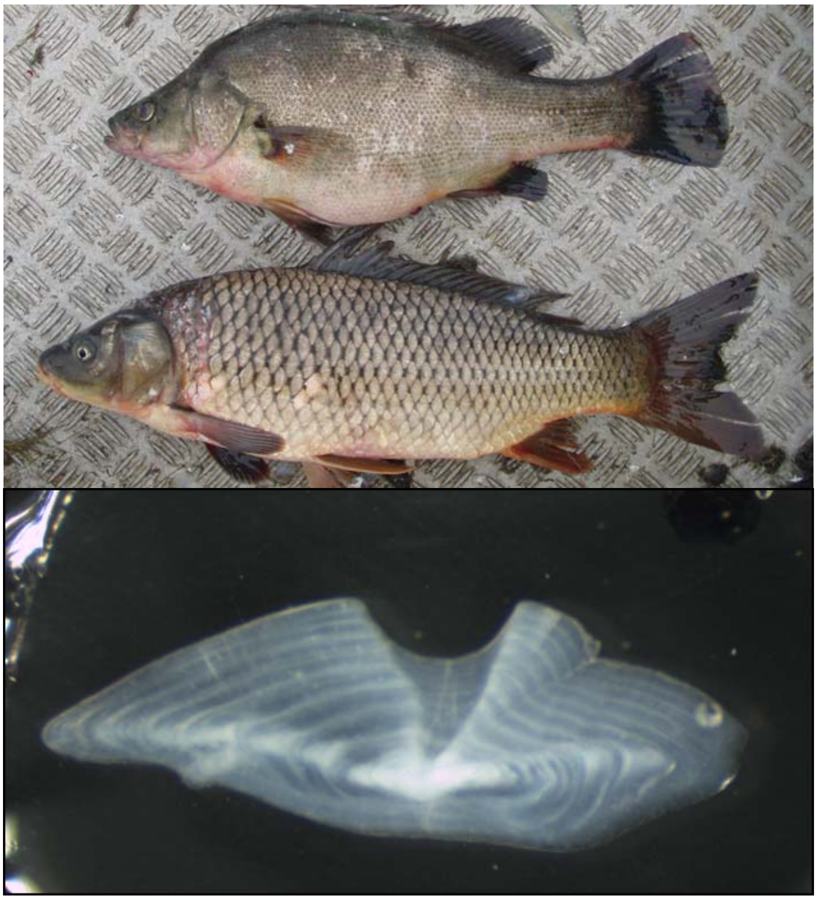
Biological information and age structure analysis of large-bodied fish species captured during the Lake Albert trial fish-down, October 2009



Chris Bice

SARDI Publication No. F2010/000159-1
SARDI Research Report Series No. 430

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March 2010

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This publication may be cited as:
Bice, C. (2010). Biological information and age structure analysis of large-bodied fish species captured during the Lake Albert trial fish-down, October 2009. Report to Primary Industries and Resources South Australia - Biosecurity. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2010/000159-1. SARDI Research Report Series No. 430. 27p.

Cover: top – adult golden perch (*Macquaria ambigua*) and common carp (*Cyprinus carpio*), bottom – transverse section of a golden perch sagittal otolith.

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Printed in Adelaide: March 2010

SARDI Publication No. F2010/000159-1
SARDI Research Report Series No. 430

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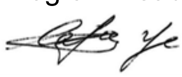
Signed:	
Date:	24 March 2010
Distribution:	Primary Industries and Resources South Australia – Biosecurity, SAASC Library, University of Adelaide Library
Circulation:	Public Domain

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ACKNOWLEDGEMENTS

This project was funded by PIRSA (Primary Industries and Resources South Australia) Biosecurity and was managed by Vic Neverauskas. The author would like to thank the fishermen of the Lakes and Coorong commercial fishery for access to their catches. Thanks to Paul Jennings, Sandra Leigh and David Short (SARDI) for assistance with fieldwork and/or help with processing and analysing otolith sections. Thanks also to Kathleen Beyer and Brenton Zampatti for reviewing this report.

EXECUTIVE SUMMARY

In response to severely reduced water levels and increasing salinity in Lake Albert PIRSA (Primary Industries and Resources South Australia) Biosecurity initiated a trial fish-down to determine the effectiveness of this technique in reducing the biomass of common carp (*Cyprinus carpio*) in the lake. Salinity, measured as electrical conductivity, was predicted to reach ~20,000 $\mu S.cm^{-1}$ by early 2010, raising fears of a large-scale kill of common carp, which were believed to be abundant in Lake Albert. A large-scale fish kill would be expected to adversely affect the quality of remaining water supplies and severely diminish the aesthetics of Lake Albert for the surrounding communities.

Whilst the fish-down aimed to remove a significant biomass (~100 tonnes) of common carp from Lake Albert it also presented an opportunity to gather biological information (e.g. size and age structures) on the large-bodied (i.e. average adult length >150 mm) fish community of Lake Albert, including the economically important golden perch (*Macquaria ambigua*). Information on the fish community of Lake Albert is limited and research has previously focused on small-bodied fish species. The information gathered during the fish-down complements previous research and provides scope for comparing the biology of selected species (i.e. golden perch) from Lake Albert with other areas of the Murray-Darling Basin to investigate potential regional variation in the ecology of these species.

The trial fish-down was carried out from 07/10/2009 – 26/10/2009 and utilised the expertise of commercial fishermen from the Lakes and Coorong Fishery. The majority of fishermen used gill nets (mesh sizes: 95 – 200 mm) and one fisherman undertook ‘power hauling’. A total of 98 tonnes of fish were removed from Lake Albert, comprising 74 tonnes of common carp, 23 tonnes of bony herring (*Nematalosa erebi*) and 1 tonne collectively of golden perch and redfin perch (*Perca fluviatilis*).

Size ranges of fish caught from Lake Albert reflect the selective gear types used (i.e. very few small fish (e.g. <250 mm) were captured). Common carp ranged from 257 – 701 mm fork length (FL), golden perch from 298 – 418 mm total length (TL), redfin perch from 183 – 350 mm FL and bony herring from 226 – 312 mm FL. Length to weight relationships were established for all species.

Otoliths from a subsample of golden perch (*n* = 46) and redfin perch (*n* = 76) were removed for ageing analysis. Golden perch ranged from 2 – 12 years of age with the age structure indicating annual recruitment between 1996 and 2006. This contrasts with age structures of golden perch from some riverine reaches of the South Australian Murray-Darling Basin where recruitment is more sporadic and there are years of no recruitment. Conditions in the Lower Lakes between 1996 and 2006 facilitated consistent recruitment of golden perch and may have important conservation implications for this species. Redfin perch ranged from 1 – 6 years of age (i.e. spawned between 2002 and 2007) with consistent annual recruitment.

Length at age relationships were investigated for golden perch and redfin perch. Both species exhibited considerable variation in length at age. This suggests there may be considerable variation in individual growth rates within these populations and that length alone is a poor indicator of age and recruitment in these species.

Whilst fishing gear types used in this study were size selective, new biological information was gathered on the large-bodied fish community of Lake Albert. Furthermore, the data provide information on the current condition of the large-bodied fish community in the face of current and potential management interventions in the region.

