





Technical report to NSW Environmental Trust and NSW Recreational Fishing Trust

Community action blueprint to enhance estuarine habitat resilience

SOLITARY ISLANDS UNDERWATER RESEARCH GROUP, INC.

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EXECUTIVE SUMMARY

The Solitary Islands Underwater Research Group (SURG) is a citizen science organisation comprised of volunteers passionate about their local marine ecosystems. SURG members have undertaken marine based projects in the Coffs coast region for over 30 years, collecting data on such subjects as coral bleaching, fish communities, the spread of corallimorphs, and marine debris assessments. SURG members have undertaken a range of projects that promote stewardship of the coastal and marine environments and deliver conservation outcomes.

The *Community action blueprint to enhance estuarine habitat resilience* project, funded by NSW Environmental Trust and NSW Recreational Fishing Trust, provided the framework for SURG members and the wider community to: participate in a range of activities aimed at understanding how human activities threaten critical habitats of aquatic organisms; encourage participation in remediation works; understand the significance of local estuarine ecosystems; and highlight ways to mitigate local threats, which in turn build estuary resilience and enhance biodiversity. Additionally, this project provided an opportunity to evaluate the ability of a community group to develop and implement an estuarine project that could be duplicated at other locations.

Estuaries are at the interface of freshwater and marine environments. They provide essential breeding and 'nursery' habitats for numerous aquatic species. In NSW, many estuaries are subject to numerous anthropogenic threats that can lead to degradation of these important habitats. Despite the known importance of NSW estuarine environments to threatened and protected marine species, limited information is available about the status of these habitats, or the level of pressures to which they are exposed.

SURG focused on four estuaries: Boambee Creek, Coffs Creek, Moonee Creek and Corindi River. These estuaries support a wide range of habitats including seagrasses mangroves, saltmarsh, rocky outcrops, coffee rock, deep holes and artificial structures. Throughout the duration of these activities a total of 62 SURG members and 74 locals contributed 5,148 volunteer hours to complete different aspects of this project. Participants assisted in mapping seagrass beds, assessed fish diversity, quantified debris and mud crab trap impacts and undertook remediation work. All these activities contributed to the development of interpretive panels and fact sheets that highlight specific threats to specific northern NSW estuaries.

Seagrass habitat mapping

In-water observations and aerial photographs were utilised to map seagrass cover in target estuaries using ArcGIS software. Spatial maps that reflect seagrass cover in 2017 were compared with records completed in 2009. Eelgrass (*Zostera* spp.) was the only seagrass species recorded during this project and was most commonly found along the shallow margins of the estuaries. Seagrass cover in Corindi River appeared to be contracting towards the entrance with patches of observed rotting, fragmenting seagrass beds. Comparison with past records indicates seagrass cover declined by up to 50% in Corindi River. In contrast, there was a 160% increase in seagrass cover in Coffs Creek. However, overall there was a 20% loss of seagrass cover throughout the Coffs region. Seagrass habitat maps will help to monitor changes in estuary habitats in the future. Loss of key habitat warrants further studies to determine the cause of the decline.

Fish Diversity and Habitat Assessment

Trained volunteers deployed underwater video cameras during summer and winter to assess fish diversity in targeted estuaries habitats. Species richness (the number of different fish species) and the average maximum number of a particular species observed in any one frame of video footage were assessed for each replicate video. Data were analysed to identify the fish species unique to and significant contributors to the fish assemblages. Fifty-seven fish species were present in the four estuaries, including the threatened and protected Estuary Rockcod and Queensland Groper. Additional threatened and protected species identified during fieldwork but not recorded on video included pipefish and seahorses.

Corindi River and Boambee Creek supported the greatest species richness (39 species) and more species were recorded during summer than winter. Yellowfin Bream and Luderick were dominant recreational species in all studied estuaries. Although species richness varied between seasons and among estuaries, it did not differ significantly among habitat types. Corindi River supported greater species richness during summer and winter than other estuaries. Boambee Creek supported the highest average fish abundance during both seasons. Fish abundance varied among estuaries but not between seasons or among habitat types. It is possible the latter is related to the transient nature of dominant species, many of which move up and downstream with tide changes.

Two fish species listed as protected in NSW were sighted during this study. Estuary Rockcod and Queensland Groper were observed during summer and winter. These fish were observed in deep holes, near pylons and coffee rock habitats. Estuary Rockcod were more abundant in Coffs Creek than the other estuaries and several were found in abandoned mud crab traps. Queensland Groper were observed in a deep hole in Coffs Creek and the near coffee rock in Corindi River. Complex estuarine habitats are important to these fish species.

Coffs Creek debris surveys

Marine debris is dangerous to estuarine organisms. Initial strandline surveys revealed high accumulation rates of debris along Coffs Creek, compared with the other targeted estuaries. Coffs Creek baseline debris data collected previously were used for comparison with data collected during the current project. Following Eckman (2014) study, three main site types (Gross Pollutant Traps, headwalls without barriers, and control sites) were targeted to identify debris hotspots. Volunteers collected marine debris from all site on Clean-up Australia Day in 2016 and 2017, using standardised Tangaroa Blue Foundation protocols.

In 2016, 35 volunteers collected a total of 2,767 items (6 sites), 81% plastic items. In 2017, 31 volunteers collected 1,831 items from four sites surveyed in 2016, 76% plastics items. The quantity of rubbish collected in 2017 indicated a 100% rate of debris accumulates over 18 months in Coffs Creek; this does not include calculations for debris washed directly to the ocean. Disturbingly, the results of this research indicate approximately 15 tonnes of debris accumulates along Coffs Creek estuary east of the Pacific Highway every year. Whilst Gross Pollutant Traps are installed to minimise debris from entering Coffs Creek, these results indicate that if the litter is not regularly cleared from these traps then they become debris hotspot.

Abandoned mud crab trap surveys

Abandoned fishing traps are a hazard to marine life. The term 'ghost fishing' is used to describe the manner in which unattended traps and nets can continue to catch and frequently kill marine life. While removing rubbish along targeted estuaries, SURG volunteers found numerous unlabelled mud crab traps, many of which were 'ghost fishing'. NSW Fisheries gave members permission to collect these traps and release any live animals. Abandoned trap surveys were conducted using visual census and side-scan-sonar. Fifty-two abandoned mud crab traps were found and removed between 2015 and 2017. Thirty-six percent of abandoned traps found in Coffs Creek contained Estuary Rockcod and/or mud crabs. Other traps caught Flathead, Yellowfin Bream, Estuary Rockcod, Queensland Groper and a dead Green Turtle.

On-ground remediation work

A high-risk erosion riverbank area was identified adjacent to the Jewfish Point boardwalk along Corindi River. During autumn of 2018, 25 volunteers (16 SURG, 9 community members) carried out remediation work along ~300 m^2 of riverbank adjacent to the Jewfish Point boardwalk along Corindi Creek. Fifty coir logs, drainage material and coir matting were installed prior to planting of Casuarina seedlings and grass species. A barrier and signage were installed in an effort to reduce foot traffic along the affected riverbank, and later inspections indicate reduced foot traffic and survival of the majority of the seedlings.

Interpretive panels and fact sheets

Interpretive panels and fact sheets were prepared using information collected during the study. Estuary-specific interpretive panels were manufactured and placed near high-visitation locations at each estuary. These panels detail local threats and suggest ways visitors can help mitigate these threats. Threat fact sheets (seagrass, erosion, litter and fishing) are available publicly including on the SURG website (www.surg.org.au) and on Facebook.

With support and funding from stakeholders this project was successful in achieving all outcomes and provided the opportunity for the wider community to participate in conservation work and gain a greater understanding of threats to estuarine ecosystems. With appropriate collaboration and guidance this project can form the foundation of future community-based estuarine threat assessment projects at other similar locations along the Australian coastline.

Nicola Fraser
President SURG

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INTRODUCTION

Estuaries are essential habitats for the survival of many aquatic species including threatened and protected marine species. These ecosystems provide important feeding and breeding habitat for a range of species, including recreationally and commercially important fish species. Additionally, other protected species such as migratory and resident birds, turtles and invertebrates are dependent on estuaries. Estuaries are the interface between freshwater and marine environments and support high biodiversity, resulting in highly productive, dynamic ecosystems.

A number of estuaries exist along the northern NSW coast, ranging in size from the large Clarence River to smaller wave-exposed barrier estuaries such as Coffs Creek. These water bodies are subjected to a number of natural events such as flooding and seasonal warm and cool waters, and house an abundance of tropical, subtropical and temperate marine species during different times of the year. NSW estuaries are dynamic environments influenced by freshwater inundation and semi diurnal oceanic tidal exchange. Marine species utilise estuarine habitats during different life cycle phases. For examples, the threatened and protected fish species such as the Goldspotted Rockcod (*Epinephelus coioides*) utilise estuaries during early life stage then migrates to the open ocean, where the adults live at the base of small drop-offs, in large caves or near shipwrecks (NSW DPI 2006). In a recent report on the distribution of threatened and protected species in northern NSW (Smith *et al.*, 2010), the Blackspotted Rockcod, Goldspotted Rockcod and the Queensland Groper were recorded in several northern NSW estuaries.

Coffs coast estuaries are also exposed to a suite of complex human-induced threats that can lead to a decline in water quality and degradation and loss of estuarine habitats, which in turn, can affect the biodiversity that relies on these ecosystems. Estuary ecosystem health is threatened by increased nutrients that can cause algal blooms, contaminants and pollution (sewage discharge), disturbance of acid sulphate soils, litter, human activity, coastal development, changes in water flow dynamics, changes to the catchment and riparian areas, invasive species, and climate change. Monitoring estuaries and evaluating estuary health can help detect specific threats to individual estuaries and identify ways to mitigate these threats.

Little information is currently available regarding critical habitats of threatened and protected marine species inhabiting estuaries along the NSW coastline, or threats to these ecosystems. Many marine species identified as vulnerable to extinction occupy estuarine environments during some life stage and there has been a decline in habitats, such as seagrass meadows, during past decades

(Evans *et al.*, 2018). Threatened and protected species represent an important component of the biodiversity of marine and estuarine habitats. Threatened species are those at risk of extinction unless specific management actions are taken (I&I NSW 2005). Northern NSW estuaries are also important habitats for many recreational and commercial fish and invertebrate species that may live in this ecosystem for their entire life cycle or be present during different times of the year, to either spawn or develop into adults before migration to oceanic waters.

PROJECT AIMS AND OBJECTIVES

The Community Action Blueprint to Enhance Estuarine Resilience project provided the framework for the Solitary Islands Underwater Research Group (SURG) members and the wider community to participate in a range of activities to understand how human activity threatens critical habitats and provided opportunities for the Coffs community to help to reduce identified threats. SURG members undertook aquatic research activities in four northern NSW estuaries over three years with results aimed to inform the wider community and government management agencies of the local threats to critical habitats of threatened and protected fauna.

The specific aims of the community action blueprint were to:

1. Undertake baseline surveys to identify critical habitats of threatened and protected marine species within four northern NSW estuaries and identify and quantify local threats to these habitats;
2. Identify site-specific important estuarine features that are potential habitats for vulnerable species, including complex submerged structure and deep holes;
3. Engage local terrestrial volunteer groups to participate in remediation of native vegetation and promote education about and awareness of significant habitats within the region to the wider community; and
4. Produce interpretive educational material highlighting the significance of estuarine habitats and informing the wider community of ways to mitigate local threats to critical habitats, which in turn will build resilience and enhance biodiversity in estuarine ecosystems of the northern NSW region.

THE SOLITARY ISLANDS UNDERWATER RESEARCH GROUP (SURG)

SURG is a voluntary community organisation, founded in 1985, dedicated to the preservation of the marine environment within the Solitary Islands Marine Park (SIMP). The organisation consists of a variety of individuals with extensive knowledge of the marine environment who actively promote marine conservation and monitor marine habitats. Many members are tertiary trained biologists and others are experienced in underwater photography (Smith and Edgar, 1999). SURG provides opportunities for university undergraduate and graduate students to undertake marine research and contribute to local activities with conservation outcomes.

SURG members actively promote stewardship of the marine environment and educate the general public about its importance and fragility. For example, SURG has been involved in many marine publications, including species lists of gastropods and opisthobranchs present in the SIMP. Furthermore, previous lobbying and submissions prepared by SURG contributed to the establishment of the SIMP and the recent zoning plan which outlines the activities permissible within the marine park (Smith and Edgar, 1999).

SURG has been actively engaged in scientific research for over 25 years and the membership is passionate about passing on knowledge and experience to the wider community. The group has produced a range of educational materials, developed a web-based marine species inventory resource, and installed an educational underwater dive trail at one of the popular SCUBA dive locations in the SIMP at North Solitary Island. SURG has also applied members' collective knowledge and time to monitor marine fish species including threatened and endangered species and to document coral disease and coral bleaching.

Recently, SURG member were involved in a project funded by NSW Environmental Trust that evaluated coral bleaching stress in the Solitary Islands Marine Park coral community. This three-year project assessed the health of coral in the Solitary Islands and found that no severe coral bleaching event occurred between 2012 and 2015, although bleaching stress was different among sites and seasons (Edgar 2015). Additionally, there were differences in coral family-level bleaching response, which was consistent with findings from earlier Northern NSW studies (Dalton and Carroll, 2011).

METHODS

ESTUARY SITES

The four estuaries that were studied during this project are wave-dominated barrier estuaries with permanently open entrances. These estuaries contain a range of habitats including seagrass, mangroves, saltmarsh, rocky outcrops, coffee rock, deep holes, snags and artificial structures (rock walls and pylons). Creese *et al.,* (2009) found that seagrass meadows were dominated by *Zostera* sp. (Eelgrass), with *Halophila* sp. (Paddleweed) also occurring, but only in Boambee and Moonee Creeks. Catchment and estuary area range between 24 km^2 to 146.4 km^2 and 0.4 km^2 to 1.9 km^2 respectively (Table 1).

