Marine Ecological Surveys for the Proposed Ballina Ocean Pool

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Report for the Ballina Ocean Pool Committee

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Executive Summary

The construction of a new ocean pool has been proposed on the rocky shore at Shelly Beach, Ballina, NSW, Australia. Intertidal reefs are highly variable habitats that can support a diversity of invertebrate species. The construction of artificial pools on rocky headlands has the potential to either negatively affect the intertidal communities by removing important habitat, or to enhance the habitat complexity and associated ecological value, depending on the natural features of the site and the pool design. Consequently, this report was commissioned to investigate the ecological importance of the proposed pool site and provide recommendations for minimising the impacts.

Surveys of the intertidal biodiversity and habitat complexity were undertaken at the proposed pool site and on the adjacent rock platform to the immediate north. The mollusc communities at Shelly Beach were then compared to four other locations in northern NSW, using previous surveys undertaken in similar habitat, using the same methodology. Survey data, using predatory whelks and cunjevoi as indicator organisms, was also analysed to compare Shelly Beach to five other sites in the region. Data on fishing related debris was also collated and analysed from the same sites. The key findings are summarised below:

- Shelly Beach supports a relatively low diversity of common intertidal species, with no significant differences between the proposed pool and north platform. None of the intertidal species identified are rare, or of conservation significance. Only a few common rock platform molluscs use this site as breeding habitat.
- The rocky shore at Shelly Beach has low habitat diversity, with no boulder fields or deep rock pools. The site has a high rugosity index indicating it is mostly flat rock or sand, although the low shore area does have many good deep crevices providing some refuges at low tide.
- The proposed site for the pool is a low relief reef and was dominated by sand at the time of the survey. The level of sedimentation is likely to change overtime, but nonetheless indicates a high level of disturbance from wave action and sand scour, thus reducing the overall habitat quality for intertidal species.
- Shelly Beach was found to support a significantly lower richness and diversity of molluscan species that other rock platforms in the Northern Rivers. The molluscan assemblage was significantly different to three other locations, primarily as a result of lower abundances for many species and the absence of several other species.
- There are relatively large populations of the predatory whelk *Dicathais orbita* in the low shore area at Shelly Beach, although similar numbers were found at three other locations. Another whelk *Cabestana spengleri* was not recorded at Shelly Beach. Human recreational collection of *D. orbita* for food and/or bait was observed during surveys at Shelly Beach.
- Similar to all other sites surveyed, the low shore area at Shelly Beach supports a good density of cunjevoi *Pyura stolonifera*. Evidence of human harvesting of *Pyura* for bait was observed at several sites in the region, including Shelly Beach.

- Surveys of recreational fishing debris found a lower number of items at Shelly Beach, but this was not significantly different to other survey locations in the Northern Rivers region.

  Overall, Shelly Beach supports common and widely distributed intertidal species and is not of particularly high value for marine biodiversity conservation. The proposed location of the ocean pool appears to be suitable, with minimal predicated impacts on the local ecological communities. Thoughtful engineering of the pool, to enhance habitat complexity at the site and to ensure connectivity to the ocean with regular flushing, has potential to increase the net biodiversity value of Shelly Beach rocky shore. Shelly Beach currently supports some recreational activity such as rock fishing and intertidal harvesting. The ocean pool is likely to attract additional recreational activity to the site, with potential for indirect impacts on the local ecological communities. Consequently, we recommend signs for community education, bins for fishing tackle and ongoing monitoring of key indicator organisms, such as whelks and cunjevoi.

Author Contributions

Assoc. Prof Kirsten Benkendorff was responsible for coordinating and designing the surveys. She undertook the invertebrate biodiversity surveys at Shelly Beach and supervised the other student projects (below). Kirsten collated all the raw data, checked for quality control, and undertook the statistical analyses. Kirsten complied and wrote this report.

Caitlin Woods assisted with the invertebrate biodiversity surveys at Shelly Beach and designed the regional molluscan biodiversity surveys. She provided the data for the regional comparisons, which was collected as part of her Honours Thesis at SCU (Woods, 2013).

Lisa McComb undertook the habitat surveys at Shelly Beach including line intercept transects for percent cover and rugosity measurements. She provided a report as part of her undergraduate Independent Study at SCU (McComb, 2017).

Additional contributors

Kai Suridge undertook the predatory whelk and cunjevoi surveys as part of his Integrated Project at SCU (Suridge, 2014).

Lachlan Farquhar undertook the surveys of fishing debris as part of his Integrated Project at SCU (Farquhar, 2014).

Cover image: Kirsten Benkendorff 2017

Acknowledgements

We thank John Wise from the Ballina Ocean Pool Committee for initiating and the project and meeting on site at Shelly Beach to show us the site of the proposed ocean pool.

We are grateful to Prof. Peter Harrison, Director of the Marine Ecology Research Centre for facilitating the project and cosupervising Lisa McComb's Independent Study. We appreciate the support and facilities provided by the School of Environment, Science and Engineering.

Introduction

Ocean pools occur all around the coast of the Australian continent, but are far more common on the rocky shores of the mid to southern coast of NSW (McDermott, 2011), with over one hundred tidal ocean pools (McDermott, 2012). The majority of these pools are located from Sydney to Forster, with only one pool located north of Forster at Sawtell. The northern beaches of NSW currently have no ocean pools of 25m or above, despite being a popular tourist destination.

The ocean pools of NSW provide recreational opportunities for residents and a large tourist market. They provide safe options for swimming at surf beaches, protecting swimmers from rips and sharks (Short, 2007). Between 1974 and 2009 there were 78 shark-human interactions in NSW waters, with 23 of those in the Northern Rivers. In that time, there were three fatalities, all in the Northern Rivers area, including one in Ballina in April 2008 (Green *et al*., 2009). In response to increased shark-human interactions, the NSW Department of Primary Industries initiated a 'North Coast Shark Mesh-Net Trial' between November 2016 and May 2017 as part of the Shark Meshing (Bather Protection) Program (Green *et al.*, 2009; NSW DPI Fisheries, 2017). Shelly Beach was one of five beaches selected for netting in this program. However, post-trial community respondents from Ballina Shire were generally opposed to the use of shark mesh nets, with strong concerns for the impacts on marine animals caught as by-catch (NSW DPI Fisheries, 2017). To provide safe swimming options for locals and tourists in the Ballina region, the Ballina Ocean Pool Committee has proposed the construction of a new ocean pool located on the rock shelf between Lighthouse Beach and Shelly Beach, Ballina (herein referred to as "Shelly Beach").

The construction of ocean pools on intertidal rock platforms requires the removal and alteration of habitat. Rocky shores are ecologically important transition environments providing feeding, resting, spawning and nursery areas for many marine and terrestrial animals across the daily cycles of high and low tide (Thompson et al., 2002). Intertidal rock platforms support a large variety of species, many of which are endemic to the bioregion (Chapman 1999; Chapman 2002; Benkendorff and Przeslawski, 2008). Therefore, it is important to establish the ecological importance of the proposed construction site.

There are no previously published studies on the intertidal rocky shore communities at Shelly Beach. However, unpublished undergraduate student projects have been undertaken Southern Cross University to assess the intertidal fishing debris (Farquhar, 2014), predatory whelks and the cunjevoi *Pyura stolonifera* (Suridge, 2014), across a number of rock platforms in the Northern Rivers, including Shelly Beach. In low-shore areas, on wave-exposed intertidal rock platforms, beds of *Pyura* provide important habitat for a range of associated intertidal organisms (Shepherd et al., 2013, Castilla et al., 2000, Monteiro, 2002). *Pyura* are also harvested and used as bait by fisherman (Monteiro, 2002; Fairweather, 1991). This involves cutting open the tunic and removing the flesh and organs, leaving nothing but base of the tunic attached to the rock substrate (Fairweather, 1991). Surveys of cut and intact *Pyura* can provide an indication of human recreational activities, in addition to the assessment of ecologically important habitat. Predatory whelks, such as *Dicathais orbita* and *Cabestana spengleri* feed on *Pyrua*, as well as a range of other invertebrates including mussels, oyster, barnacles and tubeworms. As top predators on intertidal reefs, they can provide a good indicator for ecosystem integrity. These whelks are also recreationally harvested for food and bait (Kingsford *et al*, 1991) and could be susceptible to overharvesting in areas of intensive use.

No other biodiversity surveys have been undertaken on the intertidal rocky shore at Shelly Beach to date. However, an unpublished Honours thesis did survey the biodiversity of macromolluscs across a number of other intertidal reefs in the Northern Rivers (Woods, 2013). The utility of molluscs as an indicator taxon for the rapid assessment of rocky shore biodiversity has been well established (Gladstone, 2002; Smith, 2005; Atalah and Crowe, 2012; Guangjin et al., 2013). Intertidal molluscan species richness can be effectively assessed using one-off time search surveys (Benkendorff and Davis, 2002, Benkendorff, 2003). Furthermore, using semi-quantitative abundance categories, surveys of intertidal molluscs have been shown to effectively detect changes in assemblage structure within and across rocky shore habitats (Smith and James 1999; Smith, 2005). Therefore, the previous surveys by Woods (2013) provide a baseline for regional comparison of intertidal biodiversity at Shelly Beach.

Environmental variables are often much easier to measure than biological variables and can be used to infer broad biodiversity patterns. For example, the surface rugosity of intertidal substrates can correlate with patterns in community structure (see Raimondi 1990; Berntsson et al. 2000; Berntsson et al. 2004). Intertidal reefs are highly heterogeneous providing a complex mosaic of habitats, which may include flat rock platforms interspersed with crevices, boulders, pools and sandy regions. Distinct ecological communities have evolved to live in, or on, these vastly different substrata (Benkendorff *et al*., 2008; Smith and James, 2003; Zabin et al., 2013). In the mid-to-lower intertidal zones the hard substrate provides suitable attachment sites for macroalgae, grazing molluscs and sessile invertebrates, including barnacles, mussels and other filter feeding organisms. Boulders and crevices provide breeding habitat and refuges for a high diversity of species at low tide (Benkendorff and Davis, 2002; 2004). On the other hand, sandy marine habitats can often resemble a desert (Benkendorff *et al*., 2008) and previous studies on the effects of sedimentation on rocky intertidal systems have revealed a range of effects due to scour and smothering (Airoldi and Cinelli, 1997; Taylor and Littler, 1982; Littler *et al*., 1983; Prathep *et al*., 2003; Airoldi and Hawkins, 2007 Huff and Jarett, 2007). Consequently, in 2017, McComb (2017) undertook an undergraduate independent study at Southern Cross University to provide an overview of the habitat availability, including the proportion of sand versus rocky substrate and rugosity of the intertidal rocky shore at Shelly Beach.

The purpose of this report is to provide an ecological assessment of the intertidal communities at Shelly Beach. New baseline surveys of the intertidal communities and habitat at the proposed site for the new ocean pool were undertaken. Additional data wascollated from previous undergraduate student projects to provide a broader regional assessment of ecological importance. Using molluscs as an indicator group, the intertidal assemblages at Shelly Beach are compared to similar habitat on other rock platforms in the Northern Rivers, to provide a regional perspective. Whelks and cunjevoi were used as indicator organisms and along with surveys of fishing debris, provide information on the current recreational value of the site. This data is all collated to provide an evaluation of the ecological importance of the site for environmental impact assessment. Some recommendations for mitigating the impacts on intertidal habitat are provided.

Methods

Study sites

Habitat and biodiversity surveys were undertaken at Shelly Beach, Ballina, NSW (Figure 1). The site was divided into 1) the proposed location of the ocean pool, as identified by John Wise, representative of the Ballina Ocean Pool Committee; and 2) the rocky platform north of the pool as a site control (Figure 1 inset image). Additional regional data was collated from previous surveys on rock platforms at external control locations north of Shelly Beach, including Hastings point, Cape Byron, Broken Head, Brays Beach, Lennox Head and Flat Rock (Skennars Head) (Figure 1, Table). All surveys were undertaken at low tide (Table 1).

