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Proximity effects of natural and artificial reef walls on fish assemblages

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Abstract

Habitat complexity is recognised as a key driver of fish diversity and abundance. However, the effects of small (10s m) reef structures in otherwise uniform reef areas have received little attention. Here, we assessed proximity effects of small natural and artificial vertical walls on patterns of fish assemblages, at a scale relevant to fish survey transects. We tested whether wall size affected assemblages, and whether assemblages differed between wall types. Fish assemblages were found to change in the immediate vicinity of both natural and artificial walls, with significantly higher species richness and abundance occurring at reef walls than in surrounding, flatter reef areas. The size of the effect generated by walls was found to be proportional to the size of the wall, with species richness and abundance generally increasing with wall height and length. Differences between natural and artificial walls were detected, but these were confounded by differences in size between wall types. The study builds on previous work by showing that, within reefs, local areas of higher species richness and abundance can occur in the vicinity of small but important reef features such as vertical walls. This effect introduces considerable variability into data for reef fish surveys and has implications for the design of such studies. In addition, walls appear to act as localised biodiversity “hotspots” and consideration should be given to inclusion of areas containing such features within marine reserves.

Keywords: Port Stephens; underwater visual census

1 Introduction

Distributions of fish species vary at a range of spatial scales, with global differences driven by environmental, and geographic factors including water temperature (Tittensor et al. 2010), ocean currents (Jones and Srinivasan 2007) and depth (Gray 2001). At regional and local scales, fish assemblages are influenced by currents (Fulton and Bellwood 2004), depth (Malcolm et al. 2011), habitat type (Choat and Ayling 1987; Anderson and Millar 2004), seabed structure (Grober-Dunsmore et al. 2008; Schultz et al. 2012) and topographic complexity (McCormick 1994; Walker et al. 2009).

Studies of reef fish are often confounded by high levels of spatial variability (Willis et al. 2000). Consequently, the factors contributing to this variability need to be understood in order to minimise their effect at the study design stage. Knowledge of fish species distributions, and the factors affecting them, is also important for conservation planning, as fishes make up a substantial component of marine biodiversity (Tittensor et al. 2010), and many species are of commercial importance (Pauly and Christensen 1995; Watson et al. 2004). There is a known association between “structure” on the seafloor and concentrations in fish assemblages (Bohnsack 1989; Pickering and Whitmarsh 1997), with numerous studies showing that fish species richness and abundance are

higher on reefs than in surrounding non-reef areas (Charbonnel et al. 2002; Schultz et al. 2012; Lowry et al. 2014). Studies of coral reefs have shown that fish assemblages can be strongly influenced by reef complexity (McCormick 1994; Walker et al. 2009), while studies of artificial reefs have shown increases in fish abundance and species richness, following the introduction of artificial reef systems (Bohnsack et al. 1994; Edwards and Smith 2005), and that increasing the topographic complexity of artificial reefs leads to further increases in fish abundance and richness (Charbonnel et al. 2002).

Studies examining the impact of variations in topography complexity on fish assemblages have generally used two-dimensional indices, over the entire length of study transects, such that the effects of specific features cannot be effectively determined (McCormick 1994; Pais et al. 2013). In addition, two-dimensional indices cannot account for the three-dimensional nature of some reef features, such as walls, where both height and length potentially influence assemblages. While three-dimensional methods are being developed to quantify the complexity of reefs features (e.g. using stereo imaging methods) and to link these to biodiversity values at small scales (Ferrari et al. 2016), these are unlikely to be broadly available for some time. Further study of reef fish variation in the vicinity of small but important reef features, such as vertical walls, is therefore warranted, especially for temperate reefs.

To address this knowledge gap, we examined the localised effects of proximity to natural and artificial reef walls on fish assemblages in a temperate reef system, using a scale relevant to standard fish survey transect lengths (Mapstone and Ayling 1998). We hypothesized that: i) fish species richness and abundance would be higher in close proximity to both natural and artificial reef walls; ii) the effects of walls on fish species richness and abundance would increase with increased wall size; iii) the structure of fish assemblages would differ at a local scale between walls and surrounding, flat reef areas; and iv) fish species richness and abundance would be higher at natural walls than at artificial walls. To test these hypotheses, we recorded fish species and abundances in the immediate proximity of different sizes and types (natural or artificial) of walls in the Port Stephens estuary in New South Wales (NSW), Australia. The study builds on previous work examining temperate reef fish assemblages, by examining the within-reef effects of the presence of vertical walls, and considering the implications of these effects for marine-park planning, and for studies of reef fish using underwater visual census (UVC).

