachlan River), Burrendong Dam (Macquarie River) and Copeton Dam (Gwydir River). These large impoundments are generally considered as 'put-and-take' fisheries for Murray cod in NSW because natural recruitment is absent or very limited (Forbes et al. 2015a), and the viability of these fisheries is reliant on continued stocking of hatchery-reared fish. Some impoundment fisheries such as Burrendong Dam and Lake Burrinjuck have strong linkages with the riverine environment above the dam, while in others such as Blowering Dam there is no access to riverine environments upstream of the impounded water. Many of the larger impoundment fisheries require specific stock assessments but are mentioned in this summary to facilitate understanding and discussion around migration and emigration into riverine habitats when warranted.

Until recently, little was known of the efficacy of fish stockings, and it was largely assumed that they were a primary contributor to the recovery of the species in many river systems. An assessment of stocking success was undertaken in two rivers in the southern Murray–Darling Basin and one impoundment in north-western New South Wales (Forbes et al. 2015a). There was a comparatively low proportion of stocked Murray Cod among those sampled in the Murray (7%) and Murrumbidgee (15%) rivers (Forbes et al. 2015a). In contrast, stocked Murray Cod comprised almost the entire population in Copeton Dam (94%) (Forbes et al. 2015a) and Blowering Dam (91%) (NSW DPI unpublished data). These data suggest that while stocking is helping to enhance Murray Cod populations in impoundments, natural recruitment, potentially driven by other management actions such as habitat rehabilitation and improved environmental conditions (e.g., flow) are also likely contributing to population recovery in rivers (Thiem et al. 2017).

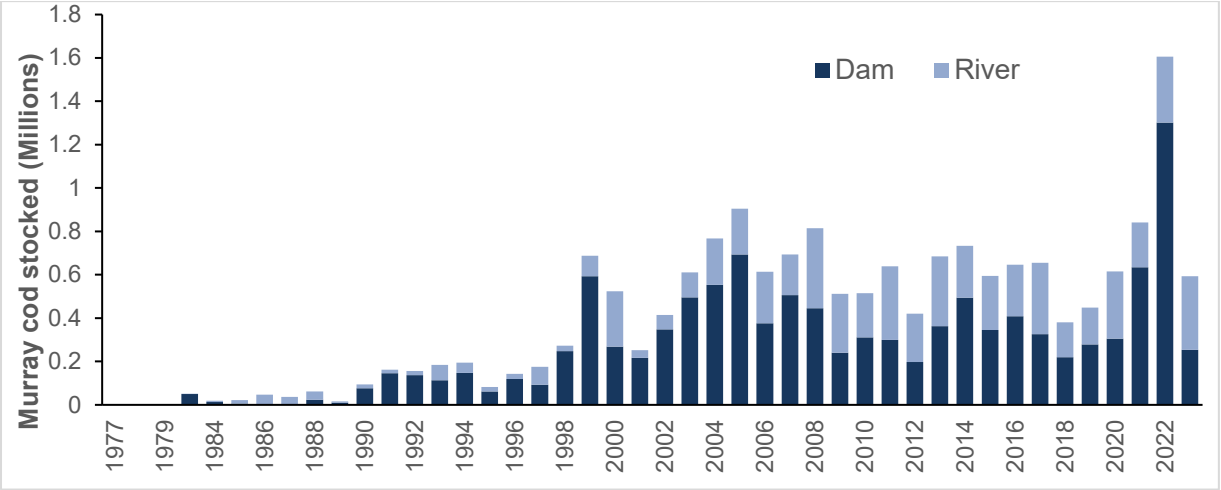

Figure 1: Numbers of hatchery-produced Murray cod stocked into NSW waterways since annual stocking began in 1977. Years represent calendar year for stocking with shading showing the numbers stocked in lakes/ dams and river environments.

FISHERY STATISTICS

Catch Information

Commercial fisheries

A commercial fishery for Murray cod existed from the mid to late 1800's and throughout the 1900's mainly in the Murray and Murrumbidgee Rivers. The inland fishery had developed quickly and in 1883 147 tons of commercial catch (mostly Murray cod and Golden perch) were sent from the Murray River to Melbourne (Rowland 1989). While fishing effort remained at around the same level, annual commercial catches declined from a high in the mid-1950s of around 140 tonnes (t), to less than 35 t by the mid-1960s, indicating a substantial decline in catch per unit effort (Reid et al. 1997, Rowland 2005). However, it was noted that the fishery had already declined sufficiently by the mid 1930's to be no longer profitable for large scale operators (Rowland 1989). Furthermore, the permitted locations for the commercial Murray cod fishery in NSW underwent a gradual reduction, ultimately restricting the fishery to approximately 5 % of the state's river systems (Kearney and Kildea 2004). The annual catch remained below 35 t in the majority of years from the 1960's until the commercial fishery was closed in New South Wales in 2001 (Rowland 1989, 2005).

