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Short communication

The 20-year Queensland's fisheries citizen science program and its potential to support fisheries monitoring - The Keen Angler Program

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ABSTRACT

Species biological and harvest data play a vital role in fisheries monitoring and understanding of the status of fish populations. This includes those dominated by recreational harvest. However, reporting in recreational fisheries is rarely compulsory, limiting the availability of catch or biological data, such as fish age and length, for use in stock assessments. Citizen science programs can be a viable way to collect large and diverse data on harvested fish species. Citizen science programs such as Queensland's (north-eastern Australian state) Department of Primary Industries' Keen Angler Program (KAP) may address this critical data gap. KAP has been in operation since 2005, and here, we describe for the first time KAP and the data collected in the program so far. In particular, we describe the number of donations and samples, the composition of samples, and patterns of donations (i.e., co-occurrence of donated species) collected through KAP over the past 20 years. Over the past 20 years, KAP has received over 55,000 fish from more than 9000 donations, with the south of Queensland having higher donation numbers compared to the north. Most of the fish donated were 'Inshore and Estuarine' species. However, there have been increasing samples of 'Coral reef' species, after their addition to the program in 2017. Recreational fishers also tended to supply multiple species in a single donation, providing insights into the targeting strategy of fishers and their use of marine habitats. The capacity to retain participants and continually contribute data could be a significant factor in the sustainability of the program. The high volume and consistent data of KAP could contribute to supporting fisheries monitoring and management.

1. Introduction

Recreational fisheries take is a significant component of many fisheries, accounting for 12 % of global fisheries harvest (Cooke and Cowx, 2004; Greiner and Gregg, 2010). However, recreational fisheries tend to target species and size classes that are different from commercial fisheries (e.g., Flink et al., 2024), though there is often limited accounting of the recreational fisheries sector in assessments and estimates of stock status. The lack of compulsory reporting within the recreational sector makes it challenging to collect catch information and biological data (Brownscombe et al., 2019; Ryan and Conron, 2019). This has necessitated novel approaches in recreational fisheries monitoring, often leveraging voluntary contributions from recreational fishers (Tarantino et al., 2025; White et al., 2025). Such programs reflect the increasing roles of citizen science, where non-experts or non-professionals participate in scientific research and/or monitoring on a voluntary basis (Fairclough et al., 2014; Florisson et al., 2018). Citizen science programs are an ever-evolving landscape of data collection, with a variety of citizen science programs contributing to recreational fisheries monitoring programs (White et al., 2025). Critically, citizen science programs represent an efficient and cost-effective method for obtaining data and insights into recreational fishery sectors in addressing key data gaps in fisheries assessments and management (Bonney et al., 2021; Florisson et al., 2018).

Citizen science programs around the world have been used to understand long-term fish population trends and are often considered

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during decision-making (Bieluch et al., 2017; Bonney et al., 2021; DiBattista et al., 2021; Harris et al., 2021). Within Australia, there have been various citizen science programs implemented to enhance our understanding of the recreational fishery, such as the Western Australian Research Angler Logbook Program, which collects fisheries information (e.g., fishing method, number of fishers, fishing duration) via a voluntary logbook (Harris et al., 2021; Tate et al., 2020). The logbook is returned to Western Australia's Department of Primary Industries and Regional Development to collate and use the data for monitoring and management (Harris et al., 2021). What is common to citizen science programs, both nationally and internationally, is that they all leverage the willingness of recreational fishers to participate and contribute to research and management (Fairclough et al., 2014). Even unique fishery-dependent (e.g., government-initiated data collection programs) citizen science programs in Australia, that focus on target fish population biology, will fundamentally rely on the willingness of recreational fishers to participate (Emery et al., 2019; Fairclough et al., 2014; Gray and Kennelly, 2016).

The biological data collected in Australian fisheries citizen science programs can vary, but most programs provide important data on length, age, and sex of harvested species, which are critical in determining key monitoring and stock assessment variables, including mortality, biomass, population growth parameters, productivity, and length-frequencies of populations (Campana and Thorrold, 2001; Fairclough et al., 2014; Schilling et al., 2023; Vølstad et al., 2020; White et al., 2025). The importance of monitoring fish biology in recreational fisheries has been identified in not only Australia's "National Policy for Recreational Fisheries" (1998) but also more recently in the South Atlantic Fishery Management Council (2021) (Bonney et al., 2021; Henry and Lyle, 2003). There are currently four recreational fisheries biological citizen science programs identified in Australia, which are; 'Framed, Tagged, and More' in Tasmania, the 'Keen Angler Program' (KAP) in Queensland, the 'Research Angler Program' in New South Wales, and 'Send Us Your Skeletons' in Western Australia (Department of Primary Industries and Fisheries, 2008; Fairclough et al., 2014; Graba-Landry et al., 2023; Schilling et al., 2023; White et al., 2025). Each has been running for differing time periods, but KAP is one of the oldest programs and has been operating for two decades (White et al., 2025).

Queensland's Department of Primary Industries (DPI) KAP still uses the foundational methods that were first used in 2001 (i.e., donation of fish frames to collect biological data). However, KAP was officially implemented as a program in 2005. With the lack of current literature discussing KAP, the date of inception was not officially known in the literature until recently (White et al., 2025). Overall, KAP has grown and evolved since its original implementation in 2005, where the fundamental goal of the program has continued to be to collect key biological data and represent harvested fish populations, based on the donations of fish skeletons (i.e., fish frames) by recreational fishers (Queensland Department of Primary Industries, 2013). Fish frames are received from recreational fishers (anglers), who also provide information on where the donated fish were caught (Department of Primary Industries and Fisheries, 2008). It was initiated to obtain samples for specific species for which biological information was lacking. The reason for KAP initiating (i.e., to collect biological data and represent harvest fish populations) is maintained, and there is a continuation to seek out anglers to donate their fish frames and submit the associated fishing trip information (Stenekes and Sahlqvist, 2011).

While the basic structure of KAP has been described in online resources, the important contribution and application of this program to fisheries management and monitoring have not been fully considered. KAP is currently used to collect biological data, primarily age data to support assessments of the status of harvested fish populations. It is able to supplement the structured sampling of age and length data conducted through other programs. Therefore, the contribution of KAP and the reliance on citizen science for sampling biological data have prompted this study. The purpose of this study is to describe the DPI's KAP and the potential applications of the information collected through the program. More specifically, we:

1. Assess the trends of donations and samples collected through KAP
2. Understand the occurrence of fish groups and species donated through KAP over time
3. Discuss the ability of KAP to simultaneously collect multiple species of KAP sampling

Investigating the key features of KAP provides opportunities to expand the applications, research, and usage of the program currently implemented by Queensland's DPI. Additionally, our research can provide context to biological monitoring programs in general and the data collected through these programs, in order to inform similar citizen science monitoring programs and initiatives in Australia and elsewhere.

2. Materials and Methods

2.1. Data Collection

The data used in the current manuscript have been provided by the Queensland Department of Primary Industries (DPI).

