Developing a Tool to Value Coastal Seascapes for Commercial Fisheries Production

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Executive Summary

Ecological Service Professionals (ESP), in association with the Moreton Bay Seafood Industry Association (MBSIA), developed a tool to assess the value of coastal seascapes (i.e. the combination of different marine habitats along the coast) to commercial fisheries (tunnel netting) adjacent to the Port of Brisbane.

This report has been prepared for the Port of Brisbane Pty Ltd (PBPL), and outlines the assessment methodology and the value of coastal seascapes to commercial fisheries adjacent to the Port of Brisbane. This information will be critical to identify and protect coastal habitat, and possibly enhance the remaining valuable natural resources on which commercial fisheries production in the area depends. Increased understanding of the links between fisheries productivity and coastal habitats, will assist in developing sound management actions to maintain or enhance fisheries productivity in the coastal habitats surrounding the Port of Brisbane, while enabling targeted, informed and sustainable expansion of essential Port facilities into the future.

We reviewed 5 years of commercial catch data from one commercial operator for the fishing ground. Intertidal habitat was mapped using existing data supplemented by georeferenced data collected in the field. This detailed habitat map was used as the basis for a spatial analysis and statistical modelling of key environmental parameters that might contribute to differences in the: composition of the catch assemblage; catch of individual species; catch per unit effort (CPUE); and average catch value.

The intertidal areas around Fisherman Islands and Whyte Island are productive commercial fishing grounds that support the catch of commercial sized fish species (average annual catch of approximately 18 tonnes per year from tunnel net fishery around the Port). Fishes of commercial significance move into the area from elsewhere in Moreton Bay, with some species occurring throughout the year, and others becoming more abundant at certain times of the year based on season and previous year recruitment patterns. Fisheries that target migratory species, such as those near Fisherman and Whyte islands, create a challenge for whole of fisheries management, as actions that are implemented in certain areas can have unexpected outcomes elsewhere.

A key attribute of the use of intertidal habitat for commercial sized fish in the study area is whether the habitat can be accessed at high tide, the length of time the habitat is submerged for, and if there is sufficient depth for commercial-sized fish to move around and forage. Furthermore, the extent of seagrass beds and their and proximity to other structured habitat such as mangroves in the study area was particularly important for species that consistently yielded the greatest wholesale value (e.g. flathead and bream). The areas at the back of the mangrove forest were not important for commercial fisheries as they are not inundated regularly, relative to the mangrove fringe. These areas are likely to provide other important ecological functions such as nutrient cycling, coastal protection, and provide important foraging habitat to juvenile fish, crustaceans and shorebirds, an assessment of which was beyond the scope of this project.

This study shows that seagrass attributes are more important than mangrove attributes for predicting the type and size of commercial tunnel net catches, and therefore the value of commercial finfish fisheries in different areas, adjacent to the Port of Brisbane. An understanding of the requirements of the netting operation is also important, as particular habitat types are unsuitable for tunnel net fishing. Other environmental attributes might be important for fisheries that target prawns or crabs. This work also shows that the value of seascapes to commercial fisheries must be considered at a local scale, because some types of habitat mosaics are of greater significance for commercial fish catches than others. Further work is required to determine how variation in the composition of coastal seascapes effects the calculation of biodiversity offsets, including “like for like” proposals (FHMOP005.2 Marine Fisheries Habitat Offset Policy, Fisheries Queensland, QLD Government), as fish assemblages from specific habitats, and the economic value of commercial fishes that depend on those habitats, vary with differences in the specific habitat characteristics of coastal seascapes.

1 Introduction

Ecological Service Professionals (ESP), in association with the Moreton Bay Seafood Industry Association (MBSIA), developed a tool to assess the value of coastal seascapes (i.e. the combination of different marine habitats along the coast) to commercial fisheries adjacent to the Port of Brisbane. This report has been prepared for the Port of Brisbane Pty Ltd (PBPL), and outlines the assessment methodology and valuation of coastal seascapes adjacent to the Port of Brisbane to commercial fisheries (tunnel netting).

1.1 Background

Coastal wetlands including mangroves, seagrass and saltmarsh, have a broadly important ecological function as fisheries habitat, through provision of nursery habitat, protection from predators and contributing to food webs, among other functions (Nagelkerken et al. 2008). These intertidal habitats are also important for a range of species other than fish such as migratory shorebirds, waterbirds and crustaceans (Manson et al. 2005; Skilleter et al 2005; Zharikov et al. 2005).

The MBSIA Board and local fishermen have identified a reduction in fisheries productivity and diversity in Moreton Bay, which they suspect is due to degradation of habitats from increased coastal urbanisation and runoff. Members of MBSIA believe that the general decline in productivity may also be due to dynamic natural variations in species-specific productivity driven by longer-term climatic changes and responses to extreme weather events such as floods. It is not clear which features of coastal seascapes are essential in sustaining fisheries productivity (i.e. the growth and subsequent capture of adult fishes), especially at the scale over which coastal developments occur (i.e. 100s of metres to kilometres), and therefore we do not know what coastal features are the most important for conserving or restoring the function and productivity of commercial fisheries (Sheaves 2009; Nagelkerken et al. 2015; Olds et al. 2016).

As a nation deriving a large proportion of the economy from maritime areas, Australia has a vested interest in sustainable development along our coastlines, particularly around our ports to secure international trade and to grow our economy. Responsible management of our coastal resources incorporates sustainable development principles, such as preserving areas that have high natural amenity and those that support the viability and productivity of coastal fisheries. The work proposed here provides a critical tool for developing a clear and consistent methodology to assess the value of coastal seascapes for commercial fisheries production to inform coastal developments into the future. The tool that ESP and MBSIA have developed will help to improve understanding of the links between the coastal seascape (particularly key habitat features of coastal wetlands) and fisheries productivity, and allow a valuation of the coastal seascape surrounding the Port of Brisbane for commercial fisheries production. This information will be critical to help managers identify and protect essential fisheries habitat, and possibly enhance the remaining valuable natural resources on which commercial fisheries production in the area depends. Increased understanding of the links between fisheries productivity and coastal habitats through this project, will assist in developing sound management actions to maintain or enhance fisheries productivity in the coastal habitats surrounding the Port of Brisbane, while enabling targeted, informed and sustainable expansion of essential Port facilities into the future.

Moreton Bay is a highly productive embayment, providing a large proportion of the commercial seafood caught in Queensland. There are 21 tunnel net licences in Moreton Bay, who operate throughout the year, although catch effort peaks in late summer, autumn and early winter. The inshore net fishery allows for both tunnel and mesh nets, with the use of tunnel nets being restricted in Queensland to Moreton Bay and Great Sandy Strait. There have been major changes in the fishery over the past 20 years, including a reduction in the total number of licenced fishers, implementation of a code of best practice and designation of the fishery with ecologically sustainable accreditation under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

1.2 Objective

The key objective of this project is to establish a tool to assess the value of coastal wetlands to commercial fisheries adjacent to the Port of Brisbane. This tool includes a detailed methodology (including key assessment criteria) to survey the ecological features of coastal seascapes, and quantify their value for commercial fisheries productivity. The tool was derived and validated by:

1. Establishing a scientifically rigorous methodology for assessing the value of coastal wetlands around the Port of Brisbane for commercial fisheries production;
2. Mapping the value of the coastal seascape surrounding the Port of Brisbane, assessing the identified habitat parameters around each tunnel net shot location (i.e. in buffers with an 800m radius), and analysing how fisheries catches relate to the spatial distribution of key habitat attributes; and
3. Mapping and ranking the most important coastal wetland areas surrounding the Port of Brisbane for fisheries production.

2 Method for Assessing the Value of Coastal Seascapes for Fisheries

The method used to assess the value of coastal seascapes to fisheries is summarised below (Figure 1).

Step 1 (see Section 3.1)

Identify the fishery, key fisheries species and their habitat requirements, including consideration of seascapes.

