SIMP'S SANDY OFFSHORE SEAFLOOR IS NO DESERT

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Abstract

Unconsolidated sediment is the most prevalent global marine habitat, yet is often perceived as lacking life, and is under-represented in the body of marine research. About 80% of the seafloor in the Solitary Islands Marine Park (SIMP), northern NSW, is unconsolidated and this habitat is important for the local fishing industry. Despite this, ecological information, which is vital for management decisions, is limited. In this study we aimed to improve understanding of the spatial patterns of species associated with unconsolidated habitat. We assessed the structure of fish and invertebrate assemblages, using 57 Baited Remote Underwater Video (BRUV) deployments at depths of 35-50m, and a drop camera, with which we took 543 images of the seafloor and associated biota. A total of 31 fish, 8 shark and ray, and 16 invertebrate species or species groups were detected, including the Endangered scalloped hammerhead shark and Threatened white-spotted guitarfish. The most abundant species was longspine flathead, which was detected in all BRUV deployments with an overall total of 853 individuals. A wide range of mobile and sessile invertebrate species were recorded, including spanner crabs, octopus and sea pens. Consistent with other recent work (Schultz et al. 2014), we found that the SIMP's sandy seafloor was not barren of life, and was utilised by a wide variety of species. A number of these species are ecologically important and form the basis of commercial and recreational fisheries. This study strongly supports the fact that this ecosystem is worth conserving and should be considered in ongoing refinement of management.

Introduction

Unconsolidated substrate is globally the most abundant seafloor habitat (Snelgrove *et al.,* 1999), yet is under-represented in ecological research (Edgar, 2001; Caveen *et al.,* 2012; Lutz-Collins & Quijón, 2014). Relative to consolidated reef, marine unconsolidated seafloor is a homogenous, unstable habitat (McArthur *et al.,* 2010), to which organisms generally display lower site attachment and less competition for space (Caveen *et al.,* 2012). Thus, studies have focussed on more complex habitat, which generally supports greater species richness than unconsolidated habitats (Coll *et al.,* 1998; Nakamura & Sano 2005; Schultz *et al.,* 2014). However, unconsolidated habitats can support important components of biodiversity, including abundant species, endemic species, threatened species, and species targeted by commercial and recreational fishing. Unconsolidated seafloor acts as both habitat for infauna and substrata for benthic organisms (Gray, 2002). Unconsolidated habitats can support taxon-rich ecosystems (Evrard *et al.,* 2010), with a diverse benthos (Dittmann, 2007). They have assemblages that are distinct from reef, with minimal overlap in these assemblages at the interface between reef and unconsolidated habitat (Schultz *et al.* 2012).

Marine unconsolidated habitats provide social and economic benefits globally, regionally, and locally, through commercial and recreational fisheries. These habitats are an important source of seafood, with line fishing, trapping and benthic trawling conducted for various target finfish and invertebrate species. For example, ~15 million km^2 of seafloor is trawled worldwide each year (Watling and Norse, 1998). Benthic trawling has a number of negative environmental impacts, which can include bycatch mortality (Bianchi *et al.,* 2000), reduced biodiversity (Duplisea *et al.,* 2002) and homogenising of habitat (Turner *et al.,* 1999). Therefore, given these biodiversity and socio-economic values, an improved knowledge of the biota associated with unconsolidated habitats is required for effective management of this extensive habitat type.

Marine conservation and resource management can include spatial management through protected areas, and fisheries management through various input and output controls. A combination of these is currently used to manage human activities within unconsolidated habitats in NSW. This includes the 720 km^2 Solitary Islands Marine Park (SIMP), which was established in 1991, covering State waters between Coffs Harbour and Sandon River. Approximately 80% of the seafloor in the SIMP is unconsolidated (NSW Marine Parks Authority, 2009). However, as is typical globally, knowledge of biotic patterns and processes within this habitat is limited in comparison to other habitat types, although this has improved over the past five years (Schultz, 2016). The infaunal assemblage in subtidal unconsolidated habitat in the SIMP is diverse, supporting at least 243 species (Smith and Rowland 1999). Fishes associated with these habitats are less species-rich, with 23 taxa recorded in surveys across the SIMP using Baited Remote Underwater Video (BRUV) (Schultz *et al.* 2014, 2015). Some of these fishes were abundant including bluespotted flathead (*Platycephalus caeruleopunctatus*), which is economically and socially important, yellowtail scad (*Trachurus novaezelandiae*), longspine flathead (*Platycephalus longispinis*), whiting (*Sillago* spp.), eastern stripped grunter (*Pelates sexlineatus*) and the endemic eastern shovelnose ray (*Aptychotrema rostrata*).