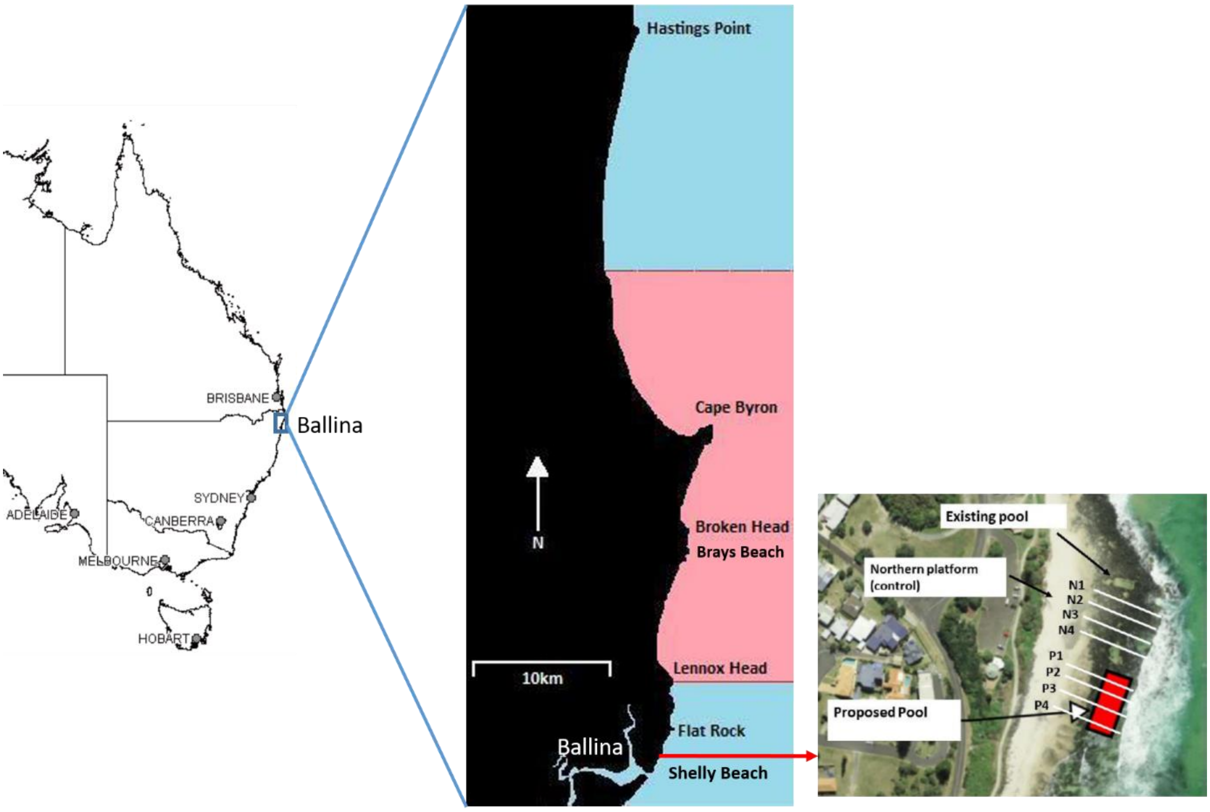

Figure 1: Map of study locations, including the proposed site for the Ballina Ocean Pool at Shelly Beach (inset image) and control locations in the Northern Rivers NSW, Australia. In the inset image N1-4 indicate habitat transects on the north platform, whereas P1-4 are transects at the pool site. The extent of the Cape Byron Marine Park is shown in pink.

Table 1: Summary of the surveys conducted at each study location. Surveys of invertebrate biodiversity and habitat at Shelly Beach were undertaken specifically for the environmental impact assessment of the proposed Ballina Ocean pool. Molluscan biodiversity surveys at other locations were undertaken by Woods (2013). Surveys of the whelks and cunjevoi were undertaken by Suridge (2014) and surveys of fishing debris were undertaken by Farquhar (2014)

Location	Date	Tide	Survey	Replicates
Shelly Beach	7th Aug 2017	0.15m @1.40pm	Invertebrate biodiversity	Two sites each with N = 4 (total N = 8)
	8th Sept 2017 23rd Sept 2017	0.6m @3.21pm 0.16m @ 4:00pm	Habitat transects and rugosity	Two sites each with N = 4 for habitat transects and N = 8 for rugosity
	6th Aug 2014	0.5m @9:43am	Whelks, cunjevoi, and fishing debris	N = 3 sites for whelks; N = 3 sites x 10 quadrats for cunjevoi; N = 3 sites for debris
Flat Rock	Aug – Oct 2013	< 0.4m	Mollusc biodiversity	N = 9 sites
	7th Aug 2014	0.5m @10:46am	Whelks, cunjevoi, and fishing debris	N = 3 sites for whelks; N = 3 sites x 10 quadrats for cunjevoi; N = 3 sites for debris
Lennox Head	18th Aug 2014 18th Aug 2014	0.3m @4:20pm 0.6m @ 8:19am	Whelks, cunjevoi, and fishing debris	Two locations with: N = 3 sites for whelks; N = 3 sites x 10 quadrats for cunjevoi; N = 3 sites for debris
Brays Beach	10th Aug 2014	0.3m @1:36pm	Whelks, cunjevoi, and fishing debris	N = 3 sites for whelks; N = 3 sites x 10 quadrats for cunjevoi; N = 3 sites for debris
Broken Head	Aug-Oct 2013	< 0.4m	Mollusc biodiversity	N = 2 sites
	11th Aug 2014	0.2m @2:30pm	Whelks, cunjevoi, and fishing debris	N = 3 sites for whelks; N = 3 sites x 10 quadrats for cunjevoi; N = 3 sites for debris
Cape Byron	Aug-Oct 2013	< 0.4m	Mollusc biodiversity	N=3 sites
Hastings Point	Aug-Oct 2013	< 0.4m	Mollusc biodiversity	N = 14

Invertebrate Biodiversity Surveys at Shelly Beach

On 7th August 2017, eight x 30min timed search surveys were conducted (Table 1), along 25m length sections of the shoreline. Four separate surveys were conducted at the proposed pool site and four were conducted on the north platform (Figure 2). At each site two surveys were in the mid-low tide zone (east of tapeline) and two were in the mid –high (west of tapeline) zones (Figure 2). All habitats were searched, including flat and horizontal rock, crevices, caves, pools, algae and sand, from the low tide swash zone to the top of the reef. There was no loose boulder habitat at either site. Invertebrate species were classified into phyla and identified to species where possible. Species were categorised into semi-quantitative abundance ranks (Table 2) based on Woods (2013) after Smith and James (2003).

Position	Degrees South	Degrees East
Nth Platform 50m	28.86588	153.59424
Nth Platform 25m	28.86654	153.59398
Nth Platform 0m	28.86634	153.59407
Pool 50m	28.86632	153.59406
Pool 25m	28.86654	153.59398
Pool 0m	28.86646	153.59399

Figure 2: Map of the study site at Shelly beach Ballina showing replicate search areas in and below the proposed Pool (P) area and on the North Platform (NP); H= High Zone; L= Low Zone; with two replicate plots (a & b) designated within each area and tidal zone.

Table 2: Abundance rank scores based on the estimated number of individuals observed during a 30 minute timed search survey.

Number of individuals	Abundance rank	Score
0	Absent	0
1-2	Rare	1
3-10	Uncommon	2
20-30	Moderately common	3
30-50	Common	4
>50	Abundant	5

Habitat Surveys at the Shelly Beach

Habitat surveys were undertaken at the proposed pool site on 23rd September, 2017 and on the northern rock platform at Shelly Beach on 8th September, 2017 (Table 1). At each site, four shore perpendicular transects were allocated a random distance from the pool (Figure 1, Table 2). Transects were laid out using a 50m tape measure from the lowest accessible point to the end of the rock platform. Each transect was surveyed by walking slowly along the transect tape and recording with an Olympus (Model Tough TG-4) camera. The footage was subsequently analysed for percent cover using VLC media player. Substrate types were recorded in cm using the line intercept method. Substrate types were categorised as sand, bare rock, turfing algae, foliose algae, Galeolaria crust and barnacles (Figure 3, Dutton & Benkendorff, 2008).

Habitat complexity was assessed along each transect by using the chain method (Risk, 1972; Komyakova , 2013). Two x 6 m fine link chains (5mm) were randomly placed along each line transect (one in the low to mid tide zone and one in the mid to high tide zone). Each chain was run along the transect line and tucked into cracks and crevices to ensure it conformed to the contours of the substratum as closely as possible. The direct linear distance that the chain covered along thetransect was then recorded and used to determine substrate complexity by the ratio of the substrate surface distance relative to linear length i.e. Rugosity = True substrate length (contoured) / linear length (6 m chain length). A flat surface will have a rugosity value = 1 (the minimum value possible), while a rougher or more complex surface, will have rugosity value closer to 0 (Du Preez, 2015; Dutton & Benkendorff, 2008).

Table 2: GPS coordinates for the line intercept transects for habitat surveys at Shelly Beach

Site	Degrees South	Degrees East
North Platform 1	28.86564	153.5998
North Platform 2	28.86583	153.5939
North Platform 3	28.86589	153.5939
North Platform 4	28.86608	153.5939
Pool 1	28.86631	153.5938
Pool 2	28.85147	153.5938
Pool 3	28.86653	153.6271
Pool 4	28.86661	153.5938

Figure 3. Substrate type categories as seen along the line transects a) sand b) bare rock, c) barnacles, d) turfing algae, e) foliose algae and f) tube worm (*Galeoria*) crust (images: Lisa McComb, 2017).

Regional Mollusc Biodiversity surveys

Mollusc diversity surveys were undertaken at a number of locations north of Shelly Beach in 2013 (Table 1) by Woods (2013). The same method was used with repeated 30-minute timed searches of rocky shore habitats, except that stratified sampling of different habitats was undertaken with repeat surveys at each headland until all areas of each habitat had been searched. In the present study, only the data from shallow-pools is used for comparison, as no boulder habitat or deep pools occurred in the survey area at Shelly Beach.

Similar to the current study, macro-molluscs (average adult body size >10mm) were identified to species level *in situ*, and any unknown species photographed for later identification, according to Wilson et al., (1993) and Cobb and Willan (2006). Species with average adult sizes less than 10mm were excluded, even when some individuals exceeded this size (for example *Eurytrochus strangei, Cantharidella picturata and Mitrella moleculina*). Six supralittoral and 'splash zone' species were also excluded, as their presence in surveyed habitats did not reflect their true abundances at the headlands (*Nodolittorina pyramidalis, Littorina unifasciata, Nodolittorina millegrana, Notoacmea petterdi, Patelloida latistrigata* and *Siphonaria funiculata*). Consequently, these species were also excluded from the Shelly Beach surveys for the purpose of regional comparisons, along with a few additional species identified by Benkendorff but not Woods at Shelly Beach. These include: *Afrolittorina acutispira* <5mm high shore, present at all sites; *Scutellastra peroni* low shore in amongst boulders at all shores; and *Siphonaria zelandica* high shore on most rocky reefs but not easily distinguished from *S. denticulata*. Semi-quantitative abundance ranks (Table 2) were allocated in each 30-minute survey.

Surveys of whelks, cunjevoi and fishing debris

Surveys of the predatory whelks *Dicathais orbita* and *Cabestana spengleri* (Figure 4a&b), as well as surveys of cunjevoi (*Pyura stolonifera*) density and harvest (Figure 4 c &d), were undertaken at a number of locations, including Shelly Beach (Table 1), by Suridge (2014). At each location, three replicate 20 metre belt transects were measured out using a 60m measuring tape. Along each transect, ten 1x1 m^2 quadrat surveys were conducted at 2 m intervals for estimates of cunjevoi density. Estimates of harvested cunjevoi (Figure 4d) were undertaken by searching up to 3m on both sides along the entire transect. After the cunjevoi surveys were completed, 5 min timed search surveys were undertaken along the same belt transects for the whelks and all individuals with maximum shell length greater than 3cm were recorded.

