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1 Acknowledgments

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2 Executive summary

Coral reefs have immense ecological, economic and cultural values including important fisheries and tourism values, and provide essential goods and services for more than 300 million people in coastal communities in Southeast Asia and globally. However, coral reefs are declining globally due to increasing disturbances from human activities including destructive fishing and climate change, as well as periodic natural disturbances. The accelerating loss of foundation reef-building corals that create the hyperdiverse reef ecosystems has created a global coral crisis. Up to 95% of coral reefs in the Philippines and other Southeast Asian countries are badly degraded or highly threatened by human activities, which compromises food security, income and welfare of coastal communities that are highly dependent on healthy reefs.

In response to the rapid loss of reef corals and increasing reef degradation, intense research is focusing on active coral restoration interventions aimed at restoring healthy foundation coral assemblages and reef function. Previous and current ACIAR supported projects (ACIAR FIS/2011/031, FIS/2014/063, FIS 2019/123) have enabled pioneering research that has successfully re-established multiple breeding populations of reef corals on highly degraded reefs in the Philippines within 2-3 years using millions of coral larvae to enhance larval supply, recruitment success and coral recovery. As predicted, these ACIAR project outcomes have also resulted in increases in reef fish abundance and fish species richness in some of the older replicate experimental larval-enhanced plots as coral colonies and populations grow to restore coral dominance on the reef areas, whereas, no significant recovery has occurred on control plots reliant on greatly diminished natural larval supply. While many reef fishes are highly dependent on specific coral microhabitats and species richness is often highly correlated with coral cover and structural diversity, empirical evidence quantifying the changes in fish assemblages and fish stocks on restored reefs is very limited. During the mid-term review of the ACIAR FIS/2014/063 project, it was recognised that there was a need to expand the scope of the fish assemblage monitoring program to quantify fish assemblages and fisheries resources and trends in additional larger reef areas.

Accordingly, this SRA project **aimed** to establish long-term monitoring and evaluation of the impacts of coral restoration on fish assemblages and other reef resources in the northern Luzon region, Philippines. The research objectives were:

- Objective 1: Quantify and compare fish communities, coral cover and reef status in remaining healthy reefs in Anda, northern Luzon, reef areas currently being restored through the ACIAR/FIS/2014/063 project, and nearby degraded reef areas, to establish 'targets' for fish populations on restored reefs.
- Objective 2: Work with local low-income fisher communities to quantify catches from local reef fishing activities, determine which fish are used for local family and community consumption versus fish sent to market and their values to low-income fishers and inclusion in the fish market chain. Outcomes from this research will establish a baseline to assess the importance of coral habitat restoration options on improved fishing outcomes.
- Objective 3: Develop a multimedia and training strategy to effectively communicate the outcomes from this project to all stakeholders including local communities, governments and the public to highlight the importance of coral reef restoration for improving the socio-economic and ecological values of restored reefs.

The Project has successfully achieved significant outcomes for the three Objectives and these are briefly summarised below, and detailed in the previously submitted Project Research Reports and ACIAR Annual Reports, and in Gomez et al. (2024) published in *Ocean and Coastal Management*.

Objective 1: The research team established detailed monitoring protocols for fish assemblages and reef benthic assemblages in 2018 and continued monitoring surveys through to 2022. The project research also expanded beyond the original plan to encompass a total of ten reef trials with replicate experimental restoration and control plots in Magsaysay Reef, Caniogan Reef, and the Hundred Islands National Park, associated with expanding restoration outcomes from the ACIAR FIS/2011/031 and ACIAR/FIS/2014/063 project. Experiment plot sizes ranged from smaller-scale 4 x 4 m and 5 x 5 m plots in the initial pilot studies up to 20 x 50 m and 1 hectare plots, with additional comparisons of fish assemblages in remnant healthy reefs with high coral cover and in other degraded reef areas with very low coral cover.

Fish assemblages were quantified using diver-based Underwater Visual Census (UVC) to quantify fish species present, counts, and sizes in plots using modified stationary point counts, or transect surveys in larger plots. Trends in fish assemblages varied between experiments and reef locations and over time. Stronger trends were evident in plots that had been established over longer periods. Overall, trends in fish assemblages varied significantly between some but not all years, and higher abundance was recorded in larval-enhanced plots compared with control plots in some but not all reef trial locations.

Fish abundance and in some cases fish biomass tended to increase over time. These metrics were higher in larval-enhanced plots compared with controls in some reef trials. Fishes in surveyed plots tended to be dominated by damselfishes and wrasses, with corallivore butterflyfishes increasing over time as coral colonies and cover increased in restored reef areas. Roving parrotfish and rabbitfishes were abundant in some plots during the surveys, with surgeonfishes, snappers, coral breams and groupers also present in some surveys. Trophic groups were dominated by benthic invertivores and herbivores with smaller numbers of detritivores, corallivores and piscivores present. Mean abundance of commercially targeted fish species varied between treatments and over years, but target fish tended to be more abundant in larval-enhanced plots compared with controls in 2019 and 2020 in longer-established restoration sites. These results indicate that mass coral larval restoration not only increases coral population recovery and initiates reef restoration, but also positively influences fish assemblages including mean fish abundance and some aspects of species and trophic composition. These observed changes in fish assemblages have potential benefits for reef ecology and fishery values and associated socio-economic benefits for local communities.

Although highly significant increases in mean coral abundance and cover were evident over time in larval-enhanced plots compared with control plots in the initial reef trials, the low degree of replication and relatively small plot sizes, combined with highly mobile and often transient occurrences of many fish groups, resulted in mostly non-statistically significant differences in fish assemblage trends between treatments. Furthermore, although these restoration and control areas are within Marine Protected Areas (MPA), there is substantial ongoing fishing pressure from mostly non-selective fishing activities occurring within the MPA and surrounding areas; hence, evaluation of the changes in reef fish assemblages is confounded by these unregulated chronic fishing pressures. Future larger scale restoration areas are likely to result in more consistent trends in reef fishes where fishing pressures are reduced or removed such as in the Hundred Islands National Park sites. Increased replication would also provide stronger statistical power to evaluate changes in fish assemblages over time and between treatments.

Objective 2: Detailed surveys of fisheries operations and fisher perceptions were completed with 53 fishers to provide a baseline profile of the fisheries in Barangay Tondol, Municipality of Anda, the village closest to the Magsaysay Reef ACIAR project coral restoration sites. Local government staff estimate that approximately 30% of the population work in the agricultural sector as fishers, farmers, or both. Interviews were completed using a comprehensive, semi-structured questionnaire that included demographics, fishing gears and practices, fish catch and dynamics, economics, and knowledge of legal guidelines. This was followed by a separate Likert-type test that surveyed fishers' perceptions on historical fish catch, coral reefs and conservation, and coral restoration at the end of each interview session.

Survey results for the Tondol fishery showed an average daily catch of 6.6 kg per fisher during "Habagat" (Southwest Monsoon, June - September) and 7.2 kg during "Amihan" (Northeast Monsoon, November - February). This equates to an estimated total catch of 28 t for Habagat and 32 t for Amihan, or a combined 60 t catch for the two monsoon seasons. The fishery is dominated by use of gill nets (bottom-set and drive-in) followed by hook and line, spear, and traps. An average of 75 fishing days were used during Habagat, and around 79 days during Amihan. Catch composition is more diverse for gill net and multiple gear users compared to line and spear fishers. The waters around Tondol are well-utilised by fishers using a range of different fishing gears, with the most frequently used fishing locations being deeper reef areas and the channels between sandbars using bottom set gill nets, lines, large traps and other fishing gears. The sandy lagoons are frequented by line and net fishers as well as for some trap fishing, while the seagrass beds are particularly used for drive-in gill nets to catch rabbitfish. Fish catch is mostly composed of various coral reef species including fusiliers, soldierfishes and emperors, with a specific target for rabbitfish, and some pelagic species including tuna, mackerel and jacks. About 43% of the catch is usually used for personal and family consumption while the rest is sold to the local community (27%) or in other markets (30%) such as the central market in Anda and in Bolinao, Alaminos, and Dagupan areas through agents. Income is low at an average of 5,200 PHP (~$133 AUD) per month. Half of the respondents are fully reliant on fishing for their livelihood, with no alternative livelihood. Very few fishers report getting support from government, NGOs or other groups. Interviewed fishers had varying levels of knowledge about fisheries-related issues including allowed areas for fishing, restricted species, open and closed fishing seasons, and prohibited methods. Only a small proportion of the fisher community had good understanding about these important issues. This highlights the need for and the opportunity to improve dialogue between local fishers, government, and management authorities on fisheries, as well as the need for more information and education campaigns for fishing communities to improve fisheries knowledge.

Surveys of fishers' perceptions revealed important insights about trends in their fisheries catch, coral reef status and importance, and their knowledge of and perceptions about coral restoration activities. The surveys also explored the influence of fishers' social demographics and fishery information on their perceptions. The outcomes from this research have been published in Gomez et al. (2024) and are summarized below. The responses of fishers showed a perceived decline in fish stocks in their fishing areas over the last 5–10 years that were mainly attributed to overharvesting, and a slight improvement in coral reef condition due to a reduction in destructive fishing. These perceived changes in fish stocks were largely attributed to human activities including increases in the numbers of fishers, and some aspects of the fisheries data and fisher perceptions indicate some degree of local overfishing, and other fishing malpractices including the use of fishing gears that are not recommended. These perceptions highlight the increasingly urgent need to better assess and manage fish stocks and other resources.

Out of the 53 fisher respondents, 72% were aware of coral restoration efforts in their area resulting from previous community engagements and discussions about coral restoration activities by the ACIAR projects teams. They also held positive perceptions about coral restoration actions that they thought could theoretically improve their fish stocks and local reef conditions through the provision of restored fish habitat functions. Perceived effectiveness of the local coral restoration efforts was also positive, but elicited a lower number of responses. Multiple hierarchical regression tests showed that, among social demographics, fishery information, and perceptions on fish stocks, perceived improvement in coral condition was associated with stronger support for coral restoration activities by the community. These findings indicate that local fishers in Barangay Tondol perceive positive effects of coral restoration for improving local coral status and fisheries.

Most of the interviewed fishers had an ecological understanding of the mechanisms by which increased coral and fish habitat recovery can positively influence fish stocks available for fishing, but most fishers were not aware of any obvious changes resulting from the small-scale coral restoration pilot study trials on Magsaysay Reef. Furthermore, most fishers indicated that they did not have opportunities to interact directly with the coral restoration activities and the recent larger-scale restoration reef trials because the restoration sites occur within MPAs that are supposed to be protected from fishing. This reinforces the need to continue to expand the previous communication and engagement plans for the coral restoration projects with participation by local fishers and early engagement with all stakeholders including other community groups, to build local reef restoration networks that will sustain the restoration outcomes in future.

Objective 3: The ACIAR project researchers developed an effective multimedia and stakeholder training strategy to transfer knowledge to stakeholders about the importance of coral reefs, the essential roles of healthy coral assemblages and fish habitats, coral reproduction and the successful outcomes from the ACIAR projects larval restoration reef trials, and fisheries management issues. Team members initially developed and presented training and capacity building workshops in 2018 and 2019, including presentations on reef fish and fisheries issues at two coral reef restoration and policy guidelines workshops organised by the ACIAR projects teams during September 2018 at Alaminos City, attended by 112 participants. An important outcome from that workshop was an agreement between Alaminos City and Anda to draft a joint resolution to patrol and catch illegal fishers in their waters, with the help of the Coast Guard and Police. The second workshop also provided training and information for 53 participants including fishers, boat and tourism operators and Barangay officials of Alaminos and Anda. Lectures and training information on reef fish and fisheries issues were also presented at a BML workshop in May 2019, attended by 15 Local Government Unit (LGU) representatives, and at meetings with various stakeholders during 2019. This workshop included staff from the Local Government of Alaminos City and the Protected Areas Management Bureau (PAMB) who co-manage the Hundred Island National Park. Additional workshops were planned for 2020 but were postponed due to COVID-19 pandemic restrictions, hence additional project presentations were included in stakeholder engagement meetings in 2021 and 2022.

Project information and key outcomes were also presented at national and international conferences and meetings including the 15th National Symposium on Marine Science in 2019 and in 2023, in team presentations at the Australian Embassy in April 2019 and in a presentation by Harrison to the Policy Advisory Council and ACIAR Commission meeting in Townsville during September 2019, which showcased the results from the combined ACIAR coral restoration and fish habitat projects in the Philippines. Project outcomes were also included in a presentation at the International Coral Reef Symposium (ICRS) in Bremen, Germany in July 2021 and presented at the 17th Philippine Association of Marine Science Symposium in Batangas and the 5th Asia-Pacific Coral Reef Symposium in Singapore in 2023. Project multimedia activities included establishing a strongly-engaged following on Facebook, with many posts being viewed by thousands of people, and strong presence on Instagram. High-quality images and video sequences taken by project members were used to create an electronic media pack to support and enhance media coverage, including 360-degree video of researchers investigating a coral restoration site that was posted on the main ACIAR Facebook page. The Project team prepared an electronic media pack housed online on Dropbox for the ACIAR Communications team in Canberra, and supplied project images to the larval restoration section of the global Coral Restoration Consortium image website. The ACIAR coral restoration projects have attracted important news coverage and media interest, including being highlighted in international BBC documentary television broadcasts and other international documentaries.

3 Background

Coral reef ecosystems have immense ecological, economic and cultural values worth $billions to national economies (Burke et al. 2011, Constanza et al. 2014, Souter et al. 2021). Healthy reefs are characterised by extraordinary hyperdiversity, high productivity and fisheries values, tourism values, and provide other essential goods and services for more than 300 million people in coastal communities in Southeast Asia and other reef regions globally (Birkeland 1997, Licuanan et al. 2019, Knowlton et al. 2021). However, coral reefs are declining globally due to increasing chronic impacts from human activities interacting with natural disturbances resulting in periodic decimation of foundation reef-building scleractinian corals that create the reef structure and provide essential habitats for most reef organisms (Harrison and Booth 2007, Hoegh-Guldberg et al. 2017, Hughes et al. 2018). Reef degradation jeopardises essential fish habitats and overfishing compromises important fish populations and other food resources, compromising food security, livelihoods and incomes for coastal communities that directly depend on healthy reefs. Unsustainable reef impacts are most severe in Southeast Asia where nearly 95 percent of coral reefs are threatened by human activities and about 50 percent of these reefs are in the high or very high threat categories, with Indonesia and the Philippines having the largest areas of threatened reefs (Wilkinson 2008, Burke et al. 2011, Licuanan et al. 2019, Souter et al. 2021). However, coral reef decline and loss is a global problem relevant to all nations with significant coral reef areas including Australia, where >50% loss of corals on the Great Barrier Reef (GBR) has occurred over recent decades, exacerbated by multiple marine heatwaves and severe mass coral bleaching and mortality events in 2016, 2017, 2020, 2022 and again in 2024 (De'ath et al. 2012, Hughes et al. 2018, Souter et al. 2021, Huang et al. 2024).

In response to the global coral reef crisis, increasing research has focused on active coral restoration interventions to restore healthy foundation coral assemblages and reef function (reviewed in Omori 2019, Bostrom-Einarsson et al. 2020, Vaughan 2021, McLeod et al. 2022, Harrison 2024). Previous and current ACIAR supported projects (ACIAR FIS/2011/031, FIS/2014/063, FIS 2019/123) have successfully re-established multiple breeding populations of reef corals on highly degraded reefs in the Philippines using millions of coral larvae to enhance larval supply, settlement and recruitment on reefs lacking sufficient natural larval supply for recovery (Harrison et al. 2016, 2018, 2021a, 2021b, 2023, dela Cruz and Harrison 2017, 2020, Harrison and dela Cruz 2022). In addition to successfully restoring breeding coral assemblages, the ACIAR project outcomes have resulted in increases in reef fish abundance and increased fish species richness in the experimental larval enhanced plots containing restored coral populations, compared with control plots where coral restoration has not occurred (Harrison et al. 2018, 2021a, 2023). This result was expected, as it has been well established that many reef fishes are highly dependent on specific coral microhabitats and abundance, and species richness can be highly correlated with coral cover and structural diversity (Sale 2002, Jones et al. 2004, Wen et al. 2013, Mora 2015, Russ et al. 2021). However, empirical evidence quantifying the changes in fish assemblages and fish stocks on restored reefs is limited (Ladd et al. 2019, Harrison et al. 2021a). Accordingly, during the mid-term review of the ACIAR FIS/2014/063 project, it was recognised that there was a need to expand the scope of the fish assemblage monitoring program in that project, to quantify fish assemblages and fisheries resources and trends in additional larger reef areas.

Assessing coral and fish habitat restoration outcomes is increasingly important for Australia and the Philippines as both nations have some of the largest coral reef areas in the world (Burke et al. 2011), but these reef systems are increasingly threatened by larger-scale changes in climate and ocean systems and some chronic human impacts including destructive and overfishing in some areas of the Philippines (Hoegh-Guldberg 1999, Licuanan et al. 2019, Souter et al. 2021). The importance of this issue for both Australia and the Philippines is recognised by the 'Memorandum of Understanding between the Philippines and Australia on Coral Reefs', which specifically recognises that "Australia and the Philippines are collaborating on projects that seek to restore coral reefs in the Philippines using coral larval reseeding", referring to the results from the previous and ongoing ACIAR Coral larval restoration projects. Coral reefs in the Philippines are a key part of the 'Coral Triangle' that has the highest diversity of corals, fish and other reef biota in the world (Carpenter et al. 2011, Licuanan et al. 2019). However, the Philippines has more than 1 million ha of degraded reefs, with a high proportion of reefs in the high or very high threat categories (Wilkinson 2008, Burke et al. 2011, Souter et al. 2021), therefore ongoing declines and loss of functional coral reefs and fish assemblages are inevitable unless reef restoration is implemented at larger scales. Reef fish and other fish provide a major part of the diet for many Philippine communities, and blast fishing and other forms of unsustainable fishing have resulted in reef degradation and declines in fisheries resources in many regions (White et al. 2000, Cruz-Trinidad et al. 2011, Licuanan et al. 2019). The research from this project is also strongly aligned with the Philippine government funding and implementation programs to develop techniques to restore damaged reefs. Similarly, the World Heritage Great Barrier Reef (GBR) and other coral reef systems are very important in Australia, which has the second largest area of coral reefs globally (Burke et al. 2011), and about 75% of Australia's reefs are managed within MPAs. Despite the high degree of MPA protection and active management of Australia's reefs, ongoing declines have been accelerating due to impacts of climate change and mass coral bleaching, severe cyclones and crown of thorns coral-predator outbreaks (De'ath et al. 2012, Hughes et al. 2018, Souter et al. 2021), and recent recovery of *Acropora* and other fast-growing corals on some reefs has effectively been negated by the 2024 mass coral bleaching event. Therefore, larger-scale active reef restoration is also recognized as being increasingly important for reef recovery and management in Australia. In response to ongoing GBR coral crisis, the Australian Government invested substantial funding for the multidisciplinary Reef Restoration and Adaptation (RRAP) program to design large scale reef restoration processes, and reef restoration will be expanded throughout the GBR in the future.

Clearly, both nations require further targeted research to more effectively manage and actively restore degraded coral reefs, improve ecosystem function and quantify the impacts of reef restoration activities on fish populations and other reef ecosystem goods and services. This provides the rationale for this ACIAR SRA Project, and the research is designed to address the following questions:

- What are the impacts on reef fish abundance and species richness of successful coral restoration on degraded reefs, and how do these fish community attributes compare with fish communities in healthy reef areas versus degraded reef areas?
- What are the appropriate 'targets' for fish abundance and species richness on actively restored reef areas, to assess the effectiveness of coral restoration activities on fish communities and potential food resources for local communities?
- What fish catches (species, numbers and sizes of fish caught) currently occur on the predominantly degraded reef areas, and what fish are used for local family and community consumption versus fish sent to regional markets?
- How can the outcomes of the fish community and reef restoration surveys be most effectively communicated to relevant stakeholders including reef management authorities and government departments, local governments, local communities and low-income fishers, to enable adaptive planning for improving long-term management of coral reef resources?

4 Objectives

The **aim** of this project was to establish long-term monitoring and evaluation of the impacts on fish communities and other reef resources of coral restoration in the northern Luzon region, Philippines.

4.1 Objectives

The three specific objectives for this SRA project were:

Objective 1: Quantify and compare fish communities, coral cover and diversity, reef status and trends in the few remaining areas of healthy reefs in Anda, northern Luzon, larger reef areas currently being restored through the ACIAR FIS/2011/031 and ACIAR/FIS/2014/063 projects, and nearby degraded reef areas, to establish 'targets' for fish populations on restored reefs. These larger scale sites will include reef areas that are currently within MPAs and adjacent areas outside of designated MPAs, to evaluate the effectiveness of current protection regimes.

Objective 2: Work with local low-income fisher communities to quantify catches from their local reef fishing activities and determine which fish are used for local family and coastal community consumption versus fish sent to market and their values to low-income fishers and their inclusion in the fish market chain. This will establish a baseline against which the importance of coral habitat restoration options on improved fishing outcomes and future trends can be assessed.

Objective 3: Develop a multimedia and training strategy to rapidly and effectively communicate the outcomes from this SRA project to all stakeholders including local rural coastal communities, local governments, reef managers and national government departments in the Philippines and Australia, coral reef researchers and the broader public to highlight the importance of coral reef restoration for improving the socio-economic and ecological values of restored reefs. This will enable effective adaptive planning for improving long-term management of fish and other coral reef resources. The communication strategy will be developed in partnership with multimedia professionals, and educators from local communities to increase outreach and public access to the research findings and to highlight the national and international significance of the SRA project outcomes.

5 Methodology

Research for **Objective 1** included establishing detailed quantitative fish and reef benthic survey and monitoring designs in 2018 and 2019, building on and extending the monitoring program for the related ACIAR FIS/2011/031 and ACIAR FIS/2014/063 coral larval restoration and fish habitat projects. The monitoring program for this SRA project was continued through to 2022, with longer-term monitoring occurring as part of the current ACIAR FIS/2019/123 regional coral restoration networks and fish habitat restoration project.

The SRA reef fish quantitative survey and monitoring design was finalised in 2019, and reef fish surveys were expanded to include all of the ACIAR coral larval restoration sites and experiments. Survey sites included all of the initial larval restoration and control plots on Magsaysay Reef starting with the *Acropora tenuis* 2013 pilot study (dela Cruz and Harrison 2017) and subsequent reef trials using *Acropora tenuis* 2016 (Harrison et al. 2021), *A. loripes* 2014 (dela Cruz and Harrison 2020), and *A. millepora* (2018), the experiment plots in Macapagal and Quezon Islands in the Hundred Islands National Park (2018), and the larger scale larval restoration plots and associated controls from the March and April 2019 larval experiments in Caniogan Reef, Anda, and Braganza Island in HINP (Figure 1). Two fish survey techniques were used to align with the different spatial scales of the larval restoration experiments, and surveys were completed annually by two observers: BML fish expert Fernando (Jun) Castrence for the longer-term Magsaysay restoration trials, and by Rickdane Gomez for the rest of the sites, to limit observer bias and maintain data consistency.

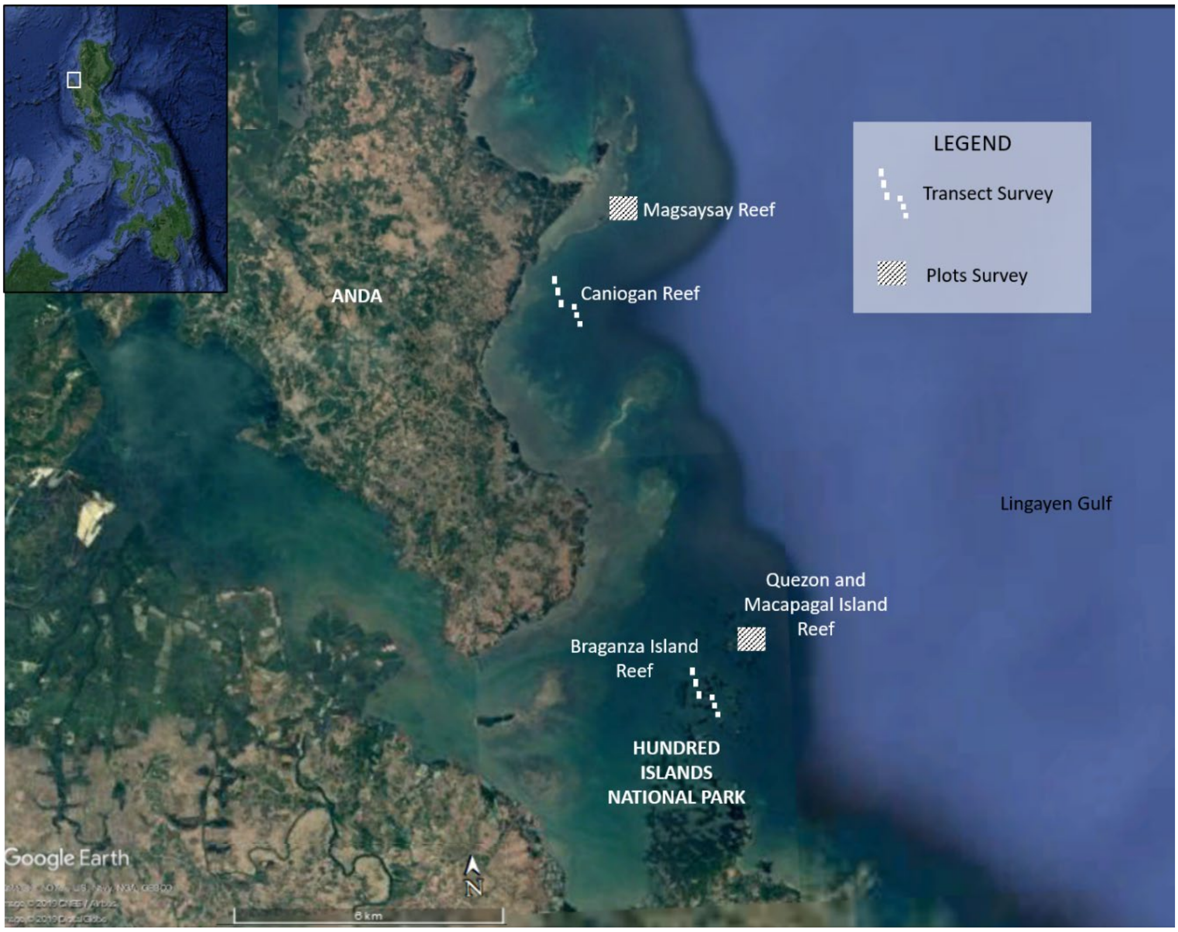

Figure 1. Locations of the experimental coral restoration plots and transect locations for fish monitoring in Anda and Hundred Island National Park, northwestern Philippines (Map image source: Google Earth).

