Indigenous people’s socio-economic values and river flows in the Mitchell River delta, Cape York

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Executive summary

This report presents the results of a two year study of indigenous socio-economic values and river flows at Kowanyama, located in the Mitchell River catchment on the Cape York Peninsula, Queensland. The project was funded by the CSIRO, and builds on previous work conducted through the TRaCK (Tropical Rivers and Coastal Knowledge) program.

Although environmental flow assessments have been undertaken in Australia for many years, they have not effectively incorporated indigenous water values and interests (Finn and Jackson 2011). Indigenous people rely substantially on aquatic resources, and environmental flows are important to support the continued provision and maintenance of these resources. However, it is naive to assume that this minimum flow requirement addresses broader indigenous values and interests, including cultural, physical and mental health benefits, as well as economic and development aspirations. Our project aimed to contribute to addressing this critical knowledge gap by quantifying indigenous aquatic resource use at Kowanyama, and assessing the impacts of changes in water flow on indigenous water values and interests. Specific project objectives were to:

- Document the significance of water and aquatic resources to the Aboriginal people of Kowanyama
- Survey Aboriginal households in Kowanyama to quantify the direct economic benefit derived from indigenous aquatic resource use
- Assess the impacts of changes to flow regime on these aquatic resources
- Develop collaborations and information that will enhance the capacity of researchers and managers in northern Australia to incorporate social assessments in water allocation decisions and planning

During our study, an initial resource mapping exercise gathered data on the spatial and temporal distribution of indigenous aquatic resource use, allowing potential relationships between important sites and flow to be determined. To quantify indigenous resource use, 40 individuals from across 28 households in Kowanyama were interviewed about their hunting and fishing trips on a monthly basis over a 16 month survey period. The economic value of aquatic resources consumed by these households was then calculated using the replacement goods method (Altman 1987), where the market price of a similar product to that being consumed is used when a product does not have its own market value. However, in the absence of a market for wild fish and game, estimating a dollar value presented some challenges for the research team. Our choice of substitute goods attempted to reflect their nutritional equivalence, and indigenous perceptions of the replacement item as being “similar’ in type to the non-market item. However, as these proxies were defined by the researchers, they did not necessarily reflect the best comparisons. Indeed, the use of economic proxies to quantify the value of aquatic resources as a function of their substitutability was foreign to indigenous resource users at Kowanyama who represented a different cultural perspective on ‘value’.

It is critical to note that the replacement cost values presented in this report are not an attempt to derive the complete value of these aquatic resources (see also Jackson et al. 2011). Nevertheless, what our application of a replacement value calculation does do is to make more explicit the relative contributions of aquatic resources to indigenous household incomes. In particular, it allows the species that make the largest contribution to be identified, encouraging more specific consideration of their environmental flow requirements.

The following results represent a series of highlights from reported findings:

- The mean number of harvesting trips per survey fluctuated from one season to the next with the highest number of trips recorded during the mid dry season (July – September), and associated with an increase in the number of people camping out bush for two to three days at a time while hunting and fishing.
Indigenous resource users at Kowanyama frequented a wide variety of aquatic habitat types for hunting and fishing but favoured creeks and waterholes above all others. These resource users switched from visiting creeks and waterholes equally during the wet season while the main river channel was flooded, to mainly fishing from creeks associated with preferred freshwater species like Black Bream and Barramundi in the early dry season, to hunting for Long-necked turtle in waterholes during the mid dry season, and then returned to mostly fish along creeks during the late dry season.

- Hunters and fishers at Kowanyama also targeted different aquatic species as they became available, switching between saltwater and freshwater fish, and between fishing and hunting for turtles. The highest numbers of Long-necked turtle were harvested during the mid dry season as declines in the numbers of Barramundi, Black Bream and Grunter caught were recorded. This indicated a strong preference for Long-necked turtle at times when other species were less available. However, Catfish was the exception as the numbers harvested remained relatively stable at between four to six fish per harvesting trip throughout the year.

- Four of the top five species harvested and consumed by Kowanyama resource users were fish species with Magpie goose eggs the only exception. Species caught and consumed in the highest numbers were 1) Magpie goose eggs, 2) Catfish, 3) Barramundi, 4) Black Bream and 5) Grunter.

- The survey question that quantified “harvest” returned the entire catch obtained from each trip in which the survey household was involved. As such, it could include the catch of more than one household. The survey question that quantified “consumption” included only those individuals of a species that were directly used by the survey household.

- The consumption of a household included the immediate on-site use of a species for food or as bait. It also included later use (such as for food) by people who lived in the surveyed household when they returned home. In addition to including the amount harvested by non-survey households on a trip, the difference between trip harvest and household consumption therefore reflected the amount of sharing that occurred between households, families and communities, which was substantial at Kowanyama. In particular, large-bodied species like Barramundi were often shared amongst family and community members.

- Species making the largest contribution to the replacement value of harvest at Kowanyama were 1) Barramundi, 2) Black Bream, 3) Catfish, 4) Grunter and 5) Long-necked turtle. However, Barramundi made a significantly larger contribution to people’s harvests than any other species, accounting for 58% of the total replacement value.

- 92% of the total replacement value derived by our survey households was represented by the top five species.

- The five sites providing the highest value of harvest, namely 1) Paroo, 2) Bottle camp/Boomerang, 3) Wonya, 4) Shello and 5) Landing, only accounted for 40% of the total replacement value.

- This suggested that while a subset of important species could be a useful representation of total replacement value, a subset of important sites represented a relatively small proportion of the total replacement value of the harvest by Kowanyama resource users from the Mitchell River.

- Previous studies by Chan et al. (2010) and Kennard et al. (2010a) suggested that a number of the species that we found to be providing a substantial contribution to indigenous household incomes at Kowanyama could be severely impacted by dry season water extraction. These species included Barramundi and Black Bream. Catfish, on the other hand, is thought to be exposed to lower levels of risk.

- Of the ten most economically valuable species, those that were identified as being at high-medium risk of late dry season water extraction made up 68% of the total replacement value for the harvest at Kowanyama in the Mitchell River Catchment. It is difficult to quantify what this level of risk might mean to total replacement value, but if water extraction resulted in a significant reduction in the harvest of these high risk fish species, the contribution that customary harvest makes to indigenous households could decline substantially.

- A clear calculation of the potential changes in indigenous harvest associated with altered flow regimes was problematic. This was in part due to incomplete ecological knowledge of flow requirements of some harvest species, and in particular due to the limited nature of information on customary fisheries harvest at different species’ population densities.
The hybrid economy (Altman 2004; see also Jackson et al. 2011) represented a useful framework through which to consider the impacts of flow alterations on indigenous livelihoods at Kowanyama, as changes in development (e.g. mining), tourism and conservation were to engage with the state (welfare), market and customary sectors of the economy.

A very general assumption of a 50% reduction in aquatic resource harvest at Kowanyama could lead to an 8% decline in indigenous household incomes. Given that any increase to the regional market economy brought about by water resource development (e.g. from agricultural expansion), is unlikely to contribute significantly to improving indigenous livelihoods, the potential influence of additional water resource extraction, particularly in the dry season, could therefore be an impost on indigenous households.

So, while gaps in our knowledge and quantitative understanding limit our ability to define the impact of flow alterations on the replacement value of aquatic resources at Kowanyama, it is apparent that the customary sector is a crucial component of indigenous economies.
1 Introduction

1.1 Background

Indigenous people value aquatic ecosystems for a number of inter-related reasons (Jackson 2005; MEA 2005; Jackson and O’Leary 2006). Water bodies are important to Indigenous people for hunting, fishing and gathering bush materials for art and ceremony and they form part of a socially and culturally significant landscape. Water resources also have the potential to sustain future water-related businesses and employment. For Aboriginal peoples, water exists within a system of rights and responsibilities to country based on people’s relationships to each other and to the land, including the resources it provides (Altman et al. 2009). It includes rules that relate to the access and use of water resources, a code of conduct and living cultural practices associated with water that are collectively referred to as customary law (Jackson 2005). Aboriginal water values cannot therefore be disentangled from Aboriginal systems of ownership, culture and everyday life, including language, songs, stories, art and rituals (Altman et al. 2009).

The customary rights of indigenous Australians in water management and policy have been accorded greater legal recognition since the Mabo decision of 1992. The Native Title Act (1993) protects the customary rights of indigenous Australians to natural resources like water. Recent national reforms propose the allocation of water to meet certain indigenous requirements for direct consumptive use, to sustain landscape and cultural heritage features and native title (Jackson et al. 2012). In northern Australia, given the significance of the size of the indigenous population, its land holdings and attachment to customary estates, the need for water planning to identify and address indigenous interests and values is considerable (Altman, Buchanan and Larsen 2007). However, Indigenous water values remain poorly understood and underrepresented in Australian water planning and management processes (Jackson et al. 2012), particularly as most customary resource use and cultural values exist outside of the market sector.

With competing land uses such as small-scale irrigated agriculture, pastoral production, mining and expanding settlements within the Mitchell River catchment (Queensland), it is necessary for greater clarity in conceptualising the nature of Indigenous water uses or needs, and for quantitative methods to assess flow requirements necessary to sustain Indigenous values (Jackson et al. 2011). In particular, water planners require a specification of some flow or range of flows that optimise, permit, or do not irrevocably harm the human (and other) uses reliant on flow in support of broad-scale sustainable development and conservation (or ecological) purposes. An understanding of the links between direct human resource use and flow regime (Finn and Jackson 2011) is also important to manage threats to long-term river health such as weeds, feral animals, climate change, unsustainable use and increasing saltwater intrusion to name but a few. In South Africa, for example, water policy refers to an ecological reserve (or minimum range of flows required for the continued conservation of aquatic ecosystems), as well as a minimum requirement for basic human consumption needs (Pollard 2000).

1.2 Economic valuation of aquatic resource use

The value of resources that are formally traded in markets can be measured in terms of their price. However, a major problem associated with the valuation of Indigenous aquatic resources that are used for customary and cultural heritage purposes is that they are characterised by non-exclusivity and are not traded in markets (Ward and Beal 2000). The harvesting of wild resources for food and other purposes, for example, encompasses productive activities based on cultural continuities (Altman 2001; Altman et al. 2009). They form part of what Altman (2006) refers to as a hybrid
In a customary economy in which customary resource use, state welfare and market-based activities support diverse Indigenous livelihoods. However, a distinguishing feature of the customary economy is that it is not monetised in the same manner as the state and market sectors, and has been largely unrecognised and unquantified (Altman 2001). It is also not some pristine, pre-contact hunter-gatherer economy (Altman 2004) but is active in a modern sense, using modern tools and methods (Altman et al. 2011) together with traditional aspects of resource use to support Indigenous livelihoods.