Surveys for recreational fishing debris were undertaken at the same sites, during the same low tides (Table 1), by Farquar (2014). Twenty metre belt transects with 2m on either side of the transect were surveyed. Thirty seconds were spent examining each square meter and all fishing debris was identified, recorded and removed using gloves and pliers, to safely remove hazardous debris, such as hooks and lures.

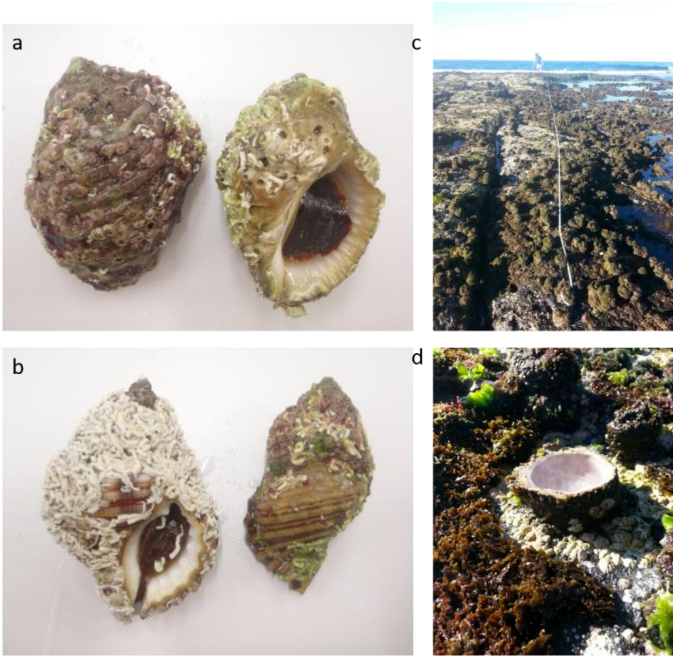

Figure 4: Intertidal indicator organisms: the predatory whelks a) *Dicathais orbita* and b) *Cabestana spengleri*, and c) beds of the filter-feeding cunjevoi *Pyura stolonifera* and d) the base of a harvested *Pyura* individual (images a & b: Kirsten Benkendorff, 2016; images c & d: Kai Suridge, 2014).

Statistical analyses

All statistical analyses were undertaken using Primer V7 + PERMANOVA (Anderson *et al*., 2008). The DIVERSE function was used to generate species richness and Shannons H ($\log_e$) index. Euclidean distance similarity matrices were generated for all univariate analyses. Bray Curtis similarity matrices, with a Dummy value of 1, were used for multivariate assemblage analyses, based on the semi-quantitative abundance scores. In all cases 9999 permutations were run using unrestricted permutation of the raw data. In all analyses, $p < 0.05$ was regarded as a statistically significant difference.

At Shelly Beach, two factor Permutational Analysis of Variance (PERMANOVA), using the site (pool vs north platform) and tidal zone (mid-low vs mid – high) as fixed factors, were used to investigate differences in invertebrate and mollusc species richness (S), species diversity (H) and assemblage composition, as well as surface rugosity. Comparisons of the mean percent cover were run separately for each substrate (sand, bare rock, tube worms, barnacles, folioise and turfing algae) using one factor PERMANOVAs to compare the pool site and the north rock platform at Shelly Beach.

Regional comparisons of the molluscan diversity in similar habitats across sites were undertaken using one factor PERMANOVA and post-hoc pairwise comparisons. A non-metric multidimensional scaling (nMDS) plot was generated to represent differences in the molluscan assemblages in two-dimensional space. Similarity of Percentages (SIMPER) analysis investigated which species contributed to the differences between Shelly beach and other locations.

One-factor PERMANOVAs were also used to compare the abundance of *D. orbita* and *C. spengleri*, as well as the density of *Pyura*, number of harvested *Pyura*, the amount of fishing debris and the total length of fishing line between sites, with post hoc pairwise comparisons using Monte Carlo tests.

Results

Invertebrate Surveys at Shelly Beach

In total, 22 species of mollusc (Table 3) and 19 other invertebrate species (Table 4) were identified from time-search surveys at Shelly Beach. Mean species richness (Figure 5a) and diversity (Figure 5b) was general higher at the north platform (control) site, than the proposed pool site (Figure 4). However, there were no statistically significant differences in species richness, diversity or assemblage structure for either molluscs or other invertebrates according to the site or tidal zone within Shelly beach (Table 5).

Most species were recorded in surveys from both the proposed pool site and the northern rock platform (Table 3 &4). There was only one mollusc species (*Oppomorus noduliferus*) that was only recorded at the pool site (as a singleton) and one unidentified white anemone was recorded as uncommon at the pool site and not at the north platform. On the other hand, two molluscs (*Trichomya hirsuta* and *Notoacmea petterdi*), as well as a crab *(Ozius deplanatus*), a colonial ascidian (*Cystodytes dellechiajei*) and unidentified yellow encrusting sponge were recorded at the north platform but not at the pool site.

Most of the recorded species are free spawning. However, benthic egg masses have been observed on the rock platform for five of the species listed (Table 3).

Table 3: Species list of Molluscs: Abundance: 1= Rare (≤ 2); 2 = uncommon (≤ 10); 3 = moderately common (≤ 30); 4 = Common (≤ 50); 5 = Abundant (> 50);
* Benthic egg masses of these species have been observed on the rock platform at Shelly Beach.

CLASS	Subclass/Family	Location	Pool High a	Pool High b	Platform High a	Platform High b	Pool Low a	Pool Low b	Platform Low a	Platform Low b
POLYPLACOPHORA		Species								
		Liolophura gaimardi			1	3			2	3
GASTROPODA	Eogastropoda									
		Cellana tramoserica	2	5	5	5	3	5	2	5
		Cellana concilliata				2				
		Patelloida latistrigata				3		5		5
		Patelloida mufria				2				
		Notoacmea petterdi				1			3	
		Scutellastra peroni		2		3		2		3
	Orthogastropoda									
	Fissurellide	*Montfortula rugosa*	1	1	5	3	3	2	4	5
	Neritidae	*Nerita atramentosa* *		4	1	4				
	Trochidae	*Austrocochlea porcata*	3	5	5	5	2	1	3	
	Turbinidae	*Lunella undulata*			1	1	2	1	1	
	Littorinidae	*Bembicium nanum* *	1	5	5	5				5
		Austrolittorina unifasciata		1	1	4				
		Afrolittorina acutispira		5		5				
	Muricidae	*Tenguella marginalba*	4	5	5	5	4	5	5	5
		Oppomorus noduliferus						1		
		Dicathais orbita *		1	1	2	2	2	3	5
	Pulmonata	*Siphonaria denticulata* *	5	5	5	2	4	5	5	5
		Siphonaria funiculata			1	1		2	3	4
		Siphonaria zelandica *		3		1				
BIVALVIA										
		Saccostrea cucullata		1		1		1	1	
		Trichomya hirsuta			1	2				
Total Mollusc Richness		**22**	**6**	**13**	**13**	**21**	**7**	**12**	**11**	**10**

Table 4: Species list of other invertebrates: Abundance: 1= Rare (≤ 2); 2 = uncommon (≤ 10); 3 = moderately common (≤ 30); 4 = Common (≤ 50); 5 = Abundant (> 50)

PHYLUM	Tidal Zone Class/Species	Pool High a	Pool High b	Platform High a	Platform High b	Pool Low a	Pool Low b	Platform Low a	Platform Low b
PORIFERA	Demospongia								
	Tethys sp. (ball sponge)								2
	Orange bulbous sponge						2		2
	White/grey encrusting sponge								2
	Yellow/orange encrusting sponge				1				2
CNIDARIA	Anthozoa								
	Oulactis muscosa	4	5	4	5	4	4	3	3
	Aulactinia veratra	1	2	3	2	2	4	4	4
	White anemone						2		1
ANNELIDA	Polychaetea								
	Galeolaria caespitosa		5	5	5	1	5		5
ARTHROPODA	Cirripedia								
	Chthamalus antennatus	5	5	5	5	5	5	5	5
	Chamaesipho tasmanica		4		4				
	Tetraclitella purpurascens	2				2		1	3
	Austromegabalanus nigrescens			2			1	2	3
	Tesseropora rosea	1	5		5	2	4	5	5
	Malacostraca								
	Ozius deplanatus				1				
	Cyclograpsus granulosus						1	1	
	Leptograpsus variegatus				2		1		
Chordata	Ascidiacea								
	Pyura stolonifera	1		3		2	2	3	5
	Cystodytes dellechiajei								2
	Pale green blob ascidian			2			3	3	3
Total richness	19	6	6	7	9	7	11	9	11

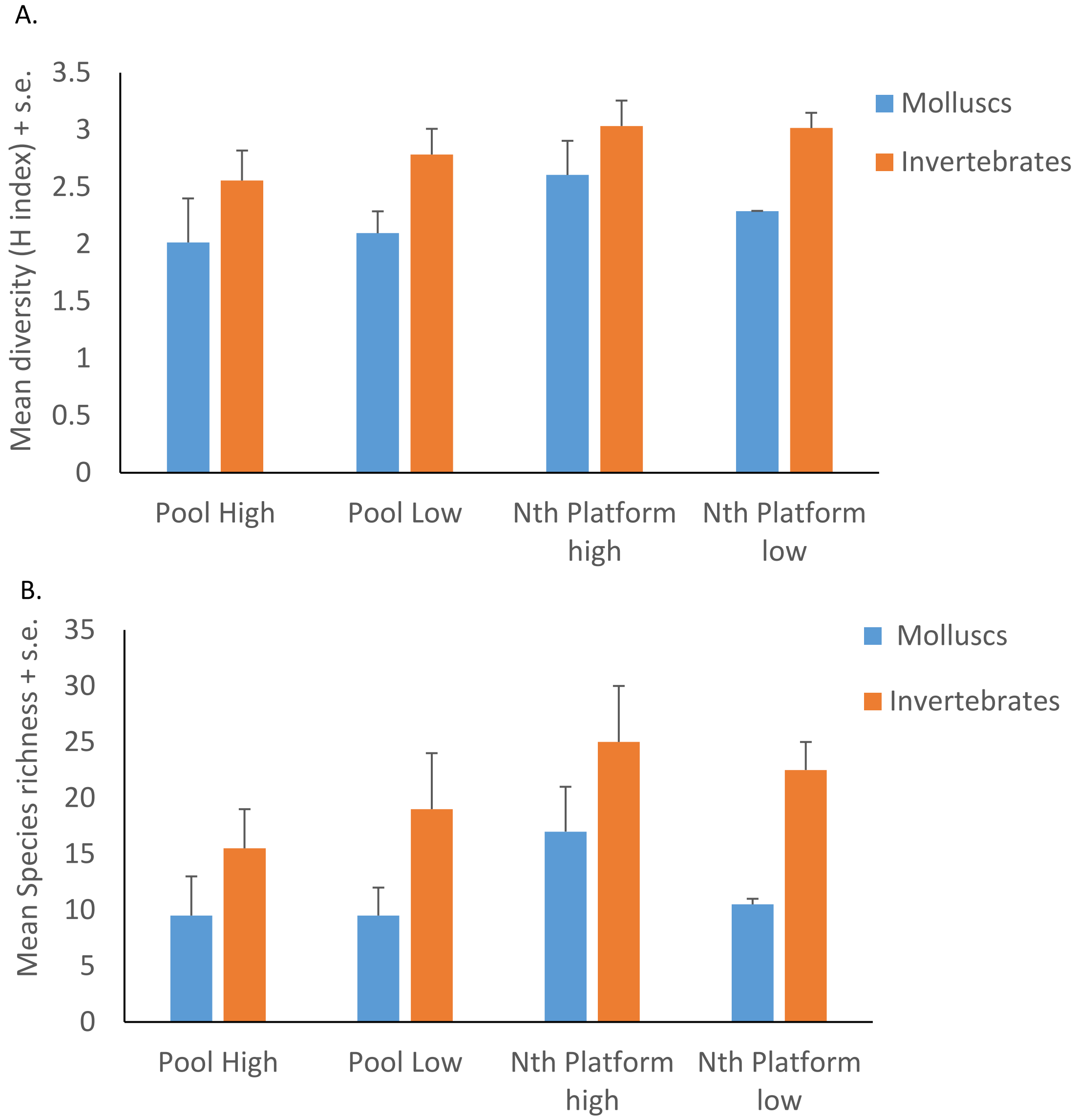

Figure 5: Invertebrate biodiversity surveys at Shelly Beach, Ballina, NSW, Australia: A) Species richness and B) Shannons H diversity index for molluscs and all other invertebrates at two sites within two tidal zones (mid-high and mid-low).