BACKGROUND AND INTRODUCTION

Worldwide, river regulation and water abstraction, principally for agricultural irrigation, have resulted in the degradation of freshwater systems (Lemly *et al.* 2000). Regulation and abstraction alter the timing and magnitude of river flows and in the most extreme cases may result in the decline or loss of wetlands and terminal lakes (see Micklin 1988; Kingsford 2000). These impacts are exacerbated under drought conditions as regulation and abstraction reduce the resilience of river systems to periods of low inflows.

Australia's longest river system, the Murray-Darling Basin (MDB), is highly regulated and experiences high levels of abstraction. Mean annual end of system flow since regulation (post 1940's) has been reduced to just ~39% (4723 GL) of natural mean annual flow (12,233 GL) (CSIRO 2008). Additionally, since 1997 south-eastern Australia has suffered an ongoing drought with below average rainfall and greater than average maximum temperatures, resulting in diminished inflows into the MDB (Murphy and Timbal 2008). This has in turn resulted in end of system flows <4723 GL every year since 1997 (DWLBC 2009). In 2007 and 2008 inflows over Lock and Weir 1 (located at Blanchtown, South Australia) near the terminus of the MDB were only 500-600 GL (DWLBC 2009).

Due to the severely decreased inflows and high rates of evaporation, water levels in the Lower Lakes of the MDB (i.e. Alexandrina and Albert) have been receding since 2006. This poses many risks to the ecological and cultural character of this Ramsar listed site as well as the agricultural, commercial fishing and tourism industries. Perhaps the most significant threat to the Lower Lakes ecosystem is the exposure of extensive areas of acid sulfate soils, which, when exposed to oxygen release sulfuric acid and may result in the acidification of remaining water (Fitzpatrick *et al.* 2008). Due to the risk posed by acid sulfate soils, Lake Albert was disconnected from Lake Alexandrina in early 2008 by constructing an earthen bank between the two lakes (i.e. at the Narrung narrows). Water was subsequently pumped into Lake Albert from Lake Alexandrina to maintain water levels above a critical acidification trigger level (i.e. -0.5 m AHD). Nevertheless, pumping ceased in June 2009 to conserve water for Lake Alexandrina.

Further decreases in water level due to evaporation and a corresponding increase in salinity are likely to occur in Lake Albert. Salinity in Lake Albert is predicted to reach 20,000 $\mu S.cm^{-1}$ (salinity measured as electrical conductivity) by early 2010 and large-scale kills of freshwater biota have been predicted. Freshwater fish are often sensitive to increases in salinity, particularly common carp (*Cyprinus carpio*), which are believed to be highly abundant within Lake Albert based on commercial fishery data (SARDI Unpublished) and anecdotal evidence. Geddes (1979) suggests a salinity tolerance limit of 15,000 $mg.L^{-1}$ or ~25,000 $\mu S.cm^{-1}$ for adult common carp and a fish kill of this species was observed in the mid-Murray in a wetland that reached 26,000 $\mu S.cm^{-1}$ and was experiencing similar acid sulfate soil impacts to Lake Albert (McCarthy *et al.* 2006). The biomass of common carp in Lake Albert is assumed to be very large (estimates vary pending a biomass estimation) and thus, a large-scale kill would negatively impact the quality of remaining water and severely diminish the aesthetics of Lake Albert for surrounding communities.

In response to predicted rising salinities in Lake Albert PIRSA (Primary Industries and Resources South Australia) Biosecurity initiated a trial ‘fish-down’ to determine the capacity of this method to reduce the biomass of common carp in Lake Albert and thus minimize the magnitude of potential fish kills. A fish-down involves the use of the greatest amount of fishing effort available, over the longest time period possible, with the aim of reducing fish biomass. This technique is considered feasible in isolated bodies of water such as Lake Albert (see IFS 2004). Fish were removed from Lake Albert by utilising the expertise of commercial fishermen from the Lakes and Coorong commercial fishery, with the initial trial aiming to remove 100 tonnes of fish from the lake over a two-three week period. In addition to removing carp, agreements were made that other fish of value (e.g. golden perch, *Macquaria ambigua*) could be retained by fishermen. Thus, given the large degree of fishing effort, the fish down provided an opportunity to gather biological data on the large-bodied (i.e. adult length >150 mm) fish community of Lake Albert which has received little research attention.

Since 2001 three separate research projects have sampled sites within Lake Albert (i.e. Wedderburn and Hammer 2003; Bice *et al.* 2008; Wedderburn and Barnes 2009) for small-bodied fish species. There are limited abundance data (catch-per-unit effort) for large-bodied fish species from the Lakes and Coorong Fishery (SARDI Unpublished) but these do not include any biological information such as length, weight, sex and age structures. The fish-down provided an opportunity to collect such information.

The aim of this project was to assess biological parameters of the large-bodied fish species of Lake Albert, including body length, weight, sex, reproductive condition and age structure. Age structure, determined via otolith microstructure analysis, was investigated for a sub-sample of golden perch and redfin perch (*Perca fluviatilis*) as this method has been validated for ageing golden perch (Anderson *et al.* 1992) and whilst it has not yet been validated for ageing redfin perch, it is a commonly used technique elsewhere (Polat *et al.* 2004; Linlokken *et al.* 2008). Other species captured did not under go otolith analysis either due to a lack of validation or common use of this technique (i.e. bony herring, *Nematalosa erebi*) or unreliability in age estimations from this technique (i.e. common carp) (see Vilizzi *et al.* 1998). This information will be used to analyse population length and age structures and investigate population growth parameters (i.e. length-weight and length-age relationships). Whilst this will complement previous research on the fishes of Lake Albert it will also provide insight on the current condition of the large-bodied fish community. Such knowledge is important given the declining state of the Lower Lakes ecosystem and potential for extreme management interventions in response to the risk posed by exposed acid sulfate soils (e.g. seawater intrusion) (see Bice and Ye 2009). Additionally, the information gathered will provide a means for comparing the biology (e.g. age structures) of large-bodied fish species, particularly the economically important golden perch (Knight *et al.* 2004), in Lake Albert with other regions of the MDB and provide insight on potential regional differences in the ecology of this species.

METHODS

Study site

At the lower end of the MDB in South Australia, the River Murray discharges into a terminal lake system, known as the Lower Lakes (i.e. Lakes Alexandrina and Albert) before flowing into the Coorong and finally through the Murray Mouth into the Southern Ocean (Figure 1). The Lower Lakes and Coorong were collectively designated as a wetland of international significance under the Ramsar Convention in 1985 based upon the regions unique ecological character and significance for migratory wader birds (DEH 2000). The region is also considered one of six 'Icon Sites' in the MDB under the Murray-Darling Basin Authority's (MDBA, formerly MDBC) 'The Living Murray' program (MDBC 2006).