Fishing, hunting and gathering therefore continue to comprise an important part of aboriginal livelihoods and diets. The 2008 National Aboriginal and Torres Strait Islander Social Survey (NATSISS) showed that approximately 60% of indigenous people over 15 years of age participated in the harvest of wild resources, and in remote communities like Kowanyama, this number increased to 72% of the population (Altman et al. 2011). High participation by the indigenous population of northern Australia in the 2003 National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003) also showed extensive contemporary involvement in the customary economy. In some parts of northern Australia, non-fish species like Long-necked turtle and Lotus lily seeds have also been recorded as important in the diet, and to the spiritual health of aboriginal people (Finn and Jackson 2011).

The varieties of habitats that support aquatic resources, in turn, are important ecological, cultural and economic resources to indigenous peoples. In western Arnhem Land, Griffiths (2003) showed that although aquatic and semi-aquatic habitats (e.g. floodplains, swamps and streams) made up only 15% of the area, they were the location of 79% of all hunting and gathering trips. Returns per hunting trip ranged from 2 – 7.5 animals in aquatic habitats as opposed to <1 animal per trip in terrestrial habitats (Griffiths 2003).

Indigenous values attributed to these important, aquatic resources and habitats need to be made explicit in Australian water policy and planning if they are to be adequately protected (Jackson and Altman 2009, Jackson et al. 2009). However, the valuation of natural resources and ecosystem services has been notoriously wrought with difficulties (Field 2002; Straton and Zander 2009). Non-market resources have typically been measured using travel cost or hedonic models, which recognise that although many of these resources may be unpriced, resource users still make sacrifices in terms of the distances travelled, or the cost of their time, in order to use them (Pearce and Turner 1990; Turner et al 1994; More et al 1996; Field 2002).

This project assumes that a principal indicator for assessing the health of the Mitchell River is its productivity and the food and other materials sourced from it by aboriginal people living at Kowanyama. Using the replacement cost method (Altman 1987), the project aims to quantify the direct consumptive use (subsistence) value of aquatic resources obtained from the river, and tries to redress the relatively small amount of research into the economic value of the use of wild resources by indigenous people in Australia (Gray et al. 2005).

The replacement cost method calculates the economic value of resources consumed at the household level by substituting the market price of a similar product to that being consumed whereas it has no market value. It is only a partial account of the ‘true economic value’ (Buchanan et al. 2009) and does not attempt to account for the social and cultural significance of indigenous resource use at Kowanyama. However, this valuation does seek to measure the relative contribution and economic value of aquatic species to aboriginal household incomes at Kowanyama. By linking what species people are harvesting to where they are harvesting these species from, we also aim to prioritise high value harvest sites, and hope to encourage more specific consideration of their environmental flow requirements.
1.3 Aquatic resource use and water flows

Environmental water management originated in North America in response to the need for water flow requirements for recreationally important fish species. Consequently, environmental flow assessments were historically aligned to ecological and conservation-driven perspectives on water management. During recent years, heightened water resource pressures world-wide have elevated the status of economic and socio-cultural values associated with water flows, in additional to environmental values (Baron et al. 2002). The definition for environmental flows has thus been expanded upon to include this:

“Environmental flows are the amount and timing of water flows required to maintain the species, functions, and resilience of freshwater ecosystems and the livelihoods of human communities that depend on those healthy ecosystems”.

Baron et al. (2002) showed that the health of freshwater ecosystems is tightly linked to the watershed or catchment of which they are part, and influenced by terrestrial processes including human activities such as the building of dams and the channelization of river channels, although the Mitchell River is largely unimpacted at present. Its flow regime, in particular, defines much of the character of a freshwater ecosystem in terms of the magnitude and seasonality of flows, degree of flow permanence, timing of extreme flows such as floods, annual variability in flow, and rates of change in discharge events (Arthington et al. 2006; Kennard et al. 2010b). Climate, catchment geology, topography and vegetation cover, in turn, influences the spatial variation of these hydrological traits, such that their interaction impacts on physical habitats for aquatic biota, the availability of refuges, the distribution of food resources, opportunities for movement and migration, and conditions suitable for reproduction and recruitment (Kennard et al. 2010b).

Understanding the natural hydrology of a freshwater ecosystem in time and space, and the associated ecological consequences of altering these patterns of flow variability is therefore, critical to making informed water policy and planning decisions (Arthington et al. 2006; Kennard et al. 2010b). As natural (unregulated) freshwater ecosystems are dynamic, they observe a natural range of variation in water quantity, quality and flow. However, flow alterations may cause this to change, shifting the ecosystem into an undesirable state (Arthington and Pusey 2003; Richter et al. 2003).

Countries such as South Africa (Pollard 2000) have adopted this logic to develop criteria for environmental flows, defined as the ecological reserve, as well as a minimum requirement for basic human consumption needs. In New Zealand, significant steps have been taken to develop methods to protect Maori instream values, using methods that capture objective and subjective data (Jackson et al. 2011). In Canada, indigenous resource rights are constrained only by conservation limits, driving governments and water managers to carefully consider whether water allocations may affect customary harvest and ensuring indigenous subsistence needs are not impacted (Durette 2008).

Although similar policy shifts have taken place in Australia with greater legislative recognition of indigenous water rights (e.g. Mitchell River Water Resource Plan 2007), environmental flow assessments undertaken by water resource agencies have made little attempt to understand the pattern and significance of indigenous resource use, and its role in the flow ecology. As a result, the choices made in the selection of target species and management objectives reflect priorities and values of non-indigenous scientists, conservation agencies and dominant user groups such as recreational fishers. These dominant non-indigenous priorities and values can differ from those held by indigenous groups, and it is these differences that need to be explicitly addressed in environmental flow assessments, rather than being overlooked on the assumption that

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environmental flows will serve as a surrogate for the protection of indigenous instream values (NWI 2004).

There is after all, a long history of interaction between indigenous peoples and aquatic ecosystems in Australia (Langton 2006). Throughout this period, indigenous resource use patterns have been shaped by environmental shocks and stresses. While freshwater ecosystems in northern Australia are subject to an annual cycle of flooding and drought, extreme flow events can cause additional hardships for people (Jackson and Douglas 2007). Persistently low water flows, for example, can reduce the connectivity between upstream and downstream habitats, affecting the spawning and migration activities of certain fish species (Pusey et al. 2004), and negatively influencing people’s fishing experiences. People’s resource use strategies, in turn, have impacted on aquatic ecosystems. Changes in traditional fishing methods to incorporate modern tools and technology (Altman et al. 2011), as well as access to better transport has changed people’s resource use patterns in terms of what areas are accessible to hunting and fishing, and the easy with which certain species can be caught in large numbers.

Aquatic resources are also not evenly distributed across space and time. Their distribution is defined by the availability of the habitat that sustains them, and the resources such as food and protection from predators that enable their survival. In the case of species that live in aquatic habitats such as wetlands and river systems, many plants and animals depend on specific flow events during some stage of their life-cycle. Barramundi (Lates calcarifer) require linkages to coastal habitats to spawn (Allen et al. 2003), while Long-necked Turtles (Macrochelodina rugosa) require annually flooded wetlands to lay and hatch their eggs (Kennett et al. 1998). Both of these species are commonly used by Aboriginal people as a source of food, so alterations in the flow regime that affect these species will also affect the ability of Aboriginal people to access and harvest them (Jackson et al. 2011).

To assess the potential impact of flow alterations (direct and indirect) on Indigenous use of aquatic resources, we need to know where each species is harvested and its life history. An example of a direct impact of flow alteration on Aboriginal harvest could be the truncation of the "run-off" by excessive harvesting of water as river flows decline after the wet season (Dec-Mar). Barramundi often feed voraciously as river flows decline post- wet season, and are commonly targeted during this time (Jackson et al. 2011). Reducing discharge more rapidly over this period could shorten the amount of time that Barramundi can be caught in large numbers, reducing the annual catch. A more indirect impact could occur through the draining and diversion of flows around coastal floodplain habitats for small-scale agriculture. The loss of coastal floodplains would reduce Barramundi spawning and nursery areas, reducing its total population size. While this impact affects a life history stage of Barramundi that indigenous people do not harvest, it could have a substantial impact on its population size in later years; ultimately reducing catch rates and affecting the value indigenous people derive from its use.

This project assesses the potential impacts of flow alterations in the Mitchell River catchment on the five most economically valuable species harvested at Kowanyama. Through exploring the links between water flows and specific aspects of these species life histories (e.g. breeding and migration), we ask what the impact will be on aboriginal household incomes if flow alternatives negatively affect resource stocks.
2 Project approach

This project was designed to:

- Document the significance of water and aquatic resources to the Aboriginal people of Kowanyama;
- Survey Aboriginal households in Kowanyama to quantify the direct economic benefit derived from indigenous aquatic resource use;
- Assess the impacts of changes to flow regime on these aquatic resources; and
- Enhance the capacity of researchers and managers in northern Australia to incorporate social assessments in water allocation decisions and planning.

The project approach was novel to the extent that it relied on local Indigenous expertise to collect the bulk of the data. During initial discussions between KALNRMO and CSIRO, the Land Office made clear their strong interest in participating as co-researchers. The KALNRMO saw value in the capacity-building role of a project of this nature and was very interested in learning new methods for assessing the condition of Kowanyama lands and natural resources, as well as for monitoring any pressures that might be developing from human use. CSIRO agreed to formally engage the Land Office as sub-contractors to undertake the surveys following a period of training and induction. Computing equipment was purchased to enable the principal researchers, Rodney Whitfield, to enter data collected.

The project was implemented in stages to ensure adequate time to build relationships with research participants. The first stage of the project involved a river use mapping exercise. This stage of the project was aimed at gathering information on the sites that people used, the species that could be found at those sites and some of the social and cultural significance of sites, species and activities such as hunting, fishing and gathering bush tucker.