The Keen Angler Program (KAP) was initiated in 2005, when only two target species (i.e., Snapper and Spotted Mackerel) were sampled in the first few years (Table 1). Despite the statewide implementation (both the northern and southern parts of Queensland), there were generally more fish frame donations in the southern part of Queensland, as a result of having a higher number of donors (Fig. 1). However, in 2021–2022, the program 're-established' (in terms of continuous samples being collected again) in the north to collect more data on the newly introduced target species, such as 'Coral reef' species, for the DPI, therefore leading to KAP expanding (Fig. 1). Other than 'Coral reef' species there has been no formal or anecdotal documentation of when fish species were introduced and removed from the program between 2005 and 2021. Currently, KAP samples 22 different species between the north and the south.

The current sampling procedure for KAP is as follows. Queensland recreational fishers are recruited by DPI staff, with little additional promotion. Recruitment is focused on avid fishers, anglers who are interested in contributing to data collection on fisheries, or anglers with some interest in data specific to the species they target. These individuals are identified by staff through various avenues (e.g., field work engagement, social groups, fishing clubs, or competitions). During the recruitment phase, DPI will ensure that quality and consistent data will be collected by the selected volunteers by ensuring they exhibit motivation and avidity to donate to the program (Gundelund et al., 2020).

KAP has established a core group of anglers who donate to the program, with contributions also from a broader group of anglers. Due to the anonymity of the program, the ability to determine the contribution and retention of this core group is not recorded for data analysis purposes, but is anecdotally known and regularly contacted by DPI staff. To maintain contact with the donating recreational fishers, quarterly eNewsletters are distributed with information regarding KAP as well as species donation tallies. Donating recreational fishers are provided with sampling kits composed of: a label to input fishing trip information (e.g., date and location caught, the number of fish caught for each species and of that the number of fish donated for each species, and contact information), and a donation bag to store the fish frames (Fig. 2). Fishers will receive multiple sampling kits so that samples from several days of fishing can be donated. Recreational fishers may donate fish frames of other fishers from a single fishing trip, but in rare instances frames from multiple vessels will be aggregated as a catch. Once the angler is ready to donate their frames from each individual fishing day(s), the bag as well as the fully completed label(s) will be collected by DPI staff or can be dropped at select locations such as local 'tackle shops' on the

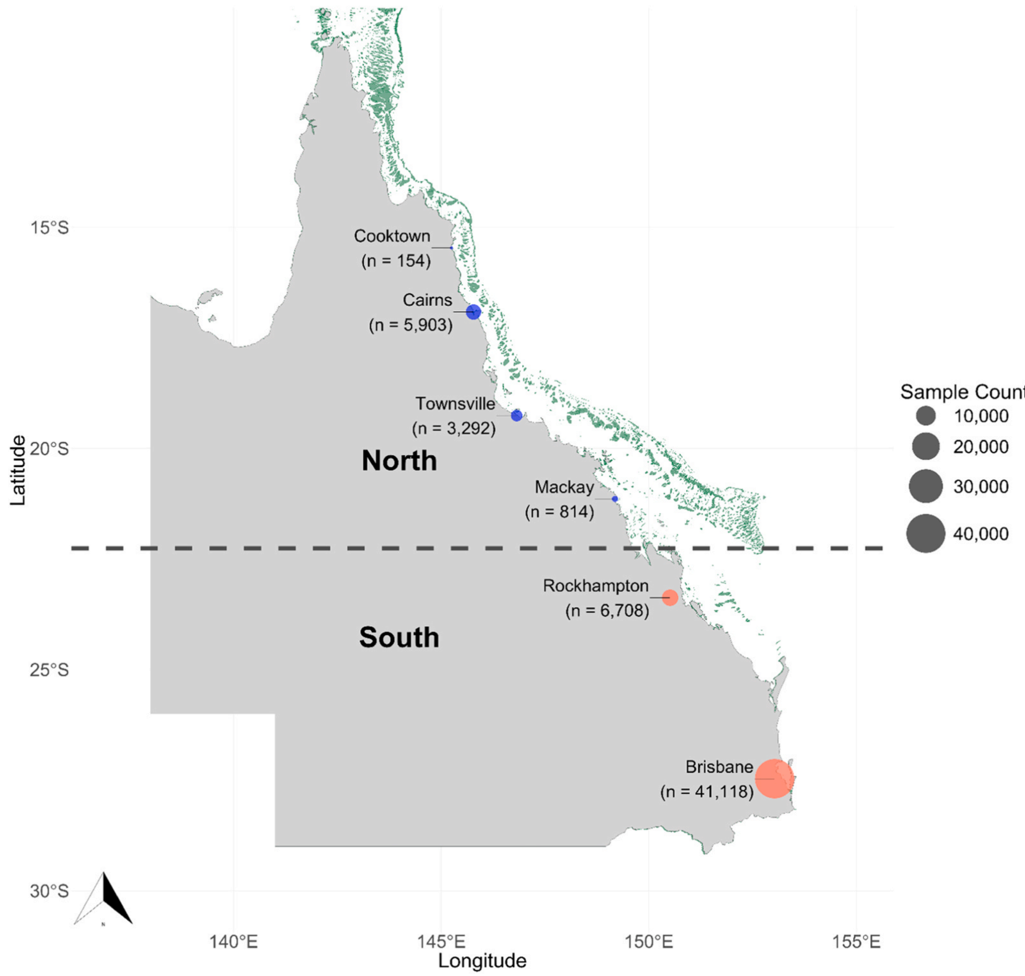

Fig. 1. Queensland map, including the Great Barrier Reef (green) with key locations of Keen Angler Program donation collections. The division of north and south is per the Queensland Department of Primary Industries description of sample collection for the Keen Angler Program, and has been distinguished by the dashed line and labels 'North' (blue) and 'South' (orange). The sample count is based on the total number of fish donated from 2005 to 2024 per key location.

Queensland coast. Drop-off locations are updated regularly on the DPI KAP webpage (Queensland Department of Primary Industries, 2024). Once donation bags have been collected from participating anglers or from the select drop-off locations, the donation bags will be taken to either the northern (Cairns, Queensland) or southern (Brisbane, Queensland) DPI laboratories. Biological information (e.g., fish length and sex) will be collected and entered into a database along with the information entered in the labels (Fig. 2). For the purposes of data analysis, a donation is classed as a single returned sampling kit, and a sample is an individual fish frame donated.

During data processing, if all the fish caught for an individual species are donated, the percentage of the 'catch donation' per species is recorded as 100 percent within the DPI database. If the percentage of the donation is less than 100 percent for an individual species and the donation has not had any smaller or larger fish lengths intentionally excluded, the percentage of the catch donated is entered into the DPI database. If any fish have been intentionally excluded from being donated, it is classed as zero percent catch sampled in the database. It is known if fishers have not donated select fish lengths due to writing on the sampling kit label the number of fish kept and the number of fish donated. This allows donated catches to be filtered in later analysis to remove length-biased catches. While not a common occurrence, this process allows for data validity during data analysis and applications. Follow-up calls to fishers will occur if details need to be confirmed. Select DPI staff will be privy to what recreational fishers are donating and their contact details, but donors are kept anonymous. Therefore, we are unable to determine individual fishers for analysis. The fork length (from the snout to the centrepoint of the caudal fin) or the total length (snout to the end of the caudal fin) is measured by DPI to the nearest centimeter. Caudal fin shape will determine if fork or total length is measured. If the caudal fin is damaged, the closest measurement will be determined for the designated measurement type. For most donated fish frames, the sagittal otoliths (two) will be removed (Payan et al., 2004). The extracted otoliths will be cleaned and stored for aging, and the unique fish number will be assigned to link the otolith sample to the catch and biological data already extracted. The sex of each fish is also determined by DPI by macroscopically examining the gonads, where they will be categorised into one of four groups- male, female, transitional (for species that change sex), or unknown.