Recreational fisheries

The recreational fishery for Murray cod has continued to grow in NSW with Murray cod now the most commonly caught species for inland fishers (Murphy et al. 2022). The fishery encompasses two main sectors; impoundment and riverine fisheries. Data on recreational fishing catch and effort in NSW and the ACT has been collected via offsite telephone-diary surveys in 2000/01, 2013/14, 2017/18, 2019/20 and 2021/22 (Henry and Lyle 2003, West et al. 2015, Murphy et al. 2020, Murphy et al. 2022). The sample frame for recruiting fishers changed from a White Pages sample in 2000/01 and 2013/14 to surveys of NSW recreational fishing licensed (RFL) households in 2017/18 onwards (West et al. 2015, Murphy et al. 2020, Murphy et al. 2022; NSW DPI unpubl. data). The change in methodology from White Pages to RFL precludes direct comparisons

between the 2000/01 and more recent catch estimates. However, a subset of data collected for 2013/14 used the RFL methodology and allows for comparison between 2013/14 and subsequent years.

Angler survey data shows that fishing effort for freshwater species has declined substantially since 2013/14 (Figure 2), with the majority of fishing effort occurring in rivers as opposed to lakes and dams (Figure 3). Declines in fishing effort have been linked to the severe drought, bushfires, widespread flooding in 2019-21, and the COVID-19 pandemic, all of which had adverse effects on human mobility and access to fishery resources (Ochwada-Doyle et al. 2023). The latest data from 2021/22 suggested that the downward trend in fishing effort may have stabilised or slightly increased for both river and dam/lake fisheries (Figure 3).

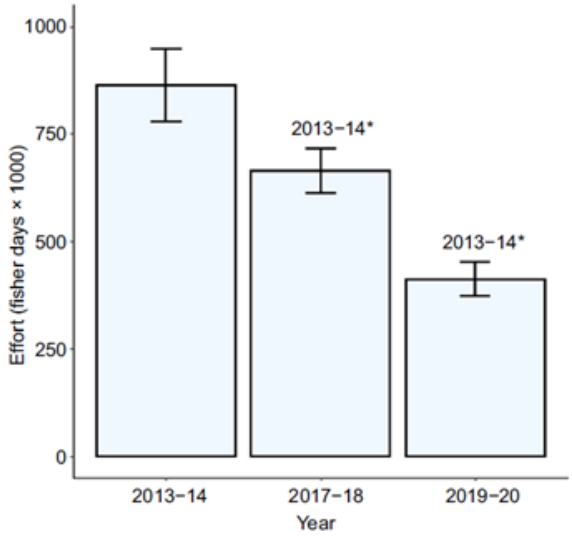

Figure 2. Estimated total effort (number of fisher days × 1000) exerted through recreational fishing activity in NSW and ACT freshwaters in 2013-14, 2017-18 and 2019-20. Error bars represent 1 SE of the total estimated effort. Significant P-values (α = 0.05) from pairwise comparisons of years are indicated by *, with the associated year in the comparison being labelled (reproduced from Ochwada et al. 2023).

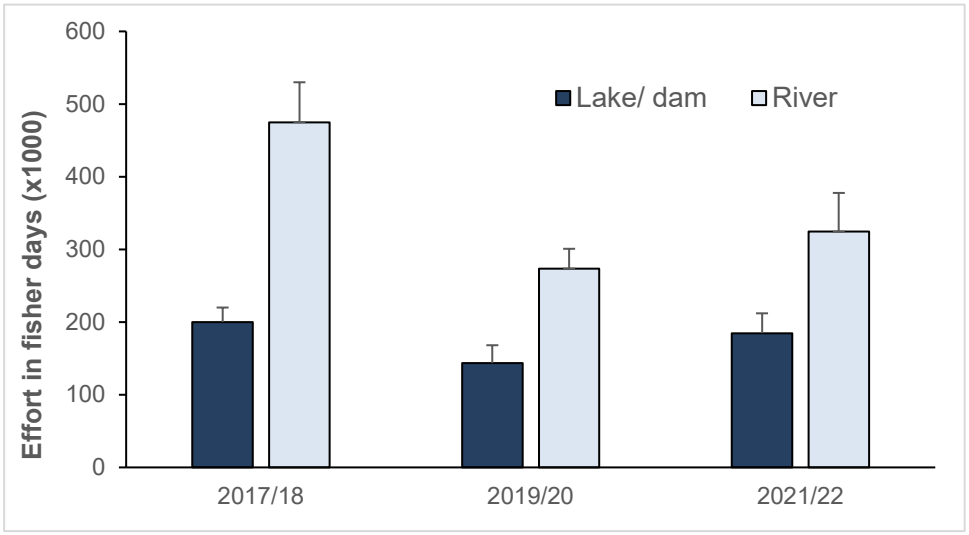

Figure 3. Waterbody based estimated total effort (number of fisher days × 1000) exerted through recreational fishing activity in NSW and ACT freshwaters in 2017–18, 2019–20 and 2021/22. Error bars represent 1 standard error of the total estimated effort.