Smaller larval restoration experimental plots - Stationary point-counts

To determine the effects of coral larval restoration outcomes on fish assemblages, modified Stationary Point-Counts (Bohnsack and Bannerot 1986) were used to survey the smaller (24-25 m^2) coral restoration experimental plots established in 2013, 2014 and 2016 at Magsaysay Reef (n=11) and equivalent control plots. These experimental plots were established during the previous ACIAR SRA and FIS Coral larval restoration projects using *Acropora* species for the larval restoration trials (Harrison et al. 2016, 2018, 2021a, 2021b, dela Cruz and Harrison 2017, 2020). The survey design was expanded to include two levels of controls, a treatment control with similar conditions to the larval restoration plots but without coral larvae added (n=10), and a healthy reef control (n=10) established at Magsaysay Reef (Figure 1) to reduce the chance of site-specific differences confounding comparisons from the study. This fish survey method was also used for the 2018 restoration trials using *Acropora tenuis* in 25 m^2 plots (n = 9) and control (n = 3) plots in Macapagal Island Reef as well as for the 49 m^2 plots (n = 3 each for treatment and control) and 80 m^2 plots (n = 1 each for treatment and control) using mixed species of *Favites colemani* and *Acropora tenuis* in Quezon Island Reef in the Hundred Islands National Park. Fish species richness, abundance, estimated biomass and fish composition were quantified using the Point-Count Method and the outcomes are reported here. The reef benthic surveys and percent coral cover and benthic community composition were assessed from photo quadrats and analysed using CoralNet (Beijbom *et al*. 2015) and were reported in ACIAR FIS/2014/063 reports.

Larger larval restoration experimental plots - Permanent belt transects

To survey larger-scale restoration areas, permanent belt transects for monitoring were established in Braganza Island Reef and Caniogan Reef. Three 25 m-long by 5 m-wide belt transects were established in each of the two treatment and two control plots (1250 m^2 each) in Braganza Island, while five 25 m-long by 5 m-wide belt transects were established in each of the three treatment and three control plots (1 ha each) in Caniogan Reef fish species richness, abundance, biomass, and fish assemblage composition were obtained from fish data collected using Underwater Visual Census (UVC) following the Reef Life Survey Protocols (Edgar and Stuart-Smith 2014). Percent coral cover and benthic composition were assessed from photo quadrats and video transects and were analysed using CoralNet.

Fish biomass (W, in grams) per individual was calculated using the formula $W=aL^b$; where L is the estimated total length of the fish and a and b are published length-weight coefficients for fish species available through FishBase (Froese and Pauly 2023). Information on fish families, trophic groups, and economic/ecological significance were sourced from a database compiled by various fish researchers partly derived and regularly updated from FishBase. Data on fish species richness, abundance, and biomass were analysed using General Linear Models (GLM). Significant results were further analysed with Tukey's HSD (Honest Significant Difference) to detect significant differences in each pairwise comparison. Tests for normality and homogeneity of variance were accounted for using Shapiro-Wilk and Levene's Test. Statistical tests were completed using Statistica Software (TIBCO Software Inc., 2023).

Methods for **Objective 2** included an initial pilot study survey of fishing gears used by local fishers and fish catch surveys that were completed at Tondol Beach near Magsaysay Reef, Anda, northwestern Philippines in September 2018 and March 2019, respectively. Tondol Beach is a small fishing village nearest to the Magsaysay Reef coral restoration areas (Figure 2). Initial inventory surveys involved interviewing three local fishermen, a fisheries organisation leader, and local government officials in Barangay Tondol, and from the Municipal Agriculture Office (MAO). Pilot surveys for fish catches involved interviewing six local fishermen on the beach as they returned from their fishing activities. These preliminary surveys aimed to identify gear used in the fishery, commonly caught fish species, fishing schedules, and landing areas.

The pilot study information was used to develop the designs for the subsequent larger detailed surveys reported below and in Gomez et al. (2024). Preliminary data revealed the use of small barrier and gill nets, fish traps, and spears as the most common methods used to catch fish. Fish catch comprised mostly of small reef fishes (e.g., soldierfish, goatfish, surgeonfish) and medium sized fishes (e.g., fusiliers, snappers, emperors). Some of the fish species caught and the gear usage patterns were mostly influenced by seasonality and catch restrictions (e.g., catching rabbitfish during the open season, use of fish traps during the northwest monsoon). Most of the catch was used for subsistence, especially for fishers using rafts; whereas, fishers on boats sold part of their catch to the local community or to agents in the fish market supply chain (Gomez et al. 2024).

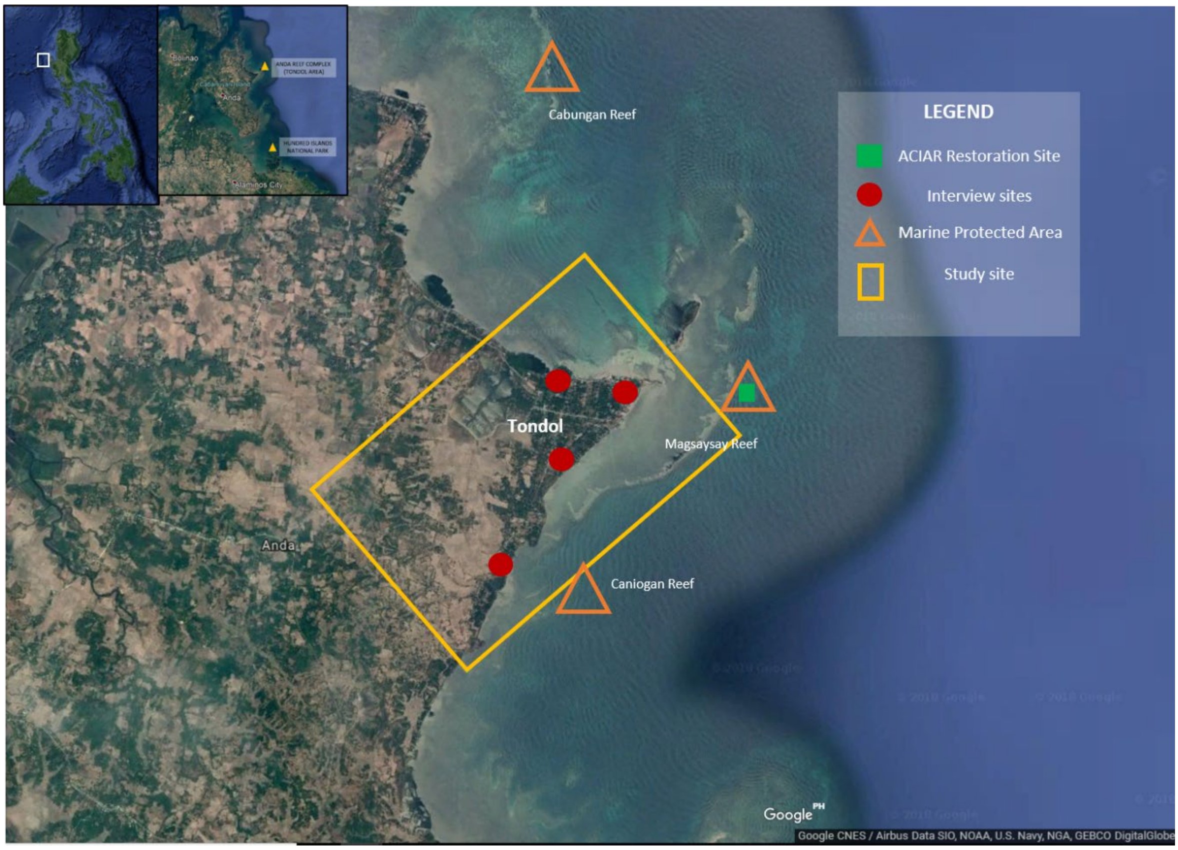

Figure 2. Barangay Tondol location and study sites used for the fisheries survey. Proximity to Magsaysay Reef restoration areas (in green) and Marine Protected Areas (orange triangles) are shown (Map image source: Google Earth).

Information from the pilot surveys was used to develop the full study design for the fisheries component with the help of Dr. Samuel Mamauag, local fisheries expert from the from the Marine Science Institute, University of the Philippines. Three different surveys were used to address the key objectives:

- a landing survey to quantify fish catch and composition
- a market survey to determine contributions of local fisheries to fish markets and to compare species caught and sold versus species found in the restoration sites
- an individual fisher survey to supplement information from the landing surveys and assess the perceptions and values of fish catch and coral restoration to local families and coastal communities (Gomez et al. 2024).

The survey plan involved landing surveys to be completed twice per year to cover seasonal variation, and coupled with market visits and surveys. Expert review of the individual fisher survey questionnaires was provided by Dr. Margaux Hein and Dr. Amy Diedrich from James Cook University, and by Dr. Samuel S. Mamauag (UP).

To provide a baseline profile of the fisheries in Tondol, which is the village closest to the Magsaysay coral restoration sites (dela Cruz and Harrison 2017, Harrison et al. 2016, 2021a), a total of 53 fishers were surveyed in August 2019. Tondol is around 0.15 km^2 and has a population of about 3,190 (Philippine Statistics Authority 2020). Fishing, farming, and tourism serve as the main livelihoods, and the total number of fishers in the Tondol area is not precisely known as fisher occupation is not specified in the census process, but local government staff estimate that approximately 30% of the population (~ 880 people) work in the agricultural sector as either fishers or farmers, or both (E. Tomas 2020, pers. comm.). Prior to conducting the surveys, courtesy visits were made to the municipal and barangay government offices to introduce the project activities and methods, and to seek permission from authorities.

A team of five enumerators from the ACIAR Coral Restoration and Fish projects and staff from the Municipal Agriculture Office (MAO) of Anda conducted house-to-house surveys in different sections of the village to include fishers in each locality (Figure 3). Respondents were determined through ‘snowball’ sampling wherein each subsequent respondent was chosen upon recommendation by the previous interviewee or as they were encountered by the enumerators, prioritizing households that had visible fishing gear or equipment. Respondents were targeted towards on-water fishers and gleaners or post-harvest actors were excluded, and questionnaires covered fisher demographics, vessels and gear used, fishery outputs (i.e., daily catch, fishing days, income), and their perceptions on fish catch, coral reef conditions, and coral restoration efforts (Gomez et al. 2024). Enumerators were fully briefed on the survey process and the questionnaires to standardise data collection. Respondents were also briefed about the study and were asked for verbal consent prior to conducting any of the interviews. Each interview lasted about 30 to 45 min, and then Respondents were debriefed after the interviews and provided with answers to any questions they might have. Questionnaires were produced in both English and Filipino but were only administered in Filipino. Locals in Tondol mainly speak the Bolinao language, along with other languages as Ilokano and Tagalog/Filipino, and a local guide aided in the translation from Bolinao to Tagalog/Filipino and vice versa when needed (Gomez et al. 2024).

Figure 3. Survey team members walking through rice paddies to reach houses of fishers around Barangay Tondol. Photo Dexter Dela Cruz.

Perceptions were tested through a combination of closed questions (i.e., Yes/No) and Likert-type items scaled from 1 through 5, with 3 as the neutral score and scores closer to 1 indicating increasing negative response and scores closer to 5 indicating increasing positive response. Questions that were answered with “I do not know” or preferred to not be answered by the respondent were scored with 0 and were excluded from the analyses of each question. The survey questionnaire was divided into seven sections to cover key aspects of the fishery including fisher demographics, gears, catch, fishing effort, fishing area and reef use, other aspects such as economics and legal restrictions. These surveys were followed by a three-part Likert scale type survey to test fishers’ perceptions about historical fish catch, coral reefs and conservation, and coral restoration efforts in their area (Gomez et al. 2024). Numerical values obtained for catch, effort, and income and expenses were based on respondent’s estimates. Fishing areas and reef use were visualized by allowing respondents to pinpoint their usual fishing grounds on a laminated grid map and label it with a marking pen. Illustrated maps were then photographed and catalogued per gear for data organization. Fish species and taxa mentioned in local language were identified by the respondents using a fish catalogue. Other information was based on fishers’ Local Ecological Knowledge (LEK). The questions covered the two monsoon seasons (Habagat or Southwest Monsoon from June to September and Amihan or Northeast Monsoon from November to February) corresponding to fishing seasons over 8 months of the year (Gomez et al. 2024).

Mean demographics (e.g., age) and fishery outputs (e.g., annual catch) per category within fisher groupings were tested using One-Way ANOVA, Kruskal-Wallis Test, or Mann-Whitney U Test whenever appropriate after meeting the test assumptions (i.e., normality, variance, etc.), and post-hoc tests (Tukey’s HSD or Wilcoxon Rank Sum test) were conducted to explore significant differences within pairwise comparisons. Likert scores on perceptions per fisher groups were analysed using non-parametric tests. Tests for significant difference in perceptions among fisher groups were explored using Kruskal-Wallis Test or Mann-Whitney U Test, whenever appropriate. When significant differences were detected, pairwise comparisons between fisher groups were completed using a Wilcoxon rank-sum test (Gomez et al. 2024). The influence of fisher groupings and perceptions on fish catch and coral condition to fishers’ perceptions on coral restoration efforts were explored using Hierarchical Multiple Regression (Barley Kincaid et al. 2014). Predictors were entered in each step/model to control for the effect of other variables and to test their influence on the response variable. The model with significant predictors explaining the variance in the dependent variable was then chosen as the final model (Gomez et al. 2024). All tests were conducted in RStudio (RStudio Team 2020).

For **Objective 3**, the Project team members contacted representatives from relevant stakeholder groups, and courtesy visits were made to the municipal and barangay government offices and senior Government officials including Mayors prior to workshops. Information about the ACIAR Project and invitations to project workshops and other meetings were sent to stakeholder groups, with detailed presentations about the importance and values of coral reefs and fish habitats, coral reproduction and the successful outcomes from the ACIAR projects larval restoration reef trials, and fisheries management issues provided to attendees at each meeting. Additional communication and engagement activities included research presentations at national and international conferences, publication of fisher perception data in Gomez et al. 2024, and regular updates on the ACIAR Project Facebook and Instagram accounts, and media and television documentary interviews to provide project information to the broader public.

6 Achievements against activities and outputs/milestones

Objective 1: To quantify and compare fish communities, coral cover and diversity, reef status and trends in remaining areas of healthy reefs in Anda Province, northern Luzon, with reef areas currently being restored through the FIS/2014/063 project, and nearby degraded reef areas, to establish 'targets' for fish populations on restored reefs

no.	activity	outputs/ milestones	completion date	comments
1.1	Complete detailed replicate seasonal surveys of fish communities (species, abundance and sizes), coral cover, reef status and trends in Anda Province, northern Luzon in reef sites encompassing the few remaining areas of healthy reefs, reef areas being restored through ACIAR projects activities, and nearby degraded reef areas (including sites within MPAs and adjacent areas outside of MPAs).	All planned surveys were completed from 2018/2019 until 2022, except during 2020 pandemic restrictions, and additional restoration and control sites were added to the project activities to include all larval restoration reef trial sites. These data and analyses have been provided in detailed technical reports comparing the status of fish communities and reef benthic communities on healthy and restored reefs versus degraded reefs. These research outputs will be included in publications on longer-term outcomes from larval restoration and fish habitat recovery resulting from the wide range of reef trials from the ACIAR Projects (e.g., Harrison et al. 2021)	May 2022, with subsequent ongoing surveys continuing through 2024	Extensive fish surveys were completed during 2018, 2019 and 2022 at Magsaysay Reef MPA including multiple previous and current larval restoration and control areas, and remaining areas of healthy reef, and nearby degraded reef areas. The project activities were expanded to include additional surveys at restoration sites in the Hundred Islands National Park, Alaminos City and at Caniogan Reef in the municipality of Anda. Fish assemblages exhibited variable trends in time and space, and between larval restoration and control plots. In reef areas with longer-term coral restoration outcomes, trends of higher mean fish abundance and increasing fish species richness are evident in some years and locations for larval restoration plots compared with control plots. Mean abundance of commercially targeted fish species varied between treatments and over years, but fisheries target fish species tended to be more abundant in larval-enhanced plots compared with controls in 2019 and 2020 in longer-established restoration sites. In more recently established restoration experiments, fish assemblage data are variable and require longer-term monitoring to detect significant trends. Surveys were integrated with ongoing fish assemblage monitoring in larval restoration and control plots from the 2016 *Acropora tenuis* reef trial published in Harrison et al. (2021), which showed a significant increase in fish abundance in larval plots in 2018, with higher abundance of pomacentrids and corallivore chaetodontids coinciding with growth of *A. tenuis* colonies and recovery of fish habitat complexity.

1.2	Integrate the fish survey and coral condition data to establish 'targets' for fish populations as coral conditions and reef status improves, and use these outcomes to inform the socio-economic objectives of the current ACIAR coral restoration project.	Fish survey data and benthic reef data are updated annually to enable longer-term trends to be analysed. Initial outcomes have been highlighted in stakeholder presentations and project research reports and will be included in research publications on longer-term outcomes from larval restoration and fish habitat recovery (e.g., Harrison et al. 2021). Research results were also used to inform reef recovery scenarios for the choice modelling research and socio-economic research of the ACIAR FIS 063 coral restoration project (e.g., Abrina and Bennett 2020)	June 2022, with surveys and analyses ongoing through 2024 to provide longer-term outcomes	Longer-term trends in fish and coral community data are being be integrated to establish recovery trajectory targets for reef restoration, incorporating comparisons with remnant healthy reefs and chronically degraded reef areas. Surveys at Magsaysay Reef were integrated with ongoing fish assemblage monitoring in larval restoration and control plots from the 2016 *Acropora tenuis* reef trial (Harrison et al. 2021), which showed a significant increase in fish abundance in larval plots in 2018, particularly increased abundance of pomacentrids and corallivore chaetodontids coinciding with growth of *A. tenuis* colonies and restoration of some reef fish habitats. Results of this research also contributed to developing realistic reef recovery scenarios for the choice modelling research and socio-economic research of the ACIAR FIS 063 coral restoration project (e.g., Abrina and Bennett 2020).
1.3	Prepare and publish multimedia materials detailing the fish community responses to improving reef conditions.	Fish community responses to increased coral cover and complexity on restored reef plots versus controls have been integrated into media presentations and training materials for stakeholders that are updated annually. Additional information has been provided on Facebook and Instagram multimedia posts to inform the wider community	July 2022 with ongoing regular updates through to 2024 about the latest fish survey results and project activities that are posted regularly on project social media accounts for public information	Project videos and still images have been prepared and included in teaching and stakeholder training materials, and presented at workshops and at national and international conferences including the 2021 ICRS at Bremen, with additional information provided to the wider public through media reports including television document interviews, and social media posts.

1.4	Conduct training courses with local communities, reef managers and researchers to build capacity for future fish surveys and reef restoration programs and management of fish resources.	Multiple project presentation and training workshops have been successfully completed in the Philippines attended by many stakeholders from diverse groups	June 2022	Training workshops were completed at Alaminos City in September 2018 and at BML in May and 2019 and were attended by a wide range of gender-balanced key stakeholders including fishers, managers and government staff, as well as tourism operators in Tondol. Project video and images have been used in training workshops, conference presentations and in other fora. Training courses and workshops planned for 2020 were delayed due to the COVID-19 pandemic, and further SRA project information was included in presentations and workshops in 2021 and 2022.

PC = partner country, A = Australia

Objective 2: To work with local low-income fisher communities to quantify catches from their local reef fishing activities and determine which fish are used for local family and coastal community consumption versus fish sent to market and their values to low-income fishers and their inclusion in the fish market chain

no.	activity	outputs/ milestones	completion date	comments
2.1	Quantify fish catches and fishing gear used by fishers using local reefs in the Anda Province, including seasonal trends in catches by individuals and at local landing and market sites.	Results from the fish catch landing surveys and interviews with fishers have been provided in detailed research reports and in project presentations for stakeholders and at conferences highlighting data on fish catches, gear used and seasonal trends among local fishers from Anda	Surveys completed June 2022, with background information used to support the Gomez et al. (2024) publication	Extensive surveys with local fishers and fish catch surveys were completed for this objective. Survey data showed average daily catch of 6.6 kg per fisher during Habagat (Southwest Monsoon, June – September) and 7.2 kg during Amihan (Northeast Monsoon, November – February). This equates to a total catch of 28 tonnes for Habagat and 32 tonnes for Amihan, or 60 tonnes for the two monsoon seasons combined. The fishery is dominated by use of gill nets followed by hook and line, spear, and traps, with 30% of fishers using multiple gears simultaneously or alternatively. Fish catch comprised mostly of small and medium sized demersal species and some pelagic species, with a specific demand for rabbitfish.

2.2	Determine which fish are used for local family and coastal community consumption, and which fish are sent to market and their values to low-income fishers and their inclusion in the fish market chain, and use these outcomes to inform the socio-economic objectives of the current ACIAR coral restoration project.	Outputs from this research include fisheries and fisher perception data presented in Gomez et al. (2024), which details fisher perceptions about trends in fish catches and reef condition, and reef restoration activities. Additional information on local fish consumption and market supply-chains and values has been provided in research reports and in stakeholder and conference presentations. Fisheries data were also provided to inform socio-economic analyses in the ACIAR 2014 063 project.	Initial research completed in June 2022, with ongoing data analyses and submission of paper resulting in the Gomez et al. (2024) publication completed in June 2024	Key findings from the fisheries data include outcomes showing that less than half of the fish catch (43%) is usually used for personal family consumption while the rest is almost equally sold in the local community (27%) or in other markets (30%) such as the central market and other villages in Anda, Bolinao, Alaminos, and Dagupan regions through agents. Fisher income is low at an average of 5,200 PHP (~$133 AUD) per month, with about half of the interview respondents being fully reliant on fishing for their livelihood.
2.3	Conduct short training courses on reef fish, the need for habitat protection and MPAs for improving fish production, and best practice reef fisheries management.	Multiple stakeholder training courses including details on fish habitat and reef protection, and fisheries management issues were completed in the Philippines	July 2022	Initial fisher and other stakeholder training workshops were completed at Alaminos City in September 2018 and at BML in May 2019 and were attended by fishers and a wide range of other key stakeholders. Fish catch and fisheries data were also presented in subsequent stakeholder engagement and training workshops, and in national and international conference presentations, and the research for this Objective provided the fisheries background information for the Gomez et al. (2024) publication.

2.4	Develop policy and advice for government and private sector decision makers on reef fisheries management and links to effective coral restoration strategies.	Results from the SRA research have been provided to government staff and reef managers during workshops and presentations, and the Gomez et al. (2024) publication provides further detailed commentary on the need for improved fisheries management and communication with local fishers. These outcomes and outputs provide useful information that can be used to update fisheries management policies and links with effective coral restoration strategies.	June 2022, with ongoing analyses and updated information provided in Gomez et al. (2024).	Outcomes from the fish assemblage and fisheries and market surveys provide important information about fisher operations, fish catches and fisher perceptions about reef fish declines and inadequate fisheries management processes on local reefs. These should be used to inform the development of new policy recommendations in consultation with relevant government and private sector decision makers to improve reef fisheries management and the need to consider links to effective coral restoration strategies.