Table 1: Descriptive statistics for the four northern NSW estuaries SURG investigated between 2015 and 2018.

Estuary	Latitude (°S)	Longitude (°E)	Catchment size (km^2)	Estuary area (km^2)	Estuary volume (ML)
Corindi River	-29.98	153.23	146.4	1.9	1,557.1
Moonee Creek	-30.21	153.16	41.1	0.4	414.3
Coffs Creek	-30.30	153.14	24.0	0.5	292.7
Boambee Creek	-30.35	153.11	48.5	1.0	804.5

SEAGRASS MAPPING

Seagrass mapping field trips along Boambee Creek, Coffs Creek, Corindi River and Moonee Creek were conducted using stand-up paddleboards, canoes, snorkelling and the National Marine Science Centre (NMSC) small outboard vessel. Repeated trips along these estuaries occurred between 2015 and 2016, during which time the location of seagrass meadows was recorded using Magellan Explorist Pro 10 waterproof GPS recorder. These data points were exported into an Excel spreadsheet and uploaded onto ArcGIS then overlaid onto northern NSW maps created by the NSW Department of Primary Industries. The seagrass location coordinates were utilised to ground truth seagrass meadows images captured by aerial photographs.

High resolution aerial photographs captured in 2016 were downloaded from the Nearmaps website and uploaded into ArcGIS. These photographs formed the background to seagrass area determination using the ArcGIS polygon measurement tool to trace around image pixels identified as seagrass from field observations. Total seagrass area (m^2) was determined for all four estuaries and data compared with measurements reported in 2009 by the DPI (refer to Creese *et al.*, 2009).

ArcGIS seagrass maps were produced, that contrasted seagrass cover between the present and the NSW DPI 2009 study.

FISH DIVERSITY AND HABITAT ASSESSMENT – REMOTE UNDERWATER VIDEO

GoPro cameras attached to remote underwater video stands were deployed in a range of estuarine habitats along four northern NSW estuaries: Corindi River, Moonee Creek, Coffs Creek and Boambee Creek. Video cameras were in place for approximately 20-30 minutes, capturing footage of fish species that occur in different habitats.

In 2015, baited and un-baited underwater videos were recorded at Corindi River and Moonee Creek. These video recordings were analysed by Emily Turk, a SCU student, who volunteered her time to determine any artefact of using bait to attract fish. Previously it has been shown that some species may scare other species away due to aggressive feeding behaviour, while other species do not respond to bait plume and will remain cryptic and out of sight of the recording camera (Lowry *et al.*, 2012). Comparing the difference in fish species richness and abundance between observation data captured by video recorded in the presence and absence of bait showed no significant statistical difference. However, threatened and protected fish species were only observed in footage captured in the presence of bait (Turk 2017). Therefore, all subsequent video deployments utilised bait bags.

Baited Remote Underwater Video deployment method

Nine baited remote underwater video (BRUV) stands were constructed by Neil Vaughan (SURG member; Fig. 1). Each unit comprised a moulded frame to hold a GoPro camera mounted in an underwater housing, with a length of conduit extending 300mm from the frame. A mesh bait bag was mounted at the end of the conduit and lead weights were attached to the base of the frame. A float was attached to the top of the frame to aid deployment and retrieval. This design enabled the BRUV units to be placed on the sandy floor of the estuaries and left for a short period to monitor fish assemblages.

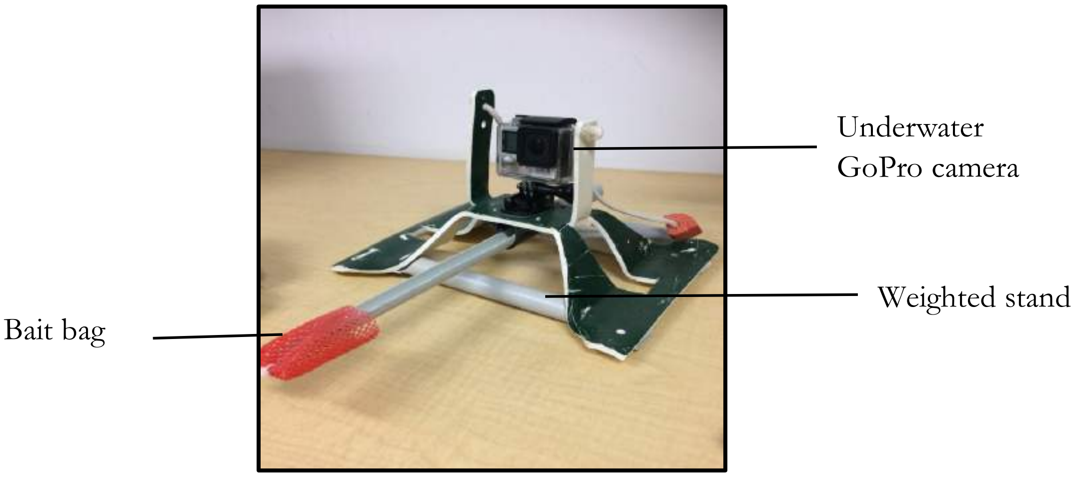


Figure 1. Baited Remote Underwater Video stand design, developed by Neil Vaughan. The bait bag was attached to a 300mm length of conduit and located in view of the camera. (Photo by Emily Turk)

Prior to deployment, each camera was inspected to ensure a fully charged battery and a blank memory card were correctly installed. The GoPro cameras were inserted into clean and dry underwater housings and moisture-absorbing pads placed inside before the housing were closed and attached to the BRUV stand. A bag containing pilchards was placed into the bait bags and secured to the end of each conduit. Each participant was provided with detailed instructions on how to prepare and deploy the BRUVs (Refer to Appendix 1).

Using canoes, kayaks, stand-up paddleboards and snorkelling equipment, SURG volunteers deployed these camera units along four estuaries within a range of different habitat types. Generally, three BRUV units were positioned approximately 50 to 100m apart in order to capture replicate footage within each habitat type, with replications of habitat types completed along each estuary.

For ease of use and improved battery life, the GoPro one-button recording function was utilised, enabling the cameras to be switched on and off by simply pressing the recording button. The LCD screen displayed for one minute and switched off for the remaining recording time. The camera's position was adjusted to ensure the bait bag could be seen at the bottom of the screen. The BRUVs were placed onto the estuary floor, ensuring that the cameras were orientated towards the habitat of interest. The cameras were positioned down current so floating material, such as kelp, did not obscure the camera lens during the recording period. Deployment time and location details including GPS coordinates and habitat type were recorded for each site and the cameras filmed for approximately 30 minutes. When the BRUV units were retrieved, the cameras were inspected to ensure they had captured adequate footage.

At the completion of each field trip, all equipment was cleaned in freshwater, dried, and the camera housings removed from the BRUV frames. Each GoPro camera was then removed from the underwater housing and recorded footage saved to an external hard drive for later analysis. Site-specific information for each replicate recording was entered into an Excel spreadsheet and original data sheets filed for future reference.

Assessment of BRUV footage

Prior to BRUV recording analysis, SURG members attended a training session where they were provided with instruction in video footage analysis (refer to Appendix 2 for details). The analysis of the footage involved the identification of different fish species observed in the recording and the determination of each observed fish species abundance using the MaxN method. The MaxN technique is a common method that records the highest number of a particular species that is observed in one frame and is calculated for all species viewed in each recording (refer to Folpp, *et al.,* 2013). Additionally, the maximum number of species (species richness – S) observed in each replicate video recording was recorded.

Prior to the beginning of each BRUV footage assessment, each observer would view the entire recording at 2 to 5 times normal speed and determine the period in the recording where the visibility was the best and note the playback time. A 15-minute portion of the recording would then be analysed by the observer, recording the presence of different fish species and MaxN data observed in the specific 15-minute playback. If an unknown species was encountered during the playback the observer would refer to the fish species identification booklet (Appendix 3 for example), or capture a snapshot of the frame for later identification. Additionally, the SURG photographic species database (https://www.surg.org.au/species) aided in identification. Recorded data were entered into a standardised spreadsheet, with the observer recording the MaxN and time of observation for each fish species observed in each footage.

Statistical analysis

The raw fish species richness and total abundance data were determined for all species observed in the video footage and total MaxN (the sum of MaxN for all species within each video footage) was calculated for each replicate BRUV recording. Differences in species richness and total MaxN were compared among the four estuaries and different habitat types. SPSS statistical analysis software was used to identify differences in species richness and MaxN among estuaries. This analysis established there were no differences in fish assemblages recorded among Boambee, Coffs and Moonee Creeks and Corindi River and that there was no seasonal preference for different species. Primer multidimensional analysis software determined the fish species that were unique and important components of the different estuary fish assemblages. Finally, critical habitat types upon which threatened and protected fauna species rely were identified within each estuary.

COFFS HARBOUR DEBRIS SURVEYS – CLEAN-UP AUSTRALIA DAY

During initial creek strandline debris collection trips, the accumulation rate of litter along Coffs Creek appeared to be considerably higher than other targeted estuaries, indicating that terrestrially derived litter entering Coffs Creek pose a potential threat to marine life that is reliant on this tributary. Marine debris has not only negative impacts on the aesthetics of estuarine and coastal environments but poses significant threats to many marine species and the habitats upon which they rely. Urban storm water runoff is the primary contributor to estuarine marine debris loading, and consequently needs effective management to ensure that debris loads are reduced (Gregory and Ryan 1997).

Following large rain events, debris enters Coffs Creek from a number of point sources, including headwall drains, gross pollutant traps and from entry points further upstream. Gross Pollutant Traps (GPTs) are retention devices placed at the downstream ends of a catchment and are designed to trap large litter item during storm events. However, GPTs can fill quickly with debris and organic material and without regular clearing accumulated rubbish will discharge from the top of the trap during subsequent high rain events.

Previous quantitative debris research completed along Coffs Creek in 2014 (Ekman 2014) provided a base line for comparison with data collected during this project and an opportunity to identify debris hot spots and assess the rate of debris accumulation along Coffs Creek.

Three distinct site types were inspected along Coffs Creek in April 2015 and 2016 to determine debris load and identify debris hotspots, these included:

1. Gross Pollutant Trap (GPT) discharge outlet (GPT01 & GPT02);
2. Headwalls without barriers (HW01 & HW02); and
3. Control sites (CON01 & CON02) - located more than 100m from any discharge point.

At each site (Fig. 2), two 50m tapes were placed along the high tide strand line extending from the storm water discharge and control sites - one paced upstream and the other downstream, positioned approximately 20 metres apart. Along both 50m tapes, three 10m plots were assessed and rubbish removed, these plots were located between 0-10m, 15-25m and 40-50m. All 10m plots extended from the high-water mark to the low tide mark and all debris larger than 5mm was collected within each transect and placed into recycled shopping bags that were labelled with the site, direction and plot details (i.e., HW01 upstream 0-10m). These bags were tied and placed into the appropriately labelled large site-specific clean-up Australia bags. To ensure subsequent surveys were repeated at the same region of the creek strand line, GPS coordinates were recorded at each site (Table 2).

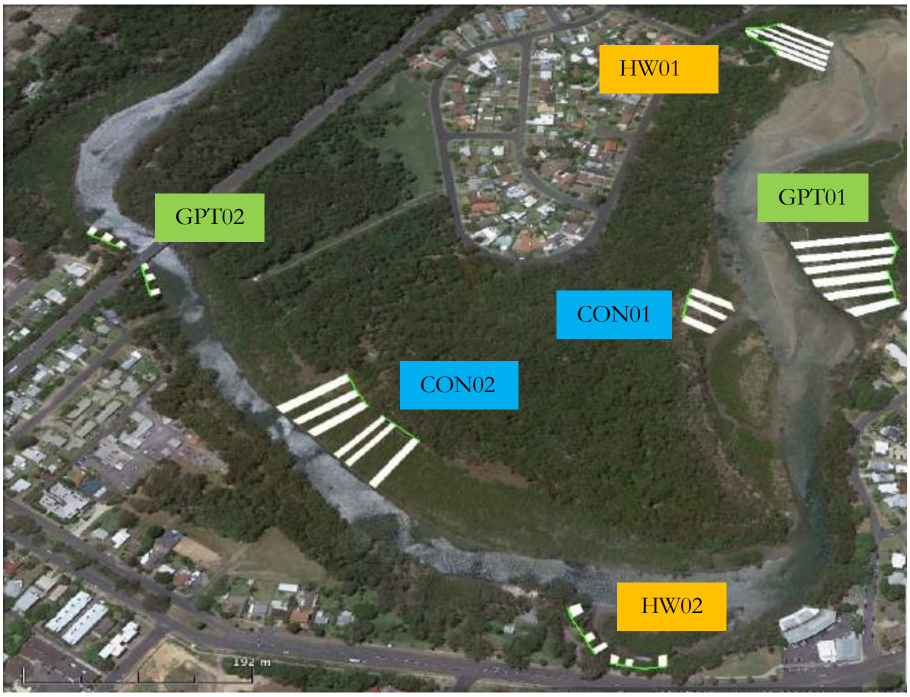


Figure 2: Debris sites surveyed during the 2015 and 2016 clean-up Australia Day. Two sites were located adjacent to: 1. Gross Pollutant Traps (green); 2. Open Headwall Drain (orange); and 3. Control Sites (blue, no adjacent creek). Only the upstream 10m plots were assessed at CT01. Image modified from Google Earth

Using the standardised Tangaroa Blue Foundation data sheets (www.tangaroablue.org) volunteers sorted all items according to standardised categories. At the completion of each survey, debris was placed into clean-up Australia bags and collected by Coffs Harbour City Council staff for disposal. Data from each site/10m plot were entered onto individual field data sheets, with site specific data entered at the top of each sheet. Raw data were entered into an Excel spreadsheet and data compared among different site types and between years.

Table 2: GPS reference for sites assessed during the SURG Coffs Creek debris surveys.