Step 2 (see Section 3.2)

Review existing information to determine if there are key habitat attributes known to contribute to increasing abundance and diversity of commercial fisheries species.

Step 3 (see Section 3.3)

Complete a gap analysis of the available data for the area and fill any gaps where possible. This may require rationalisation where data is unavailable.

Step 4 (see Section 3.4)

Collect field data to fill identified gaps in habitat use and fish catch data. Use predictive modelling if data collection is not possible. Spatial analysis of various habitat parameters relative to known catch data.

Step 5 (see Section 3.5)

Prediction of habitat with greatest value based on the results spatial analysis.

Step 6 (to be completed in a future assessment)

Revision of key habitat categories and determine the predictive power of spatial model to assess catch effectiveness/composition of existing grids and elsewhere.

Figure 1 Steps to identifying the value of coastal seascapes to commercial fisheries

3 Desktop Review and Gap Analysis

3.1 Identify Habitat for Key Commercial Fish Species

We completed a literature review and used expert opinion of fishermen to determine key habitat parameters essential for fisheries productivity and habitat preferences for ten commercially important fish species caught around the Port of Brisbane. Our literature review focussed on known technical information on fish-habitat relationships captured in two key reviews for the Fisheries Research and Development Corporation (FRDC) (Cappo et al. 1999 and subsequent detailed review completed by Sheaves et al. 2012) and the literature contained within, supplemented by additional scientific reports and articles where suitable information existed.

The following species, which comprise the typical catch of the local fishery, were assessed:

- yellowfin bream (*Acanthopagrus australis*)
- dusky and bar-tail flathead (*Platycephalus fuscus & P. indicus*)
- river and snub-nosed garfish (*Hyporhamphus regularis; Arrhamphus sclerolepis*)
- sea mullet (*Mugil cephalus*)
- tailor (*Pomatomus saltatrix*)
- black rabbitfish (black trevally) (*Siganus fuscescens*)
- butterfish (striped scat) (*Selenotoca multifasciata*), and
- sand whiting (*Sillago ciliata & S. analis*).

The habitat preferences of the above species are summarised in Table 1. Generic attributes based on the average size of fish caught, trophic level and other information on the basic biology of the species were used where parameters were not known. Trophic group was determined based on primary food sources and standard classifications (Beumer & Halliday 1991 & Elliott et al. 2007).

Specific information for habitat preference and use by adult fishes is limited. Most information comes from existing catch information or data on the abundance of juveniles. Patterns of movement among different habitats within the mosaic are unknown, which is a limitation of the current assessment (Section 5.1). Increasing knowledge of the spatial and temporal utilisation and movement of adults will further refine our understanding of the importance of different habitat types and spatial arrangements.

Table 1 Habitat preferences of fisheries species caught around the Port of Brisbane

Species	Adult Habitat	Trophic group	Primary forage groups	Home Range/ Movement	References
yellowfin bream (*Acanthopagrus australis*)	Multiple habitat types including seagrass & mangroves (dependent on seagrass in juvenile phase). Mangroves and seagrass in close proximity / sand / mud	Intermediate Carnivore	Molluscs / decapods / polychaetes / fish	Reefs within 250m of seagrass & mangroves (Olds et al 2014); few move >100m for extended periods (Sheaves 1993)	Weng 1990; Cappo et al 1998; Pittman et al 2004; Hadwen et al 2007; Meynecke et al 2008; Sheaves et al 2012; Melville & Connolly 2003
dusky flathead (*Platycephalus fuscus*)	Mangroves / mangrove channels / mangrove fringe / seagrass / Sand / Mud	Predator	Decapods / small fish	Entrance to estuaries and adjacent coastal waters (Gray & Barnes 2008) Typically within estuary but can move between 10 – 280km (Gray & Barnes 2015)	Weng 1990; Hadwen et al 2007; Sheaves et al 2012; Gray & Barnes 2008; Gray & Barnes 2015
bar-tail flathead (*Platycephalus indicus)*	Mangroves / mangrove channels	Predator	Decapods / small fish	N/A; likely to be similar to dusky flathead requirements	Halliday & Young 1996; Sheaves et al 2012
river garfish (*Hyporhamphus regularis ardelio*)	Estuaries	Planktivore / omnivore	Zooplankton / seagrass	Unknown	Gamon 2011
snub-nosed garfish (*Arrhamphus sclerolepis*)	Estuaries	Planktivore / omnivore	Plankton / seagrass	Unknown	Bray 2011; Waltham & Connolly 2006
sea mullet (*Mugil cephalus)*	Mangrove channels / seagrass	Detritivore	Algae / sediment / particulate matter	Relatively wide ranging from freshwater and estuaries as juveniles to ocean beaches	Meynecke et al. 2008; Sheaves et al. 2012;
tailor (*Pomatomus saltatrix)*	Seagrass, bare mud & sand	Predator	Small fish	Relatively wide ranging from estuaries as juveniles to ocean beaches 10-15km plus (Morton et al. 1993)	Meynecke et al 2008; Gillanders et al. 2003; Morton et al. 1993

Species	Adult Habitat	Trophic group	Primary forage groups	Home Range/ Movement	References
white spot rabbitfish (black trevally) (*Siganus fuscescens*)	Macroalgal reefs / seagrass	herbivore	Macroalgae & seagrass	Reefs within 250 m of seagrass & mangroves (Olds et al. 2014)	Bray 2011; Olds et al. 2014
butterfish (striped scat) (*Selenotoca multifasciata)*	Mangrove channels / undefined	Omnivore	Benthic invertebrates & detritus	Unknown	Gomon 2011
sand whiting (*Sillago ciliata*)	Wide range of habitat types; mangroves / sand / mud	Intermediate carnivore	Polychaetes / crustaceans	Unknown	Pittman et al 2004; Hadwen et al 2007; Meynecke et al 2008; Sheaves et al 2012; Melville & Connolly 2003; Weng 1983

3.2 Identifying Key Seascape Habitat Parameters

We reviewed scientific and grey literature to determine the key habitat parameters that are known to be important to estuarine and coastal habitat for nekton communities. Understanding how the spatial arrangement of habitats in coastal seascapes effects the distribution and abundance and marine animals is a key focus for research in the emerging field of seascape ecology (Pittman et al. 2004; Wedding et al. 2011). The spatial arrangement of habitats in coastal seascapes are known to affect the composition of fisheries species at a variety of different spatial scales (Sheaves 2009; Bostrom et al. 2011; Nagelkerken et al. 2015), and the abundance and diversity of fishes is typically associated with the most diverse and heterogeneous seascape types (Pittman et al. 2004). For example, species richness is higher in nekton communities when mangroves are proximal to continuous seagrass, when compared with mangroves adjacent to patchy seagrass or bare/unvegetated substrate (Pittman et al. 2004; Skilleter et al. 2005).

A variety of habitat parameters have been used to describe the spatial arrangement, characteristics and condition of habitat patches in coastal seascapes (Pittman et al. 2004; Meynecke et al. 2008; Wedding et al 2011). The different parameters we used in the spatial analysis of seascape grids in this study are included in Table 2.

