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On-site recreational fishery survey and research of mulloway (*Argyrosomus japonicus*) in the Yalata Indigenous Protected Area and Far West Coast Marine Park between 2009 and 2013

Paul Rogers, Tom Barnes, Yasmin Wolf, Paul Gregory, Nathan Williams, Alessandro Madonna and Aude Loisier

SARDI Publication No. F2014/000074-1
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SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

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PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

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South Australian Research and Development Institute
SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024
Telephone: (08) 8207 5400
Facsimile: (08) 8207 5406
http://www.sardi.sa.gov.au

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Author(s): Paul Rogers, Tom Barnes, Yasmin Wolf, Paul Gregory, Nathan Williams, Alessandro Madonna and Aude Loisier

Reviewer(s): Anthony Fowler and Greg Ferguson

Approved by: Dr Jason Tanner
Science Leader – Marine Ecosystems

Signed:

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EXECUTIVE SUMMARY

This report provides an example of the development of an on-site survey designed to monitor a socio-economically important and iconic recreational fishing species in a geographically isolated and spatially complex management region. This has occurred through a multi-stakeholder research and monitoring partnership and sustained development of indigenous stewardship.

Specifically, this report provides the second summary on the recreational fishery for mulloway *Argyrosomus japonicus* in the Yalata Indigenous Protected Area (IPA), Far West Coast Marine Park (FWCMP), and the new Great Australian Bight Commonwealth Marine Reserve (GABCMR) that is part of the South-west Commonwealth Marine Reserve Network.

Firstly, we summarised information collected by Natural Resources Alinytjara Wilurara (AW) and Yalata Land Management (YLM) staff and volunteers on the recreational fishery for mulloway. This included catch and effort, fisher demographics, catch composition of target, non-target and released species during the 2009–10, 2010–11 and 2011–12 spring-autumn periods.

Secondly, we provide a summary of preliminary findings of research and monitoring projects that have commenced in the Yalata IPA between 2009 and 2013.

Natural Resources AW staff and community volunteers conducted 96 fisher interviews during on-site survey events in the 2009–10, 2010–11 and 2011–12 spring-autumn seasons in the IPA. Annual totals of 29, 47 and 20 interviews were conducted over those periods, respectively.

Interviews provided information on fisher age and state of origin, numerical abundance of retained and released mulloway, fishing effort spent targeted at mulloway, catch composition, biological indicators (size and age composition), and non-target species.

Size of fisher group ranged from 1–11 people. From 2009–10 to 2011–12, 90 groups were interviewed providing demographic data. Of these groups, 39% were aged between 31–44 years and 31% were aged between 45 and 59 years.

Fishers in the IPA were predominantly from South Australia (SA) (81%), with 58% from Adelaide. South Australian groups from the far west coast (Ceduna and communities to the west) and Eyre Peninsula only comprised 10% and 12% of those surveyed, respectively. Remaining fishers were from the south-east, mid-north and Kangaroo Island.

The on-site survey recorded the landing of 478 mulloway during the spring-autumn periods of 2009–10, 2010–11 and 2011–12 combined.

In summary, 2,711 hours of fishing effort took place over 327 days spent targeting mulloway between 2009 and 2012.

The overall release rate of mulloway of all sizes over the three seasons was 75% with the remaining 25% being retained.

Mulloway in catches were estimated to be aged between 4 and 22 years. The 14 year old age class was the most common (11%). Fish in the 5–10 (50%) and 12–15 year old (33%) age classes were commonly captured and retained.

Non-target bony fishes were often released (63%). Overall, the percentage of released bony fishes, sharks and rays was 76%, with the remaining 24% being retained.

Preliminary stock structure and satellite tagging data suggests that mulloway taken in the IPA are part of a discrete western stock and this supports previous research.

This on-site survey has played a key role in the providing baseline data required to identify suitable fishery, biological and demographic indicators to integrate into future management strategies for the recreational fishery for mulloway accessed from the IPA and State managed zones of the FWCMP and the GABCMR.

We outline the gaps and priorities for future monitoring and research of the mulloway fishery in the Yalata IPA and FWCMP.

BACKGROUND

1.1. Yalata Indigenous Protected Area and the Great Australian Bight Commonwealth Marine Reserve

The Great Australian Bight (GAB) is located off the far west coast of South Australia (SA) (Fig. 1). This remote area of coastline is bordered by high-energy surf beaches, fringing rocky reefs and calcareous limestone headlands that form unique semi-protected lagoons. The GAB is the location of the former Great Australian Bight Marine Park (GABMP) that is co-managed by the State and Commonwealth Governments and is now titled the Great Australian Bight Commonwealth Marine Reserve (GABCMR) (Fig. 1). During 2013–14, when this report was being prepared, the Commonwealth jurisdiction of this marine reserve was under interim management arrangements.

The State-managed marine park boundaries extend offshore to three nautical miles and from the South Australian-Western Australian border (129° 00'E) to just west of Cape Adieu, SA (132° 00'E) (Fig. 2). Lands on the terrestrial boundary from the mean high water mark comprise the land of the Yalata Aṉangu people and the Yalata Indigenous Protected Area (IPA) that is managed by Yalata Land Management (YLM). This Aṉangu homeland adjoins the Wahgunyah Conservation Reserve that extends to the east towards Dog Fence Beach and west to the Head of Bight (Fig. 1) (www.yalata.org). Within the State-managed marine boundaries of the GABCMR is the Far West Coast Marine Park (FWCMP) that comprises several management zones that were implemented in March 2013. These include existing Restricted Access Zones (RAZ), Habitat Protection Zones (HPZ) that allow recreational and commercial fishing (other than bottom trawling), Sanctuary Zones (SZ) that preclude removal of any plant or animal, and special purpose areas (SPA) that allow shore-based recreational line fishing. Sanctuary zones are to be implemented from October 2014. Sanctuary Zones in the Yalata IPA include the ecologically unique area between the Granites and the Coombra lagoons (Fig. 2), where South Australia's western-most seagrass meadows occur in lagoons formed by reefs that provide physical barriers to the Southern Ocean.