Data on the recreational catch of Murray cod in NSW and the ACT was collected around the time of the commercial fishery closure as part of the National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003). This estimated Murray cod catch was 160,680 (±36,670), with 41,168 (±7,705 SE) retained and most fish caught from rivers (83.1%). An additional survey conducted in 2013/14 showed a similar overall catch of 165,557 (±29,865 SE), but only 20,816 (±4,383 SE) retained (West et al. 2015). Rivers remained the primary source of Murray cod catch in 2013/14, contributing to 87.9% of the total catch. (West et al. 2015). Data from both studies were derived from surveys of responders accessed via the White Pages.

The most recent estimate of the recreational catch and release of Murray cod in NSW was 335,478 (±71,748) up considerably from the estimates for 2019/20 (198,045 ±3448 SE) (Figure 4). The estimated retained portion of these catches were relatively low at 17,483 (±5,763 SE) in 2021/22 and 7,597 (±2,107 SE) in 2019/20. The latest survey continued to show that the majority of Murray cod catch (harvest and release) was obtained from rivers (80.2%) (Figure 4). These estimates encompassed catches from NSW households within which a long-term (1-3 year) Recreational Fishing Fee license holder resided (RFL household).

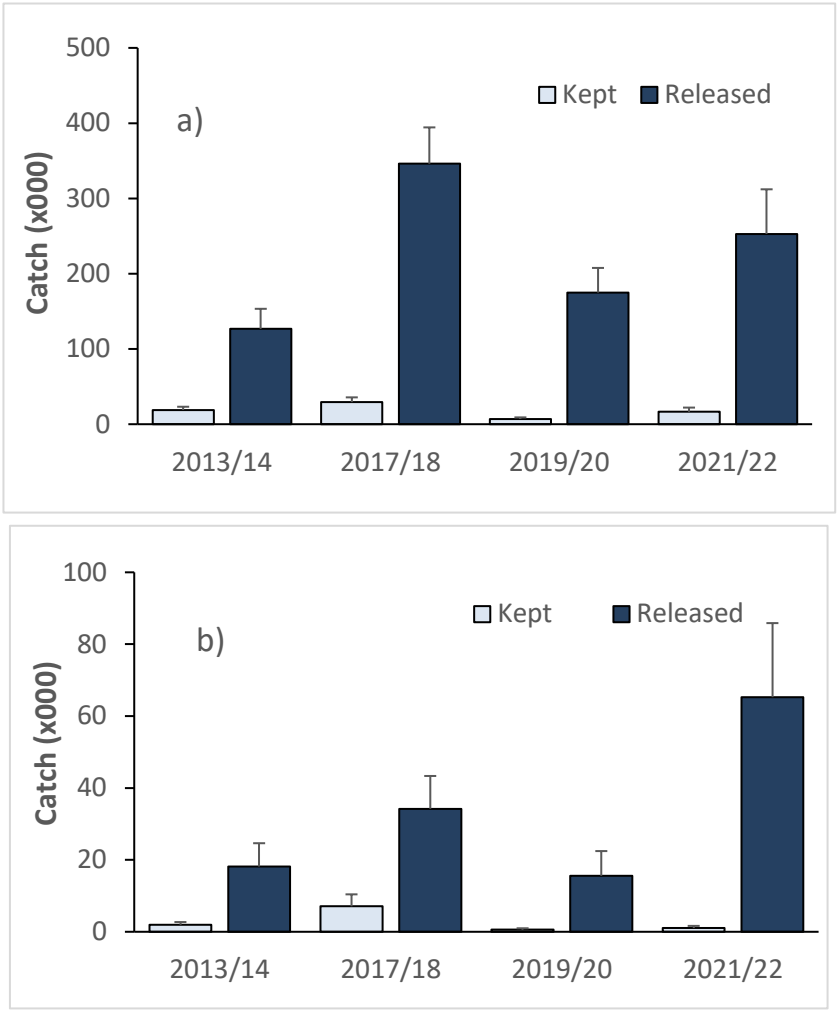

Figure 4. NSW recreational fishing catch and release estimates for the numbers of Murray cod from 2013/14, 2017/18, 2019/20 and 2021/22 surveys for a) rivers and b) lakes and dams. *a subset of data collected for 2013/14 used the RFL household methodology and allows for comparison between 2013/14 and later years.

Few other data sources exist on the Murray cod angler catches with just three creel surveys being of relevance in the NSW distribution of the species (Forbes et al. 2015b, Forbes et al. 2020, Miles et al. 2021). These surveys reported catch and release rates of 0.6 to 18.8 Murray cod released/ ha and 0.1 to 1.8 Murray cod harvested/ ha in Lake Mulwala, Murrumbidgee River and the Murray River (Forbes et al. 2015b, Forbes et al. 2020, Miles et al. 2021). Recent creel and telephone-diary surveys all suggest an increased focus on catch-and-release practices with only 1-5% of Murray cod captured being retained (Miles et al. 2021, Murphy et al. 2022). The amount of catch harvested appears to have declined from previous surveys where 4-12% of the catch was retained (Forbes et al. 2015b, Forbes et al. 2020, Murphy et al. 2020). The results of these recent surveys suggest that the recreational sector is increasingly targeting the species, but are also more commonly practising catch-and-release.