PC = partner country, A = Australia

Objective 3: To develop a multimedia and training strategy to rapidly and effectively communicate the outcomes from this SRA project to all stakeholders

no.	activity	outputs/ milestones	completion date	comments
3.1	Prepare and deliver multimedia communication campaigns highlighting project outcomes for improving fish community responses arising from reef restoration and improved reef status to local, regional, national and global stakeholders.	Multimedia communications campaigns have been successfully delivered in the Philippines and Australia through stakeholder information and knowledge transfer meetings, stakeholder training workshops, social media, news stories and television documentaries that highlight the benefits of coral and reef fish habitat restoration	June 2022, with ongoing outputs through to 2024	The ACIAR Projects teams have created substantial project video and still photo imagery demonstrating the research and outcomes from the combined ACIAR projects, and a media pack was provided to the ACIAR Communications team and is available for media and outreach campaigns. These materials were showcased during the Philippine Association of Marine Science Symposium in 2023 where the project had a dedicated information booth and a special session on restoration and fisheries issues. Social media accounts have been developed and are being maintained on Facebook and Instagram, with regular project outcomes and related news updates. Media work planned with Philippines partners was delayed by the COVID-19 pandemic restrictions, but additional media reports and stories have been ongoing from 2021 through to 2024.

3.2	Conduct training courses with local communities, reef managers and researchers to build capacity for future communication campaigns about the importance of long-term management of reef fish and habitats for improving food security, human health, and well-being for coastal rural communities including women and girls.	Gender-balanced stakeholder training workshops have been successfully completed in the Philippines, and ACIAR Project team members received media training through the ACIAR Manila Office sponsored Project Communications Training in 2021, with media trainers from Micromedia DV/Sine South Motion who provided information on photography, videography and video editing, as well as story development. This capacity building process has enabled more effective communication with stakeholders and media organisations	June 2022, with ongoing media and outreach activities through to 2024	Fisher and other stakeholder training workshops were completed in 2018 and 2019 and were attended by many fishers and a wide range of other key stakeholders. Updated fish and fisheries data from the SRA Project have been presented in subsequent training workshops in recent years, and in international and national conference presentations including recent presentations at the APCRS in 2023 and 2024. In addition, the team provided fish census training and helped the Local Government Unit of Lobo, Batangas survey the fish assemblages on their local reefs in 2023.

PC = partner country, A = Australia

7 Key results and discussion

Detailed information on the research outcomes from this SRA Project were provided in ACIAR Annual Reports and Project Research Reports and in the Gomez et al. (2024) publication, with the key results summarised and discussed in this section.

Objective 1: Fish assemblages and reef restoration status

The SRA research expanded beyond the original planned activities to include fish assemblage surveys and monitoring at a total of ten reef trial sites associated with expanding restoration outcomes from the ACIAR FIS/2011/031 and ACIAR/FIS/2014/063 projects and subsequent ongoing monitoring with the current ACIAR/FIS/2019/123. Each of these reef sites in the Magsaysay Reef and Caniogan Reef MPAs, and in the Hundred Islands National Park, included replicate experimental larval restoration and control plots, ranging from smaller-scale 4 x 6 m up to 20 x 50 m and 1 ha plots (Figure 4). Additional monitoring of fish assemblages occurred in remnant healthy reefs with high coral cover and in other degraded reef areas with very low coral cover. The main experimental design was established to focus on outcomes from increasing coral larval supply to increase live coral abundance and cover and restore fish habitats, and used a relatively low degree of replication and relatively small plot sizes in the initial reef trial studies (dela Cruz and Harrison 2017, 2020, Harrison et al. 2021a). Highly significant increases in mean coral abundance and cover were evident over time in larval-enhanced plots compared with control plots in the initial reefs trials (op. cit.), however the highly mobile and often transient occurrences of many fish groups and low degree of replication resulted in non-statistically significant differences in fish assemblage trends between larval restoration and control treatments in some reef trials.

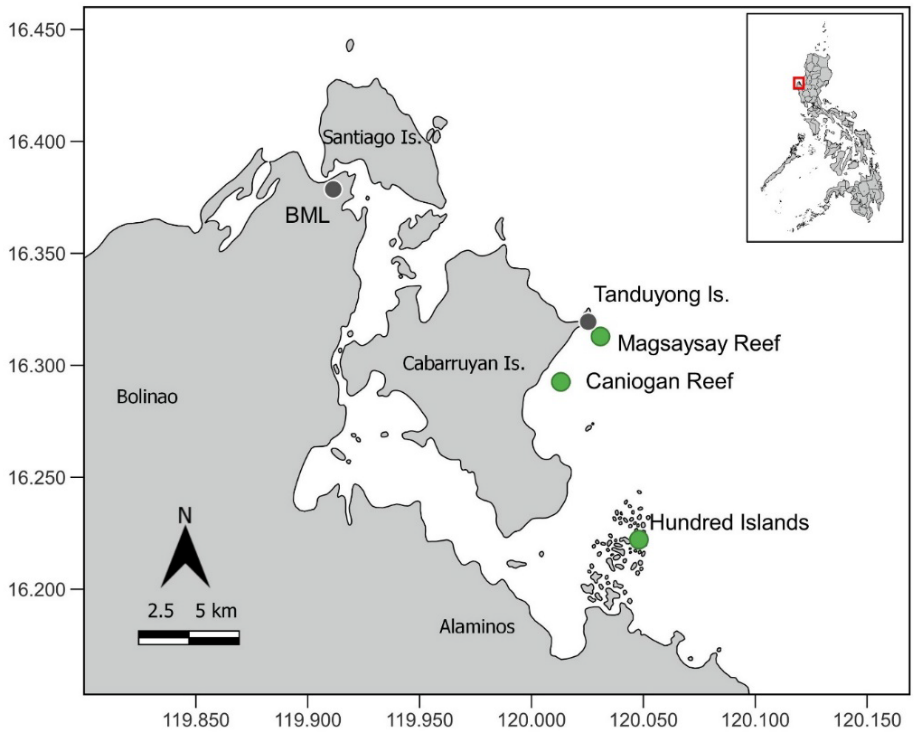

Figure 4. Map of the coral larval restoration sites in the northwestern Philippines (green dots). Black dots represent the Bolinao Marine Laboratory (BML) of the University of the Philippines and the research campground in Tanduyong Island.

Fish assemblages varied between reef experiment locations and over time, with stronger trends evident in larval restoration plots that had been established over longer periods. Trends in fish assemblages varied significantly between some but not all years, and higher abundance was recorded in larval-enhanced plots compared with control plots in some but not all reef trial locations. Although the coral and fish habitat restoration sites are mostly located within MPAs, there is substantial ongoing chronic fishing pressure from a range of non-selective fishing activities that continue to occur within the MPAs and surrounding areas, which is likely to remove fish and confound evaluations of the changes in reef fish assemblages in restored reef areas. Future larger scale restoration areas are likely to result in more consistent trends in reef fishes where fishing pressures are reduced or removed such as in the Hundred Islands National Park sites, and with increased plot replication to provide stronger statistical power to evaluate changes in fish assemblages over time and between treatments. In addition, it is important to take into account the highly degraded state of most reefs in the broader Lingayen Gulf region, which are not recovering naturally due to ongoing overfishing, illegal fishing, and other natural and anthropogenic disturbances that have decimated breeding coral populations and reduced natural larval supply (McManus and Chua 1990, Licuanan et al. 2019).

Representative data and outcomes from the extensive fish assemblage monitoring are provided and discussed below, with details of all reef trial sites provided in the 2022 Project Research Report and ACIAR Annual Reports.

2013 *Acropora tenuis* larval restoration

The first larval restoration pilot study in 2013 supplied *ex situ* cultured larvae of *Acropora tenuis* onto highly degraded reef areas on Magsaysay Reef MPA (dela Cruz and Harrison 2017). Mean fish species richness trends in both treatments were relatively similar over 9 years (Figure 5A) and ranged from 7 to 12 species per plot. No significant differences in mean values were detected between years (GLM, p=0.057) or treatments (GLM, p=0.858). Mean counts of individuals showed varying levels of abundance per year (Figure 5B), with larval-enhanced (LE) plots tending to host more fish than control plots in most survey years (average 1.02 individuals/m^2 for LE plots and 0.76 individuals/m^2 for control; GLM, p=0.022). Biomass values followed similar trends to fish abundance with generally higher mean biomass for larval-enhanced plots compared to control plots (Figure 5C). Statistically significant differences were detected between years (GLM, p=0.011) but not between treatments (GLM, p=0.237).

Analyses of the composition of fish assemblages by taxonomic family revealed a dominance by damselfishes (Pomacentridae) and wrasses (Labridae) which are mostly herbivores and benthic invertivores (Figure 6A-B). Indicator species for resilience (e.g., fishes controlling algal overgrowth) comprised the majority of the fish present, followed by groups contributing to general diversity but without identified significance (categorised as ‘Major’). Indicator groups for coral abundance such as corallivores (e.g., butterflyfishes [Chaetodontidae]) also appeared to have increased in abundance over the years of monitoring but with variable abundance in control and larval-enhanced treatments. Larger, commercially targeted fishes were present in all surveys but varied in abundance between years (Figure 6C).

Similar trends were evident in the 2014 *Acropora loripes* larval restoration experiment plots (dela Cruz and Harrison 2020), with mean fish abundance values also followed the same trend, with statistically varying significantly between years (GLM, p=0.170), and mean fish biomass in the 2021 larval-enhanced plots being significantly higher than controls and other time periods (GLM, p=0.002) (refer to the 2022 Research Report for more details).

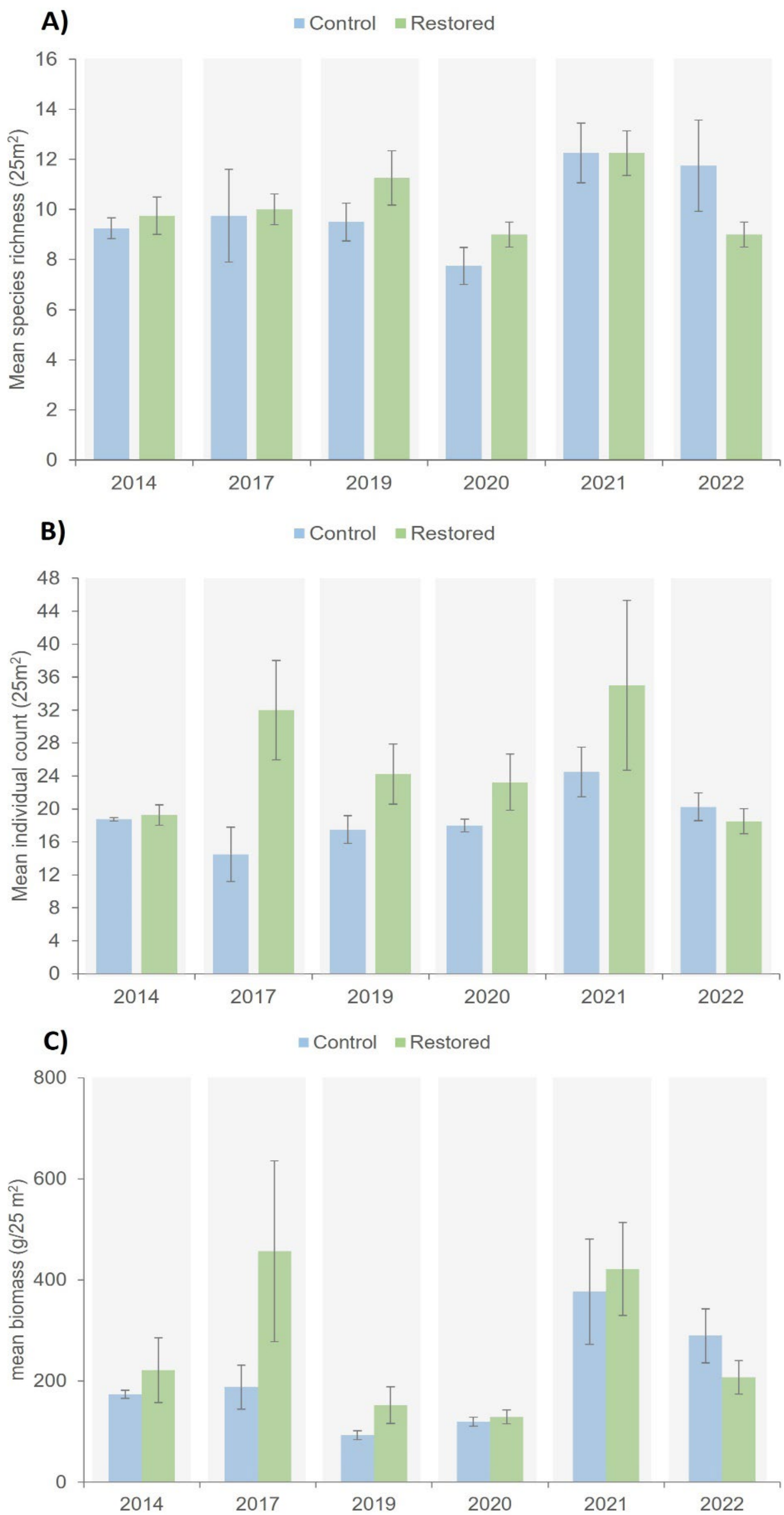

Figure 5. Fish assemblage characteristics for *Acropora tenuis* 2013 larval restoration experiment: A) mean species richness, B) mean abundance, C) mean biomass. Error bars indicate Standard Error (SE).

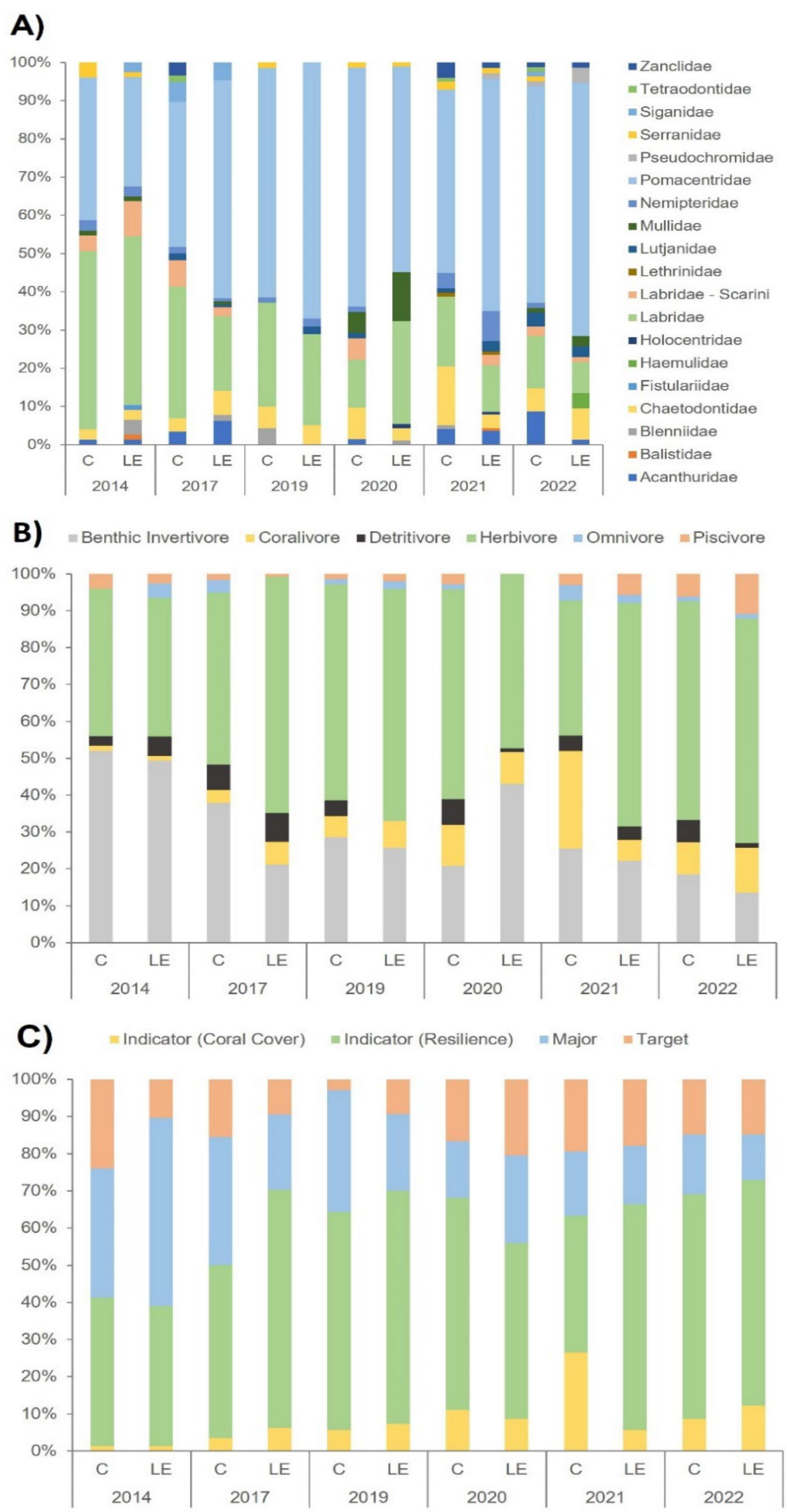

Figure 6. Fish assemblage composition for *Acropora tenuis* 2013 larval restoration experiment: A) fish families, B) trophic groups, C) ecological/economic significance. C: Control plots; LE: Larval-enhanced plots.

2016 High density *Acropora tenuis* larval restoration reef trial

The high larval density larval restoration reef trial in 2016 supplied *ex situ* cultured larvae of *Acropora tenuis* from the first spawning of the 2013 restored breeding colonies combined with larvae reared from spawn of other colonies onto highly degraded reef areas on Magsaysay Reef MPA (Harrison et al. 2021a, 2021b). Larval enhancement resulted in significantly higher larval settlement, recruitment and coral abundance and cover compared with control plots that remained moribund and degraded after three years, and rapid growth of restored colonies resulted in restored breeding colonies after 2-3 years (Harrison et al. 2021a). A small but statistically significant increase in mean fish abundance was recorded in larval enhancement plots in 2018, with higher abundance of pomacentrids and corallivore chaetodontids coinciding with rapid growth of *A. tenuis* colonies and restoration of fish habitats (Harrison et al. 2021a). Longer term monitoring of these plots during this SRA Project showed that fish species richness generally increased across treatments and years. Mean species richness in 2022 was significantly higher compared to the 2016 larval-enhanced plots (Figure 7A; GLM, p=0.003), while species richness showed variable trends over years and between larval enhanced and control plots (GLM, p=1.0).

Mean fish abundance was higher in larval-enhanced plots compared to control plots from 2018 onwards (Figure 7B), and the increase in fish abundance was significantly higher in 2021 for the larval enhancement plots compared to surveys in initial years (GLM, p=0.009). Fish biomass exhibited fluctuating trends over the years and across treatments (Figure 7C). Highest fish biomass was recorded in the larval-enhanced plots in 2021 due to the presence of roaming fusiliers (Caesionidae), but differences across years (GLM, p=0.251) and between treatments (GLM, p=0.337) were not significant.

Overall, plots were dominated by damselfishes and wrasses (Figure 8A), with butterflyfishes occurring more frequently in reef plots during more recent survey years. A greater range of fish families were recorded in the reef plots during surveys in more recent years compared to the initial 2016 baseline surveys. Benthic invertivores and herbivores trophic groups dominated the fish assemblages, with variable but generally increasing occurrences of corallivores, piscivores and detritivores in recent survey years (Figure 8B). In relation to fish groups of ecological/economic significance, resilience indicator fishes were the most abundant followed by species contributing to general diversity (i.e., Major) (Figure 8C). Fish assemblages were also characterised by a higher proportion of targeted fish species over time, with species associated with increasing coral cover contributing variable but generally increasing contributions over time (Figure 8C).

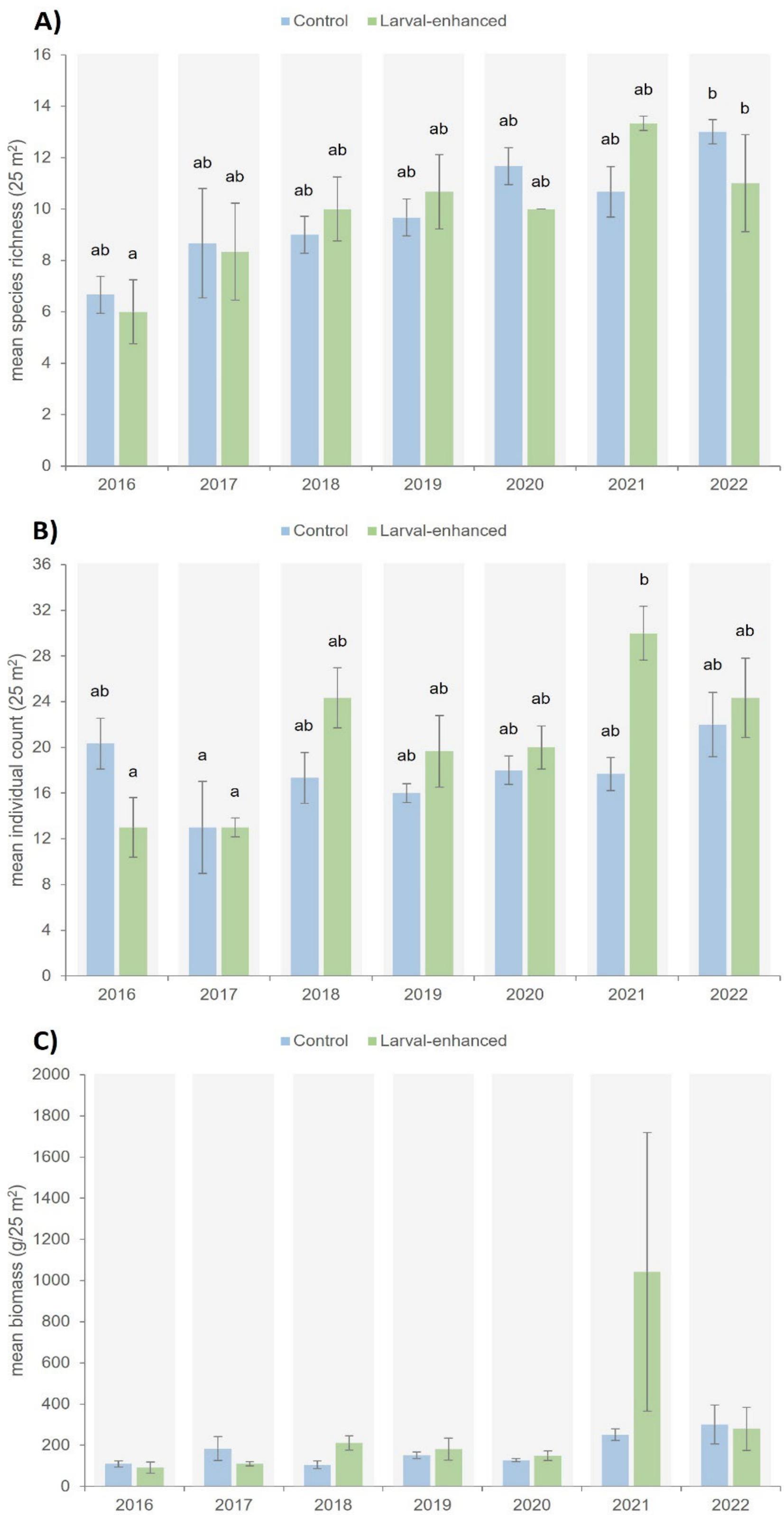

Figure 7. Fish assemblage characteristics for *Acropora tenuis* 2016 larval restoration experiment larval enhancement and control plots: A) mean species richness, B) mean abundance, C) mean biomass. Bars containing similar letters indicate non-significant differences. Error bars indicate Standard Error (SE).