The second stage of the project centred on the quantification of aquatic resource use by indigenous households, and subsequent economic valuation. This stage involved 16 months of household surveys; asking households how often they hunt and fish, which sites they had been to recently, and information on the species harvested, used and shared. The replacement method was used to value the economic contribution of aquatic resource use at the community level.

Stage three involved a desktop analysis of the flow requirements for high value species for aquatic resource use. This information was used to discuss the potential effects of flow alterations on the customary use of these resources.

While this research has advanced scientific knowledge of Indigenous aquatic resource use, its exploratory nature should be noted. Indigenous societies and cultural practice are diverse across northern Australia, and limitations to the spatial and temporal scope of research is unavoidable given resource and time constraints. This research is directly applicable to Indigenous resource users of Kowanyama, and has been influenced by the climatic, social and environmental conditions encountered during 2010 and 2011. However, much additional research is required to gain a full understanding of the value of indigenous resource use, and to help understand whether our results are typical in a broader context.

2.1 Study area

Kowanyama Aboriginal landholdings include the Mitchell River delta and the lower reaches of the Alice River located in the south-western region of Cape York Peninsula, Queensland (Sinnamon, O’Brien and Kerr 2008). The landholdings occupy approximately 4120 km², encompassing the Aboriginal Land Trust and two pastoral properties, Oriners (Helmsley) and Sefton, purchased by the
Kowanyama Aboriginal Council in 1991 and 1996, respectively. Approximately 50 km of coastline along the Gulf of Carpentaria forms the western boundary (Figure 1).

Figure 1: Mitchell River Catchment, including Kowanyama, on the Cape York Peninsula

Following concerns over expanding European settlement and associated impacts on local Aboriginal communities, the Queensland Government declared the Mitchell River an Aboriginal Reserve for the Benefit of Aboriginals of the State in 1903 (Sinnamon, O’Brien and Kerr 2008). In 1905, the Anglican Church established a Mission Station at Trubanamen, near Topsy Creek, which today marks the southern boundary of the Kowanyama Aboriginal Trust Lands. The Queensland Government took over the administration of the Reserve in 1967 but later transferred control back to the people, then represented by the newly established Kowanyama Aboriginal Council in 1987, and empowered through national legislation in support of Aboriginal self-governance.

In response to concerns over mining and fisheries development, the Kowanyama Aboriginal Council established the Kowanyama Aboriginal Land and Natural Resources Management Office (Land Office) in 1990. The Land Office functions as a department of the elected Kowanyama Aboriginal Council, which together with the Traditional Landowners, holds the decision-making authority for this country. The strategic role of the Land Office is therefore one of implementation, as it aims “to achieve sustainable Aboriginal management of the natural and cultural resources of Kowanyama land and sea country, given that the continuing cultural and biological diversity of country are integrally linked and cannot be viewed as separable” (Sinnamon, O’Brien and Kerr 2008).

In 2012, the Land Office continues to be the recognised community authority on natural resource management issues, and is home to an Indigenous ranger group, based in Kowanyama. Seventy percent of the funding for the rangers is provided by the Commonwealth Government’s Working on Country Program (WoC) in the form of salaries, and is supplemented by fee for service work. Traditional landowners also provide financial support for the Land Office, and external grants through organisations like the Christensen Fund and Technical Advisory Group for Wetlands contribute to on-ground operational costs.
The 2006 census\(^3\) for Kowanyama encompassed a population of 1021 persons of whom 946 (93%) was indigenous. The majority are direct descendents of the indigenous inhabitants of the lower Mitchell and Alice Rivers, and neighbouring areas now held by pastoral tenants (Sinnamon, O’ Brien and Kerr 2008). They include three linguistically defined groups with traditional links to country along the Mitchell River, and in adjacent lands as far south as the Staaten and Nassau Rivers. These language groups are the Kokoberra/ Kokoberrin, Yir Yorant (Kokomnjen) and Kunjen/ Olgol peoples.

The climate of the Mitchell River catchment is monsoonal with a distinct wet and dry season. Most of the rain falls as high intensity showers or is associated with monsoonal troughs and tropical lows occurring between December and March. The mean annual rainfall, measured over the last 100 years, is 1264 mm\(^4\). However, 2010 experienced a wetter and more prolonged wet season than usual with heavy showers starting in October and continuing through to April. The 2010 mean annual rainfall measured 1669 mm. The annual mean maximum and minimum temperatures are 33ºC and 21ºC, respectively.

The river bisects extensive coastal sand ridge and tidal flat complexes along the southern coast of the Cape York Peninsula (Sinnamon, O’ Brien and Kerr 2008), and is associated with numerous permanent wetlands that support large migratory bird populations (Monaghan 2005) The harvesting of fish, crustaceans, birds, turtles, eggs and other bush materials from this region forms an important part of the indigenous economy.

### 2.2 Research ethics and indigenous engagement

The project received ethics approval under CSIRO’s Human Ethics Guidelines. General protocols for ethical research practice in Kowanyama were also agreed to under the research agreement between CSIRO and the Kowanyama Aboriginal Council/ Kowanyama Land and Natural Resource Management Office. These protocols included that:

- The project was to respond to research needs identified by the Kowanyama community and the Traditional Owners.
- No research was to be undertaken in Kowanyama without the full, informed consent of the community and the Traditional Owners. Signed consent forms for work were required as per the CSIRO Ethics Agreement and Kowanyama protocol.
- Participation by the Kowanyama community and Traditional Owners in the project was voluntary, and people could commence or discontinue their involvement at any time they wished.
- The project was coordinated through the Kowanyama Office.
- The project would employ local research assistants wherever possible. The selection of local research assistants was guided by the Land Office and payment rates determined according to the Fee for Service Schedule.
- The Land Office conducted household surveys and other project work as set out in the Economic Survey Methodology and Project Plan finalised at end of March 2010. This included data collection, entry and storage procedures, as consistent with the CSIRO Human Ethics Approval and Kowanyama protocol requirements.

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\(^3\) Australian Bureau of Statistics, available online at www.abs.gov.au

\(^4\) Australian Bureau of Meteorology, available online at www.bom.gov.au
3 Methods

3.1 Resource use mapping

Resource use mapping or "river mapping" was undertaken during the early stages of the project at all survey sites. The aim of this activity was to gather data on the spatial and temporal distribution of indigenous resource use, allowing potential relationships between important sites and flow to be determined. It was one of the first components of the project to be implemented and had the added advantage of allowing strong relationships to be built between Indigenous participants and researchers. This information was derived using two methods. Firstly, Rapid Rural Appraisal (RRA) methods (Chambers 1994) were used during group sessions or with individuals where they were more comfortable working outside of the group session. Household surveys provided a second source of information on the spatial distribution of resource use. Household surveys are outlined in more detail in section 5.3.2 below.

River mapping sessions were undertaken with groups of a size and structure that made people involved in the mapping exercise comfortable (usually about 6-8 people). Often is was necessary to conduct a number of separate trips with different family groups to obtain a more complete picture of indigenous use of flow-related plants and animals on the various homeland areas like Scrubby Bore and Boomerang amongst others. Sessions remained relatively informal, with 1:100,000 scale maps of the local area and identification guides for local plants and animals used to prompt the group for information. Sessions would usually begin using the 1:100,000 scale map that included the community, with the researcher explaining the project in simple terms, the type of information that was sought during the session, and how this information was useful to researchers and may be used in the future. In addition to the maps of the area, photographs of plants and animals that might be harvested and used by were shown to prompt further discussion.

Along with the geographical locations of key sites/areas, information on the values of each site was recorded including the use of sites for hunting, fishing and collection of resources for medicines, art and craft or tools, or for other social or cultural reasons. Information was also gathered on people's knowledge of the abundance of species at sites; which species are favoured for harvest; how harvest is related to seasonal change; whether harvest is related to social or cultural activity; whether informants have witnessed change in distribution or abundance, and whether there are inter-generational differences in value attributed to species. The information will be further analysed in journal publications arising from this report.

Specific care was taken at the outset of each exercise to explain to participants in the exercise that the information given was confidential (i.e. it would not be released at a level of detail that would identify individuals and specific locations). Participants were told that they could decide at any time they no longer wished to be involved and their information could be removed from the map.

Data collected during the river mapping exercises was used to create maps of the spatial distribution of important hunting and fishing sites to the Aboriginal people of Kowanyama. Areas were people camped, or that were associated with other cultural and resource use activities like collecting materials for basket making or spears, was also recorded. These maps, in turn, informed household surveys about people’s spatial and temporal aquatic resource use patterns. Throughout the project, these maps were housed at the Kowanyama Land and Natural Resource Management Office (KLNRM) for safe storage and use by the household survey participants and greater Kowanyama community. However, due to the culturally sensitive nature of this information, these maps are not represented in this report, and were destroyed at the completion of the project at the request of the office.
3.2 Household surveys

Household surveys were conducted over a 16 month period to quantify the use and economic value of aquatic resources to the people of Kowanyama. A variety of methods including direct observation, household surveys, resource use diaries and doorstep accounting have been used to describe and quantify natural resource use in local communities (Altman 1987; Sheil and Wunder 2002; Jackson et al. 2011). Each of these methods differs in the scale to which they can be applied, the quality of information returned, and the transaction costs involved.

Intensive methods such as direct observation, where the researcher accompanies people on food quests (Altman 1987), and doorstep accounting, where the researcher enumerates catches as people return to their homes (Godoy et al. 2000, Sheil and Wunder 2002), are likely to provide accurate and detailed information. However, they are expensive to apply at large spatial and long temporal scales, and the presence of observers may influence the frequency and location of food quests. Less intensive methods such as diaries of harvesting trips that are filled out by the resource users on a voluntary basis (Gram 2001), or periodic household surveys that interview people on what they have taken in the recent past (Gray et al. 2005) can cover much larger scales. However, these methods may underestimate resource use because of poor participant recall (Gram 2001, Gray et al. 2005) or may return inaccurate information if interviewees revise their statements up or down depending on their perception of the questions and the broader context in which the research is set (Sheil and Wunder 2002).

We used repeated household surveys to quantify aquatic resource use at Kowanyama. The surveys were conducted on a monthly basis using a semi-structured interview format to speak to people about the number of times they’d spent out hunting or fishing in the last week, and their use of wild resources (e.g. food, baskets, spears, art materials etc.) over the last day (24 hours). During each household interview, participants were asked to separately discuss each trip in which wild resources were harvested. Information was collected about:

- the location of the trip
- the method of travel
- the number of men, women and children participating
- the species captured and their quantities
- the method of capture
- the final use of the species, and
- how the wild resources were shared.