The combined low harvest reported in the state-wide diary survey and by recent creel surveys suggest that the Murray cod is predominately a catch-and-release fishery, with release mortality potentially an important component of fishery mortality (Miles et al. 2021). Post-release mortality of Murray cod is dependent on fishing method, time of year, holding times and fish size (Hall et al. 2012). Mortality rates for Murray cod vary from as low as 2% in riverine environments and up to 15% in impoundment tournaments with delayed release (Douglas et al. 2010, Hall et al. 2012). However, further research is required to develop a more precise estimate of post-release mortality in the fishery and in particular to better understand the impact of cumulative catch-and-release events.

Indigenous

There are no data on the indigenous fisheries for Murray cod in NSW.

Illegal, Unregulated and Unreported

The level of Illegal Unregulated and Unreported (IUU) fishing has not been quantified.

Fishery independent monitoring

Boat and backpack electrofishing are the key methods used for monitoring Murray cod populations in NSW. The NSW DPI Freshwater Ecosystems database has records of 19902 Murray cod captures from 841 sites across NSW up until September 2023 (Figure 5 and 6). The largest number of captures came from surveys undertaken in 2005 onwards (Figure 6).

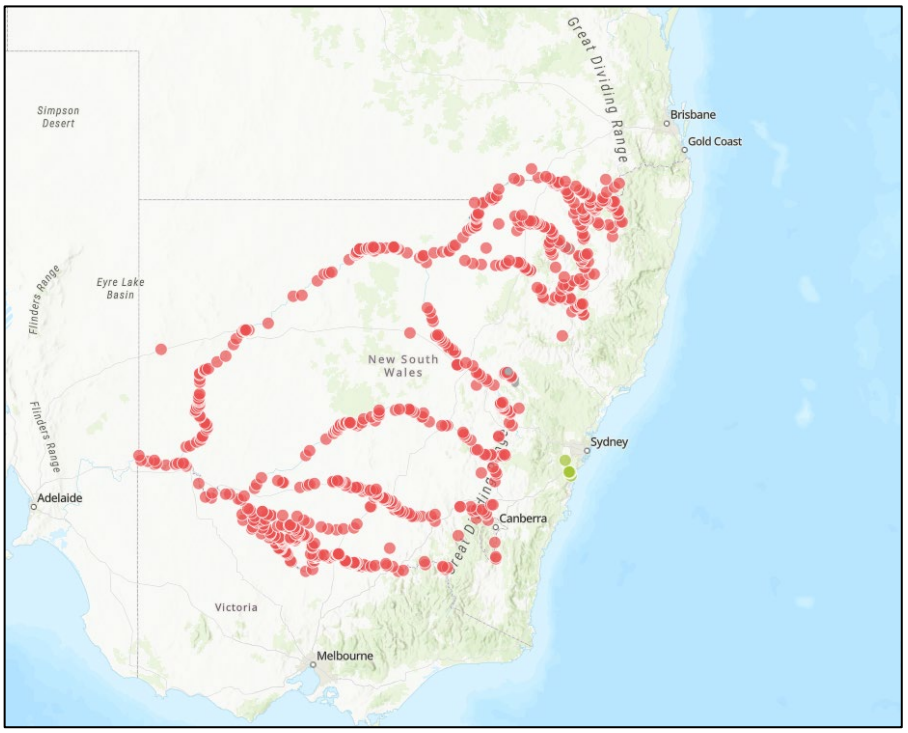

Figure 5. Boat and backpack electrofishing records for Murray cod in NSW from 1994 until 2023 (indicated by red dots).

All electrofishing data (boat and backpack methods) were collected using standardised techniques. Boat electrofishing surveys usually consisted of 10–12 'shots' of 90-s power on time at each site, whereas backpack electrofishing surveys usually consisted of 8–10 shots of 150-s power on time at each site. During sampling, fish length in mm (total length, TL, for round-tailed species) were recorded (at least the first 50 of a species in each sampling event). Abundance and biomass estimates followed the procedures outlined by Crook et al. (2023) with the inclusion of data up until August 2023. Additionally, analysis was also completed on legal size fish (500mm as a proxy for mature fish). This allowed investigation of the spawning stock of Murray cod along with general investigations.

Effort-adjusted monitoring data from the electrofishing surveys was used for the analysis (the boat data consisted of over 96% of all Murray cod captures by electrofishing). As these data are collected using a standardised electrofishing protocol, they facilitate calculation of catch-per-unit-effort (CPUE) over time. CPUE data was analysed using generalised additive mixed models (GAMMs) to directly estimate trends in relative abundance, and relative biomass of all Murray cod and mature-size (>500 mm TL) Murray cod from 1994 to 2023 (see Crook et al. 2023).

