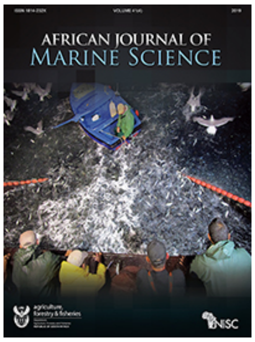

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Short communication

A tale of two habitats: preliminary comparison of fish abundance and diversity between saltmarsh- and mangrove-dominated creeks in the Nahoon Estuary, South Africa

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A preliminary assessment of abundance and richness of fishes utilising saltmarsh and mangrove habitats in the Nahoon Estuary, situated on the eastern coast of South Africa, was undertaken during July 2017. The structural composition and complexity of the two habitats were assessed and underwater cameras were used to provide preliminary insight into the use of the different habitats by fish taxa. The saltmarsh habitat had a higher fractal dimension and density of stems than the mangrove habitat. The species richness of fishes was slightly higher in the mangroves than in the saltmarsh, with nine and seven taxa recorded in the two habitats, respectively. The mean relative abundance of fishes was higher in the saltmarsh than in the mangroves and this was mainly due to the dominance of shoaling estuarine zooplanktivores in the saltmarsh. The mean relative abundance of estuary-associated marine fish species was, however, higher in the mangroves, which may be indicative of greater nursery use of this habitat by marine fishes. Although this is the first study to simultaneously assess the role of both saltmarsh and mangroves as fish habitat in estuaries of temperate South Africa, the findings are preliminary, and further study on seasonal differences in species assemblages is recommended.

Keywords: fish assemblage, habitat complexity, habitat use, pneumatophores, *Salicornia tegetaria*, temperate estuary, underwater video

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Introduction

Estuaries are important as feeding grounds (Elliot et al. 2007), areas of refugia and nursery grounds for fish and invertebrates (Beck et al. 2001; Dahlgren et al. 2006). The nursery provision of estuaries has been linked to the presence of one or more structured habitats (reviewed in Lefcheck et al. 2019), which provide protection from predation and thus increased survival and also substrate for food to grow (Heck et al. 2003). Structured habitats within estuaries include submersed aquatic vegetation, such as seagrasses, and emergent vegetation, such as saltmarshes, reeds, sedges and mangroves. Habitat structure is also thought to influence diversity, with more-complex habitats supporting greater species richness than simpler ones (Taniguchi and Tokeshi 2004).

Many studies have compared seagrass (submersed habitat) to emergent habitats, such as mangroves or saltmarshes. In a meta-analysis of 160 articles on the nursery provision of different structured habitats, seagrasses emerged as superior to all habitats, followed by mangroves (Lefcheck et al. 2019). Few studies have compared saltmarshes and mangroves. The distribution of these two intertidal habitats is determined by latitude (Little 2000) and, as such, there is little overlap. In temperate Australia, where there is some overlap in the distribution of these two habitats, studies have produced conflicting results. Bloomfield and Gillanders (2005) found that mangroves supported a greater diversity and abundance of fishes than saltmarshes, with both habitats supporting less species than seagrasses. Mazumder et al. (2005) found that, although species richness was higher in mangroves than in saltmarshes, fish density was higher in saltmarshes. These comparisons become more important as mangrove forests expand into saltmarsh habitats, as observed in countries such as Australia, the United States and South Africa (Saintilan et al. 2014; Cavanaugh et al. 2015). This expansion is a consequence of climate change and will alter the habitat complexity in the intertidal zone as the mat-forming saltmarsh species are replaced by trees with above-ground root systems.

In South Africa, saltmarshes, which typically occupy higher elevation zones, are largely replaced by mangrove forests, which dominate the lower elevation zones, in tropical latitudes and, as such, there is little overlap in their distribution (Rajkaran and Adams 2016). In the temperate Nahoon Estuary, which tends towards the southernmost limit of the distribution of mangroves, mangroves were introduced in 1969, allowing for a direct comparison between these two emergent habitats to determine whether habitat complexity and fish assemblage composition, diversity and abundance are similar between the two.