SITES	Latitude (S)	Longitude (E)
HW01	-30.297418°	153.133186°
HW02	-30.305235°	153.130674°
GPT01	-30.300941°	153.134245°
GPT02	-30.300704°	153.125475°
CON01	-30.301207°	153.131797°
CON02	-30.302757°	153.128404°

ABANDONED RECREATIONAL TRAP SURVEYS

During debris removal trips along Coffs Creek, Boambee Creek and Corindi River, SURG members came across a large number of discarded mud crab traps that appeared to be accumulating in a number of areas along each estuary. Of concern were the circular recreational traps that were half buried in the sediment and containing a number of crabs and threatened Estuary Rockcod and Queensland Groper. SURG requested and obtained permission from the NSW Fisheries to remove discarded crab traps and release any retained live animals. Discarded trap surveys were conducted yearly along Boambee Creek, Coffs Creek and Corindi River using watercraft. Additionally, a side-scan-sonar mounted on a small power vessel was used to locate traps in upstream turbid waters. Using a handheld GPS, the geographical coordinates of each abandoned trap was recorded and location data provided to NSW Fisheries Compliance Officers.

ON-GROUND REMEDIATION WORK

River bank stabilisation works were undertaken along Corindi River, adjacent to the Jewfish Point board walk. This area was identified as a high-risk area for increased erosion due to high wave action during northern easterly winds and foot traffic along the strand line. Funding from the Recreational Fishing Trust and material from Red Rock Caravan Park provided the resources to install coir logs and matting along the degraded strandline, within which seedlings were planted. Three field days were organised during which time SURG members and local volunteers assisted in the placement of coir logs, matting and drainage material before planting of she-oak seedlings and local grasses over subsequent weeks. Finally, a barrier and notice board were installed to mitigate further erosion resulting from visitors stepping off the adjacent boardwalk.

RESULTS AND DISCUSSION

VOLUNTEER PARTICIPATION

Overall, SURG members and other local volunteer participation exceeded all expectations. A total of 136 individuals were involved in at least one SURG organised estuary activity. A total of 62 SURG members and 74 members of the general public contributed 5,148 volunteer hours to a range of activities including debris surveys, BRUV surveys, discarded crab trap surveys, remediation works and other organised activities (see Table 3 for all activities and numbers of individual participants). Forty-eight students assisted with clean-up surveys, attended seagrass searches, deployed BRUV units and helped with remediation work along Corindi River. Activities such as the BRUV surveys and remediation work provided the opportunity for volunteers to participate in environmentally focused events along creeks at their back door, which gave them a sense of ownership.

Table 3: Summary of SURG and general public participation in activities undertaken as a part of the community action blueprint project.

	Total participation	**136**
	SURG members	62
	General public	74
	Adults	88
	Students	48
Activities	**Participation**	**Hours**
BRUVs	54	1,982
Clean-up Australia day surveys	65	538
Interpretive panel design and production	13	701
Mud crab trap removal	17	331
Presentation, media & reporting	29	391
Remediation work	31	337
Seagrass mapping	6	716
Seagrass critter search	23	86
Strandline clean-up	14	96
Grand Total	**252**	**5,148**

SEAGRASS MAPPING

In water seagrass mapping revealed that only one species of seagrass *Zostera spp.* (Eelgrass) was present in Corindi River, Moonee Creek, Coffs Creek and Boambee Creek. Seagrass cover ranged between 2,626 m^2 in Coffs Creek and 23,292 m^2 in Moonee Creek. Seagrass habitat was more dominant along the margins of each creek and present in shallow (< 1.5m) water in areas of low water flow. There was no seagrass present near any of the estuary entrances (Figs. 3-6). Past studies indicated that *Halophila* species were present along shallow sections of Boambee Creek, however *Halophila* was not observed during this study. In fact, no seagrass was present in the areas where *Halophila* beds were previously sighted during field surveys conducted in 2004 at Boambee Creek (https://www.dpi.nsw.gov.au/content/research/areas/aquatic-ecosystems/estuarine-habitats-maps/IINSW_EstMac_map12.pdf). Creese *et al*., (2009) also noted the presence of *Halophila* species in Boambee Creek, but not in any other studied estuaries.

In water field surveys along the Corindi River and its tributaries in 2016 revealed recent seagrass cover loss. Eelgrass meadows, which normally have stands of erect leaves, appeared to be rotting at the base. Repeated inspection of seagrass meadows particularly along Saltwater Creek (Fig. 3, Inset A) revealed seagrass cover contracting towards the coast and thick seagrass beds becoming fragmented. Growth of epiphytes on Eelgrass leaves might indicate a decline in water quality caused by increased nutrients in storm water runoff. Excess nutrients can stimulate epiphytic algal growth on the seagrass fronds, subsequently leading to smothering and plant death. Mapping of Saltwater Creek revealed the seagrass meadows have declined and become fragmented in recent years (Fig. 3, Inset A). Seagrass cover loss was also observed along the middle reaches of Corindi River (Fig. 3, Inset B). The density of seagrass beds along Moonee and Boambee Creeks also appeared to have decreased with regions of exposed sand/sediment extending between patches of fragmented seagrass stands.

Changes in seagrass cover through time

The total area of seagrass meadows declined by 9 – 50% total area at three of the four estuaries mapped, although seagrass cover increased by 160% in Coffs Creek between 2009 and 2017 (Table 4). The greatest decline was observed in Corindi River, which is the most northern estuary, and has the smallest adjacent population. In contrast, Coffs Creek and its tributaries meander through Coffs Harbour, which has a population of over 60,000 people.

Table 4: Changes in seagrass cover between 2009 and 2017 in four northern NSW estuaries.

Estuary	DPI 2009 (m^2)	SURG 2017 (m^2)	Area of change (m^2)	Percent change
Boambee Creek	25,588.21	23,292.43	- 2,295.79	9% decline
Coffs Creek	1,010.58	2,626.54	+ 1,616.07	160% increase
Corindi River	5,469.79	2,717.69	- 2,752.10	50% decline
Moonee Creek	18,413.01	11,893.20	- 6,519.81	35% decline
Total	**50,481.59**	**40,529.86**	**-9,951.73**	**20% decline**

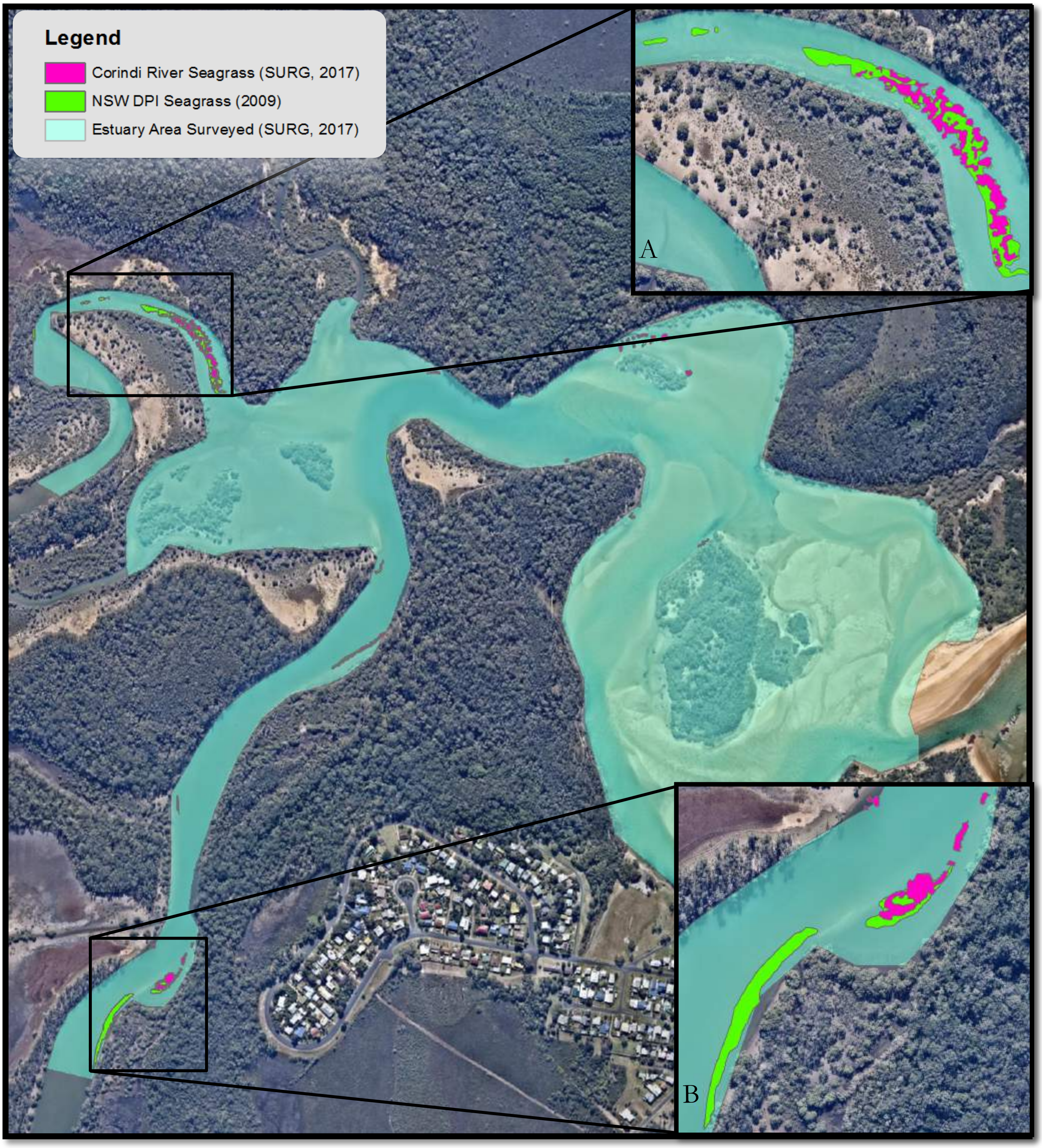


Figure 3: Corindi River seagrass map displaying estuary area mapped by SURG in 2017 and close up images (Inset A & B) comparing seagrass cover mapped by DPI Fisheries in 2009 and by SURG in 2017.

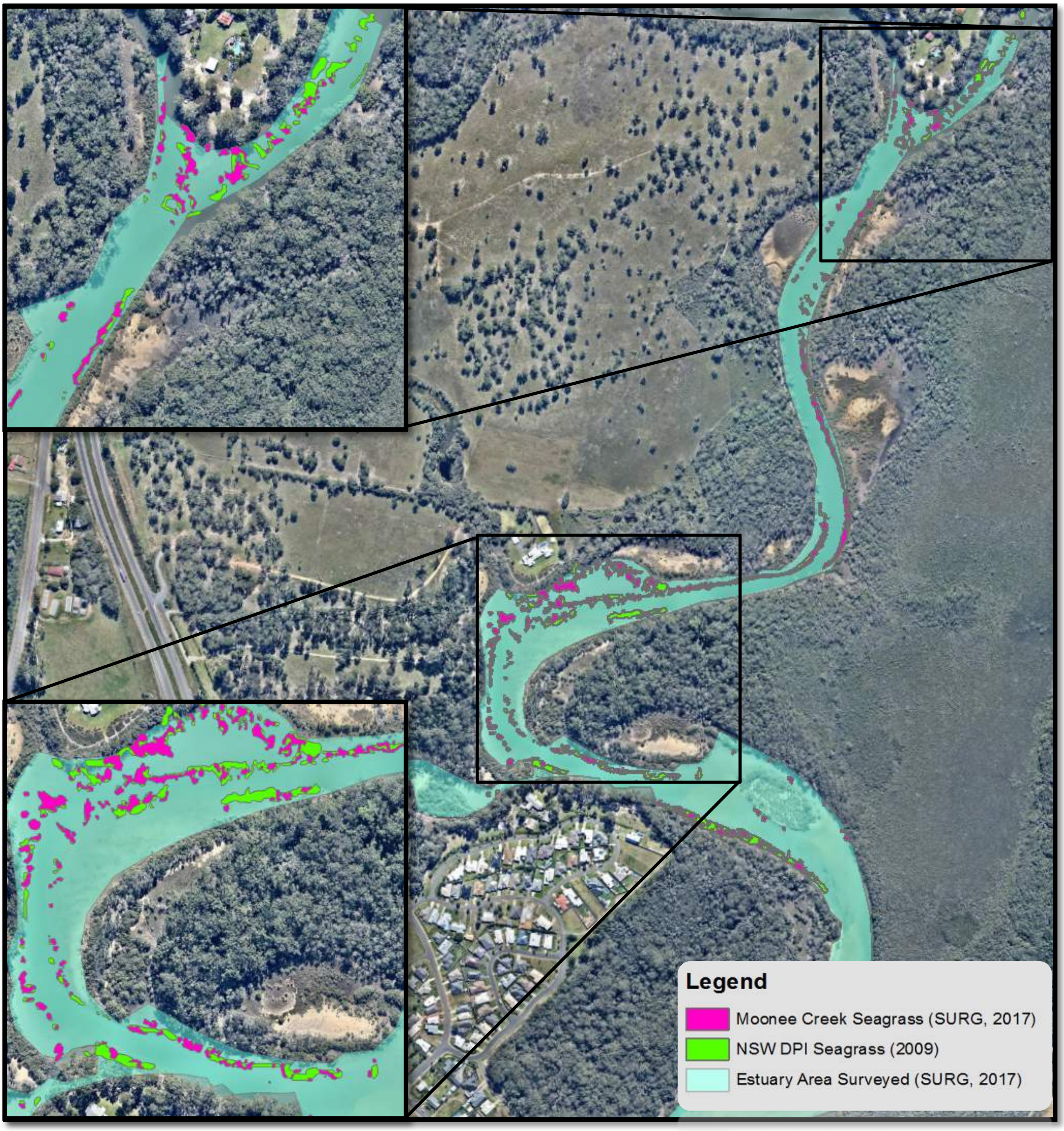


Figure 4: Moonee Creek seagrass map displaying estuary area mapped by SURG in 2017 and close up images comparing seagrass cover mapped by DPI Fisheries in 2009 and by SURG in 2017.

