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Perspective

Citizen Science Facilitates Reporting of Reef Fish Species' Ecological Health Indicators in the Great Barrier Reef, Australia

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Abstract

A collaborative learning approach between citizen scientists, experts and managers transformed metrics of coral reef fish biodiversity into indicators for use in regional waterway health report cards. We tested a citizen science tool, iNaturalist, to identify species and monitor annual changes in fish biodiversity at a regional scale in the Great Barrier Reef, Australia. The participation of almost 1000 citizen scientists between 2013 and 2025 resulted in 13,131 research grade observations of 684 species of fish. Annual biodiversity data from three years (2023–2025) was compared to 10 years of baseline data (2013–2022) and calibrated for effort. Report cards scores for fish ecological health were generally 'very good' to 'good' and we conclude that a citizen science methodology is potentially suitable for fish ecological health at multiple spatial and temporal scales.

Keywords: citizen science; community; fish indicators; report cards

Key Contribution: A collaborative, learning approach between citizen (community) scientists, experts and managers using iNaturalist transformed metrics of coral reef fish biodiversity into health indicators for use in regional waterway health report cards.

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1. Introduction

Fish are important to humans as a source of culture, food, income, recreation, tourism, and citizen or community science activities [1]. Despite their high value to humans, knowledge of fishes as indicators of their ecological health is often low. For example, we found that baseline community knowledge of 20 common fish species at 62% (see below). This is concerning, as fishes are frequently negatively affected by the direct and indirect impacts of inappropriate human actions [1–5].

"Healthy people, healthy reefs" reflects a dual understanding: that healthy coral reefs are crucial for human well-being through food, economic stability, and medicine, and conversely, that thriving local communities are interested and capable of protecting these vital ecosystems. The Reef 2050 Long-term Sustainability Plan (hereafter "the Reef 2050 Plan") is the Australian and Queensland government's collaborative overarching framework for protecting and managing the Great Barrier Reef (GBR) to 2050. The Reef 2050 Plan Objectives and Goals is a key strategic plan developed in partnership with over 100 technical and subject matter experts, and covers a selection of attributes of Healthy

Reef, Healthy People [2]. One of the key objectives is "Populations of fish and invertebrate species that are important for recreational, commercial and culturally- based fisheries are healthy". Indicators are crucial in environmental management because they provide measurable data points that help track progress, identify areas needing improvement, and inform decision-making. Commercial fisheries indicators are specific and related to fish stocks, biomass, and overfishing and are well managed in Australia [6].

Ecosystem health report cards summarise the results of environmental monitoring programs to inform partners, community, scientists, practitioners, and decision makers of the status and trends of social, cultural, economic, and environmental indicators [7,8]. The Great Barrier Reef Marine Park Authority assesses biodiversity (natural heritage) of habitats and species every 5 years [9]. The biodiversity status of bony fish was 'good' and the biodiversity status of sharks and rays was 'poor' for the period 2009 to 2024 [9]. The status for bony fishes and sharks and rays was based on limited evidence and limited consensus, and was classified at medium confidence levels [9].

There are five regional report card partnerships for the GBR region; one of which is the Healthy Waters Partnership for Dry Tropics (HWPDT), formed in 2018. The partnerships are a collaboration involving community, industry, science, and government to gather and analyse environmental, cultural, social and economic data to produce reports and scientific summaries that provide the local community with an independent picture of the health of the region's waterways and GBR [10]. The regional report cards generally include data and report card grades for water quality, habitat (seagrass, coral) and freshwater fish; but for most report cards, there is insufficient data or an approved framework for reporting on estuarine and marine fish.

For example, the HWPDT Report Card includes data on freshwater fish biodiversity and uses the POISE (Proportion Of Indigenous Species Expected) and PONISE (Proportion Of Non-Indigenous Species Expected) methodology to calculate report card scores zones for the GBR sub-region [11].