2.2. Data Analysis

Each donated catch was assigned to either the north or south region, based on its reported location (Fig. 1). The 20 different species donated

Fig. 2. Example of the Keen Angler Program's sampling kit with donated fish frames of *Lutjanus malabaricus*. The data sheet used in the program is shown and in Supplementary Figure 1. Image provided by the Queensland Department of Primary Industries, 2025.

Table 1
Species sampled from the Keen Angler Program. Each species is listed with the corresponding catch group, scientific name, and common name.

Catch Group	Scientific Name	Common Names
Coral Reef	*Lethrinus miniatus*	Redthroat Emperor
Coral Reef	*Lethrinus nebulosus*	Spangled Emperor
Coral Reef	*Lutjanus carponotatus*	Stripey Snapper
Coral Reef	*Lutjanus erythropterus*	Crimson Snapper
Coral Reef	*Lutjanus malabaricus*	Saddletail Snapper
Coral Reef	*Lutjanus sebae*	Red Emperor
Coral Reef	*Plectropomus leopardus*	Common Coral Trout
Inshore and Estuarine	*Acanthopagrus australis*	Yellowfin Bream
Inshore and Estuarine	*Lates calcarifer*	Barramundi
Inshore and Estuarine	*Platycephalus fuscus*	Dusky Flathead
Inshore and Estuarine	*Polydactylus macrochir*	King Threadfin
Inshore and Estuarine	*Pomatomus saltatrix*	Tailor
Inshore and Estuarine	*Protonibea diacanthus*	Black Jewfish
Inshore and Estuarine	*Sillago ciliata*	Sand Whiting
Mackerel	*Scomberomorus commerson*	Spanish Mackerel
Mackerel	*Scomberomorus munroi*	Spotted Mackerel
Mackerel	*Scomberomorus queenslandicus*	School Mackerel
Mackerel	*Scomberomorus semifasciatus*	Grey Mackerel
Rocky Reef	*Chrysophrys auratus*	Snapper
Rocky Reef	*Glaucosoma scapulare*	Pearl Perch

have been assigned to four Catch Groups (i.e., Inshore and Estuarine, Coral reef, Rocky reef, and Mackerel):

A unique identification code was assigned to each fish sample and donation, in addition to the date the samples were caught. Catch data were binned by financial year (i.e., the 12-month accounting period in Australia from 1 July to 30 June). *R* version 4.4.2 (2024–10–31) was used for data visualization and analysis (R Core Team, 2024). Network graphs were produced using 'R' packages such as 'ggraph', 'tidygraph', and 'igraph' (Pedersen, 2025). In the Network graph, the frequency at which any two species combinations were donated was visually displayed by the thickness of the line. Then, the number of donations each individual species occurred in was also counted, regardless of whether it was donated with another species, and was displayed as node thickness. Using these steps, the network analysis was able to be used as a visual indicator of the co-occurrence of species in one donation. We define co-occurrence as the ability for multiple species to be in a single donation (i.e., within a single fishing day). Co-occurrence is useful in the context of this manuscript as it helps us identify species co-donations or species donated together, which can lead to more cost-effective sampling for DPI, when resources are limited. Given that co-donation of more than two species cannot be visualized in a network graph, we use a Venn diagram to display co-donations of up to four species. While neither analysis is able to encapsulate total catch, the results presented allow for an indication of the sampling potential of KAP.

A non-metric multidimensional scaling (NMDS) analysis using Bray-Curtis dissimilarity was conducted to compare the species donated between the north and south over the duration of the program. The number of samples donated per species per year for each region (north or south) was converted into percent composition per species per year for each region, then Hellinger transformed to reduce zero-inflation and dominant species influence. A permutational multivariate analysis of variance (PERMANOVA; 999 permutations) was used to test group difference, and the "betadisper" R package was used to analyze the multivariate homogeneity of group dispersions (variances) (Oksanen et al., 2025)

3. Results

3.1. Trends and Representation of Donations and Samples in the Keen Angler Program

Over the 20-year sampling period of KAP, there have been over 9000 donations, where 3144 were from the north, and the remaining 5856 were donated in the south (Fig. 3). The south has had fluctuating numbers of donations for almost the entirety of the donation period for KAP, with peaks in donations for the financial years 2013–2014 and 2015–2016 (Fig. 3b). Contrastingly, there was an increasing trend in donations over the duration of sampling in the north, where the number of donations doubled from 2014-2015 (235) to 2023–2024 (500). In general, the south has always had higher levels of donations compared to the north. However, as of recent years (2023–2024), the number of donations is now similar between the north (500) and south (517) (Fig. 4a-c).

KAP has received over 55,000 samples (fish) across the > 9000 donations, over the 20-year sampling period from all of Queensland (Fig. 4a). There have been notable peaks in the overall number of samples in financial years 2009–2010, 2015–2016, and 2023–2024 (Fig. 4a). However, the most notable change in samples can be seen from 2019-2020 (2318) to 2023–2024 (5091), where the number of samples has doubled (Fig. 4a). The overall increase in the number of samples from 2019-2020 to 2023-2024, in particular, is attributed to the overall increase in the number of donations over these years compared to previous years (Figs. 3 and 4a). In general, the number of samples received is highly correlated with the number of donations (Supplementary Figure 2).

Most of the samples for KAP have been from the 'Inshore and Estuarine' catch group, with relatively consistent numbers of samples from 2006 to 2024 (Fig. 4a). An overall peak of 'Inshore and Estuarine' samples occurred in 2015–2016, where overall and in the south specifically, the number of samples made up over half the total (Fig. 4a). The following financial year (2016–2017) had an obvious decrease in the number of samples overall, regardless of the sampling group (Fig. 3a). 'Mackerel' samples have also been consistently sampled, but have declined since 2016–2017 (Fig. 4a). Contrastingly, the number of 'Rocky reef' samples has not fluctuated much between 2006 and 2024, but had a small increase between 2021-2022 to 2023-2024, which is similar to 'Coral reef' samples. Samples of 'Coral reef' species first occurred in 2017–2018, and remained a relatively low proportion of the overall number of samples until 2020–2021. From 2020–2021, the proportion of samples increased, contributing to approximately a third of the overall samples in 2023–2024 (Fig. 4a). Most of the samples of 'Coral reef' species come from the northern region (Fig. 4b).