Table 5: Summary of the two factor PERMANOVAs undertaken to compare the invertebrate communities and surface rugosity at the proposed pool and northern platform sites, across two tidal zones at Shelly Beach, Ballina, NSW Australia. Bold – statistically significant (P < 0.05).

	Location		Zone		Location X Zone	
Variable	Pseudo F	P value	Pseudo F	P value	Pseudo F	P value
Invertebrate species richness	2.467	0.1926	0.0146	0.8729	0.5456	0.4878
Invertebrate diversity (Shannons H index)	2.6874	0.1795	0.2364	0.6534	0.3236	0.585
Invertebrate Assemblage	1.535	0.2559	1.885	0.1626	0.4215	0.7671
Mollusc species richness	2.0791	0.2325	1.2158	0.3491	1.2158	0.3368
Mollusc diversity (Shannons H index)	2.2316	0.2482	0.2051	0.6879	0.5732	0.5061
Mollusc assemblage	1.8823	0.1659	2.1874	0.1201	0.4837	0.7533
Rugosity Index (1= flat)	9.2819	**0.0024**	2.6612	0.1174	0.5887	0.5204

Habitat Surveys at Shelley Beach

The surface rugosity of the substrate at Shelly Beach was closer to 1, indicating relatively flat, low complexity surfaces on average (Figure 6). However, the transects at the pool site had a significantly lower rugosity index (indicating higher complexity) that the north platform (Table 5).

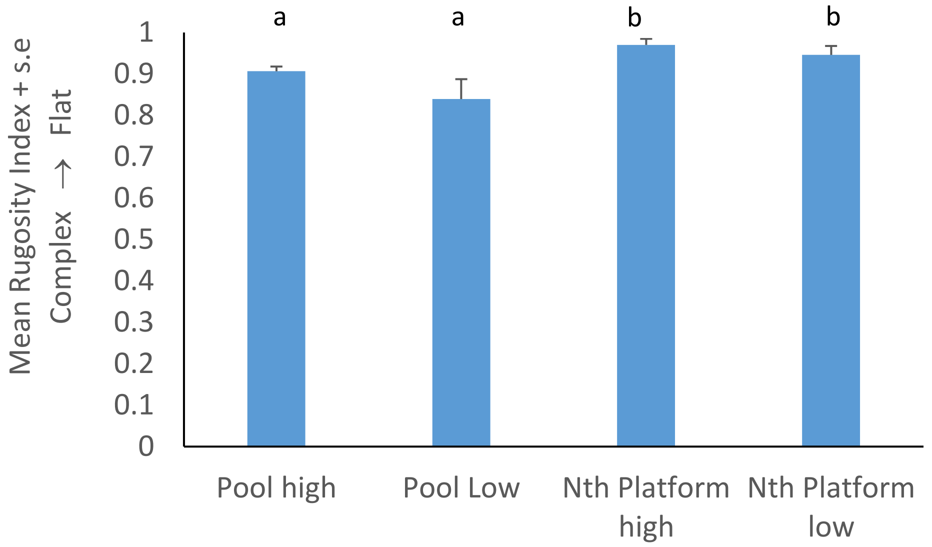

Figure 6. Mean rugosity index for the substrate at the proposed pool site and north platform at Shelly Beach, Ballina, NSW, Australia. The rugosity index is calculated from 1 = flat, down to close to 0 = high complexity. Different letters above the bars indicate statistically different means between the pool and north platform sites ($p < 0.05$).

Line intercept transect surveys of the substrate percent cover reveal that significantly more sand than rock occurs along the transects at the pool site, in comparison to the north rock platform, which has significantly more bare rock (Table 6, Figure 7). There was also a significantly higher cover of tubeworms at the north platform (Table 6, Figure 7) and a tendency towards higher barnacle and turfing algae (Figure 7), although these were not statistically different (Table 6).

Table 6: Summary of the one factor PERMANOVAs comparing the percent composition of the substrate using line intercept transects at the proposed pool site and the north platform at Shelly Beach, Ballina, NSW Australia. Bold – statistically significant ($P < 0.05$).

Variable	Pseudo-F	P(perm)	Unique Permutations
Sand	72.65	**0.0272**	35
Bare Rock	48.79	**0.0291**	35
Tube worms	15.40	**0.029**	15
Barnacles	5.674	0.0518	15
Foliose algae	3.1721	0.1131	32
Turfing algae	6.7544	0.0848	24

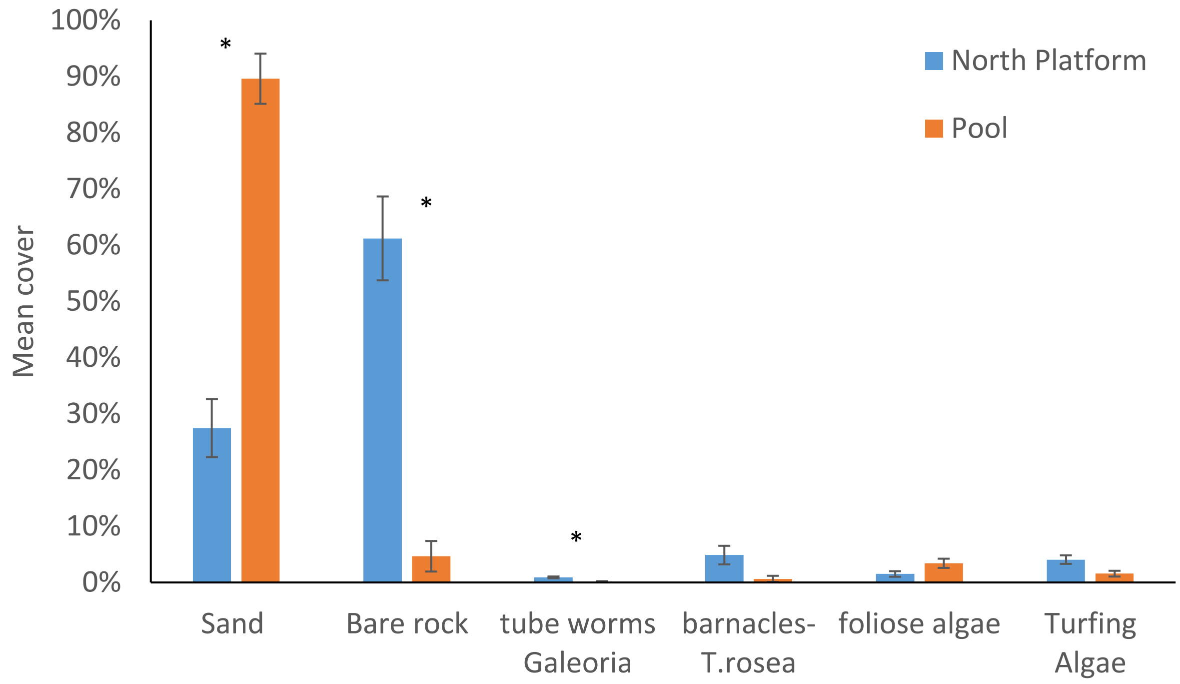

Figure 7: The mean (+ S.e.) percent cover of sand and bare rock, as well as habitat forming organisms on the rock substrate at the proposed site for the Ballina Ocean Pool and the north platform control site at Shelly Beach, NSW, Australia. * Statistically significant differences between sites ($p < 0.05$).

Regional Comparison of Mollusc Biodiversity

To provide a regional perspective, the mollusc communities at Shelly Beach were compared to similar habitats at five other rocky headlands in the Northern Rivers NSW (Refer to Appendix 1 for full species lists). The mean species richness at Shelly Beach was found to be significantly lower than the other four locations (Figure 8a, Table 7). The Shannons diversity index was also significantly different between sites (Table 7) with pair-wise tests confirming the H index was significantly lower at Shelly Beach than all other sites, except Cape Byron (Figure 8b).

Multivariate analysis of the mollusc assemblage revealed significant differences between sites (Table 7), with pair-wise tests confirming that Shelly Beach was significantly different to Hasting Point ($p = 0.0001\%$), Flat Rock ($p = 0.0068$) and Broken Head ($p = 0.0409$), but not Cape Byron ($p = 0.1258$). The multi-dimensional scaling plot reveals general clustering within sites and some overlap between Shelly Beach and all other sites except Hastings Point (Figure 8). SIMPER analysis shows that, in general, the difference between sites are due to lower abundances of a number of gastropods at Shelly Beach in comparison to the other sites (Table 8), with the exception of *Cellana tramosceria,* which was more common at Shelly Beach than Flat Rock. The large differences to Hastings Point and Flat Rock are due to a number of species detected at these locations that were not present at Shelly Beach (Table 8a & b). All of the species recorded at Shelly Beach were detected at most or all other sites (Appendix 1).

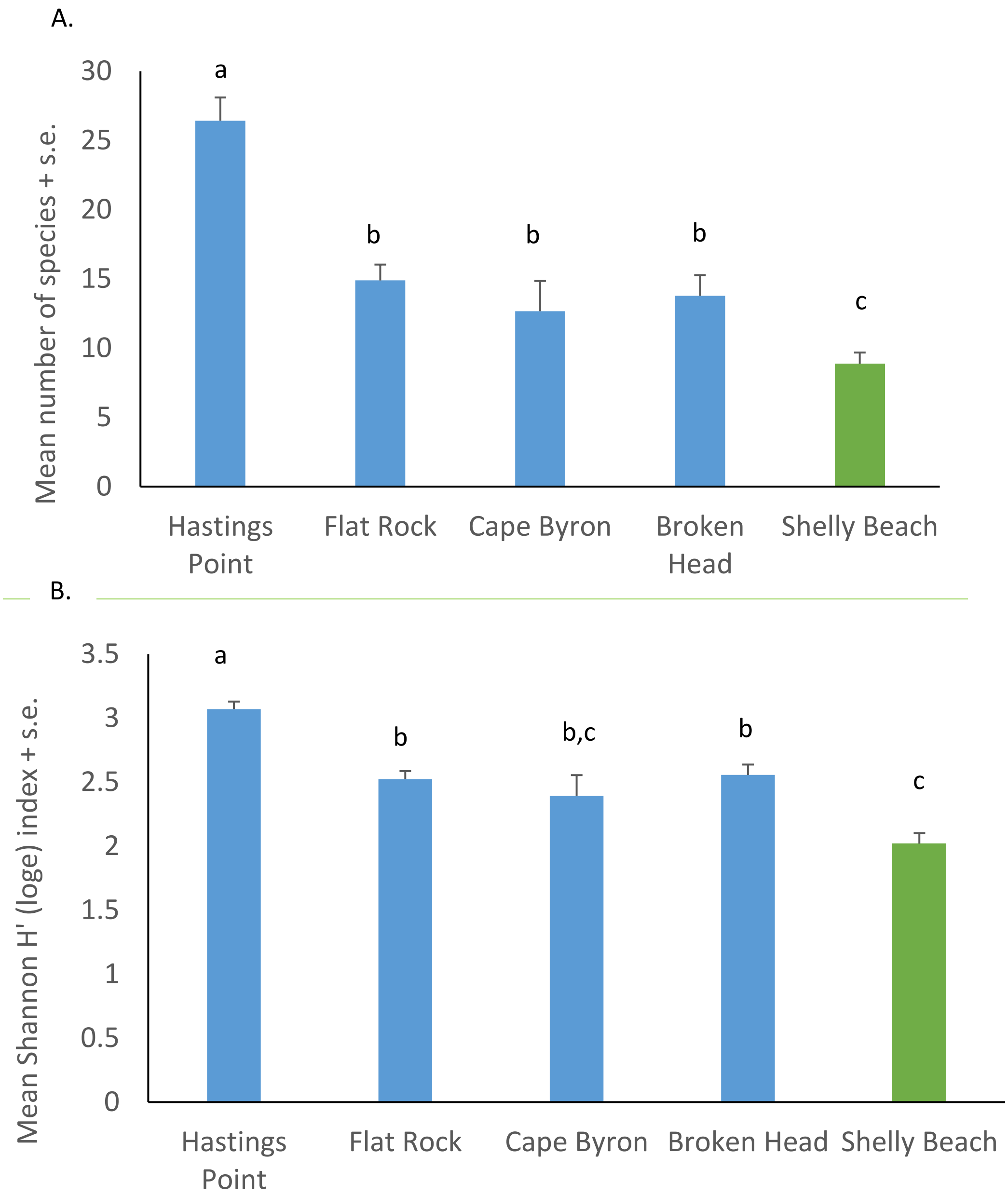

Figure 8: Regional mollusc diversity comparing five headlands in the Northern Rivers, NSW, Australia: A) mean species richness (+ s.e.) and B) mean Shannon's H ($\log_e$) index. Different letters above the bars indicate statistically different means between locations ($p < 0.05$).