It is estimated that there are 1400–2000+ species of fish in the GBR [9] and there is a low to moderate level of community and scientific knowledge of their status over time. One way to improve knowledge of fish biodiversity is through citizen science (CS) which is defined as public participation and collaboration in scientific research with the aim to increase scientific knowledge [12]. CS has enhanced the engagement in marine conservation and sustainability with CS projects increasing worldwide over the last decade [13,14]. The benefits of CS to the community are numerous with the most commonly reported being to infill regions of data scarcity and expand monitoring or investigations beyond what research or management authority budgets usually allow [15,16].

For many years citizen scientists have been diligently cataloguing fish species and recording vital supporting information. Programs such as Reef Life Survey [17], the Great Barrier Reef Marine Park Authority's Eye on the Reef [18], and Reef Check Australia [19] are among the largest contributors of coral reef fish data. iNaturalist has also been gaining popularity with citizen scientists.

A comprehensive review of CS fish data [4,5] recommended—as a high priority—the development of marine and estuarine fish metrics for inclusion among the suite of ecological indicators used by regional report card partnerships to assess and report on ecosystem condition. However, this fish metric has proven elusive due to the complexities and biases inherent in existing government, non-government organisations and research databases [2].

There are two significant data platforms the above review [4,5] did not consider as potential methods for developing ecological fish indicators: iNaturalist and eDNA. iNaturalist is a global CS platform that has the advantage of being able to obtain large amounts of data in multiple regions over extended periods of time [20]. As of 1 October 2025 there were over 278 million observations of over 536,000 species by 3,917,319 observers and 457,747 identifiers. Australia has contributed over 7.8 million research grade observations of over 51,000 species by over 103,000 observers and over 38,000 identifiers. The interactivity and interconnectivity between users, the ease of use, and the ability to provide anyone, anywhere with access to data are advantages to using iNaturalist [21,22]. However, disadvantages to using iNaturalist include: the unknown survey effort, different collection methods (divers, fishers, beach walkers), and identifying population sizes and trends [23].

Despite this rapid growth of global biodiversity data, estimates of biodiversity in many parts of the world remain at best imprecise and at worst non-existent [24,25]. Ecological indicators can be used to address data deficiency in ecological assessments and monitoring [24,25]. They provide a way to gain insights into ecosystem health and status even when detailed data on all aspects of the ecosystem are lacking. Ecological indicators are also used to measure biodiversity and assess the environmental status of ecosystems, playing an important role for effective natural resource management [26]. Species richness is a key component of biodiversity. It is regularly used as basic information for community ecology and is considered among the essential biological and ecological ocean health variables [27]. For monitoring purposes, an increase in fish species diversity is generally assumed to indicate more pristine environment conditions [3].

An expert panel assessment undertaken by First Nations organisations and scientists of the status of fish (guya) in the Wulgurukaba region (similar to HWPDT region) of the GBR, Australia, indicated “poor” for fish associated with inshore reefs, shoals and islands and “good” for offshore reefs and shoals and forecast low to medium risks for the future [28].

In parallel with the regional report cards a larger GBR Integrated Reef Fish Monitoring Program is underway, to address priority knowledge needs on fish species of recreational, commercial, cultural and ecological significance in in-shore reefs, deep water and nursery habitats. It will also develop a series of ecological indicators to monitor the population status and trends of target fish species to guide management decisions and fisheries practices [29].

Stewardship for fish may involve a mix of protective regulations, sustainable fishing practices, habitat preservation, and community involvement to ensure fish populations and ecosystems remain healthy and resilient. Within the Reef 2050 Plan, stewardship is one of five identified human dimension objectives where “. . . people and communities take individual and collective action to maintain GBR resilience”. Under this objective, five broad indicators of stewardship are described: (1) education about the GBR, (2) opportunities for community leadership and stewardship, (3) community awareness about the GBR, (4) adoption of stewardship practices and (5) non-use values for the GBR. Systematic monitoring and evaluation of these diverse contributions is required to demonstrate their efficacy in improving outcomes for the GBR [30]. Common metrics for reef stewardship include disposal of rubbish (94%), fish responsibly (90%), and participate in cleanup (60%) [31].