Overall, the north has received 10,163 samples, and the south has received 47,826 samples donated from 2005 until 2024 (Figs. 1 and 4b-c). There is a clear distinction between the catch groups donated in the

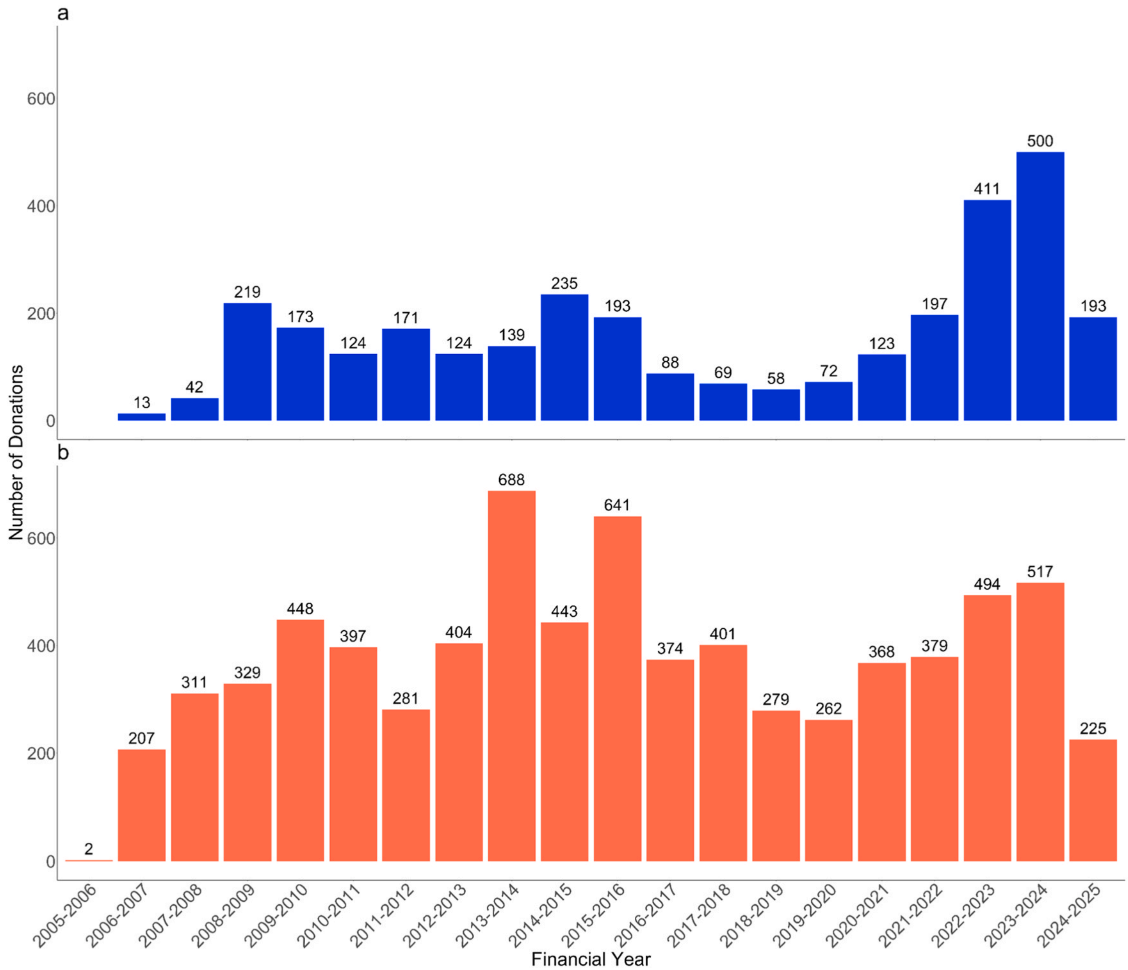

Fig. 3. The number of donations for the Keen Angler Program for each financial year from 2005 to 2025, split by north (a) and south (b) Queensland. The data for the financial year 2024–2025 only includes data up until November 2024.

north and the south (see Supplementary Figure 3 for the non-metric multidimensional scaling analysis). 'Inshore and Estuarine,' 'Mackerel,' and 'Coral reef' samples are all donated in the north and south, but there is a noticeable difference in the number of samples. 'Rocky reef' species donations, on the other hand, only occur in the south and have lower sample numbers compared to the three other catch groups. The low numbers are due to the catch group consisting of only two species: Pearl Perch and Snapper (Fig. 4c). Most of the samples in the south are composed of 'Inshore and Estuarine' species (Fig. 4c). Likewise, samples in the north are mostly composed of 'Coral reef' species (2017–2025) due to the introduction to the program in 2017, which resulted in a shift from earlier years being mainly 'Mackerel' species (Fig. 4a, Supplementary Figure 3).

Despite the overall proportion of both the north and south being dominated by one catch group, it can also be observed that a few species also dominate the number of samples for both regions. In the early years of sampling, 'Mackerel' species such as Spanish Mackerel and Spotted Mackerel were the predominant species donated in the north. Barramundi ('Inshore and Estuarine') were also a key sampled species in the north until 2016–2017 (Fig. 4b). However, in the financial year 2020–2021, there was an increase in Saddletail Snapper and Common Coral Trout samples, correlating with the increase in 'Coral reef' samples (Fig. 4a-b). From 2020–2021 to 2023–2024, the number of samples for both Saddletail Snapper and Common Coral Trout doubled. Other 'Coral reef' species also had higher sampling levels between 2020-2021 to 2023-2024, including Crimson Snapper, Red Emperor, Redthroat Emperor, and Spangled Emperor (Fig. 4b). While these species have been donated at lower numbers, they have still contributed to the rapid increase in not only the number of samples for the north in general, but the growth in 'Coral reef' species in the last five years (Fig. 4b). In contrast, Sand Whiting and Yellowfin Bream have consistently had high levels of samples over the past 20 years, ultimately contributing a large proportion of samples for KAP (Fig. 4). Snapper has also been consistently sampled over the duration of KAP, but with relatively constant numbers of samples from year to year. Other species that have been noticeably sampled in the south include Pearl Perch, Spotted Mackerel, and Tailor (Fig. 3c). Many of the highly donated species have been donated together with other species, even those from different catch groups within the KAP target species list.

3.2. *Co-occurrence of Sampling in the Keen Angler Program*

The number of samples donated followed an exponential decay curve: the majority of donations consisted of $\leq$10 samples, while only a few contained $\geq$30 samples (mean = 6.12; Fig. 5a). Most donations contain 1-2 species of samples (mean = 1.3; Fig. 5b). Looking at donation patterns for the top two species in the north (Coral Trout and Spanish Mackerel) and the south (Snapper and Yellowfin Bream) revealed that the majority of donations per species consist of $\leq$8 individuals (Fig. 5c-f).