Table 6: Summary of the one factor PERMANOVAs comparing the molluscan communities across five headlands in the Northern Rivers, NSW, Australia. Bold – statistically significant ($P < 0.05$).

Variable	Pseudo-F	P(perm)	Unique Permutations
Species richness	20.251	**0.001**	8765
Species diversity	30.849	**0.0001**	9957
Assemblage structure	4.354	**0.0001**	9916

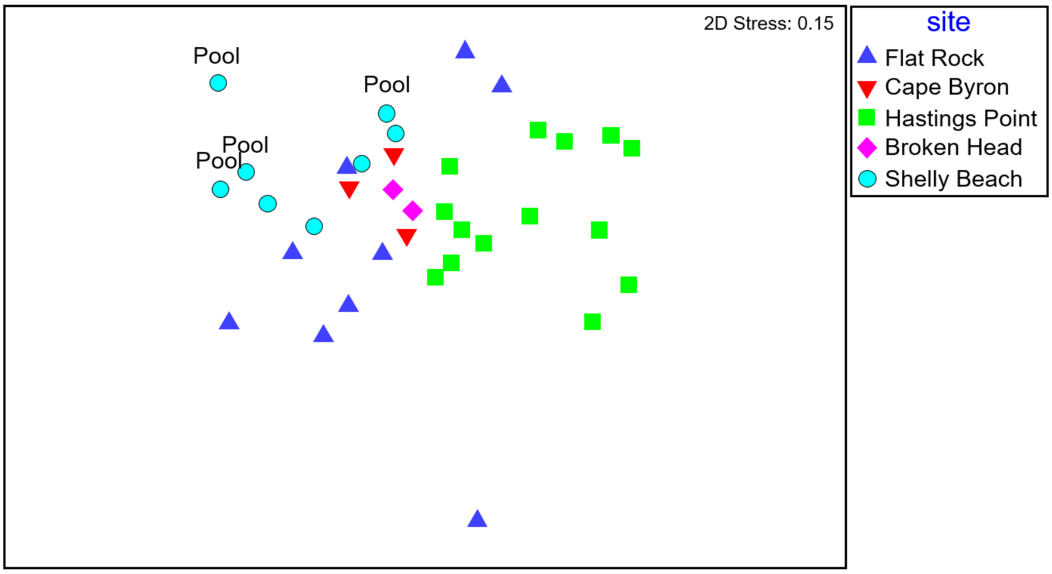

Figure 9: Non-metric multi-dimensional scale plot of the intertidal molluscs found in shallow pools with rocky substrate at five headlands in the Northern Rivers, NSW. Surveys undertaken at the proposed site for the Ballina ocean pool at Shelly Beach are indicated.

Table 8: Molluscan species contributing to the difference between Shelly Beach and other locations from similarity of percentages (SIMPER) analysis. Bold = not detected at Shelly Beach.

a) Hastings Point (Dissimilarity 52.38%)

Species	Hastings Point	Shelly Beach	Av.Diss	Diss/SD	Contrib%	Cum.%
Nerita atramentosa	4.36	1.13	3.71	1.75	7.08	7.08
***Pinctada* sp.**	**3.29**	**0**	3.42	3.51	6.53	13.61
Cronia aurantiaca	**2.71**	**0**	2.77	1.93	5.29	18.9
Liolophura gaimardi	3	1.13	2.62	1.39	5	23.89
Bembicium nanum	4.21	2.63	2.62	1.1	4.99	28.89
Onithochiton quercinus	**2.29**	**0**	2.39	1.32	4.56	33.45
Nodopelagia brazieri	**2.21**	**0**	2.24	1.1	4.28	37.74
Austrocochlea porcata	4.36	3	2.14	1.16	4.08	41.82
Nerita albicilla	**2**	**0**	2.08	1.23	3.97	45.79
Montfortula rugosa	2.86	3	1.97	1.35	3.77	49.56
Lunella undulata	2.14	0.75	1.96	1.26	3.73	53.3
Dicathais orbita	1.5	2	1.8	1.39	3.44	56.74
Oppomorus noduliferus	1.43	0.13	1.42	1	2.71	59.45
Drupella margariticola	**1.14**	**0**	1.15	0.9	2.19	61.64
Cellana tramoserica	5	4	1.13	0.75	2.15	63.79
Saccostrea glomerata	0.93	0.5	1.13	0.81	2.15	65.94
Turbo militaris	**0.93**	**0**	0.95	0.78	1.81	67.75
Siphonaria denticulata	4.36	4.5	0.88	0.99	1.68	69.43
Scutus antipodes	**0.86**	**0**	0.87	0.76	1.66	71.09

b) Flat Rock (Skennars Head) (Dissimilarity 45.08%)

Species	Flat Rock	Shelly Beach	Av.Diss	Diss/SD	Contrib%	Cum.%
Bembicium nanum	2.22	2.63	3.55	1.18	7.87	7.87
Dicathais orbita	3	2	3.48	1.63	7.71	15.59
Austrocochlea porcata	3.11	3	3.34	1.3	7.4	22.98
Montfortula rugosa	2.67	3	2.99	1.41	6.62	29.61
Onithochiton quercinus	**2**	**0**	2.88	1.05	6.39	36
Cellana tramoserica	2.78	4	2.74	1.32	6.08	42.08
Cronia aurantiaca	**2**	**0**	2.72	1.11	6.04	48.12
Nerita atramentosa	1.44	1.13	2.6	0.97	5.77	53.89
Lunella undulata	2	0.75	2.16	1.43	4.79	58.69
Scutus antipodes	**1.44**	**0**	2.04	0.86	4.52	63.21
Liolophura gaimardi	1.11	1.13	1.72	1.52	3.82	67.03
Saccostrea glomerata	0.89	0.5	1.65	0.8	3.65	70.68

c) Broken Head (dissimilarity 36.51%)

Species	Broken Head	Shelly Beach	Av.Diss	Diss/SD	Contrib%	Cum.%
Nerita atramentosa	5	1.13	4.77	2.06	13.07	13.07
Saccostrea glomerata	4	0.5	4.24	2.66	11.62	24.69
Liolophura gaimardi	4.5	1.13	4.13	2.18	11.31	35.99
Trichomya hirsuta	3	0.38	3.23	1.93	8.84	44.84
Dicathais orbita	4.5	2	3.18	1.87	8.71	53.55
Bembicium nanum	5	2.63	3.07	0.96	8.41	61.97
Lunella undulata	3	0.75	2.69	3.06	7.37	69.33
Montfortula rugosa	5	3	2.48	1.25	6.79	76.13

d) Cape Byron (dissimilarity 30.9%)

Species	Cape Byron	Shelly Beach	Av.Diss	Diss/SD	Contrib%	Cum.%
Nerita atramentosa	3.33	1.13	3.94	1.63	12.71	12.71
Bembicium nanum	4.67	2.63	3.62	1.09	11.69	24.4
Montfortula rugosa	5	3	2.95	1.21	9.52	33.92
Liolophura gaimardi	3	1.13	2.94	1.65	9.48	43.4
Dicathais orbita	2.33	2	2.64	1.33	8.53	51.93
Saccostrea glomerata	2	0.5	2.32	1.51	7.49	59.42
Austrocochlea porcata	3.33	3	2.13	1.52	6.87	66.29
Lunella undulata	2.33	0.75	2.11	1.03	6.82	73.11

Regional Comparison Whelks, Cunjevoi and Fishing Debris

Timed search surveys for whelks revealed densities of over 20 *Dicathais orbita* per 20m transect/5min search at Shelly Beach, as well as three other rock platforms in the region, but much lower densities in the boulder fields at Lennox Head (Figure 10a). PERMANOVA revealed significant differences between locations (Table 9), with significantly higher numbers of *D. orbita* at Flat Rock, Brays beach and Shelly Beach in comparison to Lennox Head. In contrast *Cabestana spengleri* was only found at a few sites and in relatively low numbers (Figure 10a). The statistical difference detected between sites (Table 9) was confirmed in posthoc tests to be due to the presence of *C. spengleri* at Lennox Head, Flat Rock and Brays Beach, but not the other sites, including Shelly Beach (Figure 10a).

The mean density of cunjevoi (*Pyura stolonifera)* was similar within the low tide zone in cunjevoi beds across all rock reefs (Figure 10b), with no significant differences between locations (Table 9). Harvested cunjevoi were detected along transects at several locations, including Shelly Beach (Figure 10b) and the pairwise tests confirmed that the statistical difference between locations (Table 9) was due to the presence or absence of cut tunics, indicative of harvesting (Figure 10b).