The commercial fishing industry is important both economically and socially in Coffs Harbour (Harrison, 2010). Unconsolidated habitats in the SIMP are an important component of the seafloor which is commercially fished. From 2009–2015 an average of ~23 NSW Ocean Prawn Trawl Fishery businesses reported landing catch from the SIMP per annum. On average, ~150 tonnes of biomass was removed by this fishery each year. The most common catches by weight during this time were king prawn (*Penaeus plebejus*), whiting, octopus (*Octopus spp.*), cuttlefish (*Sepia* spp.), bluespotted flathead, yellowtail scad and eastern fiddler ray (*Trygonorrhina fasciata*). Unconsolidated habitats in the SIMP are also important for the NSW Ocean Trap and Line fishery with an average of ~105 tonnes of spanner crab (*Ranina ranina*) retained per annum from the SIMP from 2009-2015. Increased knowledge of biotic patterns in these habitats will assist with their management.

The aim of our study is to further improve knowledge of fish and macro-invertebrate taxa associated with unconsolidated habitat in the SIMP. Our objectives include: improving understanding of spatial patterns of taxa associated with unconsolidated habitat; and increasing awareness of the value of this habitat type, both as a resource and an ecosystem.

Methods

Study area

The SIMP spans 75 km of coastline from the Sandon River (29°41' S, 153°20' E) south to Coffs Harbour (30°30' S, 153°12' E). An additional 152 km^2 is protected as the Solitary Islands Marine Reserve (SIMR), adjacent to the SIMP in Australian Commonwealth waters. The SIMP is spatially managed under the NSW *Marine Estate Management Act 2014* and through fisheries input and output controls through the NSW *Fisheries Management Act 1994*.

Field work was undertaken on unconsolidated seafloor in Habitat Protection Zone (HPZ) and General Use Zone (GUZ) of the SIMP (Figure 1). A main difference in restrictions between these two zones is that trawling is not permitted in HPZ. Recreational and commercial line fishing and spanner crab trapping is permitted in both. The study area was located proximal to South Solitary Island (30°12' S, 153°16' E) within a depth range of 35 to 50 m. Shallower fish assemblages differ from deeper fish assemblages in the SIMP and this occurs on both reef and unconsolidated habitats (Malcolm *et al.,* 2011; Schultz *et al.,* 2014; Malcolm *et al.,* 2016). The depth range in this study corresponds with an intermediate depth fish assemblage on unconsolidated habitats (Schultz *et al.,* 2014). The East Australian Current has a major influence over sea temperature and water clarity in the SIMP and this further influences biotic patterns (Malcolm *et al.,* 2010a, b; Dalton & Carroll, 2011).

The study sites were positioned both north and south of South Solitary Island. This was due to potential differences in assemblages caused by a break in unconsolidated habitats, associated with the island and subtidal reef extending eastward. Additionally, there were HPZ and GUZ zoning arrangements both north and south of this island (Figure 1).

The sampling design therefore included Location (north, south), Management Zone (GUZ, HPZ), Site (n = 3 per Location by Management Zone interaction) and level of replication within each Site depending on the field survey method used.