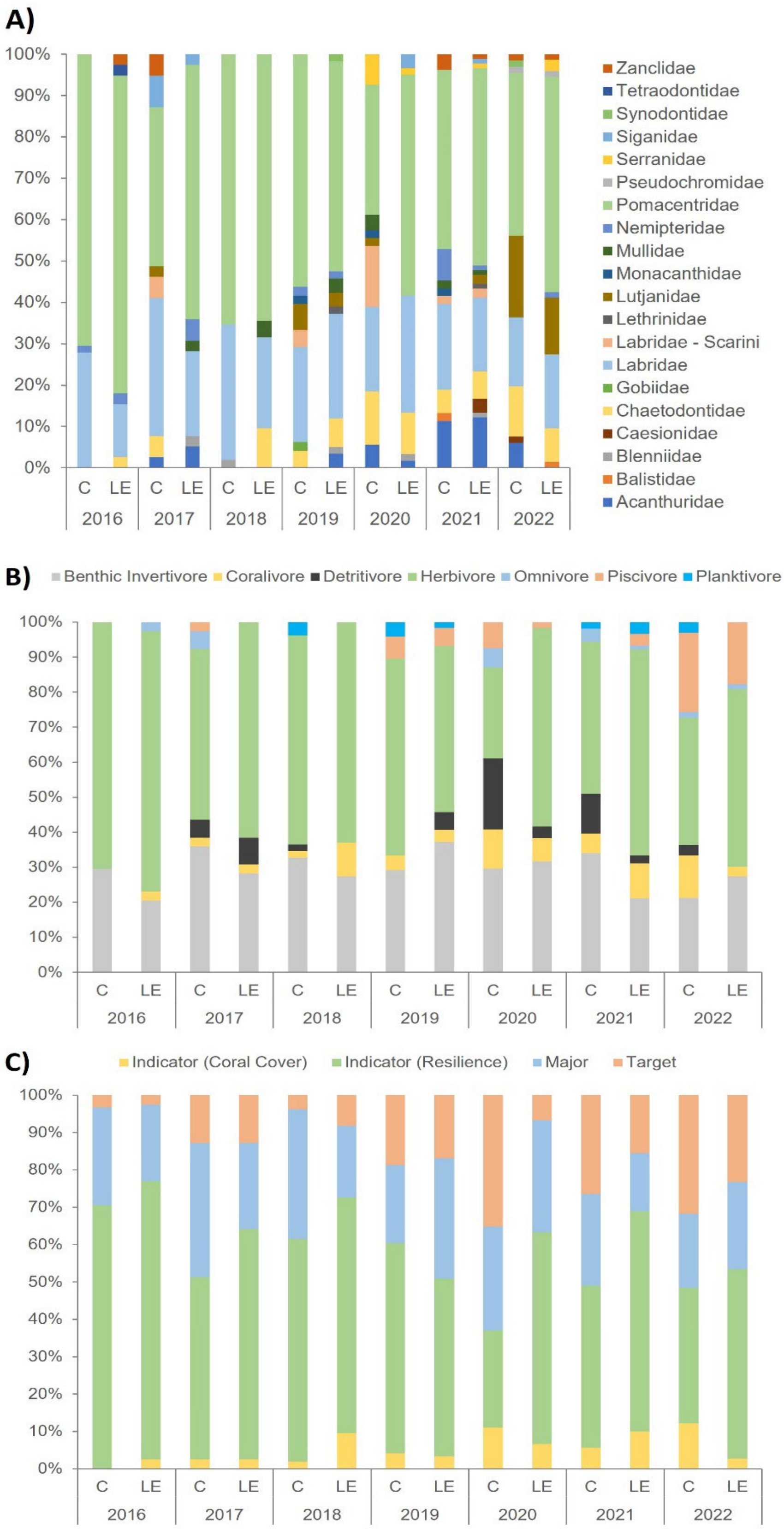

Figure 8. Fish assemblage composition for *Acropora tenuis* 2016 larval restoration experiment larval enhancement and control plots: A) fish families, B) trophic groups, C) ecological/economic significance. C: Control plots; LE: Larval-enhanced plots.

Hundred Island National Park Larval restoration reef trials

The Hundred Islands National Park lies to the south of Magsaysay Reef in the Lingayan Gulf and a range of larval restoration reef trials were completed using different larval delivery techniques during 2018 and 2019. These reef trials were initiated on degraded reefs around Quezon, Macapagal, Braganza and Mayor’s Islands (Figure 9) as part of the previous and current ACIAR/FIS/2014/063 and FIS/2019/123 coral and fish habitat restoration projects.

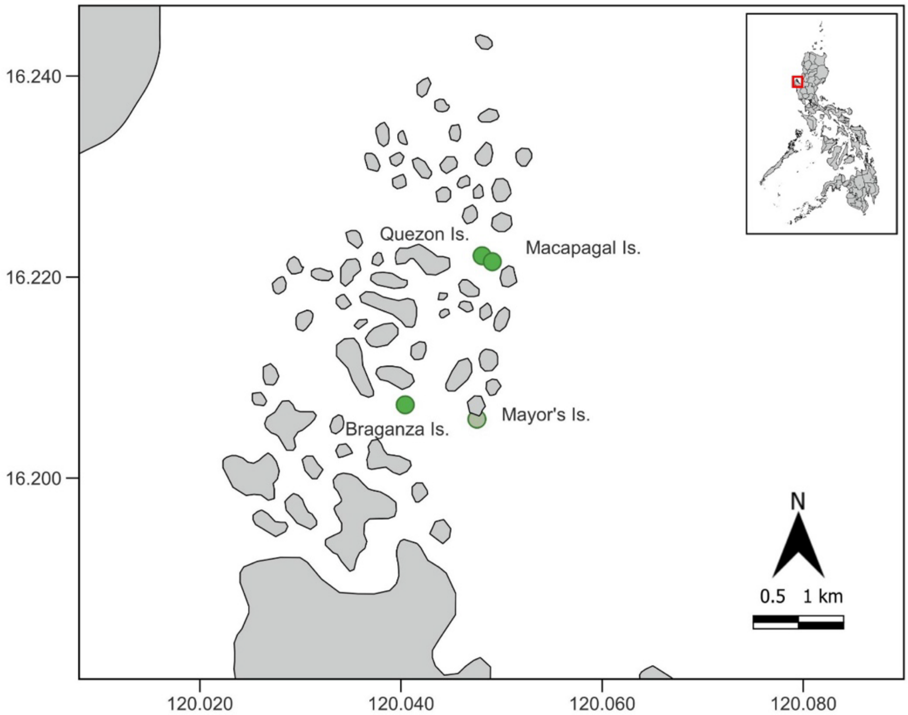

Figure 9. Map showing the locations of the larval restoration sites in the Hundred Islands National Park.

2018 Quezon Island restoration trials

Two experimental restoration trials with different plots sizes were established in Quezon Island in the Hundred Islands National Park in 2018 (Harrison et al. 2021b). *Acropora tenuis* larvae cultured from spawn collected from the *A. tenuis* 2016 larval experiment in Magsaysay Reef (Harrison et al. 2021a) were used in these reef trials to create an F_2 generation outcome from the restoration experiments. Larvae of the brain coral *Favites colemani* that were cultured *in situ* were also added into each plot making it the first multispecies larval enhancement intervention. Three 7 x 7 m plots and one larger 4 x 20 m plot (plus equivalent replicate control plots) were established and competent larvae were released under fine mesh nets to retain them on the target plots during the settlement period.

For the 7 x 7 m plots, mean species richness was higher in the larval-enhanced plots during surveys in 2019 and 2020 but was similar between treatments in 2021 and 2022 (Figure 10A). These differences in between treatments or years were not statistically significant (GLM, p=0.117 for Year, p=0.294 for Treatment). Trends in mean fish abundance and mean biomass reflected the trends for mean species richness, and showed increased values in larval enhanced plots during 2019 and 2020, but similar or lower values to control plots during the surveys in 2021 and 2022 (Figure 10B-C). These differences were also statistically non-significant for mean abundance (Figure 10B; GLM, p=0.062 for Year, p=0.226 for Treatment) and mean biomass (GLM, p=0.308 for Year, p=0.33 for Treatment).

Due to the larger mesh net size only one reef plot was established with a 4 x 20 m plot, and therefore comparisons with the control plot are necessarily descriptive. Fish assemblages in the larval enhanced and control plot have varied over time, with higher fish species richness in the large larval enhanced plot in 2019, 2021 and 2022 compared with the large control plot, and much higher fish abundance in the larval plot compared with the control plot in 2019 and 2022 (Figure 11A-B). Fish biomass values were consistently higher in the larval enhanced plot compared with the control plot from 2019-2022 (Figure 11C).

Both reef trials were in close proximity to each other and had similar fish assemblage composition. Fish assemblages in the plots were dominated by damselfishes and wrasses, with roving parrotfish (Labridae-Scarini) abundant in some surveys (Figure 12A and 13A). Other roving grazers such as rabbitfishes (Siganidae) also appeared in large numbers in some plots, and coral breams (Nemipteridae) and emperors (Lethrinidae) were consistently present in the reef plots. Herbivores and benthic invertivores had the highest proportional abundance, followed by detritivores, with variable numbers of butterflyfishes (Chaetodontidae) present in some years (Figures 12B-C and 13B-C). Resilience indicators and Major groups dominated the assemblages with targeted fishes decreasing over time (Figures 12C and 13 C).

Fish assemblage survey results for other larval restoration experiments in Macapagal Island and Braganza Island are detailed in the 2022 Research Report, and showed variable trends for the fish assemblages in larval enhancement and control plots over time.

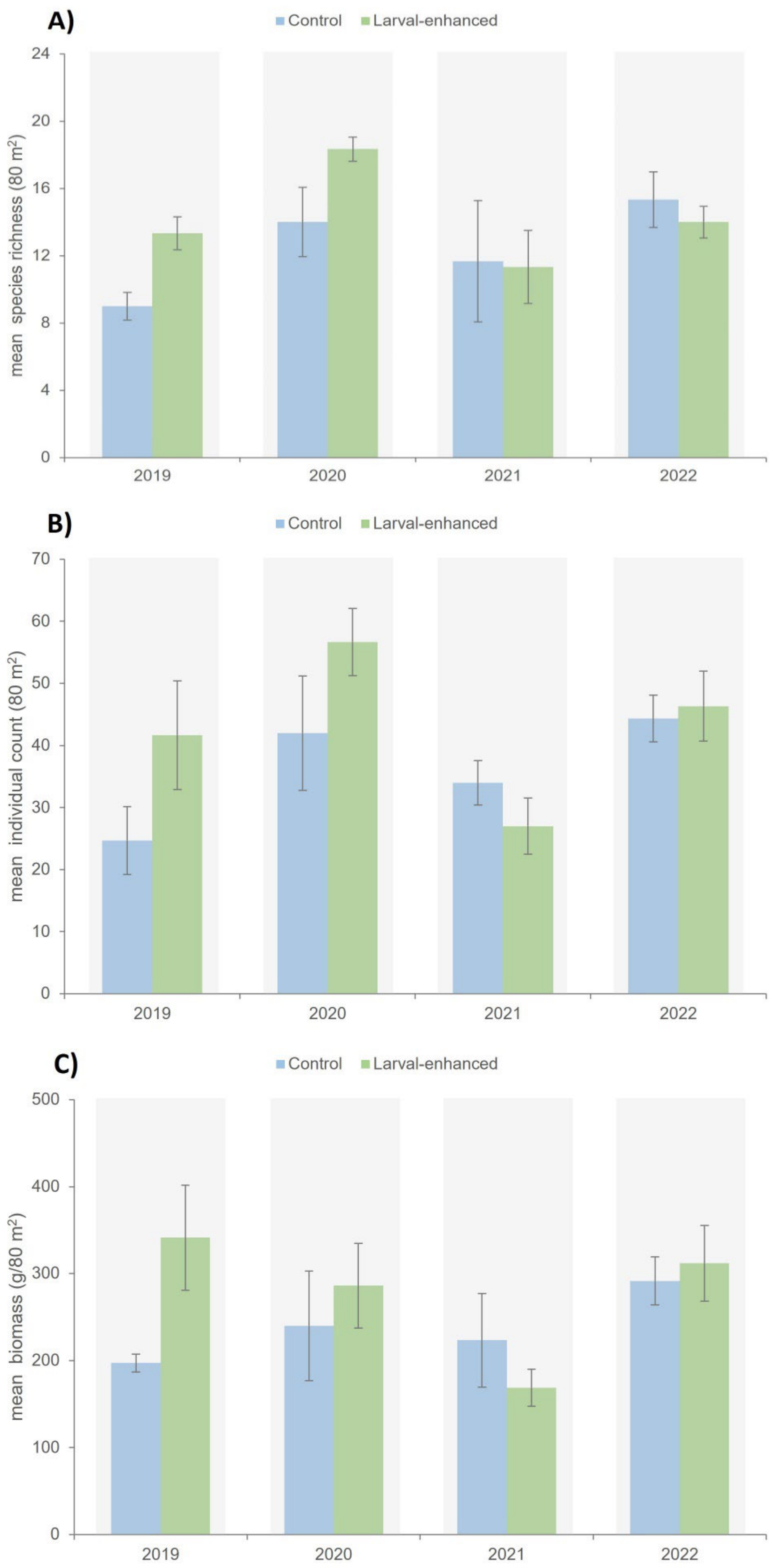

Figure 10. Fish assemblage characteristics for Quezon Island 7x7 m larval restoration experiment: A) mean species richness, B) mean abundance, C) mean biomass. Error bars indicate Standard Error (SE).

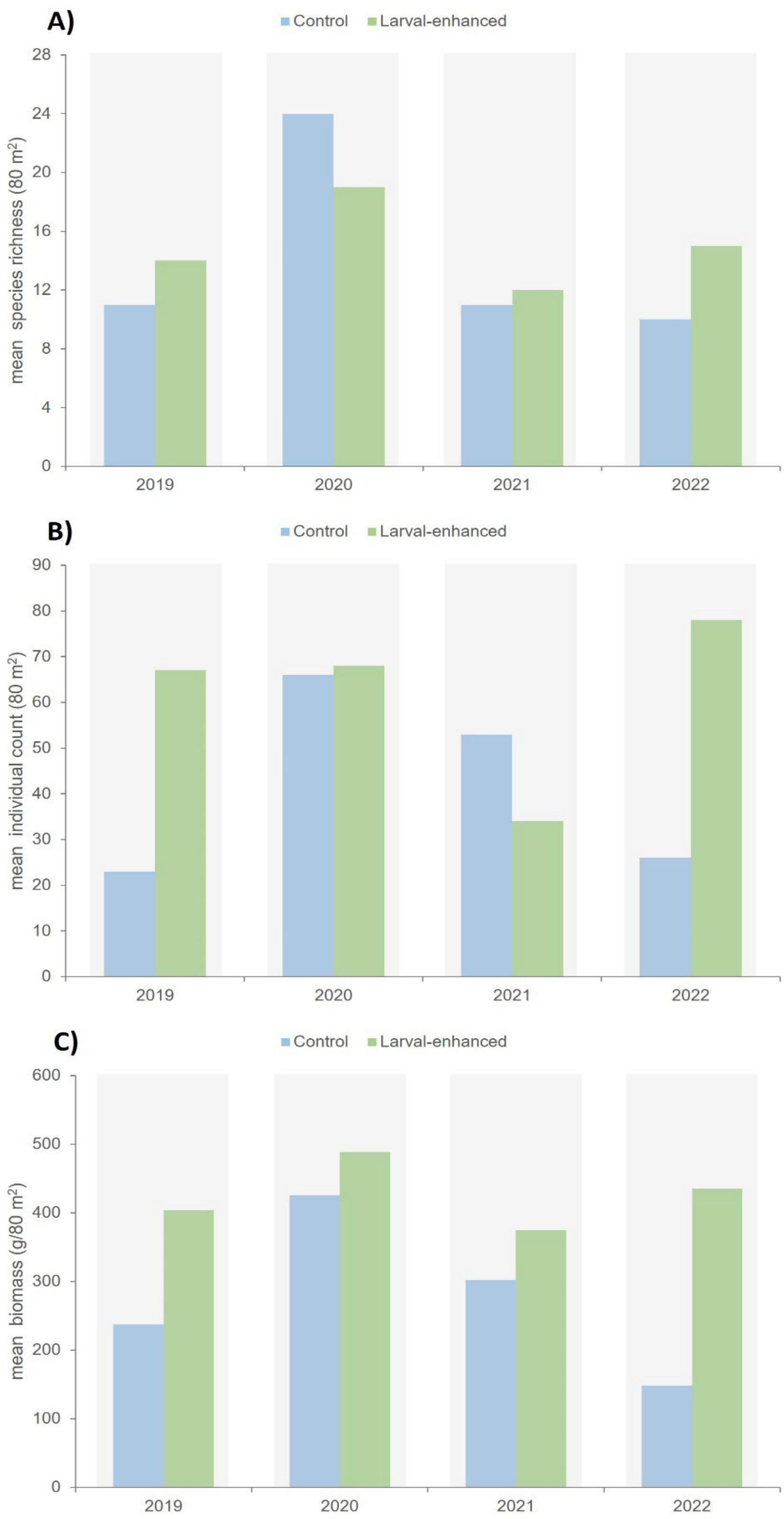

Figure 11. Fish assemblage characteristics for Quezon Island 4 x 20 m larval restoration experiment: A) mean species richness, B) mean abundance, C) mean biomass. Error bars indicate Standard Error (SE).

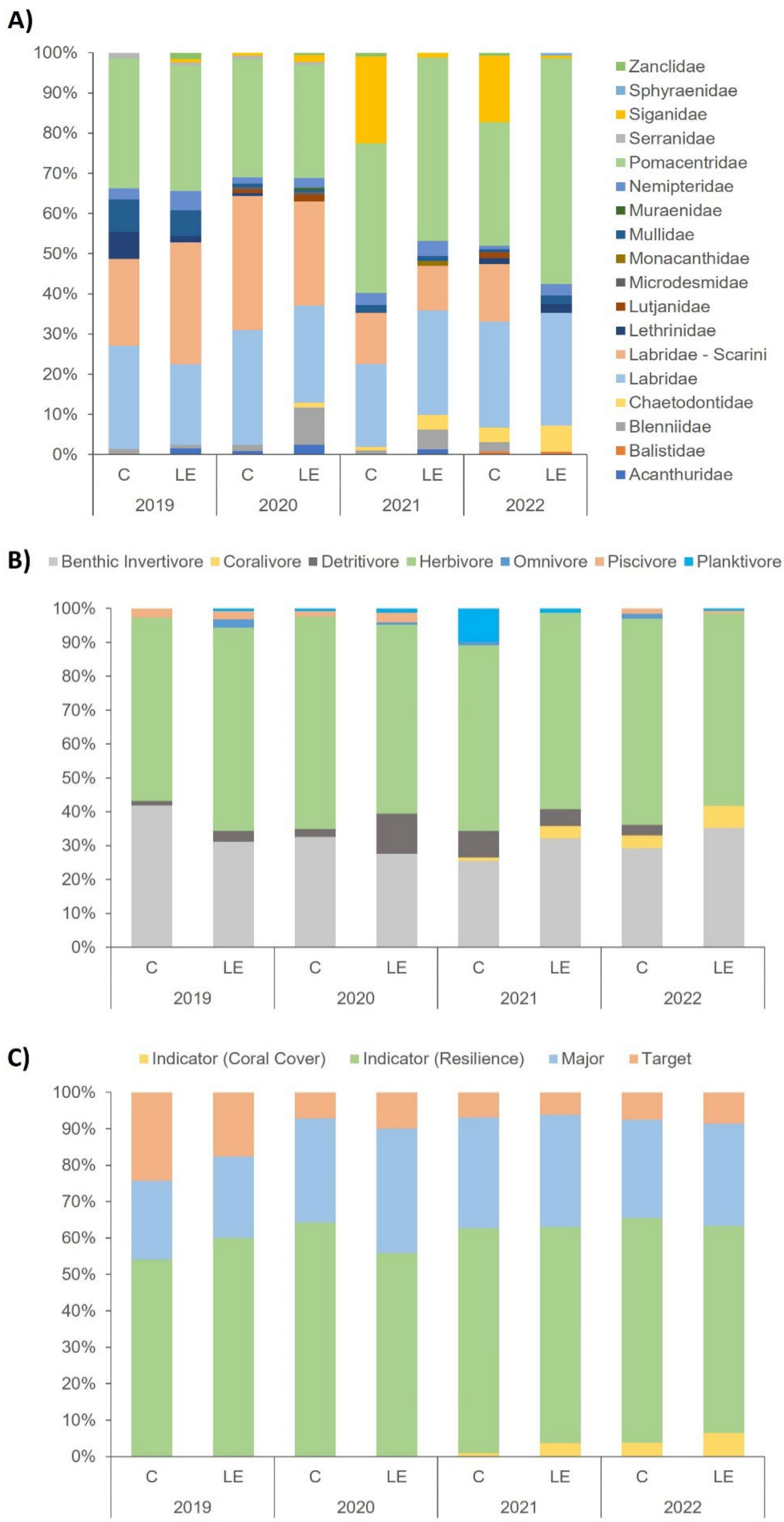

Figure 12. Fish assemblage composition for Quezon Island 7x7 m larval restoration experiment: A) fish families, B) trophic groups, C) ecological/economic significance. C: Control plots; LE: Larval-enhanced plots.

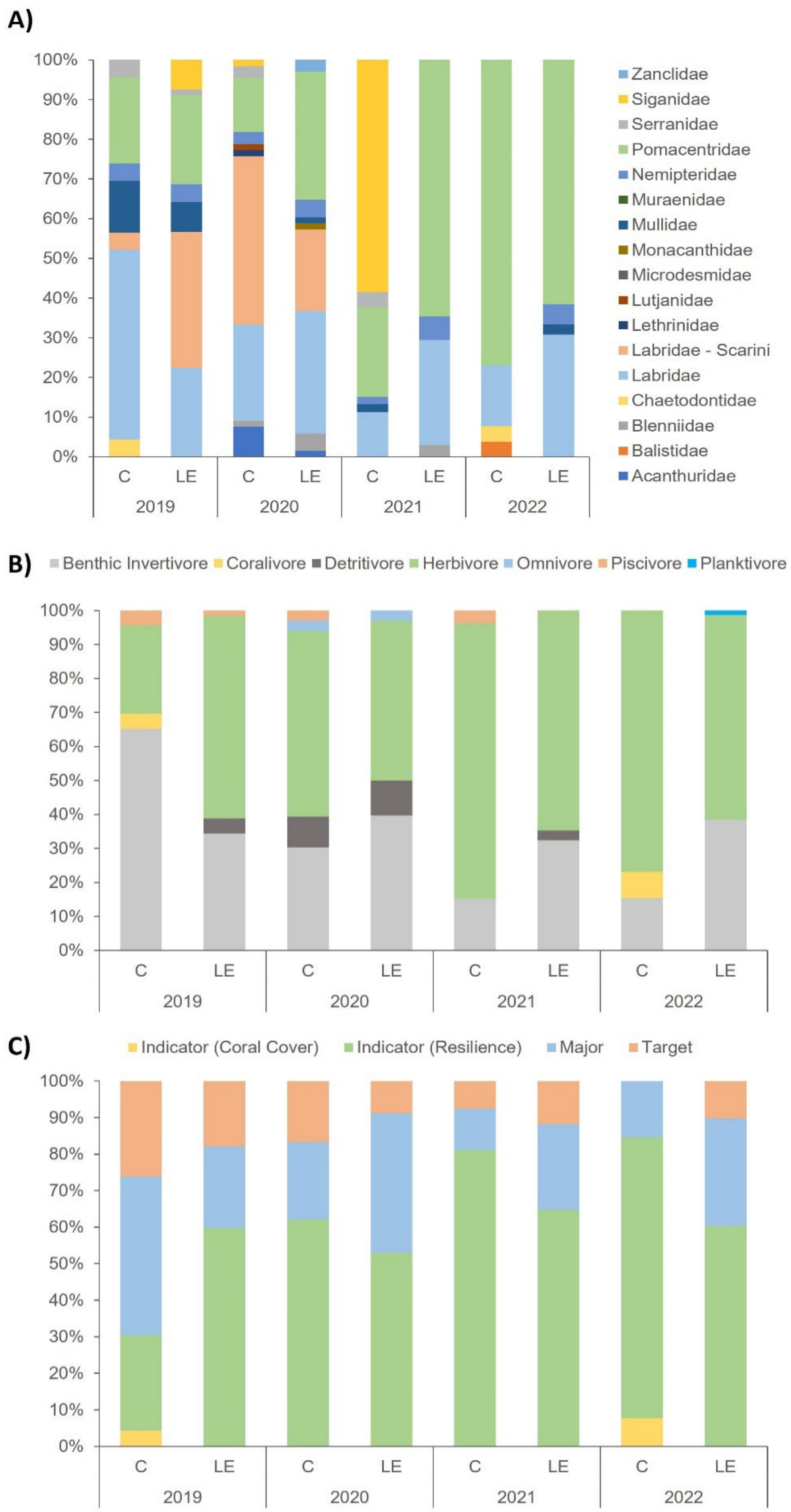

Figure 13. Fish assemblage composition for Quezon Island 4x20 m larval restoration experiment: A) fish families, B) trophic groups, C) ecological/economic significance. C: Control plots; LE: Larval-enhanced plots.

2019 Larger-scale Caniogan LarvalBot larval restoration trial

The first coral larval restoration reef trial at larger hectare scales was initiated at Caniogan Reef MPA in 2019 with three 1 ha larval enhancement plots and three equivalent sized control plots (Harrison et al. 2021b). The innovative QUT LarvalBot Autonomous Underwater Vehicle (AUV) was used to deliver millions of competent larvae over the three 1 ha plots (Dunbabin et al. 2020). Fish assemblages were monitored in each 1 ha plot using five 25 x 5 m permanent transects to facilitate surveys within each of the large plot areas. Mean species richness was similar between treatments (GLM, p=0.56) and slightly lower in 2020 compared with 2019 baseline levels (Figure 14A; GLM, p=0.012). Mean fish abundance was higher in larval enhanced plots compared with controls and lower in 2020 compared to 2019 baselines (Figure 14B; GLM, p=0.000). Mean fish biomass exhibited a similar trend to abundance, with higher values in larval enhanced plots compared with controls.

Fish assemblage data revealed a strong dominance of damselfishes, with wrasses less common (Figure 15A). Parrotfishes were more common in the 2019 baseline surveys than in 2020, while butterflyfishes and coral breams were consistently present in small numbers. These fishes are mostly herbivores and benthic invertivores trophic groups that functionally contribute to general diversity and indicators for reef resilience (Figures 15B-C). Planned monitoring for 2021 was not completed due to storms during the survey period, and loss of transect markers that are essential for resurveying the same reef areas prevented further direct survey comparisons.