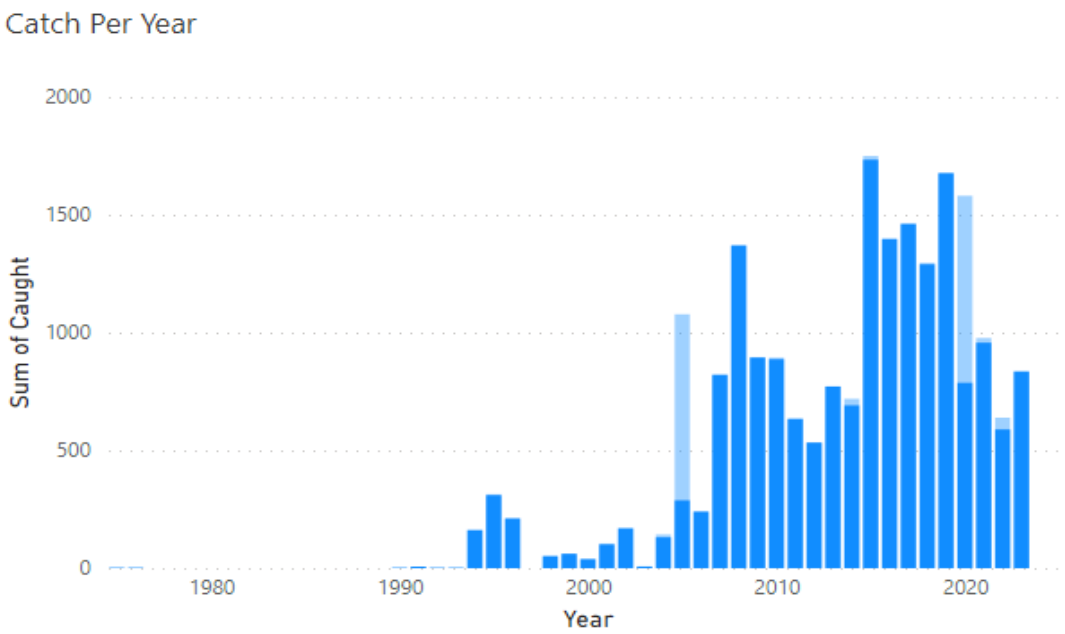

Figure 6. Total number of Murray cod caught during surveys in NSW, with contribution of boat and backpack electrofishing represented by dark blue. Other sampling methods shown in light blue.

Trends in abundance and biomass

Relative abundance estimated from electrofishing surveys of Murray cod across NSW indicates periods of increase between the mid 2000's to 2020, but some declines between 2020 and 2023 (Figure 7a). A similar pattern was also evident in mature fish over 500 mm, with an increase from 2010 but decline since 2020 (Figure 7b). The overall relative biomass across NSW has fluctuated greatly since 2001, but the relative biomass has remained similar or slightly reduced since the time of the closure of the fishery (2001). However, the relative biomass of mature fish (fish above 500 mm) has declined since 2001. There is evidence of markedly different trajectories at the catchment scale, with catchments such as the Murrumbidgee and Namoi experiencing strong upwards trends in relative abundance but others such as the Barwon-Darling Watercourse showing more variability and downward trends over the past decade (Crook et al. 2023). This variability in the relative abundance and biomass possibly reflects that some areas have seen recovery over the past few decades but other areas have suffered as a result of bushfires and drought over the past 5 years (Stocks et al. 2021, Ochwada-Doyle et al. 2023).

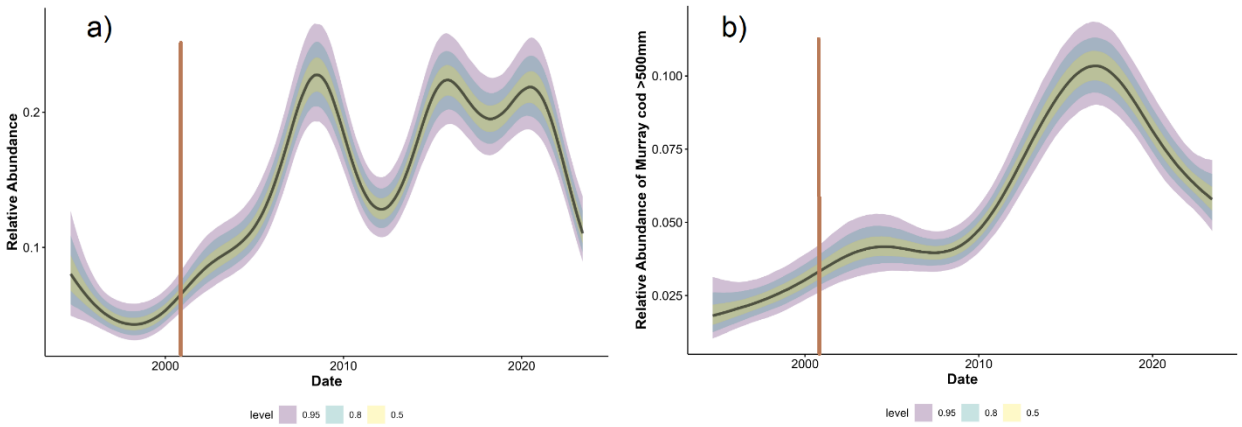

Fig. 7. Murray cod a) total relative abundance and b) relative abundance of mature-size fish (>500mm TL) in NSW since standardised electrofishing surveys commenced in 1994 based on a generalised additive mixed model. Credible intervals around the estimate (black line) are shown. The orange line shows approximate timing of commercial fishery closure. Note different y-axis scales.