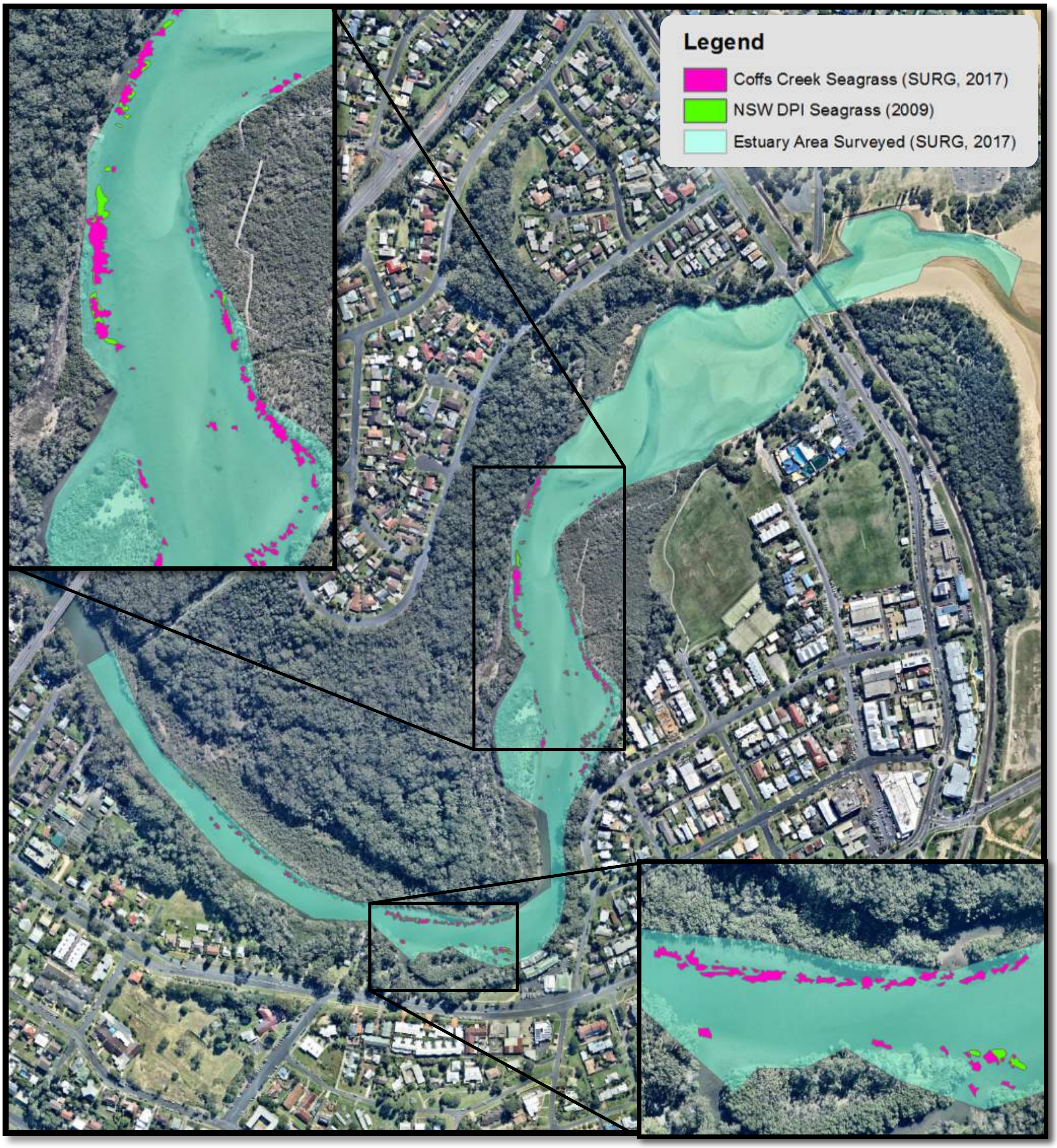


Figure 5: Coffs Creek seagrass map displaying estuary area mapped by SURG in 2017 and close up images comparing seagrass cover mapped by DPI Fisheries in 2009 and by SURG in 2017.

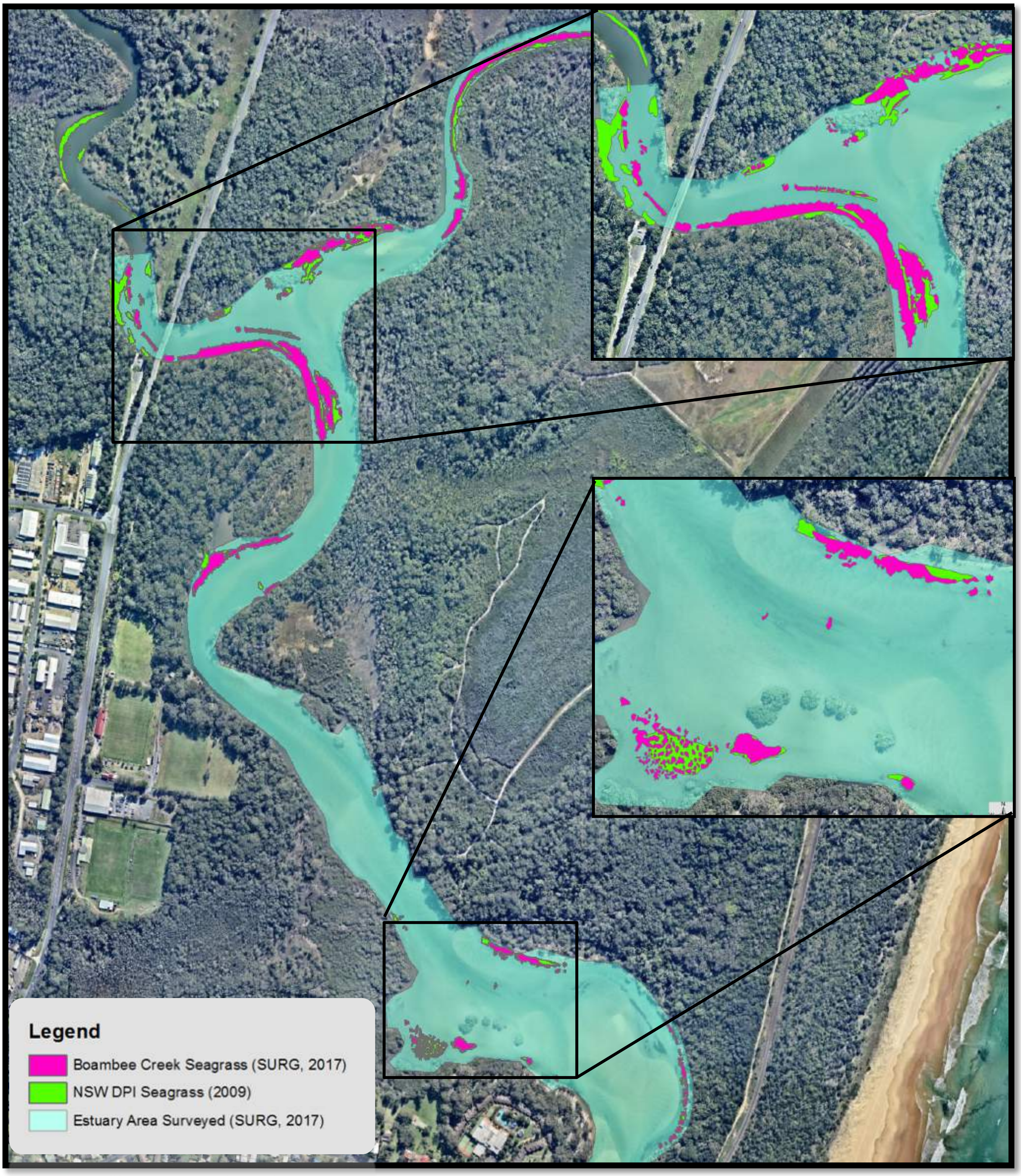


Figure 6: Boambee Creek seagrass map displaying estuary area mapped by in 2017 and close up images showing a comparison of seagrass cover mapped by DPI Fisheries in 2009 and by SURG in 2017.

FISH DIVERSITY AND HABITAT ASSESSMENT – REMOTE UNDERWATER VIDEO

A total of 57 fish species (Table 5) was recorded in 248 Baited Remote Underwater Video (BRUV) recordings captured between 2015 to 2017. This included two threatened and protected marine species, Estuary Rockcod and the Queensland Groper. Other threatened and protected species from the Family Syngnathidae (pipefish and seahorses) were observed in the field during deployment of the BRUV equipment but not were sighted in any of the video recordings. These species tend to be cryptic and may have been overlooked, as they tend to shy away from areas with high predatory pressures, such as around baited video sites.

Overall, fish species richness (total number of species recorded) observation (both summer and winter observations) was highest at Corindi River and Boambee Creek, both recording 39 species, with species richness declining at Coffs Creek (34) and Moonee Creek (26). There were considerably more species observed during summer than winter at all estuaries (Table 5).

Only four fish species (Sea Mullet, Yellowfin Bream, Luderick and Glassfish) were observed during all survey periods. Eleven species were observed at all estuaries but not during all seasons (Table 5). Four fish species (Brown Sabretooth Blenny, Flounder, Silver Sweep and Small-Scale Bullseye) were only observed during winter surveys, and nine other species were reported only during summer surveys (Table 5). These temporal observations might be related to seasonal warming conditions and difference in breeding and feeding patterns between species.

Table 5: Fish species list observed at the four estuaries surveyed between 2015 and 2017 using Baited Remote Underwater Video transects.

		Boambee Creek		Coffs Creek		Moonee Creek		Corindi River	
Common name	**Scientific name**	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**
Yellowfin Bream	*Acanthopagrus australis*	*	*	*	*	*	*	*	*
Luderick	*Girella tricuspidata*	*	*	*	*	*	*	*	*
Glassfish	*Ambassis* spp.	*	*	*	*	*	*	*	*
Sand Whiting	*Sillago ciliata*	*	*	*	*		*	*	
Sea Mullet	*Mugil cephalus*	*	*	*	*	*	*	*	*
Goldspot Mullet	*Gracilimugil argenteus*			*				*	*
Sand Mullet	*Myxus elongatus*	*	*		*		*	*	*
Fantail Mullet	*Paramugil georgii*						*		*
Eastern Striped Grunter	*Helotes sexlineatus*	*	*		*	*	*	*	*
Stripey	*Microcanthus strigatus*	*	*	*	*			*	*
Garfish	*Hyporhamphus sp.*	*	*		*			*	*
Stout Longtom	*Tylosurus gavialoides*						*		*
Blackspot Snapper	*Lutjanus fulviflamma*	*	*		*		*	*	*
Moses Snapper	*Lutjanus russellii*	*	*	*	*		*	*	
Diamondfish	*Monodactylus argenteus*	*	*	*	*		*	*	*
Mangrove Jack	*Lutjanus argentimaculatus*		*					*	*
Australian Sawtail	*Prionurus microlepidotus*		*		*		*		*
Crescent Grunter	*Terapon jarbua*								*
Bridled Goby	*Arenigobius bifrenatus*	*	*			*	*	*	*
Interspot Sandgoby	*Fusigobius imframaculatus*	*	*		*	*	*	*	*
Decorated Sandgoby	*Istigobius decoratus*		*						
Krefft's frillgoby	*Bathygobius krefftii*		*						
Exquisite Sandgoby	*Favonigobius exquisitus*	*	*			*		*	
Crested Oystergoby	*Cryptocentroides gobioides*							*	
Silver Trevally	*Pseudocaranx georgianus*		*		*		*	*	*
Bigeye Trevally	*Caranx sexfasciatus*	*			*		*	*	*
Common Silverbiddy	*Gerres subfasciatus*	*	*		*	*	*	*	*
Oyster Blenny	*Omobranchus anolius*		*	*				*	*

Table 5 con.: Fish species list observed at the four estuaries surveyed between 2015 and 2017 using Baited Remote Underwater Video transects.

		Boambee Creek		Coffs Creek		Moonee Creek		Corindi River	
Common name	**Scientific name**	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**
Brown Sabretooth Blenny	*Petroscirtes lupus*	*							
Southern Maori Wrasse	*Ophthalmolepis lineolata*		*				*		*
Pacific Blue Eye	*Pseudomugil signifer*				*				
Sprat/Anchovy	*Spratelloides* spp./*Engraulis* spp.		*						*
Estuary Stingray	*Dasyatis fluviorum*						*		*
Eastern Fortescue	*Centropogon australis*	*	*	*					
Flounder	*Paralichthyidae* spp.							*	
Dusky Flathead	*Platycephalus fuscus*						*		
Threebar Porcupinefish	*Dicotylichthys punctulatus*		*						
Sixspine Leatherjacket	*Meuschenia freycineti*	*	*	*	*		*	*	*
Yellowfin Leatherjacket	*Meuschenia trachylepis*		*						
Fanbelly Leatherjacket	*Monacanthus chinensis*		*				*	*	
Smooth Toadfish	*Tetractenos glaber*		*	*	*				
Weeping Toadfish	*Torquigener pleurogramma*	*		*	*				
Narrowlined Puffer	*Arothron manilensis*	*			*				
Southern Herring	*Herklotsichthys castelnaui*	*							*
Black Rabbitfish	*Siganus fuscescens*		*		*		*		*
Blacksaddle Goatfish	*Parupeneus spilurus*				*				
Silver Sweep	*Scorpis lineolata*	*		*					
Dusky Butterflyfish	*Chaetodon flavirostris*								*
Vagabond Butterflyfish	*Chaetodon vagabundus*								*
Crested Morwong	*Cheilodactylus vestitus*	*		*					*
Smallscale Bullseye	*Pempheris compressa*			*					
Old Wife	*Enoplosus armatus*				*				
Goldspotted Rockcod	*Epinephelus coioides*				*				
Blackspotted Rockcod	*Epinephelus malabaricus*		*		*		*	*	*
Queensland Groper	*Epinephelus lanceolatus*				*				*
Species richness		**25**	**31**	**17**	**28**	**9**	**25**	**26**	**33**

The most abundant species observed during both summer and winter included the Yellowfin Bream, Glassfish, Sea Mullet and Luderick. Glassfish are small translucent schooling species that occur in fresh and brackish estuarine waters and were observed in large schools (>500) in all estuaries and across all habitat types (Table 6). Recreationally important species such as Yellowfin Bream and Luderick are well represented in northern NSW estuaries and appear to occur in healthy numbers in all monitored estuaries.