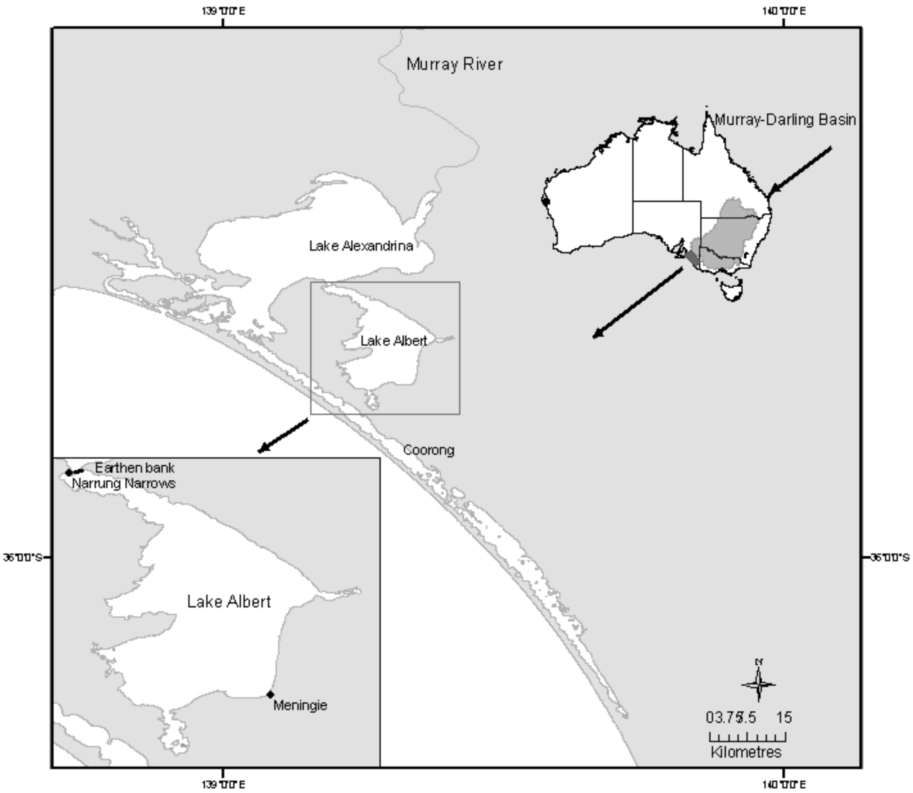


Figure 1. Map showing the MDB, lower Murray and Lower Lakes and Coorong. Lake Albert is inset showing the township of Meningie, Narrung Narrows and location of the earthen bank separating the Lower Lakes.

Lake Albert is the smaller of the two lakes (~16,800 ha compared to ~76,000 ha for Lake Alexandrina) and located immediately south-east of Lake Alexandrina (Phillips and Muller 2006) (Figure 1). Lake Albert is a shallow lake with the lowest point at -1.7 m AHD (Australian Height Datum) compared to -4.0 m AHD in Lake Alexandrina (Phillips and Muller 2006). Lake Albert does not possess a flow-through connection with the Coorong and thus water exchange occurs solely with Lake Alexandrina through the Narrung Narrows (Phillips and Muller 2006). Water level in Lake Albert generally corresponds to that of Lake Alexandrina and is typically regulated at ~0.75m AHD. Nevertheless, water levels may differ between the lakes for short periods due to wind driven movements of water through the Narrung Narrows.

Water levels in Lake Albert through 2004, 2005 and 2006 remained largely within normal operating levels (0.5 – 1.0 m AHD) but began declining rapidly in late 2006 (Figure 2). In 2007 inflow to the Lower Lakes from the River Murray was <600 GL compared to the mean annual evaporation rate of ~800 GL and consequently the water level of Lake Albert dropped below sea level in November 2007 and continued to recede rapidly toward a predicted acidification trigger level of -0.5 m AHD (DWLBC 2009). In early 2008 an earthen bank was constructed across the north-western end of the Narrows near Narrung. Water was subsequently pumped from Lake Alexandrina into Lake Albert, commencing in May 2008 to maintain water level above -0.5 m AHD (Figure 2). Pumping ceased in spring 2008 and the water level began to recede in summer 2008/2009 before reaching -0.5 m AHD in February 2009. Pumping was recommenced but then ceased in June 2009 to conserve water for Lake Alexandrina. Water levels are expected to decrease further during summer 2009/10.

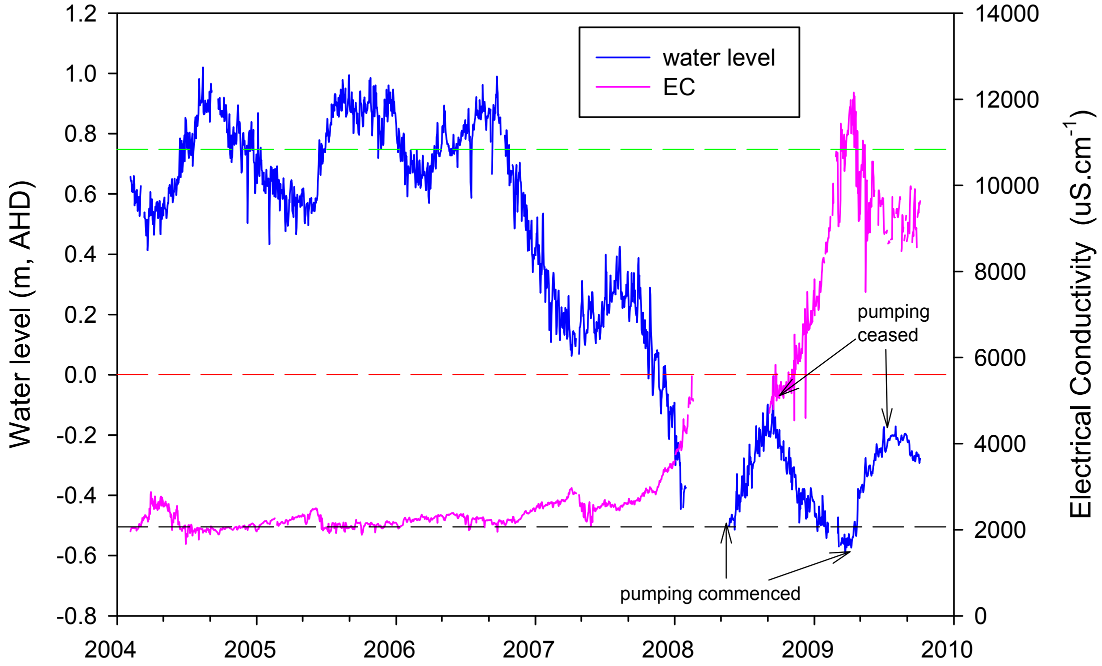


Figure 2. Water level (m AHD, Australian Height Datum) and electrical conductivity (EC, µS.cm^{-1}) in Lake Albert (recorded at Meningie) from 2004-2009. The normal regulated water level of 0.75 m AHD (dashed green), 0.0 m AHD (mean sea level, dashed red) and the predicted acidification trigger level of -0.5 m AHD (dashed black) are indicated. The commencement and ceasing of water pumping from Lake Alexandrina into Lake Albert in 2008 and 2009 is indicated. Data for this figure was obtained from the South Australian Department of Water Land and Biodiversity Conservation (DWLBC 2009).