Table 2 Seascape habitat parameters that are likely to be relevant to the Port of Brisbane

Habitat Parameter	Purpose	Measure	Predicted Response	Sources
Seascape Characteristics				
Habitat diversity / patch richness	A measure of seascape complexity	Diversity of different habitat types per seascape unit (perhaps ranked depending on proportion of different habitats).	Increasing habitat diversity = greater species diversity and abundance	Pittman et al. 2004; Wedding et al. 2011
Proximity between vegetated habitat	Diversity of habitat mosaic in seascape grid	Distance from mangrove to intertidal seagrass	Decreasing distance between vegetated habitat = increased abundance	Skilleter et al 2005; Olds et al. 2012
Proximity to subtidal habitat	Connectivity to nearshore subtidal habitat / exposure	Average minimum distance (average of 10 closest points) to subtidal habitat.	Decreasing distance between vegetated habitat = increased abundance. Likely to be correlated with proximity to channel habitat	McIvor & Odum 1988
Proximity to drainage channel/creek	Determine presence and proximity to pathway to subtidal habitat / funnelling	Minimum distance to drainage feature/creek; density of drainage features in patch buffer	Increased diversity with increased proximity to channel habitat	McIvor & Odum 1988; Sheaves 1996; Hindell & Jenkins 2005, Smith & Hindell 2005; Johnson & Sheaves 2007
Mean water depth	Water depth significantly correlated with number of fish species within mangroves (Pittman et al 2004). Abundance of fish can be influenced by water depth with and without vegetated habitat (Travers & Potter 2002)	Average water depth at high tide in each buffer area	Increased diversity and catch with increasing depth in mangroves	Wedding et al. 2011; Pittman et al. 2004; Travers & Potter 2002
Intertidal slope	Measure of average depth to width of intertidal area	minimum distance from high to low water mark from buffer centroid	Likely to be correlated with distance to subtidal/channel	Wedding et al. 2011

Habitat Parameter	Purpose	Measure	Predicted Response	Sources
Habitat Area (as proportion of total intertidal habitat per area)	The area of habitat available can influence the number of species and abundance Two studies reporting the link between mangrove area and fisheries productivity from SE Asia (Paw & Chua 1991; de Graaf & Xuan 1998 cited in Manson et al 2005) Although linear extent of mangroves may be a better indicator particularly for prawns (Manson et al. 2005).	% of total Area occupied by each habitat type; Patch area (m2) / total area for each habitat type		Pittman et al. 2004; Manson et al. 2005
Length of connected vegetated edge (i.e. between seagrass and mangroves)	measure of the degree of continuity among habitat types in each seascape unit	Total length of shared edge between different habitat types per buffer area		Meynecke et al. 2008
Length connected edge to area ratio	Proportion of edge habitat available	Length of shared edge between habitat types divided by total edge length in each area		Meynecke et al. 2008
Habitat perimeter/water interface	Influence ecological edge effects and amount of habitat available to nekton on rising tide	Seaward habitat perimeter for different habitat types	Increasing length of habitat perimeter exposed to water provides greater total habitat presented to fish	
Habitat patch shape (length/width)	compare patch shape metrics such as narrow/wide relative to overall size	Fractal dimension of patches within buffer area; perimeter to area ratio for mangroves and seagrass. Determined using Patch Analyst		Mason et al. 2003; Wedding et al. 2011; Rempel et al. 2012
Habitat Characteristics				
Vegetative/habitat structural complexity	Complexity of vegetation structure important for fish diversity (species richness and abundance increases in dense long seagrass); In mangrove forests, structural	Average patch vegetative structure such as leaf length, % coverage in seagrass, shoot density, pneumatophore density and	Increased structural complexity = greater diversity of fish species in seagrass; Moderate structural complexity in	Bell & Westoby 1986; Connolly & Butler 1996; Pittman et al 2004; Travers & Potter 2002; Laegdsgaard & Johnson

Habitat Parameter	Purpose	Measure	Predicted Response	Sources
	complexity is important (Laegdsgaard & Johnson 2001); however, high structural complexity can hinder the refuge function of habitat as it reduces fish movement (Ronnback et al. 1999).	height; tree density in mangroves; light intensity. (Measured as structural rugosity in reefs).	mangroves = maximises diversity (curvilinear response)	2001; Ronnback et al. 1999
Substrate type	Proportion and total area of each substrate type shown to influence diversity of different fish species	% mud; % sand; % gravel; % rock; % vegetated (split into mangroves and seagrass)	Species specific responses based on habitat preference	Pittman et al 2004

3.3 Gap Analysis & Existing Data

3.3.1 Fish Catch Characteristics

Numerous parameters have been used to describe commercial fish catches from estuarine areas, although most statistics are derived from catch grids that are often at a very broad scale (Manson et al. 2003; Meynecke et al 2008). We used fishing logs from a commercial tunnel net operation within the survey area, which provide data on the location and catch of individual tunnel net shots. These shots are typically up to 1.6 km in total length (800 m per wing) and are selective for the fish species previously described. Logged data from the past 5 years (2010–2015) were used to derive average values for each fished area (additional years were assessed, however, due to changes in gear type and effort they were not comparable). Fishing parameters used for comparison of different habitat areas include:

- Total annual catch per area;
- Commercial wholesale value ($AUD) to fishers;
- Average nominal CPUE for total assemblage and individual species (kg/net day); and,
- Average weight of all fish and individual species caught per shot for each area.

Spatial differences in the composition of catches (i.e. type of fish species and total weight) from each of the shot locations were assessed using a 2 factor ANOSIM, with shot locations and years as factors. Data were square root transformed prior to converting to a Bray-Curtis similarity matrix. The species contributing to any differences were assessed using SIMPER analysis. Differences in the composition of catches were compared using centroid values among shot locations and visualised using nMDS. The average value, average catch weight and catch per unit effort (shot day) were overlayed on the nMDS ordination using bubble plots with the relative size of each bubble corresponding to the value.

3.3.2 Seascape Habitat Data

A gap analysis was completed to determine the availability of seascape and habitat data for the study area; data was acquired from numerous sources, but this the review primarily focussed on data that was collected as part of the environmental monitoring program at the Port of Brisbane. A variety of seascape parameters (including landscape composition, habitat patch characteristics and habitat condition; Table 3) can be described from spatial habitat data collected in previous monitoring reports from the Port of Brisbane. Additional data on bathymetry and sediment composition was sourced from Maritime Safety Queensland (MSQ) and from field assessments. This was used to create a detailed habitat map for the area, which illustrates the distribution and ecological attributes of all habitat types.

Table 3 Available data on the distribution and ecological characteristics of marine habitats near the Port of Brisbane

Habitat	Spatial Layer Available	Characteristics of biotic habitat	Physical characteristics	Date completed	Reference
Mangrove	Yes	Species composition; condition	Sediment pollutants; Pore water salinity	1993; 2000; 2002; 2006; 2008; 2010; 2012; 2014	BMT WBM 2014
Seagrass	Yes	Species composition; % cover (interpolated from point source data). Limited to areas north of mangroves on Fisherman Islands		2003; 2006; 2010; 2013; 2014	BMT WBM 2003; 2006; 2010; 2013; 2015a
Saltmarsh/ claypan	included with mangrove layer	None			BMT WBM 2014
Macroalgae	included with seagrass layer	% cover (interpolated from point source data)		2013; 2015	BMT WBM 2013; 2015a
Sand	Moreton Bay Broad scale habitats 2008	–	limited information available at broad scale – Presence / Absence	2007	DERM 2008
Mud	Moreton Bay Broad scale habitats 2008	–	limited information available at broad scale – Presence / Absence	2007	DERM 2008
Rubble	Moreton Bay Broad scale habitats 2008	–	limited information available at broad scale – Presence / Absence	2007	DERM 2008
Shallow subtidal	Only for seagrass and corals; Moreton Bay Broad scale habitats	Presence absence for coral; % cover and species composition for seagrass		2004; 2008; 2015	BMT WBM 2015a; Moreton Bay Broad scale habitats 2008

	2008			
Sediment composition	Yes	Composition of sediment grain sizes	2015	BMT WBM 2015b
Bathymetry	Yes	Point source depth data for subtidal channels and parts of intertidal		Marine Safety Queensland; Queensland Government 2016

3.3.3 Field Assessment to Fill Spatial Data Gaps

A total area of 2180 ha of intertidal habitat was assessed (Figure 2) to characterise intertidal and subtidal marine habitats near the Port of Brisbane; this encompassed field assessments at a total of 185 points. Additional bathymetric data was collected using direct measurement at each of the 185 points, to fill gaps in the bathymetric data provided by MSQ, which were particularly prevalent in shallow intertidal areas. The additional bathymetric data collected was corrected for tide height to Lowest Astronomical Tide (LAT) using actual tidal heights and time measured at the Port of Brisbane provided by MSQ.