Participants were also asked to discuss how river flows might have impacted on their trip. For example, it was noted whether the river at important hunting and fishing sites was still or flowing, and if so, whether this flow was fast or slow, whether it was tidal and how the tides influenced what people were catching.

Participating households were selected on the basis of their location relative to important hunting and fishing sites, as identified during the river mapping exercises, to ensure good coverage of the range of habitats and sites used by the people of Kowanyama. As there was little existing information on flow-related resource use by indigenous communities, power analysis or any similar method could not be used to determine a suitable sampling size for the household surveys. A review of the international literature suggested that a minimum sample size of 5 households was needed but we aimed for what was logistically possible given resource and time constraints. In the end, a total of 40 individuals were interviewed from 28 households over the duration of the project. This sample size
represented 16 percent of the total number of households in Kowanyama. The project was expected to run for two years however when the local researcher encountered difficulties in ensuring a consistent approach to data collection it was agreed to analyse 16 months of data instead.

As part of a capacity building component to the project, a local staff member of the KLNRMO was also trained in household survey techniques, and employed on the project to assist the research team with conducting monthly household surveys and compiling this information into a database with shared access between the CSIRO and KLNRMO.

A feedback workshop was held in May 2012 to present project findings, to clarify a number of returns, to discuss more broadly the use of economic proxies for valuing aquatic resource use, and to compile a list of important stakeholders to whom the report should be sent.

### 3.3 Data analysis

#### 3.3.1 DATA INCONSISTENCIES IN THE HOUSEHOLD SURVEYS

Survey numbers started out low, peaked towards the middle of the project with 37 surveys completed during January 2011, and then tapered off towards the end of the project (Figure 2). During four months of the first year (June 2010, September 2010, February 2011 and May 2011), no surveys were undertaken either because the interviewer was away or because it was considered too wet for anyone to have gone out hunting or fishing. Consequently, a continuous dataset was not collected that detailed the complete range of spatial and temporal (seasonal) changes in aquatic resource use.

![Number of surveys over time](chart.png)

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There was also uncertainty with regard to the total species and quantities harvested for particular sites in some instances, as this data was not always accurately recorded when multiple locations were visited on one harvesting trip. As there was no way to retrospectively distinguish the catch per site in these instances, the decision was taken to aggregate the data at the highest spatial scale. For example, where two creeks were visited on the same harvesting trip, the total harvest for the trip was allocated to the greater homeland area in which the creek system is found.

In three instances, there was also a disparity with regard to the total harvest recorded on camping trips (i.e. consecutive days spent out bush hunting and fishing). The total species and quantities harvested on individual hunting and fishing trips while on-country were sometimes recorded by the interviewer, and at other times not. For consistency, the decision was taken to regard each camping trip, irrespective of the number of times people may have went out hunting or fishing to different sites, as one harvesting trip. The harvest from different locations was again aggregated at the homeland scale.

### 3.3.2 Calculating Replacement Costs

Replacement values were calculated only for “aquatic species” and only in those instances when the relevant cost data (e.g. store prices) was available. “Aquatic species” were those for which a key feature of their life history depended entirely on aquatic habitats. While many species living on the floodplain and along river corridors such as Agile Wallaby (*Macropus agilis*) may be affected by flow alterations and subsequent loss of habitat, our surveys focused on those that were considered as obligate aquatic (i.e. constrained to aquatic habitats for all or part of their lives).

The most basic list of information required to estimate the net economic value of wild resources is:

- The average amount of each species harvested;
- The number of people harvesting each species;
- The market price of each type of wild resource; and
- The cost of harvesting wild resources (Gray et al. 2005).

The net economic value takes into account the benefits obtained from the use of a particular resource less the costs and risks involved to use it. However, the gross economic value of wild resource harvest can be estimated without accounting for the costs of harvesting. While other authors have estimated the expenditure involved in obtaining wild resources, in many of these cases only a partial estimate of the costs was available (e.g. fuel costs, Buchanan et al. 2009).

While we could partially estimate travel costs based on our household survey, many costs such as the opportunity cost of people’s time while out hunting or fishing could not be accurately assessed. In those cases where people accessed multiple sites during a harvesting trip, in particular, the time spent at each location was not always recorded. Consequently, the gross replacement values of important aquatic resources were determined for this report using a replacement cost method (Buchanan et al. 2009). The choice to use this method of resource valuation was made in part because we wanted to minimise the use of a survey response we considered variable at best, and in part because we wanted to use a straightforward calculation, preserving the easily understandable nature of the replacement value method.

We estimated the gross replacement value of the harvest and consumption for each species using (Buchanan et al. 2009):

\[
GRV = (aWt*aTN*aV) + (bWt*bTN*bV) + (cWt*cTN*cV)
\]

Where:

- \(GRV\) = Gross replacement value;
• $aWt; bWt; cWt$ = mean weight in grams or a species for the large (a), medium (b) and small (c) size classes;
• $aTN; bTN; cTN$ = total number of individuals of a species harvested or consumed in the large (a), medium (b) and small (c) size classes;
• $aV; bV; cV$ = “shop value” of the replacement item for a species in the large (a), medium (b) and small (c) size classes (Appendix A)

Replacement items were chosen to reflect the predominate use of the species they were to replace (e.g. food or bait), as well as a particular strong or weak preference for the species. Barramundi, for example, was considered by Indigenous people from Kowanyama as a prized catch, and so its value was equated with a more expensive store-bought item such as ‘Yellowtail Kingfish’, priced at $39.45/kg from a popular supermarket chain store with an online catalogue for goods and prices. Catfish, on the other hand, was regarded as a more general food source, and so its value was equated with a less expensive store-bought item such as ‘Imported Barramundi’, priced at $17.82/kg. The remoteness of Kowanyama from major markets should also be noted as a contributing factor to high prices for store goods. The use of an online catalogue to price store-bought alternatives to wild resources should therefore be viewed as conservative.

However, participants could not always align the total number a species harvested with the numbers that fell into different size categories. For example, it was not unusual for a survey respondent to recall that the group had caught eight Long-necked Turtle (M. rugosa), but only be able to recall that “two were really big ones, the rest were all sizes”. Incomplete recall needed to be accounted for when assessing replacement value, as the total harvest of species was broken into size categories: large, medium and small. Where survey respondents had incomplete recall of the make-up of size categories, unallocated catch was placed in the "medium" category, effectively giving the un-sized catch the average for that species. The number of individuals consumed in each size category was taken to be proportional to the number harvested, unless the survey respondent informed us otherwise.

3.4 Assessing the potential impacts of flow alterations on the total replacement value of harvest

The potential impacts of flow alterations were assessed using a variety of data sources. The two major sources of information were:

• A semi-quantitative risk assessment of potential impacts of dry season extraction on 40 fish species (Kennard et al. 2010a), using a pressure-vector-response framework. The likely effects of dry season water extraction (pressure) on a range of vectors over 13 categories were investigated. These vector categories included the loss of riffle habitat, the exposure of bank-side habitat and refugial areas, the loss of spawning and feeding areas, and a reduction in longitudinal and lateral connectivity. The relative risk of changes to each species (response) was ranked against each vector category using 3 risk categories; high risk, moderate risk and low risk.

• A Bayesian Belief Network analysis of potential impacts of flow alterations on Barramundi and Black Bream populations, which linked dry season flows to various aspects of the biology of these species (Chan et al. 2010).
4 Results

4.1 Seasonal pattern of trips

Household surveys showed that the mean number of harvesting trips undertaken by Indigenous people in Kowanyama fluctuated from one season to the next (Figure 3). These fluctuations were partially explained by people’s access to country. During each wet season, much of this country is flooded with some areas remaining boggy well into the early dry season and only accessible by 4WD vehicles. With a wetter than usual wet season in 2010, and few people with access to 4WD vehicles, a dip in the number of harvesting trips between the wet and early dry seasons could thus be explained. June also marked the school holidays when many people were out of town, visiting family or on vacation. Others were ill and did not go out harvesting.

The highest number of trips was undertaken during the mid dry season, and could be explained by an increase in the number of people camping out bush for two to three days at a time, usually over the weekends, to hunt, to fish and to spend time on country with family. This period was followed by fewer harvesting trips undertaken during the late dry season. Lack of access to a vehicle, poor health or people being out of town were important contributing factors to this pattern, as was the closure of part of this country due to sorry business in December 2010.

![Figure 3: Mean number of harvesting trips per survey (per month) for households in Kowanyama throughout the year](image)

4.2 Frequency of trips by habitat

Harvesting activities in Kowanyama showed that people had a preference for creeks and waterholes that alternated from one season to another (Figure 4). During the wet season, creeks and waterholes were equally frequented by people, accounting for 32% and 33% of all harvesting trips, respectively.
People stated that while the main river channel was flooded during the wet season, spring-fed creeks were accessible and made for the best available fishing spots for freshwater species like Jewfish, Black Bream and Catfish. Waterholes and swamps were preferred for the harvesting of Magpie goose eggs. Floodwater habitats were next frequented with 25% of all harvesting trips made here. People stated that the fast release of floodwaters to sea helped to stop saltwater, tidal surges from coming further upstream, creating in effect, more freshwater habitats for fishing.

The early dry season was marked by 40% of all harvesting trips made to creeks, as well as an increased use of floodwaters (by 2%), associated with fishing for freshwater species like Black Bream, Barramundi and Long-necked Turtle. It was also considered by Aboriginal people as the season to collect bush materials for spear-making and ochres for ceremony.

During the mid dry season, visits to waterholes made up 39% of all harvesting trips and was associated with the harvesting of Long-necked turtle in their highest numbers. People’s use of estuaries during this period also increased from 12% to 29% of all trips. This may have been linked to Barramundi fishing in saltwater country, as the fish migrate downstream to spawn in near-marine salinities before and during the wet season (Jackson et al. 2011). People from Kowanyama stated that although it was difficult to catch Barramundi near the mouth of the river, saltwater Barramundi were usually preferred to freshwater Barramundi, which sometimes had a muddy taste.

