Integrating Social Yield Outcomes for Recreational Fishers in a NT Barramundi Harvest Strategy

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Introduction

The emergence of ecologically sustainable development (ESD) as a guiding principle in natural resource management has influenced fisheries management in Australia (Fletcher *et al.* 2002, Smith *et al.* 2007, Brooks 2010, Dichmont *et al.* 2013, Brooks *et al.* 2015) as it has in other parts of the world (e.g. Garcia and Cochrane 2005). ESD underpins the Northern Territory *Fisheries Act* (1988) which includes objectives such as: "*to maintain a stewardship of aquatic resources that promotes fairness, equity and access to aquatic resources by all stakeholder groups*" and "*by means of a flexible approach to the management of aquatic resources and their habitats, to promote the optimum utilisation of aquatic resources to the benefit of the community*".

Importantly, in the context of this review, ESD requires that natural resources such as fisheries are managed to increase the quality of life (wellbeing) for humans (Lehtonen 2004, Brooks 2010). This raises issues of social justice and the social (or cultural) contribution of fisheries to society (Brooks *et al.* 2015, Pascoe *et al.* 2014, Stephenson *et al.* 2018).

Harvest Strategies

Defined by Sloan *et al.* (2014) in Australia's National Guidelines to Develop Fishery Harvest Strategies, "A harvest strategy is a framework that specifies the pre-determined management actions in a fishery for defined species (at the stock or management unit level) necessary to achieve the agreed ecological, economic and/or social management objectives". They state "In its simplest form, a harvest strategy provides a framework to ensure that fishery managers, fishers and key stakeholders think about, and document, how they will respond to various fishery conditions (desirable or undesirable), before they occur".

The National Guidelines identify the following key elements of a harvest strategy:

- Defined operational objectives for the fishery;
- Indicators of fishery performance related to the objectives;
- Reference points for performance indicators;
- A statement defining acceptable levels of risk to meeting objectives;
- A monitoring strategy to collect relevant data to assess fishery performance;
- A process for conducting assessment of fishery performance relative to objectives; and,
- Decision rules that control the intensity of fishing activity and/or catch.

All Australian jurisdiction have developed, or are in the process of developing, harvest strategies for their key fisheries. Typically, these harvest strategies have been focussed on commercial fisheries and objectives have primarily related to rebuilding or maintaining stock levels at maximum sustainable yield (MSY) or maximum economic yield (MEY). Despite fisheries management legislation often mentioning social outcomes and many fisheries having a significant recreational sector component, harvest strategies that contain explicit social objectives relating to the recreational sector are few and far between.

Recreational fishing

Unlike commercial fishing where catch is an obvious and important benefit, retained catch is less important to recreational fishers. In a national survey (Henry and Lyle 2003) 37% of respondents cited to "relax and unwind" as their primary reason for recreational fishing: only 8 % of those surveyed identified "food" as the primary motivation for fishing. These "lifestyle" benefits are also

shown in later studies outweighing harvest (i.e., retained catch) as the primary motivation for recreational fishing (Triantafillos *et al.* 2014). In any case, motivations (and social values) will differ between and among categories of recreational fishers (Graefe and Fedler 1986, Holland and Ditton 1992, McPhee and Hundloe 2004, Johnston *et al.* 2010, McInnes *et al.* 2013, Sutinen and Johnson 2013, Giri and Hall 2015, Brown 2016, Birdsong *et al.* 2021). This diversity of motivation (and therefore fishing behaviour) introduces complexities to potential harvest strategies.

As in many developed countries (Ihde *et al.* 2011, Brownescombe *et al.* 2014, Arlinghaus *et al.* 2015, 2023), recreational fishing in Australia is waning in popularity (e.g., McInnes *et al.* 2013). With the increasing popularity of social media, young people are interacting through virtual means which has resulted in a general lack of participation in outdoor activities (Arlinghaus *et al.* 2008). Furthermore, the relative complexity of regulations may deter young people from participating in recreational fishing (Brownescombe *et al.* 2014, Arlinghaus *et al.* 2008). These issues have prompted fishery managers to promote recreational fishing participation as a healthy, active and enjoyable outdoor experience.

Recreational angler satisfaction derives from both catch and non-catch motives and can serve as a "social yield" objective for a recreational fishery (Beardmore *et al.* 2015; Johnston *et al.* 2010, 2013, 2015) rather than the typical targets of MSY or MEY usually considered in harvest strategies applicable to commercial fisheries (Sloan *et al.* 2014). In considering the development and application of harvest strategies to recreational fisheries, managers should contemplate factors other than harvest as a primary motivation for recreational fishing (Spencer and Spangler 1992, Spencer 1993, Fedler and Ditton 1994, Petering *et al.* 1995, Arlinghaus 2006, Vaske and Roemer 2013, Beardmore *et al.* 2015, Van Poorten and Camp 2019, Hunt *et al.* 2013, 2019, Brownscombe *et al.* 2019, Birdsong *et al.* 2021).

Although extension of harvest strategies to recreational fisheries is under active consideration in South Australia (PIRSA 2017), New South Wales (Fowler *et al.* 2022), Western Australia (DoF WA 2015, Fletcher *et al.* 2016) and Queensland (Fisheries Queensland 2017), the Northern Territory policy does not explicitly refer to harvest strategies for recreational fisheries management other than in a resource sharing context (NT 2015, 2016).

Including recreational objectives in the NT Barramundi Harvest Strategy

The Barramundi (*Lates calcarifer*) fishery is managed under the Barramundi Fishery Management Plan (1998)[1]. The Northern Territory is developing a harvest strategy policy for application to its aquatic resources (NT 2016). Notably, the Department of Agriculture, Water and the Environment received an application on 25 October 2021 from the Northern Territory Department of Industry, Tourism and Trade (NT DITT) seeking assessment of the Barramundi Fishery for approval under Parts 13 and 13A of the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act). The application was released for public consultation as part of the department's assessment, but in December 2022, the NT DITT wrote to the Department of Climate Change, Energy, the Environment and Water (DCCEEW) to withdraw the application while further work is undertaken to develop the management framework and Harvest Strategy for the fishery. It is an opportune time,

[1] https://legislation.nt.gov.au/Legislation/BARRAMUNDI-FISHERY-MANAGEMENT-PLAN-1998 accessed 01/08/2023

therefore, to consider integration of social yield outcomes for recreational fishers in development of the NT Barramundi Harvest Strategy.

There is considerable economic and social contribution from recreational fishing for Barramundi to the Northern Territory particularly given the emphasis on fishing-based tourism (NT Tourism undated). In contrast to other jurisdictions, recreational fishing is very popular in the Northern Territory, with one in three Territorians participating (West *et al.* 2012, McInnes *et al.* 2013). Catch and release is increasing in popularity with recreational fishers (Arlinghaus *et al.* 2007, Delle Palme *et al.* 2016) including those for Barramundi in the Northern Territory where most Barramundi caught (~70%) are released (West *et al.* 2012). Similarly, there are many fishers whose principal motivation is to enjoy the natural environment of the Northern Territory (West *et al.* 2012).

Notwithstanding its popularity, sustainable management of recreational fisheries is clearly important given that recreational fishing can have an adverse impact on the viability of fish populations (Cook and Cowx 2004, Hyder *et al.* 2017). Nevertheless, there are few sustainability concerns with regard to the Barramundi fishery (commercial and recreational) with the most recent assessment showing the stock at nearly 90% of unfished biomass (Grubert *et al.* 2021). Managers are therefore in the fortunate position of entertaining inclusion of social yield objectives for the recreational sector into the Barramundi harvest strategy. In this review of relevant literature, we explore this potential[2].

Recreational Fishing for NT Barramundi

Fishing in the Northern Territory can be categorised as Barramundi fishing and Bluewater Fishing (from NT Tourism Fishing Segment Profile accessed 3/08/2023). However, Barramundi is the prime species targeted by recreational fishers in the Northern Territory (see also Chong-Montenegro *et al.* 2021, Nyboer *et al.* 2022) and attracts anglers from within the Northern Territory, across Australia and overseas.