Assessments of habitat type in mangroves forests were completed at 95 points within the area using a variety of existing methods supplemented with additional measures outlined below (Table 2 & Table 8).

Field assessments for other intertidal habitats included: (1) characterising the type of benthic habitat by visual assessment; and (2) collection of georeferenced images of habitat type and condition using drop cameras (following methods adapted from Roelfsema & Phinn 2009), for all common habitat types in Moreton Bay (Zharikov et al. 2005). Seagrass habitat was assessed at 90 points across the survey area. At each point the percent coverage of seagrass (using 50 points overlayed on each georeferenced image in Coral Point Count; Kohler 2006) and maximum canopy height was measured from five blades collected using a grapple. Additional information was recorded at each point including whether seagrass was continuous or patchy, the seagrass species present, condition of seagrass, coverage of epiphytic algae, % coverage of macroalgae and presence of *Lyngbya*. Several transects were completed perpendicular to the shore to identify the transition between habitat types (i.e. habitat edges between mud and seagrass). This habitat data was then used to map the distribution of marine habitats in the study areas using ESRI ArcGIS (with the aid of interpretation of aerial imagery). The distribution and cover of seagrass was mapped using inverse distance weighted interpolation in ESRI ArcGIS.

Producing maps of sufficient detail at suitable spatial resolution is an essential part of any spatial habitat assessment. In this case, we needed to update the habitat maps for seagrass, mangroves and unvegetated flats to have for sufficient spatial overlap with the extent of fishing effort in the local area, suitable consistency in methods and sufficient differentiation among the various habitat parameters used in the analysis.

3.4 Spatial Assessment and Correlation with Catch Data

To determine the extent to which the composition of commercial fish catches was correlated with changes in the distribution and condition of marine habitats in the coastal seascape, we first calculated seascape metrics and habitat characteristics (Table 2) in buffers of 500 m and 800 m around each shot location (Figure 3) using the ET Geowizard tools in ESRI ArcGIS. The scale used for the spatial assessment is consistent with the size of net shot and with our understanding of the potential daily home range of most fish caught in the fishery (Faunce & Searfy 2006). Correlation between seascape metrics and fish catches was tested using a suite of multivariate and univariate models (see Section 3.5).

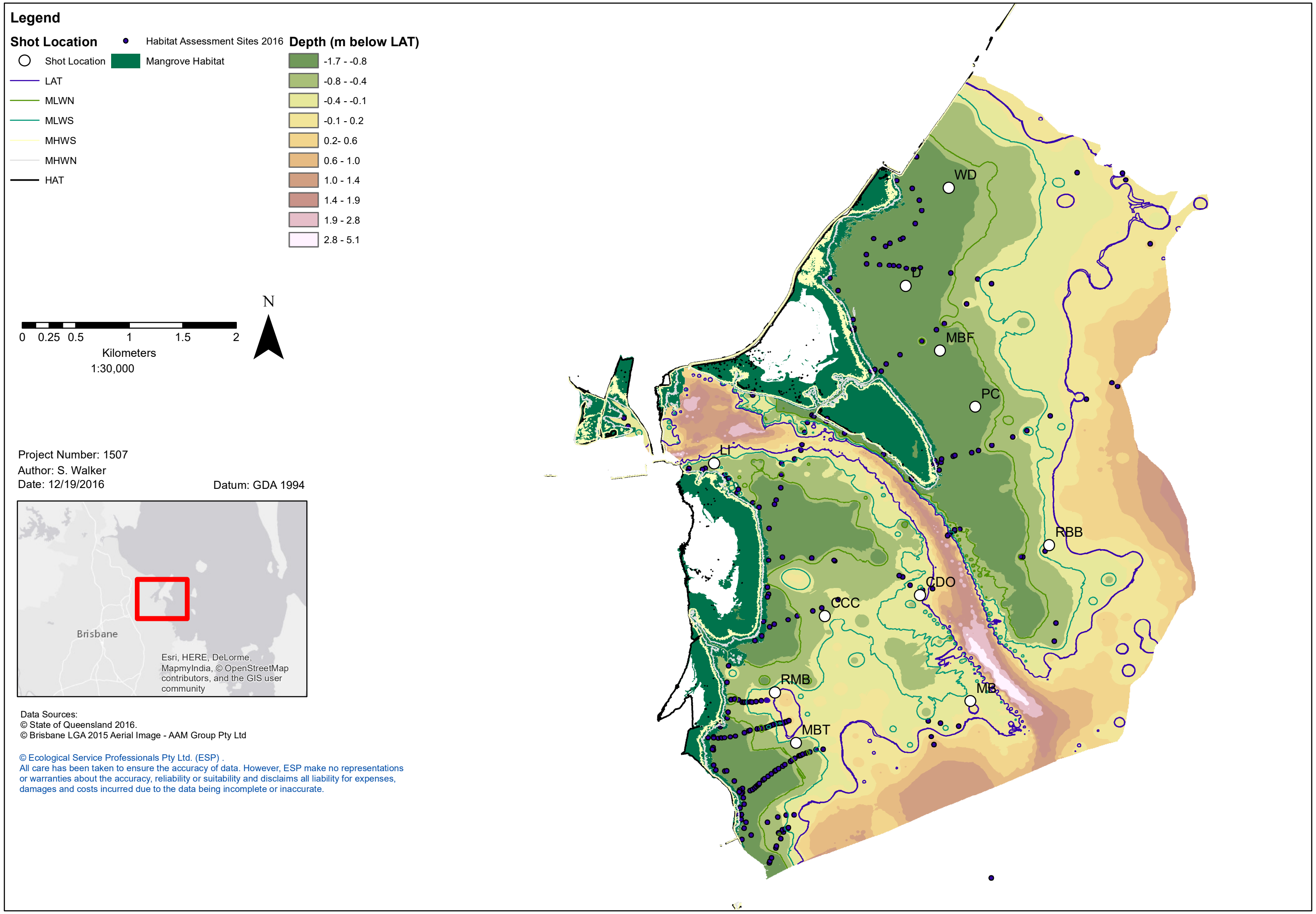

Figure 2 Map of the study area showing: water depth relative to LAT, contours for relevant tidal depth contours, habitat assessment sites and net shot locations.