Late dry season harvesting activities focused predominately on creeks, accounting for 68% of all harvesting trips. Aside from fishing, harvesting activities undertaken during this period included dragging for sea prawns, and hunting for crocodiles and flying foxes, which are used in bush medicines to cure many ailments such as asthma.
4.3 Species caught and consumed in highest numbers

Magpie goose eggs were the species harvested and consumed in the highest numbers at Kowanyama (Figure 5). However, whereas goose eggs are a seasonal resource harvested during the wet, fishing occurs year round. Four of the top five species harvested from the Mitchell River were fish species that included Catfish, Barramundi, Black Bream and Grunter (Figure 5).

In a study of fishing practices in the Kimberley, Indigenous people stated that Catfish were regularly caught, if not always actively sought after, because they were easily hooked (Toussaint 2010). At Kowanyama, even if nothing else was biting, you could always catch a Catfish. One interviewee recalled that ‘whitefellas’ sometimes referred to Catfish as scavenger fish no good for eating but he explained that Aboriginal people viewed Catfish as a gift from their ancestors, good to eat and easy to catch in different habitats from lagoons to swamps. This species was also considered as good for sport fishing. Barramundi was considered a prized catch, good for sport fishing, and because the local Aboriginal people stated that they liked to see ‘the snap’ of the fish through the water as it was caught. Barramundi was also preferred by Aboriginal people for its high meat to bone ratio (i.e. it had lots more to eat than other freshwater species) and was said to be tasty. Similarly, Black Bream was considered a tasty fish with lots of meat on the bone. One resource user stated that Black Bream was tastier and meatier than Grunter, as well as easy to cook. Black Bream were often cooked on the fire and eaten at the fishing spot. Grunter was the only saltwater fish species harvested in high enough numbers to make the Top five, whereas most of the harvesting effort in Kowanyama focused on freshwater species and habitats like creeks.

Large-bodied species like Long-necked turtle were included in the top ten species harvested and consumed (Figure 5). They were harvested in their highest numbers from waterholes during the mid-
dry season, as water in other parts of the Mitchell River receded or dried up. Long-necked turtle was favoured for its taste and large size. Moreover, as an air-breathing species capable of surviving for long periods out of water, turtles stayed alive and fresh well after capture, making them an ideal species to be shared and gifted outside of the group involved in the harvesting trip. In contrast, no bait species were included in the top ten species harvested and consumed (Figure 5).

**Figure 5: Top ten aquatic species harvested and consumed by survey households in Kowanyama**

Figure 4 also showed that the household consumption of species was always lower than the amount harvested. The amount ‘harvested’ accounted for the total numbers of a species caught by all households involved in a harvesting trip (including non-surveyed households). The amount ‘consumed’, on the other hand, included only those numbers of a species consumed by the survey household. The difference between trip harvest and household consumption, thus, reflected the amount of sharing that occurred between households, families and communities. Although it was not possible to completely distinguish the effect of multiple households on a trip from the amount of harvest shared outside of the trip, the investigation of a number of species suggested that sharing in many cases was substantial. Indeed, sharing amongst family was considered proper according to local Aboriginal custom, as was the spread of harvesting efforts, switching from one location to another on trips, and sometimes between freshwater and saltwater habitats.

### 4.4 Species with greatest replacement value (harvest)

With the exception of Magpie goose eggs, the species that made the largest contribution to replacement value were also the species that were harvested in the greatest numbers (Figure 6). However, these species were not always awarded the same weighting in terms of their value, and the numbers caught. Although Catfish were caught in higher numbers than Barramundi, for example, the former were less valuable than the latter because there was less to eat on them. Barramundi, as a large-bodied species, made the single highest contribution to the total replacement value of the harvest caught by Aboriginal people from Kowanyama. It accounted for $17 533 (58%) of the total replacement value of the harvest, and could therefore be considered irreplaceable in the Mitchell River system, not least of which from a monetary point of view of finding store-bought alternatives.
Figure 6: Gross replacement value of the Top five aquatic species consumed by survey households in Kowanyama

The five species with the highest combined replacement values (Figure 6) made up $ 27,634 (92%) of the total replacement value of the harvest. A wide range of other species, including Short-necked turtle, Jewfish (freshwater) and Sleepy cod then made up the remaining 8% of the total replacement value of the harvest. In addition to actively seeking after preferred, high-value species like Barramundi, Aboriginal people from Kowanyama thus, harvested a variety of other species to make up their diets (Table 1).

Table 1: Gross replacement value of all aquatic species consumed by survey households in Kowanyama

<table>
<thead>
<tr>
<th>Species</th>
<th>Gross replacement value ($AUD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catfish</td>
<td>2961</td>
</tr>
<tr>
<td>Barramundi</td>
<td>17,533</td>
</tr>
<tr>
<td>Long-necked Turtle</td>
<td>1,519</td>
</tr>
<tr>
<td>Short-necked Turtle</td>
<td>234</td>
</tr>
<tr>
<td>Magpie Goose</td>
<td>215</td>
</tr>
<tr>
<td>Black Bream</td>
<td>4,018</td>
</tr>
<tr>
<td>Whistling Duck</td>
<td>23</td>
</tr>
<tr>
<td>Shark</td>
<td>688</td>
</tr>
</tbody>
</table>
### Table: Gross replacement value ($AUD)

<table>
<thead>
<tr>
<th>Species</th>
<th>Gross replacement value ($AUD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jewfish (Freshwater)</td>
<td>535</td>
</tr>
<tr>
<td>Sleepy Cod</td>
<td>29</td>
</tr>
<tr>
<td>Stingray</td>
<td>95</td>
</tr>
<tr>
<td>Magpie Goose Eggs</td>
<td>517</td>
</tr>
<tr>
<td>Prawns</td>
<td>103</td>
</tr>
<tr>
<td>Grunter</td>
<td>1603</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>30074</strong></td>
</tr>
</tbody>
</table>

#### 4.5 Seasonal harvest patterns for the top five economically valuable species

During the wet season, the highest numbers of fish caught were saltwater Grunter, followed by freshwater Catfish (Figure 7). This indicated the use of a variety of different habitats by people from Kowanyama during this period. However, as much of this country is flooded every wet season, the tidal section of the Mitchell River from Bulls Crossing down to the river mouth was considered most likely where the fish were caught.

The early dry season was characterised by a peak in the numbers of saltwater Grunter, and freshwater Black Bream and Barramundi, that were caught (Figure 7). People explained that as the floodwaters receded down into the narrower, more incised portions of the river channel, the drag increased and the speed at which the water was flowing slowed to create better opportunities to successfully catch freshwater fish like Black Bream. This period was also considered by interviewees to be a good time to catch Barramundi upstream at favoured spots like Topsy Creek. It was thought that Barramundi migrate upstream perhaps in response to a change in the water temperature, as it was perceived by one interviewee to be warmer upstream rather than downstream.

The highest numbers of Long-necked turtle were harvested during the mid dry season, as people shifted from utilising mostly creeks to mostly waterholes (Figure 4). This increase in the number of turtles harvested also coincided with declines in the numbers of Barramundi, Black Bream and Grunter caught (Figure 7). It indicated a strong preference by Aboriginal people from Kowanyama for Long-necked turtle at times when other species were less available. The seasonal harvest of Long-necked turtle may therefore be an important coping strategy for people during leaner times.

During the late dry season, the numbers of Barramundi and Long-necked turtle caught declined while Grunter numbers stabilised around a mean number of six fish harvested per trip (Figure 7). The number of Black Bream harvested increased slightly. Unlike for other species, the number of Catfish harvested remained relatively stable between four and six fish per harvesting trip throughout the year.
4.6 Sites contributing high value

The top five sites providing for the highest value of harvest were Paroo, Bottle Camp (Boomerang), Wonya, Shelfo and Landing (Table 2). More than half of these sites (i.e. Bottle Camp Wonya and Landing) were creeks favoured for freshwater fishing. However, the five sites combined accounted for only 40% of the total replacement value of the harvest caught by Aboriginal people from Kowanyama. This indicated that people ultimately used a large number of sites across a variety of habitats for hunting and fishing.
Within sites, the five species contributing the highest replacement values represented 100% of the total value for those sites (Table 2). This suggested that people were actively selecting these sites because they supported the most high-value species. Barramundi, for example, made up the highest value contribution to the harvest at each of the top five sites.

<table>
<thead>
<tr>
<th>Top five sites</th>
<th>Number of trips</th>
<th>Top five species harvested</th>
<th>Gross replacement value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paroo</td>
<td>6</td>
<td>Barramundi 2579.64, Black Bream 59.49, Catfish 33.22, Grunter 9.45</td>
<td>2681.79 (100%)</td>
</tr>
<tr>
<td>Bottle Camp/Boomerang</td>
<td>4</td>
<td>Barramundi 2430.12, Grunter 198.41, Catfish 41.52</td>
<td>2670.05 (100%)</td>
</tr>
<tr>
<td>Wonya</td>
<td>6</td>
<td>Barramundi 2026.23, Catfish 136.18, Black Bream 104.11, Grunter 66.45, Shark 40.67</td>
<td>2373.63 (100%)</td>
</tr>
<tr>
<td>Shello</td>
<td>5</td>
<td>Barramundi 1561.43, Black Bream 356.94, Catfish 83.04, Long-necked Turtle 81.77, Magpie Goose 26.89</td>
<td>2110.07 (100%)</td>
</tr>
<tr>
<td>Landing</td>
<td>5</td>
<td>Barramundi 1493.89, Black Bream 267.71, Grunter 161.24, Catfish 94.66, Shark 49.82</td>
<td>2067.32 (100%)</td>
</tr>
</tbody>
</table>
4.7 Qualitative assessments of flow requirements for the Top five economically valuable species (adapted from Jackson et al. 2011)

4.7.1 BARRAMUNDI (LATES CALCARIFER) FLOW REQUIREMENTS

Barramundi are a large, iconic northern Australian fish that also occur in eastern Africa, Papua New Guinea, and many countries in south-eastern Asia (Allen et al. 2003). It is a large, predatory fish that sits at (or very near) the top of the food chain (Staunton-Smith et al. 2004). It is catadromous, migrating from freshwater to saltwater to spawn (Allen et al. 2003), and is distributed from Shark Bay (WA) north to the Mary River (Qld). Barramundi are one of the most important recreational and commercial fish in Australia (Keenan 1994) and although they are capable of tolerating marine conditions and distributing between rivers, populations in the NT usually remain within their own river catchment and do not make move great distances to other systems (Keenan 1994).