Salinity (measured as electrical conductivity (EC), µS.cm^{-1}) was consistent at ~2000 µS.cm^{-1} through 2004-2006 (Figure 2). As water levels fell through 2007, salinity gradually increased before a rapid increase in salinity through summer 2007/2008. As water levels receded through 2008 and 2009, salinity increased to ~12,000 µS.cm^{-1} in early 2009 and was ~9000 µS.cm^{-1} in late 2009. With further decreases in water levels predictions suggest salinity may reach 20,000 µS.cm^{-1} in early 2010 (Neverauskas pers. comm.).

Fishing methods and data collection

Sixteen fishermen (i.e. licences) from the Lakes and Coorong commercial fishery were contracted to undertake the trial fish-down between 07/10/2009 and

26/10/2009. Catches were disposed of at fish processing factories in Meningie where weights were recorded for different species from each fisherman.

Gill nets were used by all but one fisherman. Gill nets had mesh sizes ranging from 95 – 200 mm and the number of nets used by each fisherman was governed by licence endorsements. One fisherman used a power hauling system (net: mesh ~90 mm, length = 500 m) to capture fish and was thus able to actively target schooling carp. The majority of fishing effort was focused around the Narrung Narrows.

Where possible, sub-samples of all species landed were measured for length (fork and/or total length as appropriate; *n* = 51 - 128) and weight (g; *n* = 39 – 127). A sub-sample of golden perch (*n* = 45), common carp (*n* = 50) and redfin perch (*n* = 119) were dissected, and sex and reproductive condition determined (i.e. macroscopic staging of gonads, see Table 1). Sagittal otoliths were collected from a sub-sample of golden perch (*n* = 46) and redfin perch (*n* = 76) for subsequent analysis in the laboratory. Otolith microstructure analysis was not carried out for common carp due to the poor reliability of this technique to age this species (Vilizzi *et al.* 1998; Vilizzi and Walker 1999)

Table 1. Macroscopic categorisation of gonad stages used in the current project. Methods follow those of Mayrhofer (2007).

Stage	Characteristics	
	Female	Male
I. Juvenile	Gonads discernible, thin, threadlike, sex indistinct macroscopically	
II. Immature	Ovaries pink, round in cross-section and shorter than testes. No visible oocytes.	Testes opaque cream colour, triangular in cross-section, thin.
III. Maturing/ripe	Ovaries reddish, more bulbous, larger: filling >25% of gut cavity, developing oocytes clearly visible.	Testes white, blood vessels visible and extend for majority or whole length of gut cavity. Rounded in cross-section. Milt expressed with abdominal pressure
IV. Ripe	Ovaries large and bulbous, appearing swollen and filling gut cavity. Well vascularised, oocytes large and well-developed. Abdomen swollen and oocytes extruded with abdominal pressure. Vent typically red and swollen.	
V. Spent	Ovaries reddish, rounded and granular. Fills approximately 25% of gut cavity and appear deflated. Small number of ill-shaped remnant oocytes.	Testes flaccid, thin, mottled grey appearance, some residual milt, blood vessels visible

Otolith microstructure analysis

The internal microstructure of the sagittal otoliths of golden perch reveal an interpretable series of increments which can be used to determine the age of individual fish (Anderson *et al.* 1992). Transverse sections provide the best plane for resolving the microstructure. For preparation, sagittae were block mounted in resin and transverse sections (~0.5 mm thick) were cut through the primordium of the otolith with a diamond impregnated blade. The sections were washed and mounted on microscope slides for increment counting.

Sections were examined using a dissecting microscope (Olympus model SZX7). Each otolith was examined by three independent readers and increments were counted without knowledge of fish lengths so as to prevent bias. Age counts were then compared and where there was agreement between all readers this count was taken as fish age. If counts differed between readers otolith sections were re-examined simultaneously by all three readers and if a consensus on an increment count was reached by all three readers this was also adopted as fish age. If there was no consensus between readers this otolith was excluded from the data set. If otoliths were determined to have a ‘wide edge’ then it was assumed a new increment would be laid before the end of 2009. Thus, when back-calculating spawn dates this extra increment was taken into account.

The same method was followed for preparing and examining redfin perch otolith sections. The use of annual increment counts from otoliths of redfin perch has not yet been validated as a technique for determining age but is commonly used to determine age in this species (Polat *et al.* 2004; Linlokken *et al.* 2008) and other closely related species elsewhere (e.g. yellow perch, *Perca fluvescens*) (Vandergoot *et al.* 2008).

RESULTS

Catch composition

A total of 98 tonnes of fish were removed from Lake Albert by commercial fishermen during October 2009. This comprised 74 tonnes of common carp, 23 tonnes of bony herring and ~1 tonne of golden perch and redfin perch. There was difficulty in determining the total weights of golden perch and redfin perch due to the common practise of fishermen grouping these species together as ‘market fish’.

The majority of fishing effort was focused around the Narrung Narrows, where catches consisted almost entirely of common carp. Fishers operating outside of this area tended to report more mixed catches of common carp, bony herring, golden perch and redfin perch.

All golden perch, redfin perch and bony herring were caught in gillnets with mesh sizes 95 – 127 mm most successful. In contrast, ~34% of common carp (i.e. 25 tonnes) were captured by haul netting and the remaining ~66% (i.e. 49 tonnes) were caught in gillnets, with larger mesh sizes (i.e. > 127 mm) being most successful.

Size structure

Golden perch ranged from 298 – 418 mm TL (Figure 3a) with a mean length of 346 ± 3 mm TL (*n* = 51). Fish 320 – 359 mm TL comprised >60% of fish caught (Figure 3a). Weight ranged from 465 – 1535 g with an average weight of 695 ± 38 g (*n* = 39).

Common carp exhibited a broad size range from 257 – 701 mm FL (Figure 3b), with a mean length of 532 ± 10 mm FL (*n* = 96). Fish 480 – 619 mm FL comprised >60% of the catch (Figure 3b). Common carp also exhibited a broad range of weights from 384 – 6828 g, with a mean weight of 3563 ± 151 g (*n* = 96).

Redfin perch ranged from 183 – 350 mm FL, with a mean length of 296 ± 3 mm FL (*n* = 128). Fish 280 – 319 mm FL comprised ~60% of the fish caught (Figure 3c). Weight ranged from 109 – 766 g, with a mean weight of 477 ± 11 g (*n* = 127).

Bony herring exhibited a narrow size range from 226 – 312 mm FL (Figure 3d), with a mean length of 273 ± 2 mm FL (*n* = 100). Weight ranged from 183 – 509 g, with an average weight of 346 ± 6 g (*n* = 100).