2 Materials and methods

2.1 Study site

The study was conducted within a 3-km stretch of rocky reef on the southern shoreline of the Port Stephens estuary where a number of discrete natural and artificial reef walls occur (Figure 1). The Port Stephens estuary lies within the Port Stephens-Great Lakes Marine Park (PSGLMP), the largest marine park in NSW (NSWMPA 2010). The estuary is classified as a tide-dominated drowned river valley (Roy et al. 2001), is marine dominated, and shelters a range of habitats (Davis et al. 2016b) and diverse fish assemblages (Davis et al. 2016a). Within the study site, the seabed was predominantly a gently sloping rocky reef which extended from the shoreline down to depths >30 m, with benthic cover primarily consisting of mixed macroalgal and filter-feeding assemblages, including sponges, ascidians, and soft corals (Davis et al. 2016b). Natural walls at the study site

were formed by short sections of the drowned river channel where bedrock was exposed, while artificial walls were formed by concrete and metal structures submerged to form an artificial reef, and by concrete anchor blocks used to secure a subsea pipe.

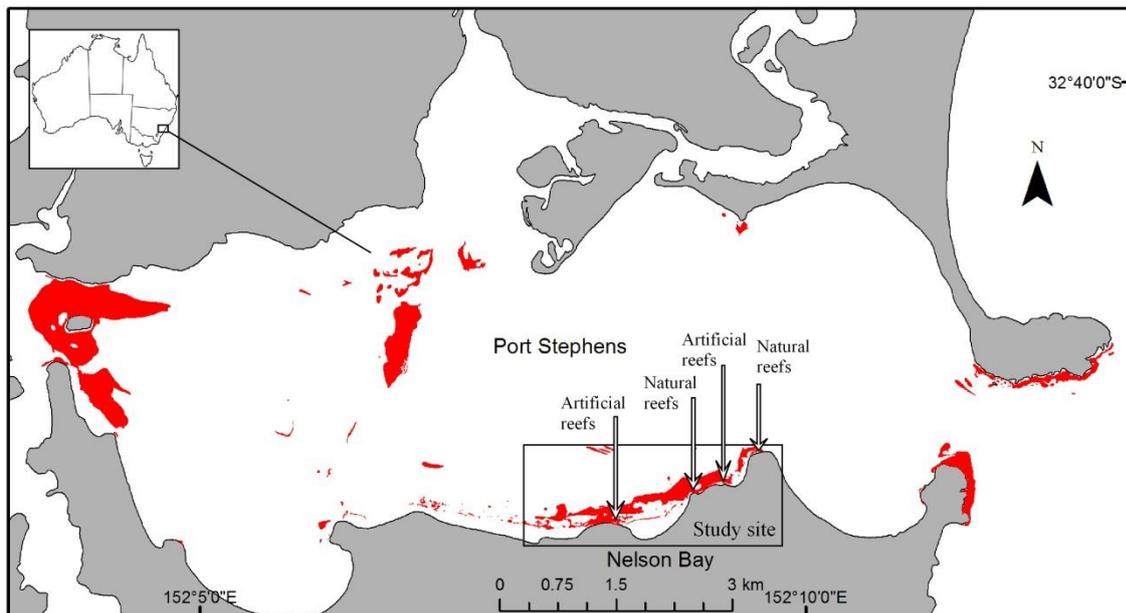


Figure 1. Study site in Port Stephens, New South Wales, Australia. Grey shading indicates land, red shading indicates subtidal rocky reef. Arrows indicate locations of natural and artificial reef walls.

Fish were assessed using a three-factor study design: *Year* (random with 2 levels - 2014/2015); *Distance* from wall (fixed with 4 levels - 0/10/20/30 m); and wall type (*Type*, fixed with 2 levels – natural/artificial). Stationary underwater visual census (UVC) (Bohnsack and Bannerot 1986) were used to assess fish assemblages as this technique provides a non-destructive method which can be applied within Marine Park sanctuary (no-take) zones (Davis et al. 2015), and allowed multiple samples to be obtained within close proximity to walls. The method involved recording the species and abundances of all fishes within a 3-m radius cylinder from a fixed observation point, over a 5-minute period. A 3-m radius was selected, in place of the 7.5-m radius used by Bohnsack and Bannerot (1986), to compensate for the lower visibility occurring in the study area, with a minimum visibility of 5 m specified for all surveys.