Here, we aim to test the applicability of CS data to estimate marine fish species biodiversity over time at a regional scale, and to summarise the results as simple indicators suitable for regional waterway health report cards. To achieve this goal, we had four specific objectives: (1) Investigate baseline knowledge of fish species by the community; (2) Retrieval of 13 years of fish biodiversity data from three marine locations in the central part of the GBR from the iNaturalist social media application; (3) Test the use of a simple indicator for marine fish biodiversity for generating an annual report card grade and compare with existing indicators and report cards; and (4) Examine metrics for measuring stewardship.

2. Materials and Methods

The overall approach was to evaluate whether an existing method for collecting field data on freshwater fish biodiversity and comparing to baseline data, and using as an ecological indicator for regional report cards is suitable to provide an ecological indicator of marine and estuarine fish.

The project involves a phased approach, beginning with defining project goals, engaging stakeholders such as the public and scientists in knowledge sharing and the design process, and choosing the right methods and level of participation (contributory, collaborative, or co-created) for a pilot field project.

2.1. Baseline Knowledge of Fish Species by the Community

An online quiz was designed using the app Microsoft Forms to include twenty individual photographs of common fish species with a question 'What is my name' and four choices (Supplementary S1). The quiz was distributed to community during field trips, trade events, and through social media.

2.2. Co-Design and Capacity Building of Citizen Scientists

In developing this CS project we undertook a literature review, targeted consultation, and facilitated a two-day social learning workshop with community to share knowledge, seek advice, and conduct a field day to train volunteers in observations and data entry. As part of this community engagement, we held a webinar [32] and produced a training video [33]. All of the co-authors and report card stakeholders collected, entered and checked field data using iNaturalist.

Initiated in 2011, iNaturalist (http://www.inaturalist.org, accessed on 14 July 2025) is a multi-taxa platform that allows participants to contribute observations of any organism, or traces thereof, along with associated spatiotemporal metadata, to a centralised website (Figure 1). Observations are initially identified by the user or with the assistance of artificial intelligence computer vision suggestions and then identified and verified to high taxonomic resolution by the iNaturalist community (Figure 1). An observation is deemed 'research grade' when it meets the site's metadata quality criteria and has two or more identifications which agree taxonomic name at a species level [22,33].

Projects can be created within iNaturalist to collate observations with a common theme into a central, publicly displayed repository to collect data for education, research and management purposes [22,33]. Collection projects collate individual observations based on their defined filters such as spatial, temporal, and taxonomy criteria. Umbrella projects can also be used to collect data from a range of separate areas or locations which fall under one major project.

iNaturalist data is publicly available, allowing us to explore the patterns in the sampling effort of CS participants for the region over time. Sampling effort was quantified as the number of 'research grade' observations of fish species in a fiscal year (1 July to 30 June) in the HWPDT region to align with report card protocols (Figure 1). Online projects were created within the iNaturalist system for several temporal periods including baseline (2013–2022) and three annual (2023, 2024, 2025) periods to ensure multiple years to examine variability.

The data collected was within the boundaries of the study region (Figure 2), an area of 24,477 sq km and encompassing approximately 120 km of mainland coastline and a distance of approximately 180 km offshore at the furthest point.