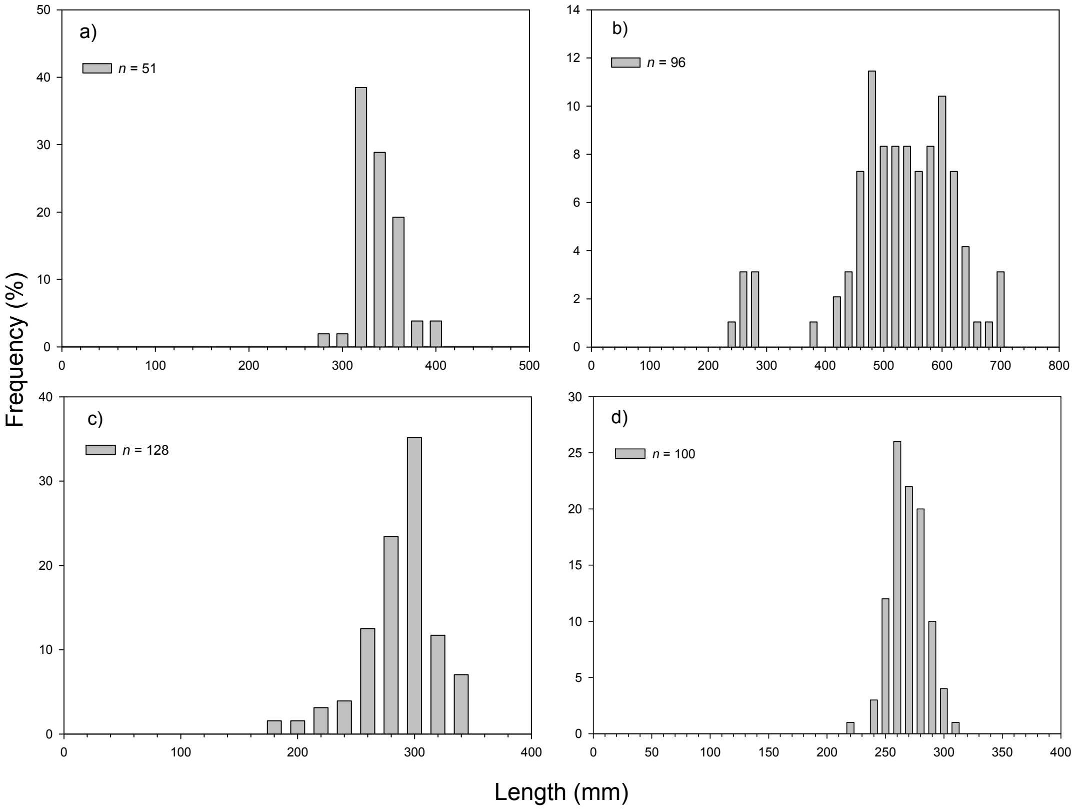
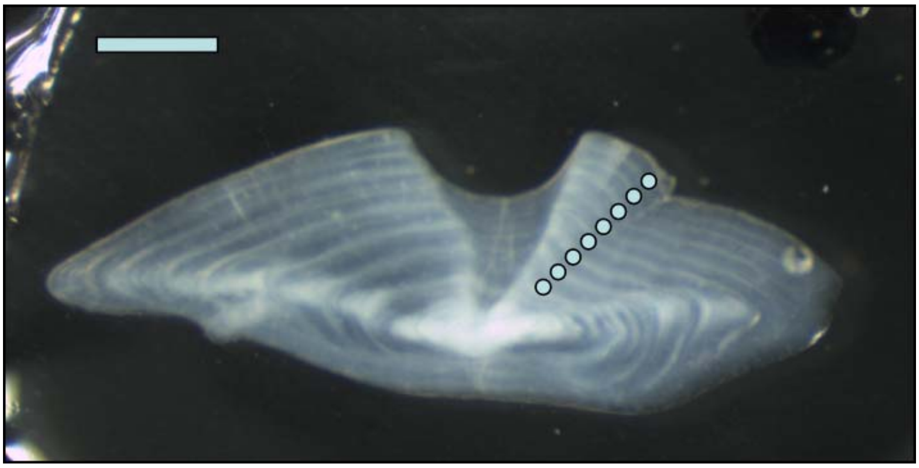


Figure 3. Length-frequency distributions for a) golden perch (TL), b) common carp (FL), c) redfin perch (FL) and d) bony herring (FL) captured during the Lake Albert fish-down, October 2009.

Age structure

Of the 46 golden perch otolith sections examined, 43 (~93%) had discernible increments (Figure 4a) with a consensus on counts reached by all readers and subsequently were included in analysis. Redfin perch otolith sections exhibited a high level of clarity (Figure 4b) with a consensus on counts reached for all sections (*n* = 76).

a)



b)

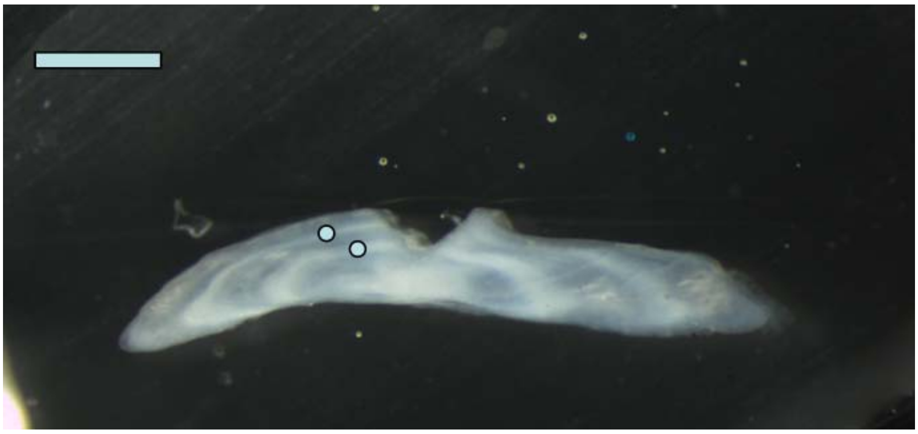


Figure 4. Images of transverse sections of sagittal otoliths removed from a) a golden perch estimated to be 8+ years of age and b) a redfin perch estimated to be 2+ years of age, captured during the Lake Albert trial fish-down, October 2009. Scale bar = 1 mm. Dots indicate increments/annual rings.

Golden perch exhibited a broad age structure with fish ranging from 2+ to 12+ years of age and these originated from annual spawning events between 1996 and 2006 (Figure 5a). Fish spawned in 2000, and 2002 – 2004 formed the dominant cohorts, collectively comprising ~75% of the total catch (Figure 5a).