Table 6: Patterns of fish species occurrence and relative abundance within the four estuaries monitored between 2015 and 2017. Relative abundance determined from recorded Total MaxN for each species - Abundant >500, Common between 100-500, Occasional between 20-99 and rare <20.

	Common name	Relative abundance
Observed in all estuaries during summer and winter	Sea Mullet	Common
	Yellowfin Bream	Common
	Luderick	Common
	Glassfish	Abundant
Observed in all estuaries	Sand Whiting	Occasional
	Black Spotted Snapper	Occasional
	Moses Snapper	Occasional
	Diamondfish	Common
	Bridled Goby	Rare
	Interspot sandgoby	Occasional
	Silver Trevally	Occasional
	Common Silverbiddy	Occasional
	Blackspotted Rockcod	Rare
	Sixspine Leatherjacket	Occasional
Observed only during winter	Brown Sabretooth Blenny	Rare
	Flounder	Rare
	Silver Sweep	Rare
	Smallscale Bullseye	Rare
Observed only during summer	Pacific Blue Eye	Rare
	Australian Sawtail	Occasional
	Decorated Sandgoby	Rare
	Sprat/Anchovy	Rare
	Estuary Stingray	Rare
	Threebar Porcupinefish	Rare
	Yellowfin Leatherjacket	Rare
	Black Rabbitfish	Occasional
	Old Wife	Rare

Average species richness ranged between 3.29 at Moonee Creek during winter to 7.21 at Corindi River during summer surveys (Fig. 7). Significantly more fish species were observed in the BRUV transects during summer compared to winter and there were significant differences between estuaries within seasons (Fig. 7; Table 7). However, there was no significant difference in the number of species that utilise different habitat types (Table 7). The number of fish species observed in Corindi River was higher in both summer and winter surveys compared to other estuaries. In contrast, fish species richness was lowest during both seasons in Moonee Creek, averaging only 4.78 and 3.29 species during summer and winter, respectively (Fig. 7).

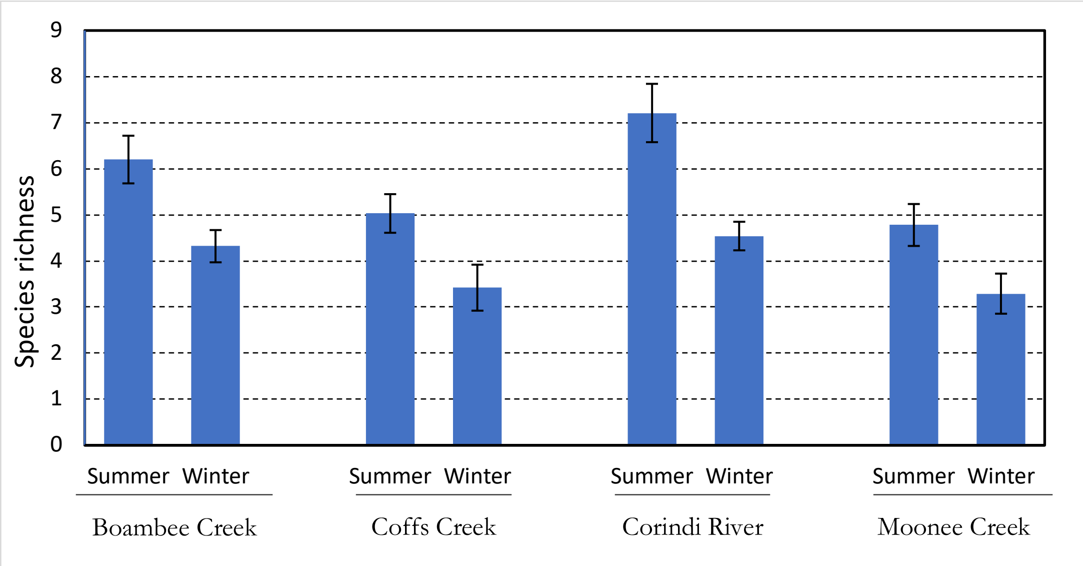


Figure 7: Average number of species (± standard error) observed at four northern NSW estuaries assessed during summer and winter between 2015 and 2017.

Table 7: Statistical comparisons of species richness data taken from BRUV footage captured at four estuaries during summer and winter surveys in 2016-2017.

Source	df	Mean Square	F	Sig. level
Estuary	3	24.068	4.215	**0.006**
Season	1	37.73	6.607	**0.011**
Habitat Type	4	1.879	0.329	0.858
Error	196	5.71		
Total	218			

Patterns of species abundance (MaxN)

Average total fish abundance (Average MaxN) was highest at Boambee Creek during both summer and winter surveys. Abundance ranged between 30.28 in winter and 31.8 during summer. The next highest average fish abundance was recorded at Corindi during summer with an average of 29 individual fish observed in each BRUV footage. Fish abundance in BRUV footage recorded along Coffs Creek and Moonee Creek was much lower than that recorded at Boambee Creek during both summer and winter surveys and in Corindi River over the summer period (Fig. 8). Statistical analysis showed that total fish abundance was very different between estuaries but there was no seasonal difference over the survey period (Table 8). Boambee Creek average fish abundance was much higher than Coffs Creek and Moonee Creek. The data also revealed that average fish abundance tended to be consistent among habitat types. Similarity in fish abundance between habitats may be due to the transitory nature of dominant species, such as Yellowfin Bream, Glassfish, Mullet species and Luderick, which tend to move upstream with the incoming tide.

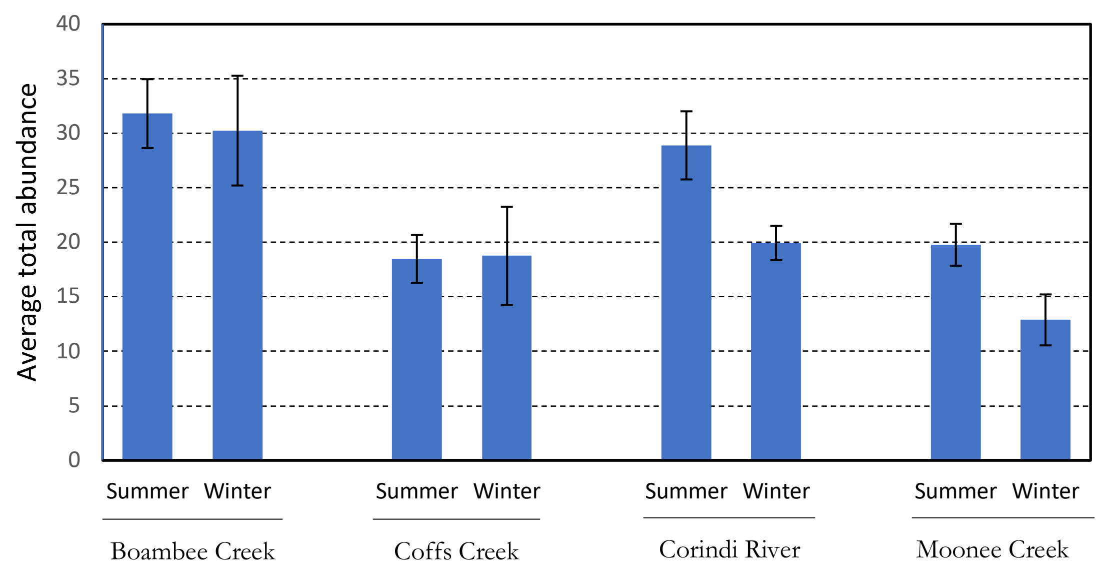


Figure 8: Average total abundance (± standard error) observed at four northern NSW estuaries assessed during summer and winter between 2015 and 2017.

Table 8: Statistical comparisons of average total fish abundance (MaxN) data taken from BRUV footage captured at four estuaries during summer and winter surveys in 2016-2017.

Source	df	Mean Square	F	Sig. level
Estuary	3	1502.074	5.33	**0.001**
Season	1	538.724	1.912	0.168
Habitat Type	4	261.476	0.928	0.449
Error	196	281.816		
Total	218			

Difference in fish species assemblage between estuaries and seasons

The fish assemblage (type of species and abundance) present within the four monitored estuaries displayed some unique patterns. Boambee Creek fish assemblage was dominated by Glassfish, Sea Mullet and Luderick throughout the year, with an abundance of Eastern Striped Grunter observed during the warmer months (Fig. 9). Glassfish comprised a high proportion of Moonee Creek assemblage in winter, with Sea Mullet and Sand Mullet present in higher numbers during winter compared to other estuaries.

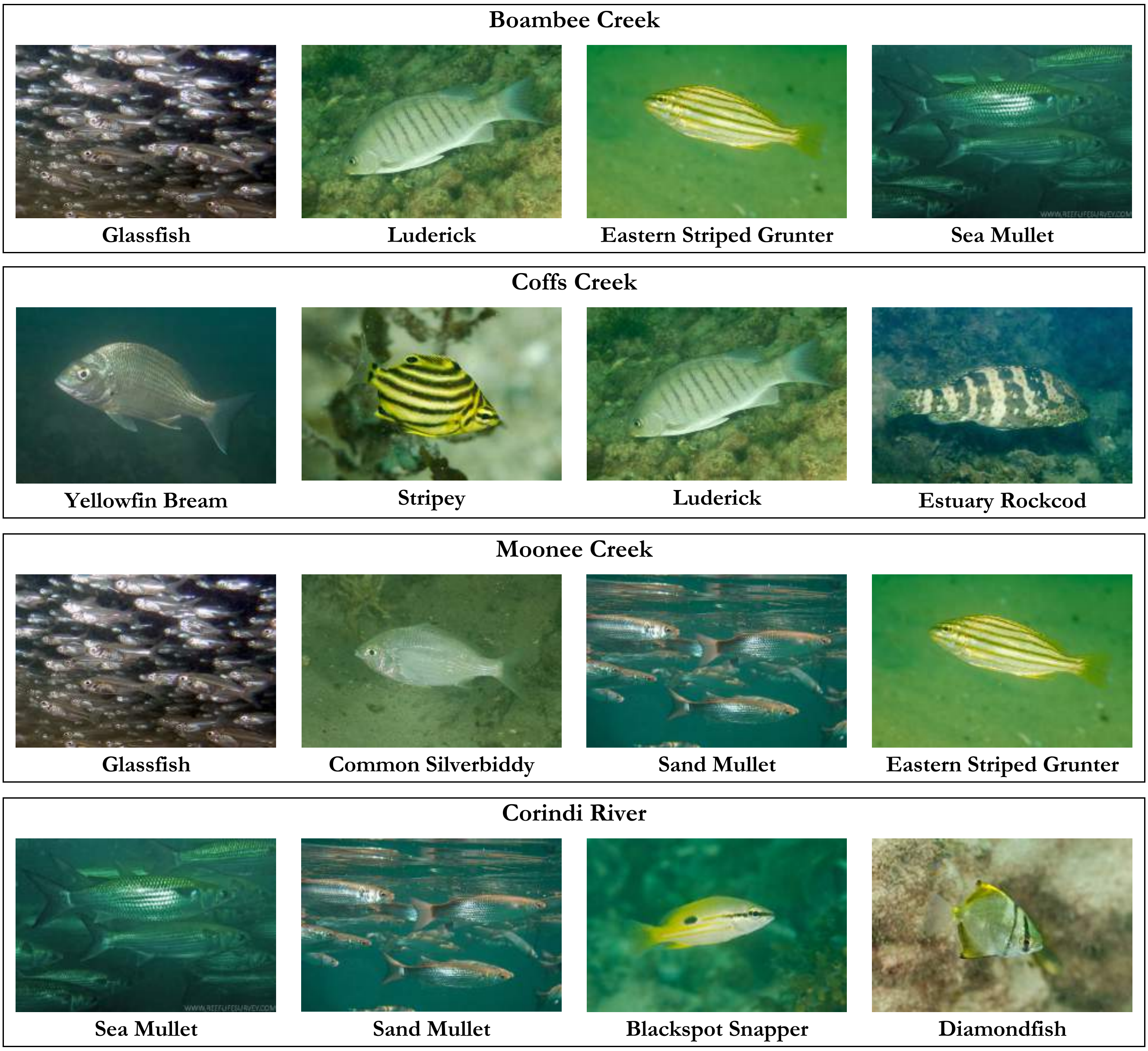


Figure 9: Fish species that contribute to the within estuary similarity and among estuary differences determined by relative abundance within each estuary. (Photos: Ian Shaw all images except, sand mullet and glassfish-fishofaustralia.net.au and sea mullet-reeflifesurvey.com)

In contrast, Yellowfin Bream dominated the Coffs Creek fish assemblage throughout the year with high abundance of Stripey and Luderick during summer and winter, respectively (Fig. 9). Estuary Rockcod species were more abundant in Coffs Creek compared to all other estuaries studied. Corindi River winter assemblages were dominated by Mullet species, with the occurrence of Blackspot Snapper and Diamondfish in summer unique to this estuary (Fig.9).

The fish assemblages within the Coffs Coast estuaries were dominated by Yellowfin Bream, Stripey, Eastern Striped Grunter and Diamondfish during the summer (Fig. 10). In contrast, during the cooler months, Glassfish, Luderick and Mullet comprised a high proportion of the fish assemblage within Coffs Creek, Boambee Creek, Moonee Creek and Corindi River (Fig. 10).