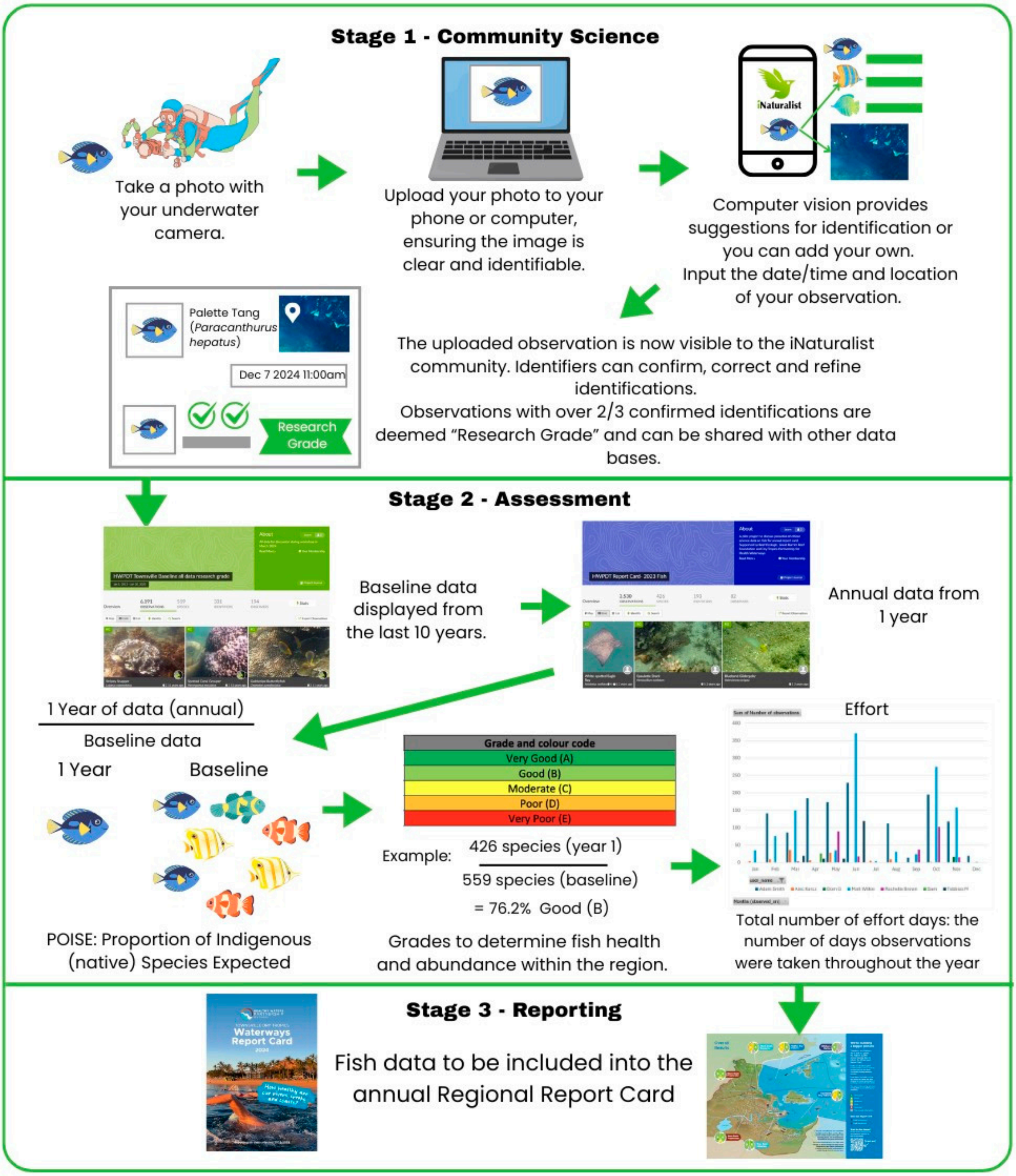

Figure 1. How to use iNaturalist to record observations of fish, calculate an indicator and include into a waterway health report card.