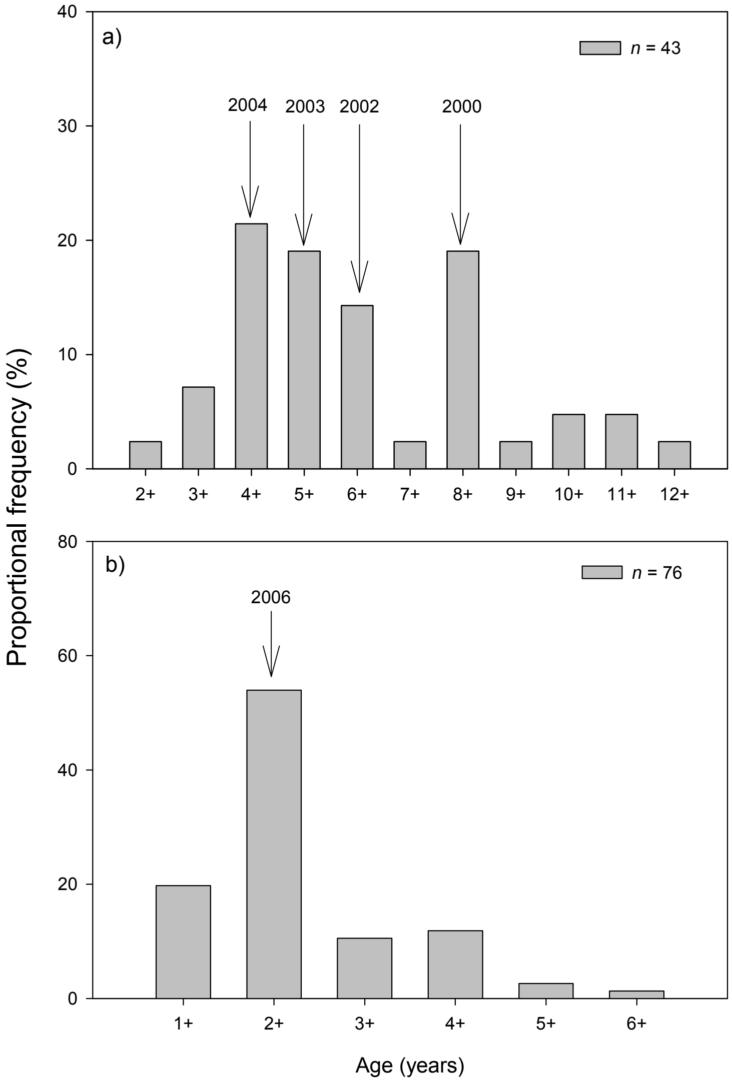


Figure 5. Age structure of a) golden perch and b) redfin perch captured during the Lake Albert trial fish-down in October 2009. Years above selected bars indicate estimated year of spawning.

Redfin perch displayed a more restricted age structure with fish ranging from 1+ to 6+ years of age and these originated from annual spawning events between 2002 and 2007 (Figure 5b). The catch was dominated by the 2006 cohort which comprised >50% of the total catch with the 2007 cohort contributing a further ~20%.

Sex ratio and reproductive condition

Sex and reproductive condition were investigated for a sub-sample of golden perch (*n* = 45), redfin perch (*n* = 119) and common carp (*n* = 50). Sex ratio was biased towards males for golden perch with a male to female ratio of 2.2:1. Conversely, sex ratios were biased towards females in both common carp and redfin perch. Common carp and redfin perch exhibited a male to female ratio of 1:3 and 1:39 respectively.

The ovaries of ~57% (*n* = 8) of female golden perch sampled were determined to be in an early or 'immature' development stage without clearly defined eggs (i.e. stage II), whilst the remaining ~43% (*n* = 6) were determined to be at an intermediate or 'maturing' development stage (i.e. stage III). No 'ripe' (i.e. stage IV) or 'spent' (i.e. stage IV) females were observed. All males (*n* = 31) were running ripe (i.e. stage III).

The majority of female redfin perch (~95%, *n* = 110) were determined to be spent (i.e. stage V), i.e. they had spawned recently. Equal proportions of the remaining females were immature (i.e. stage II, ~2.5%, *n* = 3) or well developed and likely in the process of spawning (i.e. stage IV, ~2.5%, *n* = 3). The three males collected were in varying stages of development (i.e. stages II and III).

Similarly, the majority of female common carp (~71%, *n* = 27) were spent (i.e. stage V) and thus had recently spawned. The remainder (~29%, *n* = 11) were well developed (i.e. stage IV) and likely in the process of spawning. All males (*n* = 12) were running ripe (i.e. stage III).

Population growth dynamics

Length-weight relationships

Length-to-weight relationships were developed for golden perch, common carp, redfin perch and bony herring (Figure 6). Exponential growth curves best explained the growth of all species with weight increasing in a non-linear fashion with increasing length. Golden perch show a moderately close relationship between length and weight (i.e. weight = 3E-08 length$^{4.064}$, r^2 = 0.829), yet the lack of small fish (i.e. < 300 mm TL) hinders the reliability of this estimate (Figure 6a). Both common carp and redfin perch were sampled in greater numbers and over a greater range of lengths and weights and both exhibit strong relationships between length and weight (i.e. common carp: weight = 0.0006 length$^{2.486}$, r^2 = 0.944. Redfin perch: weight = 0.0001 length$^{2.637}$, r^2 = 0.912) (Figures 6b & c). Bony herring displayed a poor relationship between length and weight (i.e. weight = 0.0002 length$^{2.551}$, r^2 = 0.761) with considerable variation in weight at length (Figure 6d). Bony herring, however, were sampled in a narrow size range (i.e. 226 – 312 mm FL).

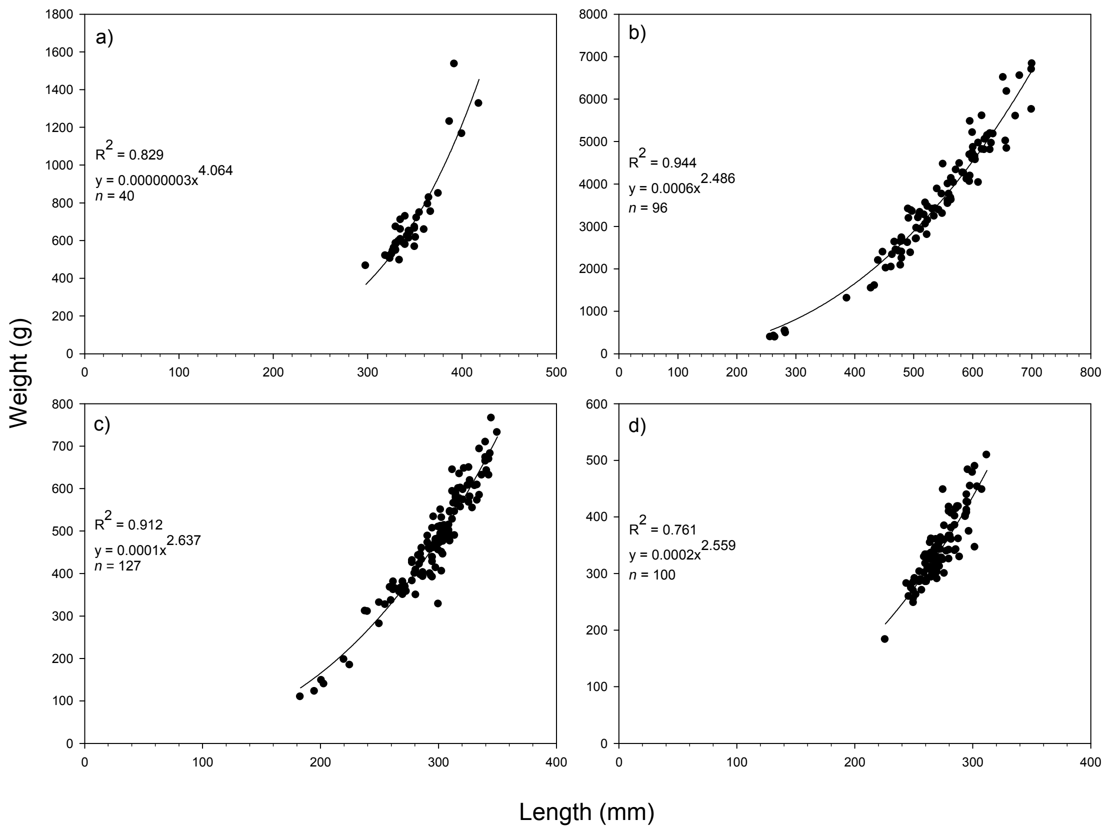


Figure 6. Length to weight relationship of a) golden perch, b) common carp, c) redfin perch and d) bony herring captured during the Lake Albert trial fish-down in October 2009.