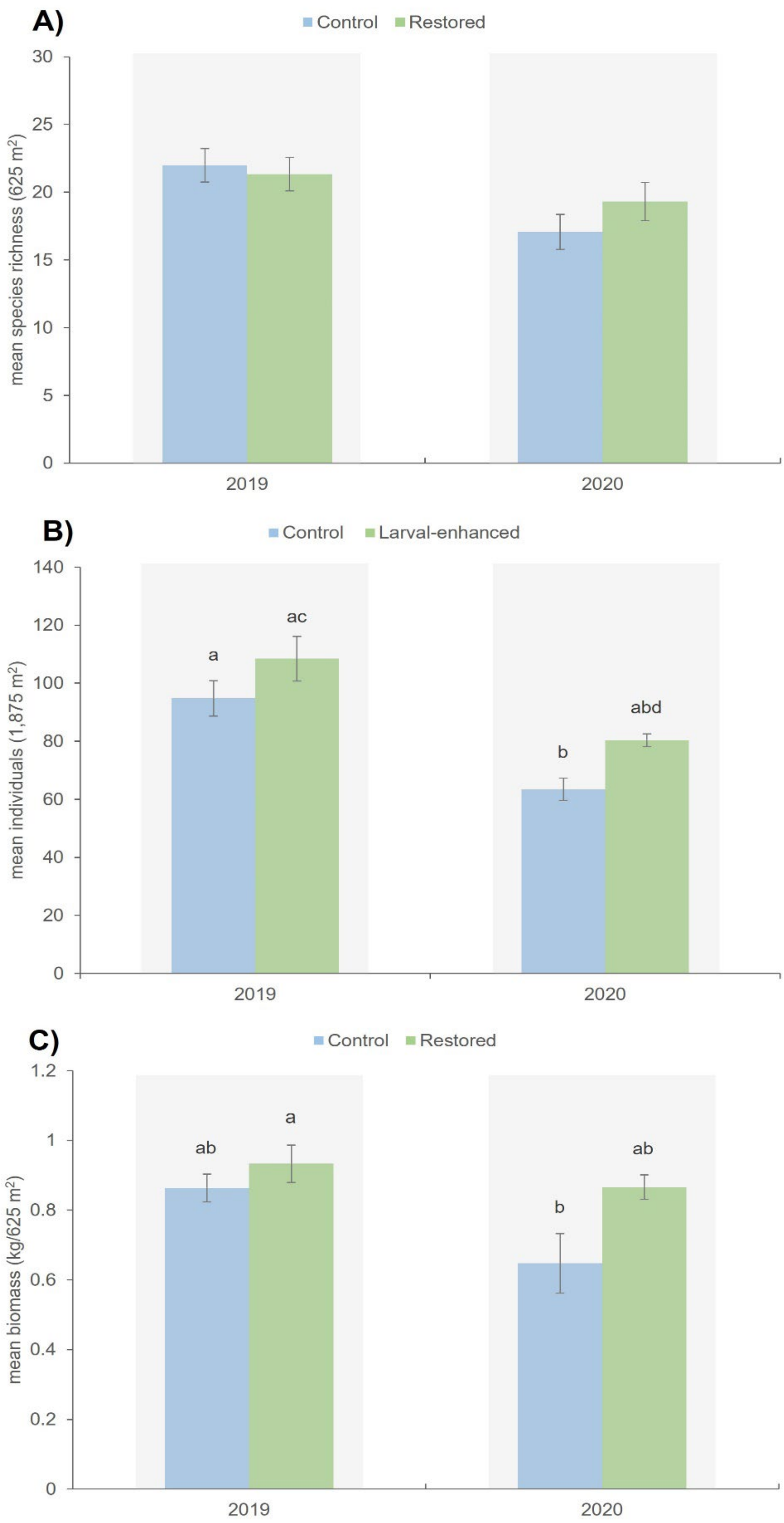

Figure 14. Fish assemblage characteristics for Caniogan Reef 2019 Larvalbot larval restoration experiment: A) mean species richness, B) mean abundance, C) mean biomass. Bars containing similar letters indicate non-significant differences. Error bars indicate Standard Error (SE).

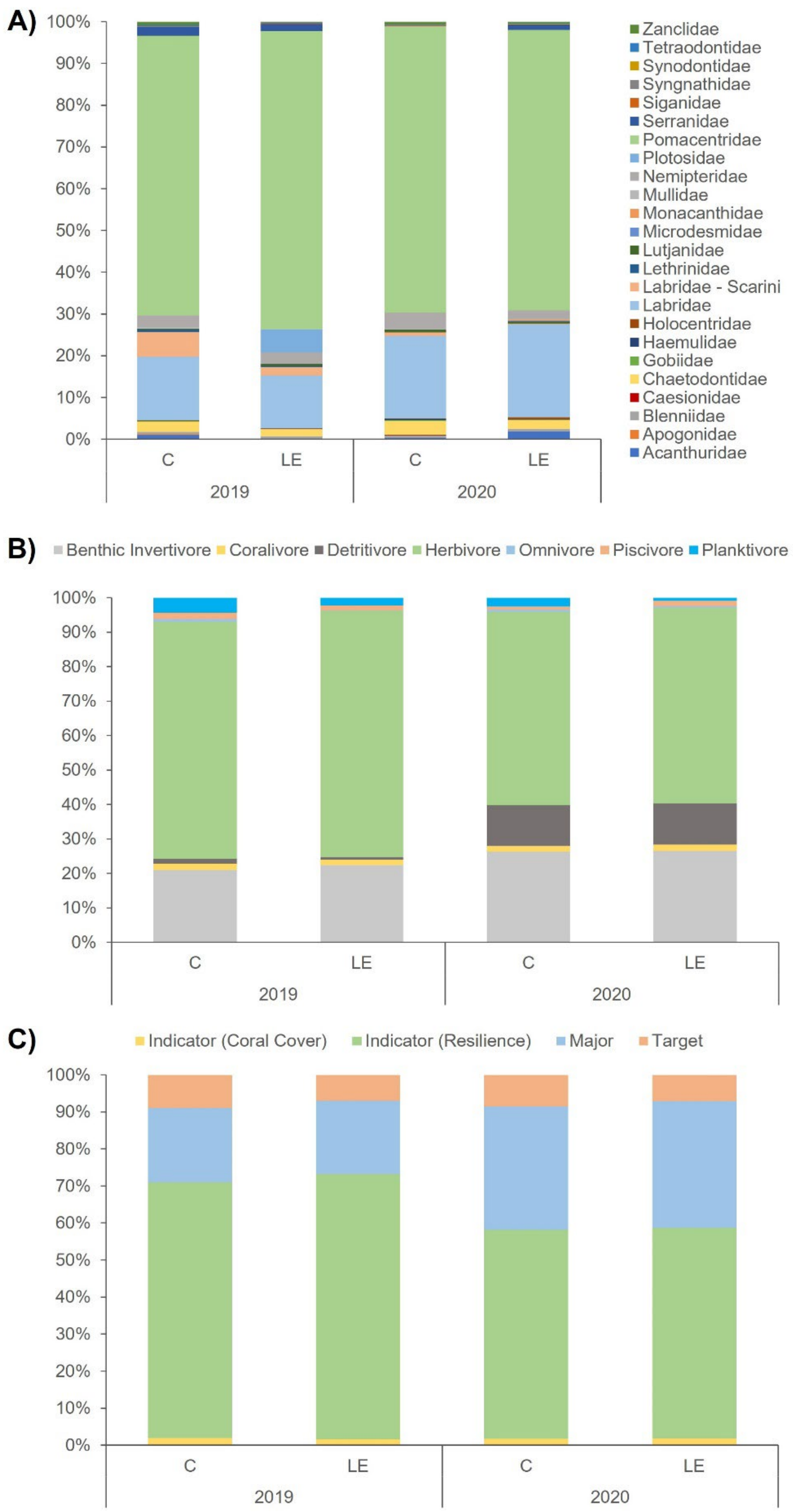

Figure 15. Fish community composition for Caniogan Reef 2019 Larvalbot larval restoration experiment: A) fish families, B) trophic groups, C) ecological/economic significance. C: Control plots; LE: Larval-enhanced plots.

Fish assemblage comparisons between larval-enhanced plots versus unrestored and control reference plots

In 2019, an expanded survey design was implemented to compare fish assemblage characteristics in the larval restoration plots (n=10) that were at least 3 years old, for comparison with their control counterparts (n=10) (hereby referred to as "unrestored") and nearby reef areas with naturally high coral cover (n=10) (hereby referred to as "control reference"). In 2019, mean fish species richness was highest in the larval-enhance plots compared to the other treatments, but species richness among treatments varied throughout the years (Figure 16A) and differences were not statistically significant (GLM, p=0.515 for Year, p=0.055 for Treatment).

Mean fish abundance also fluctuated between years (Figure 16B), with a significantly highest value recorded for healthy reference plots in 2020 (GLM, p=0.004). No significant differences among treatments were detected (GLM, p=0.46). Most fish recorded in the Magsaysay Reef surveys were small-bodied fishes (i.e., total length [TL] less than 11 cm) (Figure 16B, lightest bar plot shade). Medium-bodied fishes (i.e., TL = 11-20 cm, darker bar plot shade) were present in varying proportions per year in each treatment, while very few larger-bodied fishes (i.e., TL >20 cm) were present even in the healthy reef reference plots, possibly due to ongoing local fishing pressures within and around the designated MPA.

Mean fish biomass on Magsaysay Reef was low, with less than half a kilogram per 25 m^2. Mean fish biomass varied among years and treatments (Figure 16C) and differences between treatments (GLM, p=0.909) and years (GLM, p=0.894) were nonsignificant. Damselfishes consistently dominated assemblages within plots on Magsaysay Reef regardless of treatments (Figure 17A). Wrasses and butterflyfishes were relatively common with some surgeonfishes (Acanthuridae), snappers (Lutjanidae), coral breams (Nemipteridae) and groupers (Serranidae) present (Figure 17A).

Fish assemblages were also mostly composed of herbivores and benthic invertivores, with corallivores less common (Figure 17B). Fish groups encompassing resilience indicators and general contributors to diversity were the more abundant (Figure 17C). Commercially targeted fishes were most abundant in healthy reference plots in the initial 2019 baseline surveys, but varied among years and between treatments.

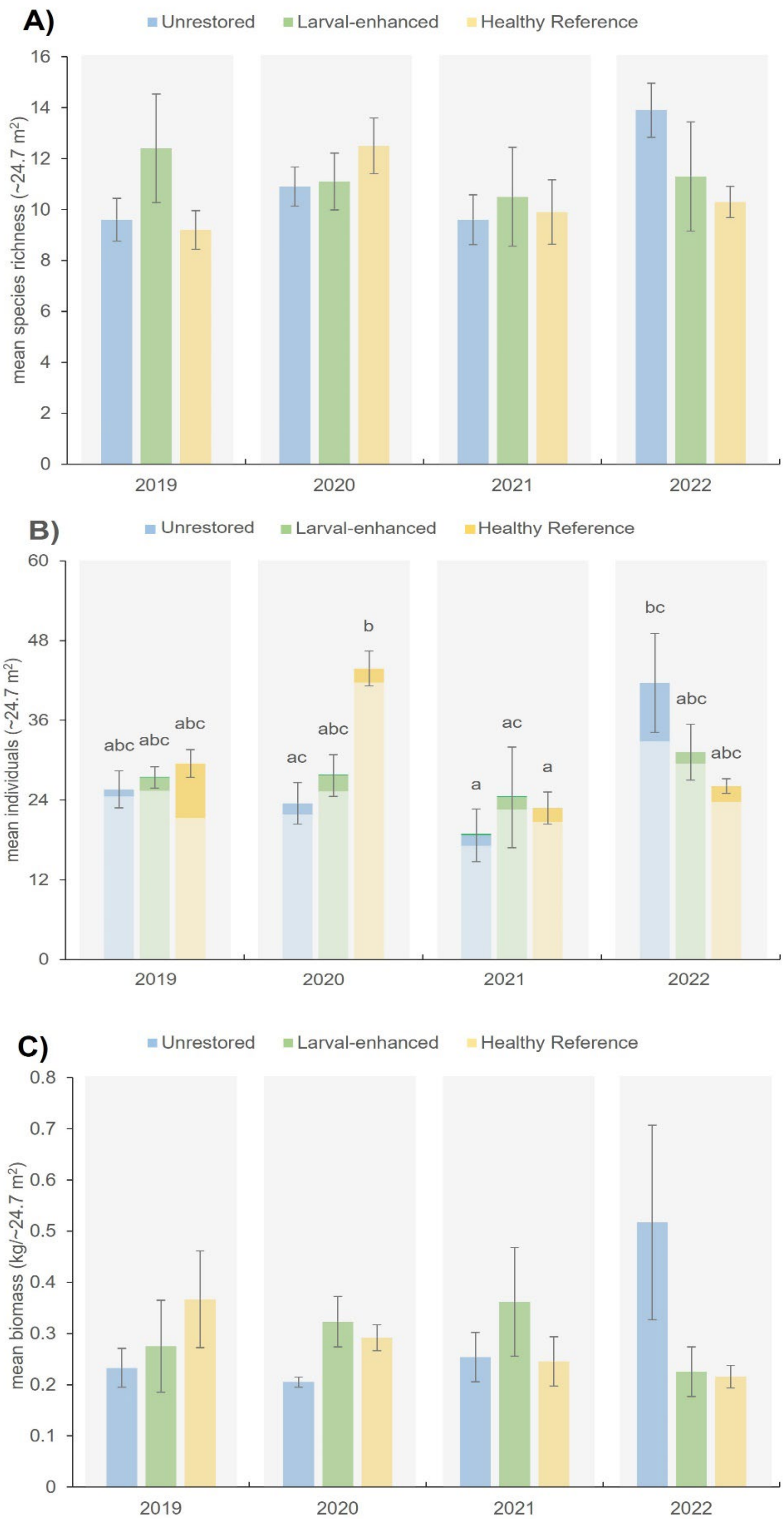

Figure 16. Fish assemblage characteristics for restored plots versus control and healthy reference plots: A) mean species richness, B) mean abundance, C) mean biomass. Bars containing similar letters indicate non-significant differences. Error bars indicate Standard Error (SE). In Fig. 16B, light shade indicates small-sized fishes (total length <10 cm), medium shade indicates medium-sized fishes (total length 11-20 cm), and dark shade indicates large-sized fishes (total length >21 cm).

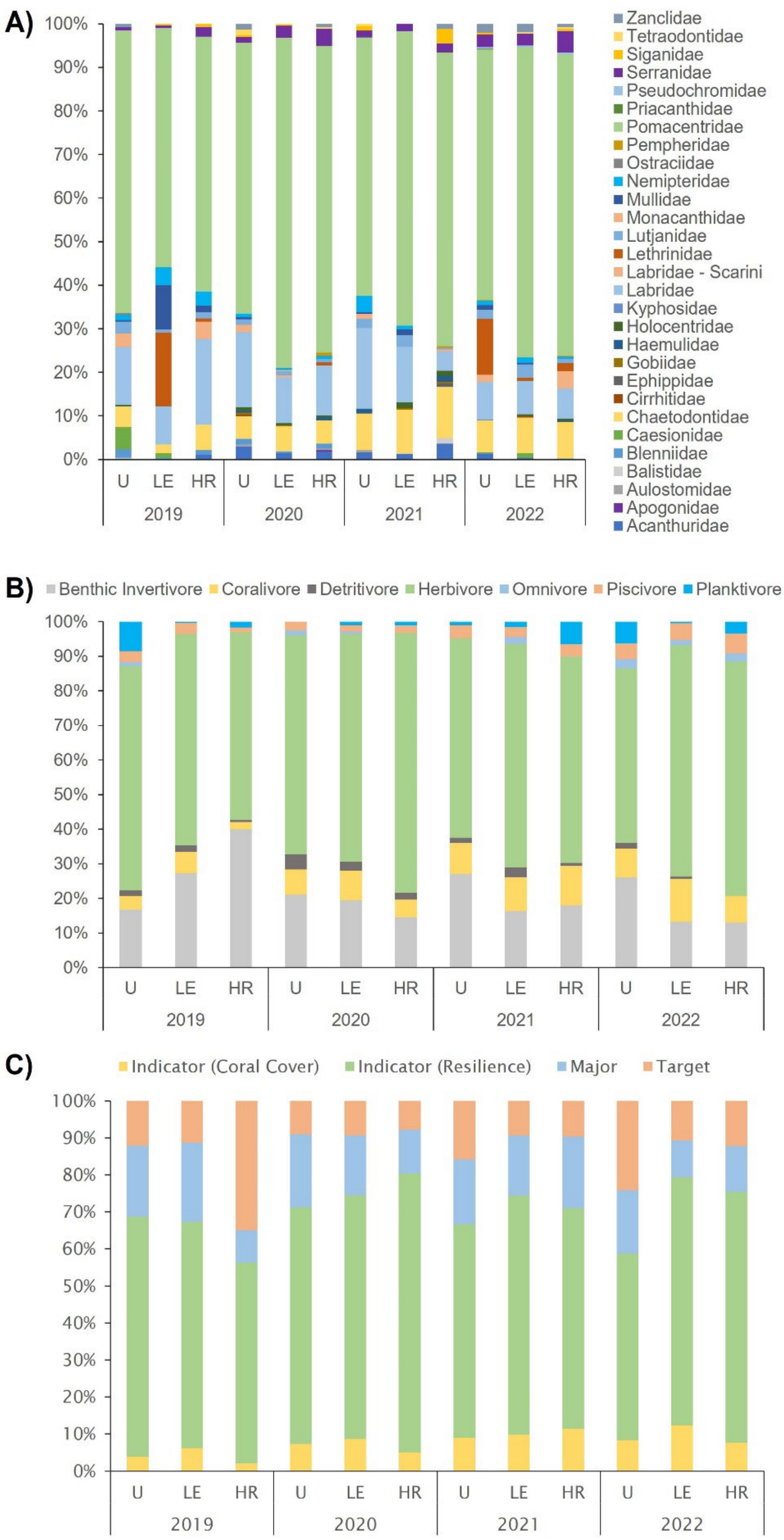

Figure 17. Fish assemblage composition for restored plots versus control and healthy reference plots: A) fish families, B) trophic groups, C) ecological/economic significance. U: Unrestored reef plots; LE: Larval-enhanced plots; HR: Healthy reference reef plots.

In summary, fish abundance and in some cases fish biomass tended to increase over time, and was higher in larval-enhanced plots compared with controls in some reef trials. Increased live coral cover generally supports more reef fish and these trends reflect the presence of increasing live coral cover and abundance on larval restoration plots over time as surviving restored colonies grow larger and reassert coral dominance on degraded algal phase-shifted reefs (Harrison et al. 2021a). However, other reef characteristics such as rugosity structural complexity and coral species richness are also important in influencing high fish species richness and abundance in reefs (Darling et al. 2017, Russ et al. 2021). Therefore, recent advances in wild spawn slick capture and mass larval culture directly on reefs (Harrison et al. 2021a, Harrison and dela Cruz 2022, Harrison et al. 2023, Harrison 2024) will result in more diverse and complex coral assemblages being restored which can support more abundant and diverse fish assemblages.

Fishes in surveyed plots and particularly in the Magsaysay Reef areas tended to be dominated by small, herbivorous damselfishes from Family Pomacentridae including *Stegastes lacrymatus, Pomacentrus burroughi, Pomacentrus chrysurus,* and *Plectroglyphidodon obreptus*. These damselfish farm turf algae and are often territorial, which limits available space within the small plot for recruitment of corals and new fish by promoting turf algae and chasing away other fish which utilize or may also potentially colonize the plot (Gochfeld 2010, Casey et al. 2014). Their direct influence on larval settlement and recruitment of corals remains inconclusive (Casey et al. 2014), but these issues should be a priority for further research given the large areas of degraded reef and abundance of turf-farming damselfish present on these reefs. The second most abundant family were the Family Labridae wrasses including *Halichoeres melanurus, H. chloropterus, H. nebulosus,* and *Stethojulis trilineata*, which are mostly benthic invertivores that tend to pick away at small food items (e.g., tiny gastropods) from the reef substrata. In some areas, such as in the Hundred Islands National Park reefs, parrotfishes from Family Labridae - Tribe Scarini (previously Family Scaridae) were also consistently abundant. These roving fishes excavate or scrape away on the reef substrata as they graze for microscopic algae and cyanobacteria and tend to be abundant on reef areas with abundant coral rubble (Bonaldo et al. 2014, Russ et al. 2015, Clements et al. 2017, Nicholson and Clements 2020). These fishes, together with wrasses and damselfishes and some other fish groups, are likely to influence the settlement and survival of corals, particularly in their earlier post-settlement life stages by accidentally dislodging them from the substrata or inhibiting their growth through algal farming (Baria et al. 2010, Trapon et al. 2013, Casey et al. 2014).

Increases in the abundance of butterflyfishes from Family Chaetodontidae in restored plots were inconsistently detected. This might seem contrary to expected outcomes given that increased coral cover can positively influence corallivorous fishes, and consequently coral-indicator species like butterflyfishes (Hourigan et al. 1988, Cole and Pratchett 2013). However, not all butterflyfishes feed strictly on corals (i.e., some species are facultative corallivores), and those that are obligate corallivores can have preferences for certain coral species (Rotjan and Lewis 2008, Cole et al. 2008), hence the restored *Acropora* species may not represent preferred food sources for some species. This also highlights the importance of using multispecies coral restoration approaches rather than single species approaches, to increase habitat diversity and therefore the likelihood of more rapidly restoring functional diversity of fish assemblages on recovering reefs.

Of particular interest from a fisheries perspective, the abundance of commercially targeted fish species in surveyed reef areas varied between treatments and over years, but target fish tended to be more abundant in larval-enhanced plots compared with controls in the longer-established restoration sites. These results indicate that mass coral larval restoration not only increases coral cover and breeding population recovery but also positively influences fish habitat and reef restoration, which in turn can positively influence fish assemblages including fish abundance and some aspects of species and trophic composition. These observed changes in coral and fish assemblages are beneficial for reef ecology and fishery values, and as restored reef areas increase in size and diversity and reach a threshold value, the associated goods and services and socio-economic benefits will be enhanced for local coastal communities that rely on healthy reefs.

Objective 2: Fisher perceptions and fisheries

Detailed outcomes from the fisher interviews from Barangay Tondol (Tondol village) were provided in previous ACIAR Annual Reports and in the recent publication Gomez et al. (2024), and key aspects are described and discussed below.

Fisher demographic profiles

A total of 53 fishers from Barangay Tondol were interviewed during the survey (Table 1). Respondents were mostly male with an average age of 44 years and an average 25 years of experience as fishers (range <1 to 58 years fishing). While women often have roles as sellers, gleaners, and intermediaries, two female fishers were also encountered during the survey, who identified their roles largely as providing support and as companions to their spouse during fishing activity.

The respondents had different levels of dependence on fishing (DOF) with most (35%) having at least one other source of livelihood and income for the family [DOF 50%], while a third of respondents (32%) were solely reliant on fishing [DOF 100%], and another third (32%) of the respondents had at least two sources of livelihood [DOF 25%] such as tourism or farming.

TABLE 1. Demographic profile of fisher respondents.

Total Respondents (N)	**Age** (Mean [Range])	**Sex**	**Civil Status**	**Highest Educational Attainment**	**Ethnicity**	**Years of Fishing** (Mean [Range])	**Dependence on Fishing** (DOF)
53	44 [16-73]	51 Male 2 Female	7 Single 46 Married	18 HS Grad 13 HS Undergrad 13 GS Grad 9 Others	37 Tondol 15 Others	25 [0.8-58]	25% - 17 50% - 19 100% - 17

Fishing vessels and Gear

About half of the fishers interviewed (51%) used motorised boats for their fishing activity (Figure 18A). These outrigger boats are about 3-4 m in length and have a motor capacity of 16 horsepower, fitting up to four people on board plus heavy nets. Smaller non-motorised boats comprise 19% of vessels used, and these boats mostly rely on oars and makeshift sails that have capacity for one person and are mostly used for line fishing (Figure 18B). A larger percentage of fishers (28%) use bamboo rafts propelled using a long bamboo stick for fishing, which carry a single fisher and are used in shallow reef flats to cast their small nets (Figure 18C). Fishers using this kind of vessel also carry another long bamboo stick with coconut husk or wood stuck on one end (called a “pulse stick”) which they use to hit the surface of the water to scare fish into their nets (Monteclaro et al. 2017). A very few fishers (2%) do not have any vessel to fish, and instead swim from the shore or walk to the sandbar during low tide carrying a woven basket which they use as flotation device and storage for fish (Figure 18D). Some spear fishers and rod-fishers make use of this method.