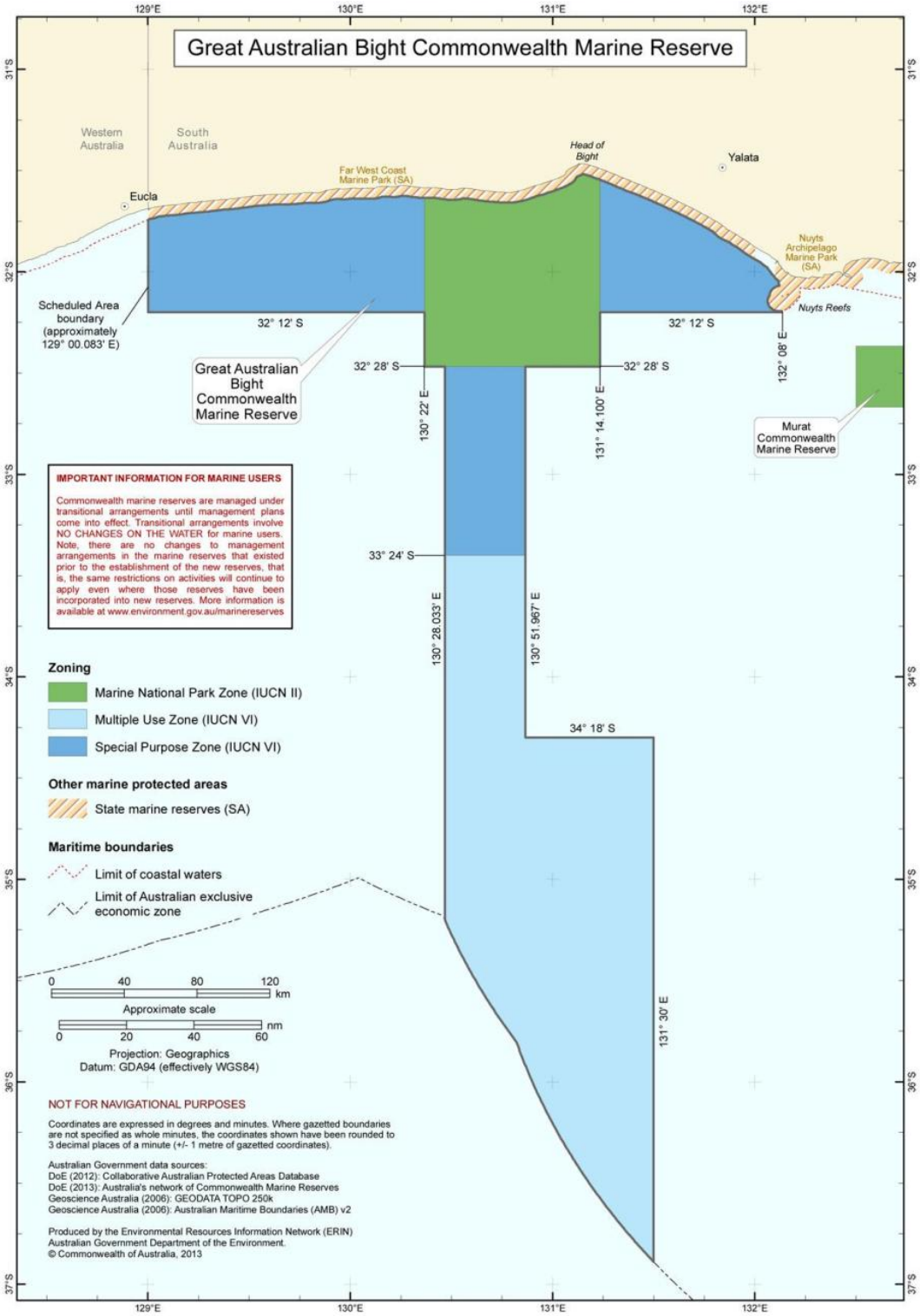

Figure 1. Great Australian Bight Commonwealth Marine Reserve. Shows the State management boundaries of the Far West Coast Marine Park against the coastline. Source: www.environment.gov.au.

1.2. Recreational Mulloway Fishery

Recreational fishing for mulloway (*Argyrosomus japonicus*) and viewing of southern right whales (*Eubalaena australis*) at the Head of Bight are the two main seasonal tourist attractions in the Yalata IPA, FWCMP, and GABCMR. Recreational fishers from the local indigenous communities, the far-west coast, Adelaide metropolitan area, around South Australia and interstate travel to the Yalata IPA to fish from the surf beaches during the spring to autumn months. Non-local visitors pay a permit fee to YLM to camp at seven designated campsites. Use of four-wheel drive and All Terrain Vehicles (ATV) and fishing related camping activities combine to have potential environmental and ecological impacts on the recreational fishery, and flora and fauna in the Natural Resources Alinytjara Wilurara region. These impacts are difficult to disassociate and quantify, however YLM and Natural Resources AW have taken steps to manage some of these forms of traffic and their impacts in and around campsites using permapine barriers and through the installation of fish waste composting facilities.

Mulloway is a large (1600 mm total length, TL), long-lived (41 yrs), slow-to-mature species (810 mm is the size at which 50% of fish attain sexual maturity, L50 and 5 yrs of age) (Ferguson, 2010). While the age and growth of mulloway have been studied in detail in south-eastern SA (SE SA), preliminary information on growth rates suggests the western population is faster growing (Ferguson 2010). The size distribution of mulloway recorded during the first on-site survey, and satellite tagging field trips indicated that medium-large juvenile and adult life history stages share the surf beach and semi-protected lagoon habitats in the FWCMP (Rogers *et al*. 2010; Barnes *et al.* 2013). This differs from the situation in SE SA and South Africa, where juveniles aggregate in protected estuarine habitats (Griffiths 1996; Ferguson *et al.* 2008). The spring-summer period, which is popular for recreational fishing, coincides with when mulloway spawn in the FWCMP (Rogers *et al*. 2010). No surveys have been conducted to assess the distribution and abundance of mulloway eggs and larvae in the areas adjacent to where spawning adults are found. It is possible, however, that the western mulloway population may also use a combination of reef-lagoon, seagrass, low energy surf beach-reef habitats as nursery habitats for post-larval and small juvenile life history stages. This forms a key question in terms of understanding the dynamics of recruitment processes that ultimately support the status of the fishery.

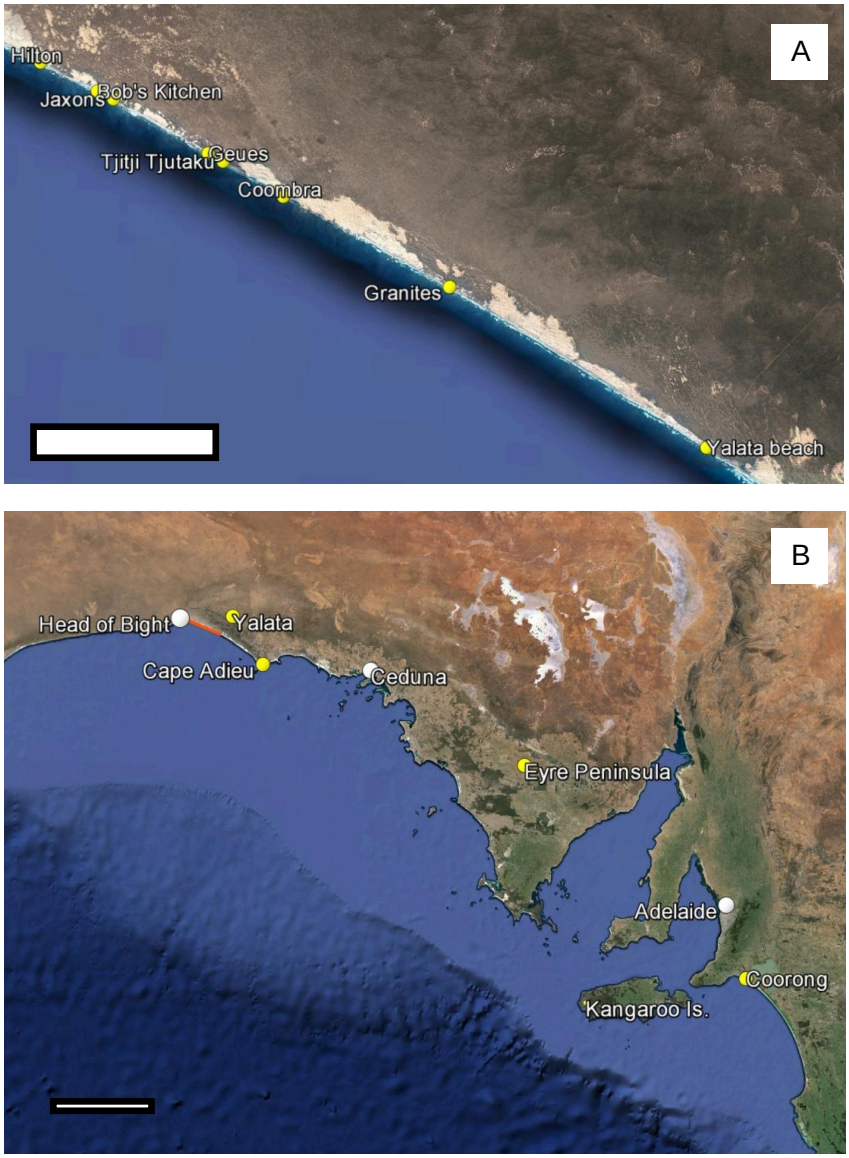

Figure 2. Map A shows the seven campsites in the Yalata IPA (scale bar = 10 km). Map B shows the region where campsites (orange strip) are located in map A and locations mentioned in this report (scale bar = 50 km).

1.3. On-site Survey: Monitoring in the Yalata IPA

Previously, the west coast community, including the Yalata Aṉangu people, expressed concern about the sustainability of the recreational fishery that targets mulloway from the beaches in the Yalata IPA; allocation and sharing of the resource; ecological impacts of camping on flora and fauna; and the management of camping refuse, mulloway and bait carcasses. Several experienced fishers suggested that catch rates had declined and that they were concerned about increases in fishing pressure. In response, Natural Resources AW and SARDI Aquatic Sciences developed and implemented an on-site survey to monitor the recreational fishery for mulloway in the Yalata IPA in 2009–10. This on-site survey is unique in Australia, and at the time of preparation of this report, was in the fourth full season of data collection. The aims of the first on-site survey report by Rogers *et al*. (2010) were to:

- Collect on-site information that could be used to assess the status of the recreational mulloway fishery at Yalata;
- Investigate the population demographics of mulloway;
- Identify the non-target species that are taken while targeting mulloway;
- Promote indigenous stewardship and cooperation with the Yalata community and the YLM team;
- Increase community awareness and education regarding mulloway fishing at Yalata.