Materials and methods

Study area

The Nahoon Estuary (32°59′07.75″ S, 27°57′02.85″ E) is a permanently open estuary situated within the warm-temperate region of South Africa (Hoppe-Speer et al. 2015). This estuary is a microtidal system and is approximately 5 km in length (Geldenhuys et al. 2016). The white mangrove *Avicennia marina* is the dominant mangrove species and is present as a stand around the creek area (Figure 1). The black mangrove *Bruguiera gymnorrhiza* and red mangrove *Rhizophora mucronata* are represented by only a few trees, with the former having a larger population size. The saltmarsh area consists of a mixture of *Sporobolus virginicus*, *Salicornia tegetaria*, *Bassia diffusa*, and a freshwater species, *Nasturtium officinale* (Geldenhuys et al. 2016), with *S. tegetaria* the dominant saltmarsh species in the lower intertidal zone (Figure 1). The seagrass *Zostera capensis* (eelgrass) is present as a narrow band along the main channel of the estuary and in patches within the creek area.

Data collection and analysis

Sampling occurred at two sites in the lower reaches of the Nahoon Estuary (Figure 1): Creek One was lined predominantly by *S. tegetaria*, whereas *A. marina* lined the margins of Creek Two. Sampling took place over four spring tides in July 2017, to allow for the full exposure of the emergent habitats during spring lows and a relatively clear water column during spring highs.

To measure aboveground vegetation structure, habitats were assessed within the first 20 m of the emergent zone. Two line transects were set up in each habitat, positioned perpendicular to the shore. Each line transect measured 20 m in length, along which quadrats were placed at 1-m intervals to assess the aquatic vegetation present. Within the saltmarsh, a 0.25-m^2 quadrat was used to measure the density and height of the vegetation. Within the mangrove habitat, the number of stems was counted within a 16-m^2 quadrat, and a 0.25-m^2 quadrat was used to count and measure the height of pneumatophores.

Three binary (black and white) images from each habitat were used to calculate the fractal dimension (D) of the *A. marina* and *S. tegetaria* stands. Fractal dimension is a measure of shape complexity determined from the outlines of items within an image. Analysis was carried out in ImageJ 1.51 software, employing a box-counting grid method. The fractal dimension is calculated as the slope of log $N(s)$ plotted against log $(1/s)$, where s is the scale (magnification) used in the analysis, and $N(s)$ is the number of objects found at that scale (as in Leslie et al. 2017).

Fish abundance in the two different habitats was assessed using GoPro Hero3 Silver underwater video cameras. Cameras were deployed simultaneously at two sites situated approximately 2 m apart, within each habitat type. Each camera was attached, using cable ties, to a brown perspex pole, 1.5 m in length and marked with depth measurements. After attaching the cameras to the poles, each pole was inserted vertically into the sediment until the camera was under water. Each camera was positioned for a field of view that was parallel to the vegetation edge (as per the methods of Leslie et al. 2017). The two cameras within each habitat were deployed for 60 minutes during late afternoon, to coincide with high tide, resulting in a total of 16 deployments of 60 minutes each. As a result of faulty batteries only 14 hours of video footage were available, with a total of 7 hours of video footage per habitat.

Upon the deployment of each camera, salinity, water temperature (°C) and pH were recorded using a YSI multiparameter probe. Water samples were collected from the surface to assess the turbidity of the water column. Turbidity was measured in the laboratory using a Hach 2100Q turbidity meter. The tidal height was recorded for each deployment. Wilcoxon signed-rank tests or *t*-tests (depending on normality of the data) were used to test for differences in environmental parameters between habitats.

Underwater footage was assessed using EventMeasure 4.42 software. An acclimatisation period of 5 minutes was considered for each film. Each 60-minute deployment was then divided into four 15-minute slots (Becker et al. 2012). Whenever a fish entered the field of view, it was identified to the lowest taxonomic group possible. Individuals that could not be identified to species level were identified to family level, with all species from the families Mugilidae, Gobiidae and Soleidae only identified to family level. Small fishes (e.g. Cape silverside *Atherina breviceps* and estuarine round-herring *Gilchristella aestuaria*) that occurred in large schools were classified by trophic group as zooplanktivores. The maximum number of individuals for each taxon observed in a single frame (MaxN) during each 15-minute slot was counted, and a mean MaxN was calculated for each hour (Becker et al. 2012).

Square-root data transformation was applied to the height of plant structures. After meeting assumptions of normality using a Kolmogorov–Smirnov test, a Student's *t*-test was used to assess differences in the height of plant structures between the mangrove and saltmarsh. Two-way crossed analyses of similarities (ANOSIM) were applied to the fish-abundance data to determine differences between habitats and sampling days. Abundance data were fourth-root transformed and nonmetric multidimensional scaling (nMDS) was performed on these data to assess patterns in species composition. The fish species contributing to groupings evident in the nMDS were identified using similarity percentages analyses (SIMPER). Data were analysed in PRIMER 6.0.