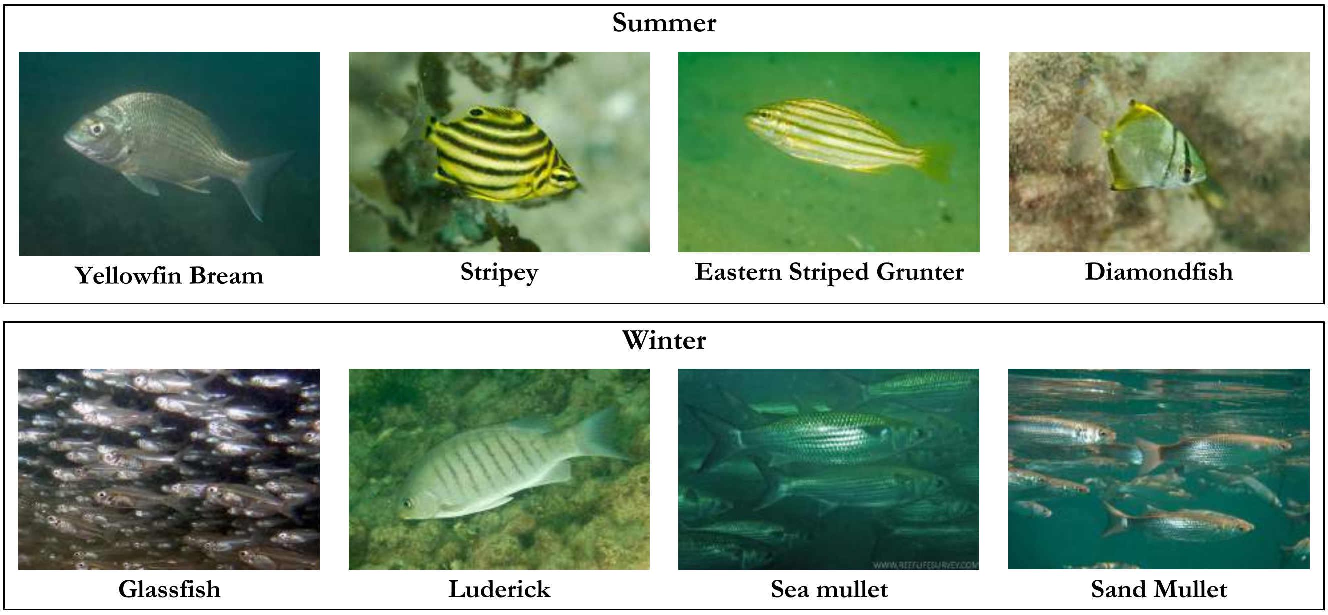


Figure 10: Fish species that contributed to the high proportion of the seasonal differences that were more abundant during summer and winter surveys completed at four northern NSW estuaries. (Photos: Ian Shaw all images except, sand mullet and glassfish-fishofaustralia.net.au and sea mullet-reeflifesurvey.com)

Presence of threatened and protected species and habitat preference

Estuary Rockcod and juvenile Queensland Groper, both listed as protected species under the *NSW Fisheries Management Act 1994*, were recorded during BRUV surveys. Estuary Rockcod were sighted in all monitored estuaries in summer, but only in Corindi River during winter surveys. This species occupied deep holes, pylon and coffee rock habitats and tended to be cryptic, cautiously appearing in the footage from under logs and other structures. Estuary Rockcod were most abundant in Coffs Creek and Boambee Creek, which had a greater number of submerged complex structures along the lower and middle sections than Moonee and Corindi estuaries. Several Estuary Rockcod species were found in abandoned mud crab traps (see Fig. 13 and text below). Additionally, one juvenile Queensland Groper was caught in an abandoned trap in Corindi River. Two Juvenile Queensland Groper were observed in BRUV footage during summer surveys. These fish were sighted adjacent to Coffee Rock in Corindi River and adjacent to a deep hole in Coffs Creek.

COFFS HARBOUR DEBRIS SURVEYS – CLEAN-UP AUSTRALIA DAY

A total of 35 and 31 volunteers participated in the SURG Coffs Creek clean-up Australia day 2016 and 2017 events, respectively. There was approximately 40% participation from non-SURG members, including eight children ranging in age from 3 to 15.

In 2016, 2,767 individual items, weighing a total of 194 kg, were removed from six sites along Coffs Creek. Plastic items comprised over 81% of all litter collected at all sites (Fig. 11A), which ranged between 42% at the one of the headwall sites and 85% at the gross pollutant trap (GPT-01) site. A total of 1,276 items was collected from GPT-01 (Fig. 11B). Metal, glass and rubber items accounted for approximately 17% of the remaining items (Fig. 11A).

The Control sites, which were located away from any storm water discharge point source, contained more litter per site than the Headwall sites, and most of the litter comprised plastic bottles and bags. Debris was only collected from the up-steam transect in Control site 01, which is evidenced by the considerably lower volume of debris removed from this site compared to Control site 02 (Fig. 11B). Unfortunately, another volunteer group removed litter from the downstream transect before SURG volunteers were able to collect and quantify the debris. Debris found in the Control sites would have been discharged into the estuary upstream and became trapped amongst the mangrove forests during tidal exchange.

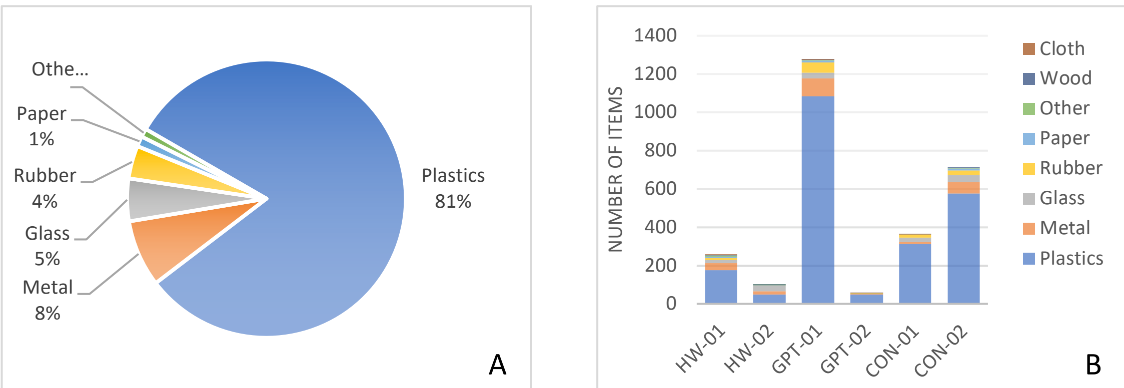
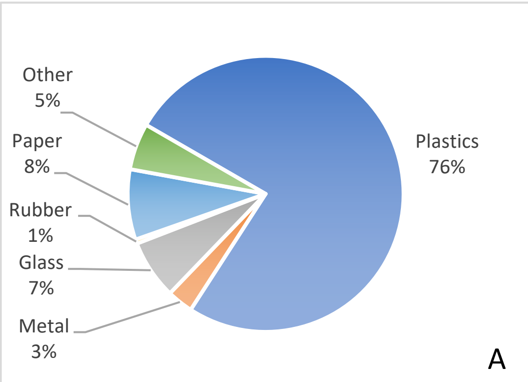


Figure 11: A) Percentage of debris categories collected from sites along Coffs Creek during the 2016 clean-up Australia Day. B) Total number of items of different litter type collected from each Coffs Creek site during the 2016 clean-up Australia day. HW = Headwall, GPT = Gross pollutant trap, and CON = Control sites.

During the 2017 SURG Coffs Creek clean-up Australia day event, debris accumulation over the past 12 months was quantified at only four sites that were previously cleaned in 2016; these sites recorded the highest debris loading (Fig. 12). A total of 1,831 items that weighed

182 kg was removed from the four sites that contained the highest loading of debris in 2016. A high proportion of debris collected was plastic (76%), with paper (8%), which included newspaper wrapped in plastic, glass (7%) and metal (3%) products also removed.

The amount of litter removed in 2017 constituted approximately 70% of the debris removed from these sites during the previous year's clean-up event. Therefore, 100% debris rate of accumulation is expected to occur within 18 months along Coffs Creek following removal. However, this does not take into account the amount of debris released into the ocean via Coffs Creek annually.



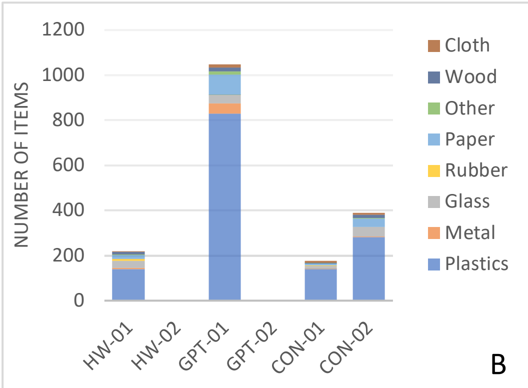


Figure 12: A) Percentage of debris categories collected from sites along Coffs Creek during the 2017 clean-up Australia Day. B) Total number of items of different debris type collected from each Coffs Creek site during the 2017 Clean-up Australia Day. HW = Headwall, GPT = Gross pollutant trap, and CON = Control sites.

Results from the annual clean-up events indicate approximately 15 tonnes of debris accumulate alone Coffs Creek east of the Pacific Highway every 12 months. The highest accumulation of litter was found in areas adjacent to storm water discharge points where gross pollutant traps were installed. It appears that these traps quickly become blocked by litter and organic material then fill with runoff water, resulting in plastic containers, bottles and bags passing through the opening at the top of the traps and becoming entangled in the adjacent mangroves.

Gross pollutant traps are specifically designed to retain debris and therefore reduce the amount of litter entering the waterways, but they can become ineffective if not regularly maintained and emptied of litter (Madhani *et al.,* 2009). This study revealed that as a consequence of GPT becoming blocked through time, light material such as plastic bottles, bags and small items are released from the top opening during periods of high-water flow.

These items can become trapped amongst mangrove stands, degrading the waterways and threatening aquatic animals.

ABANDONED RECREATIONAL TRAP SURVEYS

Figure 13: A) SURG member scuba diving to remove abandoned and buried mud crab trap. B) Discarded mud crab trap ghost fishing in Corindi River, two Estuary Rockcod and one juvenile Queensland Groper were caught in this trap. One Estuary Rockcod was dead the other two fish were emaciated. (Photos Ian Shaw)

Between 2015 and 2017, SURG members assisted in locating and removing abandoned recreational mud crab traps from Boambee Creek, Coffs Creek and Corindi River. Fifty-two traps of various types were found (Table 9), either visually whilst paddling or undertaking snorkelling and diving activities or by side-scan-sonar attached to a small vessel. Many of these traps were buried in the sediment, which made them difficult to remove. No traps were appropriately labelled and most did not have a float and rope attached.

Table 9: Abandoned or lost traps found at three northern NSW estuaries during debris surveys conducted between 2015 and 2017.

Estuary	Small circular	Large circular	Rectangular collapsible	Rectangular rigid	Fish trap	Total
Boambee Creek	6	2	2			**10**
Coffs Creek	15		3	1	3	**22**
Corindi River	9	5	4		2	**20**

Following heavy storm events traps tend to accumulate in deep holes and become buried in the sediment. This results in the openings of the circular recreational mud crab traps being covered in sand, and on several occasions, threatened species including the Goldspotted and Blackspotted Rockcods and juvenile Queensland Gropers were ensnared. Several fish appeared emaciated and one Estuary Rockcod died in a trap (Fig. 13). All live fish were released from the trap immediately upon discovery.

Twelve abandoned traps (23%) that were found continued to catch target and non-target species, with 36% of traps removed from Coffs Creek containing Estuary Rockcod and/or mud crabs (Table 10). One trap removed from Boambee Creek contained two Dusky Flathead and one Yellowfin Bream. Three abandoned traps removed from Corindi River contained three Estuary Rockcod, one Queensland Groper and a dead Green Turtle (Table 11). If these traps were not inspected and removed, they could have through time continued to ghost fish, capturing and killing other fauna.

Table 10: Total number and percentage of discarded mud crab traps observed ghost fishing.

Estuary	Ghost fishing	Percent trapped	Total
Boambee Creek	1	10%	10
Coffs Creek	8	36%	22
Corindi River	3	15%	20
Total	**12**	**23%**	**52**

Table 11: Fish and invertebrate species caught in discarded traps observed ghost fishing.

Estuary	Species trapped	Number trapped
Boambee Creek	**Flat Head**	2
	Yellowfin Bream	1
Coffs Creek	**Estuary Rockcod**	5
	Mud Crab	4
Corindi River	**Estuary Rockcod**	3
	Queensland Groper	1
	Green Turtle	1
Total		**18**

SURG 2016-17 mud crab trap collection events coincided with a NSW Fisheries compliance enforcement coastal operation targeting unlawful crab trapping and netting across all coastal areas, including northern NSW. During this and other targeted operations in 2016-17, Fisheries officers seized 1,314 crab traps that were non-compliant (https://www.dpi.nsw.gov.au/fishing/compliance/fisheries-compliance-enforcement). This indicates that illegal, lost and discarded crab traps are threats to estuarine species.

A rise in mud crab fishing effort will further threaten NSW north coast estuary ecosystem health and function. More discarded mud crab traps will increase incidental capture of target and non-target species including threatened and protected species such as Estuary Rockcod, Queensland Groper, Green Turtles, reptiles and migratory birds and may result in additional loss of vulnerable species due to human activities.

ON-GROUND REMEDIATION WORK

Three field days were organised between March and May 2018, during which time 16 SURG members and 9 local residents assisted in the installation of 50 coir logs, drainage material, coir matting and the installation of native seedlings and grasses along an eroded section of Corindi River adjacent to Jewfish Point boardwalk (Fig. 14).