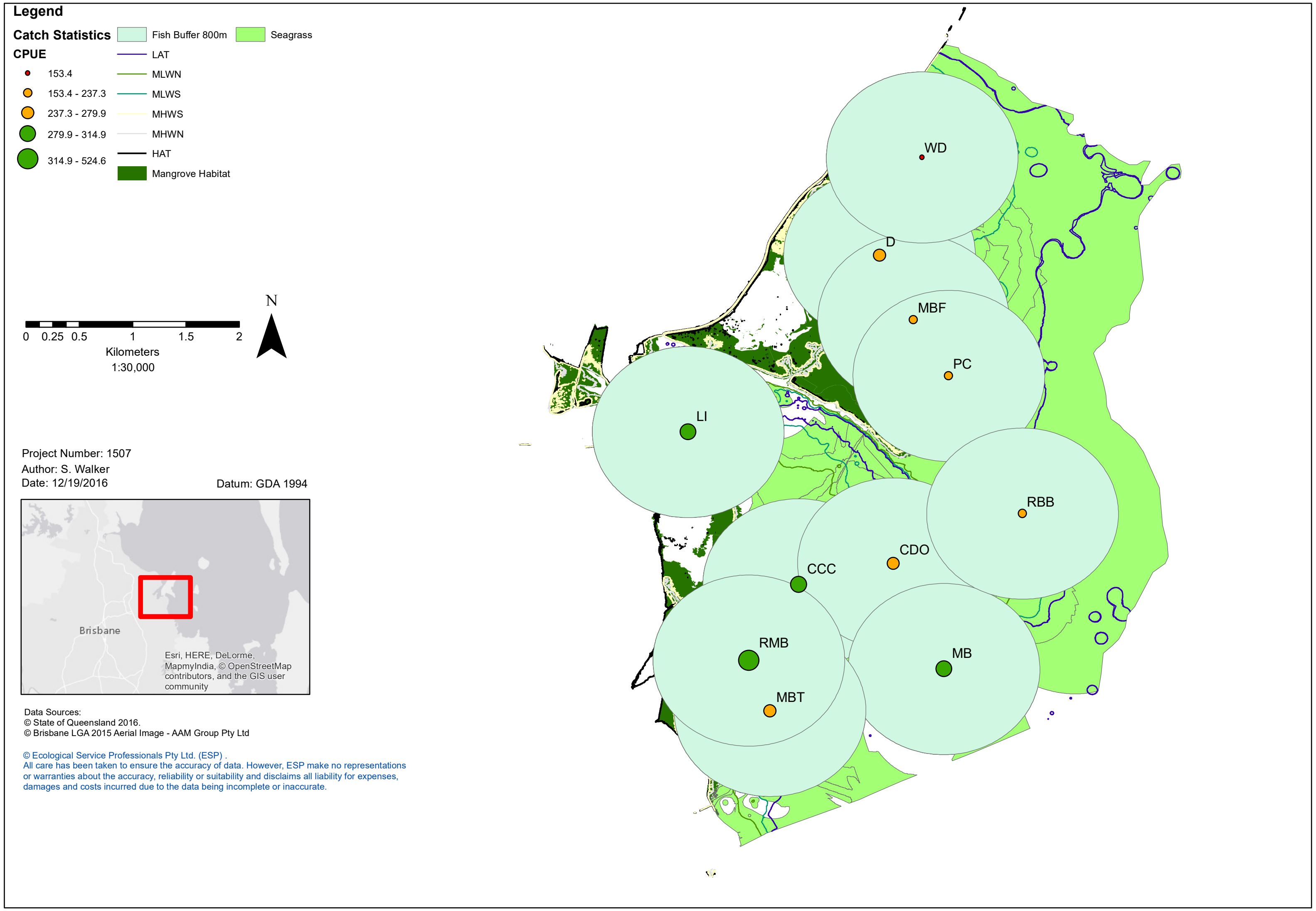

Figure 3 Buffer areas around each shot that were used to measure seascape metrics and habitat characteristics (illustrated at the 800 m scale).

3.5 Prediction of Habitat with Greatest Value to Fisheries

To determine whether there was a link between the composition of commercial fish catches and either seascape metrics or habitat characteristics, we compared each of the environmental attributes (and combinations of up to 5 parameters) with the commercial fishing data (e.g. catch per unit effort and total catch weight), using BIOENV Analysis and Distance Based Linear Modelling (DistLM) in PRIMER (Clarke & Gorley 2006; Clarke et al. 2008). Analyses were based on Bray-Curtis similarity matrices calculated from square root transformed fish assemblage data. We tested for multicollinearity among environmental attributes using the DistLM routine and draftsman's plots. Principal Coordinate Analysis (PCO) was used to visualize environmental attributes that were most strongly correlated with the composition of commercial fish catches (Anderson 2004).

We tested for possible correlations between the distribution of individual fish species (i.e. in terms of both CPUE and total weight) and important environmental attributes (i.e. seascape metrics and habitat characteristics identified using BIOENV) using generalized additive models (GAMs) (Hastie & Tibshirani, 1986) and the MCGV package in R. Model overfitting was reduced by running all possible combinations of ≤ three variables and using ≤ three model knots (i.e. individual polynomial functions that combine to smooth GAMs) (Zuur et al., 2009). Models were compared using Akaike information criterion corrected for finite sample sizes (AICc) with the MuMin package in R; bestfit models had the lowest AICc values (Burnham & Anderson, 2002). The relative importance of variables in each model was calculated by summing weighted AICc values across all models containing the variable of interest; with higher important values (closer to 1) indicate greater contribution. The estimated effect was plotted for variables that were considered important (i.e. >0.5 value of importance).

4 Results

4.1 Mapping Seascape Characteristics

The seascape around the port is a mosaic of different habitat types, dominated by shallow sloping intertidal banks with continuous and patchy seagrass (Figure 2 & Figure 4). Seagrass either extends to the mangrove forest or is separated from mangroves by bare mud flats. The intertidal flats are dissected by a variety of tidal channels and gutters, and at least one unnamed tributary drains into a deeper subtidal pool in the south of the study area.

There are several large areas of intertidal seagrass, which are only fished when tides are suitable (i.e. when there are sufficiently low tides to allow for a runoff the banks into the tunnel, which is placed in deeper water). These large seagrass meadows are over 1 km from adjacent mangroves, are separated from the mangroves by deeper tidal channels and gutters, and are closer to deeper channels and subtidal seagrass beds (see shot locations RBB, MB and CDO in Figure 2).

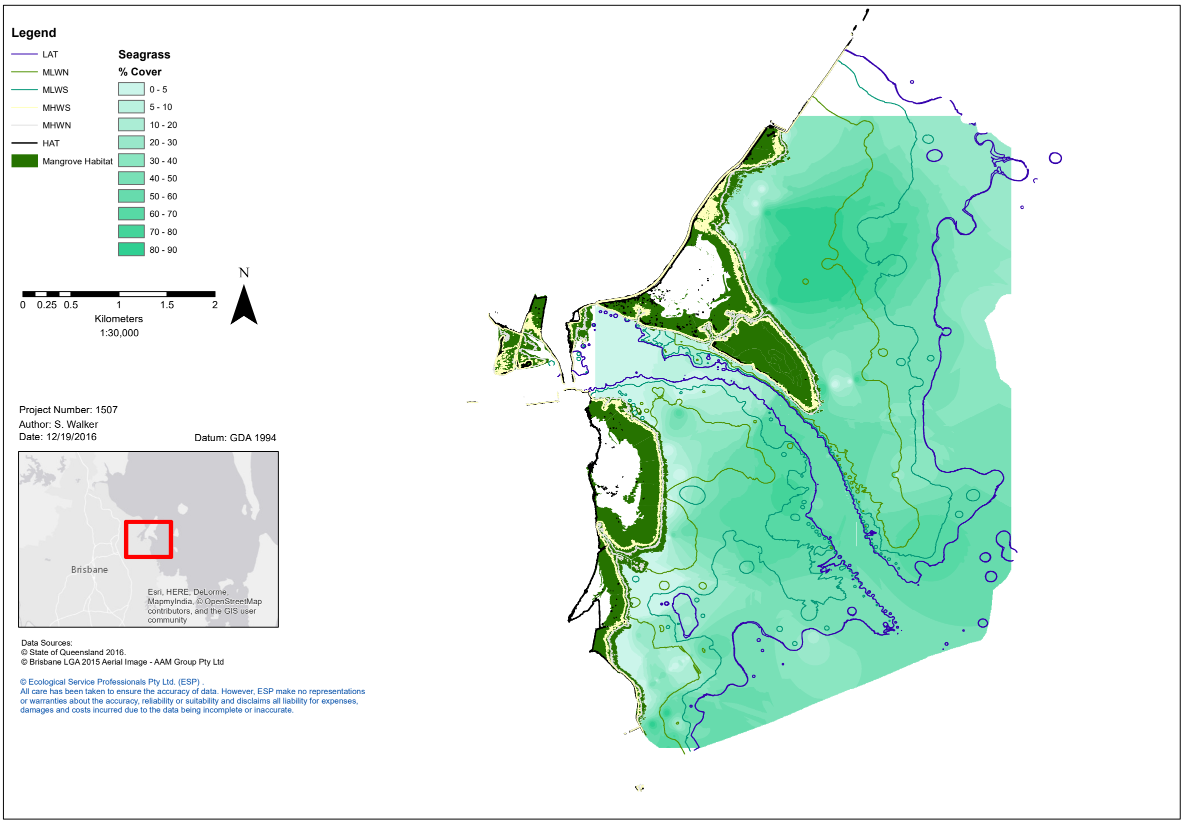

Figure 4 Map of the percent coverage of seagrass and area of mangroves in the study area.