Fish assemblages were assessed for four replicate walls, for each year, for each wall type with UVC at the base of the wall (0 m), and then at 10 m, 20 m, and 30 m away from the wall giving a total of 64 UVC counts. At each wall, UVCs were conducted at a fixed depth, with the 10-m buffer between UVC used to ensure independence of samples. Natural and artificial walls were interspersed (Figure 1) and walls were randomly selected from a list of *a priori* identified walls (supplementary Table S1) to minimise spatial bias between wall types and between years. Stationary UVC was conducted immediately on arrival at each census location to minimise biases associated with diver disturbance. All surveys were conducted by the same diver (TRD) on high tide, at slack water, to provide the requisite visibility of >5m, while a second diver monitored time and recorded habitat details. Walls were chosen to have comparable topographic complexity (i.e. continuous flat-faced walls)

with a vertical, or near-vertical, face of at least 1 m in height, and at least 5 m in length. The walls selected had heights that ranged from 1.0–3.5 m, and lengths that ranged from 5–50 m (supplementary Table S1). All walls were surrounded by rocky reef with relatively uniform cover of benthic growth (i.e. not surrounded by sand), and were in the depth range 5-15 m with similar exposure to tidal currents.

Wall height, overall length, and coverage of benthic growth were measured at each wall as potential explanatory variables for changes in fish species richness and abundance. Benthic cover was assessed by taking eight vertical photo-quadrats across the four stationary UVC sites at each wall, and analysing 25 random points in each photo to ascertain the proportion of points covered by growth (i.e. not bare reef). Each quadrat covered an area approximately 600 x 400 mm, and analysis of benthic cover was conducted using the CPCe software package (Kohler and Gill 2006).

2.2 Statistical analysis

Data were analysed using univariate and multivariate analysis tools from the PRIMER-E and PERMANOVA+ software packages (Anderson et al. 2008; Clarke and Gorley 2015). Three-way PERMANOVA analyses were conducted on univariate data for fish species richness (S) and fish abundance (N) for factors of *Year*, *Distance* and *Type*. Pairwise PERMANOVA analyses were then conducted to further examine significant effects and to test the hypotheses that: fish species richness (S) and abundance (N) is higher in close proximity to walls; and, fish species richness and abundance is higher at natural than artificial walls. Single-factor PERMANOVA analyses were used to test for potential confounding effects caused by significant differences in wall height, wall length, and benthic cover between natural and artificial walls. Abundances of pelagic fishes can be highly variable, concealing patterns occurring in less numerous but more prevalent species (McClanahan et al. 2007; Smith et al. 2008) and data for pelagic fish were therefore excluded from all analyses.

Metric multidimensional scaling (mMDS) (Clarke 1993), was used to visualise differences between on-wall (i.e. at 0 m) and off-wall (i.e. at 10/20/30 m) assemblages by *Type*, and to visualise differences among on-wall assemblages by *Type* and *Year*, with 95% confidence intervals obtained by bootstrap averaging, with replacement, across samples within factors. Three-way PERMANOVA analyses were conducted on multivariate assemblage data for factors of *Year*, *Distance* and *Type*, using a similarity matrix assembled from data which were square-root transformed to reduce the influence of abundant species. Pairwise PERMANOVA analyses were then conducted to further examine significant effects and to test the hypothesis that that the structure of fish assemblages differed between walls and surrounding flat reef areas. Where significant effects were detected, Similarity Percentages (SIMPER) analysis was used to identify species making the largest contribution to differences in fish assemblages between factors. Species trophic groups were identified using the global fishes trait database from Stuart-Smith et al. (2013).

The distance-based linear model (DISTLM) routine (Anderson et al. 2008) was used to generate linear models for the relationships between measured fish species richness (S) and fish abundance (N), and selected explanatory variables (wall height, wall length, and percentage benthic cover). DISTLM analyses were based on Euclidean distance, with all off-wall censuses assigned a zero value for wall height and length. A step-wise procedure and the R^2 selection criterion were used to find the best models, and marginal tests were used to determine the strength of the relationship between the measured variables and each explanatory variable

(Anderson et al. 2008). The DISTLM models were then used to test the hypothesis that fish species richness and abundance increases with wall height and length.