Recreational fishers can be categorised broadly as: resident recreational fishers, tourist fishers and "Grey Nomads[3]". Although grey nomads comprise a relatively small proportion of recreational fishers in the Northern Territory, they have a relatively high harvest (24t) compared with the more numerous residents (96 t) and tourist sport fishers (66 t) as they tend to have higher consumption rates (West *et al.* 2012).

More than 30% of Northern Territory residents engage in Barramundi fishing (West *et al.* 2012, Matthews *et al.* 2019, Nyboer *et al.* 2022). Fishing for Barramundi is mostly (92%) from boats fishing in rivers and estuaries. Catching a large fish (> 1 m, ~ 15 kg) is a goal of dedicated anglers with most (~70%) choosing to release the fish after capture (West *et al.* 2012). Landing a Barramundi greater

[2] Please note that some people may classify fishing by Indigenous people in remote NT communities as "recreational", but we consider that in most cases it is better described as "cultural fishing" conducted to meet the dietary and social needs of the community. As such, we do not include cultural fishing by Indigenous fishers or traditional owners in this review. Importantly in this respect, we must be cognisant of FRDC project 2021-098 "Incorporating Aboriginal perspectives into fishery management review processes, using the Northern Territory Barramundi Fishery as a case study". Running in parallel to the current project, it is imperative that the results of both projects are considered in any future changes to the objectives and decision rules of the NT Barramundi harvest strategy.

[3] A relatively recent saying for retired people (generally over 55 years old) who travel independently and for an extended period around Australia, particularly in a caravan or motor home.

than 1 metre in length is a driving ambition, particularly for fishing tourists who are willing to pay for a destination experience.

There are currently 63 operating fishing tour operators in the Northern Territory including 31 tourism accredited. Most tour operators (serving an estimated 80% interstate anglers among total customers) are based in Darwin operating tours to rivers and estuaries in the surrounding regions of Mary River, Adelaide River and Daly River. Further to this, specialised fishing lodges offer remote fishing experiences for anglers including the Tiwi Islands, West and Central Arnhem Land, Mary River Conservation Park and in the Daly River Region. Helicopters may be used to take anglers to more remote location adding an adventurous dimension to the fishing experience (Golden *et al.* 2019).

The popularity of Barramundi fishing in the Northern Territory is exemplified by the 27 annual fishing competitions held each year including the Barra Nationals and the Barra Classic. About half of total competitors (~200) are from interstate. Importantly, these competitions are held outside peak tourism season and are a valuable source of revenue to Northern Territory businesses. A profile of Barramundi fishers shows a typical fisher to be male, aged between 30-60, with middle to high income, and seeking an iconic fishing experience (NT Fishing Tourism undated). Further to this, Tourism NT is aiming to attract more recreational fishers to the Northern Territory through its "Million Dollar Fish" campaign. This campaign offers attractive cash prizes to anglers lucky enough to catch a tagged Barramundi and has been credited with increasing tourism revenue by more than $7 million.

No licence is required to fish recreationally in the Northern Territory although permits may be required if fishing on Aboriginal land (see below). There are no plans (nor political will) to introduce recreational fishing licences in the NT. This reflects a socio-political decision: "*Many residents of the NT are attracted to the life style. They don't want to live in a "nanny" state overburdened with regulation*". Recreational fishers are represented by the Amateur Fisherman's Association of the NT (AFANT), a peak body active in stakeholder consultative arrangements applicable to fisheries management in the Northern Territory. Current management controls applicable to the Barramundi recreational fishery are detailed in the Barramundi Fishery Management Plan (1998) but include: gear restrictions; seasonally closed areas; a minimum size limit of 55 cm; a maximum size limit of 90 cm in Fish Management Zones; and a possession limit of 5 in all areas other than Fish Management Zones, where the possession limit is three.

Drivers behind recreational fishing

There are diverse motives driving participation in recreational fishing and these motivations can be categorised into psychological, experiential, social or challenging/skill development (Fedler and Ditton 1994). Despite this diversity, there are generally three categories of angler considered in the recreational fisheries literature (Johnston *et al.* 2010, Van Poorten and Camp 2019, Birdsong *et al.* 2021):

- Social (or generic) anglers whose primary aim is recreation and social activity. Catching fish is not an essential driver of their satisfaction from fishing.
- Harvest anglers whose primary aim is to catch and retain fish i.e., catch applicable bag limits (e.g. the Grey Nomads, see above).

- Trophy anglers who target large fish and who are motivated by the challenge and experience of landing a large fish of a particular species. Trophy anglers usually practice catch and release. They are also willing to pay more than other types of anglers to meet their expectations of a quality fishing experience.

Of these categories, social fishers tend to be more numerous than harvest anglers who outnumber Trophy anglers. Henry and Lyle (2003) found in a national survey of recreational fishing that 15% of all recreational fishers were responsible for more than 40% of recreational fishing effort. A similar result was found for the Northern Territory (West *et al.* 2012). Trophy anglers tend to be highly skilled, invest considerably in fishing gear and equipment and are willing to travel large distances to catch large fish. In the Northern Territory, there is also a thriving charter boat industry (or fishing tour operators) providing services to all types of anglers. Fishing tour operators offer trips to anglers around metropolitan Darwin and to remote locations favoured by trophy fishers seeking to land a large Barramundi.

Human dimensions research within a social-ecological system framework is relevant to considering motives, behaviours and responses of recreational fishers to management intervention (Hunt *et al.* 2013) including harvest strategies. Managers can't control motivations among fishers but they can influence behaviour and enjoyment through regulation and governance. Nonetheless, there is challenge to translate general management goals such as "optimum social yield" (Johnston *et al.* 2010) into operational objectives. Relationship between human thoughts and actions (cognitions, behaviours, and relationships) regarding fish, fishing, governance and management transcends disciplines usually considered in fisheries management but these psychological factors are particularly relevant to the successful management of recreational fisheries. Cognitions are a key concept in social psychology which include basic values, perceptions, beliefs, attitudes, rewards sought (e.g. utility) and response to interventions e.g. management regulations (Hunt *et al.* 2013). These are pivotal to influencing behaviour (and impacts) of recreational fishers. Salient issues relevant to recreational fisheries are summarised below.

Emotions affect attitudes and motivations and help to shape cognition e.g. attitude change and affect preferences and intentions and actions (Hunt *et al.* 2013, 2019). Harvest strategies will influence behaviour such as choice of fishing location, effort allocation, or fish harvesting decisions. ***Understanding how recreational fishers learn and share information is an important need for managers in formulating appropriate strategies.*** Shared information among fishers can influence preferences intentions and actions e.g., preferred fishing sites, fishing seasons (Hunt *et al.* 2013).

Motivations are expected psychological benefits sought by anglers when they decide to fish or visit a particular fishing spot (Gundelund *et al.* 2019, Hunt *et al.* 2019). Motivations precede behaviour. Satisfaction is a post behaviour concept (difference between expectations and the actual experience) (Gundelund *et al.* 2019, Hunt *et al.* 2019, Birdsong *et al.* 2021). Because motives are so closely related to expected outcomes and expected outcomes are critical in determining satisfaction, there is a relationship between motives and satisfaction (Gundelund *et al.* 2019). For recreational fishers, motives apply to general activity (e.g., being outdoors) and specific activity (e.g., catching fish) (Hunt *et al.* 2013, 2019; Gundelund *et al.* 2019).

Most research targeting general motivations in recreational fishing has found non-catch outcomes to be more important that catch outcomes, whereas most research on satisfaction has found catch

to be the key factor (Gundelund *et al.* 2019, Scyphers *et al.* 2021). Thus, when developing harvest strategies for recreational fisheries managers need to address motivations that influence behaviour with satisfaction linked to meeting the expectations of different types of anglers. However, differences between what managers recognise as a satisfactory fishery and what anglers expect from a fishing experience may differ (Spencer and Spangler 1992).

Magee *et al.* (2018) examine heterogeneity among recreational fishers in Australia (New South Wales) based on motivations which can be generally grouped as:

- Mastery (meeting challenges, competence, achievement);
- Social (nurturing relationships); and,
- Escapism (relaxation, stress relief).

They used a person-centred approach to show that motivational preferences are contextual and influenced by a range of factors (Magee *et al.* 2018). Mastery and relaxation were both significantly more important to freshwater anglers than to other angler types (Birdsong *et al.* 2021). Mastery is particularly important in motivating trophy anglers (Magee *et al.* 2018).