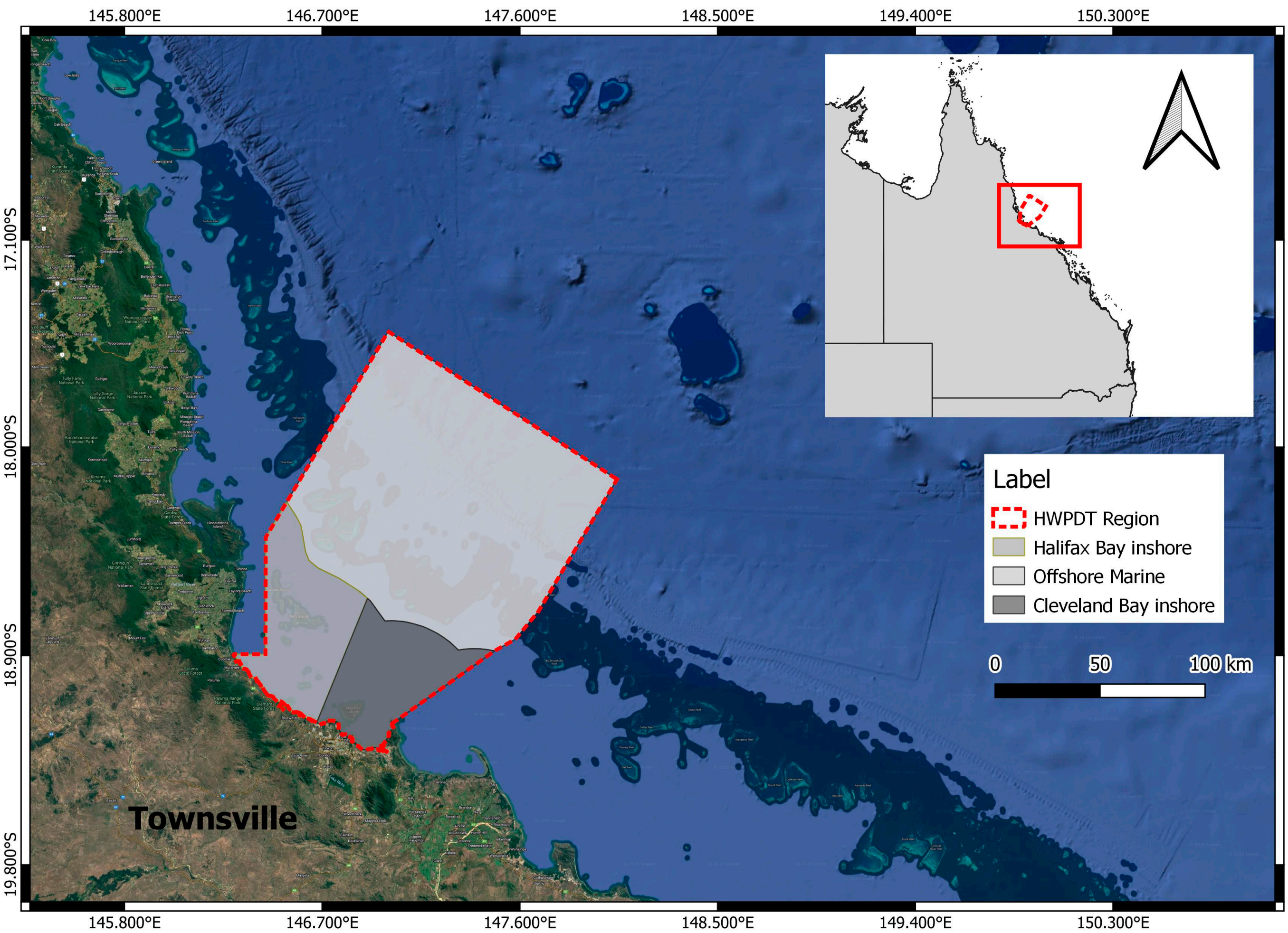

Figure 2. Map of the Healthy Waters Partnership for the Dry Tropics (HWPDT) study region and three zones: Cleveland Bay inshore, Halifax Bay inshore and Offshore marine.

2.3. Data Analysis and Interpretation

We followed the technical protocol established for regional report card indicators for fish biodiversity [34] and compared marine fish species biodiversity between years and areas (Figure 1). This was achieved by using a variation of the POISE (Proportion Of Indigenous Species Expected) metric where we corrected for sampling effort [35].

The calculation of POISE is the number of fish species documented from the spatial location (standardised for annual sampling effort) and year of interest divided by the total number of fish species documented from the same spatial location for the entire baseline period. This calculation results in a species richness index for a spatial location in a given year that is expressed as the proportion of the fish species documented from the same spatial location for the entire baseline period [36,37].

The percentage of species was then converted to a report card score based on standardized percent ranges: A (very good) 81–100, B (good) 61–80, C (moderate) 41–60, D (poor) 21–40, and E (very poor) 0–20.

3. Results

3.1. Baseline Fish Knowledge

A total of 196 people completed the quiz with an average time of 7:30 minutes. Individual scores ranged from 2 (10%) to 19 (95%) and averaged 12 (62%). Correct identification of individual species ranged from 94% for Giant moray to 27% for Surf parrotfish

(Table 1). Feedback on the quiz was that it was too easy (4%), too hard (12%) and fun and interesting (84%).