The north has had fewer species sampled compared to the south; however, the network graph and the Venn diagram indicate that the north has received more donations that include multiple species in a single donation (Fig. 6). There have been a high number of donations

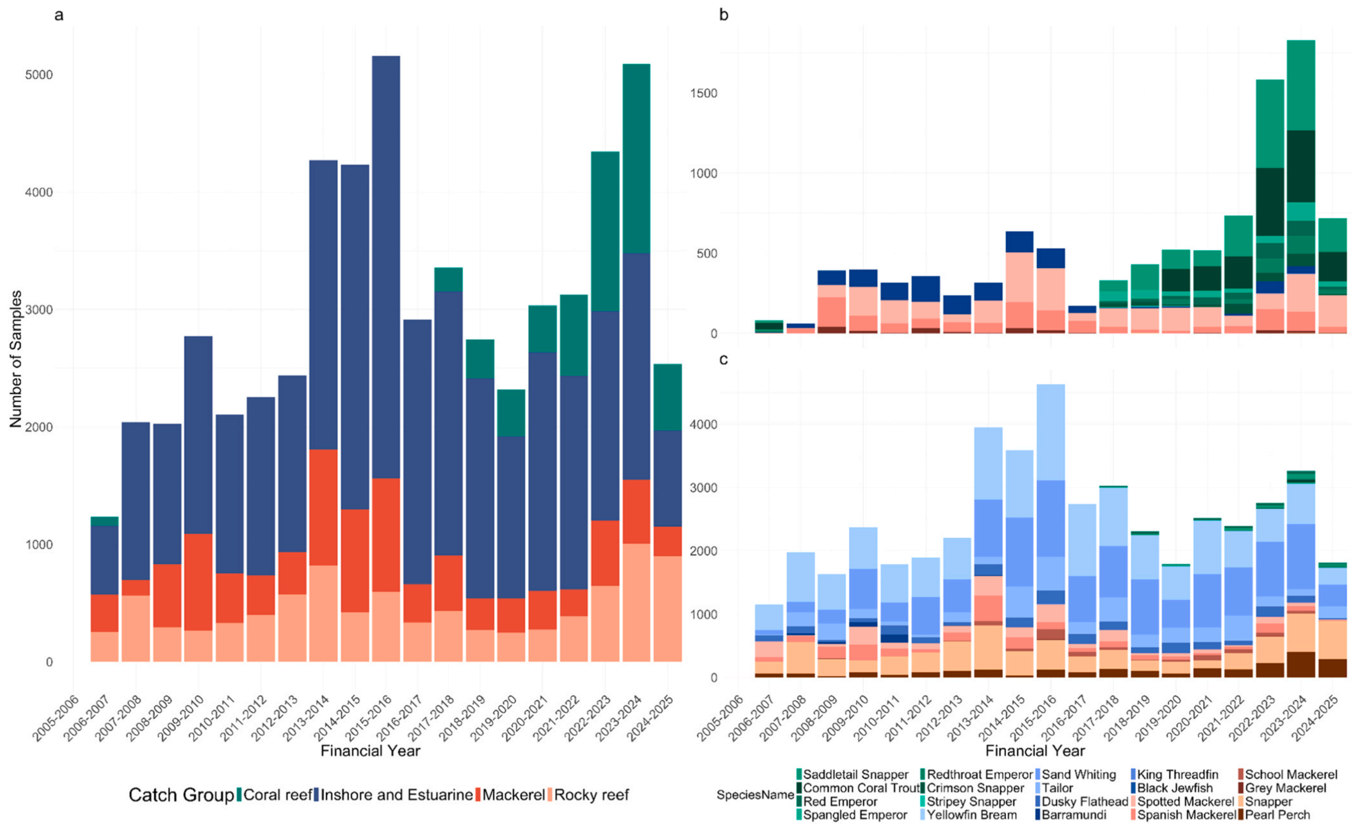

Fig. 4. The number of samples for each catch group of the Keen Angler Program sampled overall (a) and the number of samples donated for each species in the north (b) and south (c), coloured based on catch group. Coral reef: Common Coral Trout, Crimson Snapper, Red Emperor, Redthroat Emperor, Saddletail Snapper, Spangled Emperor, and Stripey Snapper. Inshore and Estuarine: Barramundi, Black Jewfish, Dusky Flathead, King Threadfin, Sand Whiting, Tailor, and Yellowfin Bream. Mackerel: Grey Mackerel, School Mackerel, Spanish Mackerel, and Spotted Mackerel. Rocky Reef: Pearl Perch and Snapper. The data for the financial year 2024–2025 only includes data up until November 2024.

that have included two or more 'Coral reef' species; Saddletail Snapper and Red Emperor have been donated together 44 times (Fig. 6a). Red Emperor has also had a high number of donations with other 'Coral reef' species, including Common Coral Trout, Redthroat Emperor, and Spangled Emperor (Fig. 6a). Saddletail Snapper has also had a high frequency of donations with Common Coral Trout and Spangled Emperor, but also with Crimson Snapper (Fig. 6a). Spanish Mackerel and Spotted Mackerel have been donated a notable number of times together. However, Spanish Mackerel has also been donated with 'Coral reef' species at a high frequency. Common Coral Trout, in particular, has been donated with Spanish Mackerel 46 times, which is higher than the number of times Common Coral Trout has been donated with other 'Coral reef' species (Fig. 6b). Eight donations in northern Queensland are composed of at least four species (i.e., Common Coral Trout, Red Emperor, Saddletail Snapper, and Spanish Mackerel) (Fig. 6b). While multiple species are identified to be donated together in the north, there are three species donated in isolation, compared to the south, where there is only one (Fig. 6a-b). 'King Threadfin' is consistently donated on its own between the north and south (Fig. 6a-b).

While there are a greater number of species donated in the south overall, the donations from the south are dominated by a few species, including Dusky Flathead, Sand Whiting, Snapper, and Yellowfin Bream (Fig. 6c). Sand Whiting and Yellowfin Bream have not only been donated individually at a high frequency, but also together, with 389 donations involving both species (Figs. 3c and 5b). Dusky Flathead has also been donated frequently with Sand Whiting ($n = 71$ donations) (Fig. 6d). Snapper and Yellowfin Bream have been donated 1268 and 904 times, respectively, either individually or with other species, not including Dusky Flathead, Sand Whiting, or Snapper (Fig. 6d). However, much like the north, donations in the south indicate that recreational fishers will fish in multiple catch groups during a single fishing day. The two sampled 'Rocky reef' species, Snapper and Tailor, have not only had a high number of donations together, but they have both been donated frequently with Yellowfin Bream, which is an 'Inshore and Estuarine Species' (Fig. 6b). Snapper specifically has been donated with Yellowfin Bream a total of 80 times. While the frequency of paired donations is much higher than some of those in the north, a difference that occurs between donation interactions between the north and south is that there is only one occurrence where all four species (i.e., Dusky Flathead, Sand Whiting, Snapper, and Yellowfin Bream) have been donated together (Fig. 6b). This indicates that species in the south are generally donated individually or in pairs.