Angler satisfaction shapes preferences for regulations, compliance with rules and general angler behaviours (Birdsong *et al.* 2021). As managers are unlikely to be able to manage motivations and some contextual factors (e.g. weather, social experience, environmental appreciation) a focus on catch is important for managers to address satisfaction in anglers (Gundelund *et al.* 2019, Hunt *et al.* 2013, 2019). In particular, catch rate (CPUE) and size of largest retained fish were the primary determinants of satisfaction with catch across all angler types (Beardmore *et al.* 2015). Accordingly, regulations that are likely to improve catch rates or size of the fish caught will be important to a improve social yield outcomes in a Barramundi harvest strategy.

Social context, although less influential than CPUE or size of fish, was also an important driver of satisfaction with catch, with the number of anglers in the group being negatively associated with evaluations of catch outcome. As noted above, the negative influence of crowding on angler utility has been regularly reported in models of fishing site choice including in the Northern Territory (AFANT, West *et al.* 2012). Managers could accommodate expectations and outcome preferences of different anglers by tailoring regulations and stocking preferences to the knowledge of which angler types are locally present (Johnston *et al.* 2010). Specialised e.g., trophy anglers are particularly averse to crowding (Fedler and Ditton 1994, Van Poorten and Camp 2017, Carruthers *et al.* 2019, *et al.* 2021). Thus, regulations (and harvest strategies) that encourage dispersal of effort may be effective in managing crowding.

Meeting diverse angler expectations

Harvest strategies and associated management regulations will influence actions such as effort allocation or fish harvesting decisions. Managers cannot control motivations but they can influence behaviour by managing fish stocks to meet the expectations of anglers. ***Understanding how fishers will react to management intervention is therefore important in developing appropriate harvest strategi***es (Hunt *et al.* 2013). Managers must also address and mitigate fishers' resistance and noncompliance that might emerge from management decisions responsive to harvest strategies (Hunt *et al.* 2013).

In general, catch rate (CPUE) and size of largest retained fish were the primary determinants of satisfaction among recreational fishers (Arlinghaus 2006, Johnston *et al.* 2010, Hunt *et al.* 2019, Vaske and Roemer 2013, Beardmore *et al.* 2015, Hunt *et al.* 2019). This finding was true for all categories of angler (Johnston *et al.* 2010). Anglers often rank non-catch related motives as more important than catch motives. This is because anglers have more control over the non-catch components of satisfaction (e.g., location, companions, timing, weather) whereas the catch-related components are often out of their control (Arlinghaus 2006). Satisfaction increases with the size of the fish caught (particularly for trophy fishers) unlike catch where there is diminishing marginal return on fish caught (Birdsong *et al.* 2021). The sum of satisfactions approach assumes that total satisfaction is composed of individual satisfactions with components of the experience in an additive fashion. This is considered to be the best predictor of overall satisfaction (Burns *et al.* 2003).

An important aspect of social-psychological research is to link motive and actual behaviour. ***The relevance of catch motives for recreational fishers was greater when examined in a context-specific fashion*** e.g. location, companions (Beardmore *et al.* 2011, Birdsong *et al.* 2021). Angler satisfaction is a strong predictor of angler behaviour and the development of management preferences and harvest strategies should consider this in planning to improve social yield outcomes. There are strong relationships among drivers of satisfaction among recreational fishers and preferred management policies (Beardmore *et al.* 2015). Anglers who are highly skilled towards a given fish species e.g, Barramundi will be particularly unhappy if fishing quality declines (e.g. catching fewer or no large fish) and this is an important consideration when developing harvest strategies. Furthermore, specialised anglers tend to be more vocal politically e.g. through fishing media, and influential in decisions affecting recreational fisheries (Kearney 2002, McShane *et al.* 2021).

Sharing the space with other anglers

Providing recreational fishers with satisfactory fishing experiences while maintaining sustainable fish stocks and productive habitats is a primary aim of governance of recreational fisheries (Van Poorten and Camp 2019). Managers can control harvests through input and output controls on harvests, but they can't necessarily control non-catch sources of satisfaction e.g. social interactions, experiencing nature, relaxation. This is an important consideration in developing harvest strategies that consider social yield outcomes (Johnston *et al.* 2010, 2013,2015). The peak recreational fishing body AFANT has noted that increased competition and the presence of others, is one way that quality of the fishing experience may be diminished.

The enjoyment of recreational fishing is about much more than just the catching of fish. For participants, the activity is about the experience as a whole (Hunt *et al.* 2019, Birdsong *et al.* 2021). The enjoyment, social and lifestyle values of recreational fishing experiences can be impacted by informal competition with, or the presence of, other fishers on the water. This is especially the case in regional settings where enjoying space on the water is usually an intrinsic part of the visitation experience in the Northern Territory. AFANT found that only 36% of fishers stated that the presence of others does not impact on their enjoyment (or satisfaction) of fishing. This finding is shared by studies of other recreational fisheries around the world where "crowding" has a significant negative effect on enjoyment or satisfaction derived from recreational fishing (Fedler and Ditton 1994,

Johnston *et al.* 2007, Beardmore *et al.* 2015, Dabrowska *et al.* 2017, Carruthers et. al. 2019, Van Poorten and Camp 2019, Birdsong *et al.* 2021). Space is valuable to anglers because it provides freedom of choice and allows them to find sites to meet their catch and non-catch experience preferences (Birdsong 2021). Yet in an open access fishery (not withstanding spatial restrictions which may apply on Aboriginal land as noted below), managers have little control on where anglers fish. Harvest strategies that encourage fishers to fish in particular but varied locations (e.g., where there is a high probability of catching large "trophy" Barramundi) may assist in dispersing recreational fishing effort and therefore increasing satisfaction and social yield among participating anglers. In any case, trophy anglers are more likely than other types of anglers to prefer remote (and potentially expensive) locations to avoid crowding (Golden *et al.* 2019).

Sharing the resource with other sectors

Commercial sector

There are currently 14 commercial barramundi licences in the Northern Territory managed through tradeable units. Each unit consists of 100 metres of monofilament gillnet with a cap of 10 units per licence. The current unit configuration consists of: 8 x 10 unit licences, 1 x 2 unit licence; 3 x 5 unit licences; and, 1 x 3 unit licences. The fishery is closed from 1 October each year until 31 January the following year and there are extensive closures of entire river systems to commercial fishing.

Despite strategic intent, resource sharing among sectors of, and harvest strategies applicable to, Australian fisheries is not generally guided by formal evaluation of economic and, particularly, social metrics (Pascoe *et al.* 2013, Fletcher *et al.* 2016, Fowler *et al.* 2022). Participation rates by recreational fishers, particularly in the Northern Territory, are much higher than those of commercial or indigenous fishers and, as in other regions of Australia, the activities of recreational fishers are generally concentrated near major population centres (Henry and Lyle 2003, Brown 2016). Furthermore, many recreational fishers have resources (high net incomes, knowledge, social network) and political influence (McShane *et al.* 2021) that many commercial fishers lack (Agrawal 2003, Jentoft 2007). They can therefore influence access to fisheries often at the expense of commercial fishers (McShane *et al.* 2021).

In Australia, resource sharing between recreational and commercial fishers is often managed through spatial access arrangement. Commonly this is implemented as closures to commercial fishing particularly near major population centres which, in Australia, tend to be on the coast (Brown 2016). In Queensland, off Mackay, commercial harvest of Barramundi exceeds recreational harvest but around Cairns, recreational catch (including released fish) was almost 3 times commercial harvest by net fisheries (Brown 2016). In Australia, recreational fishers often don't want to share their infrastructure (water access, boat ramps, beaches) with commercial fishers (Kearney 2002). Thus, spatial separation is a blunt but effective way of reducing or removing conflict among recreational and commercial fishers, and this is now commonplace in Australia (McShane *et al.* 2021). However, unlike most commercial fisheries in Australia, recreational fishing is open access and recreational fishers have few restrictions on their individual total catch, other than though bag- or possession-limits. There are only a few Australian fisheries in which the recreational sector has a stated allocation of a total allowable catch. Thus, where there are high levels of recreational fishing, care must be taken to ensure ESD objectives relating to the viability of fish stocks are not threatened.