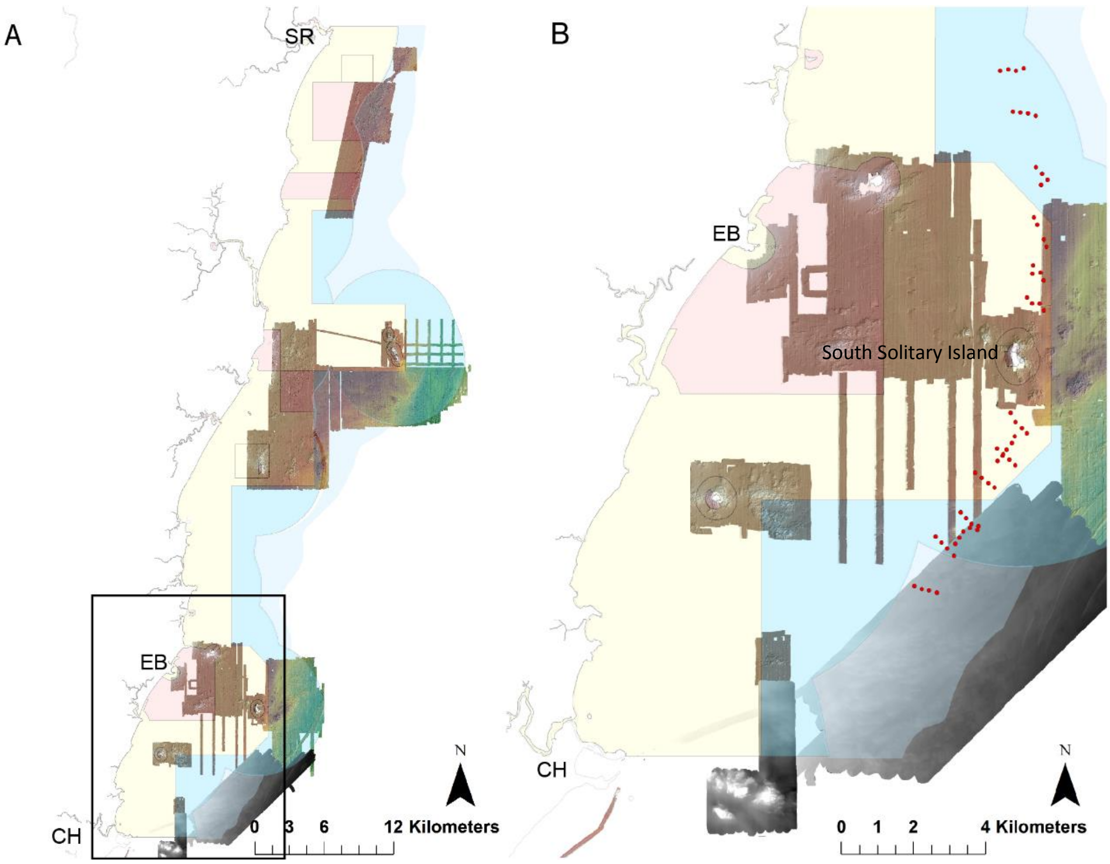

Figure 1: Study location at the A) Marine Park and B) site scale. The black box on map A indicated the location of map B. Pink shading= SZ (SIMP), yellow= HPZ (SIMP), blue= GUZ (SIMP) and light blue= SIMR. Red circles indicate the location of BRUV deployments. SR= Sandon River, EB= Emerald Beach, CH= Coffs Harbour.

Field methods

Fifty-eight Stereo-BRUV deployments were undertaken to record both fish and invertebrate assemblages. Ten deployments were undertaken in August 2015 (2 Management Types x 5 replicates) and 48 were undertaken in March and April 2016. Four replicate stereo-BRUVs per site were deployed in 2016 (2 Locations x 2 Management Types x 3 Sites x 4 replicates). Each stereo-BRUV unit consisted of calibrated (Harvey & Shortis, 1998) stereo-pair High Definition Canon cameras (Canon Inc.) in PVC underwater housings (SeaGIS Pty Ltd) with flat acrylic end ports. The housings were forward looking attached to a negatively buoyant steel frame. Cameras were angled downwards by 10° from the horizontal in order to facilitate measurement of flat fishes (Schultz, 2016). Approximately 800g of pilchards (*Sardinops sagax*) were placed into a mesh bait bag before being crushed to increase the bait plume and attached to units using a 1.5-m PVC pole (Hardinge *et al.,* 2013). The BRUV units were connected to the surface using ~70-m long ropes and floats. Deployments were made to allow a soak time of one hour, which begins when the BRUV unit lands on the seafloor and any disturbed substrata clears from the water column.