Figure 14: Remediation works carried out along Corindi River: A) Example of erosion in 2015; B-D) SURG members and local residents installing coir logs and matting along eroded section of Corindi River; E) Installation of Coir matting to stabilise river bank; F) Site barrier and information panel installed to inform visitors of remediation works; and G) Planting and watering of seedlings and grasses along remediated site.(Photos: SURG members)

Approximately 300 m^2 of Corindi River stand line was remediated, which will assist in reducing further bank erosion from storm surge and visitor foot traffic. During subsequent follow-up inspections and plantings, we found that the barrier and signage appears to have reduced the amount of foot traffic along the remediation area, most of the seedlings have established and, in time, will provide root structure to stabilise the river bank. Bi-annual follow-up inspection and additional planting will occur during the next couple of years.

INTERPRETIVE PANELS AND FACTSHEETS

Data and information collected during this project regarding estuarine condition and threats to critical habitats formed the basis of four distinct interpretive panels and four threat specific activities fact sheets. Interpretive panels have been designed, constructed and positioned adjacent to high visitation areas along Boambee Creek, Coffs Creek, Corindi River and Moonee Creek. These panels (Figs. 15-18) highlight the uniqueness of each estuary, identify local threats and suggest ways visitors can assist in mitigating threats to critical habitat of estuarine flora and fauna. Additionally, four fact sheets (Appendix 4) provide an online educational resource that highlight mitigation strategies to enhance local estuarine habitats.

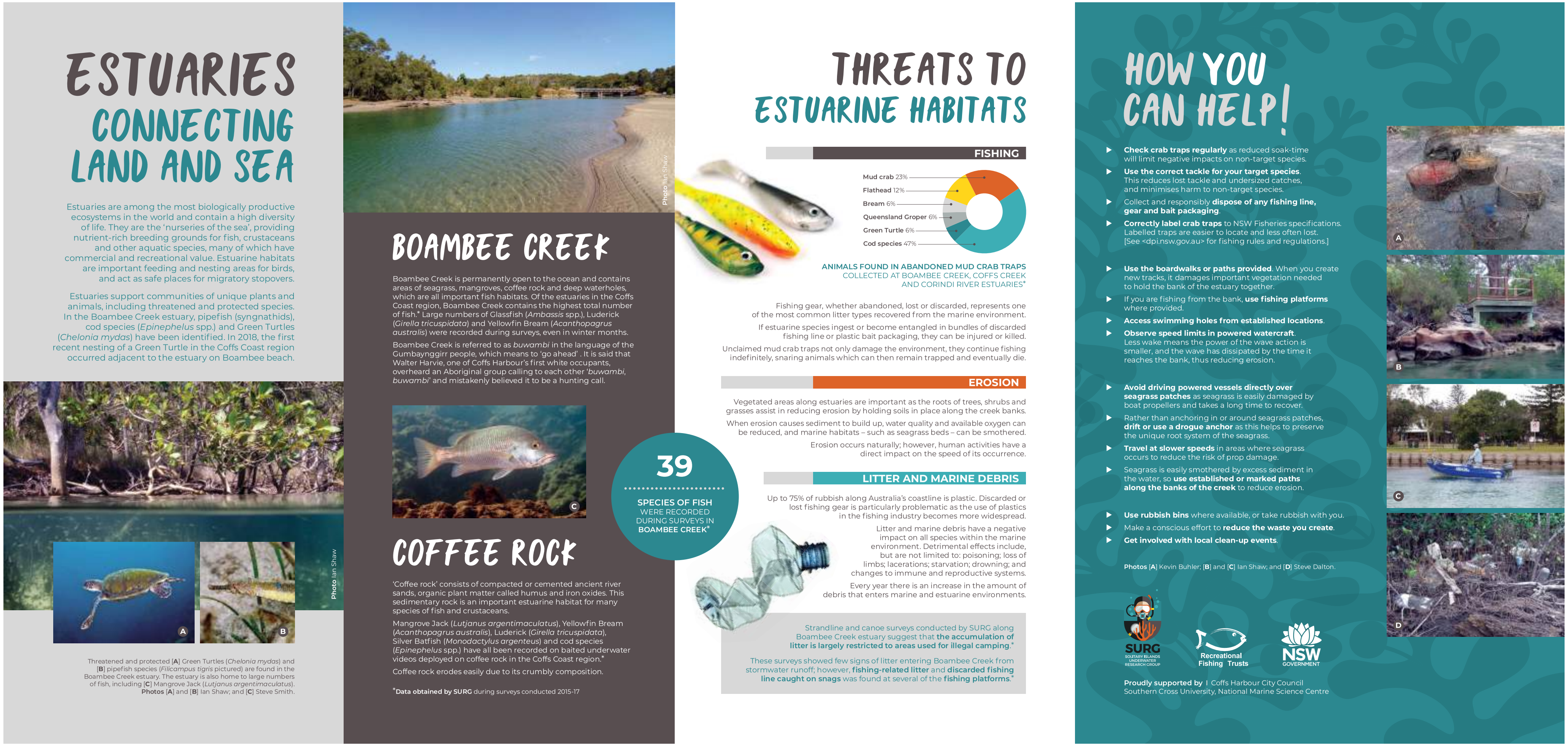


Figure 15: Boambee Creek interpretive panel

Figure 16: Coffs Harbour interpretive panel

Figure 17: Corindi River Interpretive panel

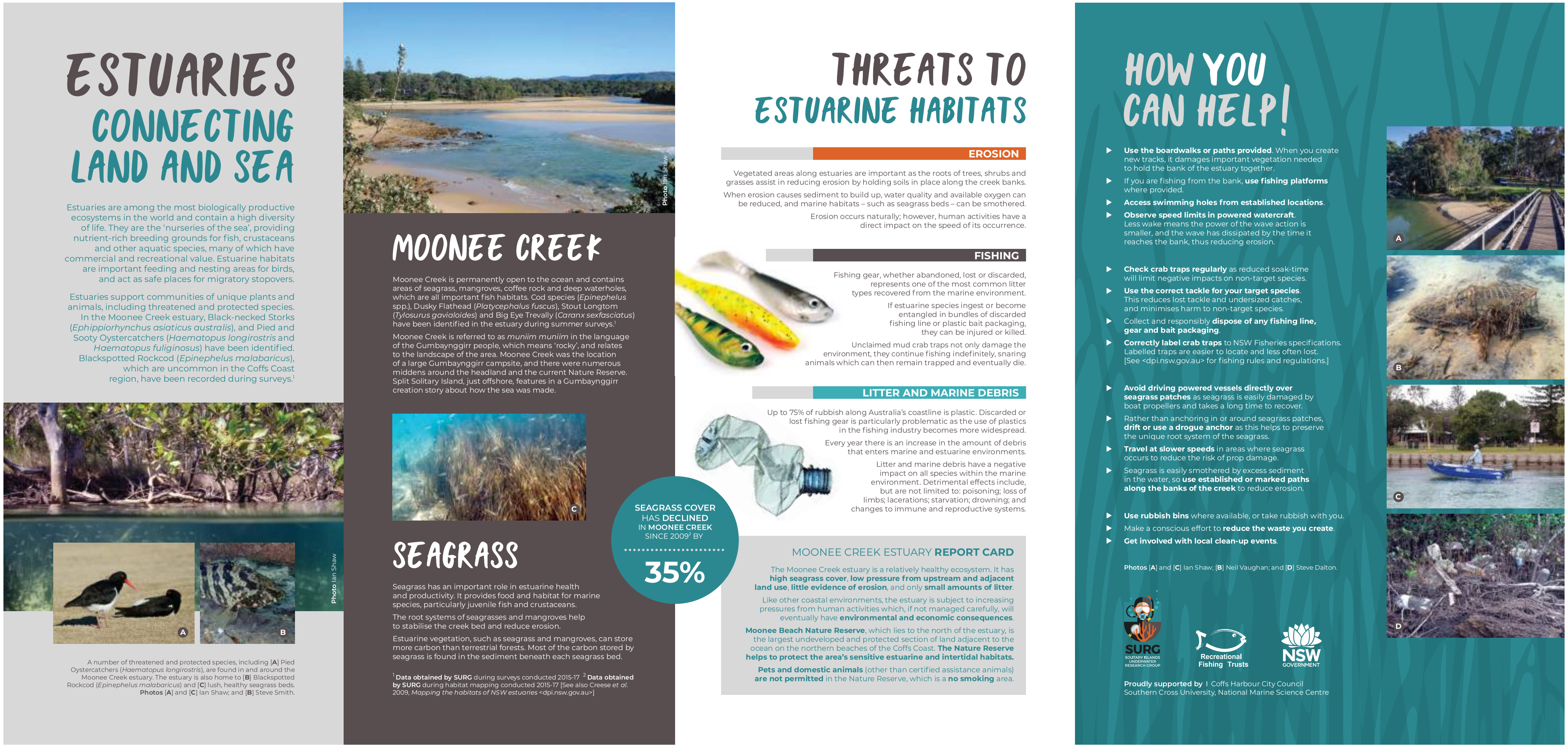


Figure 18: Moonee Creek interpretive panel

ACKNOWLEDGEMENTS

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REFERENCES

Creese, R.G., Glasby, T.M., West, G., and Gallen, C. (2009) Mapping the habitats of NSW estuaries. Industry & Investment NSW, Nelson Bay.

Dalton, S.J., and Carroll, A.G. (2011) Monitoring coral health to determine coral bleaching response at high latitude eastern Australian reefs: an applied model for a changing climate. Diversity **3**(4), 592-610.

Edgar, R.J. (2015) An assessment of the 'health' of corals in the Solitary Islands Marine Park, northern NSW. A Solitary Islands Underwater Research Group Inc. Report to the NSW Environmental Trust, NSW Office of Environment and Heritage. May 2015. 30 pp.

Ekman, T. (2014) Urban storm water runoff: the composition, density, and size of debris in the Coffs Creek Estuary. Unpublished integrated report. School of Environment, Science and Engineering, Southern Cross University, Lismore.

Evans, S.M., Griffin, K.J., Blick, R.A.J., Poore, A.G.B., and Vergés, A. (2018) Seagrass on the brink: Decline of threatened seagrass *Posidonia australis* continues following protection. PLOS ONE 13(4), e0190370.

Folpp H, Lowry M, Gregson M, Suthers IM (2013) Fish assemblages on estuarine artificial reefs: natural rocky-reef mimics or discrete assemblages? PLoS ONE 8(6): e63505.

Gregory, M. and P. Ryan (1997). Pelagic plastics and other seaborne persistent synthetic debris: a review of Southern Hemisphere perspectives. Marine Debris, Springer: 49-66.

Lowry, M., Folpp, H., Gregson, M., and Suthers, I. (2012) Comparison of baited remote underwater video (BRUV) and underwater visual census (UVC) for assessment of artificial reefs in estuaries. Journal of Experimental Marine Biology and Ecology 416-417, 243-253.

Madhani, J.T., Kelson, N.A., Brown, R.J. (2009). An experimental and theoretical investigation of flow in a gross pollutant trap. Water Science and Technology 59(6): 1117-1127.

NSW Department of Primary Industries (2018) List of protected fish species, https://www.dpi.nsw.gov.au/fishing/closures/identifying

Turk, E. (2017). Using Baited Remote Underwater Video (BRUV) to monitor fish assemblages within north coast estuaries: A comparison of baited vs un-baited. Unpublished integrated report. School of Environment, Science and Engineering, Southern Cross University, Lismore.

Smith, S.D.A., and Edgar, R.J. (1999) Description and comparison of benthic community structure within the Solitary Islands Marine Park. Solitary Islands Underwater Research Group Inc. Report prepared for Environment Australia, Canberra.

Smith, S.D.A., Dalton, S.J. & Purcell, S.W. (2010). Distribution of threatened and protected species in marine habitats of the northern rivers region of New South Wales. Report prepared for the NRCMA. NMSC, SCU, Coffs Harbour. Pp. 36

APPENDIX 1 – DEPLOYING GOPRO BAITED REMOTE UNDERWATER VIDEOS (BRUVS) IN ESTUARINE FISH HABITATS

Over the next three years SURG will be assessing threatened and protected fish and recreationally important fish species occurrence in five northern NSW estuaries, Corindi River, Moonee Creek, Coffs Creek, Boambee Creek and Bonville Creek. This document outlines the methods for deployment of GoPro Baited Underwater Videos (BRUVs) in fish habitats along the lower to middle reaches of these systems.

Each estuary has been divided into three sections determined by the distance from the estuary mouth, referred to as lower, middle and upper locations. Within each location a number of habitat types will be monitored using BRUVs, these habitats will include Artificial Rockwall, Coffee Rock, Deep Holes, Macroalgae, Pylons, Rocky Outcrops, Seagrass and Snags. In Bonville Creek, key habitats of threatened species such as Black and Estuary Rockcod, including deep holes, rocky outcrops and snags will be opportunistically monitored for species sightings over the duration of the project.

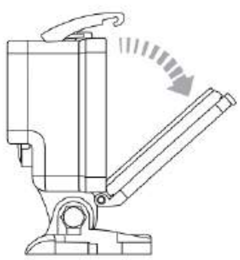
BRUV camera mounts were designed and constructed by Neil Vaughan and have been trialled at a number of locations. With the assistance of many SURG members we have developed a protocol for preparing and deploying BRUVs into fish habitats. Below is a step-by-step outline of how to set up, activate and deploy the BRUVs for the purpose of monitoring estuarine fish species.

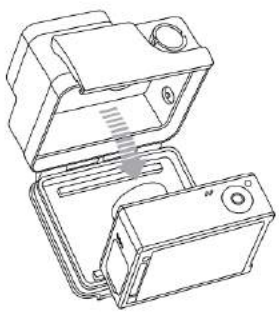
Six GoPro Hero 4 Silver Edition cameras and housing have been purchased by SURG that will be used for the BRUV monitoring program. Additionally, SURG has four Intova SPI cameras that will be used to capture images of estuarine species during snorkelling observation surveys throughout the project.