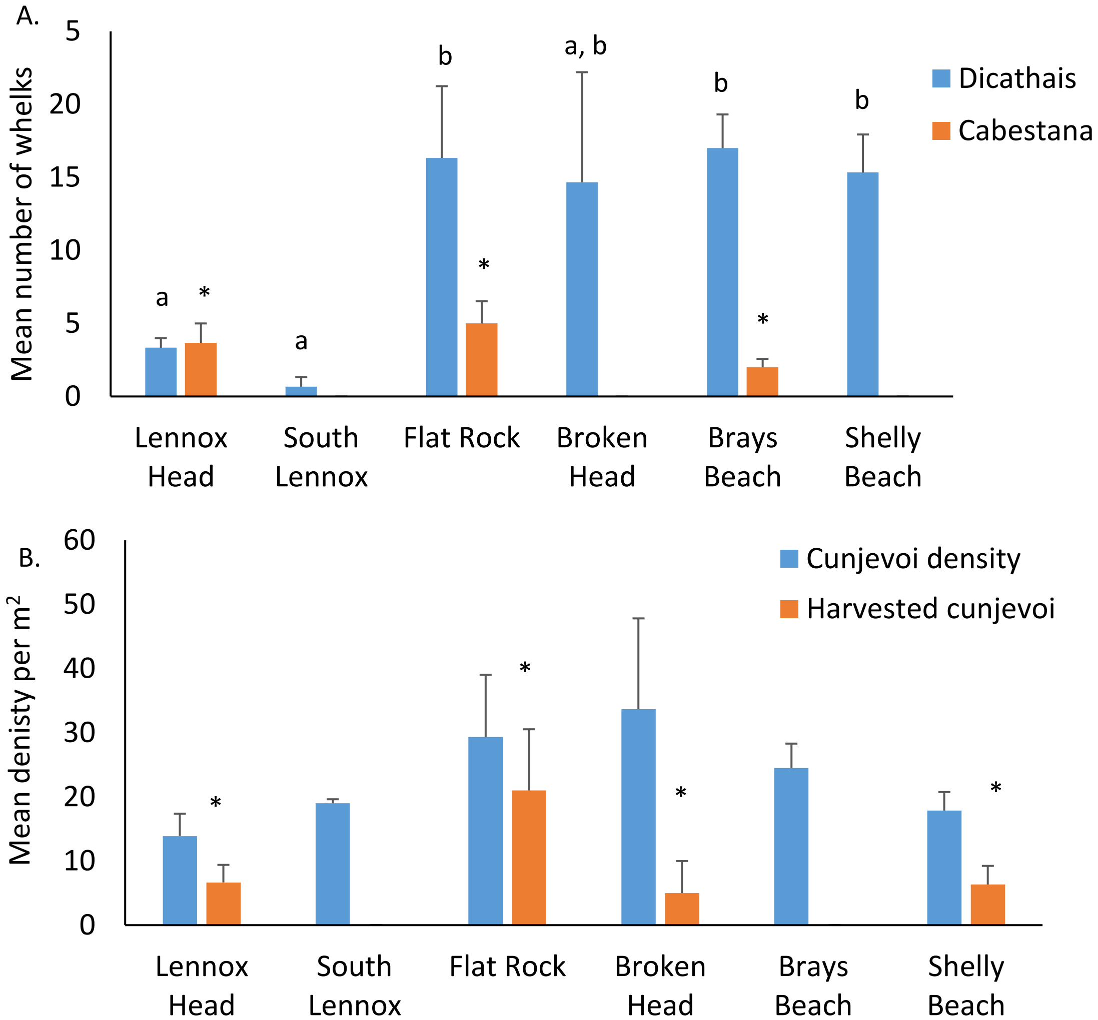

Figure 10: Comparison of indicator organisms at six rocky shore locations in the Northern Rivers, NSW, Australia: A) Mean number (+ s.e.) of predatory whelks *Dicathais orbita* and *Cabestana spengleri* per 5 min search and B) mean (+ s.e.) density of cunjevoi per m^2 and number or harvested cunjevoi per 20m transect.

Table 9: Summary of the one factor PERMANOVAs comparing the density of indicators organisms and recreational fishing activity across six rocky shores in the Northern Rivers, NSW, Australia. Indicator organisms include the predatory whelks *D. orbita* and *C. spengleri* as well as the cunjevoi *Pyura stolonifera*. Fishing activity is indicated by the number of harvested cunjevoi, the number of items of fishing debris and the total length of fishing line found at each site. Bold – statistically significant (P < 0.05).

Variable	Pseudo-F	P(perm)	Unique Permutations
Dicathais orbita	4.8332	**0.006**	9931
Cabestana spengleri	12.318	**0.0002**	1882
Cunjevoi density	1.8834	0.1332	9929
Harvested cunjevoi	3.5384	**0.0159**	8683
Fishing debris items	1.9942	0.0967	4957
Length of line	2.4086	0.10405	774

Fishing related debris, including sinkers, hooks, lures and bait bags, were found in surveys at all locations (Figure 11a). On average, fewer items were recorded at Shelly Beach (Figure 11a), and no fishing line was recorded at Shelly Beach (Figure 11b). However, there were no statistically significant differences in the number of items or length of line recorded between locations (Table 9).

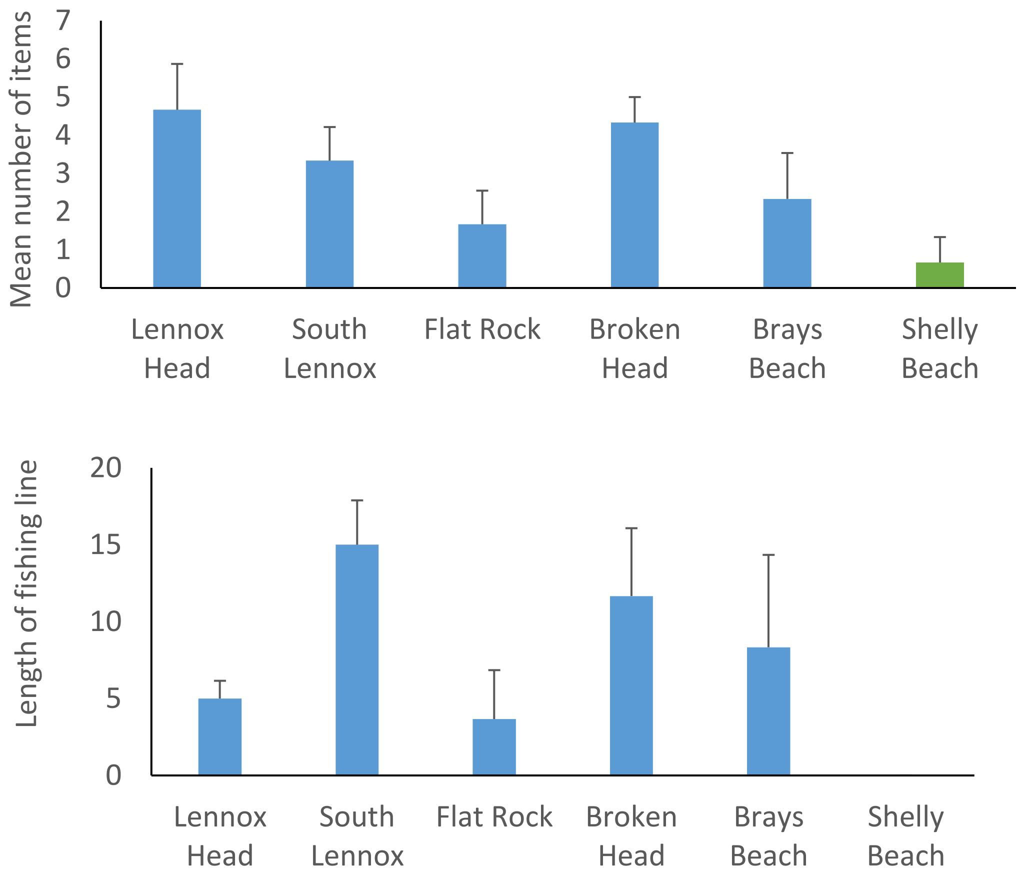

Figure 11: Comparison of fishing rubbish at six rocky shore locations in the Northern Rivers, NSW, Australia. A) Mean (+s.e.) number of items of fishing related debris per 20m transect and B) total length of fishing line.

Evaluation and Recommendations

Overall, the intertidal surveys at Shelly Beach indicate that this is a suitable location for construction of the Ballina Ocean pool. The location of the proposed pool is a low relief rocky reef area impacted by significant sand scour, thus providing less rocky substrate for attachment of habitat forming sessile organisms. The proposed pool site was found to have a lower diversity of species that the within site control rock platform to the immediate north. Furthermore, when placed in a regional context, Shelly Beach molluscan communities have significantly lower richness and diversity than a number of other rocky shores in northern NSW. Significant differences in the molluscan assemblages at Shelly Beach compared to other rock platforms were primarily due to lower abundances of some molluscs and the absence of other species. All of the molluscan species recorded in surveys at Shelly Beach were detected in surveys of least some other rocky headlands in the region. Shelly Beach has a reasonably large population of the predatory whelk *Dicathais orbita* and some dense beds of the cunjevoi *Pyura stolonifera*, but in these regards, it is not significantly different to other rock platforms in the region. There is evidence of recreational fishing activity at Shelly Beach, but overall less fishing debris was found at this site compared to other rocky seashores in the region. Table 10 provides an overall evaluation of the ecological value of Shelly Beach intertidal reef and the possible implications of the pool for the ecological communities, with some recommendations for mitigating the impacts.

Wave-exposed intertidal reefs are naturally harsh environments and typically support communities dominated by highly adapted marine species (Bennett, 1992). Shelly Beach, Ballina is a typical wave exposed rocky shore and the species identified at this site are all common intertidal species, which have been detected at many other locations in NSW Australia (Smith and James, 1999; 2003; Benkendorff and Davis 2000; Gladstone, 2002; Benkendorff and Przeslawski, 2008; Woods, 2013, Atlas of Living Australia, 2018). None of molluscs recorded at Shelly Beach can be regarded as numerically or spatially rare, according to the definitions of Benkendorff and Przeslawski (2008) for intertidal molluscs. Only two species were identified at the proposed pool site that were not on the northern platform. Of these, only one individual of the mollusc *Oppomorus noduliferus* was found at Shelly Beach, and this species has a broad distribution on the east coast of Australia (Atlas of Living Australia, 2018) and was much more common in shallow pools at Flat Rock (Skennars Head) and Hastings Point (Woods, 2013). The other species was an unidentified white anemone, possibly *Anthothoe albocinta*, which is commonly found further south on the east coast of Australia (Billingham and Ayre, 1997). More likely, these unidentified anemones, which were found in sandy pool areas at Shelly Beach, could just be bleached or unpigmented varieties of *Oulactis mucosa*, similar to that illustrated by the Australia Museum (2009). Overall, the intertidal species community assemblages at Shelly Beach are not of particular concern for biodiversity conservation.

The low species diversity and richness recorded at Shelly Beach is most likely due to a combination of low habitat diversity and frequent physical disturbance from wave exposure and sand scour. Hotspots of intertidal biodiversity typically occur on reefs that provide complex boulder habitat, with areas of habitat that are relatively sheltered from the prevailing swell (Bustamante and Branch, 1996; Benkendorff and Davis, 2002). Shelly Beach has no boulder fields, which when present on intertidal shores, can provide refuge for a more complex community of intertidal species (Chapman, 2002; 2005; Benkendorff, 2005), and breeding habitat for many molluscs that deposit benthic egg masses (Benkendorff and Davis, 2004). Notably the most species diverse rocky shores in the Northern Rivers region, as surveyed by Woods (2013) also have complex boulder fields. The species recorded in boulder fields were not included in the comparison to Shelly Beach in this study, however they do significantly add to the total species richness at those sites, thus confirming the importance of habitat diversity in this region.

On highly wave-exposed rocky shores, boulders can be subjected to repeated disturbance from wave action and burial by sand (Mc Guinness, 1984), thus reducing the habitat quality. Heavy sand deposition on rocky shores can smother and scour sessile organisms (Airoldi and Cinelli, 1997; Littler *et al*., 1983) and interfere with settlement and recruitment patterns (Taylor and Littler, 1082). The high percentage of sand recorded during the line-intercept transect surveys at the proposed pool site at Shelly Beach is an indicator of a highly naturally disturbed area, thus explaining the relatively low species diversity at this site. Species diversity on the Shelly Beach headland could potentially be enhanced by creating an area of complex habitat, using larger more stable boulders with cracks and crevices to provide a range of habitat refuges from sand scour and harsh conditions at low tide. The boulders could be placed below the pool wall, similar to previous use of artificial boulders to create new habitat below seawalls (Chapman, 2006; Chapman, 2012; Green et al 2012).

Artificial swimming pools can potentially add to the diversity of habitats on wave exposed rock platforms. In a survey of intertidal mollusc breeding habitats on the Illawarra Coast, Benkendorff and Davis (2004) found that artificial pools significantly contributed to the total number of gastropods depositing egg masses at all nine sites where the swimming pools occurred. They recommended that such pools should not be constructed in complex intertidal habitats, particularly boulder fields, which would impact important breeding habitat, but rather could be constructed on rock platforms, with consideration to water flow and potential for regular flushing to maintain connectivity to the marine environment. From an ecological perspective, the low relief area of reef at Shelly Beach, which has low habitat complexity and low species diversity, appears to be a suitable location for a sensitively constructed ocean swimming pool.