A high resolution (750 TVL) Deep Blue Pro drop camera (Ocean Systems, Inc.) attached to a 60-m military-grade umbilical cable was used to live stream and record footage of the seafloor and associated biota. In 2015, we trialed dropping and retrieving the camera and drift-towing for approximately one hour each. In 2016, five drops were undertaken at each site between each adjacent BRUV, giving 15 drops per site and a total of 180 drops, plus one extra at the northern-most HPZ Site due to the distance between replicates. The seafloor was recorded for approximately one minute for each of the 181 drops.

Image analysis

Throughout the analysis, some organisms could not be identified to the species level and were given a higher taxonomic classification. Thus, from herein taxonomic groups are generally referred to as taxa rather than species, unless their identification as species is clear.

The footage from the 57 BRUV deployments was analysed using EventMeasure software (SeaGIS Pty Ltd). This software enables video to be stopped and stepped-through frame by frame as required, and captures and tabulates data by taxa (Figure 2). One BRUV deployment failed, and was consequently not analysed. For each taxa, MaxN was recorded. MaxN is a conservative estimate of relative abundance (Cappo *et al.,* 2004), given by the maximum number of a taxon seen in one frame at any time throughout the BRUV recording. The use of stereo-pair cameras facilitated length measurements for taxa of interest. It was also possible to record the sex of some crab and elasmobranch taxa (Figure 2).

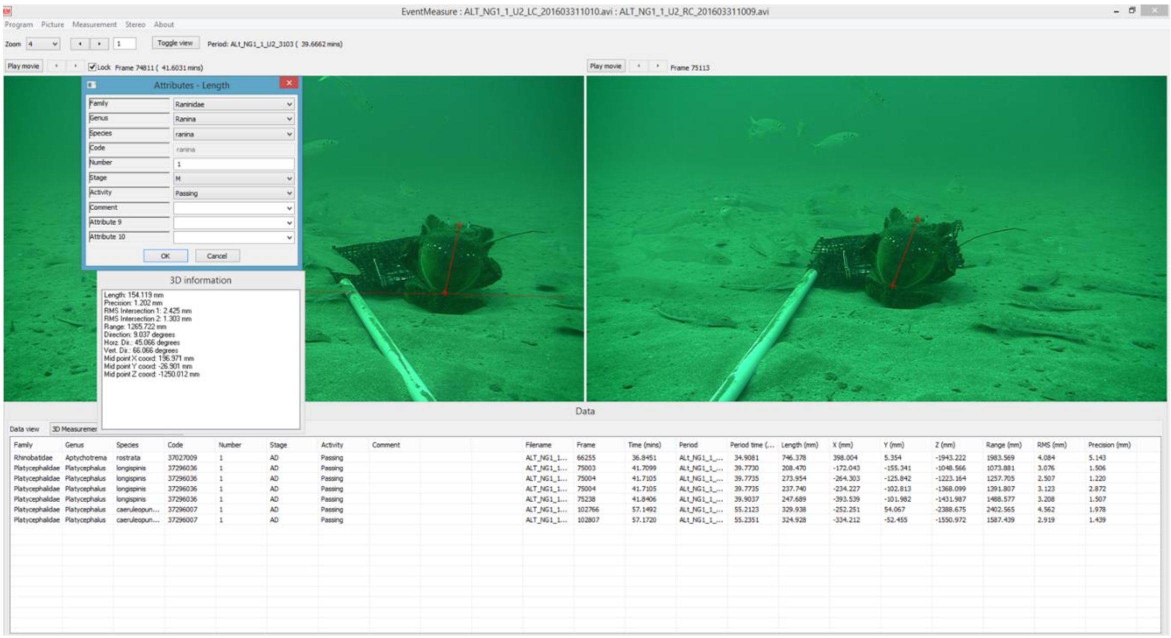

Figure 2: Using EventMeasure software (SeaGIS Pty Ltd) to calculate a length measurement for a male spanner crab *(Ranina ranina*) on unconsolidated habitat in the Solitary Islands Marine Park. Footage was taken using stereo-Baited Remote Underwater Video.

In 2015, all low-mobility or sessile benthic macro-invertebrates, which were detected from live footage, were recorded. In 2016, for each of the 181 videos taken by the drop camera, three single image grabs were analysed. Images were chosen so that the seafloor being analysed did not overlap (i.e. biota were not double-counted) and the image was as clear as possible.