Diligent management is necessary to generate a safe operating space for fisheries that balances social and economic benefits with conservation targets and solves allocation issues in mixed commercial-recreational fisheries (Brownscombe *et al.* 2019). This remains a challenge for Australian fisheries (McShane *et al.* 2021). In the NT, unlike other jurisdictions where there are overt conflicts between commercial and recreational fishers (e.g., Kearney 2002), the relatively small participation rate of commercial Barramundi fishers (14 licences) combined with extensive closures to commercial Barramundi fishing, determines that there is little conflict with the recreational fishery under contemporary NT management arrangements. Annual harvests from commercial (~270 t) are similar to recreational (~150t) (Grubert *et al.* 2021) because most Barramundi caught by anglers are released (West *et al.* 2012, 2019).

Indigenous cultural fishing

The relationship between Aboriginal people and the NT coastline dates back more than 50,000 years. Their historic cultural and spiritual connection to Land and Sea Country is recognised under the NT Fisheries Act, as is their right to continue traditional fishing practices which includes customary, commercial, aquacultural and recreational activities. Many marine and freshwater species are totemic for NT coastal Aboriginal groups who continue to practise customary management and education relating to the sea that has been passed on through generations in stories, dance, song, art and ceremony.

Although some people may classify fishing by Indigenous people in remote NT communities as "recreational", we consider that in most cases it is better described as "cultural fishing" (also referred to as traditional or customary fishing). This may be considered as fishing activities and practices carried out by Aboriginal people for the purpose of satisfying their personal, domestic or communal needs, or for educational or ceremonial purposes or other traditional purposes**.** As such, we do not include cultural fishing by Indigenous fishers or traditional owners in this review.

Harvests by Indigenous communities are estimated to be ~ 150 t annually (Grubert *et al.* 2021) but these estimates are not current and there is a need to more accurately quantify Indigenous harvests responsive to management arrangements (McShane *et al.* 2021). While there is no single Indigenous entity overseeing Indigenous fishing and fisheries, there are four regional Land Councils in the Northern Territory: the Northern Land Council (NLC) covering the Top End; the Anindilyakwa Land Council (ALC) covering Groote Eylandt in the Gulf of Carpentaria; the Tiwi Land Council (TLC) covering Bathurst and Melville Islands; and, the Central Land Council (CLC) in the southern half of the Northern Territory (Knuckey *et al.* 2019). The first three are heavily involved in Sea Country rights and the management of Sea Country. The Central Land Council is more involved in Freshwater Country. Separate from the Land Councils, the North Australian Indigenous Land and Sea Management Alliance Ltd (NAILSMA) assists Indigenous Land and Sea managers and Traditional Owners across northern Australia to engage in the market economy and to value and strengthen their own cultural values, beliefs and practices.

Whilst not strictly commercial licences under NT legislation, Aboriginal Coastal licences (ACLs) are available to Aboriginal people living full time in Aboriginal communities to provide a "start-up" opportunity for economic development and sustainable commercial activities in coastal Aboriginal communities. An ACL allows the licence holder to catch fish near their community. Catches of up to 5t per year may be sold but important commercial species such as barramundi, king threadfin

salmon, Spanish mackerel, trepang and mud crab may not be targeted. The ACL is viewed as a potential pathway for Indigenous individuals/communities stepping into the ownership and operation of full commercial fishing licences. Indigenous people are involved in a number of NT commercial fishing license ventures either directly or indirectly through their communities. This is increasing with the newly formed Aboriginal Sea Company[4].

Of significance to future Indigenous involvement in NT fisheries and aquaculture, Knuckey *et al.* (2019) highlight the implications of the 2008 Blue Mud Bay (BMB) High Court decision, which recognised Traditional Owners' rights to the intertidal zone on Aboriginal Land, affecting somewhere between 80-85% of the NT coastline. Under this, permission to access tidal waters over Aboriginal Land will be mandatory in accordance with the requirements of the Aboriginal Land Rights (Northern Territory) Act 1976 (Cth) (ALRA), except in areas that have entered into an agreement with the Government for open access. Although this has raised significant concerns regarding future access arrangements for both commercial and recreational fishers, Indigenous people are exploring the significant economic and community development opportunities that may result from working constructively with both of these sectors in these regions.

Although the government relies heavily on the above Land Councils for general advice on cultural fishing activities, the existing Management Advisory Committee (MAC) structure can assist in building collaborative approaches to resource sharing. However, representation on individual fishery MACs (e.g., Barramundi) is seen as too formal (given indigenous aspirations for resource sharing) (unpublished consultation with NT Fisheries Management). Access arrangements and their impact on the recreational fishery for Barramundi remain to be further developed. This will require consideration in the development and application of harvest strategies particularly as spatial restriction of recreational fishing effort (e.g., through more restrictive access arrangements) will concentrate fishing with a negative impact on recreational fishing experience and therefore social yield. The existing collaborative approach to resolving stakeholder conflict (through MACs) provides an opportunity to address issues arising from harvest strategy development.

Importantly, running parallel to the current project, FRDC project 2021-098 is investigating the incorporation of Aboriginal perspectives into fishery management review processes, using the Northern Territory Barramundi Fishery as a case study. Obviously, it will be imperative that the results of both projects are considered in any future changes to the objectives and decision rules of the NT Barramundi harvest strategy.

Fisher Behaviour relating to Harvest Strategy adoption

The effective management of fisheries requires explicit acknowledgement of recreational fisheries with a clear definition in policy, extensive co-management processes, transparent and effective stakeholder consultation, clearly defined biological economic and social monitoring structures and efficient and transparent cost-recovery mechanisms (Potts *et al.* 2019).

In developing harvest strategies, managers should not concern themselves with items that they cannot directly control (e.g., motivations). In open access recreational fisheries, managers generally apply the following regulations: closed areas/seasons, size limits, and bag limits (reviewed by

[4] https://www.nlc.org.au/media-publications/history-made-with-aboriginal-sea-company-incorporation

Arostegui *et al.* 2021). All of these management tools are used in the NT Barramundi fishery. Length-based harvest restrictions may promote larger catch sizes and satisfy trophy fishers but may frustrate harvest anglers (Gwinn *et al.* 2013). Modifications to size limits i.e., slot limits (combined upper and lower size limits) have been shown to improve fishing outcomes particularly for trophy fishers (Arlinghurst *et al.* 2010, Ayllon *et al.* 2019, Garcia-Asorey *et al.* 2011, Ahrens *et al.* 2020) and a maximum size limit is often mentioned in consultation with Northern Territory anglers (AFANT unpublished). This currently occurs in Fish Management Zones where a maximum size limit of 90 cm is applied.

Other management interventions such as catch quotas and harvest tags may also be applied to recreational fishers, but are not under consideration by fishery managers in the Northern Territory. Catch and release is not mandatory for recreational fisheries in the Northern Territory (including for Barramundi) but it has a high voluntary application (West *et al.* 2012, 2019, Matthews *et al.* 2019). Stock enhancement of Barramundi in some freshwater impoundments in the Northern Territory has been ongoing since 2004 and this is also considered in the context of improving recreational fishing experience.

How does the suite of potential management interventions relate to inclusion of social yield objectives in harvest strategies for recreational fisheries?

Management tools and social yield

Optimal input and output regulations can vary substantially among different angler types (Johnston *et al.* 2010). However, given the known drivers of angler satisfaction (see above), managers wishing to maximise angler satisfaction are advised to focus on maintaining high catch rates and ensuring a supply of large fish for anglers to take home. The non-linear relationship between catch and utility explains why minimum lengths are often more important than stock enhancement for determining angler wellbeing (satisfaction) (Johnston *et al.* 2018).

Consumptive motives are declining in many recreational fisheries (Arlinghaus *et al.* 2007, Gwinn *et al.* 2015). A key management objective is therefore not to maximise MSY but optimising the quality of fishing experience (satisfaction) to anglers i.e., optimal social yield (Johnston *et al.* 2010, Gwinn *et al.* 2015). This will influence the regulations applicable to the recreational harvest strategy for Barramundi. Harvest as opposed to catch is not an emphasis in recreational fisheries management. However, harvests (by both recreational and commercial fishers) will have an influence on stock levels and potentially the catch rates of large fish important in influencing the quality of fishing experiences expected by recreational anglers.