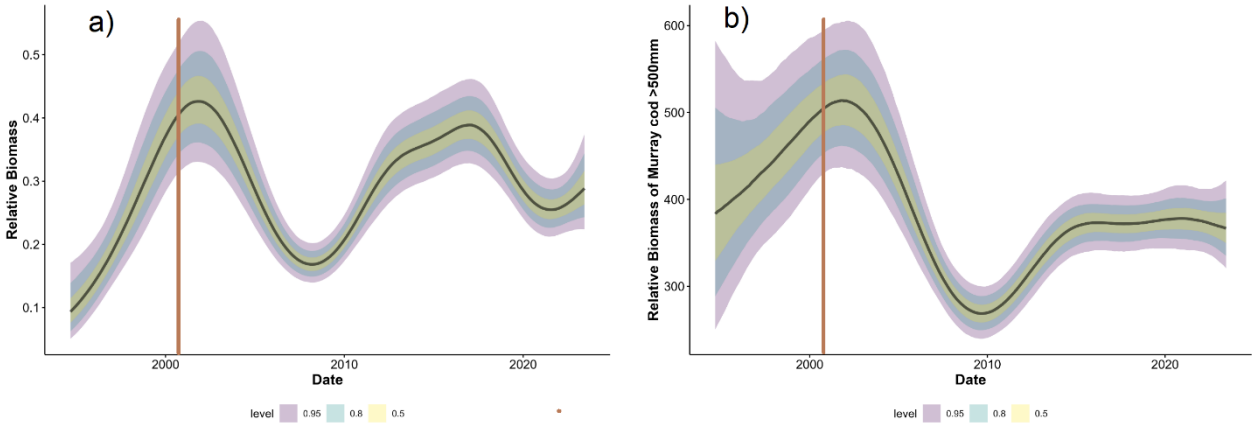

Fig. 8. Murray cod a) total relative biomass and b) relative biomass of mature-size fish (>500mm TL) in NSW since standardised electrofishing surveys commenced in 1994 based on a generalised additive mixed model. Credible intervals around the estimate (black line) are shown. The orange line shows approximate timing of commercial fishery closure. Note different y-axis scales.

Recruitment

Length-frequency data for Murray cod collected across NSW by all electrofishing methods was frequently unimodal (Figure 6). Furthermore, although there is regular recruitment (or successful stocking), there is little evidence of strong recruitment pulses since 2010 (Figure 6). Strong recruitment pulses have been reported for Murray cod in the Murray River sporadically between 2000- 2019 (Lyon et al. 2021), but similar patterns were not evident in NSW state-wide data presented here suggesting recruitment may be variable between locations.

Length frequency data indicates that a large portion of the population is below the lower bound of the slot limit (550mm) with very few fish in the population within the slot limit or above the upper bound slot limit of 750mm (Figure 6). Truncation at the size limit has been reported previously for Murray cod, with few harvestable fish reported in a recent creel survey (Miles et al. 2021). This may suggest high fishing mortality once fish become of legal size with few fish surviving beyond the harvest slot limit.