Barramundi spawn in near-marine salinities (28—32 pps) at the mouths of tidal rivers and estuaries (Keenan 1994). They spawn in coastal areas before and during the wet season (Staunton-Smith et al. 2004), and often do this on the spring (large) tides when flooding can fill temporary coastal nursery swamps and provide large amounts of larval habitat (Milton et al. 2008).

Post-larvae use estuarine wetlands as nurseries, and depart these areas at the end of the wet season (Milton et al. 2008). By the 15th day after hatching, juvenile Barramundi can tolerate completely freshwater and will move to exploit flooded wetlands adjacent to river mouths. Juveniles will migrate upstream into freshwater within the first year when possible; otherwise they will remain in tidal creeks until they can migrate (Staunton-Smith et al. 2004). Here, sub-adult Barramundi will stay until they have reached maturity. Barramundi have increased growth and survivability in freshwater, but it does not appear critical for their survival (Milton et al. 2008) and individual Barramundi can complete their entire life-cycle in marine and estuarine water (Staunton-Smith et al. 2004).

Barramundi will migrate to saltwater during floods once they have reached sexual maturity (Staunton-Smith et al. 2004). The maximum size of Barramundi is approximately 180cm, and they are commonly captured up to 120cm long. They change sex from male to female when they are approximately 80cm long (Allen et al. 2003). In Australian rivers, it appears that mature Barramundi do not return to freshwater once they have migrated downstream to spawn (but may remain in the estuary for a number of years) (Staunton-Smith et al. 2004).

Northern Territory populations do not undertake extensive movements between river systems (Keenan 1994).

Although Barramundi can complete their life-cycle in saline water, good connectivity between fresh and saltwater systems appears critical for healthy populations. Flooding of coastal wetlands provides extensive habitat for larvae and juveniles, and strong connectivity allows juveniles to migrate to upstream areas where they grow faster. Barramundi populations are most vibrant in the Gulf of Carpentaria and the Northern Territory where longitudinal connectivity of rivers is good, and there is extensive seasonal flooding of coastal wetlands.

Extensive flooding of coastal wetlands will ensure abundant spawning habitat.

4.7.2 BLACK BREAM (HEPHAESTUS FULIGINOSUS/JENKINSI) FLOW REQUIREMENTS

Black Bream are a solid perch-like fish that lives in freshwater habitats in northern Australia. It is also commonly called Sooty Grunter (Chan et al. 2010). It is abundant in the freshwater areas of coastal catchments from the central Queensland to the Daly River, NT (Allen et al. 2003) but is also found in waterholes, spring-fed creeks, billabongs and the main river.
Black Bream spawn exclusively in freshwater (Hogan and Nicholson 1987). The spawning habitat in low gradient rivers is unknown (Pusey et al. 2004) but as they spawn during the wet season, flowing water microhabitats will nearly always be available (Pusey et al. 2004). The spawning migration is upstream in most rivers, but has been observed to be in a downstream direction in the Alligator rivers region (Pusey et al. 2004).

Black Bream spawn in summer in response to monsoonal rains (Allen et al. 2003), and rising water levels have been suggested to trigger spawning (Pusey et al. 2004). Black Bream have demersal eggs that sink into crevices in sediments, and are slightly adhesive, which may help prevent them from being swept downstream (Pusey et al. 2004).

Adults are found in a wide range of aquatic (lentic and lotic) habitats and appear quite hardy, surviving in a water pH as low as 4, and water temperatures ranging from 12 °C to 34 °C (Allen et al. 2003). However, annual wet season flooding (even in habitats well away from rivers and creeks) would appear essential for a strong population. Longitudinal connectivity may also be important for upstream and downstream spawning migrations.

4.7.3 FORK-TAILED CATFISH (ARIUS SPP.) FLOW REQUIREMENTS

Six species of the large Ariidae family regularly occur in freshwater habitats in northern Australia but of these, A. graeffei, A. leptaspis and A. midgleyi are most likely to be encountered. These species are medium to large in size and occur in freshwater and estuarine habitats, with A. midgleyi occurring exclusively in freshwater. The three species utilise off-channel floodplain habitats, indicating a preference for clear waters, and are tolerant of a moderate range of pH levels (Pusey et al. 2004).

The three species begin breeding prior to the onset of the wet season, although where spawning takes place is unknown. Spawning occurs in the late wet/early dry season for A. graeffei and the late dry/early wet season, preceding flooding, for A. leptaspis (and perhaps A. midgleyi). The timing of spawning could be the result of an increase in temperature, day length and enhanced production in the river systems (Pusey et al. 2004). The species exhibit a high degree of parental care of their young with A. graeffei and A. midgleyi males inhabiting deeper water during incubation.

Movement is an important part of the life history of these species. A. midgleyi embarks upon small scale migration to deeper water during incubation (Kailola and Pierce, 1988 in Pusey et al. 2004) and may move onto floodplains during times of inundation. The movement of A. leptaspis is also relatively unknown although it is believed likely to move between its estuarine habitats and upstream areas (Pusey et al. 2004).

The most detailed movement biology exists for A. graeffei, which has been researched in numerous fishway studies (Pusey et. al., 2004). These studies show A. graeffei moves upstream through fishways at a temperature range between 18 – 29°C. In the Fitzroy River (Camballin) barrage in Western Australia fish mostly moved at temperatures above 23 °C and in numbers of around 1000 fish a day when water temperature surpassed 27°C. The studies also showed migration occurring at a wide range of discharge and flow conditions although times of low discharge recorded the highest fish movements. Migration upstream occurred throughout the year although studies found it to be greatly reduced in the cooler months of July and August. The studies also make note that larger A. graeffei are more successful at ascending fishways than smaller individuals and that a higher number enter the structures than are able to reach the top.

Substantial migrations of Fork-tailed Catfish suggest that reductions in longitudinal connectivity may restrict these movements. Given the high biomass of Catfish that have been observed moving up the Fitzroy River (e.g. 12.7 tonnes per month) (Stuart 1997 in Pusey et al. 2004)), river regulation that restricts movement along the river channel may have a substantial effect on indigenous harvest. More generally, river regulation and flow alterations that reduce the frequency of flooding and the area inundated, or reduce longitudinal and lateral connectivity in river systems, is likely to impact the three catfish species considered here (Pusey et al. 2004).
4.7.4 GRUNTER (POMADASYS KAAKAN) FLOW REQUIREMENTS

The Javelin Grunter is found throughout the Indo-West Pacific region, including the Red Sea, along the east coast of Africa to south-east Asia, north to Taiwan and south to Queensland, Australia. It inhabits marine, brackish (saltwater) environments, often associated with reefs, but is also found in estuaries and off the deeper banks near river mouths, characterised by sandy to muddy bottoms up to a depth of 75 m. The fish may tolerate water with low salinity, sometimes associated with inshore wrecks. They spawn near river mouths during the winter, and the juveniles of this species appear estuarine dependent (Robertson and Duke 1990). Pajuelo et al. (2003) also documented protracted (non-seasonal) spawning in *P. kaakan* populations around the Canary Islands, in response to low amplitude oceanographic cycles. Consequently, flow alterations that result in a reduction of the longitudinal connectivity between freshwater and saltwater systems to maintain healthy estuaries, as well as the amount of brackish habitats in the lower river reaches, are likely to have a substantial impact on Grunter populations.

4.7.5 LONG-NECKED TURTLE (MACROCHELODINA RUGOSA) FLOW REQUIREMENTS

The Long-necked Turtle is a relatively large freshwater turtle that lives in both billabongs and rivers, and is distributed across tropical Australia, from Cape York (Qld.) across to the Kimberley (WA). The Long-necked Turtle is abundant in seasonally inundated floodplain swamps and wetlands, and has an elongated neck that allows it to be largely predatory, catching fish from ambush positions (Kennett and Tory 1996).

The Long-neck turtle is the only reptile known to lay its eggs underwater (Kennett et al. 1998). Turtles lay their eggs in shallow water at the edge of seasonally inundated wetlands at the end of the wet season. The eggs don’t develop until they dry out during the dry season (Kennett et al. 1993). They develop through the dry season and hatch when the first wet season rains soften the soil; this allows the hatchlings to emerge from the nest at a time when it is more likely there will be water nearby (Kennett et al. 1993). Long-neck turtles lay multiple clutches of eggs over the wet season in a ‘scattergun’ approach that means at least some eggs should be viable when the next wet season starts (Kennett 1999). The flooding of nests is not facultative; it is a requirement for the survival of embryos and emergence of hatchlings (Fordham et al. 2006).

As wetlands dry, adult Long-necked turtles bury themselves in the mud to aestivate until the next wet season. In very wet years when water remains in the billabong, turtles do not aestivate (Fordham et al. 2007). However, it appears that even when turtles do not aestivate (i.e. remain swimming in the water column) they stop feeding at the end of the dry season.

Long-neck Turtles depend on the seasonal wetting and drying of wetlands and billabongs for their breeding. Eggs that are not held underwater suffer the same high mortality as those that are held under water for too long (>25 weeks) (Fordham et al. 2006). So, while aestivation is facultative (not absolutely necessary), the inundation and drying of nests appears critical.

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6 *Pomadasys kaakan*, available at [http://www.fishbase.us/summary/Pomadasys-kaakan.html](http://www.fishbase.us/summary/Pomadasys-kaakan.html)
5 Discussion

5.1 Patterns of indigenous harvest

The species harvested by Indigenous people from Kowanyama in the greatest numbers were relatively abundant and widespread species (see also Jackson et al. 2011). This suggested that the high availability of these species, at least in part, contributed to Indigenous household incomes. People’s personal preferences for tasty species such as Barramundi and Black Bream with high meat to bone ratios, as well as cultural preferences for sharing the harvest amongst kin also influenced harvesting patterns.

The seasonal pattern of change in the habitats used for hunting, fishing and gathering bush materials at Kowanyama was driven by a combination of habitat availability and accessibility (Monaghan 2005), as well as the seasonal abundances of target species, subject to their life histories. This provided further evidence that Indigenous harvest of aquatic species is strongly linked to existing flow regimes, and is likely to be substantially affected by flow alterations that modify habitat availability and species distributions.