3 Results

A total of 64 stationary UVC were conducted identifying 3,032 fish from 90 species. Of the species identified, 25 were found only on-wall (i.e. at 0 m), 17 occurred only off-wall (i.e. at 10/20/30 m), and 48 occurred both on and off walls (supplementary Table S2). The ten most abundant species were from eight different family groups (Table 1), with the scorpidid *Atypichthys strigatus* being the most abundant species overall and the most abundant species occurring both on and off natural walls (Table 1). The sparid *Acanthopagrus australis* was the second most abundant species and the most common species occurring on artificial walls (Table 1), while the mullid *Parupeneus spilurus* was the most abundant species occurring off artificial walls, with this species occurring at relatively even abundance levels across all areas (Table 1).

Table 1: Average abundance (Av. N) and percentage occurrence for the ten most abundant fish species sighted during replicate, 3-m radius, stationary underwater visual census at natural and artificial walls (on-wall) and in the immediate vicinity of walls (off-wall) with family. Percentage contributions of species to dissimilarities between on-wall and off-wall assemblages (% diss. on-wall / off-wall), and to dissimilarities between natural and artificial wall assemblages (% diss. natural / artificial), calculated using similarity percentages (SIMPER) analyses with square-root transformed data.

Species	Family	Av. N on-wall (natural)	Av. N on-wall (artificial)	Av. N off-wall (natural)	Av. N off-wall (artificial)	Occurrence on-wall (natural)	Occurrence on-wall (artificial)	Occurrence off-wall (natural)	Occurrence off-wall (artificial)	% diss. on-wall / off-wall	% diss. natural / artificial
<i>Atypichthys strigatus</i>	Scorpididae	40.00	5.00	15.67	0.42	50%	13%	42%	4%	7.58	7.72
<i>Acanthapagrus australis</i>	Sparidae	12.38	6.38	5.04	1.42	88%	38%	75%	29%	5.95	6.97
<i>Parupeneus spilurus</i>	Mullidae	3.38	2.25	3.17	2.54	75%	100%	67%	63%	3.68	4.87
<i>Hypoplectrodes maccullochi</i>	Serranidae	4.13	3.50	1.92	1.21	100%	88%	83%	54%	3.45	3.64
<i>Cheilodactylus fuscus</i>	Cheilodactylidae	3.88	4.25	1.88	0.29	75%	50%	46%	21%	4.11	3.58
<i>Pseudolabrus guentheri</i>	Labridae	2.63	2.88	1.88	0.79	88%	88%	63%	38%	3.44	3.68
<i>Pempheris affinis</i>	Pempheridae	7.63	0.50	0.00	0.00	13%	25%	0%	0%	1.55	0.73
<i>Pelates sexlineatus</i>	Terapontidae	7.50	0.00	0.00	0.00	25%	0%	0%	0%	1.70	0.84
<i>Notolabrus gymnogenis</i>	Labridae	1.88	2.38	2.13	0.71	88%	88%	71%	33%	3.06	3.75
<i>Pagrus auratus</i>	Sparidae	1.38	1.88	2.00	1.46	63%	75%	92%	79%	2.23	2.56

3.1 Variations in fish assemblages with Year, Distance, and Type

PERMANOVA analysis identified significant differences in fish species richness, abundance, and assemblages with *Year*, and *Distance*, and significant interactions between *Year* and *Type*, but identified no other significant interactions (Table 2). Pairwise analyses among levels of *Distance* identified that species richness, abundance, and assemblages were all significantly higher on-wall than off-wall ($P < 0.039$ all comparisons). Thus, species richness was 69% higher, and fish abundance was 157% higher, on-wall (Figure 2). No significant differences were detected between off-wall distance pairs ($P > 0.132$ all comparisons). mMDS analysis of similarity of mean fish assemblages, with bootstrap averaging by *Distance* (with off-wall data combined) and *Type*, showed distinct differences between on-wall and off-wall assemblages for both natural and artificial walls (Figure 3a). SIMPER analyses identified that a wide range of species contributed to the dissimilarity between on-wall and off-wall assemblages, with differences driven by higher on-wall abundances of schooling species (e.g. *A. strigatus*, *A. australis*) and reef-associated species (e.g. *Hypoplectrodes maccullochi*, *Cheilodactylus fuscus*, Table 1).