Harvest strategies are often developed in response to declining fish populations with restrictions on effort necessary to build stocks and to improve catch rates for recreational fishers. In the Northern Territory, Barramundi stocks are healthy and not currently threatened by overfishing (Grubert *et al.* 2021). Accordingly, managers have the opportunity to integrate social yield objectives to improve the experience of recreational fishing, mainly by measures to increase catch rates particularly of large fish. This approach could include introducing constraints e.g., slot limits to promote the capture of trophy fish to high-spend trophy fishers. Impositions of restrictive regulations may temporarily dissuade effort but consequently improve fishing quality (Post *et al.* 2003).

Anglers with a strong release orientation have been found to be more likely to support harvest constraints, whereas more committed anglers held more negative beliefs about the behaviour of commercial fisheries, anglers and conservation activity (Slaton *et al.* 2023). Trophy anglers have more to lose from resource degradation because of their frequent participation and generally higher level of psychological and behavioural commitment to angling i.e., trophy anglers tend to be more supportive of catch and release and resource conservation (Slaton *et al.* 2023). Among recreational fisheries, there is growing recognition of the importance in maintaining diversity in age classes and demographic structure of fish populations (Arlinghaus *et al.* 2016). Conservation of large individuals is particularly important to the angling experience of trophy-orientated anglers (Arlinghaus *et al.* 2016).

In many instances, it is difficult to evaluate the effect of different management tools (e.g. bag limits, possession limit, size limits, seasonal closures) for recreational fisheries, mainly due to the challenges of accurately monitoring recreational catches and discards, the absence of incentives to minimise discarding, and fluctuations in catch efficiency and effort (Cooke and Cowx 2006, MacKenzie and Cox 2013). Potential management interventions applicable to the Barramundi fishery and the development and application of a harvest strategy are evaluated below.

Spatially distinct management approaches.

Water-body specific regulations can be implemented to provide different types of fishing opportunities (Van Poorten and Camp 2019) i.e., doing different things in different places. Anglers self-sort towards locations best suited to their desires. For example, high minimum size limits favoured by trophy anglers would redirect harvest anglers to other waters which have lower size limits. One size fits all strategies are likely to leave diverse anglers dissatisfied and risk overfishing particularly in easily accessible waters.

Bag limits

Restrictive bag limits reduce attractiveness to harvest anglers and incentivise them to switch to fisheries with higher bag limits (Johnston *et al.* 2010, Beardmore *et al.* 2015). Regulated daily bag limits may have little effect unless they are low enough to be achieved (Johnston *et al.* 2013). Bag limits are usually only important to harvest anglers (Johnston *et al.* 2010), social anglers are not solely motivated by catch and trophy anglers are mostly catch and release (as summarised above). Specialised anglers often prefer or tolerate restrictive harvest provisions (Arlinghurst *et al.* 2007, Oh and Ditton 2006) and respond to them differently than other anglers (Johnston *et al.* 2013). There is no evidence that the current bag limit of 5 applicable to daily catches for Barramundi in the Northern Territory affects satisfaction of recreational anglers (Matthews *et al.* 2019, West *et al.* 2012, 2019). Furthermore, there are no sustainability concerns given the current assessment of Barramundi stocks in the Northern Territory (Grubert *et al.* 2021). Bag limits will therefore remain an important component of harvest strategies for recreational fisheries generally (Fletcher *et al.* 2016, Jackson *et al.* 2016, Fowler *et al.* 2022) and the NT Barramundi fishery in particular.

Size limits

Size limits provide a tool to better accommodate recreational harvests without compromising fishing quality (Garcia-Asorey *et al.* 2011). At high fishing effort levels, length-based limits are needed to prevent overfishing (Gwinn *et al.* 2015) and these are typically used to limit fishing

mortality in recreational fisheries (Ayllon *et al.* 2019). The choice of size limit type or level can lead to different population trajectories and thus to different trade-offs between conservation and fishery objectives. When preserving population size is favoured over trophy fish, minimum size limits are the best policy, whereas maximum size limits are best to preserve large fish important to anglers seeking trophy fish (Garcia-Asorey *et al.* 2011). Importantly for the NT Barramundi fishery, studies of recreational fisheries elsewhere show that quality overfishing can occur even with healthy recruitment e.g. through the reduction of the abundance of large trophy fish (Garcia-Asorey *et al.* 2011). In fisheries where a management goal is to maintain trophy-size fish in the population, slot limits and maximum size limits substantially outperform minimum size limits (Arlinghurst *et al.* 2010, Ayllon *et al.* 2019, Garcia-Asorey *et al.* 2011, Ahrens *et al.* 2020) by reducing negative selection on large maturation size and increasing positive selection on growth rate. This is an important consideration for the Barramundi harvest strategy responsive to maximising social yield.

In general, size limits are well received by anglers although harvest anglers can be adversely affected (Arostegui *et al.* 2021). Models designed for recommended management approaches for recreational fisheries need to consider discard mortality and non-compliance. Although minimum sizes have been shown to maximise yield and allow sufficient reproductive effort before harvest, they can be ineffective at reducing fishing mortality when discard mortality is high (Johnston *et al.* 2015, Bohaboy *et al.* 2022). Furthermore, there is potential for joint evolution of life-history traits such as age and size at maturation, reproductive investments and juvenile growth rate, which all affect body size at adult age and may evolve in response to size-selective recreational fisheries (Matsumura *et al.* 2011, Gwinn *et al.* 2015). Matsumura *et al.* (2011) found that minimum size limits exerted the most negative impact on body size evolutions due to negative selection on growth rate and size at maturation. Even so, there is little evidence of high discard mortality or a size-selective response in Barramundi fisheries (Lestang *et al.* 2004, Chong-Montenegro *et al.* 2021, Grubert *et al.* 2021).

Slot limits

Slot limits usually include a minimum and maximum size within which fish are permitted to be harvested (Beardmore *et al.* 2015, Gwinn *et al.* 2015, Arostegui *et al.* 2021). Given the concern over evolutionary shifts in growth and fecundity of fish caused by size-selective fishing (see above), slot limits can be useful. Fishers often selectively harvest the largest fish which has been shown to favour fish that reproduce at smaller sizes, but invest less energy into growing large and surviving to older ages resulting in population-wide shifts in these life history traits (Bohaboy *et al.* 2019, Cooke and Cowx 2006). Fish outside slot limits must be discarded and enforcement efforts directed at compliance. Slot limits protect young immature fish and large spawners (see also Gwinn *et al.* 2015).

Slot limits are currently used as part of the Management in the Barramundi Fish Management Zones. Barramundi are protandrous hermaphrodites, meaning they change sex from male to female. They become sexually mature as males at about three to four years of age but turn into females from about five or six years of age (about 80 cm in length), when they migrate into saltwater (Lestang *et al.* 2004). As such, use of slot limits is particularly important for Barramundi, and work well because of the low discard mortality of Barramundi (Lestang *et al.* 2004, Berkeley *et al.* 2004, Gwinn *et al.* 2015). Slot limits are useful because the maximum size favours individuals that grow

quickly through the harvest slot at the cost of delaying reproduction to larger sizes. Therefore, protecting these large fecund fish from harvest safeguards the stock whilst providing enhanced opportunities for catch and release trophy fishers. However, harvest slots are more difficult to assimilate by anglers and to implement in harvest strategies (Pierce and Tomcko 1998, Garcia-Asorey *et al.* 2011).

Removal of large fish can affect fecundity and recruitment dynamics (Gwinn *et al.* 2015) and diminish the quality of fishing favoured by catch and release trophy anglers (Arlinghurst *et al.* 2010, Ayllon *et al.* 2019, Garcia-Asorey *et al.* 2011, Ahrens *et al.* 2020). Thus, conservation and potentially social yield metrics are maximised under slot limits (Ayllon *et al.* 2019). Outreach and education will therefore be an important component of linking slot limits to harvest strategies.