Results and Discussion

In total, 55 taxa were detected from the 57 BRUV deployments. This included 31 teleost, 8 elasmobranch, and 16 invertebrate taxa (Table 1). Overall, 2904 individuals were recorded. The most abundant species was the longspine flathead, (MaxN= 853), which were observed on every BRUV deployment. Whiting were the second most abundant taxon (MaxN= 621): however, they were patchy and variable in their occurrence. Brittle stars were the most abundant invertebrate taxon (MaxN= 497) and third most abundant taxon overall. Bluespotted flathead were also numerically abundant (MaxN= 275). The most abundant elasmobranch was the eastern shovelnose ray (MaxN= 35). Of the sessile invertebrates recorded, sea pens (Pennatulacea) were the most abundant (N= 63). However, 186 individual invertebrates were classified as “unidentified” due to low clarity from the drop-camera footage.

Table 1: Taxa list with abundances across the entire study for both Baited Remote Underwater Video and drop camera deployments. *= fish species not previously recorded using BRUV on off-shore unconsolidated habitat in the SIMP RE= regionally endemic, WS= wide spread (globally), WSA= wide spread in Australia, -= intentionally left blank as this varies between species. Source: Edgar, 2008; Davie, 2011a, b; D. Makin, unpublished data; http://www.fishbase.org/; https://www.iucn.org/ and www.dpi.nsw.gov.au/.

Scientific name	Common name	Abundance	RE or WS	Commercial importance (Y/N)
Teleost fish				
*Aluterus monoceros**	Unicorn leatherjacket	1	WS	Y
Anoplocapros inermis	Eastern smooth boxfish	7	IP	N
*Aulopus purpurissatus**	Sergeant baker	1	WSA	Y
*Echeneis naucrates**	Slender suckerfish	3	WS	N
*Fistularia commersonii**	Smooth flutemouth	1	WS	Y
Lagocephalus sceleratus	Silver-cheeked toadfish	46	WS	N
*Meuschenia freycineti**	Six-spine leatherjacket	1	WSA	Y
*Monacanthus chinensis**	Fanbelly leatherjacket	1	WS	Y
*Nelusetta ayraudi**	Chinaman leatherjacket	2	WSA	Y
*Nemipterus theodore**	Theodore’s threadfin bream	4	RE	N
Paralichthyidae	Sand flounder	2	-	Y
Parapercis nebulosa	Pinkbanded grubfish	2	WSA	N
*Parapercis ramsayi**	Spotted grubfish	16	WSA	N
Pelates sexlineatus	Eastern striped grunter	30	RE	Y
*Platycephalus arenarius**	Flag-tailed flathead	1	WS	N
Platycephalus caeruleopunctatus	Bluespotted flathad	275	RE	Y

Platycephalus longispinis	Longspine flathad	853	WSA	N
*Priacanthus macracanthus**	Spotted bigeye	3	WS	N
Pseudocaranx dentex	White trevally	9	WS	Y
*Rhabdosargus sarba**	Tarwhine	16	WS	Y
Sarda australis	Australian bonito	10	WS	Y
*Saurida undosquamis**	Brushtooth lizardfish	1	WS	N
Sillago spp.	Whiting	621	-	-
Teleost fish sp.	Unidentified teleost fish	1	-	-
*Torquigener pleurogramma**	Weeping toadfish	1	WSA	N
Torquigener spp.	Toadfish	31	-	N
*Torquigener squamicauda**	Scailytail toadfish	7	RE	N
*Trachinocephalus myops**	Snakefish	1	WS	N
Trachurus novaezelandiae	Yellowtail scad	13	WS	Y
*Upeneichthys lineatus**	Blue-lined goatfish	1	WSA	Y
*Upeneus tragula**	Bartail goatfish	1	WS	Y
Elasmobranchs				
Aptychotrema rostrata	Eastern shovelnose ray	35	RE	Y
*Carcharhinus limbatus**	Blacktip reef shark	1	WS	Y
Orectolobus maculatus	Spotted wobbegong	1	WSA	N
Rhynchobatus australiae	White-spotted guitarfish	4	WS	Y
*Sphyrna lewini**	Scalloped hammerhead	1	WS	N
Stingaree sp.	Stingaree	1	-	-
Torpedo spp.	Electric ray	2	-	-
Trygonorrhina fasciata	Eastern fiddler ray	2	RE	Y
Invertebrates				
Armina spp.	Armina seaslug	2	-	N
Asteroidea	Seastar	11	-	N
Astropecten spp.	Astropecten starfish	18	-	N
Astropecten vappa	Comb sand star	5	WSA	N
Ceriantharia	Tube-dwelling anemone	1	-	N
Charybdis feriata	Coral crab	4	WS	Y
Crinoid	Feather-star	5	-	N
Gastropod spp.	Snail	17	-	-
Octopus sp.1	Octopus specie one	13	-	-
Octopus sp.2	Octopus specie two	2	-	-
Ophiuroidea	Brittle star	497	-	N