4.2 Fish Catch Characteristics

The tunnel net operation used for this assessment is accredited as a sustainable fishery due to the methods employed, speed of delivery of product and minimal (if any) bycatch. The fishing operation has enjoyed a substantial increase in efficiency, and the catch per unit effort almost doubled between 2010 and 2015 (Figure 5a). Increased efficiency has meant there has also been a reduction in fishing effort from 49 days in 2010 to 34 days in 2015 (Figure 5b); and average catch weight has increased (Figure 5c). Improving efficiency and decreasing effort is necessary to reduce the overall impact of the fishery on the environment, increase the availability of fresh fish to consumers and increase business profitability with the wholesale value of fish increasing with increased catches (Figure 6).

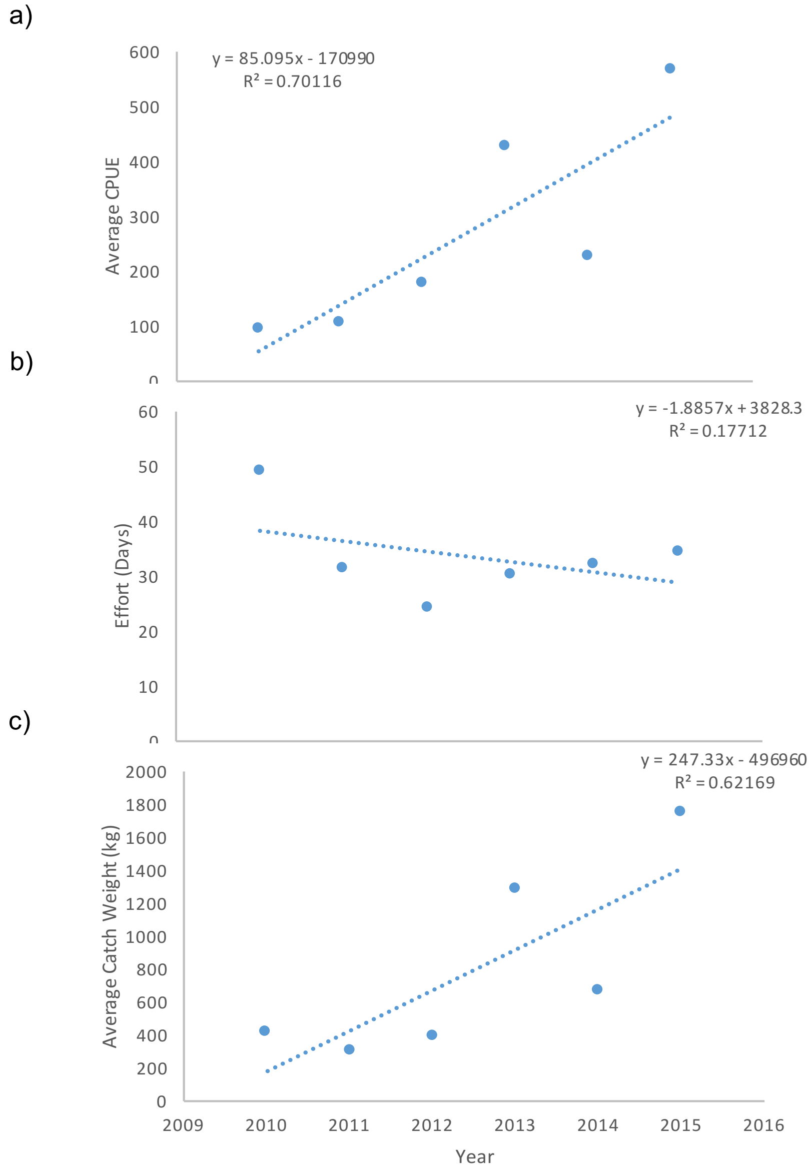

Figure 5 The (a) average catch per unit effort, (b) total effort (fishing days), and (c) total catch weight per year, between 2010 and 2015

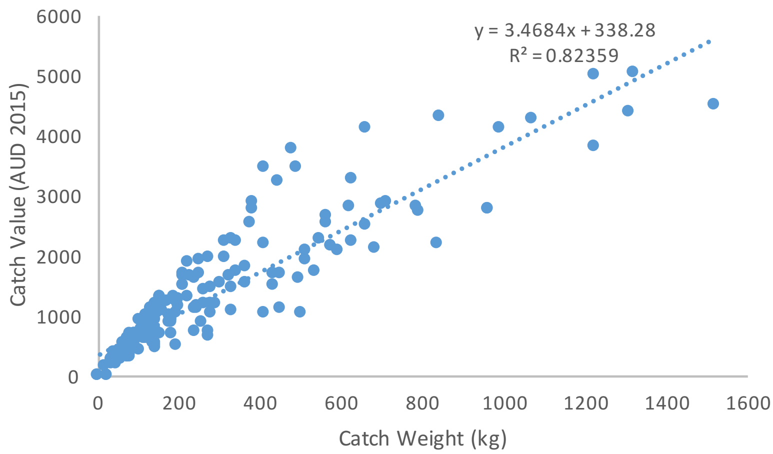

Figure 6 Wholesale catch value (AU$ 2015) versus catch weight pooled across all years from 2010 to 2015

The composition of fish catches varied spatially (ANOSIM Global R = 0.14, p = 0.04) and temporally (ANOSIM Global R = 0.18, p = 0.01). The fish assemblages caught did not, however, differ among shot locations that shared similar habitat characteristics (Table 4, Figure 7). The key fish species that discriminate shots from different types of locations were flathead, mullet and bream, which each contribute up to 20% of the dissimilarity in catch composition among shot locations (SIMPER, Appendix A). Net shots taken close to mangroves, which are separated from seagrass beds by mud flats (e.g. MBT, CCC, CDO), were dominated by flathead, mullet and bream (SIMPER, Appendix A). Whilst, shots taken over large seagrass banks that were separated from seagrass by tidal channels (e.g. RBB and MB) were dominated by flathead and supported lower numbers of whiting, mullet, bream and squid. By contrast, net shot LI is typically taken over a narrow intertidal bank adjacent to an eroding shoreline with few mangroves; it is not often fished due to low catch rates over the past 5 years (shot LI was only fished twice in 2015 targeting mullet).

Table 4 Pairwise Comparisons following ANOSIM

Shot Location	CCC	CDO	D	LI	MB	MBF	MBT	PC	RBB	RMB
CDO	0.09									
D	0.08	0.10								
LI	0.00	-0.50	-0.10							
MB	**0.42***	-0.08	0.17	^						
MBF	**0.66*****	**0.53****	0.14	0.21	-0.33					
MBT	0.13	-0.04	0.07	0.50	-0.16	**0.62*****				
PC	**0.40*****	**0.30****	-0.05	-0.22	0.06	**0.32***	**0.37****			
RBB	**0.40*****	0.18	**0.20***	0.50	-0.11	**0.50****	**0.28****	0.15		
RMB	0.28	-0.56	0.08	^	^	^	-0.08	^	^	
WD	**0.63*****	**0.40****	**0.20***	0.29	-1.00	-0.13	**0.61*****	0.15*	**0.42****	^