Pairwise analyses of species richness for *Type* within *Year* found no significant differences in species richness, abundance, or assemblages between wall types for 2014 ($P > 0.067$, all tests), but found significant differences in all of these variables in 2015 (Figure 2, $P < 0.001$, all tests). mMDS analysis of similarity of mean fish assemblages at walls (0 m), with bootstrap averaging by *Year* and *Type*, showed greater similarity in average assemblages between wall types in 2014 than in 2015 (Figure 3b). SIMPER analyses identified that differences between wall types were caused by differences in abundances and occurrence across a wide range of species (Table 1), with total abundance significantly higher at natural walls than at artificial walls in 2015, but with similar values in 2014 (Figure 2b).

Table 2: Results for 3-factor PERMANOVA analyses with factors: *Year* (random with 2 levels – 2014/2015); *Distance* from wall (*Distance*, fixed with 4 levels - 0/10/20/30 m); and wall type (*Type*, fixed with 2 levels - natural/artificial). Results for analyses based on species richness (S) / abundance (N), and multivariate assemblage data (Z). * indicates a significant difference with $P < 0.05$

	df	SS (S / N / Z)	MS (S / N / Z)	F (S / N / Z)	P (S / N / Z)
<i>Year</i> (Y)	1	116/6683/6077	116/6683/6077	9.88/4.38/3.13	0.005*/0.045*/0.007*
<i>Distance</i> (D)	3	777/35282/13510	259/11761/4503	77.17/76.69/4.32	0.004*/0.002*/0.001*
<i>Type</i> (T)	1	156/21830/12028	156/21830/12028	1.93/2.21/1.62	0.387/0.375/0.212
YxT	1	81/9900/7433	81/9900/7433	6.92/6.49/3.83	0.012*/0.015*/0.001*
YxD	3	10/460/3124	3/153/1041	0.29/0.10/0.54	0.825/0.963/0.966
TxD	3	7/3820/6764	2/1273/2255	0.26/4.89/0.95	0.863/0.125/0.526
YxTxD	3	27/782/7083	9/261/2361	0.76/0.17/1.22	0.530/0.918/0.227

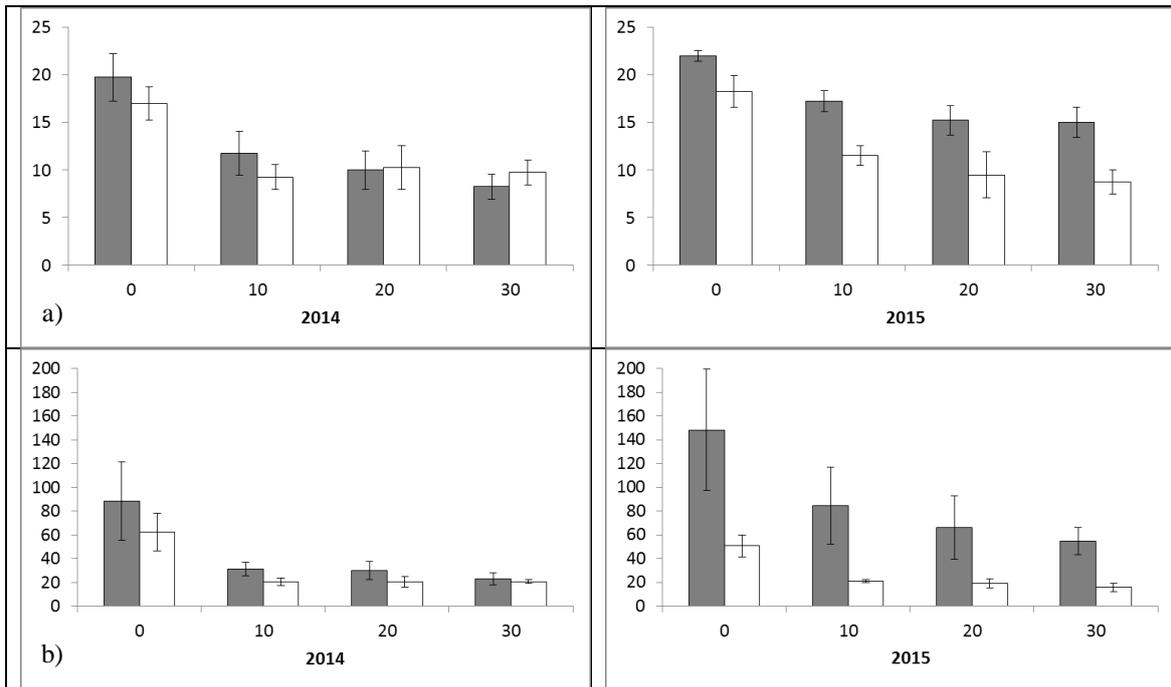


Figure 2: Variation with distance from walls by year (2014/2015) for: a) fish species richness; and b) fish abundance. Natural reef walls (filled bars), artificial reef walls (unfilled bars, mean \pm SE, n = 4). Data from 3-m radius stationary underwater visual census.