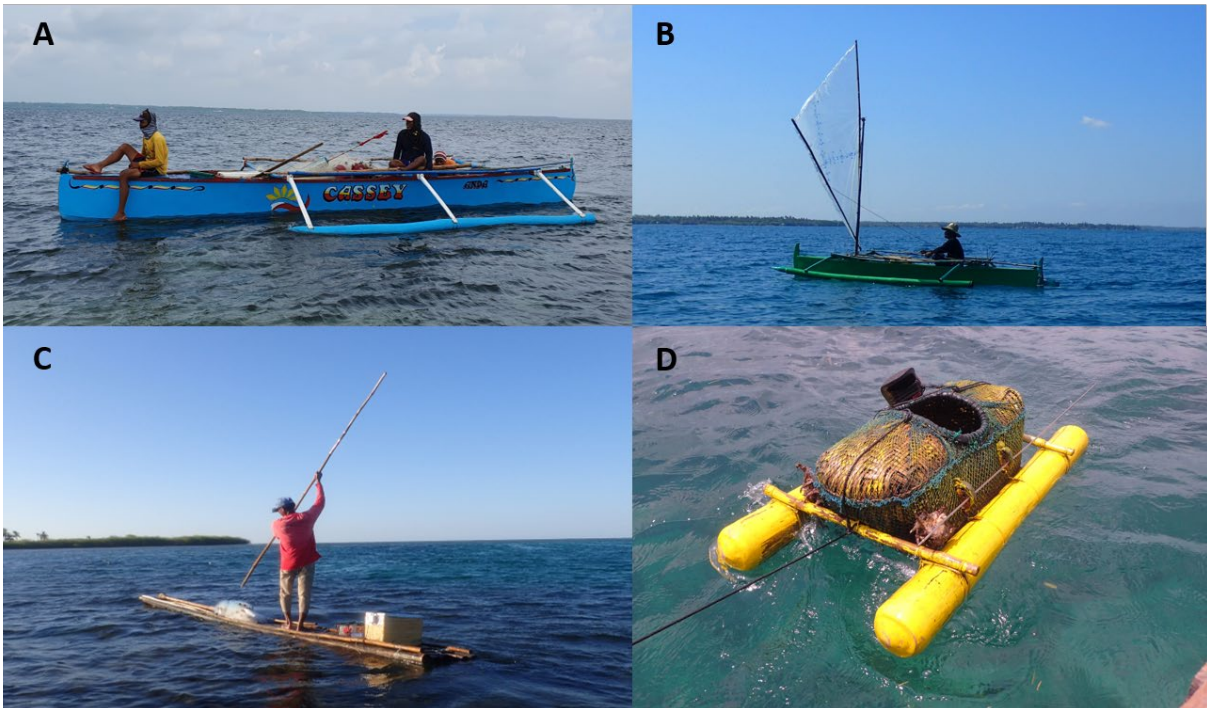

Figure 18. Different vessel types used in the fishery: A) motorised boat, B) non-motorised boat, C) raft, D) shore entry/floater (Source: Gomez et al. 2024).

Most of the vessels (58%) (boats or rafts) used for fishing are owned by the fisher respondents, while other fishers (42%) borrow boats from their employers or friends or opt to join other fishers to form groups. This is particularly common among gill net fishers who fish in groups of two to four in motorised boats and usually fish with their friends or family relatives.

Fishing gears used included Gill Net (62%), Hook and Line (16%), Traps (7%), and Spear (13%), with another boat seine gear type (1%) used by some fishers to catch surface-dwelling species such as needlefish and halfbeaks, as well as squids, and are operated from slightly larger boats with groups of 3-5 people. Gill Nets were further subdivided into bottom-set Gill Nets (38%), and encircling Gill Nets (24%), while Hook and Line were divided into Hand Line (4%), Long Line (4%), and Jiggers which were used to catch cephalopods (7%). These gear types were described in detail in previous ACIAR Annual Reports. Survey respondents indicated that these fishing gear types are used to some extent year-round, regardless of monsoon seasons. However, while most fishers (70%) tend to use a single gear type, other fishers (30%) use several types of gears alternatingly, or sometimes simultaneously during a single fishing trip. Therefore, to account for use of multiple gears, an additional combined 'Multiple' gear type category was used in the analyses with multiple gear users forming the second largest number of fishers, after gill net users.

Fishing effort

Average fishing days recorded per month were fairly consistent at around 20 days during Habagat and 21 days during Amihan monsoon seasons (Table 2). During these two seasons, fishers spend around 162 days fishing, equivalent to 44% of the year (minus four months of inter-monsoon). Varying trends in effort were evident in relation to gear type, except for hook and line fishers who used equal numbers of fishing days in each monsoon season. Line fishers had the highest fishing days at 28 days per month, or a total of 224 days in two seasons (61% active days per year). Multiple gear users had 19 fishing days during Habagat and 22 days during Amihan (45% active days per year), whereas gill net users fished for 19 and 20 days respectively per season (42% active days per year). Spear fishers fished less frequently on 17 days during Habagat, and more during Amihan at 20 days (41% active days per year). Line fishing had the highest number of fishing days and compared to gill netting, line fishing is easier to operate with only a single person, thus reducing the dependence on companions (or their schedule and availability) to help in fishing. Hooks and nylon can also easily be replaced to immediately continue fishing when gear is destroyed, whereas nets often need to be repaired or sometimes replacements purchased from nearby towns or more distant locations. Line fishing is also considered less tiring than active spearfishing and is not affected by some adverse water quality conditions such as increased water turbidity after rain events or strong winds.

TABLE 2. Average fishing days per monsoon season.

	Average fishing days per month		**Average total fishing days per season***		**Average total fishing days per monsoon seasons****	**Percent active days per year**
	Habagat (SE Monsoon)	**Amihan (NW Monsoon)**	**Habagat (SE Monsoon)**	**Amihan (NW Monsoon)**		
General	19.60 ± 0.28	20.96 ± 0.28	78.40 ± 0.28	83.84 ± 0.28	162.24 ± 1.92	44%
Gill Net	18.79 ± 0.36	19.79 ± 0.38	75.14 ± 0.36	79.14 ± 0.38	154.29 ± 1.41	42%
Hook and Line	28.00 ± 0.00	28.00 ± 0.00	112.00 ± 0.00	112.00 ± 0.00	224.00 ± 0.00	61%
Multiple Gear	19.29 ± 0.50	21.57 ± 0.53	77.14 ± 0.50	86.29 ± 0.53	163.43 ± 3.23	45%
Spear	17.33 ± 1.09	20.00 ± 0.82	69.33 ± 1.09	80.00 ± 0.82	149.33 ± 3.77	41%

Fishers spend an average of 6 fishing hours per trip during monsoon seasons, and may fish during 1 to 2 trips per day (Table 3). This is fairly consistent among gill net, hook and line, and multiple gear fishers, while spear fishers spend around 5 hours fishing per trip during both monsoon seasons. Gill net fishers often go fishing twice a day for three hours during early morning and late afternoon to evening, while line fishers and spear fishers spend the 5-6 hours at sea during the day.

TABLE 3. Average fishing hours per monsoon season.

	Total Hours/Day Habagat	Total Hours/Day Amihan	Trip Frequency Habagat	Trip Frequency Amihan
General	5.68 ± 0.35	5.89 ± 0.36	1.44 ± 0.08	1.43 ± 0.07
Gill net	5.77 ± 0.52	6.16 ± 0.45	1.57 ± 0.11	1.61 ± 0.09
Hook and Line	5.75 ± 0.96	5.75 ± 0.96	1.00 ± 0.00	1.00 ± 0.00
Multiple	5.71 ± 0.58	5.36 ± 0.59	1.32 ± 0.14	1.24 ± 0.12
Spear	4.67 ± 0.54	4.67 ± 0.54	1.00 ± 0.00	1.00 ± 0.00

Catch

Mean daily catch per fisher varied slightly between monsoon seasons. Fishers report an average catch of 6.6 kg per day during the Habagat or Southwest Monsoon with a slight increase to 7.2 kg during the Amihan or Northwest Monsoon (Table 4). This overall value represents the combined Catch Per Unit Effort (CPUE) of the whole fishery using various gears. Analysing these data further shows that fishers using gill nets and multiple gears having higher catches compared to line fishers and spear fishers. Gill net fishers report their highest catch during Amihan (7.96 kg) compared to Habagat (6.82 kg), while multiple gear users report almost identical catches (7.42 kg Habagat, 7.35 kg Amihan) over both monsoon seasons. These two gear types have the same mean catch for the combined monsoon seasons at 7.39 kilograms. Line fishers and spear fishers reported no perceived differences in their catch for both monsoons. Differences in catches per season may be affected by several factors associated with weather patterns that characterise each monsoon season: Habagat has heavy rains and storms, while Amihan has strong, cold winds resulting in larger waves. These prevailing weather conditions influence the frequency of fishing activities and conditions for fishing.

Combining the data for the mean daily catch, the number of fisher respondents as a proxy for numbers of fishing units, and the number of total fishing days, the Total Catch per monsoon season can be calculated as 28 metric tonnes for Habagat and 32 tonnes for Amihan. Combining these estimates for the two monsoon seasons that encompass two-thirds of the year, it is estimated that fishing from Tondol can produce up to 60 tonnes of fish from its surrounding waters (Table 4).

TABLE 4. Total Catch per monsoon and per gear type

	CPUE (kg/ fisher-day)		Fishing Units (fisher)		Fishing Days (day)		Total Catch (kg)		Sum	Percent share to total
	Haba-gat	**Ami-han**	**Haba-gat**	**Ami-han**	**Total Habagat**	**Total Amihan**	**Total Habagat**	**Total Amihan**		
OVERALL	6.62	7.24	53.0	53.0	78.40	83.84	27,507.42	32,171.08	59,678.51	100%
Gill Net	6.82	7.96	30.0	30.0	75.14	79.14	15,374.23	18,899.31	34,273.54	57.43%
Hook and Line	4.88	4.88	4.00	4.00	112.00	112.00	2,186.24	2,186.24	4,372.48	7.33%
Multiple	7.42	7.35	16.0	16.0	77.14	86.29	9,158.40	10,147.20	19,305.60	32.35%
Spear	3.00	3.00	3.00	3.00	69.33	80.00	624.00	720.00	1,344.00	2.25%

Fisheries catch composition

Figure 19 shows the fish families that were identified as being caught by fishers, and percentages represent the frequency of fish types mentioned, hence these percentages do not represent the actual proportions of the catch. Fish types reported by fishers using different gear types appear to vary less between monsoon seasons except for spear fishing where only caesionids (fusiliers) and scarids (parrotfish) were common between monsoon periods. For spearfishers, scombrids (tunas and mackerel) were often caught during Habagat, while cuttlefish were often caught during Amihan. Fishers mentioned that scombrids and carangids (jacks and scads) frequented the shallow lagoon area during the rainy season of Habagat (Figure 19). This may be related to increased surface runoff due to heavy rains bringing more nutrients to the shallow areas and contributing to blooms of plankton and lower trophic level organisms that these fish feed on (Bellwood 1988, Sivakami 1996, Honebrink 2000). Line fishers mostly caught serranids (groupers), nemipterids (sea bream), and lethrinids (emperors), together with octopus and cuttlefish since many of the line fishers specifically target these cephalopods.

As expected, gill net fishers and multiple gear users mentioned catching the greatest range of fish types belonging to more families, compared to line and spear fishers. This reflects the fact that nets are less discriminating and catch a wider range of fish species, whereas certain types of fish get attracted to bait or are specifically targeted by spear fishers. For both of these gear types, the most frequently mentioned fish caught were lethrinids (emperors), scarids (parrotfish), siganids (rabbitfish), carangids (jacks and scads), and scombrids (tunas and mackerel). Rabbitfish were often first mentioned in fisher interviews as they are the most targeted species with a constant market demand. Rabbitfish, together with juvenile emperors and snappers are processed as dried fish locally called *danggit* which can fetch around PHP 400 (AUD $10.2) per kilogram in the market.

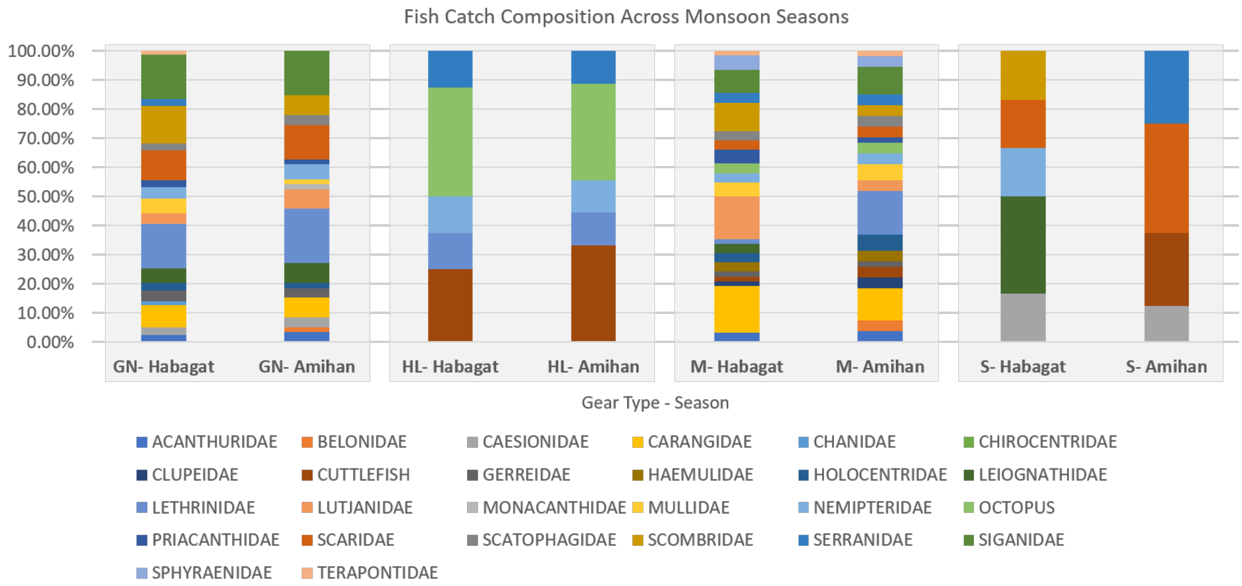

Figure 19. Frequently mentioned fish groups that were caught by fishers using different gear types (gill nets, hand lines, multiple gears, and spear fishing) and across monsoon seasons.

Fishing areas and reef use

The marine habitats around Tondol include a sandy lagoon (1-8 metres depth), seagrass beds (0-2 m), coral reefs (1-15 m), and the offshore sea areas (>20 m). Within this area, Tanduyong Island and several sandbars serve as barriers influencing the ecology and oceanographic dynamics in the area that affect the fishery activities and yields.

The marine region near Tondol is widely used by fishers with different fishing gears deployed in shallow to deeper water habitats (Figure 20). Areas with intermediate water depths and along the outer side of sandbars appear to have the highest overlap in terms of fishing areas used for different fishing gears. Deeper canals occur between sandbars and these serve as passageways for fish species connecting different habitats from the lagoons and seagrass beds to the reef, making these areas particularly suitable for fishing. Areas adjacent to the outer sides of the sandbars have benthic areas dominated by macroalgal assemblages and coral reefs, and support a larger variety of fish species. Further details on specific gear types used in different habitats are provided in previous ACIAR Annual Reports.

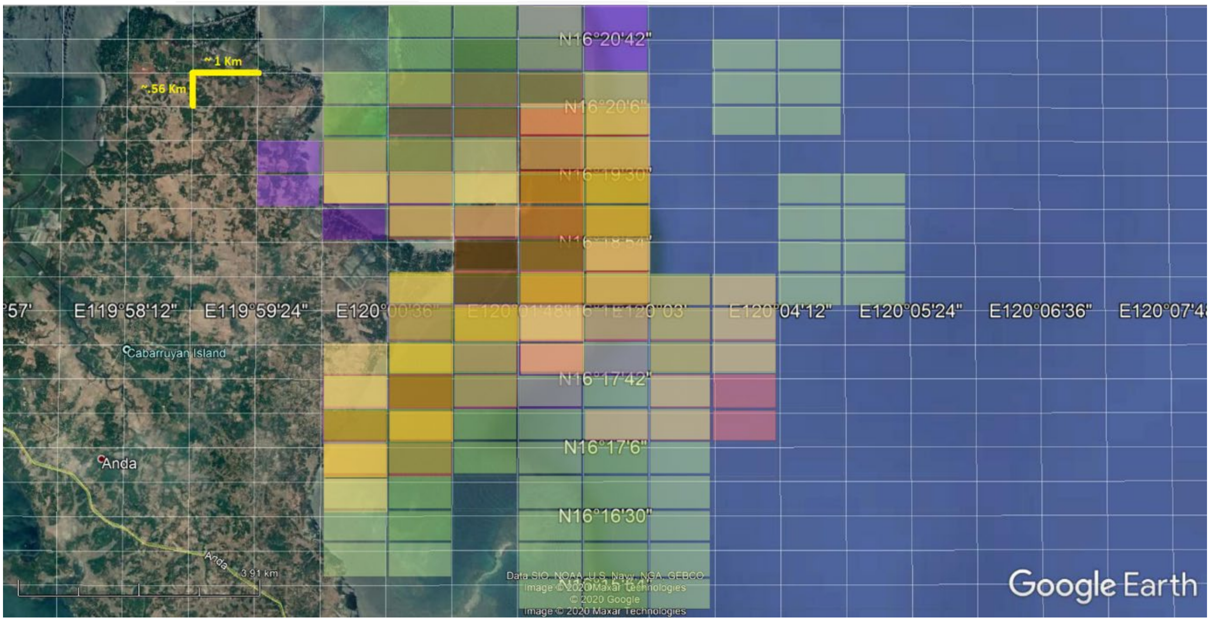

Figure 20. Summary of fishing areas reported by fishers. Colours identify different gear types: Green = Gill Nets; Red = Hook and Line; Violet = Traps; Yellow = Spear.

<u>Fisheries, employers and market chain agents</u>

The majority of fishers interviewed (68%) in Tondol do not have employers and therefore independently decide on their fishing activities and what to do with their catch. Fisheries employers are known in the local language as “amo” or financiers, and own the boats and fishing gears that are loaned in return for a portion of the catch. In some cases the boat owner employers sell the whole catch and return some of the proceeds to the fishers at the end of the week.

Most fishers (81%) report selling their catch in part or in whole to supply chain agents or ‘intermediaries’. Those who do not sell to intermediaries either only fish for family consumption or sell the fish themselves. Intermediaries play significant roles in Tondol fish supply chains, and fishers who sell to intermediaries have a consistent market. Although the presence of intermediaries has been considered to be problematic in other types of trade due to the high price markup and lack of equity, most of the few prominent intermediaries in Tondol are fishers themselves, and appear to have an amicable relationship with other members of the local fishing community.

Interviews with fishers revealed that for an average fishing catch of 7 kg, less than half (44%) of the catch is usually reserved for personal and family consumption while the rest is sold, mostly through the intermediaries. Of the 56% that is sold, about 26.6% of the catch gets sold in the local community and the remaining 29.7% is brought to other markets. Gill net fishers allocate almost equal parts of their catches for consumption versus sale, whereas multiple gear users allocate more of the catch for sale. Line fishers allocate more than half of the catch for personal consumption and only a small percentage gets sold to the community as most fish are sold to other markets. Spear fishers allocate smaller portions for personal consumption and sell most of their catch to the local community, probably because the spearing method damages fish, making them less able to be sold in other markets.

Fish catch allocated for sale goes to several markets including the local community. In Tondol, less than half (47%) of the catch is sold in the local community and the majority is sold in other markets. Intermediaries are mostly responsible for bringing local catch into other markets, or intermediaries serve as collection points for local catch, then higher level buyers purchase these collected fish from the primary intermediaries and take the fish into central markets, where stall owners sell the fish. These other markets include the town markets in Anda, Alaminos City, Bolinao, and Dagupan City, as well as smaller markets in other villages in Anda.

Fisher income, expenses, and alternative livelihoods

Fishers reported an average weekly income of around 1,300 PHP (~$33 AUD) for both monsoon seasons which equates to an income of about 5,200 PHP (~$133 AUD) monthly, which is below the minimum wage rate (5,640-6,800 MWR) for the region (NWPC 2019). Line fishers appeared to have the highest mean weekly income of 2,450 PHP (~$63 AUD), although this value is probably influenced by jigger users who catch octopus and cuttlefish that fetch higher prices compared to most fish. Spear fishers report the lowest income, and this is particularly the case during Habagat, where periods of fair weather suitable for spear fishing can be very limited. Encircling gill net users who fish alone on the shallow lagoon and seagrass beds often catch less compared to bottom-set gill net users. On a productive trip, bottom set gill nets can haul up to 30 or 40 kg of fish whereas encircling gill nets report catches up to 8 or 10 kg. However, the sale of the larger catches from the larger bottom set gill nets have to be divided between number of fishers on the boat, the boat owner/employer/financier, and this method has higher expenses for fuel and food on each trip. In contrast, the encircling gill net user has no expenses and uses the whole catch. Multiple gear users earn more than gill net users, probably due to the use of several gears during each fishing trip that can increase the total catch or provide flexibility to use different gears to suit different conditions and habitats. Large traps, for example, can provide up to 50 kg for a good catch, although catches are highly variable, and these are only deployed occasionally.

Fishers reported varying amounts of income from fishing, although the minimum amount reported was often zero, which indicated they only caught enough for personal consumption or less, and none was available for sale. Average expenses per week of fishing were highest for gill net and multiple gear users using motorised vessels, and these expenses equate to about 35 to 40% of their average weekly income. For line fishers, gill net users on rafts, and spear fishers, expenses are almost negligible. Other expenses fishers identified included ice, bait (for line fishers), food and occasionally materials for repair of lines, hooks, net, and traps as well as boat maintenance.

About 45% of the fisher respondents depended solely on fishing activities and may not have other sources of income and support for their families in situations where fishing is not favourable or allowed. During Habagat, more than half of the respondents or their families (55%) have alternative livelihoods including work on rice farming, which is highly seasonal due to the rainy season. Other fishers work in retail stores, coconut wine making, livestock, net repair, automotive work, construction and carpentry work, and only 4% of fishers engaged in jobs related to tourism. During Amihan, more fishers (21%) work in tourism as boat operators and tour guides, as more visitors use the white sand beaches and resorts of Tondol. Other fishers continue working in rice farming (14%), construction and carpentry (8%), and other trades (11%).

Although the local fishery provides fishers with minimal income and many fishers do not have alternative livelihoods, most fishers confirmed that they do not receive any support from government (88%) or other non-government entities (98%). The few fishers (12%) who responded that they received some support from the government mentioned being provided with boat frames and nets, while those that received support from NGOs (2%) mentioned being given seminar or training opportunities about the fishery.

Fishing restrictions

Interesting information was provided by fishers' about prohibited areas, species, and methods for fishing. Most fishers (75%) were aware of marine protected areas (MPAs) as restricted fishing areas, while almost a quarter of respondents (22%) indicated there are no restricted fishing areas, which is of concern for fisheries management. There are three designated marine sanctuaries near Tondol: Magsaysay Reef Marine Sanctuary (where the ACIAR coral restoration sites are located), Caniogan Marine Sanctuary, and Cabungan Fish Sanctuary (Figure 4). To the south of Tondol, the Hundred Islands National Park also has an established protected marine reserve, and the ACIAR coral restoration project now has restoration sites established within that region (see above). Evaluating the effectiveness of these smaller MPAs and their management, was beyond the scope of this report. However, during interviews, several fishers complained about the weak enforcement of these MPAs and the need for enforcement and compliance to be re-established. A few fishers (4%) also noted that other barangays have restricted areas, and some fishers report incidents whereby people from neighbouring villages repelled non-resident fishers in their waters.

Another concerning outcome from the fisher interviews was that almost a third (30%) responded that there are no fish species restricted from being fished. Clearly much more work is needed to engage with local fishers and the broader community to provide clear information about MPAs and restrictions on fishing to better protect these marine resources in future. Of the fishers that were aware of restrictions on taking legally protected species, the most commonly identified groups were turtles (20%), rabbitfish fry ("padas") (20%), giant clams (8%), and sharks and rays (8%, 6%) as well as corals (3%). Other species such as clownfish, dolphins, whales, whalesharks, "mother bangus" or milkfish breeders etc. were also mentioned (Others 8%). Thus, although some fishers had reasonable knowledge of fishing restrictions and protected species, some fishers seemed to be completely unaware of these important management issues. Some fishers mentioned that while 'true' giant clams (*Tridacna gigas*) in the area were not allowed to be taken because they were restocked by the University of the Philippines, other "natural" species (*i.e., T. squamosa, T. maxima, T. crocea)* could be taken, which is a misinterpretation of the legal requirements since all giant clam species are protected.

When fishers were asked about restricted fishing methods and gears, dynamite (31%) and cyanide poison fishing (23%) were the most frequently identified issues, followed by the use of fine mesh nets (17%). These methods and gears were often mentioned as they have been reported to be still prevalent in the area. Cyanide fishers coming from locations away from Tondol continue to concern local fishers, as do dynamite blast fishers who occasionally travel from distant areas and blast fish offshore. ACIAR project staff periodically hear blasts from fishers operating in the Lingayen Gulf, so although blast fishing has been banned in the Anda and Bolinao regions and does not affect the restoration sites, this is clearly an ongoing problem that will require further enforcement. Fine mesh nets have also been observed in the Tondol area, especially for some fishers who use encircling gill nets. The Republic Act 8550 and the Philippine Fisheries Code of 1998 and as amended by RA 10654, defines fine mesh nets as nets with mesh sizes smaller than 3 cm and these are considered illegal except for catching small fry.