Results

There were no significant differences between the two habitats in salinity (mangrove mean = 34.7 [SE 0.02], saltmarsh mean = 34.4 [SE 0.2]; $W = 37.5$, $p = 0.05$), water temperature (mangrove mean = 19.9 °C [SE 0.2], saltmarsh mean = 19.3 °C [SE 0.2]; $t = -2.48$, df = 21.96, $p = 0.05$) and turbidity (mangrove mean = 3.3 NTU [SE 0.6], saltmarsh mean = 4.3 NTU [SE 1.2]; $W = 68$, $p = 0.84$). The water column was, however, significantly

Figure 1: The lower reaches of the Nahoon Estuary, South Africa. Creek One was selected as the study site for the saltmarsh habitat, and Creek Two as the mangrove habitat. Image: Google Earth ©2018 Google, ©2018 AfriGIS (Pty) Ltd

deeper ($W = 16$, $p = 0.03$) in the mangrove habitat (mean depth = 117 cm [SE 5.3]) than in the saltmarsh habitat (mean depth = 95 cm [SE 3.8]).

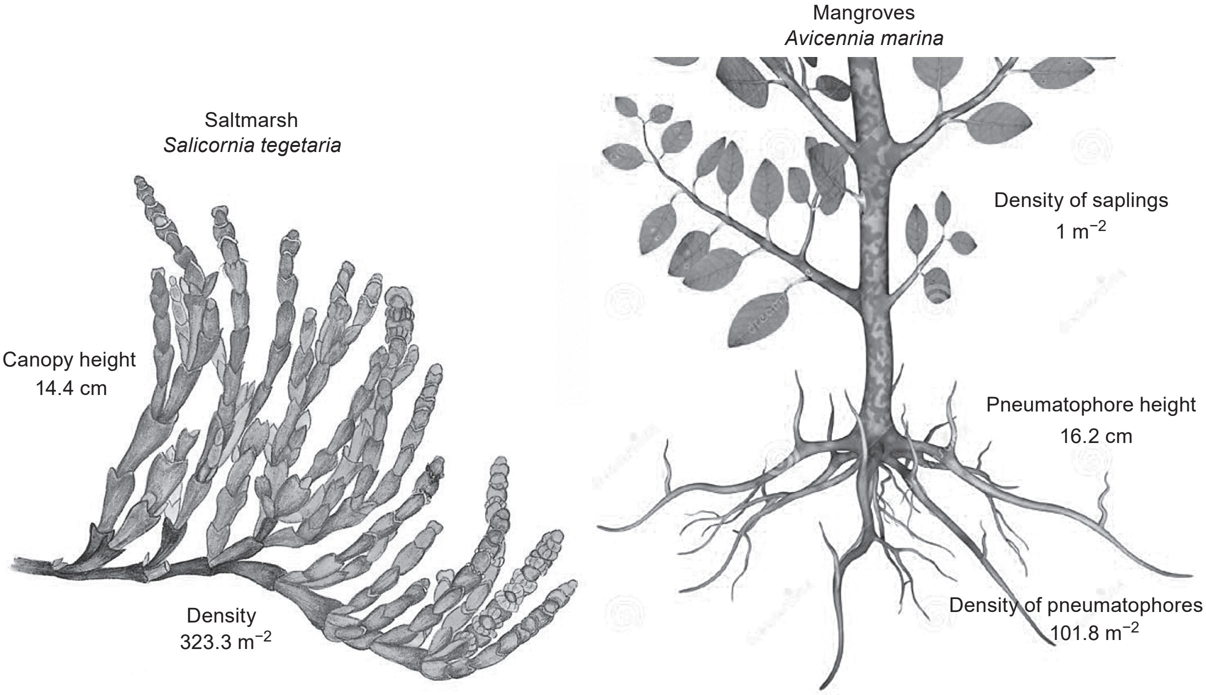
The height of vegetation within the saltmarsh habitat (14.4 cm [SE 0.3]) was significantly shorter than the height of the pneumatophores (16.2 cm [SE 0.3]) of *A. marina* present in the mangrove habitat ($t = 6.08$, df = 1 244, $p < 0.05$). The densities of the pneumatophores (101.8 m^{-2} [SE 5.3]) and the saplings (1.0 m^{-2} [SE 0.2]) were lower than the density of the saltmarsh vegetation (323.3 m^{-2} [SE 21.2]). As a measure of habitat complexity, the saltmarsh had a higher fractal dimension ($D = 1.93$) than the mangroves ($D = 1.88$) (Figure 2).

The species richness of fishes was slightly higher in the mangroves, with a total of nine recorded taxa, compared with seven taxa in the saltmarsh. The saltmarsh-dominated creek supported a higher mean relative abundance of fish than the mangrove-dominated creek, with a mean MaxN of 35 fish (SE 10) and 24 fish (SE 5) recorded in the respective habitats. The higher mean relative abundance of fishes in the saltmarsh relative to the mangrove creek was due to a higher abundance of Gobiidae and shoaling zooplanktivores, which are estuarine-resident species. Up to 90% of the fishes recorded in the saltmarsh were estuarine-resident species, whereas only 63% of the fishes in the mangroves were estuarine residents. Although the overall mean relative abundance of fishes was lower in the mangrove creek, the mean relative abundances of estuarine-associated marine species such as Cape stumpnose *Rhabdosargus holubi* (2.0 [SE 0.1]), mugilids (2.0 [SE 0.8]), unknown sparids (1.6 [SE 1.1]), evileye blaasop *Amblyrhynchotes honckenii* (0.8 [SE 0.2]) and estuarine bream *Acanthopagrus vagus* (0.3 [SE 0.1]) were higher in the mangrove creek (Table 1).

The nMDS ordination separated the fish community into two main groups based on habitat (Figure 3). Two-way crossed ANOSIM analysis showed a significant difference between the saltmarsh and mangrove fish assemblages ($R = 0.5$, $p < 0.05$) and not between sampling day ($R = 0.07$, $p > 0.05$). SIMPER analysis showed that the dissimilarity of fish assemblages between habitats was driven by four main taxa: zooplanktivores, *R. holubi*, *A. honckenii* and mugilids, which collectively accounted for 72% of the dissimilarity between these two assemblages. The relative abundance of zooplanktivores (mean MaxN = 90) was highest at the saltmarsh camera deployments, whereas the relative abundances of *A. honckenii*, mugilids, and particularly the sparid *R. holubi* were highest at the mangrove deployments (Table 1).

Discussion

The present study identifies the saltmarsh as the more complex habitat due to a higher aboveground density and fractal dimension. This is contrary to the general understanding that saltmarsh is a relatively less complex habitat than mangroves (Whitfield 2017), which might be due to the species of mangrove present at the Nahoon Estuary. The mangrove species *Avicennia marina* lacks prop roots like those of *Rhizophora mucronata*, hence



	Saltmarsh	Mangroves
Fractal dimension (measure of shape complexity)	1.93	1.88

Figure 2: Structural complexity of *Salicornia tegetaria* saltmarsh (image from Flora of Victoria, vicflora.rbg.vic.gov.au) and *Avicennia marina* mangrove (image from freeart.com), studied in the lower reach of Nahoon Estuary, South Africa

Table 1: Mean relative abundance (MaxN, mean of the 4 slots within each hour) and percentage contribution of the fish taxa recorded in two habitats of the lower reach of Nahoon Estuary, South Africa, in July 2017

Taxon	Mangrove		Saltmarsh	
	MaxN (SE)	%	MaxN (SE)	%
	Estuarine fishes			
Zooplanktivores	13.9 (4.8)	60	30.2 (10.1)	85
Gobiidae	0.8 (0.2)	3	1.7 (0.5)	5
	Marine fishes			
Sparidae	3.8 (1.8)	15	0.25 (0.1)	0.7
Rhabdosargus holubi	2.0 (0.8)	8	0.1 (0.1)	0.2
Acanthopagrus vagus	0.3 (0.1)	1	0	0.3
Unidentified sparids	1.6 (1.2)	6	0.1 (0.05)	0.2
Mugilidae	2.0 (0.8)	8	1.0 (0.5)	3
Tetraodontidae	0.8 (0.2)			
Amblyrhynchotes honckenii	0.8 (0.2)	3	0.2 (0.1)	0.6
Soleidae	0.07 (0.05)	0.3	0	0
Clinidae	0.04 (0.04)	0.1	0	0
	Unknown fishes			
Unidentified species	2.3 (0.7)	9	1.9 (0.5)	6

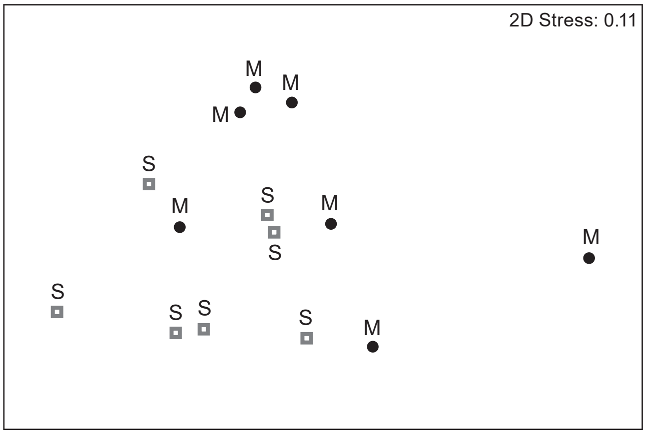


Figure 3: Nonmetric multidimensional scaling ordination (nMDS) of fish assemblages in saltmarsh (S) and mangroves (M) of the Nahoon Estuary, South Africa, over 4 days during July 2017

reducing its structural complexity. The pneumatophores of *A. marina* are thin, pencil-like structures. Ultimately, the density of saltmarsh vegetation allowed for an increased small-scale complexity (smaller spaces between leaves and shoots), whereas the spatial distribution of pneumatophores allowed for large-scale complexity (larger spaces between pneumatophores and saplings). Ellis and Bell (2004) found that denser habitats often provide more shelter and foraging sites to fishes and crustaceans.

Differences in the structural morphology of the macrophytes within these habitats influenced the use of the two habitats by fishes. Although the overall abundance of fish was higher in the saltmarsh creek than in the mangrove creek, these elevated densities were attributed to high numbers of one or two species of small-bodied shoaling zooplanktivores, which contributed over 90% to the mean relative abundance. Similar findings were found in North American estuaries when comparing saltmarsh creeks and seagrass beds, with high numbers of one or two species in the creeks resulting in higher overall fish densities in the creeks compared with the seagrass beds (Weinstein and Brooks 1983; Sogard and Able 1991). In contrast, in the mangrove creek, although zooplanktivores were still dominant (60%), fish species richness was higher, with more taxa recorded.

Taniguchi and Tokeshi (2004) found that body size of benthic freshwater invertebrates tended to decrease with increasing fractal structure. Habitats with greater fractal dimensions can give shelter to small individuals, with cavities serving as ‘refugia’ only if their sizes match the sizes of organisms. It has been suggested that saltmarsh is not an important feeding habitat for juvenile fishes in South African estuaries (Leslie et al. 2017; Whitfield 2017), but the complexity it provides affords small fishes shelter from large piscivorous fishes, particularly during spring high tides (Paterson and Whitfield 2000). This highlights the importance of saltmarsh as habitat for fishes in a mosaic of habitats found in estuaries, and is significant in the Nahoon Estuary, where the area of saltmarsh might be declining due to encroachment by mangrove (Geldenhuys et al. 2016).

Estuarine-associated marine fish species, which are predominantly found in estuaries as juveniles, comprised a higher proportion of the overall abundance in the mangrove creek compared with the saltmarsh creek, with members of the Sparidae and Mugilidae being particularly important. Mangrove creeks have been found to support high numbers of estuarine-associated marine species and this is associated with both shelter and food provision (reviewed in Whitfield 2017). Meynecke et al. (2008) found that the value of intertidal habitats (mangroves and saltmarshes) in providing protection from predation decreases for larger fishes and the provision of food becomes more important. This might be particularly true for mangrove habitats, which provide extensive food resources for fishes (Whitfield 2017).

Preliminary findings from this study indicate that fish species richness was slightly higher in the mangroves than in the saltmarsh and this was related to a higher number and abundance of estuary-associated marine species. This might be indicative of greater nursery use of mangrove habitat by marine fishes. The mean relative abundance of fishes was higher in the saltmarsh than the mangroves but this was mainly due to the dominance of shoaling estuarine zooplanktivores (*A. breviceps* and *G. aestuaria*) in the saltmarsh. The small-scale complexity provided by the saltmarsh probably affords small fish shelter from large piscivorous fishes. A longer-term study is recommended to determine whether there are seasonal differences in habitat use in the estuary.

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