4. Discussion

4.1. Representation of the Keen Angler Program

The increase in the range of species sampled in the Keen Angler Program (KAP) is the result of the program's value in providing more biological data for key target species through the program expansion and demonstrating the interest of the public to contribute to science. The methods used to obtain samples have also benefited both the Queensland Department of Primary Industries (DPI) and Queensland's recreational fishing sector. Recreational fishers can not only participate in a physically and mentally beneficial activity, but also contribute to the monitoring of target fish populations (Gundelund et al., 2020; Moore et al., 2023). DPI benefits from the time and cost efficiency of sourcing fish frames for data collection due to being provided by recreational fishers. Additionally, the level of rapport that is built between DPI and recreational fishers is beneficial when implementing management

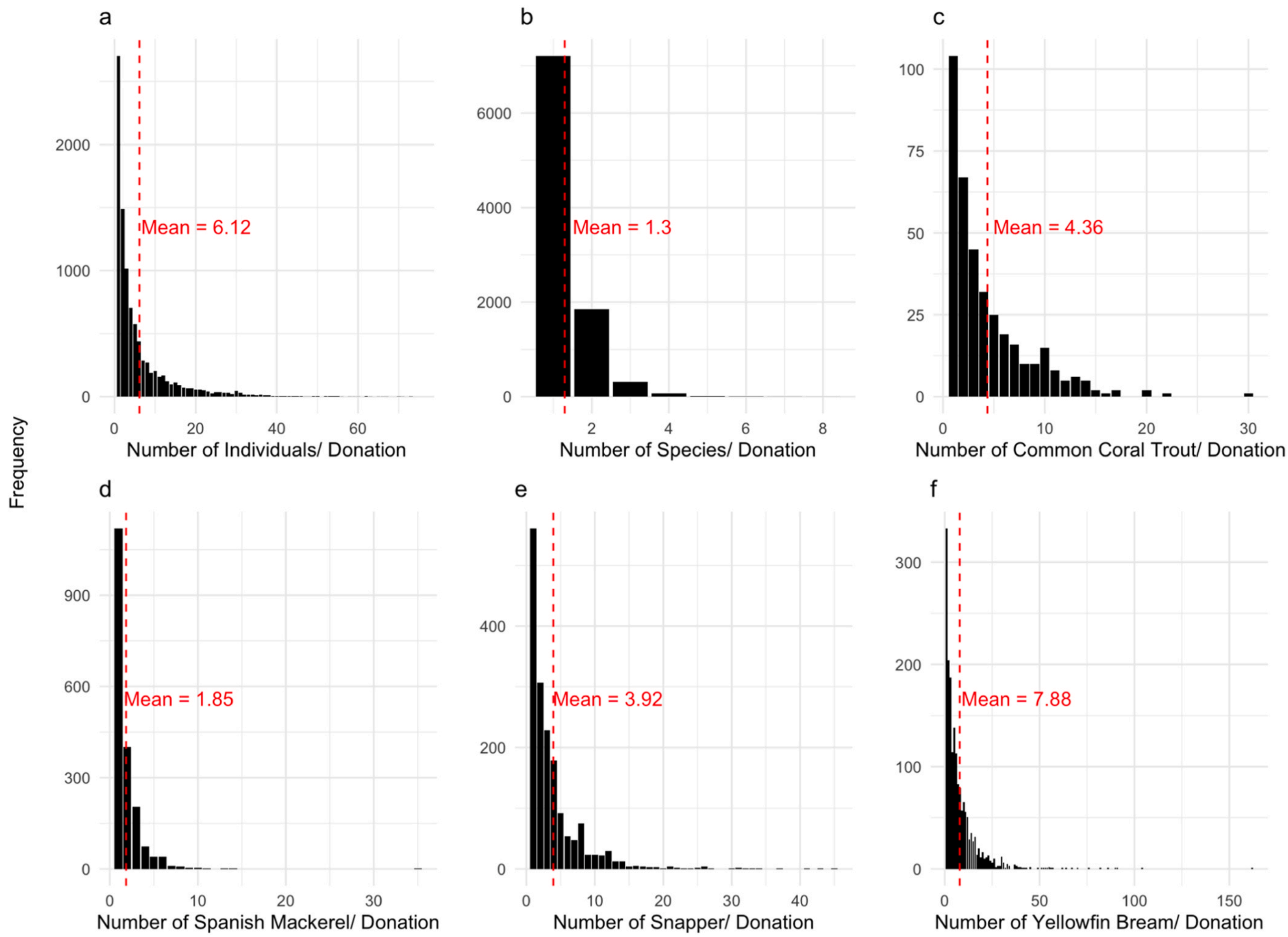

Fig. 5. Frequency of the Number of Individuals (a), Number of Species (b), Number of Common Coral Trout (c), Number of Spanish Mackerel (d), Number of Snapper (e), and Number of Yellowfin Bream (f) per donation. The red dashed lines and the inset texts indicate the mean value for each plot. These samples can include donations from more than one angler. We do not collect information on the number of anglers who have contributed to the donation. In rare instances, it is possible for multiple days or boats from multiple anglers to be aggregated with all monitored species donated.

policies due to knowing the opinions of recreational fishers (Fairclough et al., 2014; Henry and Lyle, 2003; Tracey et al., 2013; White et al., 2025).

It could be assumed that recreational fishers will target fish species within one catch group or species group. However, we observe that species of different catch groups (e.g., north- 'Coral reef' and 'Mackerel', south- 'Inshore and Estuarine' and 'Rocky Reef') are often donated together (Fig. 6). Out of all donations over the duration of KAP, 23.9 % have multiple species donated. By understanding these interactions, there is potential to understand the general catch of recreational fishers when a particular species is caught, even if the entire catch is not donated. Additionally, if donations include species from multiple catch groups (e.g., Spanish Mackerel donations with Saddletail Snapper), then we can potentially gain insight into incidental catches that occur within the recreational fishery, which reflects the diverse and diffuse nature of the recreational fishery, where different gears are used, and different fish habitats are fished in a single trip (Chizinski et al., 2014). While we were limited in the capacity for the data to be used to represent total catch, our analysis provides indications of sampling co-occurrences due to fishers donating catch that is composed of a significant number of samples and of multiple species.

The spatial differences between species co-donation in the north and south of Queensland also allow us to infer that fishing behaviour and target species will change based on catch group accessibility (Fig. 6). For example, fishers in the north of Queensland have ready access to reef environments, thereby explaining the high number of 'Coral reef' species donated in recent years (Figs. 1, 4, and 5a-b). Comparatively, while there are some locations in south Queensland where 'Coral reef' species can be caught, most samples are from 'Inshore and Estuarine' and 'Rocky reefs' catch groups (Figs. 1, 4, and 5c-d). There is a high diversity of catches and a large representation of target species for KAP donations in both the north and south. Both factors indicate that some fisheries and locations are particularly successful for frame donation programs due to multiple species being caught. Additionally, larger recreational fishing population sizes in some geographic locations could contribute to the discrepancies in donation and sample values between the north and south.