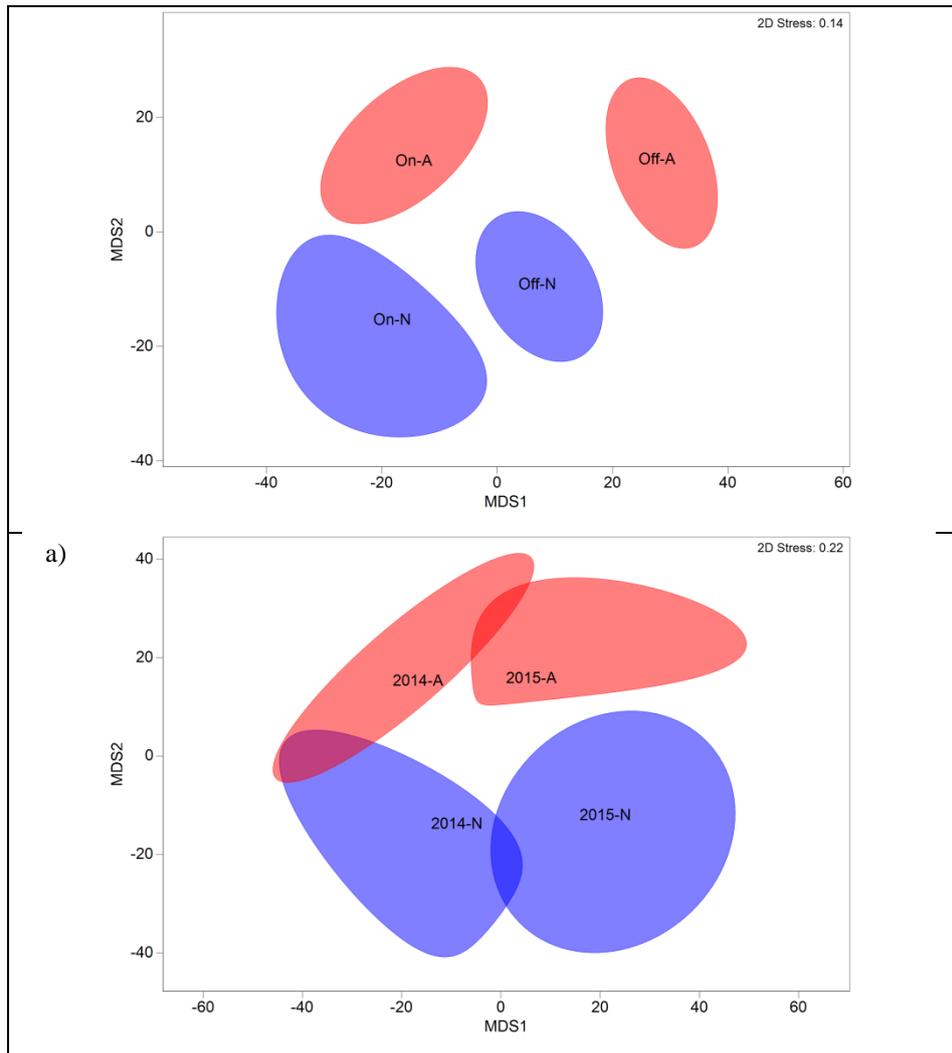


Figure 3: Metric multi-dimensional scaling plot showing similarity of mean fish assemblage data by wall type: “N” = natural reef walls, “A” = artificial walls: a) by location, On = on-wall (0 m), Off = off-wall (10, 20, 30 m); and b) by year, 2014/2015, for on-wall (0 m) assemblages. Ellipses show approximate 95% confidence boundaries for average assemblages calculated by bootstrap averaging across replicates with replacement.