The on-site survey has played a key role in encouraging indigenous stewardship and the development of research, monitoring and engagement (RME) in the Natural Resources AW region. The first survey report focused on development of the on-site survey and the results of the first season, and was provided to Natural Resources AW and PIRSA Fisheries in 2010 (Rogers *et al*. 2010). The on-site survey has provided a cost-effective method for monitoring the recreational mulloway fishery, and has led to a better understanding of key coastal management issues related to recreational fishing. Findings of the first report have been pivotal in educating a wide range of stakeholders regarding the unique fishery that exists in the Yalata IPA, as well as some of the logistical challenges of running surveys in such geographically isolated areas. The first report also highlighted some of the issues associated with broader recreational survey methods, particularly in terms of gaining representative data from isolated, regionally important fisheries that target iconic species.

Mulloway research in the Yalata IPA

Size and age information

Fish size and age data represents biological information crucial to informing the management of exploited finfish populations. Assessment of the size and age of fish captured in recreational fisheries provides an indication of the strength of the year classes that are supporting the fishery and forms an indicator of the state of the SA mulloway population. Ongoing annual sampling of otoliths from catches is currently being undertaken via three means: 1) collection from fish caught by fishers camping in the Yalata IPA and sampled during on-site surveys, 2) otoliths are collected by fishers and provided to Natural Resources AW or SARDI Aquatic Sciences, and 3) mulloway carcasses with otoliths are being deposited in large compost bins at two campsites (Bob's Kitchen and Geue's). It is planned that otoliths will be extracted by SARDI during winter-spring 2014.

Population structure and movement from satellite tagging

Genetic information collected during the on-site surveys and movement data from mini pop-up satellite archival tags (mini-PSAT) deployments are providing insights into the regional separation and spatial connectivity of mulloway populations (Barnes *et al*. 2013). This is the first time that this form of archival electronic tracking technology has been used on a benthic fish species, and these techniques are facilitating a new understanding of the spatial scales of movement and habitat use that will allow future assessment of human impacts at the population level.

1.4. AIMS

The aims of this report are to:

1) Provide summaries of:
   - the recreational fishery survey data for mulloway in the Yalata IPA between 2009–10 and 2011–12;
   - fisher demographic information collected in the Yalata IPA between 2009–10 and 2011–12;
   - Non-target species taken by the recreational fishery for mulloway in the Yalata IPA;
   - biological information collected on mulloway in the Yalata IPA between 2009–10 and 2012–3.

2) Provide advice on future monitoring and management of mulloway stock(s);

3) Provide baseline information relevant to the future monitoring of the FWCMP and GABCMR.

2. METHODS

2.1. On-site survey

Interviews with recreational fishers who were camping in the Yalata IPA were conducted to collect data on the numbers of mulloway landed and released, fishing effort, non-target species landed and released, and fisher demographic information. Fishers were interviewed on-site by moving through the seven campsites from Granites to the Hilton (Fig. 2). A small number of interviews were also conducted at Yalata Beach, and in the Wahgunyah Conservation Reserve.

A total of 96 interviews of 380 fishers were conducted by NR AW staff and YLM during on-site survey days between the 2009–10 and 2011–12 fishing seasons (refer to summary of interview dates and locations in Appendix 1). Annual totals of 29, 47 and 20 interviews of fisher groups were conducted. The interview form used is provided in Appendix 2. Campsites were visited during daylight hours from east to west, based on occupancy/campsite bookings and allowable time. Fisher demographic and additional information collected included length of stay, number in fishing group, and whether an ATV was used to access fishing gutters that did not have immediate vehicular access. If fisher groups did not provide effort data as in several cases in 2009–10, the average number of hours fished per day was used and it was assumed the group fished for a minimum of one day. Fisher demographic data were collected including fisher age and postcode.

Key Assumptions:

- In 2009–10, we used permit data to estimate that ~35% of fishers who paid permits to enter the Yalata IPA were surveyed on-site (Rogers *et al.* 2010).
- As we have not sampled every permitted fisher, and it is not possible to estimate total landings, percent of catch retained or fishing effort by fishers that entered illegally (without permits), we assume that information provided in this report represents conservative estimates of those parameters in the Yalata IPA.

2.2. Size and age distribution

Mulloway that were available during the on-site survey interviews were measured (total length, TL in cm), or size was measured or estimated as accurately as possible by fishers (e.g. by marking their fish lengths on objects of known length). When length data were not available if mulloway were weighed, an allometric length-weight relationship was used to estimate total length (fish wt = $a.TL^b$). Fish size data were binned into 10 cm classes and presented as size distribution histograms. Otoliths or ear-bones (sagittae) were dissected from mulloway larger than the minimum legal size (MLS, 750 mm TL) as described by Rogers *et al.* (2010). Otoliths were also collected from carcasses found on beaches and in the sand dunes (note: not all sets of otoliths were accompanied by length and/or weight data and these were only used for age structures). In the laboratory, each otolith was weighed on a microbalance (±0.001 g). The age of each individual was estimated using the linear regression between otolith weight and age (G. Ferguson, unpublished data). Age distributions were binned by age classes and summarised as percentage histograms following Rogers and Ward (2007).

2.3. Genetic population structure

Tissue samples were collected from a sub-sample of mulloway landed in the Yalata IPA. These were preserved in 100% ethanol. DNA was extracted from muscle tissue and used to develop microsatellite markers to differentiate mulloway sampled in the Yalata IPA from those from other regions of Australia (Barnes *et al.* 2013). Microsatellite markers and DNA were used to genetically group individual mulloway from across the SA geographical range (T. Barnes, unpublished data). Genotype frequencies used to group mulloway populations were analysed using STRUCTURE software to assign individuals to populations. These assignments were then plotted using DISTRUCT™ software that allows visualisation of difference in population structure.

2.4. Movement

Mini-pop up archival tags (mini-PAT) (Wildlife Computers™) were deployed on 17 mulloway in the FWCMP from the Yalata IPA between 18/2/12 and 13/12/13. The deployment periods of each tag was programmed at 100 days. A tag was attached to a fish using a 30 mm titanium or surgical stainless steel dart attached to a short length of monofilament leader (400 lb test). The

dart was inserted into the dorsal musculature between the third and fourth dorsal spines using a stainless steel applicator. A total of 15 mulloway were tagged at one location in the east of the Yalata IPA and two were tagged at Bob's Kitchen.

Tagging and pop-up locations were plotted using Google Earth Pro™ to show the directions moved and estimated minimum straight-line distances travelled by the individual mulloway. Detailed methods are provided in Barnes *et al.* (2013).

2.5. Trial of fish waste compost bins

In February 2012, two fish waste compost bins were installed by the YLM team adjacent to campsites at Geues and Bob's Kitchen for the disposal of mulloway carcasses (Natural Resources AW Newsletter, March 2013). The aims of the implementation of these composting systems were to provide a repository for fish carcasses and other organic waste at two key fishing camp-sites and reduce the potential impacts of terrestrial predators (feral dogs, dingos and ravens) on nesting shorebirds, with the view to possibly rolling out further bins in the future if the trial is successful. During winter following each fishing season, mulloway otoliths will be sampled for age determination from the decomposed carcasses.

3. RESULTS

3.1. On-site survey

Fisher demographics, local and interstate visitation

Fisher group size ranged from 1–11 people, with an average of four fishers per group. Visiting fishers were predominantly male. Over the three seasons, from the 90 groups interviewed that provided demographic data, 39% were aged between 31–44 years and 31% were aged between 45 and 59 years (Fig. 3). Fishers in the Yalata IPA were predominantly from South Australia (81%), with 58% from the Adelaide metropolitan area. South Australian fisher-groups from the far west coast and Eyre Peninsula comprised 10% and 12% of those surveyed respectively, with the remainder from the south-east, mid-north and Kangaroo Island. Interstate visitors comprised groups from Victoria (11%), New South Wales (7%), and Western Australia (1%) (Fig. 4). Interstate visitation to the Yalata IPA increased from 15% in 2009–10 to 20% in 2011–12.

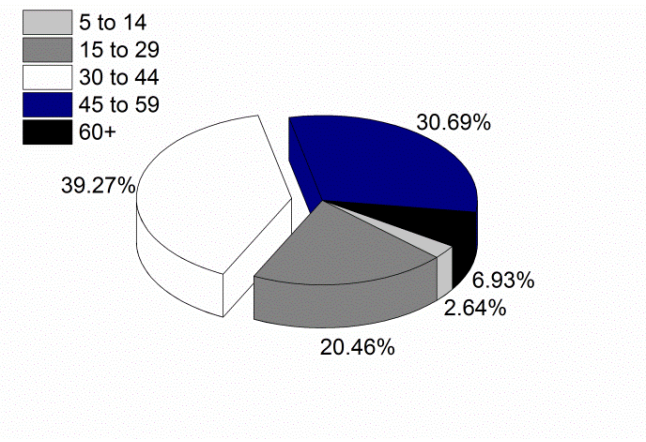

Figure 3. Age demographic of fishers visiting the Yalata IPA to target mulloway between 2009 and 2012.