The size and extent of KAP is a clear demonstration of the important contribution that citizen science programs can make to providing important biological data that underpin fisheries management. The ability for KAP to obtain > 2000 samples at the beginning of the program from 2007 to 2008 is a clear example of the program's ability to obtain data at a rapid rate. Additionally, the significant increase in samples once KAP began to sample 'Coral reef' species indicates the ability for KAP to adapt to the data needs of DPI (Fig. 4). Being able to obtain such large numbers of samples in short periods of time can be indicative of the potential of the program to meet new or changing data needs. Ongoing or increased recruitment efforts are also likely to further increase the size and extent of the program (Fairclough et al., 2014). However, the size and growth of the program will be conditional upon

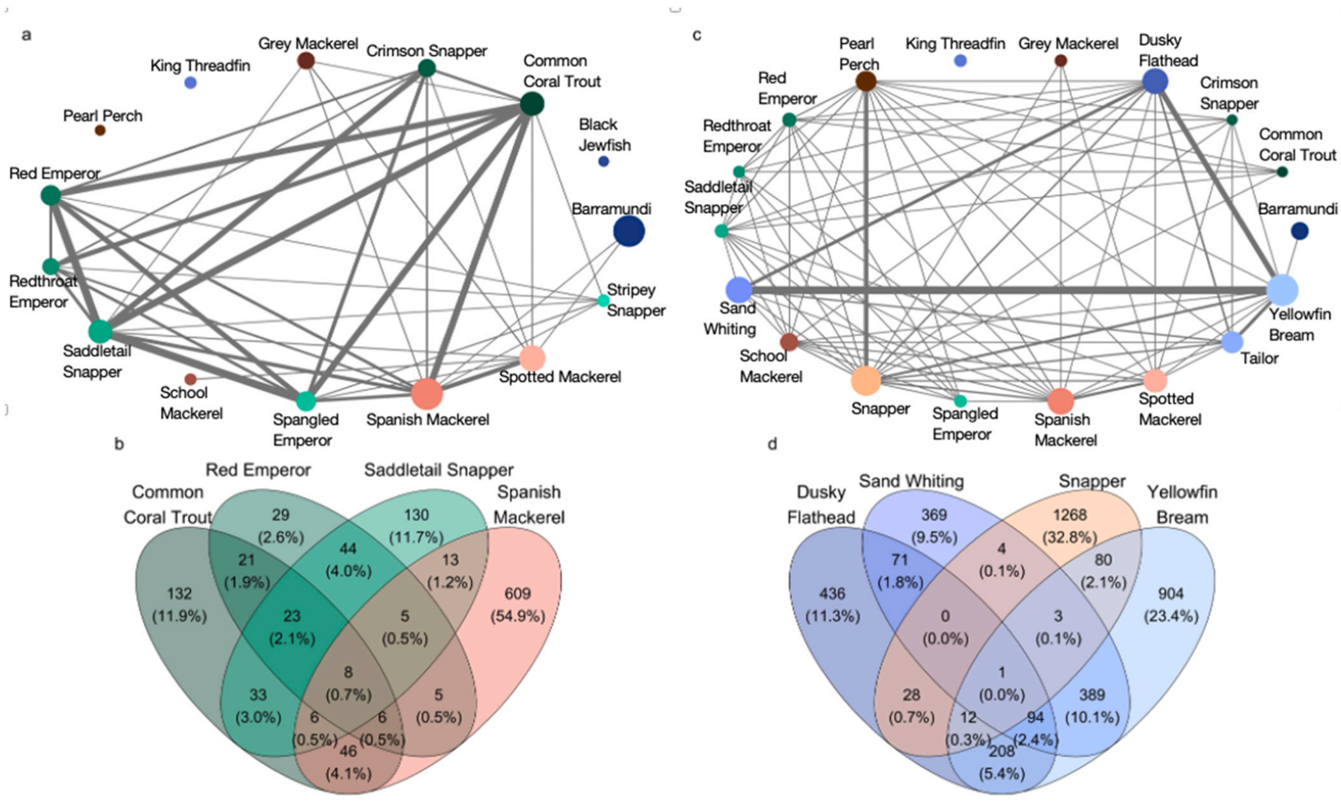

Fig. 6. A network analysis of donations in the north (a) and south (c) of Queensland, where the node size indicates the number of times the species was donated, and line thickness indicates the frequency at which species have been donated together. No line connections means the species has not been donated with another. Node colour indicates each species' catch group (i.e., green- Coral reef species, blue- Inshore and Estuarine species, red- Mackerel species, and pink- Rocky reef species), consistent with Fig. 4. The values of the Venn Diagram reflect the number of times one species was donated with three other highly donated species, as well as the cumulative number of times it was donated either individually or with other species, excluding the other three listed species, in the north (b- Common Coral Trout, Red Emperor, Saddletail Snapper, and Spanish Mackerel) and the south (d- Dusky Flathead, Sand Whiting, Snapper, and Yellowfin Bream). The percentages in the Venn Diagram are the percentage of donations for each of the four species listed and species combinations.

the willingness of recreational fishers to be involved in community citizen science sampling (Fairclough et al., 2014). There have been multiple 'outreaches' for people to get involved in KAP over the duration of the program. 'Outreaches' involve either DPI staff inviting recreational fishers personally at boat-ramp surveys to participate in KAP or through social media posts. However, it is unknown to what extent these 'outreaches' have contributed to the growth of KAP, as distinct from continual recruitment and retention of individual fishers. Regardless, continued communication about KAP to varying stakeholders (e.g., recreational fishers) can lead to further increases in the number of donations and samples as new fishers are recruited and recurring fishers continue to donate (Figs. 3 and 4) (Fairclough et al., 2014).

4.2. *Applications of the Keen Angler Program*

Citizen science programs, such as KAP, are an important tool for engagement (Hansen and Bonney, 2022). There is ongoing research on the need and importance of stakeholder engagement with citizen science programs to understand the limitations and constraints of such programs (Schläppy et al., 2017). Individual participants may contribute to citizen science programs for different reasons based on their values, and thus require different approaches in regards to recruiting into programs (Gundelund et al., 2020; Hansen and Bonney, 2022). Thus, it may be necessary to change perspectives when it comes to recruitment to have more meaningful engagement, by shifting from 'science' as the main focus of these programs to 'citizens' involved and their priorities to invoke social change (Schläppy et al., 2017). While engagement is a smaller component of KAP, the capacity for it to be able to collect samples over a 20-year period is indicative of the potential the program has in extending and maintaining engagement with a key stakeholder group (Figs. 3 and 4). Continuing to understand how KAP has been able to engage recreational fishers is important in determining the program's true value in fisheries monitoring and the outcomes of future expansions in the engagement of recreational fishers.

It is important to note that while people may initially show willingness and excitement to participate in programs such as KAP, there is potential for respondent fatigue, affecting the number of samples and donations received within KAP from year to year (Gundelund et al., 2020). While the program is ultimately driven by the biological data needs of DPI, the notable temporal variations in the number of samples and donations over the 20 years of sampling could be the result of varying recreational fisher behaviour. Citizen science programs, such as KAP, consistently face recruitment and retention challenges and therefore could experience high volunteer turnover rates (Frensley et al., 2017). However, the intentional anonymization of participants in KAP would make it difficult to know the retention and turnover of participants within KAP. Gundeland *et al.* (2020) investigated the retention rates of recreational fishers participating in '*Fangsterjournalen*.' They found that there were several factors influencing the retention of participants, including 'motivation, avidity, attitudes, beliefs, demographics, and personality' (Gundelund et al., 2020). The retention levels within '*Fangsterjournalen*' varied, but ultimately, they determined that advertising the program as a conservation and management tool could have contributed to the high retention of highly committed fishers. Additionally, there is potentially a component of programs such as KAP that contributes to 'respondent fatigue.' There has been little research on how respondent fatigue influences the retention within fisheries citizen science programs; however, much of the literature discussing the concept identifies that program difficulty, and over-concentration of similar programs, can contribute to and enhance 'respondent fatigue' (Frensley et al., 2017; Geoghegan et al., 2016; Gundelund et al., 2020). Due to the nature of KAP and fishers having to contact DPI or drive to another location, there is potential that this contributes to periods of reduced retention of volunteers and increased 'response fatigue.' However, the relationships and rapport built between DPI and recreational fishers could ultimately be more beneficial than retention (Fairclough et al., 2014). More research into this concept is necessary to ensure that recruits are retained, but also people's attraction to programs such as KAP is maintained to ensure the continued longevity of the program (Fairclough et al., 2014).