3.2 Effect of wall dimensions, depth, and benthic cover on fish species richness and abundance

Single-factor PERMANOVA between natural and artificial walls for the factors of wall height, length, and benthic cover identified that the natural walls were significantly higher and longer than artificial walls ($P < 0.004$, both tests), but found no significant difference in benthic cover between wall types ($P = 0.130$). Differences in average wall heights and lengths, between natural and artificial walls, therefore confounded the ability to attribute differences among fish assemblages in 2015 entirely to wall type, with

differences in assemblages between wall types potentially also influenced by differences in size between wall types.

Distance-based linear modelling (DISTLM) identified significant correlations between fish species richness and wall height, wall length, and percentage benthic cover (Table 3). Species richness was found to increase with wall height and length with analysis using individual variables (i.e. marginal tests), showing that wall height provided the greatest explanatory power for differences in species richness between walls ($R^2 = 0.418$), followed by wall length ($R^2 = 0.380$) and then percentage benthic cover ($R^2 = 0.089$, Table 3). DISTLM also identified significant correlations between fish abundance and wall height and wall length, but found no significant correlations for percentage benthic cover (Table 3). Fish abundance was found to increase with wall height and wall length, with wall length providing the greatest explanatory power for differences in abundance ($R^2 = 0.575$), followed by wall height ($R^2 = 0.431$, Table 3).

Table 3: Distance-based linear modelling analyses between fish (species richness/abundance) and (wall height/wall length/wall type/percentage benthic cover). Combined data from 3-m radius stationary underwater visual census in 2014 and 2015 at natural and artificial walls ($n = 64$). Censuses >10 m from walls considered to have zero wall height and length. Significant values in bold.

	Wall Height	Wall Length	% Benthic Cover
Species richness	$R^2=0.418$, $P < 0.001$	$R^2 = 0.380$, $P < 0.001$	$R^2 = 0.089$, $P = 0.016$
Abundance	$R^2=0.431$, $P < 0.001$	$R^2 = 0.575$, $P < 0.001$	$R^2 = 0.002$, $P = 0.757$

4 Discussion

Fish assemblages are influenced by factors that operate at large scales, with larger reefs supporting greater abundance and species richness of fishes (Bohnsack et al. 1994) and increased recruitment (Schroeder 1987). Here we found that fish assemblages are also influenced at a local scale (i.e. 10s m) by small but important reef features, such as isolated vertical reef walls. Vertical walls were found to support denser and more diverse fish assemblages than surrounding flat or gently sloping reef areas. This effect was detected at both artificial and natural walls, with the magnitude of the influence of walls on fish assemblages increasing with length and height. Our results supported our initial hypotheses that: fish species richness and abundance is higher in close proximity to both natural and artificial reef walls; the effects of walls on fish species richness and abundance increase with increased wall size; and, the structure of fish assemblages differs at a local scale between walls and surrounding flat-reef areas.

The observed changes in fish assemblages at walls were potentially attributable to a number of factors, with reef fish requiring food, shelter, suitable environmental conditions, and sites for spawning and recruitment (Sumich and Morrissey 2004). Studies examining changes in fish assemblages between reefs

and surrounding, less-complex areas have suggested that increased diversity and abundance of fishes results from reefs: providing new habitats (Bohnsack 1989); attracting adult fish (Pickering and Whitmarsh 1997); and supplying settlement sites and shelter for larval recruits (Anderson et al. 1989). Vertical walls within flatter reef areas, as examined in this study, potentially enhance these benefits, with Rilov and Benayahu (2000) finding that vertical surfaces of jetty pilings attracted a greater abundance and species richness of fish than the moderately sloping surfaces of neighbouring natural reefs. They attributed the differences to higher complexity of vertical structures, which provided more niches for fish species and more effective shelter for recruits when compared with surrounding flatter natural reef areas. In contrast, Rees et al. (2014) found no strong correlation between fish species richness and abundance and localised vertical relief of the seabed, for natural rocky reef systems in south-eastern Australia. Our results found significantly greater abundance and species richness at vertical walls for both natural reef systems and artificial reef structures.