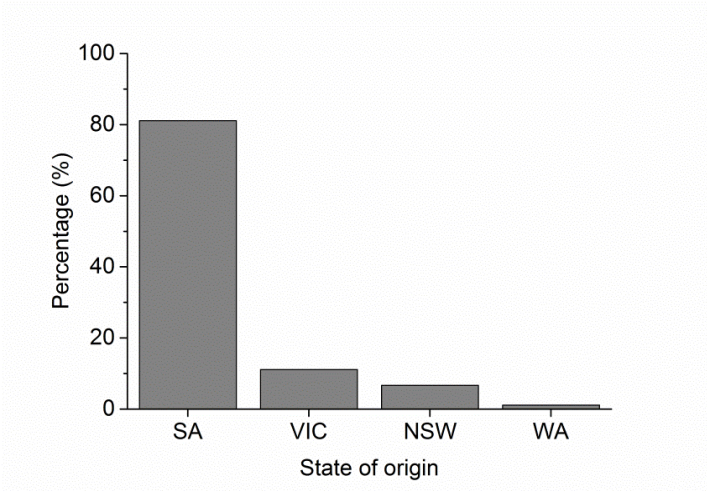

Figure 4. State of origin of fishers visiting and camping in the Yalata IPA to target mulloway between 2009 and 2012.

All terrain vehicle usage

A total of 40 (42%) of the groups surveyed that provided additional information used all terrain vehicles (ATV) or quad bikes to access remote fishing areas beyond beaches directly adjacent to the seven camp-sites. There are insufficient data to provide a robust assessment of inter-annual patterns in ATV use.

Fishing effort estimated during on-site survey

In 2009–10, 29 groups and 114 fishers reported that they targeted mulloway for an estimated total of 642 hours over 87 days of fishing effort. During the 2010–11 season, there was a substantial increase (up by 40%) in survey coverage from 29 to 47 fisher groups interviewed. In this second season, 190 fishers reported that they targeted mulloway for a combined total of 1,611 hours over 171 days. During 2011–12, interview coverage decreased from 47 to 20 fisher groups interviewed. In this third season, fishers targeted mulloway for a combined total of 458 hours over 69 days. In summary, there was an estimated 2,711 hours fished over 327 days targeting mulloway in the Yalata IPA in the three spring-autumn periods from 2009–2012.

3.2. Catch rate

The average catch rate estimate (fish per day) of mulloway of all size classes combined fluctuated between 1 fish.day^{-1} in 2009–10, 1.8 fish.day^{-1} in 2010–11 and 1.2 fish.day^{-1} in 2011–12 (Fig. 5). Overall, this equated to an average of 1.5 fish.day^{-1} of all size classes. When apportioned to size classes, the catch rate of mulloway <MLS increased from 0.4–0.8 fish.day^{-1} between 2009–10 and 2011–12 (Fig. 5). Catch rates of mulloway between the MLS and size at 50% maturity (L50, Females) were low in all years. Catch rates of fish greater than the size at which 100% are mature (L100, Females) declined from 0.4.day^{-1} in 2009–10, to 0.2.day^{-1} in 2010–11, and was 0.3.day^{-1} in 2011–12 (Fig. 5). For mulloway >L100, this equates to estimated rates of 2.6 days.fish^{-1} (days of fishing effort per fish) in 2009–10, 4.9 days.fish^{-1} in 2010–11 and 3.5 days.fish^{-1} in 2011–12.

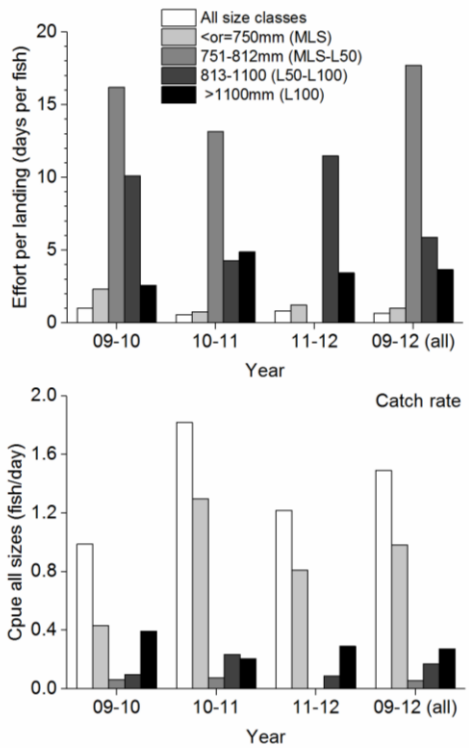

Figure 5. Effort per landing and catch rate (CPUE; Catch Per Unit Effort; fish per day) by size class for mulloway in the Yalata IPA between 2009 and 2012.

3.3. Composition of landings of target and non-target species

As the patterns of composition or numerical abundance of landings and non-target species did not vary substantially between years, these data were grouped to provide a summary of the non-target fish, shark and ray species landed while targeting mulloway from beaches in the Yalata IPA between 2009 and 2012. Overall, the on-site survey recorded a total capture of 478 mulloway comprising 41% of total landings (Fig. 6). In addition, there were 680 bony fish, sharks and rays taken during the spring 2009 to autumn 2012 period. Bony fish, not including mulloway (or species typically used on-site for bait) comprised 7% of the landings. This consisted of low individual percentages (1–5%) of snapper (*Chrysophrys auratus*), flathead (*Platycephalus* sp.), tailor (*Pomatomus saltatrix*), wrasse (Labridae), and King George whiting (*Sillaginodes punctatus*) (Fig. 6). A group of small-medium sized bony fishes that are targeted as bait for mulloway comprised 28% of landings. This 'bait' group comprised Western Australian salmon (*Arripis truttaceus*) (21%), yelloweye mullet (*Aldrichetta forsteri*) (5%), sea sweep (*Scorpis aequipinnis*) (1%) and Australian herring (*Arripis georgianus*) (0.2%).

Sharks, rays, and wedgefishes (southern fiddler and western shovelnose rays) were the most common non-target species and comprised 24% of landings (Fig. 6). Sharks included the bronze whaler (*Carcharhinus brachyurus*), gummy shark (*Mustelus antarcticus*), school shark (*Galeorhinus galeus*), Port Jackson sharks (*Heterodontus portusjacksoni*) and white shark (*Carcharodon carcharias*) (released). Rays included the southern eagle ray (*Myliobatis australis*), and stingray spp. The most common non-target elasmobranch species were the southern eagle ray and the gummy shark, which comprised 8% and 5% of all landings, respectively. The numerical ratio of non-target sharks and rays per legal-sized mulloway was 2:1.