Table 1. Results of a multiple-choice quiz 'What is my name?' (n = 196). C—Commercial, T—Threatened, AE—Aquatic Emblem, E—Endangered, R—Recreational.

Common Name	Scientific Name	Knowledge (%)	Category
Giant moray	*Gymnothorax javanicus*	94	
White spotted puffer	*Arothron meleagris*	84	
Grey reef shark	*Carcharhinus amblyrhynchos*	83	C, T
Barrier reef anemonefish	*Amphiprion akindynos*	83	AE
Lemon damsel	*Pomacentrus moluccensis*	83	
Humphead wrase	*Cheilinus undulatus*	72	E
Blue tuskfish	*Choerodon cyanodus*	72	
Longfin batfish	*Platax teira*	71	
Dot and dash goatfish	*Parupeneus barberinus*	71	
Goldstripe butterflyfish	*Chaetodon aureofasciatus*	69	
Blue streak cleaner wrasse	*Labroides dimidiatus*	67	
Leopard coral trout	*Plectropomus leopardus*	60	C, R
Chinese demoiselle	*Neopomacentrus bankieri*	59	
Red squirrelfish	*Sargocentron rubrum*	58	
Barred rabbitfish	*Siganus doliatus*	58	
Narrow barred Spanish mackerel	*Scomberomorus commerson*	54	C, R
Stripey snapper	*Lutjanus carponotatus*	54	C, R
Harlequin sweetlip	*Plectorhinchus chaetodonoides*	54	
Moorish idol	*Zanclus cornutus*	44	
Surf parrotfish	*Scarus rivulatus*	27	

3.2. iNaturalist Data Collection

A total of 16,020 observations of 750 species were recorded by citizen scientists of which 13,131 observations and 684 species were classified as 'research grade' by experts and used for more detailed assessment.

We investigated several datasets including Wildnet [38], Atlas of Living Australia (ALA) [39] and iNaturalist as potential sources to generate baseline data on fish biodiversity in the marine environment. Wildnet applies to land not marine, ALA has a maximum limited search of 10 km radius of a location and iNaturalist appeared the most suitable as it contained research grade data for spatial and temporal data searches. iNaturalist contained 472 species for the nominated 10 year baseline period of 2013–2022.

3.3. Annual Fish Observations

The number of observations varied annually and spatially with a majority in the larger, offshore marine zone and fewer in the smaller, nearshore estuarine and freshwater zones (Figure 1). Very similar numbers of fish species (422–427) were recorded annually between 2023 and 2025. CS effort was recorded for number of observers and observer days (Table 2). The number of observers ranged from 83–113 (Table 2). Total effort of observer (number of people) varied from 241 to 355 days and was lowest in 2023 and highest in 2024.

Table 2. Fish biodiversity, citizen science effort, POISE indicator and indicative Report card scores for the Healthy Waters Partnership Dry Tropics (HWPDT) overall study region. Note years are Australian Government financial years 1 July–30 June. NA—Not applicable.

Year	Species Count	Effort (Number of Observers)	Effort (Days)	Baseline Days/Year Days	Species * Days (Scaled)	POISE	Fish Health Report Card Grade
2013–2022 (Baseline)	472	132	276	1	472	NA	NA
2025	422	99	241	1.14	483	1.02	A
2024	425	113	355	0.78	330	0.70	B
2023	427	83	324	0.85	363	0.77	B

* Species Days is calculated from Species Count × Baseline Days/Year Days.

3.4. Development of Stewardship Metrics

We quantified simple operational metrics associated with this project for the year 2024 into categories of project, training, guideline, video, field and quiz (Table 3). The number of deliverables ranged from 1 to 5 for the categories. The highest category was guidelines for fish and marine species which were developed for different locations. Our assessment for the three indicators is that the operational metrics were similar for all indicators and the interpretation is dependent on involvement as a leader or participant.

Table 3. Operational metrics associated with three of the five developmental stewardship indicators associated with the Reef 2050 plan.

Indicator	Project	Training	Guideline	Video	Field	Quiz
Education about the Reef	1	1	5	2	4	1
Opportunities for community leadership and stewardship	1	1	5	2	4	1
Community awareness about the Reef	1	1	5	2	4	1

3.5. Report Card Indicators

Baseline fish biodiversity data from 2013–2022 were compared with three annual periods 2023–2025 (Table 3). The total number of fish species varied between 422–472, number of citizen scientists varied from 83–132 and effort of citizen scientists varied from a total of 241 to 355 days (Table 2).

Indicator for Smaller Areas

A range of fish species (58–305), observations (80–1942), observers (17–50) and effort (29–91 days) were recorded for three zones: Cleveland Bay inshore, Halifax Bay inshore and Offshore marine. Due to a relatively lower number of species and observations for the three zones compared to the HWPDT region we consider lower confidence in the data and we did not complete a POISE calculation or report card scores for the smaller areas.

4. Discussion

Society is facing complex socio-ecological challenges such as the climate crisis, biodiversity loss and global health issues. Finding solutions to these complex problems requires creation of sound scientific evidence while enhancing societal ownership and embracing different knowledge domains. Here, CS can act as a transformative change agent by fostering participatory, societally relevant knowledge generation.

Our results build on the key recommendations and learnings from a comprehensive review of CS fish data [4] that seeks to incorporate data into regional and other waterway health report cards, i.e., 1. Standardisation of methodologies (where appropriate and possible); 2. Coordination and collaboration: sampling and reporting; and 3. CS empowerment and investment in CS guidance.

A major finding was that CS data compiled through the iNaturalist platform can contribute extensive data on biodiversity of fish over time [14,21,24,33,36,40–42] and provide a simple indicator of fish health for a regional report card. The indicator resulted in interpretations of 'very good' to 'good' health for regional marine fish biodiversity between 2023–2025. This status is consistent with the GBRMPA outlook report of 'good' for bony fishes [9].

Since 2018 there has been a gap in knowledge with insufficient data and no report card grades for marine and estuarine fish health in the HWPDT Report Card and four other regional report cards in the GBR region [4,5]. Our study provides an opportunity to introduce a framework and preliminary grades to inform the science, community and management. Our challenge, in this study, was balancing the value and use of grass roots CS data with other scientific methods that are costly and complicated and ultimately designing a simple stakeholder-government collaborative monitoring tool. In future, there are several technical and administrative steps that need to be taken including review by an independent technical advisory committee [43] to evaluate the suitability of this proposed methodology for management and stewardship reporting.

The HWPDT Report Card assesses urban water stewardship [44] but does not measure or assess reef habitat or species stewardship. The conceptual reef stewardship framework is a starting point for stakeholders to consider what aspects of stewardship are important to monitor in specific contexts and circumstances and why [30]. In this project we considered that three of the five potential indicators could be quantified: (1) education about the GBR, (2) opportunities for community leadership and stewardship, and (3) community awareness about the GBR. Our metrics associated with citizen science education differ from previous stewardship reporting metrics associated with marine debris, compliance, habitat restoration and sustainable fishing [31,45].

The National Social and Economic Survey of Recreational Fishers reported that Queenslander's spend an estimated six million days fishing each year and 57% felt confident that they can accurately identify species caught [45]. This estimate is similar to the results of fish species knowledge quiz of 62% from this study. Some species were relatively easy to identify by participants such as Giant Moray, Grey Reef Shark and Great Barrier Reef Anemonefish (the aquatic emblem of Queensland) which may be attributed to their shape, unique features of popularity in media. However it was surprising that only 54–60% of people accurately identified very popular commercial and recreational species: Leopard coral trout, Narrow barred Spanish mackerel and Stripey snapper. A study of fishers' knowledge of species in Brazil was positively related to fishers' perceptions on fish abundance, size, and importance to fisheries [40].