Catch and Release

Catch and release is increasing in popularity due to stricter harvest regulations and shifting conservation ethics (Cooke and Schramm 2007, Brownscombe *et al.* 2014). Most Barramundi (~70%) caught by recreational fishers in the Northern Territory are released alive (West *et al.* 2012) and survival rates are greater than 90% (Lestang *et al.* 2004). The lack of the neocortex in the brains of fish suggests that they are consciously unable to experience pain and suffering (Rose 2002). Even so, societal concerns over fish welfare threaten the practice of catch and release fishing (Arlinghaus *et al.* 2007). Choice of gear and handling techniques can influence fish wellbeing and therefore discard mortality. Codes of practice can minimise stress and post-release mortality (Arlinghaus *et al.* 2007) and adherence and promotion of such codes can assist in assuaging concern over fish welfare. Training programs are important to minimise post-release mortality (Cooke *et al.* 2002). Short fishing workshops can transfer information on catch and release practices and improve outcomes for catch and release fisheries (Delle Palme *et al.* 2016). Best handling practices include: minimizing air exposure by keeping fish in water during hook removal, handling fish with wet hands, and avoiding excessive handling for dermal abrasion (Delle Palme *et al.* 2016).

The Northern Territory has a direct link to the National Recreational Fishing Code of Practice (Smith *et al.* 2016). However, surveys indicate that the national code is not well known or used by Australia's 3.5 million rec fishers (Smith *et al.* 2016). The loss of mucus and scales due to dermal abrasion considerably increases the susceptibility to water borne pathogens and may substantially decrease post-release survival. To increase the chance of post-release survival, it is recommended that Barramundi should be caught and released using a knotless flat-bottomed type of landing net (Lestang *et al.* 2004).

Closed areas/seasons

Recreational-only fishing zones can reduce conflict between recreational and commercial sectors (Kearney 2002, Brown 2016, McShane *et al.* 2021). Closed areas and closed seasons are key components of the Barramundi Management Plan. They have been largely used over time to remove commercial fishing effort away from areas of high recreational fishing, particularly around Darwin to reduce intersectoral conflict, but there are also recreational closures, specifically the Daly River Seasonally Closed Area. Fishing closures may intensify effort in open seasons (Arostegui *et al.* 2021) and or in other open areas. Although not technically a fishery closure, the implications of the BMB decision requiring permits for recreational fishers to access on 85% of the NT coast are yet to

play out. This will be an important aspect to consider in any future Barramundi harvest strategy for all extractive sectors (Indigenous, recreational and commercial.

Stock enhancement

Stock enhancement should generate large social and economic benefits when natural reproduction is lacking whereas harvest regulations will socio-economically outperform most stocking events in self-sustaining stocks (Johnston *et al.* 2018). The Darwin aquaculture centre has been stocking fingerlings of Barramundi since 2004. Barramundi stocks in freshwater impoundments are enhanced with hatchery-reared fingerlings. This is because Barramundi in such water bodies are unable to successfully breed (requiring salt water). For other recreational fisheries, stocking is only economically viable when natural reproduction was impaired or absent (Johnston *et al.* 2018). Stocking meets socio economic objectives (increasing the population of catchable fish) particularly large fish (Camp *et al.* 2017). Stock enhancement restricts neither catch or effort. Biological interactions between stocked and wild fish which are problematic elsewhere (Arlinghaus *et al.* 2016, Camp *et al.* 2017) but such issues are not relevant in discrete freshwater bodies in the Northern Territory. Stock enhancement is not under consideration for other wild populations of Barramundi in the Northern Territory.

Other Management Interventions

Other management interventions are described below. However, they are unlikely to be popular in the Northern Territory given a general reluctance to embrace regulations that infringe on perceived liberties of recreational fishers (McShane *et al.* 2021).

Catch quotas

Under a joint catch quota system, the allocation of catch between commercial and recreational fishers (and potentially Indigenous fishers) will be socially optimal (McShane *et al.* 2021). If the recreational fishers value the stock more highly than the commercial fishers, the total allowable catch will be reduced compared to what the commercial fishers would like and vice versa (Arnason 2009).

Abbott *et al.* (2009) evaluated options for rights-based shares of catches for recreational fisheries. These include, individual transferrable quotas (ITQs) usually applied to limited entry commercial fisheries rather than to open-access recreational fisheries. Harvester cooperatives that guarantee quota holders some share of a total allowable catch within a well-defined spatial unit apply in some recreational fisheries outside Australia (Abbott *et al.* 2009). Catch quotas already exist for some recreational fisheries e.g., in Western Australia (Fletcher *et al.* 2016, Jackson *et al.* 2016) and nominally in South Australia (PIRSA 2017, McShane *et al.* 2021). Rights-based systems are under consideration for several recreational fisheries elsewhere (see Johnston *et al.* 2007, Sutinen and Johnston 2003) but not (currently) the Northern Territory (McShane *et al.* 2021). Catch quotas could be linked to a harvest tag system (see below).

Harvest tags

Harvest tags grant rights only to those who obtain them (Arostegui *et al.* 2020) and thus are similar to catch quotas (Abbott *et al.* 2009, see above). When combined with ample enforcement and angler education, tags provide a means to set a firm upper bound on fish harvest (Abbott 2014,

2015). However, tags only internalise fishing mortality when discard mortality is zero. If anglers react to harvest tags by high grading or catch and release, then fishing mortality is considerably underestimated. But this is also an issue with bag limits.

A capped harvest tag system can discourage anglers with a lower willingness to pay (e.g. social or harvest anglers), reducing harvest levels and allocating it to anglers who value (and are willing to pay for) the fishing experience (e.g. trophy anglers). In a comparative evaluation (Johnston *et al.* 2007) found that harvest tags provided increased control over total harvest, reduced crowding and generated funds to support management and research of tag-regulated species. Such an outcome is consistent with maximising social yield (Johnston *et al.* 2010). However, a tag allocation process may not achieve goals of equitable access across demographic groups particularly Indigenous fishers (McShane *et al.* 2021). Furthermore, anglers typically express strong opposition to limited entry in local fisheries (Arostegui *et al.* 2020) especially in the Northern Territory (McShane *et al.* 2021).

Most harvest tag programs exist primarily to improve information on catch and effort (Johnston *et al.* 2007) although several programs use tags to control harvest e.g., of snapper in the Western Australian Shark Bay fishery (Jackson et al 2016). In the Shark Bay fishery, a total allowable catch was set which limited the recreational catch according to the number of harvest tags made available each year via a ballot. This initiative promoted recovery of a severely depleted stock. Notably, harvest tag recipients were mostly non-locals (Jackson *et al.* 2016). Locals preferred to fish elsewhere where less restrictions applied. Even so, in Western Australia harvest tags have been shown to be effective in management, widely accepted by recreational fishers with a reasonable cost per tag reasonable and compliance high (Jackson *et al.* 2016). Fishers were willing to pay $10/tag. Willingness to pay also applies to other tag fisheries e.g., in recreational fisheries in the USA: US$30 for goliath grouper and US$50 for Atlantic tarpon. Harvest tag programs can also increase satisfaction with fishing experience (Johnston *et al.* 2007).

A tagging system for Barramundi in the Northern Territory could provide greater participation options for those recreational fishers who sought it e.g., high-spend trophy fishers. Thus, they could acquire permits (or tags) that would allow for greater take (e.g., from other fishers or purchase from a limited tag pool (Jackson *et al.* 2016). Accompanying this (for example a tagging scheme) would be an information gathering program that would evaluate the impact of increased participation. However, given the resistance to licencing of recreational fishers in the Northern Territory, such a scheme is unlikely to be popular in the first instance.

Co-management and harvest strategy development

Co-management promotes stakeholder investment in management that can further socio-ecological resilience and is considered most effective when implemented at more local scales where stakeholders are well connected to the resource (Van Poorten and Camp 2019). Stakeholder engagement will be important in the Northern Territory particularly in negotiating recreational access to Aboriginal land (see Knuckey et al. 2019). The engagement of Aboriginal people e.g., through relevant land councils will be important in co-management and development of appropriate harvest strategies for Barramundi fisheries.