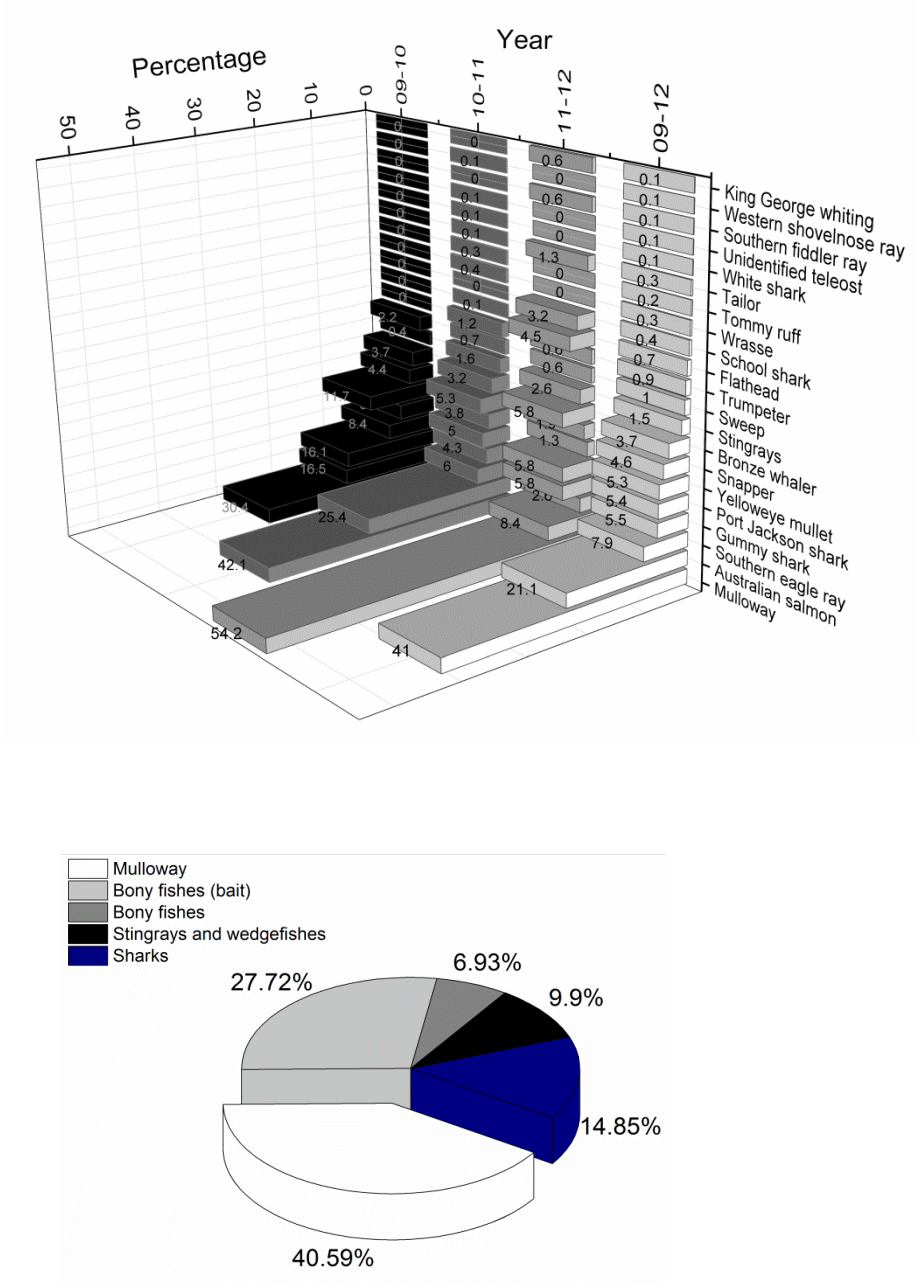

Figure 6. Catch composition by species indicating mulloway as a percentage of the total landings in the Yalata IPA between 2009 and 2012. Pie-chart shows percentage composition of landings by species group.

3.4. Fate of landed fish, sharks and rays

Of the mulloway landed, 66% were released because they were smaller than the MLS. In 2009–10, the release rate of mulloway smaller than the MLS was 44%. The release rate of mulloway due to being of sub-legal length then increased to 72% in 2010–11, and remained high at 68% in 2011–12. The overall release rate of mulloway of all sizes over the three seasons was 75% with the remaining 25% being retained (Fig. 7). The release rate of large, mature-sized fish of ≥1100 mm was 41% in 2009–10, 3% in 2010–11, and 25% in 2011–12. There was insufficient information available to determine the reason for release of the legal-sized fish in each individual case.

Medium-sized bony fishes that are popular as bait for mulloway fishing, including Australian salmon and mullet, were mostly retained (97%) (Fig. 7). Non-target bony fish were often released (63%), with the remainder retained. The on-site survey showed that all rays were reported as having been released. An estimated 33% of sharks were retained, with the remaining 67% released. Overall, the rate of release of bony fish, sharks and rays was 76%, with the remaining 24% retained (Fig. 7). There was no reporting of discarding of dead fish, sharks or rays.

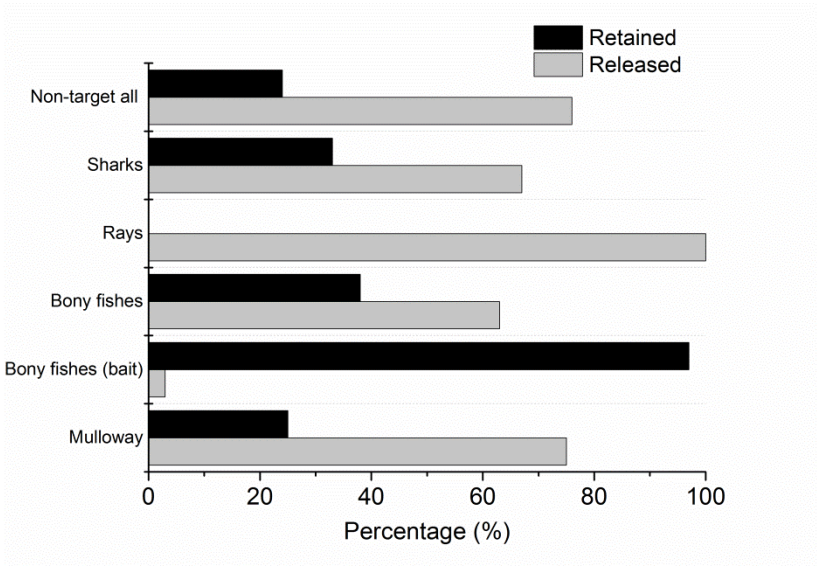

Figure 7. Fate of landed species and species groups in the Yalata IPA between 2009 and 2012.

3.5. Size distribution

Size information was collected for 255 mulloway during the on-site surveys between 2009 and 2012. There was one mode present in the size distribution below the MLS, and two legal-size modes present in catches during each season from 2009–10 to 2011–12. These included mulloway in the 450–550, 850–950 and 1200–1300 mm size classes (Fig. 8). Of note was the decline of 14% to 5% in the largest 1450 and 1550 mm size classes between the 2009–10 and 2011–12 seasons (Fig. 8).

Mulloway larger than the size at which 100% are sexually mature (L100; 1100 mm, Ferguson 2010) formed 19% of the landings. In 2009–10, these large fish formed 41% of the landings, however this declined to 11% in 2010–11 and was 24% in 2011–12 (Fig. 8). Table 1 shows the size breakdown of the landings. The proportion of landings ≥ MLS was 57% in 2009–10, 28% in 2010–11, 32% in 2011–12, and 34% overall.

Table 1. Number and percentage by size of mulloway landed in the Yalata IPA between 2009 and 2012. Length classes are separated into numbers and percentages under or equal to the MLS (≤750mm), between the legal size (751 mm) and the size at which 50% are estimated to be mature (L50) (812 mm) (Ferguson 2010), the size range between L50 and the size at which 100% are estimated to be mature (1100 mm) (L100), and the size beyond which all fish are expected to be mature (>1100 mm) (Ferguson 2010).

Length class	09-10	%	10-11	%	11-12	%	All yrs	%	Cumulative %
≤ 750 mm	35	43	222	72	56	68	313	66	66
751–812 mm	5	6	13	4	0	0	18	4	70
813–1100 mm	8	10	40	13	6	7	54	11	81
>1100 mm	34	41	35	11	20	24	89	19	100
Total	82	100	310	100	82	100	474	100	
>=MLS	47	57	88	28	26	32	161	34	

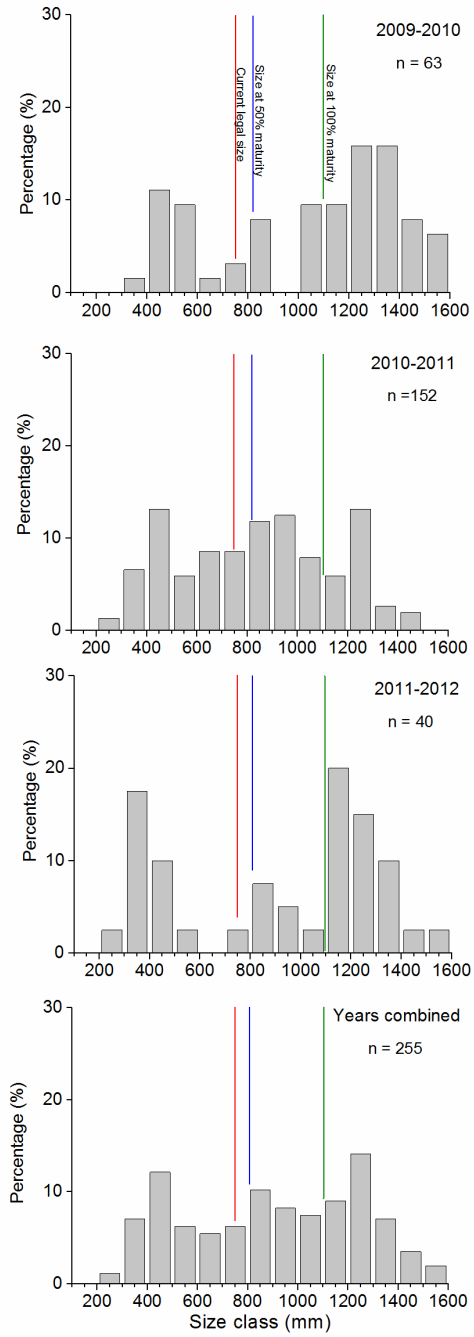

Figure 8. Percentage size distributions for mulloway (n = 255) during on-site surveys in the Yalata IPA during the 2009–12 seasons and during all years combined. Includes all fish retained or released. Numbers of mulloway recorded are shown in each plot.