The wet season was characterised by seasonally inundated areas of river country that restricted where people could go on harvesting trips. As the main river channel was flooded, most harvesting trips were made to creeks and waterholes, although some floodwater habitats were also utilised for fishing. Monaghan (2005) showed that during this period, many Indigenous people would travel on foot, via woodland ridges and elevated levee banks between flooded parts of country, to access nearby wetland habitats (i.e. within a 4-5 km radius from the community) to collect goose eggs and to fish.

Chase and Sutton (1981) documented that other Indigenous groups on the Cape York Peninsula found this to be a difficult time because of their increased reliance on less preferred foods that required more effort to prepare, in addition to the physical and psychological constraints of being confined to small camps. At Kowanyama, Catfish which were regarded by certain fishermen (predominately non-Indigenous) as scavenger fish and unpleasant to eat, were harvested in their highest numbers by Indigenous people during the wet. Rather than preferred for its taste, Catfish were regarded as a stable food source because they were easy to catch throughout the year. However, the harvesting of Catfish was particularly important as a coping mechanism during the leaner, wet season period when much of the country for hunting and fishing was cut off by floodwaters.

During the early dry season, most harvesting trips at Kowanyama were focused on creeks, followed by floodwater habitats. The highest numbers of saltwater Grunter, as well as freshwater Barramundi and Black Bream, were harvested at this time. It corresponded with the upstream migration of subadult Barramundi to feed and to grow before migrating back to saltwater country to spawn in the following wet season floods (Milton et al. 2008). Black Bream, on the other hand, were found exclusively in freshwater habitats throughout their lifecycle (Pusey et al. 2004). However, as the fastest flowing waters at the top of the water column began to slow down from the wet to early dry season, the fish were easier to hook. Similarly, Jackson et al. (2011) noted that this period was excellent for catching Barramundi at locations where flooded creeks drained back into the main river channel of the Fitzroy River, Western Australia.

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As much of the country dried out towards the middle of the dry season, waterholes then became a major focus of harvesting trips with the highest numbers of Long-necked turtle harvested from these habitats during this period. The mid dry season was also when the highest number of trips per survey was recorded throughout the year for people from Kowanyama. This corresponded to an increase in
the number of people camping out bush for extended periods of time to hunt and fish and spend

time on country with family. Monaghan (2005) similarly showed that larger social groupings of
people concentrated around the deeper lagoons found on interfluves inland of the coast towards the
mid-dry season (July to September) to harvest bush tucker and other materials.

Late dry season harvesting activities focused predominately on creeks, accounting for 68% of all
harvesting trips. Of the top five most economically valuable species, Black Bream were harvested in
the highest number because they preferred the slow, flowing water conditions of the late dry to the
fast-flowing wet season floods. Aside from fishing, harvesting activities undertaken during this period
included dragging for sea prawns, and hunting for crocodiles and flying foxes, which are used in bush
medicines to cure many ailments such as asthma.

5.2 Resource valuation of aquatic resource use

The calculation of replacement value multiplied the number of a species harvested by body size and
shop value. So, the list of “valuable” species in terms of their replacement value was different to the
list of the species harvested in high numbers. In particular, large-bodied and preferred species like
Barramundi and Long-necked turtle were of high-value and expensive to replace with store-bought
alternatives. Although our analysis only accounted for the consumptive use value of these species,
cultural values associated with family totem animals like Long-necked turtle also contributed to their
significance for Kowanyama people, as documented for other Indigenous groups (Cooper and
Jackson 2008; Toussaint 2010). Most of the species that ranked highly in terms of replacement value
were common and widespread.

The species that made up the highest value contributions, combined, accounted for 92% of the total
replacement value for the harvest at Kowanyama. Barramundi made up the largest single
contribution, followed by Black Bream, Catfish, Grunter and Long-necked turtle. This suggested that
these species could be targeted during environmental flow assessments as indicator species of river
health, particularly if there was an interest in the economic contribution made by their direct use
towards the overall value of the river.

On the contrary, the five sites providing for the highest value to harvest (combined) accounted for
only 40% of the total replacement value. This suggested that while Indigenous people actively
targeted key species at harvest sites where they knew they could be successful, they also utilised a
high number of peripheral or secondary sites and habitat types across Mitchell River country. This
appeared consistent with the ‘proper way’ to go hunting and fishing, according to local aboriginal
custom. During the feedback workshop in 2012, participants explained that people would
traditionally move around a lot, switching between saltwater and freshwater harvest sites, and
between fishing for Barramundi and hunting for Long-necked turtle on specific trips. It was
considered proper to not go harvesting at the same site every trip but to move from one site to
another in order to allow for the fish or resource stocks to replenish. Those people that did not
adhere to this practice were considered ‘greedy’ and ‘disrespectful’ to that place or that species. In
such instances, it was the prerogative of the traditional owners of that country to ‘close’ that country
for use. While sustainability principles thus seem central to Indigenous harvesting practices at
Kowanyama, a regional approach is required to monitor environmental flow requirements for a
range of harvest sites across different habitat types.

The health of the country and of the people was also regarded by workshop participants as
intimately connected, such that a ‘poor harvest’ could be considered as a sign that all was not well
with the land, or perhaps with a family member who owned that country. As documented for other
Indigenous groups (Cooper and Jackson 2008), it was believed that country was inhabited by
ancestors, connected to the land through dreamtime stories of creation, and responsible also for the
health of that country, and for the resources it provides to the people of Kowanyama. Water places,
in particular, have been associated with such strong spiritual presences central to Indigenous identity
and religion (McFarlane 2004; Jackson 2008). It makes sense that in the event of a death in the
family, that country is ‘closed’ for a time of mourning – and to allow time to heal. When the country is reopened, this is usually marked by much hunting and fishing and time spent reconnecting with the land and spirits. The cultural practice of closing country for an extended period of time, whether in response to an environmental or social cue, may also provide additional benefits, for example, if used to actively create and maintain refugia for important species and habitat types to buffer against the impacts of future flow alterations due to climate change (Green, Jackson and Morrison 2009) or anthropogenic causes (Connor et al. 2009).

These results strongly support the findings of Jackson et al. (2011) in the Daly and Fitzroy River catchments for prioritising key indicator species for environmental flow assessments, and adopting a regional-scale approach to protecting important sites and habitats for indigenous aquatic resource use. However, the use of the replacement cost method for determining the direct consumptive use value of aquatic resources at Kowanyama was not without some challenges.

Direct use values represented only part of the ‘true economic value’ of the harvest, not encompassing any non-use values attributed to knowing of the continued existence of the river (i.e. existence value), or its protection for future generations to enjoy (i.e. bequest value). The emphasis placed on the economic value of aquatic resources therefore downplayed the importance of harvesting and fishing practices to social and cultural life at Kowanyama, where ‘camping out bush’ contributed to the highest number of harvesting trips per survey, recorded during the mid dry season. In addition to creating opportunities for people to go hunting and fishing, ‘camping out bush’ was also seen as an important time to spend with family and to connect with country. Monaghan (2005) similarly documented the prominent feature of temporary camps across the Kowanyama hinterland in his thesis on the use of social and geographical space by Indigenous groups in this area.

During the feedback workshop in May 2012, participants further stated that the value of the Mitchell River was in being able to take younger generations out on hunting and fishing trips, and to teach them about their culture and country. Not accounting for a discount rate was therefore a gap in our economic analysis of the value of aquatic resource use at Kowanyama, and should be a priority for future research studies.

The replacement cost method also relied on comparisons between dissimilar or incommensurate items (Jackson et al. 2011). Indeed, the use of economic proxies to quantify the value of aquatic resources as a function of their substitutability was foreign to resource users at Kowanyama. One reason for this was that scarcity could not be expressed as a function of resource availability and accessibility alone but rather that it was associated with a strong cultural component as well. The worldview held by Kowanyama residents was that their ancestors were responsible for the land and the resources it provided to them in perpetuity. Consequently, if hunting or fishing trips were unsuccessful, or resource stocks were perceived to be diminishing, workshop participants stated that this was because people had behaved ‘disrespectfully’. The culturally appropriate response was identified as the closure of this country for use to allow for these resources to be replenished. In contrast to western, market-based systems, where cost-benefit calculations determine decisions, institutions (i.e. rules, codes of conduct, cultural protocols etc.) often play a bigger role in Indigenous natural resource management.

Despite its focus on a snapshot of aquatic resource use values in time, our analysis does add to the existing body of literature on valuing wild resources (Gray et al. 2005), and more importantly, it provides a means for prioritising Indigenous values in environmental flow assessments.

5.3 Potential impacts of flow alterations on Indigenous harvest

Given the current lack of large-scale water infrastructure or extractions in the Mitchell River catchment, there is currently no way to manipulate high flows, and dry season impacts are the most likely over the short to medium term.
Previous studies by Chan et al. (2010) and Kennard et al. (2010a) suggested that a number of species providing a substantial contribution to indigenous household incomes at Kowanyama could be severely impacted by dry season water extraction. These species included Barramundi and Black Bream. Catfish, on the other hand, suffered lower levels of risk (Kennard et al. 2010a).

Of the ten most economically valuable species, those that were identified as being at high-medium risk of late dry season water extraction (Kennard et al. 2010a) made up 68% of the total replacement value for the harvest at Kowanyama in the Mitchell River Catchment. It is difficult to quantify what this level of risk might mean to total replacement value, but if water extraction resulted in a significant reduction in the harvest of these high risk fish species, the contribution that customary harvest makes to indigenous households could decline substantially. Barramundi alone accounts for 50% of the total replacement value. Consequently, any flow alternations that impact on the longitudinal connectivity between saltwater nurseries and freshwater habitats for growing population numbers will have a significant impact on aboriginal household incomes at Kowanyama.

The summary of the life histories and flow requirements of the five species contributing most to replacement value suggested that flows occurring immediately after the wet season may be important to many species. There is some potential for alteration of these flows early in the dry season as heavy extraction of water into off-stream storages as wet season flows decline could limit the extent and duration of downstream flooding (Pusey et al. 2004) and increase the rapidity of drawdown substantially.

In the case of Barramundi, large wet season flows appear critical for the maintenance of flooded coastal habitats used by juveniles as nurseries (Milton et al. 2008), while a substantial period of connectivity during the early dry season allowed sub-adult Barramundi to move upstream into the more productive freshwater habitats to feed and grow to maturity (Staunton-Smith et al. 2004). The early dry season also marked the time when Barramundi were caught in their highest numbers, largely from creeks.