Ocean swimming pools can enhance the recreational opportunities on rocky shores (Short, 2007). By providing a relatively safe swimming environment, they can attract more family orientated tourism to the area. However, this could also lead to additional recreational pressure on the local intertidal reef. Recreational impacts on intertidal reefs include trampling (Keough and Quinn, 1998), harvesting for food and bait (Underwood and Kennelly, 1990; Kingsford *et al*. 1991; Underwood, 1993; Keough *et* al., 1993) and rubbish left on the reef, which can be washed into adjacent marine ecosystems (Smith and Edgar, 2015). Surveys of the fishing debris and cunjevoi (*Pyura stolonifera*) harvested for bait at Shelly Beach indicate that this rocky shore is currently a site of moderate recreational activity. The pool could attract additional fishing activity from tourist families, with potential for more fishing related debris. Furthermore, during surveys at Shelly Beach, a number of recreational users were observed harvesting intertidal molluscs for bait and food. In particular, the whelk *Dicathais orbita* was targeted for recreational collection. This is an ecologically important species with functional food value (Benkendorff, 2013) and is likely to be vulnerable to over-harvesting. Shelly Beach currently supports healthy populations of both *D. orbita* and one of its food sources, the bait species *Pyrua stolonifera*. Ongoing monitoring of the populations of these species and other potentially recreationally important rocky shore molluscs (Underwood and Kennelly, 1990; Kingsford *et al*. 1991) is recommended to assess any indirect impacts from increased recreational activity at Shelly Beach after the construction of the Ballina Ocean Pool.

In order to mitigate the potential increased pressure from recreational activities on the rocky shore, community education is required. Signage should be installed to advise users of the current bag and size limits for recreational harvest. Fishing Line Recovery Bins or Tangler Bins are a useful tool for collecting unwanted fishing tackle and waste. Tangler Bins were introduced to a number of NSW fishing areas in 2006 and by 2010 these bins had collected over 10 tonnes of discarded fishing line (OceanWatch Australia, 2010). Instalment of these bins with signs educating the public on appropriate disposal of fishing waste at Shelly Beach would help mitigate the impacts from increased recreational use.

Conclusions

The rocky shore at Shelly Beach, Ballina has low habitat complexity and supports a relatively low diversity of common intertidal species. The proposed location of the pool is subject to sand smothering, contributing further to low diversity in the area. The construction of an artificial pool on this site is unlikely to have any significant ongoing impacts that will negatively affect the ecological communities or ecosystem function (Table 10). A carefully constructed pool with the provision of some new complex sheltered habitat has the potential to increase the biodiversity value of the site (Table 10). Shelly Beach is currently used for a moderate level of recreational activities, including intertidal harvesting and rock fishing. The proposed pool is likely to increase the level of recreational activity at the site. Consequently, community education and some ongoing monitoring of key indicator organisms is recommended to assess any long-term indirect impacts (Table 10).

Table 10: Evaluation of ecological importance of Shelly Beach intertidal rocky shore and implications of the proposed Ballina Ocean Pool

Criteria	**Current status**	**Predicted Impact**	**Mitigation**
Naturalness	Predominately natural with small shallow human made pool on the north platform	Increased artificial structure on site with some visual impact but with low predicted impacts on the ecological function of the natural intertidal ecosystem	Sensitive construction materials and design to help the new structure blend into the natural rocky reef
Size	Moderately sized intertidal reef, much smaller than most rocky shores in the region	The proposed pool will impact less than 10% of the available rocky shore habitat at Shelly Beach and an insignificant area of regional intertidal habitat	Carefully engineered construction on top of the low relief area of reef should minimise construction impacts or changes to water flow and sedimentation
Habitat diversity and complexity	Relatively low habitat diversity and complexity due to lack of natural boulder fields or deep pool areas. However, the rockplatfom has significant caves and crevices with a mosaic of rocky outcrops, sand and shallow pool areas	The proposed pool will be constructed over fairly common and low quality habitat naturally impacted by sand scour. No specific habitats will be lost by the construction. There is potential to increase habitat diversity with the deep pool.	An area of complex habitat could be created on the low shore side of the pool using large natural boulders (e.g. Green et al 2012). Microhabitats as cracks and crevices on the walls of the pool will provide refuges for grazing gastropods and sessile invertebrates
Species richness and diversity	Relatively low compared to other rock platforms	No predicted impact. Possible increase in diversity through the provision of new habitat.	Constructing habitat to support a diversity of species (see above)
Species assemblages and abundance	Species composition typical of most intertidal rock platforms in NSW but with relatively low abundance of many species.	No predicted impact, except possible indirect effects form increased recreational harvesting.	Maintain a diversity of flat rock, shallow pool and crevice habitats. Monitoring of target indicator organisms.
Species rarity	No rare species were detected at the site.	No predicted impacts.	More complex boulder habitat behind the pool providing refuge from strong swell and desiccation at low tide will support more regionally rare species.

Species of conservation importance	No species of conservation importance were detected in the surveys. However, the Sooty Oystercatcher *Haematopus fuliginosus* does occasionally use the site and is listed as vulnerable in NSW	Minimal predicted impact on species of conservation importance, except potential indirect effects from increased recreational use.	Minimise disturbance to cunjevoi beds, which provide feeding grounds for the Sooty Oystercatcher at low tide.
Breeding habitat	Not an important breeding site. Egg masses of only 5 common gastropods have been found at the site and these species breed on all intertidal reefs in the region. However, the site does seem to support an unusually large population of *Dicathais orbita* juveniles.	Minimal predicted impact. The proposed pool could in fact provide additional breeding habitat for a greater range of other species.	Maintain vertical rockwall habitat and crevices for *Dicathais orbita* egg deposition and recruitment. During pool maintenance avoid cleaning if there are large spawning aggregations e.g. seahares (*Aplysia* spp.) communally spawn in pools (Benkendorff and Davis, 2004)
Ecological linkage	Most species on intertidal rocky reefs are well connected in the broader marine systems due to free spawning and/or pelagic larvae	The proposed pool is not expected to impact connectedness in the local marine system	No specific action required but the pool design should be carefully engineered to ensure it is well flushed
Recreational fishing value	Shelly Beach rocky shore is used for recreational fishing, similar to many other reefs in the area. The cunjevoi *Pyura stolonifera* is harvested for bait, as well as a range of other potential species (Kingsford et al 1991), including chitons, limpets and whelks (as observed during intertidal surveys)	The proposed pool will have no negative impact on recreational fishing. However, the pool could attract more recreational fishers to the area, which may generate more fishing debris and increased harvest of target bait species.	Install bins and signs for recreational fishing waste. Monitor future recreational use and impact.
Overall value	All intertidal rocky reefs have ecological value. However, the intertidal reef at Shelly Beach is not particularly unique and does not have particularly high biodiversity or resource value	Minimal negative impacts are predicted	Monitoring during construction and post-construction phase would detected unpredicted impacts and generally improve knowledge of intertidal systems for impact assessment.

References

Airoldi, L., and Cinelli, F., 1997. Effects of Sedimentation on subtidal macroalgal assemblages: an experimental study from a Mediterranean rocky shore, *Journal of Experimental Marine Biology and Ecology*, 215: 269-288.

Airoldi, L., and Hawkins, SJ. 2007. Negative effects of sediment deposition on grazing activity and survival of the limpet *Patella vulgata. Marine Ecology Progress Series*, vol. 332: 235-240.

Anderson, M.J., Gorely, R.N., Clarke, K.R., 2008. PERMANOVA+ for PRIMER: Guide to Software and Statistical Methods. Plymouth Marine Laboratory, United Kingdom.

Atalah, J., and Crowe, T. P. (2012). Nutrient enrichment and variation in community structure on rocky shores: The potential of molluscan assemblages for biomonitoring. *Estuarine, Coastal and Shelf Science, 99*, 162-170.

Atlas of Living Australia (2018). Atlas of living Australia database website at http://www.ala.org.au. Accessed 15/3/2018.

Australian Museum (2009) White Oulactis Anemone in rock pool. Image Gallery. https://australianmuseum.net.au/image/white-oulactis-anemone-in-rock-pool accessed 15/3/2018.

Benkendorff, K. (2003). Rapid biodiversity assessment on rocky intertidal reefs: an examination of molluscan species richness. *Records of the South Australian Museum Monograph Series, 7*, 67.

Benkendorff, K. (2005) Intertidal molluscan and echinoderm diversity at Althorpe Island and Innes National Park, South Australia. *Transactions of the Royal Society of South Australia* 129, 145-157.

Benkendorff K. (2013) Natural product research in the Australian marine invertebrate *Dicathais orbita*. *Marine Drugs*. 11(4):1370-98.

Benkendorff, K., and Davis, A. R. (2002). Identifying hotspots of molluscan species richness on rocky intertidal reefs. *Biodiversity and Conservation, 11*(11), 1959-1973.

Benkendorff, K. Fairweather, P. and Dittmann, S., 2008. Intertidal Ecosystems. Ch 10 In Natural History of the Gulf St Vincent. Ed. S. Shepherd, S. Bryars, Kirkegaard, I., Harbison, P. and Jennings J.T. Royal Society of S.A. Adelaide, Australia.

Benkendorff, K., and Przeslawski, R. (2008). Multiple measures are necessary to assess rarity in macro-molluscs: a case study from southeastern Australia. *Biodiversity and Conservation, 17*(10), 2455-2478.

Bennett I. 1992. Australian Seashores. HarperCollins Publishers: Pymble, NSW.

Berntsson K.M., Jonsson P.R., Larsson A.I., Holdt S. (2004) Rejection of unsuitable substrata as a potential driver of aggregated settlement in the barnacle *Balanus improvisus*. *Marine Ecology Progress Series* 275: 199-210

Berntsson K.M., Jonsson P.R., Lejhall M. and Gatenholm P. (2000) Analysis of behavioural rejection of micro-textured surfaces and implications for recruitment by the barnacle *Balanus improvisus*. *Journal of Experimental Marine Biology and* Ecology 251: 59-83

Billingham, M. and Ayre, D. (1996) Asexual reporduction and genetic determination of colour atterns within populations of the subtidal sea anemone *Anthothoe albocincta. Marine Ecology Progres Series* 156: 121-130

Bustamante R.H. and Branch G.M. 1996. Large scale patterns and trophic structure of southern African rocky shores: the roles of geographic variation and wave exposure. *Journal of Biogeography* 23: 339–351.

Castilla, J.C., Guinez, R., Alvarado, J., Pacheo, C. and Varas, M. (2000). Distribution, population structure, population biomass and morphological characteristics of the tunicate *Pyura stolonifera* in the Bay of Antofagasta, Chile. *Marine Ecology*, 21 (2): 161-174

Chapman, M.G. (1999). Are there adequate data to assess how well theories of rarity apply to marine invertebrates? *Biodiversity & Conservation, 8*(10), 1295-1318.

Chapman, M.G. (2002). Patterns of spatial and temporal variation of macrofauna under boulders in a sheltered boulder field. *Austral Ecology*, 27, 211–228.

Chapman, M. G. (2005). Molluscs and echinoderms under boulders: Tests of generality of patterns of occurrence. *Journal of Experimental Marine Biology and Ecology, 325*(1), 65-83.

Chapman, M.G. (2006). Intertidal seawalls as habitats for molluscs. *Journal of Molluscan Studies* 72: 247-257.

Chapman, M.G. (2012). Restoring intertidal boulder-fields as habitats for “specialist” and “generalist” animals. *Restoration Ecology* 20: 277-285.

Dutton, A. and Benkendorff, K., 2008. Biodiversity Assessment and Monitoring of the Port Stanvac Intertidal Reef. Report to the Adelaide and Mt Lofty Natural Resource Management Board. (Flinders University, Adelaide).

Fairweather, P.G. (1991). A conceptual framework for ecological studies of coastal resources: An example of a tunicate collected for bait on Australian Seashores. *Ocean and Shoreline Management*, 15(2), 125-142.

Farquhar, L. (2014). Assessing the impacts of fishing debris on rocky reef in Cape Byron Marine Park, NSW. Unpublished Integrated Project Report, School of Environment, Science and Engineering, Southern Cross University.

Keough, M.J. and Quinn, G.P. (1998). Effects of periodic disturbances from trampling on rocky intertidal algal beds. *Ecological Applications* 8, 141-161.

Keough, M.J., Quinn, G.P. and King, A. (1993) Correlations between human collecting and intertidal mollusc populations on rocky shores. *Conservation Biology* 7, 378-390.