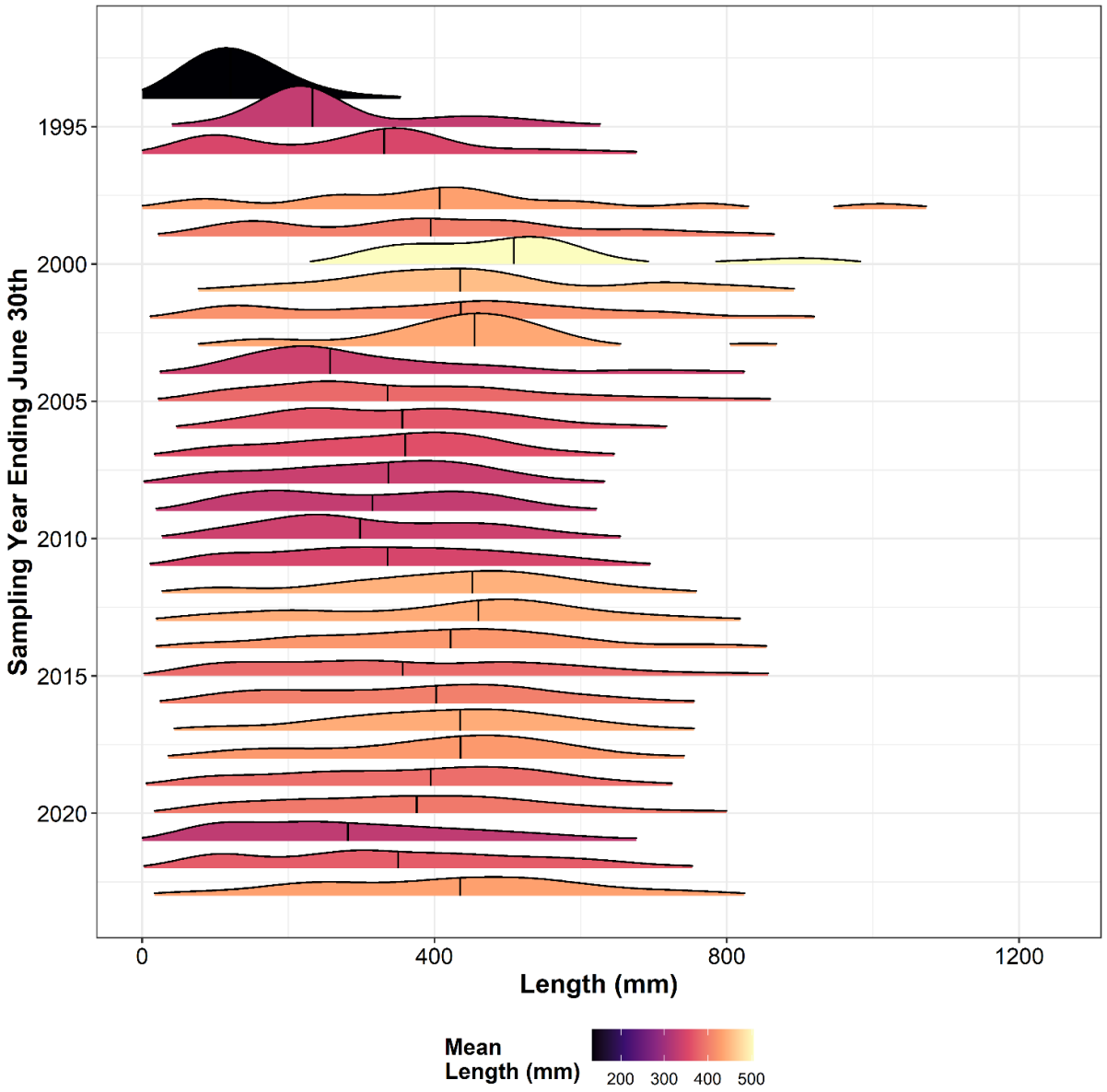

Figure 6. Length-frequency (total length) distributions of riverine Murray cod in NSW since standardised electrofishing surveys commenced in 1994. Vertical lines on the plots show the median size for each year.

STOCK ASSESSMENT

Stock Assessment Methodology

Year of most recent assessment

2022/23

Assessment method

A review of indicators (weight-of-evidence approach) was used to assess the status of the NSW riverine Murray cod stock. Impoundment fisheries although sometimes linked to riverine fisheries above them are primarily considered put-and-take, so stock assessment has focused on riverine fisheries which rely on wild recruitment. Quantitative stock assessment based on fishery catch data was not possible because commercial fishing for Murray cod ceased in 2001 and there are currently insufficient data on recreational and Indigenous harvest to support quantitative stock assessment.

Baseline estimates for the Murray cod biomass are not available, however, expert opinion suggest a potential 90% decline in native fish stocks in the Murray-Darling Basin (MDB) since European settlement. Habitat degradation and other human disturbances have likely reduced habitat support for native fish biomass in the MDB over the past two centuries. Recent droughts and bushfires have also limited suitable habitat for Murray cod in NSW. Consequently, estimating the unfished biomass of Murray cod (pre-European settlement) is not considered a suitable approach for reference points in the current fishery.

For the purposes of this report, estimates of relative abundance and relative biomass from fishery independent surveys (Figure 7 and 8) are used as a proxy of stock status. Relative abundance and relative biomass at the time of closure of the commercial fishery (2001) are used as the Limit Reference Point. This reference point assumes that in 2001 the stock was degraded and therefore stock abundance and biomass below 2001 levels pose unacceptably high risks. The relative abundance and biomass estimates were supported by examining the length composition data from the electrofishing data. The development of formalised methods for establishing indicators and reference points to support future quantitative stock assessment is a high priority for freshwater species in the future.

Main data inputs:

- Fishery independent, effort-adjusted monitoring data collected using electrofishing from 1994 to 2023 (NSW DPI Freshwater Ecosystems Unit database; Crook et al. 2023).
- Recreational fishing catch and effort data for NSW/ACT collected via household surveys from White Pages in 2000/01 and 2013/14 (Henry and Lyle 2003, West et al. 2015) and offsite telephone-diary surveys of RFL households in 2013/14, 2017/18, 2019/20 and 2021/22 (West et al. 2015; Murphy et al. 2020, Murphy et al. 2022).

Key model structure & assumptions:

There are several key analytical considerations for interpreting the GAMM outputs (see Crook et al. 2023). These include the efficiency of electrofishing, which can vary considerably based on species, size classes within species, and environmental factors like water conductivity, depth, and turbidity. Random effects were used in the statistical analyses to account for detection probabilities and estimate trends in relative abundance and biomass. The representativeness of sampling sites also has important implications and may be influenced by the initial sampling design or limitations posed by environmental conditions like drought. Site weighting was not used to account for

potential site selection bias; however, the analysis is considered robust due to the large number of widespread sites and consistent sampling methodology over the time series. The modelling approach optimises the available data but doesn't address situations with no data or differentiate mechanisms governing fish abundance. For example, intense droughts can lead to unsampled dry sites, potentially biasing relative abundance estimates. Although few dry sites were encountered, their exclusion might alter model outcomes. Concentration of fish in remaining waterholes during low water levels might also obscure trends, and the random effect structure in the model partially addresses this variability. Predictions during extreme water levels should be approached with caution, as they might not fully depict actual abundance patterns. Changes in sampling efficiency over time, such as due to technological upgrades, have the potential to influence the model outputs. However, standardized sampling procedures using consistent electrofishing equipment were closely followed throughout the study period, minimizing concerns regarding the impact of technological improvements on the analyses.