Length at age

Golden perch exhibited considerable variation in length-at-age (e.g. the 5+ cohort ranged 298 – 375 mm TL) but little variation in length between cohorts (Figure 7a). The majority of fish that were aged ranged in length from 320 – 370 mm TL regardless of age (Figure 7a). Coupled with the fact that neither 0+ nor 1+ individuals were collected a growth model could not be developed for golden perch. Nonetheless, growth rate during early years (e.g. first 3 years) appears to be greater than in subsequent years but this may vary between individuals.

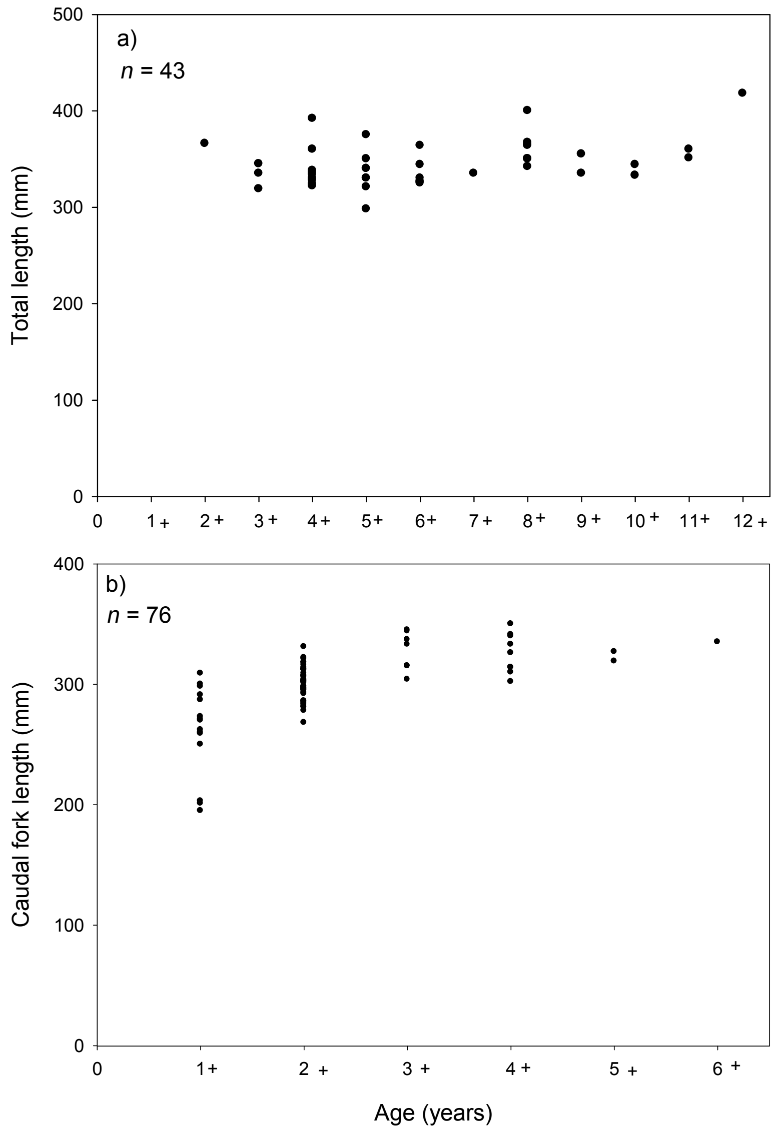


Figure 7. Length-at-age of a) golden perch and b) redfin perch captured during the Lake Albert trial fish-down in October 2009.

Redfin perch also exhibited considerable variation in length-at-age (e.g. the 1+ cohort (spawned in 2007) ranged from 195 – 309 mm FL) (Figure 7b) and limited variation in length between cohorts. Thus a growth model could not be applied for this species. Similar to golden perch, growth appears greatest in early years but may vary between individuals.

DISCUSSION

The current project aimed to gather biological information from large-bodied fish captured during the trial fish-down of Lake Albert. Despite the worsening environmental conditions (e.g. decreasing water level and increasing salinity) in Lake Albert and, present and potential management interventions in the region, knowledge on the biology of fishes in Lake Albert was previously limited. Whilst the fishing gear types (i.e. gill nets) used in the trial fish-down were, somewhat species and size selective, new information was gathered on the presence, size structure, age structure, sex ratios and growth parameters of large-bodied fish in Lake Albert.

The abundance of the four species captured (i.e. golden perch, common carp, redfin perch and bony herring) was difficult to quantify due to the large number of fishermen and different gear types being used. Nevertheless, the catches revealed that common carp and bony herring are abundant in Lake Albert and dominate the large-bodied fish biomass, while golden perch and redfin perch are less abundant.

Three other large-bodied freshwater species which have previously been recorded in Lake Albert (SARDI Unpublished) were not captured during the trial fish-down. These are silver perch (*Bidyanus bidyanus*) and eel-tailed catfish (*Tandanus tandanus*), both of which are protected under the *Fisheries Act* (2007), and Murray cod (*Maccullochella peelii peelii*), listed as 'vulnerable' under the Commonwealth's *EPBC Act* (1999). Silver perch and eel-tailed catfish are similar in size to golden perch and would likely be caught in gill nets of similar mesh size but due to there protected status, any caught were to be returned to the water immediately. To the authors knowledge, however, no silver perch or eel-tailed catfish were reported by fishermen and are likely rare in Lake Albert.

The status of Murray cod in Lake Albert remains unknown as the gill nets used during the trial fish-down had mesh that is too small (largest mesh size was ~200 mm) to effectively capture adults of this species. There has been limited recruitment of Murray cod in the Lower Murray below lock 1 in recent years and consequently the majority of fish present are >700 mm TL (Ye and Zampatti 2007). Gill nets with mesh >200 mm are required to capture individuals of this size and a targeted sampling program would be required to determine the status of Murray cod in Lake Albert.

Size structure

The length frequency distributions exhibited by all species reflect the fishing gear types used in the trial fish-down as indicated by the capture of few small individuals (<250 mm TL or FL). Nevertheless, this does not preclude fish <250 mm in length being present in Lake Albert.

The length frequency distribution of golden perch captured in Lake Albert was similar to that reported by Mayrhofer (2007) from commercial samples collected from Lake Alexandrina in 2006/07 using gill nets with mesh sizes 100 – 150 mm. In the current study fish 320 – 359 mm TL comprised >60% of the total catch with a small proportion of larger fish and these results concur with Mayrhofer (2007) who reported fish of 330 – 370 mm TL comprising >60% of the commercial catch.