The emergence of co-management of fisheries in Australia (Hollamby *et al.* 2010, Bolton *et al.* 2015) represents a shift towards participatory bottom-up decision making. This has been found to be successful in stakeholder engagement elsewhere (Jentoft 1989, Sen and Nielsen 1996, Jentoft *et al.* 1998, Noble 2000, Cooke *et al.* 2013, MacKenzie and Cox 2013, Flannery *et al.* 2018, Krupa *et al.* 2018) but this stakeholder-driven approach, and co-management more generally, is yet be influential in access and allocation for fisheries in Australia (McShane *et al.* 2021). In the absence of formal co-management arrangements, strong stakeholder representative groups (e.g. Industry Associations such as AFANT) can reduce management costs by extending user-group representation responsive to harvest strategy development. Stakeholder engagement is a necessary pre-requisite to equitable resource access and allocation. This relates to principles of social justice (Jentoft *et al.* 1998, Ranjan 2014). Effective co-management approaches will be important in developing recreational harvest strategies for recreational fisheries in the Northern Territory particularly engaging Indigenous communities.

Participatory processes

Constraints to stakeholder participation responsive to recreational fisheries management include lack of time and money; lack of access to or knowledge of facilities; and inconsistent delivery of satisfactory boating and fishing products, services, and facilities (Fedler and Ditton 2011). There is an identified need for a coordinated effort to promote recreational fishing in outreach and communication programs that are national in scope, regional in application, and local in implementation (Fedler and Ditton 2011). Communication, engagement and participatory processes that involve recreational fisheries are key to boosting effective management and sustainability of recreational fisheries. In this regard, digital platforms can be useful including social media (Sbragaglia *et al.* 2023, see also Information and Education programs below).

In the Northern Territory, co-management is promoted through Management Advisory Committees (MACs) including a Barramundi Fishery MAC. This committee comprises an independent chair, representatives from the commercial fishery, the recreational fishery (AFANT), the tourism sector, conservation, fisheries science, Aboriginal/traditional and aquaculture. Such a stakeholder representative group would be well placed to consider development and application of a Barramundi harvest strategy.

Information and Education Programs

In developing and applying harvest strategies, education and awareness raising will be pivotal to engagement with recreational fishers and other stakeholders (e.g. Indigenous communities). Anglers generally have a poorer understanding of fishery dynamics than commercial fishers (Brown 2016, Borch 2010). Even so, they are vocal and influential in sector advocacy and influential in the political process responsive to access and allocation in fisheries (Kearney 2002, McShane *et al.* 2021). In a similar context to development and application of a harvest strategy (potential stakeholder conflict), public consultation and education was effective in the rezoning of the Great Barrier Reef Marine Park (Fernandes *et al.* 2005, Sutton and Tobin 2009). This provides a useful example of how to engage stakeholders in management decision making, particularly changed management arrangements.

Anglers are less likely to respond to complex regulations relative to simpler regulations and accordingly do not comply (Page and Radomski 2006). Angler education and social learning has been shown to improve compliance, reduce conflicts, and inspire stewardship by invoking voluntary changes in behaviour (Cooke *et al.* 2013, Elmer *et al.* 2017). Fishing tour operators can also play a key role where guides provide education to anglers about local species, angling ethics and conservation issues (Elmer *et al.* 2017). Education campaigns may also benefit by allowing for more effective engagement by tapping into the different motivational classes and needs of fishers (Magee *et al.* 2018). Studies of recreational fisheries in the USA reveal that angler awareness, when underpinned by effective engagement and outreach activities, can enhance angler satisfaction (Scyphers *et al.* 2021) and therefore improve social yield (Johnston *et al.* 2010).

Environmentally friendly behaviour and attitudes (important in fisheries conservation) are formed in children (Ahnesjo and Danielsson 2020). Organised recreational fishing in school may positively affect interest in recreational fishing, nature and environmental awareness (Delle Palme *et al.* 2016). Mandatory angler education programs exist in several European countries (e.g., Switzerland, Germany) and are associated with the licencing process (Cooke *et al.* 2013). These programs present best-handling practices and adopt conservation-oriented behaviours that benefit fish survival and welfare. They could also be extended to raise awareness, improve compliance, and promote support for harvest strategies aimed at optimal social yield.

Voluntary institutions and behaviours offer potentially-valuable alternatives to formal regulations in recreational fisheries management (Cooke *et al.* 2013). Examples include: voluntary sanctuaries, informally enforced seasonal closures, personal daily bag limits, self-imposed constraints on gear, development of entirely live release fisheries, and adoption of fish and aquatic ecosystem conservation-orientated gears and release practices (Cooke *et al.* 2013). These voluntary behaviours can stem from angler education programs. Angler education and voluntary changes in angler behaviour are often overlooked as alternatives to traditional i.e., mandatory regulations. Bottom up approaches may be more effective in getting stakeholder support than top down regulatory approaches although this increases the need for communication, participation and transparent decision making (Cooke *et al.* 2013).

Social media and electronic applications

Patchy and time dependent nature of recreational fishing make it difficult to get reliable data from surveys. Recreational surveys tend to be logistically demanding and are generally conducted infrequently. The last recreational survey in the Northern Territory was 2009 (West *et al.* 2012). Angler apps present a potentially rich and useful source of recreational fishing data (Venturelli et al 2017). App data are only useful if they are abundant and relevant, of good quality and can be integrated into existing research and management frameworks (Muller and Taylor 2013). There are three challenges for app-based data collection: recruitment and retention; data quality; and integration (Venturelli *et al.* 2017). The use retention of an average phone app is just 5% after 3 months. To maximise recruitment and retention well designed apps, user feedback and transparency with respect to data use: easy to use, looks good, well incentivised and versatile. Importantly, the apps must be easy to use, particularly as the main demographic in the Northern Territory are males aged between 30 and 60 whereas younger individuals are more likely to use electronic media (Venturelli *et al.* 2017). Accordingly, app data may be spatially biased because of

user demographics, the relative popularity of different locations or app design and content (Venturelli *et al.* 2017, Fowler *et al.* 2022). Apps that require a network connection are likely to generate data with a spatial bias (Venturelli *et al.* 2017). Avidity bias (towards those with a strong interest in recreational fishing) is also a potential problem with app-based data collection (Arlinghaus *et al.* 2019). Image recognition software may be useful (e.g., in species identification and estimation of fish length) (Venturelli *et al.* 2017).

Consultation with fishery managers in Queensland revealed the following barriers to adoption of app-based data collection programs:

- At least half of recreational fishers in Queensland are not technologically literate enough to operate smart phones for data collection
- Fishers don't trust the government to use the information in the best interests of the recreational fishing community.
- The data provided by individual fishers would be open to Freedom of Information requests.

It is probable that similar barriers to adoption exist among recreational fishers in the Northern Territory. Stakeholder consultation will therefore be an important element of developing and applying app-based approaches to information collection from recreational fisheries in the Northern Territory.

Development of a Harvest Strategy

General considerations

Many fisheries in Australia now have harvest strategies consistent with the national guidelines (Sloan *et al.* 2014). Typically, performance indicators relate to the status of the stock (e.g., biomass). Economic and social values are also considered among operational objectives in harvest strategy development but, to date, they are rarely managed as performance indicators or included as decision rules. Harvest strategies provide for a shared understanding (among stakeholders) of management principles and metrics applicable to particular aquatic resources e.g. individual fisheries that trigger changes to management.

Harvest strategies require monitoring programs to collect relevant ecological, economic and social data sufficient to evaluate operational objectives, performance indicators and reference points. Decision rules prescribe pre-determined management actions that will be taken to influence fishing activity (e.g., catch, shares of the resource). They are explicitly linked to quantifiable performance indicators and reference points (e.g., as shown in Figure 1). Importantly, under the Northern Territory harvest strategy policy, all stakeholders (including recreational fishing sectors) have input into implementation through co-management arrangements (NT 2016).