ASSEMBLING THE GoPro CAMERA HOUSING

To Remove the Camera From the Housing:

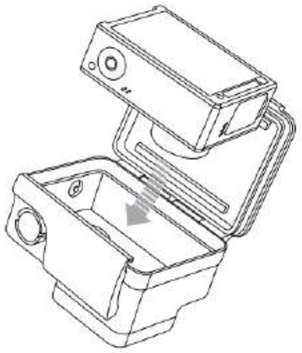
1. Lift the front of the latch up to disengage it from the camera housing.
2. Pivot the latch backward and pull it up to release the backdoor.
3. Pull housing back door open and remove the camera.

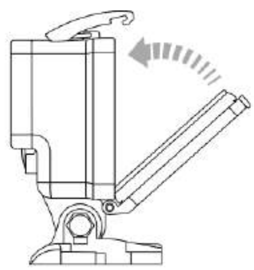




To Secure the Camera in the Housing:

1. Open the housing and place the camera into position.
2. Make sure the seal around the backdoor is free of debris, clean with a lint free cloth if needed.
3. Slide the anti-fog pad between the housing and the bottom of the camera, ensuring that the cloth will not obstruct the backdoor when closed.
4. Close the housing backdoor and squeeze it closed to ensure a good seal.
5. Pivot the hinged arm backwards and hook the lip of the latch into the grooved top of the housing backdoor.
6. Push the latch down to snap it into place.





BRUV set up:
The evening prior to any SURG estuary field trip where BRUVs will be deployed all cameras are charged and micro SD cards cleared of past files. Once the cameras are charged and micro SC cards inserted, they can be placed into the GoPro housing, the white sealing ring needs to be inspected for any sand and salt particles and other fine material that may compromise the sealing of the housing. Using a lint free cloth, lens wipes or a Q-tip any foreign material should be removed from the housing seal. Before closing the housing, place the anti-fog pad into the bottom of the housing ensuring that is located completely past the back of the camera and will not get caught in the housing back door.

Each GoPro is fitted with a GoPro clip that complements the clip mount located on each of the GoPro stands.

Camera activation:
The GoPro four silver edition cameras have been set up to recording using the QuickCapture function that enables an easy method to activate the record function of the cameras.
With QuikCapture selected, you can quickly turn your camera on and begin capturing video or Time Lapse photos.

To Capture Video with QuikCapture:
With the camera powered off, press and **release*** the Shutter/Select button [button on the top of the housing]. Your camera automatically powers on and begins capturing video. This will activate the LCD screen for viewing what is being recorded and the recording lights on

the camera will flash. The LCD screen will remain on for five minutes then will shut off. The camera will still be in recording mode.

With the screen activated you can align the bait at the bottom of the field of view prior to the deployment of the BRUV.

To Stop Recording:
Press and release the Shutter/Select button to stop recording and power off the camera.
*NOTE: If you press and hold down the shutter/select button this will activate the Capture Time Lapse Photos mode and the camera will record still photos instead of recording video.

Deploying the BRUV:
During transect to deployment site, ensure the cameras are not exposed to direct sunlight, which can fog up the inside of the lens resulting in poor quality recording.

Once you have reached the site for BRUV deployment, gently lower the unit into the water using the floated rope and a deployment conduit. Ensure that the unit is located in a spot/orientation where the field of view is not obstructed by seagrass. Try to place the unit in an area of low seagrass cover or locate the BRUV on the sand adjacent to and facing the seagrass bed. It is important to ensure that a reasonable open space is available to enable the camera to capture fish swimming about.

APPENDIX 2 – BAITED REMOTE UNDERWATER VIDEO ANALYSIS

GoPro cameras have been attached to baited remote underwater video (BRUV) stands and have been deployed in a range of estuarine habitats along four northern NSW estuaries, including Corindi River, Moonee Creek, Coffs Creek and Boambee Creek. Video cameras have been deployed for approximately 20 – 30 minutes and recorded the fish species that occur in different habitats. At present a total of 212 individual BRUV deployments have been completed during the cooler and warmer months of 2015 and 2016. We have hundreds of other recordings that will need to be assessed and I thank all the members for assisting with the capture and assessment of the footage.

During recording the video recordings have been split into 4 Gigabyte files, each of which corresponds to approximately 17 minutes of recording. This means that some video drop footage is contained in two files, which have been labelled accordingly. For example, if you open the Baited video data form and click on the Data records worksheet you will see a list of all the individual BRUVs that have been recorded. Each individual BRUV recording (transect) has its own unique number (ID) shown in Column A, with additional information for that transect provided in subsequent columns. If recording went for longer than 17 minutes then there are two files for that transect (see column K and J), which provide the unique label for each recording file.

To standardise each recording that will assess key recreational fish species we will only assess 15 minutes of footage from each transect. However, to assess threatened and protected species the entire footage for each transect will be viewed. This will allow us to determine if threatened and protected species are present in these estuaries and if so in what habitat they occur. With the recreational species assessment, we wish to quantify (estimate) the number of species and individuals present and compare between different habitats and estuaries; therefore, we need to standardise our viewing time. Below I have provided a blow-by-blow methods section to step you through the procedure.

Assessing Video recordings

Open each BRUV video and quickly play the footage at fast speed (2 to 5 times) to assess the quality of the footage and to determine if the footage is assessable. If the field of view is obscured by seagrass or algae that has covered the camera, make a note of this in the corresponding note cell and move onto the next transect to be assessed. If the baited bag is obscured from view do not assess the footage. During this initial viewing there may be a section of the recording where the field of view is not obstructed and/or water quality improves making it easier to assess the transect for fish species. I recommend that you use this section of footage to assess for recreational fish species occurrence. Video footage quality may improve during the drop period because the tide has slowed, and cleaner marine water has pushed up stream.

View the footage at normal speed and start to count all species of fish that are present one minute from the start of the recording or at a time where the footage viewing quality has improved.

Total maximum number (MaxN) is the information that you will be recording for all recreational and threatened and protected species seen in the video footage. MaxN is the maximum number of individual fish species observed at any one time and recorded for all species seen in the video transect. For example, if you play back the footage and at some point you observe 6 Yellowfin Bream in the frame, and 6 is the maximum number of bream you observe during the entire 15 minutes observation period, then you record 6 in the data sheet next to Yellowfin Bream. You will also need to note the recording time this was observed and add to the cell immediately adjacent to the MaxN score for that species in your data sheet. Each fish species observed in the BRUV video will have its own MaxN number and observation time.

MaxN is **NOT** the total number of all fish seen during the entire recording, but the maximum number of individual fishes seen at one time for a species. Each species that you observe in a transect will have a MaxN value.

MaxN will enable us to estimate species richness and abundance and compare these measures between creeks, seasons and habitat types.

You may want to write down the fish species you see and record the MaxN next to the species name and record time on a note pad then you can update these values if more fish are seen later during the play back. Once you have finished assessing each video recording, you can then add the data to your observer worksheet.

I have created an observer worksheet for each observer and added the meta data for each BRUV recording that will be assessed by each observer. Please make a copy of this file, including your name to the file name and add your observation data to your observer worksheet.

You may encounter fish species that are not shown on the fish ID guide or listed in the data sheet, if you can identify these species please insert another row and add the species name to column A in your data sheet and add the MaxN and observation time in the corresponding cells.

If you cannot identify the species add the values to the cells that aligns with the Other species 01 row. You might want to take a snap shot of the unidentified species for reference later. Every time you see this species in the recordings that you assess you will use the Other species 01. If you take a snap shot of the image and save the file adding the Other Species 01 to the file name and email the image to me, I can circulate to our fish experts to confirm identification.

Once you have completed the each individual BRUV transect and added the data to your data sheet please email me the updated excel sheet and I will update the master sheet.
I will organise a training session where we can all get together and go over the methods for assessing the footage.

Thanks for volunteering to assess these recordings and I hope that you find some interesting critters.

APPENDIX 3 – EXAMPLE OF FISH IDENTIFICATION SHEETS

 Dusky Butterflyfish Adult	 Dusky Butterflyfish Juv.
 Vagabond Butterflyfish	 Threadfin Butterflyfish
 Pencil Surgeonfish Juv.	 Pencil Surgeonfish
 Convict Surgeonfish	 Orangeblotch Surgeonfish Juv.
 Dusky Surgeonfish Juv.	 Pale Surgeonfish

Image by Ian Shaw

APPENDIX 4 – THREATS TO ESTUARY HABITATS FACT SHEETS

SEAGRASS FACT SHEET

THREATS TO ESTUARINE HABITATS

Photo Ian Shaw

Estuaries are among the most biologically productive ecosystems in the world and contain a high diversity of life. They are the 'nurseries of the sea', providing nutrient-rich breeding grounds for fish, crustaceans and other aquatic species, many of which have commercial and recreational value. Estuarine habitats are important feeding and nesting areas for birds, and act as safe places for migratory stopovers.

Threats such as marine debris, erosion, recreational fishing and boating all have an impact on estuarine species and the habitats that they rely upon.

HOW YOU CAN HELP

- **Avoid driving powered vessels directly over seagrass patches** as seagrass is easily damaged by boat propellers and takes a long time to recover.
- Rather than anchoring in or around seagrass patches, **drift or use a drogue anchor** as this helps to preserve the unique root system of the seagrass.
- **Travel at slower speeds** in areas where seagrass occurs to reduce the risk of prop damage.
- Seagrass is easily smothered by excess sediment in the water, so **use established or marked paths along the banks of the river** to reduce erosion.

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KEY FACTS

Seagrass has an important role in estuarine health and productivity. It **provides food and habitat for marine species**, particularly juvenile fish and crustaceans.

The extensive **root systems** of seagrasses, which extend both vertically and horizontally, help to **stabilise river beds** and **reduce erosion** by trapping and binding sediment.

Estuarine vegetation, such as **seagrass and mangroves, can store more carbon than terrestrial forests**. Most of the carbon stored by seagrass is found in the sediment beneath each seagrass bed.

Photo Ian Shaw

FISHING FACT SHEET

THREATS TO ESTUARINE HABITATS

Photo Ian Shaw

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Threats such as marine debris, erosion, recreational fishing and boating all have an impact on estuarine species and the habitats that they rely upon.

HOW YOU CAN HELP

- **Check crab traps regularly** as reduced soak-time will limit negative impacts on non-target species.
- **Use the correct tackle for your target species**. This reduces lost tackle and undersized catches, and minimises harm to non-target species.
- Collect and responsibly **dispose of any fishing line**, **gear and bait packaging**.
- **Correctly label crab traps** to NSW Fisheries specifications. Labelled traps are easier to locate and less often lost. [See <dpi.nsw.gov.au> for fishing rules and regulations.]

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KEY FACTS

Fishing gear, whether abandoned, lost or discarded, represents **one of the most common litter types recovered from the marine environment**.

Unclaimed mud crab traps not only damage the environment, they **continue fishing indefinitely**. In a process commonly referred to as '**ghost fishing**', the traps keep snaring crabs, fish and other animals. Many of these animals die imprisoned in the trap and themselves become bait for still more ghost fishing.

If estuarine species ingest or become entangled in bundles of discarded fishing line or plastic bait packaging, **they can be injured or killed**.

Photo Steve Smith

LITTER FACT SHEET

THREATS TO ESTUARINE HABITATS

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Threats such as marine debris, erosion, recreational fishing and boating all have an impact on estuarine species and the habitats that they rely upon.

HOW YOU CAN HELP

- **Use rubbish bins** where available, or take rubbish with you.
- Make a conscious effort to **reduce the waste you create**.
- **Get involved with local clean-up events**.
- Collect and **responsibly dispose of** any **fishing line, gear and bait packaging**.
- **Collect additional pieces of rubbish** when leaving the beach, waterway or park. Every piece of litter you pick up reduces the litter that ends up in our waterways and environment.

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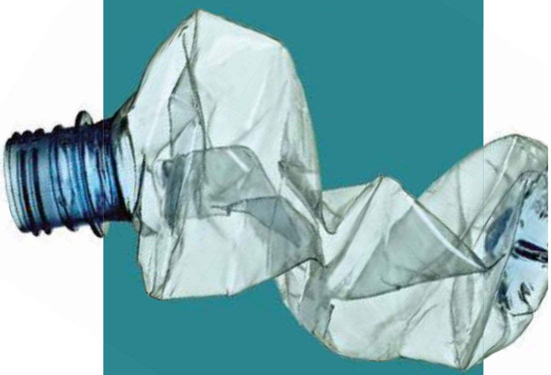
KEY FACTS

Up to 75% of rubbish along Australia's coastline is plastic. Discarded or lost fishing gear is particularly problematic as the use of plastics in the fishing industry becomes more widespread.

Litter and marine debris have a **negative impact on all species** within the marine environment. Detrimental effects include, but are not limited to: poisoning; loss of limbs; lacerations; starvation; drowning; and changes to immune and reproductive systems.

Every year there is an increase in the amount of debris that enters marine and estuarine environments.



EROSION FACT SHEET

THREATS TO ESTUARINE HABITATS

Photo Ian Shaw

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Threats such as marine debris, erosion, recreational fishing and boating all have an impact on estuarine species and the habitats that they rely upon.

HOW YOU CAN HELP

- **Use the boardwalks or paths provided**. When you create new tracks, it damages important vegetation needed to hold the bank of the estuary together.
- If you are fishing from the bank, **use fishing platforms** where provided.
- **Access swimming holes from established locations**.
- **Observe speed limits in powered watercraft**. Less wake means the power of the wave action is smaller, and the wave has dissipated by the time it reaches the bank, thus reducing erosion.

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Recreational Fishing Trusts

NSW GOVERNMENT

KEY FACTS

Vegetated areas along estuaries are important as the roots of trees, shrubs and grasses assist in reducing erosion by holding soils in place along the river banks.

When **erosion causes sediment to build up**, water quality and available oxygen can be reduced, and **marine habitats** – such as seagrass beds – **can be smothered**.

Erosion occurs naturally; however, **human activities have a direct impact on the speed of its occurrence**.

Photo Ian Shaw