Pennatulacea	Sea pen	63	-	N
Phyllacanthus parvispinus	Eastern slate pencil urchin	16	RE	N
Portunus armatus	Blue swimmer crab	1	WS	Y
Ranina ranina	Spanner crab	52	WS	Y
Sepia spp.	Cuttlefish	2	-	-
"Unidentified" invertebrate	"Unidentified" invertebrate	186	-	-

Endangered and vulnerable taxa

The scalloped hammerhead shark is listed as an endangered species in NSW (NSW Department of Primary Industries, 2011) and by the IUCN (Baum *et al.,* 2007). This species occurs in temperate and tropical coastal and semi-oceanic waters globally (Baum *et al.,* 2007). Scalloped hammerheads may occur as far south as Sydney in warmer months (NSW Department of Primary Industries, 2012). While scalloped hammerheads cannot legally be retained in NSW (NSW Department of Primary Industries, 2012), they are targeted in other areas within their geographic distribution (White *et al.,* 2008; Bejarano-Alvarez, *et al.,* 2011), with the high value of their fins increasing fishing pressure (Baum *et al.,* 2007). We detected one immature female, of 142.9-cm length, during our study (females do not mature until they have reached 220.0 cm - White *et al.*, 2008) (Figure 3).

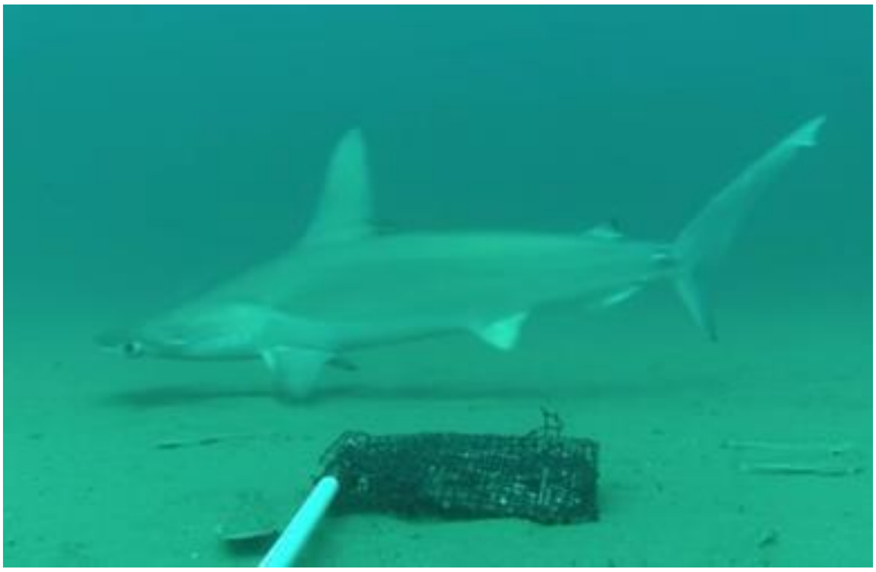

Figure 3: An immature female scalloped hammerhead shark (*Sphyrna lewini*) recorded using Baited Remote Underwater Video on unconsolidated habitat in the Solitary Islands Marine Park.