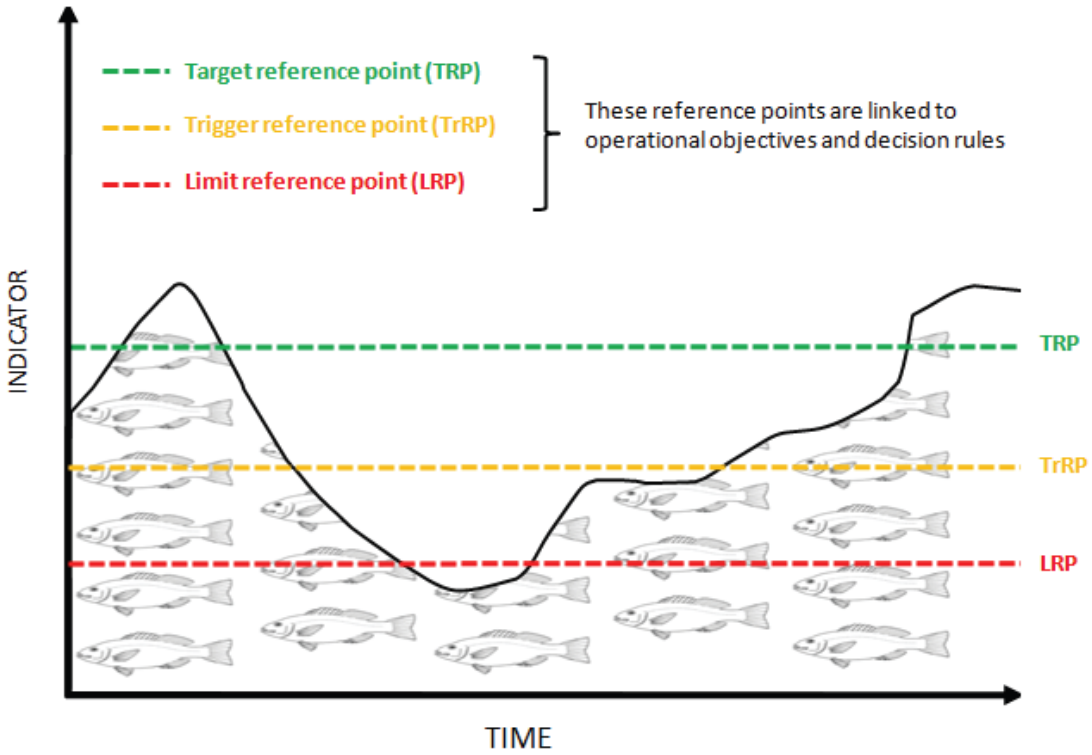

Figure 1. The relationship between a performance indicator, reference points, and decision rules. The relationship of biomass (of a fishery) with time is shown relative to indicators (from NT 2016).

Application to recreational fisheries

Harvest strategies have been primarily developed for commercial fisheries with an emphasis of conserving the spawning stock and maximising sustainable or economic yield (Dowling *et al.* 2015, Dichmont *et al.* 2020). Most social objectives for recreational fishing fall outside the scope of traditional harvest strategies and, instead, are dealt with in management plans (Fowler *et al.* 2022). Harvest strategy performance for recreational fisheries will depend on the relative importance of social objectives and whether these can be achieved by controlling harvest. As noted above, utility and satisfaction are both maximised when catch rates are high and catches of large fish are accessible. The potential extent of conflict within the recreational sector (e.g., trophy fishers vs harvest fishers) suggests that developing equitable harvest strategies may be challenging. Even so, the available evidence suggests that catch rates and frequency of catch of large fish are universally satisfying among recreational anglers (Johnston *et al.* 2010, Hunt *et al.* 2019).

Some examples of harvest strategies applied to Australian recreational fisheries are provided in Appendix 1.

Inclusion of the Charter Sector

Charter fishing may not be representative of amateur recreational fishers as charter operators are professional fishers that may fish similar areas but have greater knowledge and experience. Even so, in the Northern Territory, fishing tour operators are required to report catch and effort among other metrics (e.g. visitor origin) as part of their licence requirement. Such data (potentially including size data for Barramundi before release) could be used against satisfaction metrics of catch rate and frequency of large fish. Performance indicators derived from tournament monitoring

may be affected by tournament rules including selective catch based on size. Nonetheless, such data may be useful in measuring performance against social yield of the Barramundi fishery in the Northern Territory.

Integrating social yield outcomes in a harvest strategy for Barramundi

The literature reviewed above reveals there is a diversity of motivations among recreational fishers but primary driver of angler satisfaction are catch rate and/or catching large fish. Managers cannot control motivations to fish (e.g. to enjoy nature) but they can influence catches through regulations. Thus, in formulating a harvest strategy to improve social yield outcomes, management interventions should focus on ensuring some level of catch rate and that large fish remain abundant in the population and available to anglers.

A potential operational objective of recreational harvest strategy for Barramundi is to improve social yield outcomes. The primary performance indicator for social yield is the satisfaction of recreational fishers. Although this is a relatively imprecise indicator, it does feature as a performance indicator for both New South Wales (e.g. Fowler *et al.* 2022) and South Australian (e.g. PIRSA 2017) recreational fisheries (see Appendix1). Catch metrics influential in angler satisfaction are much easier to manage, familiar to both fishers and managers, applicable to stock assessment, and useful de-facto measures of satisfaction. Nevertheless, if such catch metrics are to be used in achieving recreational social yield objectives, then good performance indicator data are required from the recreational sector. This will need to be addressed. Monitoring of recreational performance indicators may potentially be derived from fishing tournament statistics, occasional recreational fishery surveys, and potentially fishing apps linked to smart phones. Depending on the performance of such recreational indicators, management interventions (given reference points applicable to catch rates, frequency of large fish and, potentially, satisfaction) may require adjusting bag limits and spatial application of size limits. In this way a manageable and potentially attractive harvest strategy applicable to the recreational fishery for Barramundi can be developed and applied consistent with the overarching objectives of ecologically sustainable development.

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Appendix 1 Examples of recreational harvest strategy objectives

New South Wales

In developing potential harvest strategies for application to recreational fisheries in New South Wales Fowler *et al.* (2022) noted that all the social operational objectives (relating to fishing experience and satisfaction) except one were found to lie outside the scope of a harvest strategy and need to be addressed using other fisheries management processes e.g., management plan (Fowler 2022). For example, "maximise access to fishing locations" is not influenced by harvest activity or biological aspects of the stock and is therefore unlikely to be achieved using typical harvest control rules. The exception was "minimise interactions with other people" which could potentially be addressed in a harvest strategy with "move on" management controls. Economic objectives in the NSW harvest strategy evaluation included: maximise profit for charter and tackle as well as maximise the monetary value of the recreational experience at individual fisher level (Fowler *et al.* 2022) and these are metrics that could apply to a harvest strategy for Barramundi.

If operational objectives in recreational harvest strategies are not linked to data sources that can effectively monitor performance, truly equitable harvest strategies are unlikely to be achieved. In New South Wales data on fisher satisfaction are available through state wide surveys and on-site ramp surveys (Fowler *et al.* 2022, see also West *et al.* 2012 for the Northern Territory). However, the nature of the data are currently too imprecise to apply to any specific operational objective (Fowler *et al.* 2022). Satisfaction data are also not stock-specific, limiting their utility within harvest strategies (Fowler *et al.* 2022). Linking indicators to objectives is a necessary step for explicit inclusion of the recreational fishing sector in harvest strategies, rather than relying on fishery-wide objectives (Fowler *et al.* 2022).

South Australia

South Australia is seeking to develop measures to meet its policy objectives for resource sharing and harvest strategy development (Brooks 2010, PIRSA 2011, 2017, Triantafillos *et al.* 2014). It includes a management plan for recreational fisheries with performance indicators and reference points across ecological, economic, and social objectives. Harvest strategies apply to key species to ensure that recreational catches are maintained within allocated shares (PIRSA 2017). Management tools available to maintain recreational shares within allocated limits include: bag limits, size limits, spatial and temporal closures, and gear modifications (PIRSA 2017).

The management plan for recreational fishing in South Australia (PIRSA 2017) defines management goals, objectives, strategies and reference points for management of recreational fisheries including social and economic indicators and reference points. Performance indicators (e.g., level of satisfaction) are specified but not currently evaluated. A nominal reference point applicable to a

satisfaction level is "< 50% of fishers indicate they are neutral or highly satisfied with their fishing overall but this proportion is increasing". Alternatively: "a declining proportion of fishers are indicating that they are satisfied with their ability to achieve the benefits most important to them" (PIRSA 2017).