Kingsford, M.J., Underwood, A.J. and Kennelly, S.J. (1991) Humans as predators on rocky reefs in New South Wales, Australia. *Marine Ecology Progress Series* 72: 1-14.

Huff, T.M., and Jarett, J.K., 2007. Sand addition alters the invertebrate community of intertidal coralline turf, *Marine Ecology Progress Series* 345: 75-82.

Gladstone, W. (2002). The potential value of indicator groups in the selection of marine reserves. *Biological Conservation, 104*(2), 211-220.

Green, M., Ganassin, C., and Reid, D.D. (2009). Report into the NSW shark meshing (bather protection) program. NSW Department of Primary Industries. Orange, Australia: NSW DPI Fisheries Conservation and Aquaculture Branch.

Green, D.S., Chapman, M.G. and Blockley, D.J. (2012). Ecological consequences of the type of rock used in the construction of artificial boulder-fields. *Ecological Engineering* 46: 1-10.

Guangjian, X., Yulian, L., Chongbo, H., and Henglong, X. (2013). Congruency analysis to determine potential surrogates of littoral macroinvertebrate communities: a case study in intertidal ecosystems of northern Yellow Sea. *Journal of the Marine Biological Association of the United Kingdom,* 93(3), 601.

Littler, M.M., Martz, D.R. and Littler, D.S., 1983. Effects of recurrent sand deposition on rocky intertidal organisms: importance of substrate heterogeneity in a fluctuating environment, *Marine Ecology Progress Series* 11: 129-139.

McComb, L. (2017) Habitat assessment of the proposed ocean pool site on Shelly Beach, Ballina, NSW and a look at the benefits of ocean baths as ecologically engineered structures. Unpublished Independent Study Report. School of Environment, Science and Engineering, Southern Cross University.

McDermott, M. (2011) *Ocean Baths.* Dictionary of Sydney. Available at http://dictionaryofsydney.org/entry/ocean)_baths

McDermott, M. L. (2012). Wet, wild and convivial: past, present and future contributions of Australia’s ocean pools to surf, beach, pool and body cultures and recreational coasts. Ph.D. Thesis. Edith Cowan University.

Monteiro, S.M., Chapman, M.G., Underwood, A. J. (2002). Patches of the ascidian *Pyura stolonifera* (Heller, 1878): structure of habitat and associated intertidal assemblages. *Journal of Experimental Marine Biology and Ecology.* 270, 171-189.

NSW DPI Fisheries (2017). NSW North Coast Shark meshing trial final report. Fisheries Final Report Series No. 154. [online] NSW Department of Primary Industries. Available at: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0009/734535/FFRS-154_Dept-Primary-Industries-2017.pdf [Accessed 30 Oct. 2017].

OceanWatch Australia (2010) Tangler Bin. http://www.oceanwatch.org.au/Backup/our-work/tangler-bin/ accessed 17/03/2018

Prathep, A., Marrs, R.H. and Norton, T.A., 2003. Spatial and temporal variations in sediment accumulation in an algal turf and their impact on associated fauna, *Marine Biology*, 142: 381-390.

Raimondi P.T. (1990) Patterns, mechanisms, consequences of variability in settlement and recruitment of an intertidal barnacle. *Ecological Monographs* 60: 283-309

Smith, S. D. A. (2005). Rapid assessment of invertebrate biodiversity on rocky shores: where there's a whelk there's a way. *Biodiversity and Conservation, 14*(14), 3565-3576.

Smith, S.D.A and Edgar, R.J. (2014) Documenting the density of subtidal marine debris across multiple marine and coastal habitats. *PLOS ONE* https://doi.org/10.1371/journal.pone.0094593

Smith, S. D. A., and James, K. A. (1999). *Surveys of rocky shore habitats: Sandon Bluffs and Station Creek Headland.* Report prepared for the NSW Marine Park Authority, Coffs Harbour. National Marine Science Centre, Southern Cross University.

Smith, S. D. A., and James, K. A. (2003). Rapid assessment of rocky shore biodiversity in the Cape Byron Marine Park. Report prepared for the NSW Marine Parks Authority. National Marine Science Centre, Southern Cross University.

Shepherd, S., Edgar, G., (2013). Ecology of Australian Temperate Reefs: The Unique South. CSIRO Publishing, Collingwood, Victoria

Short, A. D. (2007). *Beaches of the New South Wales Coast: A guide to their Nature, Characteristics, Surf and Safety*. Sydney University Press.

Suridge, K. (2014). A study of bait harvesting on *Pyura stolonifera* and associated predatory whelks within Cape Byron Marine Park. Unpublished Integrated Project Report. School Environment, Science and Engineering, Southern Cross University.

Taylor, P.R. and Littler, M.M., 1982. The roles of compensatory mortality, physical disturbance, and substrate retention in the development and organisation of a sand-influenced, rocky-intertidal community, *Ecology*, 1982: 135-146.

Thompson, R. C., Crowe, T. P., and Hawkins, S. J. (2002). Rocky intertidal communities: past environmental changes, present status and predictions for the next 25 years. *Environmental Conservation, 29*(2), 168-191.

Underwood, A.J. (1993). Exploitation of species on the rocky coast of New South Wales (Australia) and options for its management. *Ocean & Coastal Management* 20: 41-62

Underwood, A.J. and Kennelly, S.J. (1990). Pilot studies for designs of surveys of human disturbance of intertidal habitats in New South Wales. *Australian Journal of Marine and Freshwater Research* 42:165-173

Woods, C. (2013). Long-Term monitoring of rocky shore biodiversity in the Cape Byron Marine Park. Unpublished Honours Thesis. School of Environment, Science and Engineering, Southern Cross University.

Zabin, C. J., Danner, E. M., Baumgartner, E. P., Spafford, D., Miller, K. A., & Pearse, J. S. (2013). A comparison of intertidal species richness and composition between Central California and Oahu, Hawaii. *Marine Ecology, 34*(2), 131-156.

Appendix 1: Regional surveys for molluscs: FR = Flat Rock, CB = Cape Byron, HP= Hastings Point, BH = Broken Head, SB = Shelly Beach

Species	FRS 1	FRS 2	FRS 3	FRS 4	FRS 5	FRS 6	FRS 7	FRS 8	FRS 9	CBS 1	CBS 2	CBS 3	HPS 1	HPS 2	HPS 3	HPS 4	HPS 5	HPS 6	HPS 7	HPS 8	HPS 9	HPS10	HPS11	HPS12	HPS13	HPS14	BHS 1	BHS 2	SBP 1	SBP 2	SBNP 1	SBNP 2	SBP 3	SBP 4	SBNP 3	SBNP 4
Ischnochiton elongatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ischnochiton australis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liolophura gaimardi	1	1	1	1	2	2	2	0	0	2	2	5	5	4	3	0	3	3	0	1	0	5	4	4	5	5	4	5	0	0	1	3	0	0	2	3
Onithochiton quercinus	0	0	3	2	5	5	2	1	0	0	0	3	3	4	2	0	0	0	1	0	3	3	3	4	5	4	0	3	0	0	0	0	0	0	0	0
Callochiton crocinus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amblychilepas nigrita	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scutus antipodes	0	0	0	2	3	5	2	0	1	0	0	0	1	1	0	0	0	1	0	0	1	0	0	2	4	2	0	2	0	0	0	0	0	0	0	0
Montfortula rugosa	0	3	5	3	5	5	3	0	0	5	5	5	5	4	4	1	3	0	0	0	3	3	3	5	5	4	5	5	1	1	5	3	3	2	4	5
Tugali parmophoidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nerita atramentosa	5	1	0	2	0	0	0	5	0	2	5	3	5	5	5	4	0	2	5	5	5	5	5	5	5	5	5	5	0	4	1	4	0	0	0	0
Nerita albicilla	1	0	0	0	0	0	0	0	0	0	0	0	2	3	5	0	0	0	5	3	2	3	2	1	0	2	0	0	0	0	0	0	0	0	0	0
Austrocochlea porcata	5	0	5	5	3	0	5	5	0	3	3	4	5	5	5	5	3	3	5	5	5	5	5	0	5	5	4	5	3	5	5	5	2	1	3	0
Lunella undulata	0	3	3	3	1	2	2	2	2	1	1	5	3	5	1	2	1	0	0	0	0	2	3	4	5	4	3	3	0	0	1	1	2	1	1	0
Turbo militaris	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	3	3	0	0	0	2	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0
Hinea brasiliana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Bembicium nanum	5	0	0	3	2	0	5	5	0	4	5	5	5	5	5	5	3	3	5	4	5	0	5	5	4	5	5	5	1	5	5	5	0	0	0	5
Clypeomorus petrosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monetaria annulus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	4	1	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Monetaria caputserpentis	0	0	1	0	0	1	0	0	0	0	0	0	2	1	0	0	1	2	0	0	0	0	1	0	1	2	0	0	0	0	0	0	0	0	0	0
Mauritia arabica	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Erronea errones	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Nassarius gaudiosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mitra cookii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mitra litterata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Turritriton labiosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gutturnium muricinum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranella australasia	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Monoplex parthenopeus	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cabestana spengleri	0	0	0	1	2	1	4	0	2	0	0	0	2	2	0	0	0	2	0	0	2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Charonia lampas	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pascula ochrostoma	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tenguella marginalba	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	4	5	5	5
Oppomorus noduliferus	0	0	0	0	0	0	0	3	4	0	0	0	0	1	0	2	4	1	3	3	4	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Cronia aurantiaca	3	0	0	0	3	1	2	5	4	0	0	1	1	4	1	3	3	4	3	4	4	4	0	1	2	4	0	0	0	0	0	0	0	0	0	0
Ergalatax pauper	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	2	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Bedeva paivae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Thais ambustulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phycothais botanica	0	0	0	0	0	0	0	0	0	0	0	5	0	0	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agnewia tritoniformis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	0	0	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Drupella margariticola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	3	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dicathais orbita	0	4	3	0	5	5	5	0	5	2	0	5	3	3	0	0	0	3	0	0	1	1	0	3	4	3	4	5	0	1	1	2	2	2	3	5
Pardalinops testudinaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euplica varians	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nodopelagia brazieri	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	4	3	4	5	4	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peristernia reincarnata	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engina zonalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cominella eburnea	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engina lineata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phos sculptilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conus aplustre	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conus sponsalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conus musicus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conus catus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conus ebraeus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conus coronatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conus miliaris	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Conus sp.1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellana tramoserica	2	1	2	3	3	5	5	4	0	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	2	5	5	5	3	5	2	5
Siphonaria denticulata	5	5	5	5	5	5	5	2	5	5	5	5	5	4	3	5	5	5	5	4	4	4	4	3	5	5	5	4	5	5	5	2	4	5	5	5
Patelloida mufria	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Aplysia dactylomela	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	2	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aplysia parvula	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dolabrifera sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Berthella stellata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Berthellina citrina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rostanga arbutus	0	2	2	0	0	0	0	1	1	0	0	0	0	1	0	0	1	2	1	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Hypselodoris obscura	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austraeolis ornata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Doriopsilla miniata	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flabellina rubrolineata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Umbraculum umbraculum	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cardita aviculina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saccostrea glomerata	5	0	0	0	0	0	0	3	0	0	2	4	5	0	1	0	0	0	0	0	0	0	1	3	3	0	5	3	0	1	0	1	0	1	1	0
Scintilla sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichomya hirsuta	0	3	0	0	0	0	0	2	0	0	0	1	0	1	1	0	0	0	0	1	0	1	0	2	0	0	4	2	0	0	1	2	0	0	0	0
Modiolus peronianus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chama sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kellia sp. (Galeomattidae)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isognomon perna	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinctada sp.	3	1	0	0	0	0	1	2	0	0	1	0	4	3	4	2	2	3	4	5	4	4	3	2	3	3	0	1	0	0	0	0	0	0	0	0
Irus crenatus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinna sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Barbatium pistachium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Streptopinna saccata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Turridrupa bijubata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Octopus sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Orange vermetid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capulus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sabia australis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0