The planktivore, *Atypichthys strigatus*, was a large contributor to the differences between walls and surrounding areas. Associations between reef walls and planktivores have previously been found at fringes of coral-reef systems where currents generate upwelling of plankton, and hence increased food availability (Hamner et al. 1988; Hamner et al. 2007). The reef walls in Port Stephens are exposed to strong tidal flows (Poulos et al. 2015), and a similar phenomena may be occurring at these walls, with tidal flows increasing food supplies, and hence boosting the abundance of planktivores. However, *Atypichthys strigatus*, has also been observed feeding on the benthos in areas disturbed by other fish, and acting as a cleaner for other fish species (Glasby and Kingsford 1994). Higher abundance of *A. strigatus* on walls may therefore also be influenced by the presence of other fish species. Mutualistic and commensal associations between fish species occur for a number of reasons including; cleaning (Grutter 1999), feeding associations (Glasby and Kingsford 1994) and mixed shoaling for mutual protection (Pitcher and Parrish 1993). These relationships were all observed on walls at the study site, with inter-species cleaning (e.g. by *Labroides dimidiatus* and *Coris picta*), feeding interactions (e.g. *Achoerodus viridis* with *A. strigatus*) and mixed shoaling (e.g. *Scorpiis lineolata* with *A. strigatus*) all occurring (pers. obs.). Mutualistic and commensal associations between fishes may therefore have contributed to the increased abundance and species richness of fishes on walls, where opportunities for positive associations with other species were greater. Opportunities for shelter, and higher abundance of fishes (prey) on walls may have also attracted piscivorous predators, with studies of predatory fishes finding increased abundance in areas with high topographic complexity (Carraro and Gladstone 2006), and increased prey abundance (Connell and Kingsford 1998): our study also found a greater abundance of many higher-order carnivores at walls.

Benthic invertivores, especially *Acanthapagrus australis*, were also major contributors to the higher abundance of fish on walls. *Acanthapagrus australis* is an important commercial and recreational fished species (West and Gordon 1994) and increased abundance on walls of this species, and other targeted fish species (e.g. *Girella tricuspidata* and *Platycephalus fuscus*), indicates that walls can act as aggregation sites for commercial and recreational fish species. The attraction of reef structures for fished species has

led to substantial interest in the construction of artificial reefs to enhance fishing (Baine 2001). However, studies comparing fish communities between natural and artificial reefs have had inconsistent results. While some studies have found greater abundance and diversity of species on natural reefs (Burchmore et al. 1985; Carr and Hixon 1997), others have identified greater abundance and diversity on artificial reefs (Bohnsack et al. 1994; Rilov and Benayahu 2000).

In this study, we found no significant difference between natural and artificial reefs in 2014, but identified differences in assemblages, and higher abundance and species richness of fishes at natural reefs in 2015. The failure to detect differences between natural and artificial reefs in 2014 was potentially a type II error, however, with the relatively small number of replicates at each wall type in each year making it difficult to demonstrate significant differences between types. In addition, our study was partly confounded by unavoidable differences in size between artificial and natural walls, with natural walls, on average, larger than artificial walls. Confounded studies of differences between natural and artificial reefs are not uncommon, with comparisons frequently occurring among natural and artificial reefs that differ in size and age (Carr and Hixon 1997). Our results, therefore, do not unequivocally support our initial hypothesis that fish species richness and abundance are higher at natural walls than at artificial walls, with further work required to isolate differences in fish assemblages between wall types.

5 Conclusions

The highly localised nature of the increases in fish species richness and abundance on walls (i.e. within 10 m) has important implications for the planning of surveys conducted using UVC belt transects. Typically, UVC transects extend over lengths of 20-50 m (Mapstone and Ayling 1998) and where transects intersect or approach walls, increases in fish species richness and abundance are likely. The presence of natural or artificial reef walls within UVC study areas will, therefore, substantially increase variability in transect-based UVC data, requiring increased replication in order to obtain adequate precision (Lincoln-Smith 1989). A detailed understanding of seabed structures, such as walls, is therefore advantageous when undertaking investigations of local fish assemblages, particularly where studies incorporate UVC transects or where they are focussed on determining suitable locations for protection of fish biodiversity.

The study has demonstrated the importance of vertical walls for temperate reef fish assemblages, with walls acting as fish aggregation sites in both natural and artificial reef systems. The apparent “universal” effect of natural and artificial reef walls as aggregation sites for diverse fish assemblages indicates that these sites have importance when planning marine reserve boundaries. Walls appear to act as local biodiversity “hotspots” with their impact on assemblages increasing with increased height and length, most probably due to larger walls providing a greater range of opportunities for food and shelter, and hence more niches for fish species. The detection of vertical or near vertical regions of the seafloor can be easily achieved using modern sonar technologies (Jordan et al. 2005), and therefore mapping of such features should be considered at the planning stage for marine parks where protection of fish biodiversity is an objective.

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