A critical contribution of the KAP program is providing data on population structure (age, length, and sex) for important fisheries species. Fairclough et al. (2014) found that Western Australia's citizen science program data, *Send Us Your Skeletons*, which operates similarly to KAP, was able to estimate fishing mortality with age from donated fish samples. It should be noted that there is a chance that those involved in KAP donate fish frames of varying lengths compared to other recreational fishers or fishing sectors, and thus provide a wider size range of the target fish population to encompass the varying shifts in populations and also determine age-at-length data (Fairclough et al., 2014; Methot and Wetzel, 2013). A previous study by Crisafulli et al. (2022) found that different sampling methods could be used to standardise harvest rates. However, there has not been a direct comparison within and between sectors, nor has there been direct comparability of lengths between sampling programs. For these reasons, further examinations would be beneficial in determining KAP's true applicability within stock assessments and monitoring of fisheries health, and its capabilities to be used in isolation or in conjunction with other DPI monitoring programs, sampling commercial and broader recreational sectors. It is theorised that KAP data could be potentially biased towards collecting larger fish. While for most fisheries citizen science programs this is untrue, there is a need to compare KAP to other DPI fisheries sampling programs to uncover the limits and true potential of KAP (Fairclough et al., 2014; Gundelund et al., 2021).

Beyond the use of KAP's biological data for stock assessments, there is potential for the data to extend or reconfigure the understanding of species distributions (Fig. 3). Tasmania's 'Framed, Tagged, and More' program was found to improve the representation of species distributions and their historical and future changes compared to other citizen science programs, such as *Redmap* (Graba-Landry et al., 2022, 2023). The data collected in KAP have shown differences in the species that can be sampled between the north and south of Queensland (Figs. 3, 4, and 5). However, having a thorough investigation of exact catch groups compared to other programs with similar spatial distribution data could be critical to knowing the true capacity of KAP in representing current and future spatial distributions (Graba-Landry et al., 2022, 2023). Determining where species are currently being donated from in Queensland has meant that if DPI needed to collect targeted samples or recruit fishers targeting select species, there is a way to focus efforts. Additionally, by knowing what species are donated together, there is the capacity to recruit fishers for one species, and thus infer that the other species are likely to be caught and donated as well (Figs. 4 and 5).

Data collected through KAP will have the greatest utility in conjunction with other structured (stratified spatially and temporally) monitoring programs in Queensland. Currently, 'Boat Ramp Surveys' are used to sample Queensland recreational fishers, where trained DPI staff will interview returning recreational fishers. Length and catch data will be collected for the same target species as KAP to determine the trends of estimated harvest levels of the recreational fishery in Queensland (White et al., 2025). Similarly, 'Commercial Catch Sampling' will be used to collect length data, but of fish caught via the commercial fishery. With all three programs collecting length data, there is potential for data complementation, whereby, when used in conjunction, a more representative length-frequency distribution can be determined. Further research should be conducted to determine the additional applications of KAP and its ability to fit with data from other monitoring programs, such as 'Boat Ramp Surveys' and 'Commercial Catch Sampling.'

4.3. Lessons Learnt and Path Forward

Until the present manuscript, little to no information has been previously published about KAP and its data, and therefore, its potential applications have not been fully evaluated. We have demonstrated that KAP has the ability to sustain data collection over long periods and is valuable to the Queensland Department of Primary Industries (DPI) in building rapport with recreational fishers. As one of the longest-standing fishery citizen science programs in Australia, it highlights the ability of this program to be dependable as a data source. We believe that the anonymity of donors has contributed to the trust built between the donors and DPI, helping DPI collect consistent long-term data. We highlight that the relationships developed within KAP should not be underappreciated, as the increased levels of rapport could also increase the willingness of recreational fishers to contribute to management by donating priority species. Without maintaining this relationship, there would be little to no data collected, which has been seen in other fisheries sectors (White et al., 2025). However, because donors are anonymous, volunteer retention cannot be quantified in KAP. This may be a short fall of the current program, and future work could investigate the feasibility and potential consequences of adding unique identifiers to donations.

We also found that some fishers would donate multiple fish and multiple species within a single donation. This is valuable information to consider for recruiting new members or engaging new recruitment programs, given that some donations are more likely to provide species from multiple targeted catch groups. Consideration of the co-occurrence of species in donations has not been previously investigated, and could be a path to enhance the value of the program.

Currently, KAP data contributes to determining the age-frequency distribution of target populations. It additionally collects sex and length data, which contributes to the biological data collected at DPI. The evolving nature of recreational fisheries highlights the need to source fisheries information from multiple avenues. Moving forward, more research is needed to determine the applicability of KAP data to other areas of fisheries. While KAP provides a wealth of potentially useful fisheries data available (e.g., catch, spatial, and temporal), we have learnt that fluctuations in the data do occur and donations are not systematic like other fishery programs. Therefore, we suggest further research is conducted to determine if KAP data is comparable to other fisheries-dependent programs, to extend its applicability to areas such as stock assessments.

5. Conclusion

Queensland's Department of Primary Industries (DPI) fisheries biology citizen science program, 'The Keen Angler Program' (KAP), has had a large spatial and temporal representation of select fish populations in Queensland waters. In the two decades that this program has been running, there have been increases in the number of samples and species, particularly in the north of Queensland, and especially in the last five years. It has also been identified that while species may be individually donated, there is the potential to also have other species donated simultaneously, even if they are from a different catch group. The critical biological data collected within KAP could play a more significant role in DPI's ability to assess the status and trends in fished stocks. There is, however, a need to understand the compatibility with other programs to predict future spatial distributions or length-frequency representations of fish populations. Further research should also be considered about the participants of KAP, in regards to the retention of fishers, and whether retention is ultimately influenced by sampling fatigue. However, the anonymity of participants is a factor that does have to be considered. KAP has been a pioneer of fisheries biology citizen science programs in Australia, but like all citizen science programs, it is reliant on the willingness of volunteers to ensure ongoing growth and persistence. Importantly, programs such as KAP provide unprecedented insights into the recreational fisheries sector, while also providing important biological data necessary for broader fisheries management. Further investment in the program could lead to greater growth in the program, thereby expanding the data available to monitor DPI-priority species.

CRediT authorship contribution statement

Sophie M. White: Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Conceptualization. **Amos Mapleston:** Writing – review & editing, Writing – original draft, Supervision, Data curation, Conceptualization. **Morgan S. Pratchett:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Reniel B. Cabral:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Amos Mapleston reports a relationship with Queensland Department of Primary Industries that includes: employment. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.fishres.2026.107668.

Data availability

The authors do not have permission to share data.

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