3.6. Age distribution

Years combined

Otoliths were analysed from mulloway caught by recreational fishers from the Yalata IPA during the spring periods between 2009 and 2013 (Fig. 9). Mulloway in catches were estimated to be aged between 4 and 22 years (Fig. 9). Mulloway in the 14 year old age class were the most common (11%), with fish in the 5 to 10 year old (50%) and 12 to 15 year old age classes commonly captured (33%) and retained (>10%). A minimum of 17 age classes were present in the fishery. There are insufficient data to provide a robust assessment of inter-annual patterns in age structures.

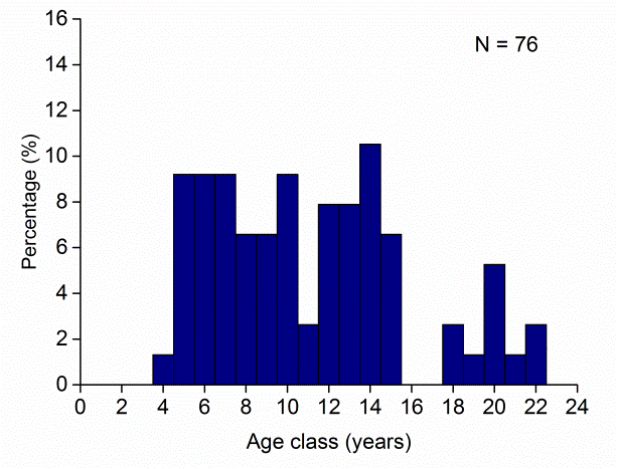

Figure 9. Age distribution of mulloway in the Yalata IPA between 2009 and 2013.

The age-length plot showing the MLS, L50 and L100 based on age estimates from otolith weight showed that mulloway that were slightly larger than MLS were estimated to be ~5 years of age (Fig. 10). Mulloway larger than the L100 were estimated to be between 8 and 22 years of age. The largest individuals caught in the Yalata IPA (1400–1600 mm, TL) were estimated to be 20 to 22 years of age.

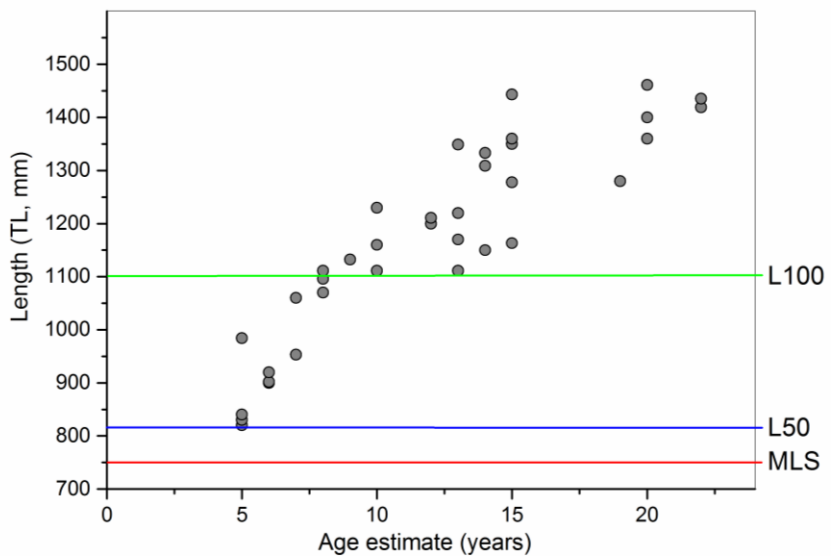

Figure 10. Age-length plot showing the MLS, L50 and L100 for mulloway based on age estimates from otolith weight.

3.7. Population connectivity: genetic structure and movements

We combined data-streams on genetic structure and movements of mulloway from satellite tagging to provide preliminary insights into the geographical distances that are relevant in terms of the connectivity of populations that support the recreational fishery in the Yalata IPA.

A total of 33 mulloway sampled from the Yalata IPA were genotyped, along with other fish sampled from the GAB, and three other SA gulf and south-eastern regions. Analysis of microsatellite DNA data suggested that the mulloway caught from the Yalata IPA originated from the same genetic population as those sampled offshore in the GAB (Fig. 11). Analyses showed that mulloway from this GAB population were genetically different to those sampled in Spencer Gulf, Gulf St Vincent and the Coorong. There appears to be occasional migration from the GAB to Spencer Gulf, however the remainder of the SA population appears to mostly form a single genetic cluster (Fig. 11).

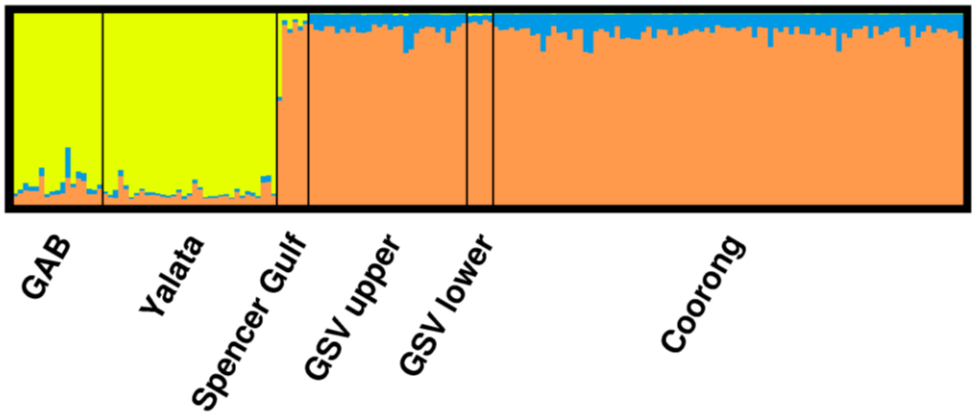

Figure 11. Plot from program *Structure* showing proportions of individual genotypes assigned to three genetic clusters represented by the different colours. Individuals shown as each vertical column are grouped by region.

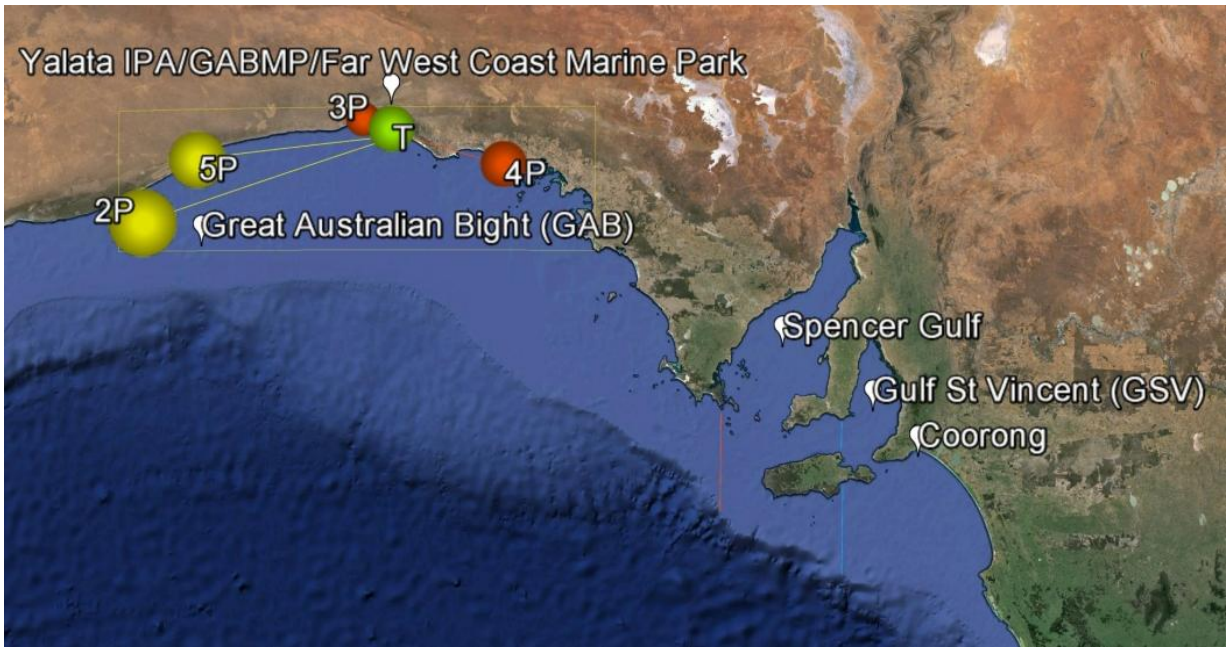

Figure 12. Movements of mulloway 2–5 that were satellite tagged from the Yalata IPA. The green symbol shows where the pop-up satellite archival tags were deployed. The relative sizes of the symbols represents the relative distance travelled during the spring-summer (red) and summer-autumn deployments (yellow). T = tagging location, 2P to 5P represents the pop-up locations for fish 2 to 5.