^ undefined too few replicates; Significance: *p<0.05, **p<0.01, ***p=0.001

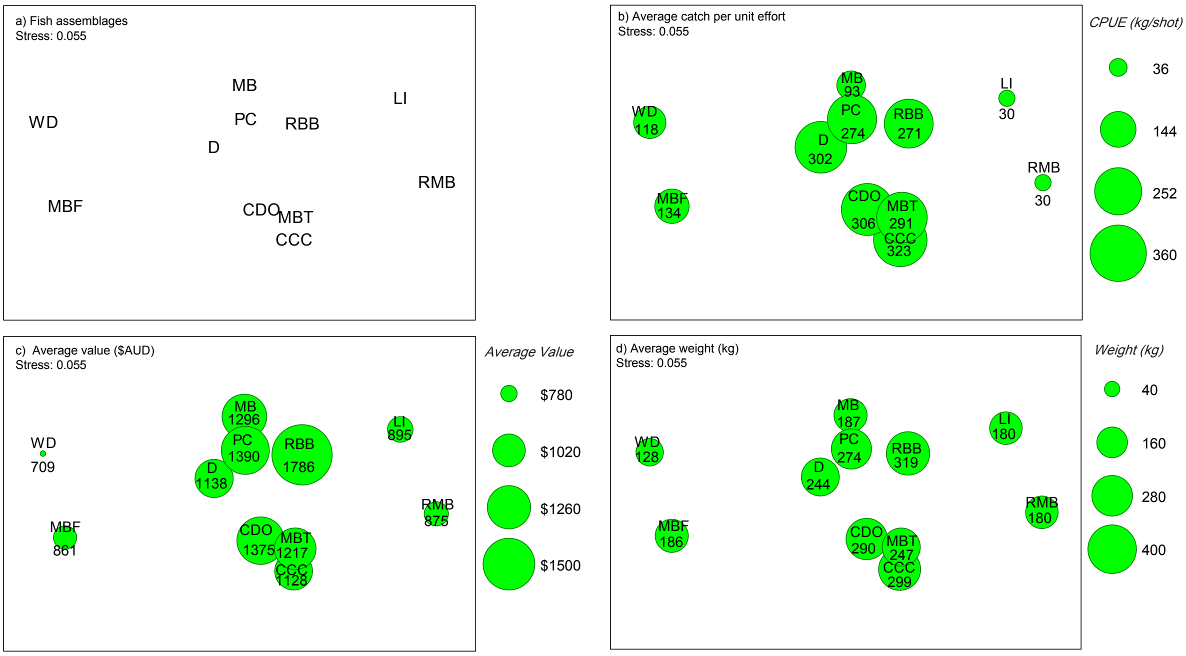

Figure 7 nMDS ordination of the differences in (a) composition of fish catches among shot locations; (b) overlayed bubble plot the average catch per unit effort; (c) average shot value; and, (d) average total weight, for each shot location. Actual values are shown below each shot location.

4.3 Linking Commercial Catches to Fish Habitat Characteristics

We tested whether the composition of fish catches was correlated with 29 different environmental attributes (i.e. seascape metrics and habitat characteristics) (Table 2). These same environmental attributes were then tested for correlations with total CPUE and the CPUE of six commercially important taxa (i.e. flathead, mullet, whiting, dory, bream & sharks), which were abundant and dominated catches in terms of both catch frequency and weight caught. Spatial variation in the composition of fish catches was weakly correlated with five environmental attributes, including: (1) seagrass proximity to LAT; (2) length of seagrass edge in 800 m buffers; (3) seagrass cover; (4) area of mud; and (5) fractal index for seagrass patches (BIOENV; Rho = 0.34, p = 0.32). The single most important environmental attribute was the proximity of seagrass to LAT (i.e. the extent of intertidal seagrass area available to fishes at high tide) (BIOENV Rho = 0.29) (Figure 9). The p-values for these tests were high due to a low number of catches from certain habitat combinations and high degree of temporal variation in catches at each net shot location. We predict that a more explicit test of the differences in fish assemblages among different combinations of habitats and categories would yield much stronger correlations.

The average wholesale value of shots was correlated with four environmental attributes, including: (1) the length of seagrass edge in 800 m buffers; (2) proximity of mangroves to seagrass; (3) area of seagrass; and (4) seagrass patch fractal index (BIOENV; Rho = 0.54, p = 0.06). This was primarily due to higher catches of species with high wholesale value, such as flathead and whiting, in these types of locations. The average CPUE was correlated with five environmental attributes, including: (1) length of seagrass cover; (2) proximity of seagrass to MHWS; (3) area of seagrass (as a % of total buffer area); (4) area of mud; and (5) seagrass patch fractal index (BIOENV; Rho = 0.44, p = 0.09). CPUE differed among the net shot locations being greatest at sites adjacent to the mangroves on Whyte Island (Shots RMB & CCC) and on the outer seagrass banks (Shot MB) (Figure 8). Consistent CPUE of high value species was a key consideration for whether a net was set in a specific area. For example, CPUE for shot LI was high due to some catches of mullet and butterfish; however, catches are very inconsistent and anecdotal changes to the availability of habitat including erosion of the mangrove fringe and deepening of the boat channel have reduced catches substantially over the past few years to the point where Shot Li is now rarely fished (only 2 shots between 2010 and 2015).