The white-spotted guitarfish (*Rhynchobatus australiae*) is listed as Vulnerable by the IUCN (White & McAuley, 2003). This species is widespread throughout the Indo-West Pacific region (White & McAuley, 2003). In NSW, white-spotted guitarfish are an uncommon component of by-catch (NSW Department of Primary Industries, 2010), with only 142 kg of this species reported as landed in the SIMP by the NSW Ocean Prawn

Trawl Fishery from 2009–2015 (D. Makin, unpublished data). Four white-spotted guitarfish were detected during the study (Figure 4), all of which were sexually mature females, measuring from 136.7 cm to 156.9 cm in length. This species is habitat-dependent and displays high site fidelity (White & McAuley, 2013). It is therefore plausible that marine unconsolidated habitat around South Solitary Island may be important habitat for this Vulnerable species.

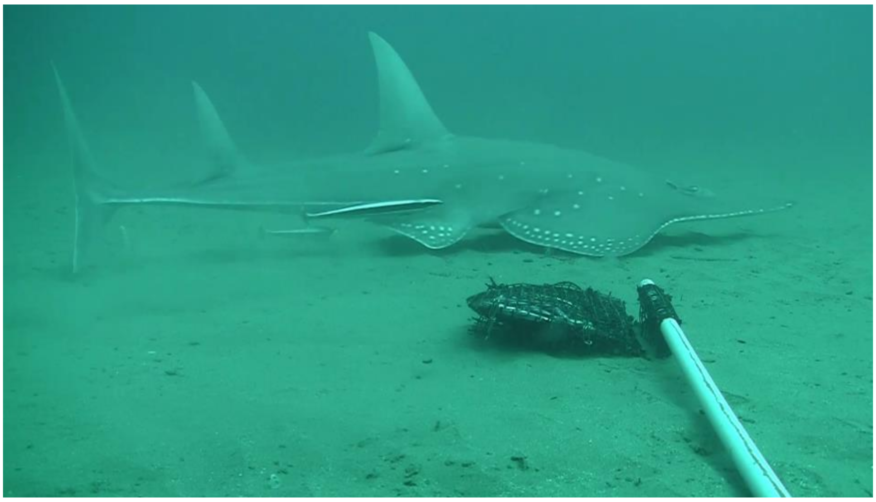

Figure 4: A vulnerable white-spotted guitarfish (*Rhynchobatus australiae*) accompanied by two slender suckerfish (*Echeneis naucrates*) recorded using Baited Remote Underwater Video on unconsolidated habitat in the Solitary Islands Marine Park.

Endemic taxa

Seven species which are endemic to eastern Australia were recorded during this study (Table 1). This included two elasmobranchs: the eastern fiddler ray, which occurs from Southern Queensland to Eden in Southern NSW, and eastern shovelnose ray, which ranges from Moreton Bay in Queensland to Jervis bay in NSW (Edgar, 2008) (Figure 5). Two teleost fish species which are endemic to tropical and subtropical eastern Australia were recorded; Theodore's threadfin bream (*Nemipterus theodore*) and scalytail toadfish (*Torquigener squamicauda*). Two teleost fish species which are endemic to subtropical and temperate eastern Australia were the bluespotted flathead and eastern striped grunter. Eastern slate pencil urchin (*Phyllacanthus parvispinus*), which is endemic to Southern Queensland and NSW, was also encountered. With limited spatial distribution, conservation opportunities for these species are limited to Marine Protected Areas in NSW and Queensland. The number of Marine Protected Areas where this particular assemblage of endemic species can occur is even more limited.