The unimpacted nature of wet season flows is likely to continue in many northern catchments, as the ability to capture and store water using impoundments is highly constrained by topography and climate in northern Australia (CSIRO 2009). However, there is certainly ongoing political pressure to develop mining ventures upstream of Kowanyama. Additionally, the potential for wet season flows to be impacted by anthropogenic or natural changes to climate and precipitation is currently poorly known due to the variability in predictions for northern Australia, and the tendency for the best estimates to show little future change (CSIRO 2007).

Should wet season flows be altered, there could be substantial impacts to some of the key species harvested by indigenous people at Kowanyama. Long-necked Turtle, for example, lay their eggs under water along the edges of seasonally inundated billabongs (Kennett et al. 1998). The eggs need to dry, then rewet for development and hatching (Fordham et al. 2006, Kennett et al. 1993). Although Long-necked turtle only accounted for 8% of the total replacement value for the harvest at Kowanyama, they were of important cultural value because turtles were extensively shared amongst individuals, families and within the community.

A clear calculation of the reduction in the total replacement value of indigenous harvest associated with flow alterations is problematic. This is so on part because published information on quantified relationships between many of the species harvested and riverine discharge is limited.

We can however use household consumption data to estimate the value of customary use of aquatic resources as a proportion of indigenous household income (Table 3). Household income data derived from 2006 census data (ABS 2006) for the “Urban Centres and Localities”, show that Kowanyama (Qld) has a median fortnightly indigenous income of $1938 (Kowanyama). The value of household consumption of aquatic species represented 5.2% of the median fortnightly income (Table 3).
Table 3: Fortnightly consumption value of ‘wild’ aquatic resources as a proportion of fortnightly household incomes, and as proportion of total value of food consumption for indigenous households. Median household income was taken from 2006 census.

<table>
<thead>
<tr>
<th>Mitchell (Kowanyama)</th>
<th>Fortnightly Consumption Value</th>
<th>% household income</th>
<th>% total food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 5 Species</td>
<td>$75.30</td>
<td>3.9%</td>
<td>18.1%</td>
</tr>
<tr>
<td>Top 10 Species</td>
<td>$95.42</td>
<td>4.9%</td>
<td>21.9%</td>
</tr>
<tr>
<td>All Species</td>
<td>$99.99</td>
<td>5.2%</td>
<td>22.7%</td>
</tr>
</tbody>
</table>

Perhaps more tellingly, the imputed value of household consumption of bush foods (non-market) represented a substantial proportion of the total value of household food consumption (non-market and market/store bought). A parallel study to ours collected data on household expenditure on store bought foods in the Mitchell River catchment (Stoeckl et al., 2011). When the total value of food consumed by indigenous households was compared with the imputed value of bush foods, the percentage contribution of bush foods represented 22.7% of the total in the Mitchell (Table 3). From such a figure we can conclude that the long-standing reliability and ready availability of wild harvests and catches contributes important food supplies to these communities.

5.4 Potential implications of flow alterations for the hybrid economy

Critical knowledge gaps constrain our ability to quantify the potential effect of flow alterations on the economic value of indigenous aquatic resource use. However, conceptual models such as Altman’s hybrid economy (Altman 2001) can inform the likely impacts of flow alterations on indigenous livelihoods.

Whereas conventional economic frameworks largely consider the flow of resources between two sectors (market and state), the hybrid economy includes a third referred to as the customary sector. The customary sector accounts for productive activities such as hunting and fishing for subsistence and cultural purposes that are not captured in market systems (Altman 2001; Jackson 2008). These activities nevertheless play an important role in buffering indigenous communities against unwanted changes through supplementing household incomes and creating a safety net option for people during times of hardship when household budgets are strained (Altman 1987; Altman et al. 2009; Jackson et al. 2011).

Our study on the household consumption of aquatic resources at Kowanyama suggested that the replacement value of this harvest to surveyed households was 16% of the median household income. However, as the survey focussed only on aquatic species, it did not include others such as wallabies and feral pigs that were frequently harvested within aquatic habitats but were not dependent on the river for all or part of their life histories. Our survey also only focused on the township of Kowanyama, whereas indigenous harvest, and the sharing of resources between family and kin, usually occurs within and between communities (Jackson et al. 2011). Consequently, the replacement values we have presented are a conservative estimate of the total value.

A likely trajectory of change under a future development scenario in the Mitchell River catchment would result in some additional removal of water from aquatic ecosystems for industrial growth (e.g.
agriculture and mining), conservation and tourism. However, Stoeckl et al. (2011) showed that growth in the agricultural sector for the Mitchell River catchment would deliver only moderate returns in income and employment generating opportunities for indigenous people (i.e. rising by less than 10 percent over a 20 year period given a five percent increase in agriculture) with potentially serious implications for future water availability if water-efficient techniques are not used (i.e. a doubling of consumptive water demands when compared to 2006 levels). An increase in the extraction and use of water from the Mitchell River for agriculture and mining could therefore accentuate the vulnerability of indigenous households through direct impacts on aquatic resource use stocks, or indirectly, by impacting of household incomes. Water resource developments that alter river flow regimes, modify habitat availability, restrict access and influence species distributions could reduce fishing and harvesting rates, in turn affecting indigenous livelihoods and well-being.

While largely unaccounted for in official estimates of food production, subsistence activity is a key feature of the remote indigenous customary economy (Altman 2001), providing households with a low-cost means of supplementing low incomes in economically disadvantaged regions. Financial stress is widely reported across north Australia with, on average, close to 30% of indigenous households stating that they had experienced difficulties paying for everyday necessities in the 12 months prior to interview, including food, clothing, medical bills and housing costs (23.9% Queensland’s population) (ABS 2008).

Flow alterations that negatively impact on species important to the Kowanyama community, such as Barramundi, may have knock-on effects for the local tourism industry. Recent research by Chan et al (2010) and Kennard et al (2010a), for example, showed that flow alterations under future development scenarios for the Daly River (NT) could have a substantial impact on populations of fish species that contribute greatly to the indigenous customary economy. This may include adverse effects on sport fishing enterprises and/or camping accommodation for visitors owned by indigenous people or other parts of the tourism sector that indigenous people may contribute their skills and expertise to. At Kowanyama, the local community obtains direct benefits from these forms of fishing and tourism. In fact, revenue from these activities underwrites land management by the Kowanyama Land and Natural Resource Management Office.

Of course, the extent and magnitude of any impacts depends on current and future indigenous involvement in water planning and policy. However, if we made the very general assumption that extensive flow alterations reduced the consumption of aquatic resources by 50%, and all other factors such as effort remained constant, the result could be an 8% reduction in household incomes at Kowanyama (about $78 per week).

Should water policy change, it is possible that new opportunities and constraints to mining, tourism and conservation will emerge for Kowanyama residents. For example, should the state change the existing property rights regime to the benefit of indigenous landowners by providing them with alienable water rights, trading of water may be brought about between indigenous landowners and commercial water users. Whatever these changes, if regional economic stimulus can only be achieved at the expense of indigenous access to aquatic resources, indigenous livelihoods will be made increasingly vulnerable, given the continued importance and strength of the customary sector.
Conclusion

Aquatic resources make a substantial contribution to household incomes at Kowanyama in the Mitchell River catchment. This contribution, currently unaccounted for in mainstream metrics of indigenous household economies, provided a means for indigenous households to supplement their incomes (Buchanan et al. 2009) which, by national standards, are low.

As in the Daly (NT) and Fitzroy (WA) river catchments (Jackson et al. 2011), a relatively large proportion (>90%) of the gross replacement value that we calculated for aquatic species at Kowanyama was made up of a relatively small subset of high value species. In contrast, the replacement value of species harvested was distributed across a large number of locations. This is an important feature to note for water resource management, particularly when attempting assessments of environmental flow requirements to meet indigenous values and interests. Our study showed that environmental flow assessments need to adopt a regional approach (e.g. at the catchment scale) by identifying a set of core monitoring sites to define flow requirements for the most valuable species to be monitored intensively, as well as a set of secondary monitoring sites to define flow requirements for a wide range of other species that are harvested across multiple habitats, which could be sampled less intensively (e.g. every second or third year rather than annually).

Substantial gaps in knowledge remain, ranging from the flow requirements of species harvested by indigenous people to the relationship between species’ population dynamics and indigenous harvest success. These gaps mean that clear calculations of changes in the replacement value of aquatic species associated with flow alteration scenarios remain problematic. However, the substantial contribution of the customary sector to indigenous livelihoods makes Altman’s (2001) hybrid economy a useful conceptual framework within which to consider impacts of environmental flows on the adaptive capacity and resilience of regional and remote communities to unwanted changes.

As our quantification of replacement value focused only on the consumption of aquatic species, the figures presented in this report are conservative. If the broader range of productive activities contributing to the customary economy such as hunting, fishing, gathering, art, craft, and caring for country activities (Buchanan et al. 2009) were included, the value of the customary sector would be more accurate of its true importance to indigenous people. This critical knowledge gap represents scope for future research to build on this work.

Moreover, assessing the impacts of water resource development on key species, and allocating or protecting flows to minimise indigenous impacts cannot occur effectively without a clear understanding of the indigenous values associated with aquatic resources, and the flow requirements necessary to support them. The scientific determination of indigenous water requirements will be essential if governments are to fulfil their obligations under the Native Title Act (1993) to guarantee traditional landowners customary rights in water.
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## Appendix A

### Apx-Table A.1: Table of characteristics of aquatic species used in replacement value calculations

<table>
<thead>
<tr>
<th>Species</th>
<th>Large size class</th>
<th>Medium size class</th>
<th>Small size class</th>
<th>GVR (AUD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean weight</td>
<td>No. individuals</td>
<td>Shop value</td>
<td>Mean weight</td>
</tr>
<tr>
<td>Catfish</td>
<td>807</td>
<td>36</td>
<td>17.82</td>
<td>466</td>
</tr>
<tr>
<td>Barramundi</td>
<td>2276</td>
<td>41</td>
<td>39.45</td>
<td>1574</td>
</tr>
<tr>
<td>Long-necked Turtle</td>
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<td>Black Bream</td>
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<td>17</td>
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Australia is founding its future on science and innovation. Its national science agency, CSIRO, is a powerhouse of ideas, technologies and skills for building prosperity, growth, health and sustainability. It serves governments, industries, business and communities across the nation.