Other illegal or inappropriate fishing methods mentioned by fishers include rabbitfish trawls, use of air compressors, triple nets, and root poison. Triple nets make use of multiple layers of legal sized-nets to make the effective mesh sizes smaller, despite each net having larger mesh holes, and therefore this method overlaps with issues associated with the use of illegal fine mesh nets. The use of air compressors has also been controversial and causes disputes among some groups, but formal laws about the use of compressors and possible restrictions have not be finalised. While the use of compressors has led to several cases of paralysis and death due to decompression sickness, some fishers argue that without access to this method, nets get stuck on corals and cause further damage to the reef. These results show that there is a clear need for further engagement and dialogue with government organisations, fishers, NGOs and other key stakeholders, as well as new information and education campaigns to properly manage the local fishery and enable it to become more sustainable.

Fisher perceptions and coral restoration

The other key aspect of the research this objective was based in fisher perception interviews, and the results from this research have recently been published in Gomez et al. (2024), and the following information is derived from that publication.

<u>Fish catch perceptions</u>

More fishers perceived a decrease in their fish catch over time than numbers of fishers who perceived an increase in catch (Figure 21). In relation to catch volume, more fishers were inclined to say that they were catching less fish (median=2, 37%). This perception was more prevalent among middle-aged and older fishers and more experienced fishers, fishers who finished high school, fished part-time and those who used non-gillnet gear. Respondents who fished within nearby reefs and farther away on outside reefs both perceived a slight decrease in catch volume. The same decreased trend was also perceived in terms of the variety of fish catch (median=2, 42%, Figure 21). Middle-aged and older fishers reported this decrease, as did newer and mid-experienced fishers. Fishers who finished high school were significantly more sensitive to this decrease (Mann-Whitney U test, $p<0.05$).

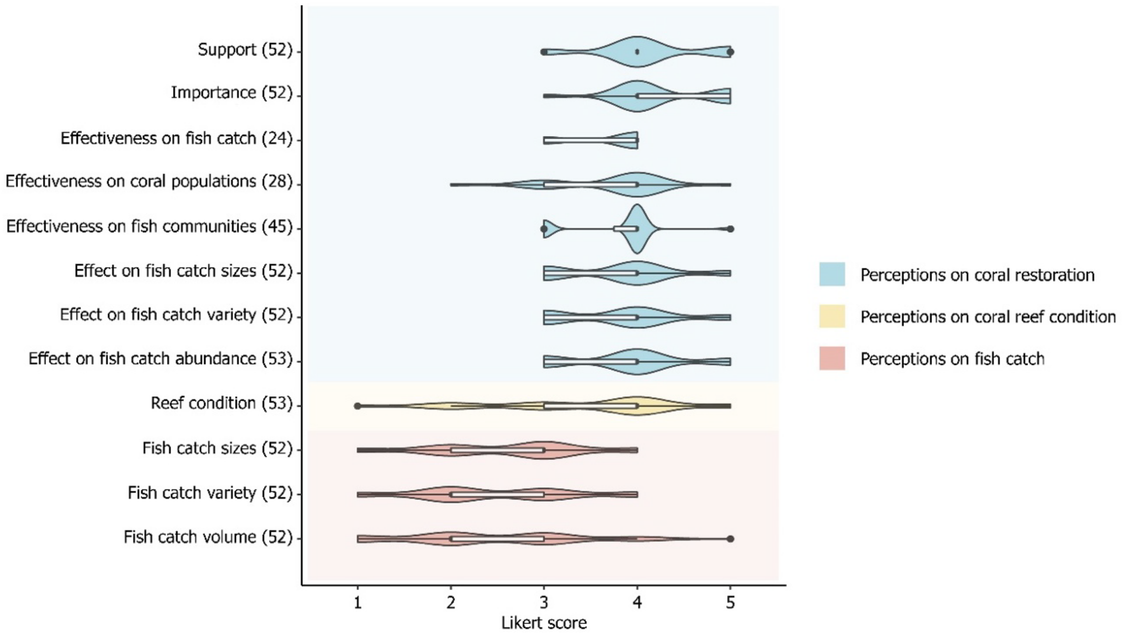

Figure 21. Violin plots of Likert scores showing fisher perceptions on each question within the themes: fish catch, coral reef condition, and coral restoration. Scores towards 1 show increasing negative perceptions (e.g., strong decline/degradation/negative impact), and scores towards 5 show increasing positive perceptions (e.g., strong increase/improvement/positive impact). Numbers in parentheses represent number of valid responses out of 53 (Source: Gomez et al. 2024).

Respondents who fished within and on outside reefs also reported a decrease in the types of fishes caught, and those who fished on outside reefs noted significantly lower variety of fish being caught throughout the years (Wilcoxon Rank Sum test, $p<0.05$). Fishers generally perceived that the size of fishes was relatively constant over time (median=3, 48%, Figure 21), although middle-aged and older fishers, and those that finished high school, and line and spear fishers reported a decrease in sizes.

Reasons cited for perceived decreases in fish catch (total n=37 fishers) were mostly related to overharvesting: “more fishers”, “outside fishers”, use of small mesh sizes and targeting even smaller fish, lack of big, spawner fishes, and increased demand (Figure 22). Other reasons given were due to continued illegal and destructive fishing, as well as due to “changing times” and climate, and “dirtier waters” and increased pollution. In contrast, among fishers who perceived an increase in their catch (n=7 fishers), top reasons related to a decrease in illegal and destructive fishing such as the use of cyanide—making their reefs “more beautiful than before”, and improvement of their gear quality and a change in fishing area where “there is more food for fish” (Figure 22).

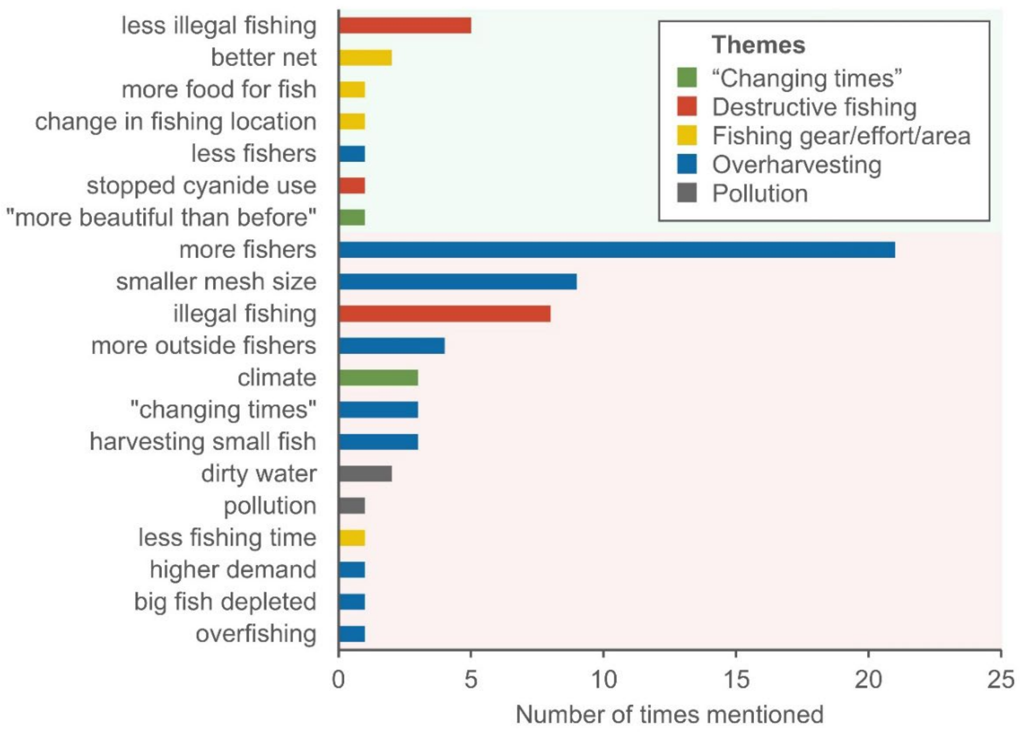

Figure 22. Perceived reasons for changes in fish catch. Light green shaded upper region of the plot indicates positive responses while light red lower section of the plot indicates negative responses. Responses were gathered from 44 fishers (Source: Gomez et al. 2024).

As noted in Gomez et al. (2024), fisher perceptions align with the reductions in fish catch that have been an ongoing trend throughout the Philippines based on national fisheries data (Bureau of Fisheries and Aquatic Resources, 2022) and this has also occurred the Lingayen Gulf, where reduced catches have been observed since the 1980s (Calud et al. 1989). Decrease fish catch was perceived to relate to overharvesting issues including increased effort due to an increased number of fishers, use of small mesh sizes that target fish outside recommended harvestable sizes, and the depletion of large spawning fish that have been noted in previous research (Hsieh et al. 2010; Hixon et al. 2014). The survey results indicate increased levels of overfishing within this small fishing village, which highlights the need for detailed investigation of the effects of overfishing on fish catch trends, particularly on fish sizes of the most commonly landed species to inform and develop more effective fisheries management strategies.

Decreases in the species richness in fish catches have also been noted in other areas in the Philippines (Nañola et al. 2011; Muallil et al. 2014; Anticamara and Go 2016; Lavides et al. 2016). Among the Tondol fishers, there were no clear patterns in perceived changes in the sizes of fishes caught, and this may reflect the shorter reference period used (last 5–10 years) being insufficient to detect consistent trends, or that fish sizes have not recovered or have remained stagnant after historical levels of high exploitation.

Perceptions about coral reef condition

About half of the fishers interviewed perceived that their coral reef conditions slightly improved over the last 5–10 years (median=4, 49%, Figure 23), particularly among young and middle-aged fishers and less-experienced fishers. Older and more-experienced fishers scored closer to neutral, indicating they perceived less or no obvious changes in reef condition. Fishers who used drive-in gillnets and spears scored no improvement nor decline in reef condition, while fishers using bottom-set gillnet and hook and line gear were more positive about the reef condition. Fishers operating within nearby reef sites also scored improvements in their reef, compared to those that fished outside who were neutral.

The main reason for perceived improvements in reef condition (n=30 fishers) was related to alleviation of illegal and destructive fishing, with fishers citing that there are “no more dynamite” blasts in their reef (Figure 23). Establishment and enforcement of Marine Protected Areas (MPA) and “better protection” were also important themes related to perceived improvement, along with seeing “more corals”, people having “more awareness” and the presence of restoration programs also mentioned by one fisher (Figure 23).

Fishers who perceived a decline in reef condition (n=12 fishers) noted the persistence of illegal fishers and the use of cyanide and dynamite, the lack of proper enforcement, and effects of other anthropogenic activities (e.g., boat grounding, ash from post-harvest burning and fertilizer runoff from farms) and natural or indirect human disturbances (e.g., coral bleaching and storms) (Figure 23). One fisher mentioned that “corals were better before” and another that the reef is now covered with more green algae.

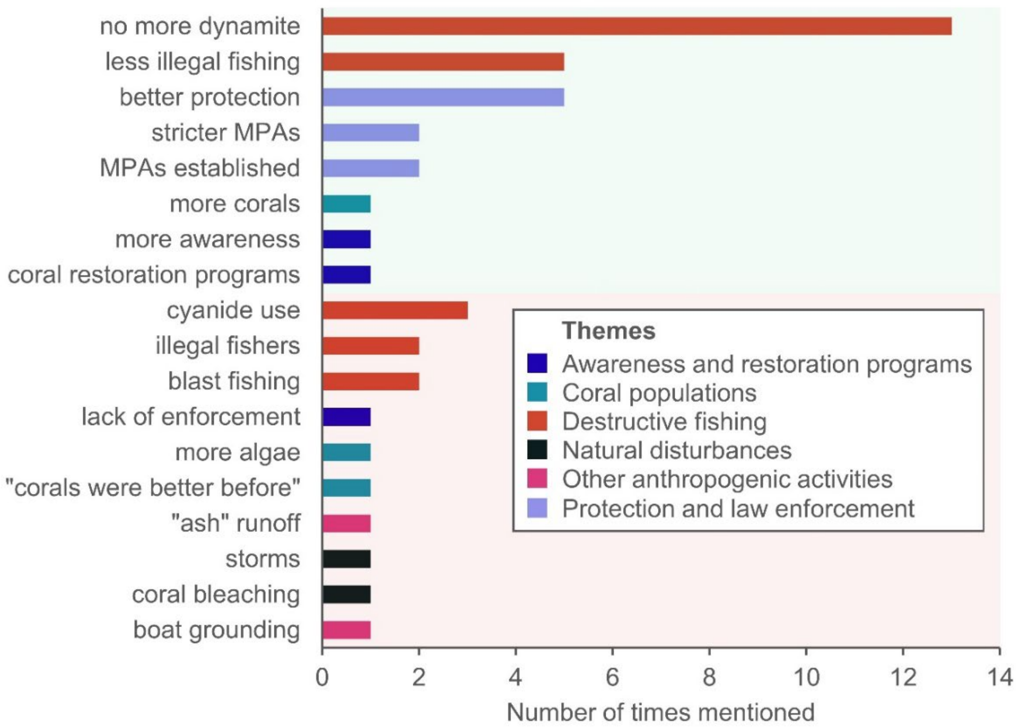

Figure 23. Perceived reasons for changes in coral reef condition among interviewed fishers. Light green shaded area of the plot indicates positive responses while light red shaded plot area indicates negative responses. Responses were gathered from 41 fishers (Source: Gomez et al. 2024).

In relation to local reef status, the Magsaysay Reef and the majority of the Lingayen Gulf reefs have been perturbed by natural and human-induced disturbances (McManus and Reyes 1997; Cruz-Trinidad et al. 2009; dela Cruz et al. 2014). Crown of thorns starfish (COTs) outbreaks, infestation by *Drupella* sp., coral bleaching, and storms have reduced coral cover in these reef areas over the last decades (dela Cruz et al. 2014). Blast and cyanide-fishing were mentioned by fishers in most conversations as historical and ongoing events, and some older fishers recounted hearing blasts daily and seeing them from the shore. While blast fishing no longer occurs in the nearby reefs and is not used by the local community, sounds of intermittent blasts can still be heard on reefs further away, which demonstrates that this critical management issue is still unresolved. The perceived decline in fish catch and coral reef condition by 20% of the fishers was mainly due to the persistence of these destructive fishing practices, which occurs despite the establishment of Marine Protected Areas (MPAs) in their fishing sites. In contrast, 36% of fishers noted that the reduction in these destructive and illegal fishing practices is the reason why they perceive that local reef condition has improved.

Fisher perceptions on coral restoration

Almost two-thirds (72%) of the respondents were aware that there were coral restoration efforts in their local area. When asked about what effects coral restoration could have on their fish catch, fishers were generally positive that growing more corals can improve fish catch volume (median=4, 58.5%), variety of fishes (median=4, 51.9%), and fish sizes (median=4, 55.8%) to some extent (Figure 24). These perceptions were noted by all fisher groups except for old fishers, drive-in gillnet fishers, and those that fish outside the reef environment who scored closer to neutral.

Fishers who believed coral restoration could enhance their fish catch (n=24 fishers) noted coral reef functions such as providing habitat (providing “nesting” and “mating” sites, providing “playground”), offering refuge and protection (e.g., “fish eggs are protected”, “protection from disturbance”), and providing food as well as habitats (e.g., “fish eat there”) thereby increasing fish abundance and allowing them to grow bigger (Figure 24). The 7 fishers who said doing coral restoration has no effect on fish catch included single respondents who noted that the corals grow slowly, or their rapid mortality (e.g., “corals die off easily after planting”) and “dirty water”. One fisher mentioned that their “fishing grounds are far from the restoration sites”, making them unable to observe its effects (Figure 24).

In relation to perceptions about the effectiveness of local coral restoration efforts in their area, only the scores of fishers who were aware of its existence were recorded (n=38 fishers), and then answers were further reduced where scores of 0 (i.e., “I don’t know” or declined to answer) were excluded (final n=31 fishers). Respondents were positive that the local restoration efforts improved their reef fish communities (median=4, 45%), coral reef condition (median=4, 34%), and local fish catch (median=4, 30%) to some extent (Fig. 3). This response was consistent among most fisher groups except for old fishers who were neutral about its effectiveness on coral reef condition, drive-in gillnet fishers who were neutral on its effectiveness for improving reef fish communities, and outside fishers who believed restoration had some actual positive effects on reef fishes and corals but to a much lesser degree. Overall, fishers of all groups were positive that coral restoration is important (median=4, 63%) and should be promoted (median=4, 65%).

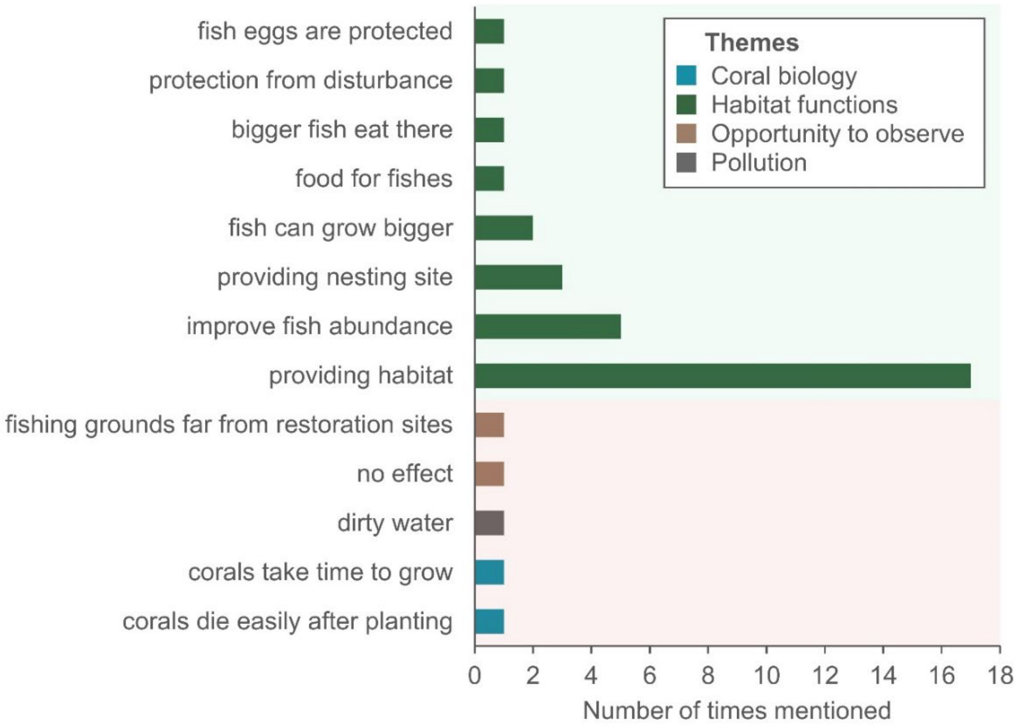

Figure 24. Perceived reasons for effectiveness or lack of effectiveness of coral restoration. Light green shade plot indicates positive responses while light red plot indicates negative responses. Responses were gathered from 31 respondents (Source: Gomez et al. 2024).

In relation to coral and reef restoration, fishers showed a clear understanding of the relationships between corals and reef fish communities, and noted that growing more corals meant providing more habitat, refuge, and food to allow more types of fishes to increase in abundance and size. The richness in nuanced habitat functions that some fishers highlighted including providing “mating place”, “nesting place”, “hiding place”, “playground”, “hunting ground”, “food table”, etc. indicates the local ecological knowledge that fishers possess (Berkstrom et al. 2019). Despite this, not all of the fishers interviewed knew about the restoration efforts that are occurring in their area, and some fishers who were aware of the restoration projects mentioned having no chance to observe the effects since they do not fish near the restoration areas, as it is within an MPA. This outcome highlights the need to provide better information about the coral restoration efforts to fishers and the wider community. Among fishers that were aware of the local restoration efforts, they perceived that it had brought positive impacts to their reef fishes, coral condition and fish catch, and recounted seeing more fish and corals near the restoration areas. Coral restoration was deemed to be important by the various fisher groups, and this was related to the many functions and ecosystem services they provide not just to reef organisms but also to people. This understanding aligns with their positive perception about promoting restoration efforts in other areas as well. These outcomes reinforce the importance of engaging strongly with local communities including fishers when planning and managing coral and fish habitat restoration projects, which aligns with the rationale underpinning the current ACIAR/FIS/2019/123 Coral restoration and stakeholder network project, and knowledge transfer and capacity building approaches being used by the project team for that project to scale up active restoration with local community and regional stakeholders (Harrison et al. 2023).

Objective 3: Stakeholder communication and training

Project team members have contributed to multiple workshops with stakeholders in conjunction with presentations by the ACIAR Coral Restoration Project team. These included fish and fisheries presentations during two one-day workshops on Coral Reef Restoration and Policy Guidelines on 27 and 28 September, 2018 at Alaminos City, Northwestern Philippines (Figure 25). The workshops were attended by 112 participants from a wide range of different stakeholder sectors including local government, law enforcement, tourism sector, and fisherfolk organisations.

The first workshop on 27 September was attended by 59 participants from local government departments from Anda and Alaminos City including the Vice Mayor of Anda, Police, Coast Guard, DENR and Tourism. In addition to presenting outcomes from the ACIAR projects to key stakeholders, an important outcome from the workshop was an agreement between Alaminos and Anda to draft a joint resolution to patrol and catch illegal fishers in their waters, with the help of the Coast Guard and Police. A total of 53 participants attended the second workshop on 28 September, including representatives from local fisher organisations, Barangay officials of Alaminos and Anda, and boat and tourism operators. Presentations about the SRA project and research outcomes were very well received, especially by the fisher community who had been working with the project team for the fisheries surveys. The workshops and presentations also provided good opportunities for discussions on fisheries management issues and policies.

Figure 25. Participants at the Coral Reef Restoration and Policy Guidelines workshops held on 27 and 28 September 2018 at Alaminos City, northwestern Philippines.

The SRA project team also contributed information about monitoring fish assemblages, fisheries data and management issues at the Coral Reef Enhancement Training Workshop conducted by the University of the Philippines at BML in May 2019, which was attended by 15 representatives of LGU Ilocos Sur, Sarangani, Legaspi City and private sectors from Surigao (Figure 26).

Figure 26. Participants at the Coral Reef Enhancement Training Workshop in May 2019 at the UP Bolinao Marine Laboratory.

In addition, SRA Project updates have been presented during meetings with partner stakeholders including the Local Government of Alaminos City and the Protected Areas Management Bureau (PAMB) who manage the Hundred Islands National Park. Participants were particularly interested to hear about pilot survey observations in the HINP sites including the presence of top-predator species (e.g., juvenile blacktip reef sharks, barracuda) and pelagic species (juvenile pompanos), and the general high abundance of fish present on some reef areas despite the low coral cover. Site survey data from the project was also presented to inform stakeholders about the overall poor reef conditions in most of the island reefs in HINP, which prompted discussions about stakeholder concerns and requests for further reef surveys and fish monitoring to be continued. Additional presentations on SRA outcomes have been included in stakeholder meetings during 2021 and 2022 to provide updates on project findings and outcomes.

In September 2019, information about the outcomes from the ACIAR supported coral larval restoration and fish habitat and fisheries projects were presented by Harrison to the Policy Advisory Council and ACIAR Commission meeting in Townsville. This provided an important opportunity to showcase the results from the combined ACIAR coral restoration and fish habitat projects in the Philippines, and plans for future regional expansion and stakeholder networks. Results from the SRA project were also presented during the 15^{th} National Marine Science Symposium held at Aklan State University, Aklan, Philippines in July 2019, and in an abstract accepted for presentation at the International Coral Reef Symposium (ICRS) in Bremen, Germany that was originally scheduled during July 2020 but was postponed until July 2021 due to the COVID-19 pandemic. SRA Project outcomes were also presented at the17^{th} Philippine Association of Marine Science Symposium in Batangas and 5^{th} Asia-Pacific Coral Reef Symposium in Singapore in 2023.

Social media accounts

Facebook and Instagram social media accounts were developed for both the ACIAR Coral Restoration and Fish Habitat and this SRA Fisheries projects to facilitate efficient delivery of information to stakeholders and the wider public. These accounts enable team members to post activity updates and research outcomes from the projects (Figures 27 and 28). Use of "hashtags" in each post and tagging people and organisations involved in the project enables viewers to find posts easily and showcases the efforts of the people behind the research.

These accounts were managed by the SRA project's research assistant Rick Gomez, and are now managed by other team members. The social media sites have been regularly updated with new posts and a focus on creating specific educational materials such as infographics and videos about Philippines coral reefs, coral restoration project outcomes, and ocean conservation.