Long-term research indicates that fish communities of the GBR from the 1990s were substantially different from today [46]. Specifically, in the northernmost parts of the GBR (which are closest to the equator), the numbers of different fish species, in particular species of omnivores, plankton feeders and herbivores, have reduced. In the southern part of the GBR, reef fish species richness has experienced big fluctuations—flipping from periods with high numbers of different species, and periods where that richness has been very low. There was no specific mention of trends in the central region, which is the area of interest in this study (Figure 1). Conversely the indicators for fish in management outlook reports for the GBR region over the past 20 years have remained relatively consistent [9]. These uncertainties, changes and declines will continue in a changing climate and will be of future interest to government, business and community to quantify and manage fish biodiversity.

4.1. Benefits

The observations of citizen scientists are widespread and numerous for many taxonomic groups and appropriate use of these data in research and management is growing (application requires careful consideration of the methodology and interpretation). As the temporal extent of iNaturalist data grows, observations may increasingly be used to estimate trends in biodiversity over time (such as tracking occurrence over time). The BioBlitz or ReefBlitz methodology, where data is collected within a short time period of 2–8 days rather than 365 days, may be an opportunity to increase rigour of sampling and reduces biases.

CS in Australia yields financial benefits by leveraging free community data collection to offset costs. We estimated annual benefits based on daily observer effort of AUS $120,500–172,500 per annum. This figure is increased to AUS $216,018–246,566 if an annual economic benefit per volunteer of $2182 pa [47] through avoided healthcare costs due to increased health and resilience from environmental volunteering is included.

4.2. Limitations

Numerous community (or citizen) science datasets have low frequency sampling, low resolution taxonomy, limited species monitored, poor or undocumented sampling rigor and or quality control, a time lag between observations, identification and reporting, and or the data is not available to the public [15,22].

A limitation of the study was selection of appropriate baseline data [15]. A relatively recent baseline collated over a 10 year dataset from iNaturalist for the period 2013 to 2022 is not independent. Ideally, a longer or older baseline of 50–250 years ago would be preferable before major impacts of fishing and global warming. We investigated and rejected other potential fish biodiversity baselines associated with the Atlas of Living Australia (due to errors in species) and different methodologies [47–49]. A future opportunity is to expand the iNaturalist 10-year baseline data is a multi-disciplinary inventory of fish species from the region, similar to Russell [50].

Careful consideration must be given to biases in the iNaturalist data set in these applications, including increasing numbers of observations over time and seasonality of observations within years. Even comparing relative, instead of absolute, abundance between species may be difficult using these data without accounting for differences in ease of detection and documentation [51].

One of the challenges for spatial data is grouping or splitting data from regions to subregions because finer scales generally have less abundant data. Our working hypothesis for fish biodiversity and report cards is that less than 500 observations per spatial area provides low confidence, 500–1000 observations provide medium confidence and 2000 plus observations provide high confidence in report card scores for fish biodiversity.

5. Conclusions

Our citizen science method, using iNaturalist, is a novel approach to demonstrate the potential for a social media platform to contribute to education and knowledge of marine fish [4,5,36]. Our pilot study of the utility of marine fish biodiversity data for developing reef fish ecological health and people (stewardship) indicators for waterway health report cards in the GBR region has potential for community, science and government to collaborate, share knowledge and improve stewardship.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/fishes10110547/s1, Supplementary S1. QUIZ—Fish Species of the Great Barrier Reef.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of REEF ECOLOGIC (2024).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Summary data is available here: 2013–2022 FishWatch Townsville Baseline. https://inaturalist.ala.org.au/projects/fishwatch-townsville-baseline, accessed on 20 July 2025; 2023 FishWatch Townsville Report Card. https://inaturalist.ala.org.au/projects/fishwatch-townsville-report-card-2023, accessed on 20 July 2025; 2024 FishWatch Townsville Report Card: https://inaturalist.ala.org.au/projects/fishwatch-townsville-report-card-2024, accessed on 20 July 2025; 2025 FishWatch Townsville Report Card. https://inaturalist.ala.org.au/projects/fishwatch-townsville-report-card-2025, accessed on 20 July 2025. More detailed data on zones is also available on request.

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Conflicts of Interest: The authors have no declared conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

HWPDT	Healthy Waters Partnership for the Dry Tropics
CS	Citizen Science
GBR	Great Barrier Reef
eDNA	Environmental DNA
POISE	Proportion Of Indigenous Species Expected

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