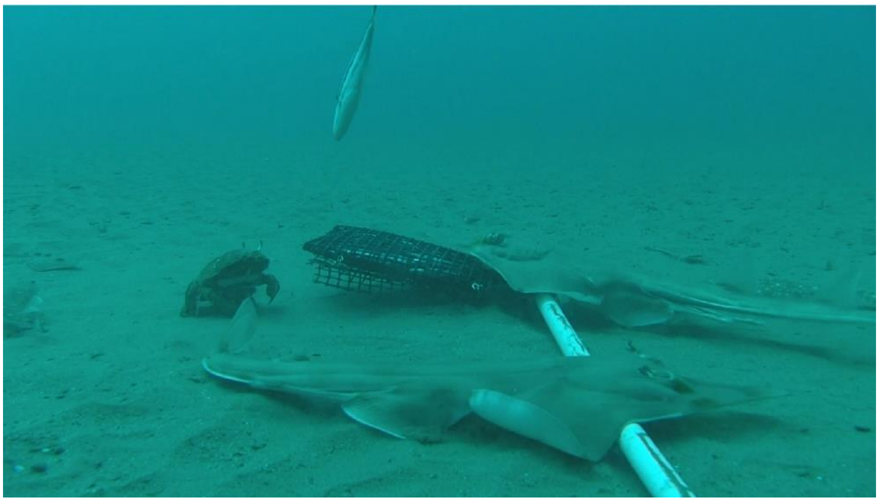

Figure 5: Two male eastern shovelnose rays (*Aptychotrema rostrata*) recorded using Baited Remote Underwater Video on unconsolidated habitat in the Solitary Islands Marine Park. Eastern shovelnose rays are endemic to subtropical and temperate eastern Australia.

Commercially important taxa

Twenty-two commercially important taxa were recorded during our study (Table 1). Bluespotted flathead (Figure 6), yellowtail scad, eastern fiddler ray and eastern shovelnose ray collectively comprise a high portion of catch for the NSW Ocean Prawn Trawl Fishery in the SIMP. Whiting, octopus and cuttlefish are also major components of landings for this fishery, however, we were only able to identify these taxa to the genus level, and therefore not all individuals recorded may be of commercial importance. Spanner crabs (Figure 2 & 6) were also recorded, and this species is important in the NSW Ocean Trap & Line fishery.

Figure 6: Longspine flathead (*Platycephalus longispinis*) and commercially important coral crabs (*Charybdis feriata*), spanner crabs (*Ranina ranina*) and bluespotted flathead (*Platycephalus caeruloepunctatus*) recorded using Baited Remote Underwater Video on unconsolidated habitat in the Solitary Islands Marine Park.

Habitat forming sessile macro-invertebrates

Sea pens were the only large sessile macro-invertebrate detected in our study with the potential to provide structural habitat to other taxa as a biotic habitat former. Sea pens are the most complex of the Anthozoa (Eckelbarger *et al.,* 1998) and are the only members of this Class which live both above and within the substrate (Soong, 2005) (Figure 7). We recorded 63 sea pens during the study indicating they occurred in low density in these unconsolidated habitats in this region and depth range. Their abundance appeared to be higher in 2015 than 2016, which may have been due to spatial variation between different sites that were sampled. Sea pens are known to be patchy in their distribution and can form high densities on a local scale elsewhere (Soong, 2005). Sea pens are active filter feeders (Edgar, 2008), and therefore this difference in abundance could be attributed to food availability. However, sea pens are usually retracted into the substrate during the day (Soong, 2005), so our sampling may have under-represented abundance.

Figure 7: A sea pen (Pennatulacea) on unconsolidated habitat in the Solitary Islands Marine Park.

Spatial planning considerations

Human activities influence biodiversity (Vitousek *et al.,* 1997). Demersal trawling can have ecosystem-wide effects (Hobday *et al.,* 2011; González-Irusta *et al.,* 2012) including reduced productivity (Duplisea *et al.,* 2002), reduced mean size of individuals (Collie *et al.,* 2000; Kaiser *et al.,* 2002) and impacts on non-target taxa through by-catch (Kennelly *et al.,* 1998). Trap and line fishing can have a range of impacts, with a number of species considered either "overfished" or "growth overfished" in the NSW Ocean Trap and Line fishery. Management objectives of Marine Protected Areas in NSW include promoting the health and biodiversity of the marine environment (NSW *Marine Estate Management Act 2014*). Therefore, given the importance of unconsolidated habitats to a range of protected, endemic, and/or targeted species, the influence of fisheries on unconsolidated habitats requires consideration when planning the spatial arrangement of marine park zones.

Conclusion

In this study we detected one endangered, one threatened and 22 commercially important taxa as well as seven taxa that are endemic to eastern Australia. A number of these taxa are also recreationally and socially important. We detected an additional 20 fish species (only including those which could be identified to the species level) not previously recorded from off-shore unconsolidated habitat in the SIMP. This clearly illustrates that the SIMP's sandy seafloor is by no means barren of life, but is utilised by wide variety of taxa. Considering the economic and ecological values of unconsolidated habitats in the SIMP, management decisions should reflect that this is an ecosystem worth conserving.

Acknowledgements and approvals

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