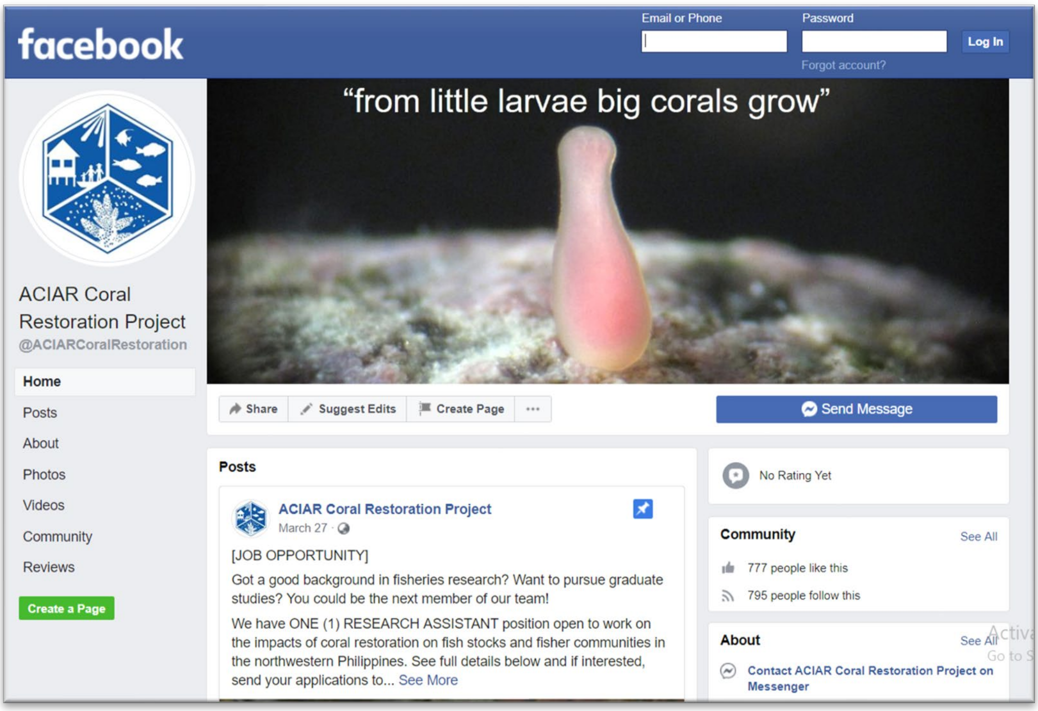

Figure 27. Facebook account for the ACIAR Coral Restoration and ACIAR Fish Habitat Projects

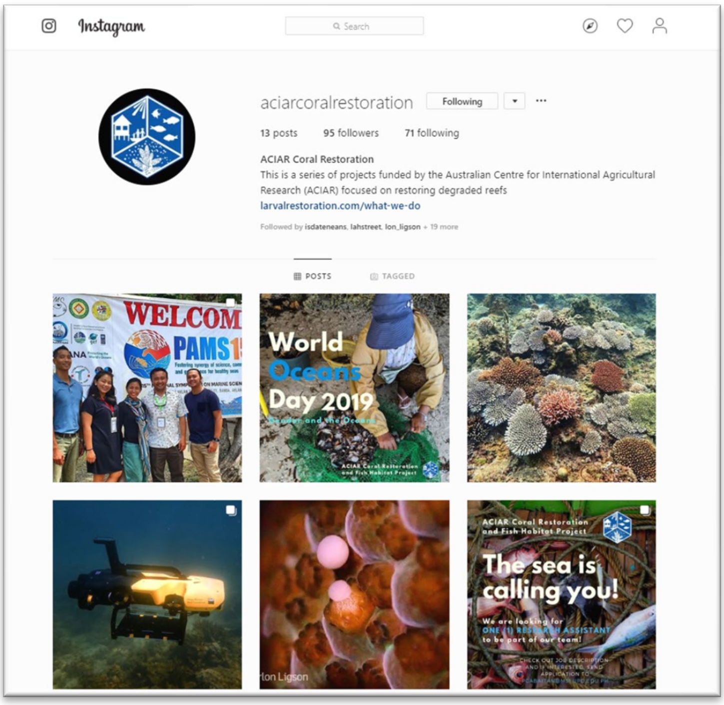

Figure 28. Instagram account for the ACIAR Coral Restoration and ACIAR Fish Habitat Projects

Project images and electronic media pack

The ACIAR projects team have created extensive libraries of still and video imagery as part of the project objectives, and have created an electronic media pack housed online on Dropbox that includes photos and video with descriptive information included in the labels. This resource enables ACIAR and media agencies to access resources to promote the project without needing to travel to the Philippines to capture the imagery required to support their stories (Figure 29).

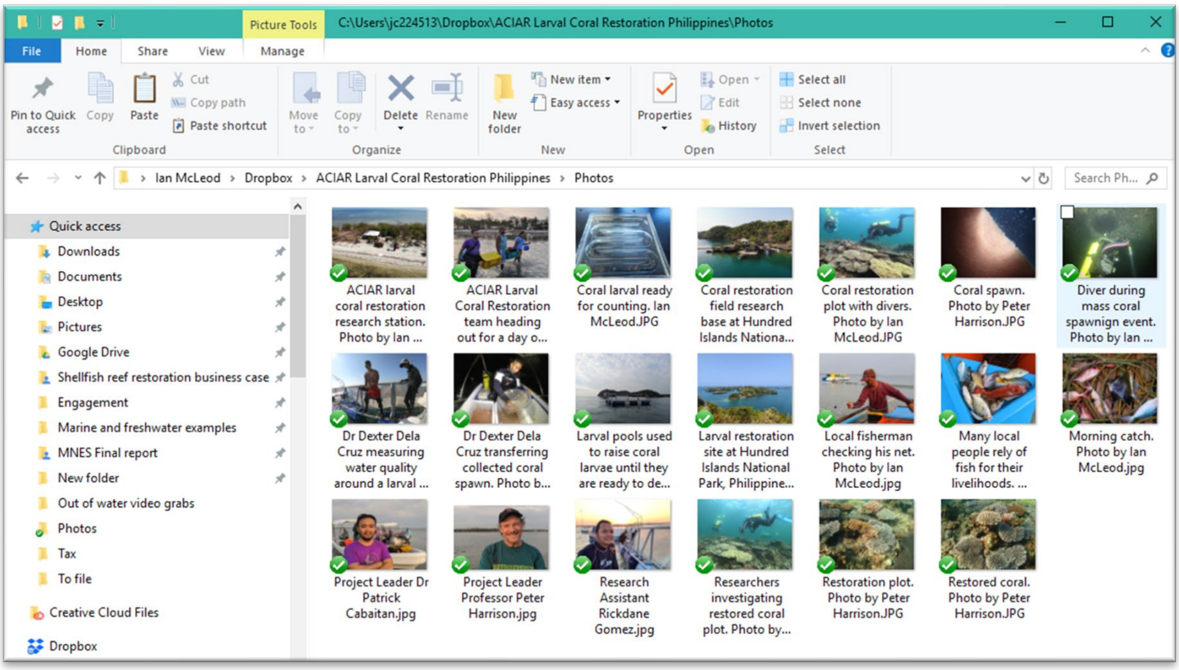

Figure 29. Electronic media pack uploaded to Dropbox for use by ACIAR and media agencies to promote the ACIAR Coral Restoration projects globally significant outcomes.

The project team also provided high-quality photos for an image-based website to promote coral restoration projects globally hosted by the Coral Restoration Consortium (Figure 30).

Figure 30. Photography-based website providing images highlighting ACIAR project outcomes for media.

Project investigator Ian McLeod produced an innovative underwater 360-degree video during March 2019 showing project researchers diving on healthy corals in previously established coral restoration plots resulting from the previous ACIAR FIS projects. Video imagery was colour-corrected, edited and posted on the ACIAR Facebook account on World Oceans Day in 2020 (Figure 3). The video can also be used with a headset to allow viewers to experience diving on a restored coral reef and is useful for local stakeholders who do not dive or would otherwise not have the opportunity to experience the project restoration outcomes in person. This media pack was shown and showcased in the project booth during the the 17th Philippine Association of Marine Science Symposium in Batangas.

Figure 31. Screenshot from the underwater 360-degree video sequences showing project researchers diving and monitoring growth of restored corals on one of the restoration plots at Magsaysay Reef (Image: Ian McLeod).

<u>Television documentaries</u>

The ACIAR FIS Coral restoration projects continue to attract very significant international media attention. Project leader Peter Harrison was interviewed for *BBC Blue Planet Live* at Heron Island on Australia's southern Great Barrier Reef in March 2019. One of the live interviews included Harrison's video sequences of the ACIAR coral restoration plots and highlighted the presence of fish using the restored coral habitats, and the documentary was seen by millions of viewers.

One of Ian McLeod's video sequences of Harrison diving under a large coral spawn slick on the Magsaysay Reef restoration site in 2019 was included in a recent environmental documentary series 'Age of Nature'. The series is an international co-production with Brian Leith Productions and explores human relationships with nature, and includes interviews with Harrison about the declining status of coral reefs globally and coral restoration projects in the Philippines that are supported by ACIAR, and on the GBR.

8 Impacts

8.1 Scientific impacts – now and in 5 years

Research from this project has resulted in important scientific impacts through new knowledge of responses of reef fish assemblages to different coral and fish habitat restoration outcomes, increased knowledge of local fishing and fisheries issues, and fisher perceptions about the status of local fisheries and lack of effective management on local reefs. Outcomes from the detailed and expanded fish assemblage monitoring for this SRA project are continuing to show positive effects of coral larval restoration for restoring fish habitats that support reef fish assemblages on degraded reef areas. Surveys during 2019 and 2020 of the fish assemblages in experimental sites established during the earlier coral restoration reef trials from 2013 to 2018 using larvae of a range of branching *Acropora* species, have demonstrated increases in mean fish abundance and mean fish species richness in the larval restoration plots compared with the control plots at some sites. Analyses of fish assemblage composition and trophic groups present have shown that these assemblages are mainly dominated by herbivores and invertivores, with some increases in corallivorous fish in recent years, particularly in some larval-enhanced plots, corresponding to increased coral cover. Mean abundance of commercially targeted fish species has varied between treatments and over years, but target fish have tended to be more abundant in larval-enhanced plots compared with control plots over time. These results indicate that mass coral larval restoration not only increases coral population recovery and initiates reef restoration, but also positively influences fish habitats and fish assemblages with potential benefits to fishery values, even on badly degraded reef systems.

Monitoring of fish assemblages in the more recently established and larger-scale larval restoration reef trials has shown variable patterns of mean fish abundance, species richness, biomass, composition and trophic groups between treatments and among years. These sites will require longer-term monitoring to detect consistent and significant trends, but are predicted to follow similar trajectories to those in the longer-established larval restoration plots noted above. Based on the ongoing coral assemblage recovery trajectories and the subsequent changes in reef fish assemblages on restored reef sites evident to date, the scientific impacts from the coordinated fish assemblage monitoring programs across the ten restoration sites in multiple reef areas are likely to show stronger evidence of positive impacts of fish habitat restoration on fish assemblages in 5 years from now, hence longer-term monitoring of these sites is recommended.

Detailed surveys of fisheries operations and fisher perceptions have provided important new baseline information about the fisheries in Tondol, which is the village closest to the original Magsaysay Reef ACIAR project coral restoration sites. The total number of fishers in the Tondol area is not precisely known and fisher occupation is not specified in the census process, but local government staff estimate that approximately 30% of the population work in the agricultural sector as fishers or farmers. Survey results from interviews of 53 local fishers indicated an average daily catch of 6.6 kg per fisher during Habagat (Southwest Monsoon) and 7.2 kg during Amihan (Northeast Monsoon). This equates to an estimated total catch of about 60 tonnes for the two monsoon seasons combined. The local fishery is dominated by use of gill nets, hook and line, spear, and traps, with ~30% of fishers use multiple gears during fishing trips. Catch composition is more diverse for gill net and multiple gear users compared to line and spear fishers. The waters surrounding Tondol are well-utilised by fishers using a range of different fishing gears. The most frequently used fishing locations appear to be the deeper reef areas for most fishing types and the channels in between sandbars. The sandy lagoons are frequented by line and net fishers and for trap fishing, while the seagrass beds are particularly used for encircling gill nets to catch rabbitfish. The deeper waters were mainly used by fishers using bottom set gill net and lines, and fishers deploying large traps.

Fish catch is mostly composed of various demersal species and some pelagic species, with a specific fishery demand for rabbitfish. Less than half of the catch (43%) is usually used for personal and family consumption while the rest is sold almost equally to the local community (27%) or in other markets (30%) such as the central market and other villages in Anda, Bolinao, Alaminos, and Dagupan regions through agents. Income remains low at an average of 5,200 PHP (~$133 AUD) per month, with about half of the respondents fully reliant on fishing for their livelihood with no alternative income.

Fishers have strong local ecological knowledge of their reefs and fish habitats but varying levels of knowledge about fisheries-related issues including which areas are allowed for fishing, restricted species, and prohibited methods, and only a small proportion of the fisher community know enough details about these important issues. This highlights the need to improve communication between local fishers and government and management authorities on these issues, as well as the need for more information and education campaigns to improve fishery management. Some aspects of the fisheries data and fisher perceptions indicate some degree of local overfishing, which highlights the increasingly urgent need to better assess and manage fish stocks and other resources. These research findings need to be acted on to ensure that within the next 5 years, the information discovered in this research is acted on to better educate and integrate local fishers into an improved fisheries management structure.

Fisher attitudes towards the importance of coral reefs and the need to protect these resources were consistently positive, whereas their perceptions about the health status of local reefs elicited a wider range of responses. Fisher awareness about the previous threats operating in their waters previously and those that continue now, led to suggestions for improving fishing practices within their community and the need for better enforcement and management of MPAs. These responses indicate that there is strong potential for collaboration and engagement between fishers and government and management authorities that can lead to improved fishery, socio-economic and environmental outcomes, but as noted above, this engagement needs to occur soon to ensure that better integration occurs within the next 5 years.

The majority of fishers' interviewed believe in the potential for coral restoration to positively change and improve their reef status. Most fishers have an ecological understanding of the mechanism by which increased coral and fish habitat recovery can positively influence fish stocks available for fishing, but most fishers were not aware of any obvious changes resulting from the small-scale coral restoration trials on the nearby Magsaysay Reef areas so far. This is to be expected because of the smaller scales at which the initial coral restoration pilot studies were done and the early stages of coral recovery resulting from these initial restoration interventions. Furthermore, most fishers had not had opportunities to interact directly with the coral restoration activity and the recent larger-scale restoration because the restoration sites occur within MPAs and therefore are largely protected from fishing. This finding reinforces the need to continue to expand and build on the previous communication and engagement plans for the coral restoration projects through future planned workshops and hands-on training activities with participation by local fishers and other community groups and stakeholders to build local reef restoration networks that will sustain these local restoration outcomes in future after the current ACIAR projects have been completed.

8.2 Capacity impacts – now and in 5 years

This SRA project has provided strong training opportunities and capacity building for the staff involved in the project, including Rickdane Gomez who has now moved overseas to complete his research Master's degree. Rick's capacity to identify reef fish was enhanced by working with BML Technician Jun Castrence, who is a fish identification expert at BML. Jun initially trained Rick during fish surveys to build skills for surveying reef fish assemblages enabling Rick to expand the SRA activities to encompass monitoring of fish assemblages over a wider range reef restoration sites. Rick also gained important skills in drafting the research manuscript on fisher perceptions and managing the editing process with team members for the submission, review and revision leading to the publication of his first research paper Gomez et al. (2024) in Ocean and Coastal Management: 255 107233.

In addition to improved skills with scientific methods and replicated monitoring designs, team members have developed new skills in fisheries interviews, project planning and fieldwork implementation, budgeting, and time-management, as well as a variety of other practical skills. In addition, project staff have developed scientific presentation skills and contributed to multiple formal stakeholder training and capacity building workshops. They have also gained public speaking and scientific presentation skills through presentations to research colleagues at conferences, including at the 15th National Marine Science Symposium held at Aklan State University, Aklan, Philippines in early July 2019, and the international 5th Asia-Pacific Coral Reef Symposium in Singapore in 2023. The research and training opportunities enabled through this SRA will also have long-term benefits for the researchers, staff and assistants as well as volunteer and community participants including improved knowledge of coral reef ecology and fisheries management, as well as scientific research skills, statistical analyses and increased self-confidence and public speaking skills that are important for their career development.

8.3 Community impacts – now and in 5 years

A wide range of stakeholders including local community members and government staff have engaged in this project through participation in fishery surveys and at workshop presentations and discussions where the SRA research outcomes have been highlighted. Community members actively participated in Coral reef restoration and Policy guidelines workshops organised by the combined ACIAR projects teams during September 2018 at Alaminos City, attended by 112 participants. The second workshop also provided training and information for 53 participants including fishers, boat and tourism operators and Barangay officials of Alaminos and Anda. Lectures and training information on reef fish and fisheries issues were also presented at the BML workshop in May 2019, attended by 15 Local Government Unit representatives from Ilocos Sur, Sarangani, Legaspi City and private sectors from Surigao. Additional SRA fish assemblage monitoring and fisheries related information has been presented at stakeholder training and capacity building workshops with local community members in 2021 and 2022, and more recently in 2023 and 2024 as part of the stakeholder engagement and local community restoration network development with the current ACIAR/FIS/2019/123 project. Additional community impacts are anticipated over the next 5 years and beyond as the restoration sites and fish habitats recover over time, leading to increased fish production and subsequent fish spillover effects that can provide increased fishing opportunities for coastal communities (Russ and Alcala 2011).

8.3.1 Economic impacts

The economic impacts of this research will not be able to be fully assessed until further detailed data are obtained from longer-term fish assemblage monitoring and fisheries surveys within and around the restoration sites, and particularly the more recently established larger-scale restoration sites. We predict that economic benefits will occur from increasing fish abundance and species richness on larger restored reef areas, particularly if the trends of increasing abundance of fish species that are targeted by fisheries continue in the restoration sites. However, these economic benefits are more likely to be evident if fishing pressures are effectively managed within the designated MPAs so that fish populations re-establishing on the coral restoration sites can grow large enough to breed and provide recruits to other reef areas where fishing is allowed. At present, the MPAs where the coral larval restoration has been initiated are not effectively managed, and some fishing still occurs within the MPAs which will potentially confound evaluation of the economic impacts of the restoration outcomes and fisheries benefits in future. As noted above, it is important that these MPAs are more effectively managed within the next few years to ensure that the ecological and socio-economic impacts of the coral restoration and fish habitat recovery are fully realised.

8.3.2 Social impacts

As with the economic impacts, the broader social impacts from this SRA project will require further time to become evident, however the positive interactions with local fishers and other community stakeholders and LGU staff through the SRA research and engagement activities have provided important knowledge transfer about the importance of maintaining and managing healthy coral reefs, coral ecology and the status of reef fish assemblages, and the benefits of larger-scale coral and fish habitat restoration. The positive responses of fish assemblages with respect to increased mean abundance of target and other fish species and increased mean species richness in most of the longer-established restoration sites that are characterised by increasing coral cover are encouraging. Based on the trends evident in the repeated fish and benthic monitoring surveys in the longer-established restoration plots, it is likely that fish assemblages will continue to exhibit increased abundance and higher species richness in larval enhancement plots compared with control plots over coming years. Healthy coral reefs provide important goods and services that are socially and economically important at local and regional scales throughout the Philippine archipelago (Alcala and Russ 2006, Cruz-Trinidad et al. 2011). Consequently, the social benefits and impacts are likely to increase as restored coral populations continue to grow and provide improved reef habitats for fish and other reef resources of direct benefit to local communities and businesses. Increased fish and other reef resources could also provide some indirect social benefits including fishers being able to spend more time onshore in the community and with their families due to reduced travel times for fishing and increased CPUE outcomes through increased breeding populations on restored reefs (Harrison et al. 2021b). Additional social impacts may also result from the growing network of local people engaged with coral larval restoration and the social capital that is being built around these activities.

Future restoration activities should plan for increased engagement with local fishers and other community members and targeted educational training with schools to increase the social impacts of the restoration projects. One of the important early outcomes from the training workshops at Alaminos City was the agreement between Alaminos and Anda to draft a joint resolution to patrol and catch illegal fishers in their waters, with the help of the Coast Guard and Police. This initial agreement should be further developed to promote increased collaboration among local authorities, fishers and other community stakeholders to more effectively protect coral reef habitats in future, especially in the designated MPAs and coral and fish habitat restoration sites.

8.3.3 Environmental impacts

Evidence of increasing fish abundance and increased fish species richness in the longer-established larval enhancement plots compared with natural control reef areas with low coral cover indicate that positive environmental impacts are resulting from the ACIAR coral larval restoration and fish habitat projects. The stakeholder engagement and training workshops and other educational and communication activities involving local fishers and communities, LGUs, and discussions and collaboration among local Mayors and other municipal staff in the Bolinao and Anda regions and the City of Alaminos, are improving the opportunities for more effective protection and management of local reef fish resources in the future. Further training and education workshops and practical involvement with the restoration activities by local fishers and other community members would lead to improved and more sustainable use of these restored reef areas by fishers, particularly in the more highly-protected reef sites within the HINP and hopefully in the other MPAs in future when fishing activities are more effectively managed.

8.4 Communication and dissemination activities

Results from the fish assemblage monitoring and fisher and fisheries surveys from this project have been effectively communicated to a wide range of different stakeholders including research scientists and reef managers, local fishers and community members, and municipal authorities and the broader public through presentations at multiple local and regional workshops, national and international conferences, and in media releases and television documentaries. Project outcomes were also highlighted in a presentation to the Australian Ambassador and government and other stakeholders at the Australian Embassy in April 2019, and to the Policy Advisory Council and ACIAR Commission meeting in Townsville during September 2019. These presentations showcased the results from the combined ACIAR coral restoration and fish habitat projects in the Philippines, and elicited very positive feedback from attendees.

Project outcomes have been communicated in presentations during national conferences including the Philippine Association of Marine Science (PAMS) Symposium in Aklan State University in 2019 and in Batangas State University in 2023, where the project had a dedicated information booth and a special session highlighting the positive trends emerging among fish assemblages on restoration areas. The project team have also presented outcomes from this project in coral larval restoration presentations at international conferences, including the International Coral Reef Symposium (ICRS) in Bremen, Germany in July 2021 and detailed data and conclusions were presented at the 17th Philippine Association of Marine Science Symposium in Batangas and at the 5th Asia-Pacific Coral Reef Symposium in Singapore in 2023. We have also established a strongly-engaged following on Facebook, with many posts being viewed by thousands of people, and a growing presence on Instagram. High-quality images and video sequences taken by project staff have been used to create an electronic media pack to support and enhance media coverage, and we have supplied project images to support other international coral restoration initiatives including the global Coral Restoration Consortium website. The ACIAR coral restoration projects continue to attract a lot of news coverage and media interest, including being highlighted in international BBC television broadcasts and other documentaries.

9 Conclusions and recommendations

This SRA Project has been successful and has achieved the aim of establishing long-term monitoring and evaluation of the impacts of coral restoration on fish assemblages in multiple reef sites in the northern Luzon region of the Philippines, and providing important new information about local fishing and fisheries issues, and fisher perceptions about the status of their local reefs, fish resources and coral restoration activities in the Tondol region.

9.1 Conclusions

This SRA Project has successfully completed the planned research and communication activities for the three objectives. We expanded the scope of the initial planned fish assemblage and benthic reef monitoring surveys to encompass a total of ten restoration sites and comparison with experimental controls, healthy reef areas and additional degraded reference reef sites. Monitoring of fish assemblages has demonstrated variable trends among sites, over years and between treatments including some significant increases in fish abundance and species richness and target fish species in longer-established larval restoration areas compared with some control areas that are not recovering naturally. Fisheries survey data in Barangay Tondol indicate that almost 60 tonnes of fish are caught during the two monsoon seasons using gill nets, hook and line, fish traps, and spearing as the most common fishing methods, with 30% of fishers using multiple gear types. Fish catch is mostly small, demersal species and some pelagic species, with a specific fishery demand for rabbitfish. Less than half of the catch is usually used for personal consumption with the rest sold to markets. Income is low, averaging 5,200 PHP (~$133 AUD) per month, with about half of the fishers interviewed fully reliant on fishing for their livelihood. Only a small proportion of the fisher community have good knowledge of which areas are allowed for fishing, restricted species, and prohibited fishing methods, which highlights the need for further information and education campaigns to improve fishery management. The majority of fishers' interviewed believe coral restoration can improve local reef status but most have not been able to directly interact with the restoration areas within MPAs, therefore further work is needed to actively engage with local fishers and other stakeholders to integrate them into stakeholder networks that can provide essential support for long-term protection of remaining healthy reef patches and restored reef areas to support increased breeding fish assemblages and spillover effects to replenish fish resources in nearby fishing areas.

9.2 Recommendations

Building on the successful SRA Project outcomes, it is recommended that the detailed quantitative monitoring of fish assemblages and reef benthic assemblages in restoration and nearby degraded coral sites be continued over longer periods to fully assess the effects of coral restoration on improved fish stocks and potential benefits for local fisheries. In addition, longer-term monitoring should include social science research with adjacent fisher communities to determine if there are any changes in perceptions about local fisheries and restoration activities. These potential changes in perceptions and also in community engagement and commitment can be encouraged by further integration of fisher and other local community representatives in future larger-scale coral and fish habitat restoration campaigns. Outcomes from the longer-term monitoring program should be regularly communicated to fishers and other local community members, LGU and municipal staff, and national fisheries and reef management authorities through local education campaigns, regular workshops and training opportunities, reports, conference presentations, and through research publications and media campaigns for the wider national and international community. The fisher and fisheries research highlighted some important issues that should be addressed, including improving dialogue between local fishers, Barangay and fisheries management staff to create greater awareness about areas that are allowed for fishing, restricted species, and prohibited fishing methods. Further integration of fisher and other local community representatives in future larger-scale coral and fish habitat restoration campaigns is also strongly recommended to build knowledge and capacity, and support local communities who depend on healthy reef ecosystems for essential food resources and livelihoods.

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10.2 List of publications produced by project

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11 Appendixes

11.1 Appendix 1: