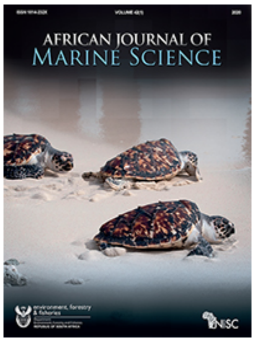


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Short Communication

# Mapping subtidal estuarine habitats with a remotely operated underwater vehicle (ROV)

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**Subtidal habitats have not yet been accounted for in habitat maps of South African estuaries. In this study, a novel method for mapping subtidal estuarine habitats, using a remotely operated underwater vehicle (ROV) piloted from a boat, was developed and tested in the Knysna Estuary. Video footage was recorded along 48 transects across the width of the estuary, and then reviewed to identify, classify and map habitats. Using the method developed in this study, 21 hours of footage was recorded over 15 days of sampling, and about 30 hours of post-processing was carried out to map an area exceeding 850 ha. This study has produced the first baseline dataset of subtidal habitats for a South African estuary. Additionally, the study revealed the previously unknown distribution of the invasive red seaweed *Asparagopsis taxiformis*, and the underestimation in previous studies of the estuary of area cover of eelgrass *Zostera capensis* by 130 ha.**

**Keywords:** *Asparagopsis taxiformis*, habitat maps, Knysna Estuary, southern Africa, submerged aquatic vegetation, underwater drone, *Zostera capensis*

## Introduction

Habitat maps present valuable information on the condition of ecosystems in a straightforward yet effective manner. In the coastal and marine environment habitat maps provide a basis for understanding and managing these ecosystems sustainably and holistically (Kurland and Woodby 2008). The supratidal and intertidal habitats of South African estuaries have been well mapped (Adams 2016; Adams et al. 2019), but subtidal habitats (i.e. those beneath the spring low-tide mark) have received little attention, and no baseline datasets for estuarine submerged aquatic vegetation (SAV) in the country have been produced. Baseline habitat maps are necessary to accurately monitor changes over time, thus avoiding 'shifting baseline fever' as described by Pauly (1995). Addressing this knowledge gap presents opportunities for expanding on the current knowledge of estuarine ecosystems, with many potential implications for their management.

The difficulty of accessing underwater areas presents a logistic challenge for mapping subtidal habitats. Remote sensing, particularly the use of acoustic techniques, is commonly used for this purpose, but ground-truthing through underwater videography is often required. This is expensive and not always feasible. Direct video surveys are an attractive alternative approach. Towed camera systems have been used in various subtidal habitat surveys (e.g. Grizzle et al. 2008; Davis et al. 2015), but the potential for using remotely operated underwater vehicles (ROVs) for SAV mapping has not yet been explored thoroughly. ROVs have proven to be useful tools in other aspects of coastal and marine science, including bathymetric, geologic and archaeological surveys (e.g. Bachmayer et al. 1998; Ludvigsen et al. 2007; White et al. 2010). However, such studies have made use of expensive ROVs that require extensive technical training to operate. The recent advent of affordable and accessible ROV technology presents an opportunity for cost-effective subtidal habitat mapping.

This study aimed to develop a practical method for mapping subtidal estuarine habitats with the use of an ROV, and then tested this method in the Knysna Estuary. The development of this method included the identification and classification of subtidal habitats. It is envisioned that this approach, once verified and standardised, can be used to inform future estuarine management.

## Materials and methods

The study took place in the Knysna Estuary (Western Cape Province, South Africa), stretching from the mouth to the White Bridge (Figure 1) and covering three of the four hydrographic regimes of the estuary (the bay, lagoon and

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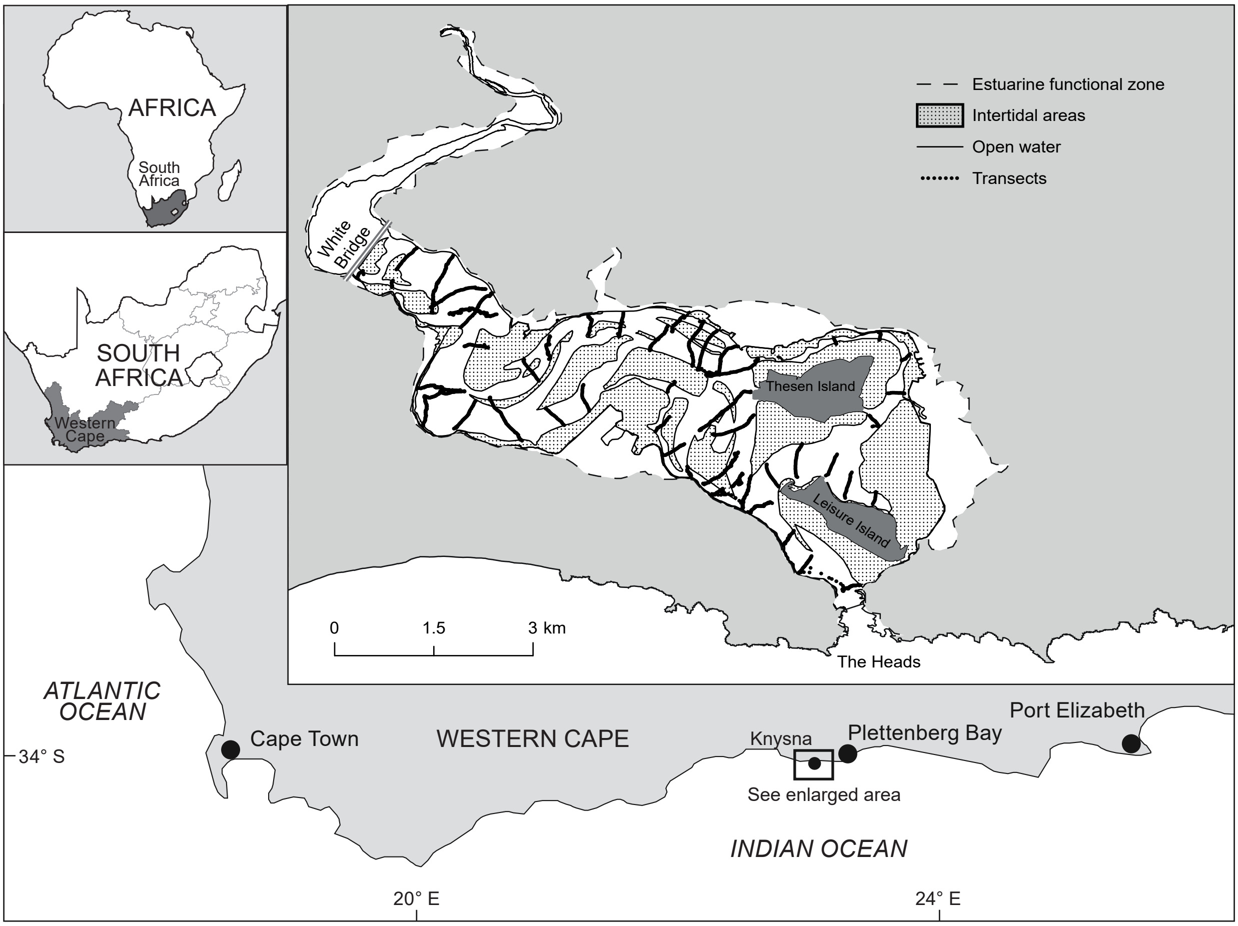


**Figure 1:** Location of the underwater video transects carried out in the study area of the Knysna Estuary, Western Cape Province, South Africa

Ashmead Channel) as described by Largier et al. (2000) and Switzer (2003). The mapping method presented below was adapted from Davis et al. (2015), but an ROV was used instead of a towed camera system and the layout of transects differed. This study made use of a Sofar Trident underwater drone (https://www.sofarocean.com/products/trident)—a comparatively inexpensive (US$1 695) ROV. The ROV was operated from a small boat and video footage was recorded along transects that spanned the width of the estuary and were spaced at approximately 500-m intervals (Figure 1). This ROV does not have an on-board global positioning system (GPS), so a GPS device (Garmin eTrex Touch 35) was used on the boat to record GPS tracks for each transect.

At the start of each transect, the location was logged on the GPS, and the ROV was deployed from the side of the boat and manoeuvred to near the bottom of the estuary. Once there, the ROV was steered along the transect while recording video footage. This was done as slowly as possible to capture clear footage. The boat followed the ROV closely to ensure that the GPS tracks being recorded were as accurate as possible. Given the need to move slowly, transects were conducted during high tide on calm days only, when wind speeds were less than 10 knots.

After the transects were completed, the video footage was reviewed, and the different subtidal habitats were identified and classified using the decision process illustrated in Figure 2. At the start of the footage for each transect, the habitat type was noted. Following this, the time on the video was recorded each time there was a change from one habitat type to another (i.e. at each habitat boundary). Habitat boundaries were identified as a discernible change in vegetation that continued for at least 10 seconds (as per O Masens, University of Newcastle, Australia, unpublished data[1]). As the ROV did not necessarily move at a constant speed at all times, some discretion was used when identifying habitat boundaries. The recorded times were then cross-referenced with the times of the GPS tracks to determine the coordinates of each habitat boundary.

Once the habitat boundaries along each transect were located, the subtidal habitats could be mapped. First, the coordinates of each habitat boundary along the transects were plotted as points in ArcMap 10.6 (ESRI 2018)

[1]Masens O. 2009. Methods of monitoring distribution and heterogeneity of subtidal reef habitats within the Port Stephens–Great Lakes Marine Park using underwater video surveillance with emphasis on urchin barrens. Honours thesis, University of Newcastle, Australia.

and overlaid on a satellite image of the estuary. Then, the habitat boundaries were plotted as line segments connecting points of the same type of habitat boundary. In shallow areas, where vegetated habitats were visible from satellite images, line segments were plotted over the visible habitat boundaries. Where habitat boundaries could not be distinguished from satellite images, and the plotted points displayed no clear pattern, it was assumed that habitats followed the shoreline. Any areas where habitat boundaries were still unclear at this point were revisited, and another transect was conducted there to provide additional video data at a finer scale. After plotting the habitat boundaries, the different habitats were plotted as polygons between them to produce the final habitat map.

## Results

A total of 48 video transects (Figure 1), covering an area of 856.4 ha (Table 1), were completed in 15 days, in June and July 2018. Roughly 21 hours of footage was captured. Eight distinct subtidal habitat types were identified in the Knysna Estuary (Figure 3). The area covered comprised nearly 74% vegetated habitats, almost 26% unvegetated habitats, and >1% sponges and soft corals (Table 1).

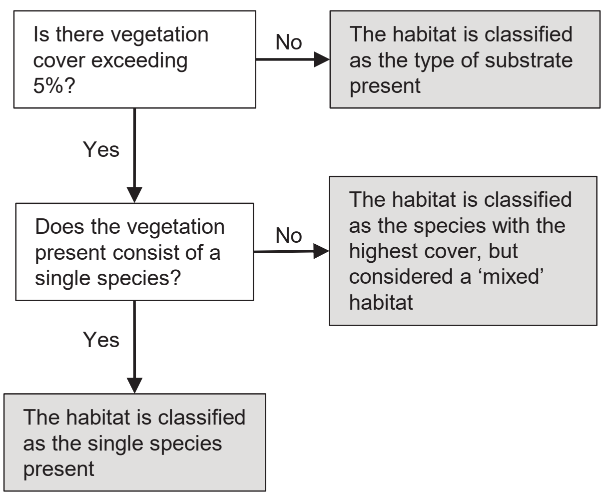


**Figure 2:** The decision tool used in this study for classifying subtidal habitats in the Knysna Estuary, South Africa

In the vegetated habitats, submerged macrophytes and macroalgae commonly occurred together, with these mixed habitats being classified based on the dominant species (Figure 3). *Zostera capensis* was the dominant macrophyte but was often found among macroalgae and sparse small patches of saltweed *Halophila ovalis*. Macroalgal habitats were dominated by the green seaweed *Caulerpa filiformis*, although the invasive red seaweed *Asparagopsis taxiformis* was widespread throughout.

*Asparagopsis taxiformis* covered an area of approximately 514.59 ha in the middle reaches of the estuary (Figure 4). This species was previously recorded only in the small-boat harbour at Leisure Island and in the canals of the Thesen Island marina (Figure 1) (Bolton et al. 2011; Claassens 2016).

## Discussion

This study has developed a method for mapping subtidal estuarine habitats with an ROV. A baseline subtidal habitat map for the Knysna Estuary has been produced—the first of its kind for a South African estuary. This method has numerous applications, including mapping the distribution of different habitats (Figure 3) or of a single species (Figure 4).

A number of useful insights have been provided by using this habitat-mapping method. Notably, the exclusion of subtidal areas in previous assessments (such as the National Biodiversity Assessment: van Niekerk et al. 2019) resulted in the area of vegetated habitat in South African estuaries being greatly underestimated or completely overlooked (instead, subtidal habitats were mostly mapped as 'open water'). This study revealed that the area cover of *Zostera capensis* in the Knysna Estuary has been underestimated by at least 130 ha since the last estimate (238 ha) by Schmidt (2013). Furthermore, other substantial habitats like *Caulerpa filiformis* have not been previously accounted for. Quantification of these overlooked habitats can provide useful information for estuarine conservation. For example, the area cover of subtidal vegetation can be applied to update the potential area of occupancy of the Endangered Knysna seahorse *Hippocampus capensis*, as stated in the IUCN assessment (Pollom 2017), to approximately 6.3 km$^2$ (in the Knysna Estuary alone). Additionally, the distribution of the invasive *Asparagopsis taxiformis* in the Knysna Estuary (Figure 4) was found to be much more widespread than the first record of the species in South Africa in 2009 (Bolton et al. 2011). This species is

**Table 1:** Area cover of the subtidal habitats within the study area of the Knysna Estuary, South Africa

| Description | Habitat | Area (ha) | |
|---|---|---|---|
| Unvegetated | Unvegetated sediment | 218.5 | 221.9 |
| | Natural rocky areas | 3.4 | |
| Submerged macrophytes | *Zostera capensis* | 130.4 | 316.0 |
| | *Zostera capensis* mixed | 185.6 | |
| Macroalgae | *Asparagopsis taxiformis* mixed | 41.3 | 315.9 |
| | *Caulerpa filiformis* | 12.3 | |
| | *Caulerpa filiformis* mixed | 262.3 | |
| Other | Sponge and soft corals | 2.6 | 2.6 |
| Total | | 856.4 | |

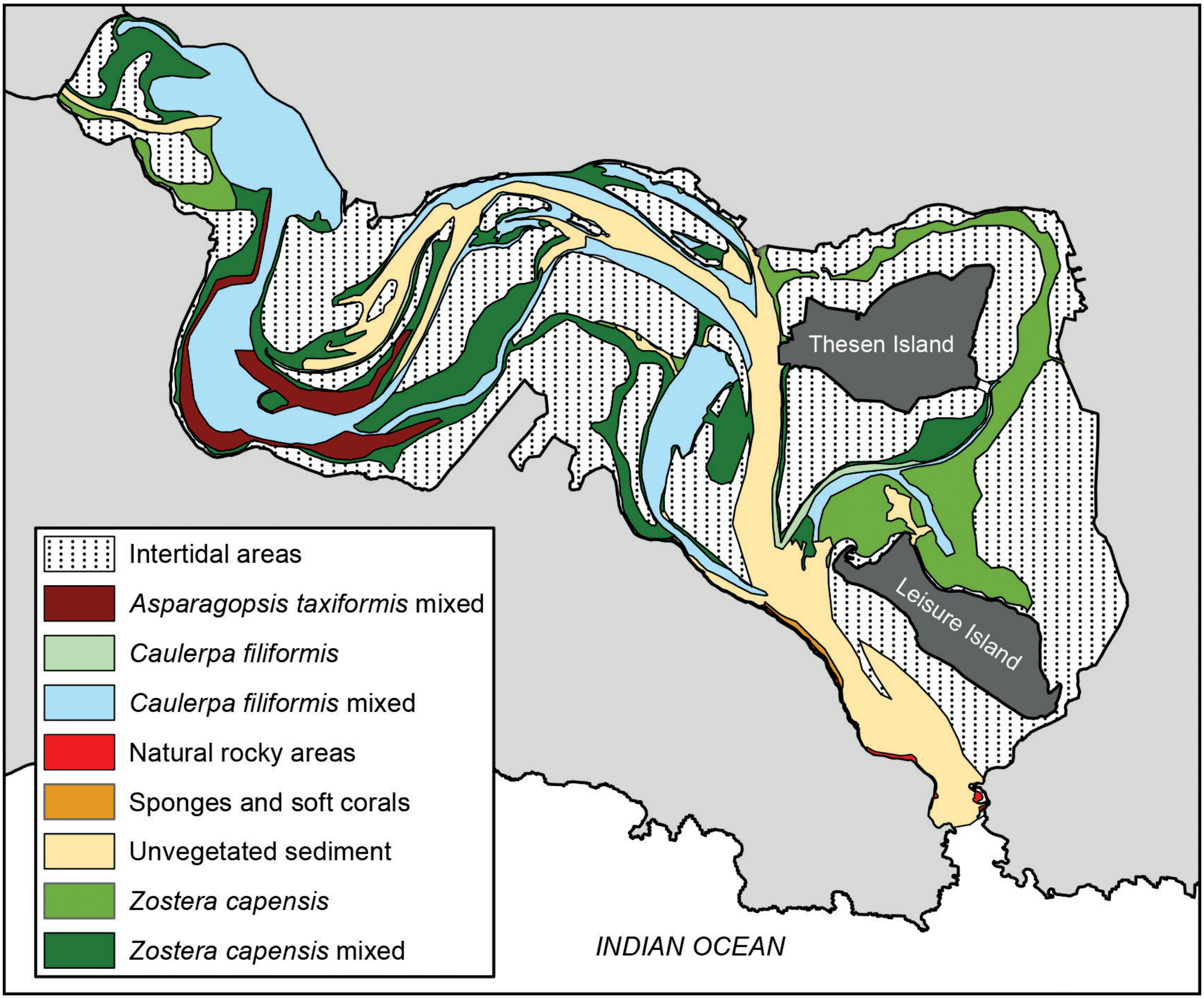


**Figure 3:** Distribution of subtidal habitats within the study area of Knysna Estuary, South Africa

an extremely successful invader (Williams and Smith 2007), and together with *C. filiformis*, another highly competitive alga (Zhang et al. 2014) abundant in the Knysna Estuary, it is likely placing strong competitive pressure on the estuary's important *Z. capensis* beds. There is much potential for this method to be applied to other estuaries for the development of baseline habitat maps to guide estuarine research and management into the future.

While testing the method developed here, some challenges were discovered. The greatest challenge was the absence of an onboard positioning system on the ROV used. Although ROVs with such systems are available, they are much more expensive (often costing more than US$100 000). This can be addressed relatively easily by piloting the ROV right next to the boat, but this can be problematic in deeper (>5 m) or turbid waters. Another limitation was the necessity for calm conditions (wind <10 knots and during high tides only) for performing the transects. However, subtidal habitat mapping with towed camera systems is similarly limited to calm conditions (Davis et al. 2015). Both of the aforementioned challenges are likely lessened in smaller systems, especially temporarily open/closed estuaries which are typically shallower (<2 m) and experience little tidal influence (Whitfield 1992). Another limitation was the inability to accurately estimate the percentage cover of vegetation. As the depth of the ROV varied, the field of view alone could not be used to calculate cover consistently. However, the ROV used allows for multiple payloads to be attached, including a small quadrat, and it is recommended that this is done if this method is applied to vegetation surveys. Other challenges that might arise could include limited battery life (although it was sufficient for the purposes of this study) and high boat traffic.

Despite these challenges, this method was found to be a feasible approach for mapping subtidal estuarine habitats. It is a cost- and time-efficient option for determining the composition and distribution of subtidal habitats.

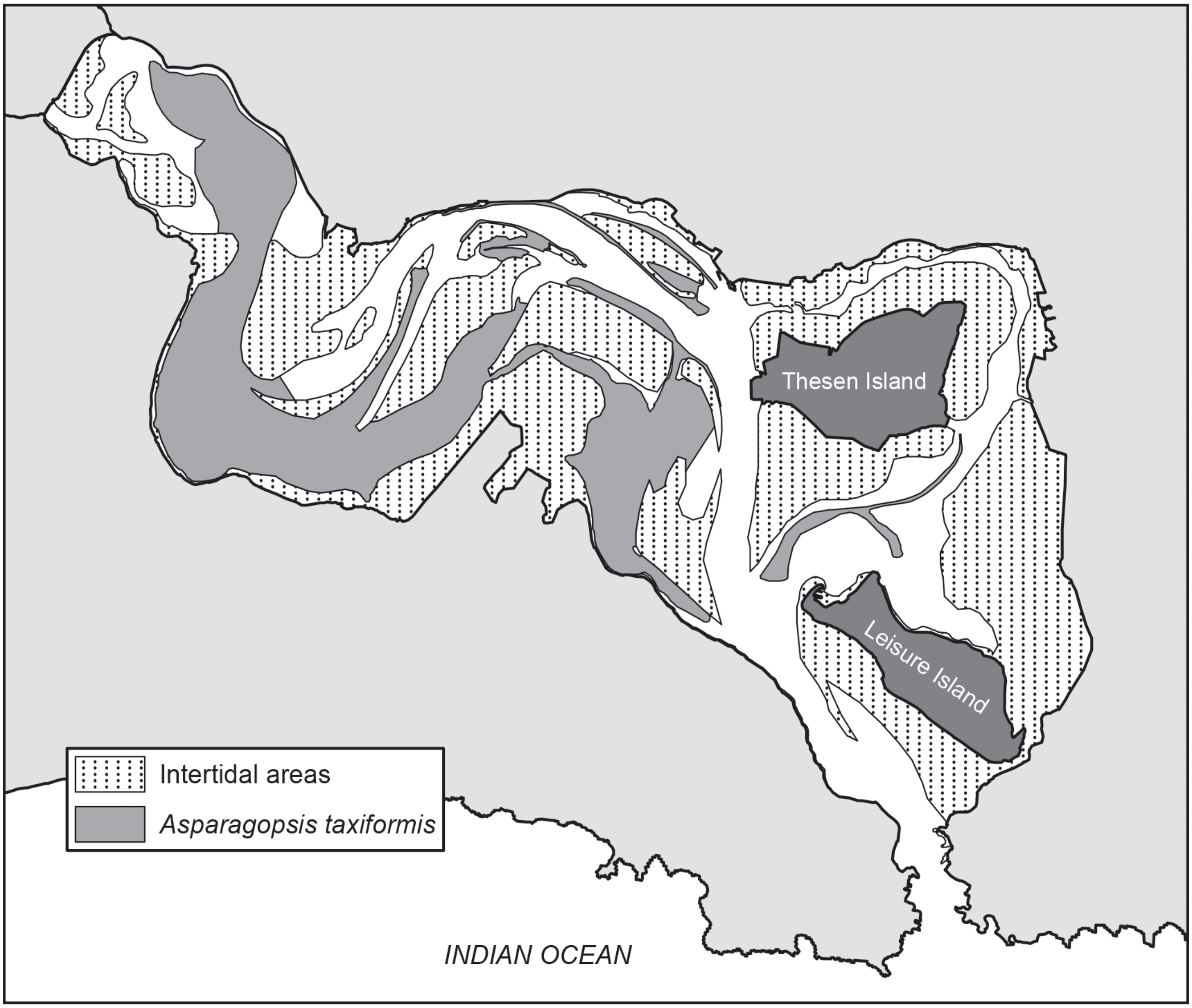


**Figure 4:** Distribution of *Asparagopsis taxiformis* in the Knysna Estuary, South Africa

Furthermore, it is flexible in that it can be applied at different spatial scales for fine- or broad-scale mapping and monitoring. Recommendations for the application of this method include creating baseline habitat maps (as done in this study), monitoring species of special concern, biodiversity, and other conservation issues such as invasive vegetation, identifying sensitive areas, and planning the zonation of activities in estuary management plans. There is much potential to expand on this method and apply it in other estuaries as a tool for providing previously unavailable information with implications for management and conservation.

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