Age structure

Golden perch captured from Lake Albert ranged from 2+ to 12+ years old, similar to the age range of 1+ to 12+ reported by Ye (2005) from the Lower Lakes in 2002 and an age range of 2+ to 11+ reported by Mayrhofer (2007) from Lake Alexandrina in 2006/07. The age structure from Lake Albert in October 2009 indicates that recruitment occurred annually between 1996 and 2006, with the strongest cohorts from 2000, 2002, 2003 and 2004. No fish were captured that were spawned in 2007 or 2008 but failure to capture these individuals may be a result of mesh size limitation. Mayrhofer (2007) also reported annual recruitment in Lake Alexandrina and strong year classes corresponding to those reported in this study, particularly the 2000 cohort. Furthermore, Ye (2005) noted the appearance of a relatively strong cohort from the year 2000 in the Lower Lakes from research sampling in 2002 (at that time this cohort was 1+ years of age).

Annual recruitment of golden perch in riverine reaches of the South Australian MDB is typically variable resulting in populations dominated by a low number of strong cohorts (Ye 2005; Zampatti *et al.* 2008). From data gathered in 2002/03 (a combination of 'reach' commercial fishery data and research sampling data) Ye (2005) reported that annual recruitment had occurred in the main channel of the River Murray in South Australia between 1989 and 2000 but the contribution of each cohort differed considerably. In 2008, however, research in the Chowilla anabranch system (Zampatti *et al.* 2008) failed to detect cohorts from the years 2002-2004, inferring that recruitment was either very low or may not have occurred in these years. Whilst there is inter-annual variation in recruitment in Lake Albert there were no years in which recruitment was absent and cohorts from spawning in the years 2002-2004 represent some of the strongest cohorts in the population. Whilst inference from the data presented in this project is limited due to the small sample size and limitations of sampling methods (i.e. mesh size selectivity), the presence of three strong cohorts, which were absent from the Chowilla anabranch system in 2008 suggests a regional difference in the age structure of this species.

It was originally hypothesised that golden perch were highly dependent upon floods for spawning and recruitment (Lake 1967; Harris and Gehrke 1994). Nonetheless, it has been recently demonstrated that spawning and recruitment of golden perch in the MDB may occur in association with increased within-channel flows (Mallen-Cooper and Stuart 2003) and during periods of no increase in flow (Balcombe *et al.* 2006). Thus, golden perch may not be dependent upon floods for spawning and recruitment, but increased flows and floods may facilitate greater recruitment success. The strongest cohorts detected in Lake Albert (2000, 2002, 2003 and 2004) coincide with years of below average inflow from the River Murray to the Lower Lakes (DWLBC 2009). Whilst inflows to the Lower Lakes in 2000 (~3807 GL) were below the post regulation average (~4723 GL) there was a period of increased flow in spring/summer 2000 that peaked at ~37,900 $ML.day^{-1}$. This flow rate is similar to within-channel flows that facilitated recruitment in the mid-Murray as reported by Mallen-Cooper and Stuart (2003). Nevertheless there were no distinct peaks in flow from the Murray River in 2002, 2003 and 2004.

Age structure variability between golden perch populations in the South Australian MDB suggests that conditions in the Lower Lakes during years when water levels are maintained within normal regulated levels (i.e. 0.5 – 1.0 m AHD) may facilitate frequent recruitment. The majority of investigations into golden perch recruitment have assessed riverine populations (e.g. Mallen-Cooper and Stuart 2003; Balcombe *et al.* 2006; Roberts *et al.* 2008) whilst lake populations have received only limited attention. Ebner *et al.* (2009) discuss the presence of juvenile golden perch in the Menindee Lakes in New South Wales and back-calculation of spawn dates from otoliths indicated that spawning was not associated with increased flows. Large lakes, such as Lakes Alexandrina and Albert, often experience variable water levels and hydraulic conditions on a local scale as a result of wind-driven water movement (i.e. seiche). Additionally, several smaller tributary streams (e.g. the Finniss River) discharge into the Lower Lakes. Flows in these streams are more dependent upon local rainfall and therefore may influence lake hydrology on a local scale. Localised lake hydrology may influence golden perch recruitment; nevertheless, the mechanisms facilitating consistent recruitment in the Lower Lakes remain unknown and warrant further research.

Sex ratio and condition

The ratio of males to females in fish populations is often not equal but may be biased towards one sex (see Bohlen and Ritterbusch 2000; Maehata 2007). Golden perch from Lake Albert exhibited a biased ratio towards males. This contrasts with Mayrhofer (2007) who reported an equal sex ratio from Lake Alexandrina in October 2006. The current study, however, only investigated sex ratios from a small sample size of golden perch. Redfin perch exhibited a heavily female biased sex ratio and this may be related to the sexual growth dimorphism seen in this species, whereby female fish generally have a greater growth rate and reach a greater ultimate size than male fish (Craig 2000). Few fish were captured <250 mm TL due to the size selectivity of the gill nets used and thus gill net mesh sizes may have been too large to capture a large proportion of the ‘smaller’ males.

Common carp also displayed a female biased sex ratio, with the majority of fish captured from spawning aggregations (spawning activity was observed in the Narrung Narrows regularly during the trial fish-down) suggesting females may out number males in such aggregations. This result, however, contrasts that of Brown *et al.* (2005), who report male biased sex ratios from spawning aggregations in the mid-Murray River. This disparity may represent a regional difference in the ecology of this species or be a result of the small sample size in the current study.

Macroscopic ovary analysis of female golden perch revealed that no recent spawning had occurred as of October 2009 but this species may have been yet to spawn. A large proportion of both redfin perch and common carp were presented with ‘spent’ ovaries indicating that spawning took place recently.

Growth parameters

Growth of golden perch in Lake Albert is highly variable between individuals and this has previously been observed elsewhere in this species (Anderson *et al.* 1992; Mallen-Cooper and Stuart 2003; Roberts *et al.* 2008). Thus, length is not a reliable indication of age or recruitment in golden perch from Lake Albert. Redfin perch also exhibited variation in individual growth rates. Variation in length at age, particularly for 0+ individuals is common in redfin perch in the northern hemisphere and is due to differences in the timing of ontogenetic dietary shifts which infer variation in growth rates (Beeck *et al.* 2002; Heermann *et al.* 2007). Differential growth rates in early years may infer variation in adult length at age and may explain the pattern observed in Lake Albert.

Conclusion

Significant biological information was gathered on the large-bodied fish species of Lake Albert, complementing past research on the small-bodied fishes of the lake and providing some information on current condition. As expected, common carp and bony herring were highly abundant. The golden perch captured exhibited a broad age distribution indicating consistent annual recruitment of this species in the Lower Lakes between 1996 and 2006. This contrasts the situation for golden perch from the Chowilla anabranch system and may indicate regional differences in the ecology of this species within South Australia but requires further research. This information is important considering the potential for radical management interventions in the Lower Lakes region (e.g. seawater intrusion) and the conservation of this commercially and recreationally important species. Additionally the information gathered in this project (e.g. size distributions, length at age relationships) provides a basis for comparison with future research and monitoring of fish populations in the Lower Lakes.

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