Between February 2012 and December 2013 a total of 17 mulloway were tagged with mini-PATs. Tagged mulloway ranged in size from 950 to 1500 mm TL (Table 2). Some males and females tagged were in spawning condition (running milt in males and scuffed and bitten vents on females). At the time of preparation of this report, data had been recovered from five of the first 11 deployments and movement data had been analysed for fish 2–5. The satellite-tracked mulloway moved the largest estimated minimum straight-line distances of 200–300+ km during autumn. The average minimum straight-line distances travelled by fish 2 and 5 were >250 km. Individuals tagged in autumn moved westward during 100 days at large (Fig. 12). One fish tagged during summer (fish 4) moved >150 km to the east. A second fish tagged in summer (fish 3) moved west (Fig. 12).

Table 2. Summary of mulloway tagged using mini-PATs in the Yalata IPA in 2012 and 2013.

Fish/tag #	Capture date	Total length (mm)
1	18/02/2012	980
2	20/02/2012	1160
3	20/02/2012	960
4	10/11/2012	950
5	11/11/2012	1300
6	11/11/2012	1500
7	11/11/2012	1300
8	11/11/2012	1400
9	12/02/2013	1300
10	8/02/2013	1200
11	13/02/2013	950
12	14/11/2013	1200
13	14/11/2013	1300
14	12/12/2013	1350
15	12/12/2013	1200
16	13/12/2013	1500
17	13/12/2013	1200

Preliminary data suggested that the tether of at least one tag that was recovered on the beach was snagged on the bottom by a fish until the release pin corroded on the programmed date. Archived data showed that the depth of the tag remained constant and indicated only minor tidal fluctuations in the period between five days after the deployment and the programmed release date. In summary, the preliminary satellite tagging data provided evidence of seasonal movements of mature mulloway away from the Yalata beaches, and suggested some fish may migrate westward and into shelf waters during autumn where they may be taken in other fisheries. Detailed analyses of the complete movement and population structure datasets will be provided as part of scientific journal articles and a PhD thesis (T. Barnes) due to be submitted in 2014.

3.8. Post-release survival of line-caught mulloway

At the time of preparation of this report, none of the satellite tags deployed on mulloway had triggered the programmed animal mortality function. As this function has not been triggered, it can be assumed that all mulloway survived the initial capture, handling, tagging and release processes that all occurred in surf conditions. In addition to the lack of reporting of mortalities, a total of 45% of the first eleven mulloway tagged had reported data to the Argos satellites suggesting that those fish had survived.

3.9. Trial of fish waste compost bins

Prior to the 2012–2013 season, two in-ground compost bins were installed by the YLM team adjacent to campsites at Geues and Bob's Kitchen for the disposal of mulloway carcasses (Fig. 13). The bin at the Geues campsite was checked by SARDI on 5 November 2013, and seven mulloway heads and backbones had been deposited in it by camping fishers. Once the mulloway heads have decomposed they will be sampled for otoliths for analyses of population age distribution. Other fish waste had also been deposited in the bin. This was a positive outcome in terms of community engagement relating to a key issue raised as causing major concern. A structured monitoring program is required to determine the potential impacts of recreational fishing related camping activities and the presence of terrestrial scavengers on nearby endangered shorebird habitats.

Figure 13. Fish waste compost bin and fish cleaning tables installed adjacent to the Geues campsite by Yalata Land Management.

4. DISCUSSION

One of the objectives of this report was to provide baseline information to develop biological and demographic indicators to inform management of the recreational fishery for mulloway accessed from the Yalata IPA and State-managed zones of the FWCMP and GABCMR. This nationally-recognised and publicised recreational fishery forms one of two key seasonal tourist attractions to the Great Australian Bight region. This report summarises recreational fishery information collected during the 2009–10, 2010–11, and 2011–12 spring to autumn seasons, and will contribute to the broader assessment of the status of mulloway populations across SA. The diversity of issues and complexity of current and future spatial management strategies planned for the far west coast region required that we include multiple government agencies, non-indigenous and indigenous stakeholders in the development and implementation of this research, monitoring and extension project. In addition, we propose that this report provides a 'case study' that could be used to develop on-site surveys to monitor other recreational fishery resources in complex and geographically-isolated management regions through the development of indigenous stewardship and multi-stakeholder partnerships.

The National Recreational and Indigenous Fishing Survey (NRIFS) (Henry and Lyle 2000) summarised indigenous fishery information in northern Australia, but did not present such information for SA, or recreational fisheries on indigenous lands. With the exception of preliminary information provided by Rogers *et al.* (2010), issues related to recreational fisheries for iconic and traditionally significant species on indigenous land have not been addressed or assessed previously in SA. Similarly, issues related to the sustainability of recreational fisheries on indigenous lands that overlap with marine parks and reserves in SA are poorly understood. This research and monitoring program provides information to address these knowledge gaps for a key recreational fishery for an iconic species. However, there is a need to improve resourcing of the on-site survey and to build the capacity by training of members of the Yalata community and YLM team to undertake it, given the additional levels of spatial management to be introduced in October 2014 as part of the State Government marine park implementation processes.

Size distributions of mulloway taken by recreational fishers in the Yalata IPA between 2009 and 2012 showed that the area supports small to medium juveniles through to large adults near the maximum size for the species. The size distribution from 2010–11, and the overall size distributions, showed four strong size classes that were smaller than the MLS (released fish) that were likely to enter the recreational fishery. Age distributions also showed a consistent presence of sub-adults, suggesting recruitment was occurring on an annual basis. The broad distribution of size and age classes suggests that previous and current fishing mortality is yet to have a significant impact on these population parameters. However, it is worth noting that this species can live to 41 years of age (Ferguson *et al*. 2010) and the oldest fish in the age distribution from Yalata was 22 years of age. The age structure data we present for mulloway in this recreational fishery showed a broader range of year classes than is present in the Coorong and adjacent ocean beach fishery (Ferguson *et al*. 2014). This suggests that fishing mortality may be lower for the far west coast population compared to the Coorong. It may also be due to a combination of differences in regional environmental conditions and degrees of recreational and commercial fishing effort combined with the stock structuring that we have highlighted in this report.

Importantly, the interpretation of size and age data needs to include consideration that this recreational fishery directly targets large, mature-sized mulloway in the Yalata IPA. This effort to catch the largest mulloway and the techniques used (e.g. large baits and terminal tackle), may bias size and age data from this survey. However, there is anecdotal evidence to suggest that small juveniles (280 mm) and large adults (1600 mm) are taken on the same hook, bait and gear configurations, as even the small fish have mouth gapes large enough to swallow the large hooks that are typically used. As such, it is crucial to continue to collect more accurate size data and otoliths for age estimation from the catches in the Yalata IPA, with the view of presenting robust age structure data. Formal age estimates of mulloway based on counts of annuli from sectioned otoliths will also improve this age structure information as more resources become available.

Anecdotal information suggesting that the catches of mulloway had declined over recent decades formed part of the impetus for development of the on-site survey in 2009–10. This report presents catch rate data for three years of recreational fishing in the Yalata IPA. The on-

site survey recorded total landings of 478 mulloway (including fish <MLS) over 327 days and 2,711 hours of fishing effort between 2009 and 2012 in the Yalata IPA. Overall, this equated to an average of 1.5 fish per day across all size classes and catch rates of fish larger than L100 declined from 0.4 fish per day in 2009–10, to 0.2 fish per day in 2010–11. In 2011–12, it remained below the first season average at 0.3 fish.day^{-1}. Importantly, we do not have baseline catch rate information with which to compare these data.