The size composition of fishery independent catches is used in the calculations and may bias larger fish sizes of the population. If the size composition of the surveys is not representative of size composition of the Murray cod in NSW, then estimates may not accurately reflect changes.

A non-representative length composition could occur if:

- Electrofishing practices bias selectivity of certain size classes (due to flow, water clarity or susceptibility to the gear type)
- Previous work has suggested river turbidity associated with increased river discharge negatively influenced capture probability. Increasing fish length increased detection of fish up to 500 mm (for Murray cod), but capture probability decreased again after this size (Lyon et al. 2014).

A detailed discussion of the structure and assumptions associated with the NSW recreational fishing survey data is provided by Murphy et al. (2022).

Sources of uncertainty evaluated:

General data limitations and uncertainty was considered in the weight-of-evidence approach. Uncertainty in the modelled estimates of relative abundance and relative biomass is represented by credible intervals along the time series. Time series data is also starting to be collected for Murray cod recreational fishery, but the data point currently available show little variation between survey periods.

Status Indicators - Limit & Target Reference Levels

Biomass Indicator or proxy	Estimates of relative biomass (CPUE) of mature-sized fish from fishery independent surveys
Biomass Limit Reference Point	Relative biomass (CPUE) of mature-sized fish at the time of commercial fishery closure (2001)
Target Reference Point	N/A
Fishing Mortality indicator or proxy	Retained catch estimates from recreational fishing surveys
Fishing Mortality Limit Reference Point	Retained catch based on 2000/01 recreational fishing survey results (41168 fish pa, rivers only)
Fishing Mortality Target Reference Point	N/A

Stock Assessment Results

The NSW Murray cod stock is classified as being fished at **depleted** levels. The status is based on:

1) Fishery independent, effort-adjusted catch data from the riverine fishery demonstrates a stable relative abundance and reduced relative biomass since 2001 with evidence of sharp decline since 2020.
2) Stable recreational catch and fishing effort since 2013/14.

Stock Assessment Result Summary

Status in relation to Limit	Reduced relative biomass (CPUE) of legal-sized fish since 2001
Status in relation to Target	N/A
Fishing mortality in relation to Limit	Retained catch has decreased substantially since 2000/01 and 2013/14 recreational fishing surveys. Retained catch estimate (rivers only) for 2021/22 is 16,440 fish (± 5642 SE) (NSW DPI unpubl. data). However, angler discard has also increased during this period and is estimated at 252,733 (±59376 SE) for rivers in 2021/22.
Fishing mortality in relation to Target	N/A
Current SAFS stock status	Undefined

Fishery interactions

N/A

Qualifying Comments

The weight-of-evidence approach used here to assess Murray cod stock status reveals some uncertainty due to the fragmentation of the population that occurs across NSW and the lack of data on catch-and-release mortality estimates for the species. Furthermore, the reliance on one data type (fishery independent boat electrofishing) does mean there is susceptibility to detectability bias (which may be less efficient at capturing large and small fish). Nevertheless, there appears to be little recovery in the species since the closure of the fishery in 2001. This is especially so for the spawning stock (fish over 500mm) which has appeared to have declined in relative biomass, but possibly showed an increase in relative abundance before declining since 2020. On this basis, the NSW Murray cod fishery is classified as **depleted**.

This summary focusses on the sustainability of fishing activity for Murray cod in NSW. There is strong evidence that environmental conditions are a limiting factor for the recruitment for Murray cod. For example, fragmentation and habitat degradation has adverse effects on recruitment for many species across the MDB (Rowland 2005, Koehn et al. 2014), and large-scale fish kills during hypoxic conditions can cause severe depletion in affected regions (Stocks et al. 2021). In comparison with these environmental factors, fishing mortality from harvest is considered to have a lesser effect on the NSW stock. However, the length frequency diagrams show that few fish are of harvestable size and the number of fish moving through the harvest slot for protection is very low and may warrant further evaluation (Allen et al. 2009, Koehn and Todd 2012, Gwinn et al. 2015). In addition, discard mortality might be an important part of fishing mortality (Douglas et al. 2010, Hall et al. 2012) especially as recreational fishing catch (particularly catch-and-release) has remained the same or potentially showing a slight upward trend since 2019/20. Nonetheless, it is recognised that the long-term sustainability of Murray cod populations in NSW is contingent on the continuation of appropriate management of the fishery which should include recovery in some areas and continued sustainable management in other areas which have experienced a decline. Furthermore, formalised indicators/proxies, limit reference points, and target reference points are required to support stock assessment for Murray cod.

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