Use of mini-pop-up satellite archival tags that are normally reserved for pelagic marine predators represents the first applications of this tracking technology during research on an iconic demersal fin fish species in Australian waters. Information collected from these satellite tags will address knowledge gaps regarding the scale of connection between the mulloway population(s), and will provide insights into the post-release survivorship of line-caught mulloway in the Yalata IPA. To date, none of the mini-PSATs deployed on 17 large, mature-sized mulloway captured on rod and line from the surf beaches in the Yalata IPA have reported data to inform us that they have registered as a post-release mortality. This is positive preliminary information regarding post-release survival, however, it must be considered that for these tagged individuals, fight times were mostly kept to a minimum, most of the fish had been jaw hooked, and handling was minimised. Further research is required to resolve this issue under a range of fishing scenarios that are typical of recreational fishing and handling practices. The satellite tagging component of the project has been successful from the perspective of developing community stewardship in fishery research in the Yalata IPA, with community members playing important partnership roles by attending the tagging field trips, assisting with tag deployments, and during the search and retrieval of tags that had washed ashore.

Preliminary genetic stock structure data indicated that the mulloway population that inhabits the FWCMP and broader GAB comprise a separate sub-population to that found in SE SA and Spencer Gulf. These findings are consistent with recent regional analyses of elemental composition of otoliths (Ferguson *et al*. 2011). Following these lines of evidence, and given the short spatial scale movements observed during our satellite tag deployments both during and following a known spawning period (Nov–Jan), it is likely that these two populations may require management at a region scale. Further movement and genetic data will be collected over the

next year to clarify this structure. Given the preliminary nature of these data, these findings should be viewed cautiously.

One of the main issues highlighted as requiring attention prior to and during the 2009–10 survey was the need for management of mulloway carcasses due to their potential to lead to negative impacts on resident and migratory shorebirds by attracting terrestrial scavengers, including wild dogs, dingos and ravens. This was followed by recommendations to develop a cost-effective composting system to manage the issue and alleviate community concerns. During the 2012–13 season, the YLM team installed two large compost bins as a pilot project to assess if this was a viable means of managing this issue. This was supported by Natural Resources AW. The objectives of this pilot project are to: 1) provide a means for campers to deposit mulloway and other fish carcasses, 2) provide an additional means of collecting biological samples including otoliths 3) reduce fish waste availability for wild dogs, dingos, and ravens with the broader aim of having a positive flow-on effect by reducing disturbance to other components of the ecosystem in the Yalata IPA, including the migratory and resident shorebird fauna. In November 2013, we visited the campsite at Geues to check use of the compost bin. Several mulloway carcasses were in the bin suggesting that it was working as planned. There remains a need to monitor the activity of scavengers around the bins and campsites.

The fisher demographic, fisheries and biological indicators that we recommend to continue to be monitored in the Yalata IPA include:

- Fisher visitation;
- ATV use;
- Size of released mulloway;
- Size, age, sex and maturity stage of retained mulloway;
- Catch and effort data for mulloway;
- Catch composition (target and non-target), release rate, fate of landings and discards.

This suite of recreational fishery indicators will form a strong baseline for comparison for future monitoring of fish, shark and ray populations in the FWCMP and GABCMR. It also places

Government agencies in a strong position to inform the development of sustainable strategies and trigger points on which to base improved arrangements.

4.1. Future research, monitoring and extension needs

Annual consultation that includes the scientific advisory role of SARDI and University of Adelaide researchers has been a positive means of improving the feedback loop between the Yalata community, universities, and government departments responsible for the management of recreational and indigenous fisheries. This process has identified a need to better resource the on-site survey in the Yalata IPA and FWCMP in light of the additional layers of spatial management to be implemented in October 2014, and the development of exploration interests in the GAB. In its recent and current format, the success of the survey has largely depended on the good-will, support and participation of a range of stakeholders, however there is a need for ongoing financial, logistical and training support.

Key research and monitoring gaps to address in the future include:

- Understanding the annual indigenous fishery catch by region;
- Development of an indigenous stewardship program for coastal rangers in the Yalata IPA, including compliance training in MPAs;
- Information on the size and age at sexual maturity in the Yalata IPA. Current L50 and L100 for mulloway are based on the broader SA population and better resolution of these parameters is required;
- Identification of mulloway spawning and nursery habitats, and pattern of distribution and abundance of eggs and larvae in the Yalata IPA;
- Post-release survival of line-caught mulloway;
- Understanding the economic value of the fishery in the Yalata IPA to the State economy and the Yalata community.

Stewardship and capacity building

The on-site survey program in the Yalata IPA addresses several research development and extension (RDE) principles outlined by the Indigenous Reference Group (IRG) at the Cairns

Forum in 2012 (Calogeras, 2012). This IRG is part of a strategic and planned approach to identify National RDE priorities for indigenous participation in fishing and aquaculture in Australia. We suggest there is potential to further develop the current program, and other State-wide indigenous stewardship-based projects, by drawing upon the progress made in the Yalata IPA as a case study to guide the evaluation and development of similar approaches in other regions, including the area east of the Yalata IPA, southern Eyre Peninsula, Lake Eyre Basin, and the Coorong. There is a need to discuss the potential development of this program with the Natural Resources AW, YLM, community stakeholders, DEWNR Far West Coast Marine Park and GABCMR management, and PIRSA Fisheries and Aquaculture to identify and refine the needs and objectives pertaining to maintaining and improving the current program. The key focus areas should include improving indigenous stewardship, capacity building and cultural representation in fishery resource research and management in SA regional areas.

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Yalata IPA website: www.yalata.org

APPENDIX 1. Summary of survey dates and camp-sites. W = Wahgunyah Conservation Reserve and YB = Yalata Beach.

Survey date	Location									
	1	2	3	4	5	6	7	8	9	10
15/11/2009	Hilton	Bobs	Jaxson's	Geues						
19/11/2009				Geues						
1/12/2009	Hilton			Geues	Tjitji					
4/12/2009										SARDI
30/12/2009								YB		
14/01/2010	Hilton	Bobs		Geues			Granites			
15/02/2010		Bobs		Geues			Granites			
19/02/2010						Coombra				
22/02/2010						Coombra				
17/03/2010	Hilton	Bobs								
2/10/2010		Bobs								
20/10/2010			Jaxson's							
25/10/2010		Bobs								
28/10/2010			Jaxson's					YB		
1/11/2010				Geues						
5/11/2010								YB		
8/11/2010	Hilton	Bobs	Jaxson's							
11/11/2010	Hilton						Granites			
19/11/2010				Geues						
20/11/2010			Jaxson's	Geues	Tjitji		Granites			
24/11/2010				Geues	Tjitji	Coombra				
26/11/2010		Bobs	Jaxson's				Granites			
1/12/2010	Hilton		Jaxson's							
2/12/2010								YB		
3/12/2010									W	
5/12/2010		Bobs								
13/12/2010	Hilton	Bobs	Jaxson's				Granites			
14/12/2010				Geues						
23/12/2010		Bobs	Jaxson's		Tjitji					
5/01/2011	Hilton	Bobs	Jaxson's							
15/01/2011								YB		
10/02/2011			Jaxson's							
25/10/2011		Bobs								
26/10/2011				Geues						
24/11/2011		Bobs	Jaxson's	Geues		Coombra				
30/11/2011	Hilton	Bobs								
13/12/2011								YB		

21/12/2011		Bobs								
10/01/2012	Hilton	Bobs		Geues			Granites			
21/01/2012				Geues		Coombra				
24/01/2012			Jaxson's							
7/04/2012		Bobs								
15/04/2012								YB		

APPENDIX 2. On-site survey interview form.

Alinytjara Wilurara NRM Board
Yalata Lands Recreational Fishing Interview Form

Date..... **Time of interview**..... **Location Camped at**.....

Time of High Tide..... **Swell** (direction and strength).....

Wind (direction and strength)..... **Cloud cover**..... **Temperature**.....

Moon (e.g. Full + 2days).....

No. in Fishing Party..... **Total No. of Fishers**..... **Males**..... **Females**.....

Age group: 5 – 14 ☐ **15 – 29** ☐ **20 – 44** ☐ **45 – 59** ☐ **60 or more** ☐ **Postcode**.....

No. of days fished..... **Total no. of hours fished (approx)**..... **Total no. of fishing lines**.....

Use of ATV: Yes No **Shore Type:** Beach Reef Combo Other

Target Species.....

Bait caught at Yalata (CY) or brought in (BI).....

Catch Data

Fish No.	Species	Location	Retained Y/N	Released Y/N *If yes, give reason*	Size of Retained Fish (mm)	Sex (M/F) Stage of Maturity *Refer to table*	*Please label the sample with fish no., date, size and sex*	
							Ear Bones Collected Y/N	Tissue Sample Collected Y/N