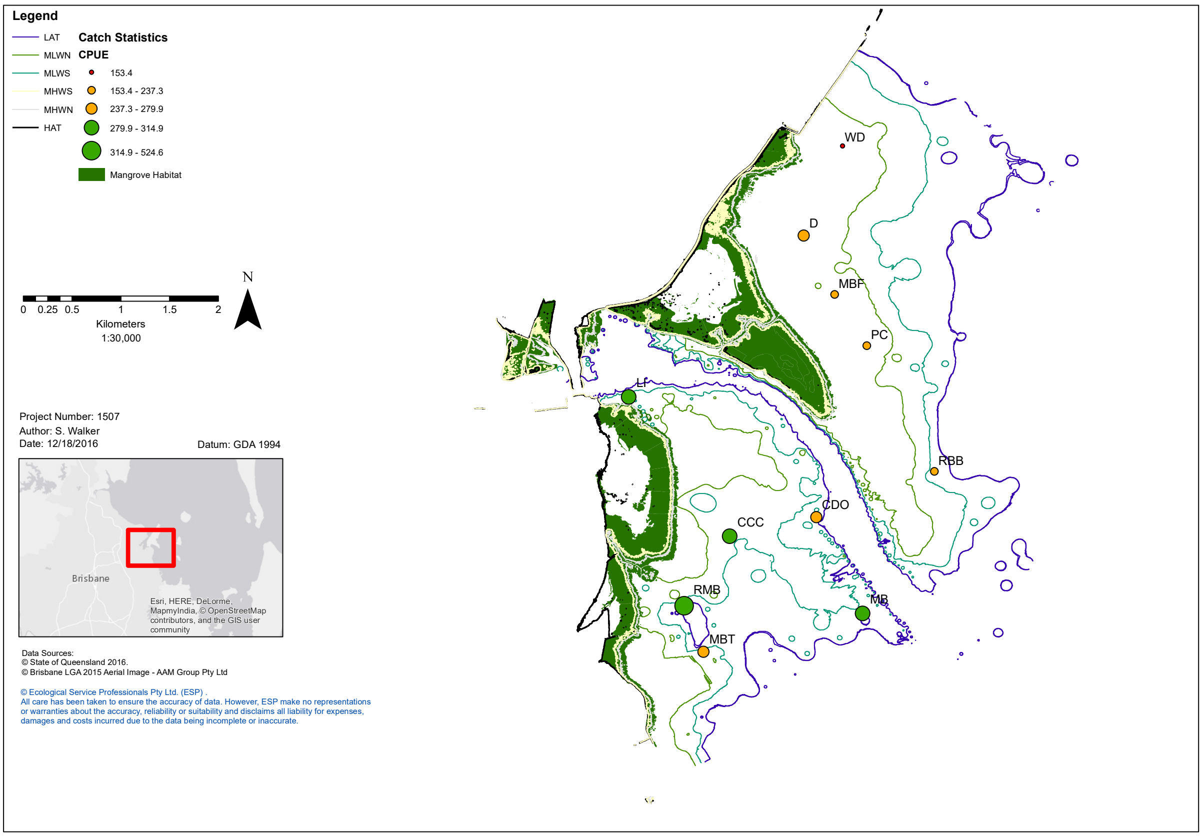

Figure 8	CPUE at different shot locations

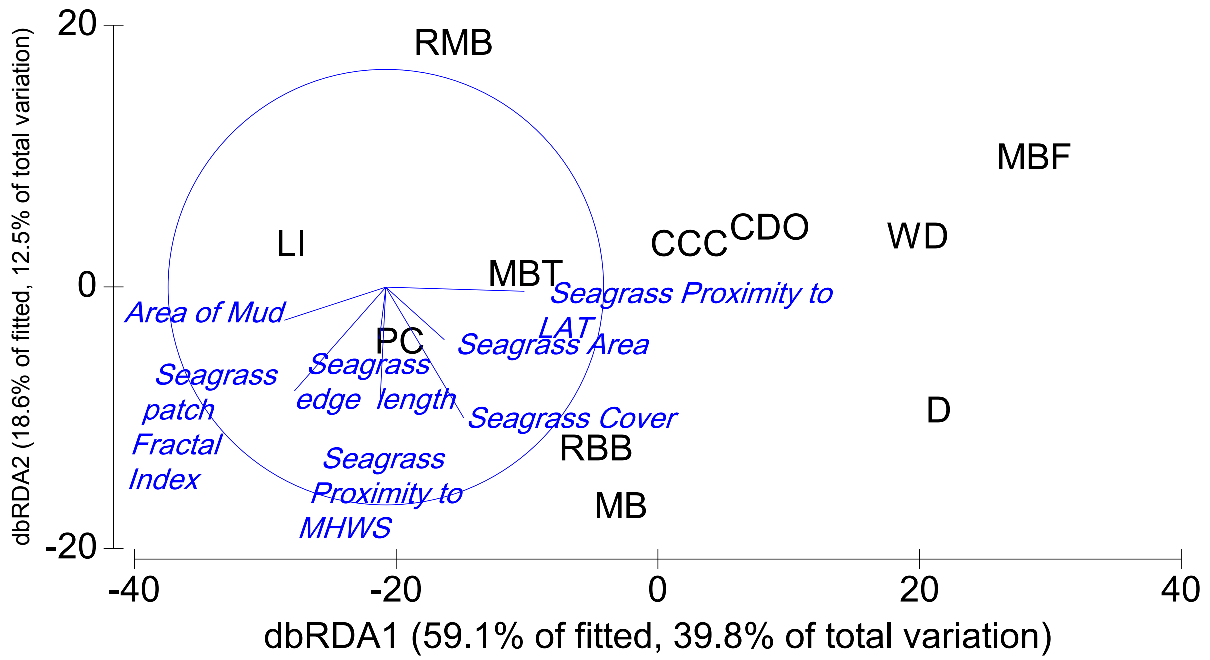

Figure 9 PCO after DistLM for catch per unit effort including the relative contribution of key environmental attributes

The composition of fish caught were most strongly correlated with the ecological attributes of seagrass meadows (i.e. seascape context, area, condition). Seagrass attributes were also similarly important to the catches of individual fish species. For example, flathead and mullet catches were correlated with the proximity of seagrass to MHWS and seagrass fractal index, while bream and whiting catches were correlated with the ecological attributes of both seagrass meadows and mangrove forests (Table 5; Figure 10). These models do not, however, explain a large proportion of the variation in fish catches, which are only weakly correlated with the environmental attributes of the study seascape (Table 5). Targeted assessment using stratified sampling of fish assemblages (for example with Remote Underwater Video Stations) across a larger number of sampling locations from a wider variety of seascape contexts would likely improve the predictive power of our models, as fishing catch rates can be affected by a variety of other environmental factors such as weather. We plan to complete these targeted assessments in the future where possible.

Flathead catches were highest over seagrass meadows that were further from the mean high water spring tide mark. Catches were frequently high in areas close to mangrove forests, but the largest catches of flathead occurred on the edge of continuous seagrass banks further offshore (i.e. shots MB and RBB, which were > 1500 m from mangroves) (Figure 11a). Bream catches were also greatest at shots further offshore (Figure 11d). Catches of whiting were greatest in shots on Fisherman Islands (Figure 11c). By contrast, mullet were caught mostly at locations with large areas of bare mud near mangroves (Figure 11b).

Table 5 Best fit generalised additive models (GAMs) relating individual species or group catch rates to key environmental parameters (importance values included in parentheses).

Species/group	Variable included in best fist model						
	Rank 1*	Rank 2	Rank 3	Rank 4	Rank 5	R^2	Models
Total catch weight	Seagrass Proximity to MHWS (0.50)	Mangrove patch fractal index (0.38)	Seagrass fractal index (0.34)	Seagrass Proximity to LAT (0.32)	Mangrove area (0.30)	–	15
Flathead	Seagrass Proximity to MHWS (0.92)	Seagrass fractal index (0.40)				0.19	2
Mullet	Seagrass Proximity to MHWS (0.61)	Seagrass patch fractal index (0.54)	Seagrass cover buffer (0.43)			<0.01	4
Bream	Seagrass patch fractal index (0.66)	Seagrass Proximity to LAT (0.52)	Mangrove patch fractal index (0.36)	Mangrove area (0.35)	Seagrass Proximity to MHWS (0.30)	0.02	15
Whiting	Average depth (0.67)	Mangrove patch fractal index (0.65)	Seagrass patch fractal index (0.60)			0.04	4

* Environmental variables ordered by their rank importance value

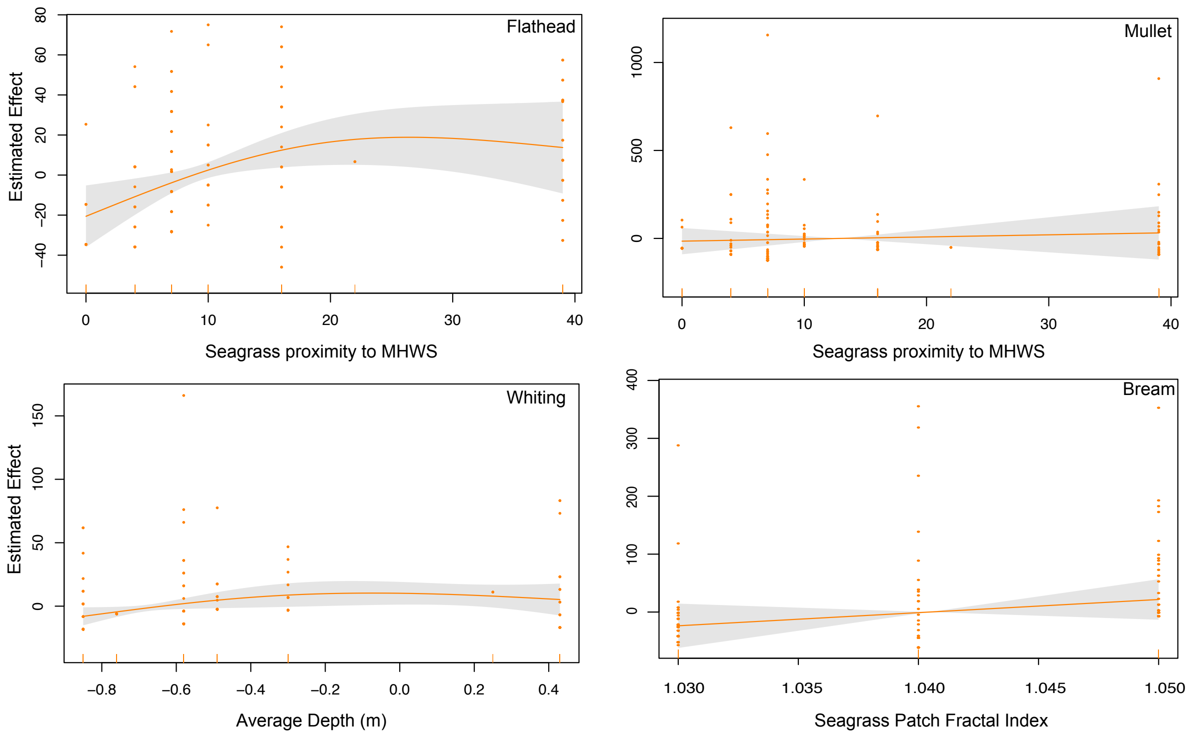

Figure 10 GAMs relating the catch rates of different species with environmental parameters. Grey area indicates 95% confidence interval.

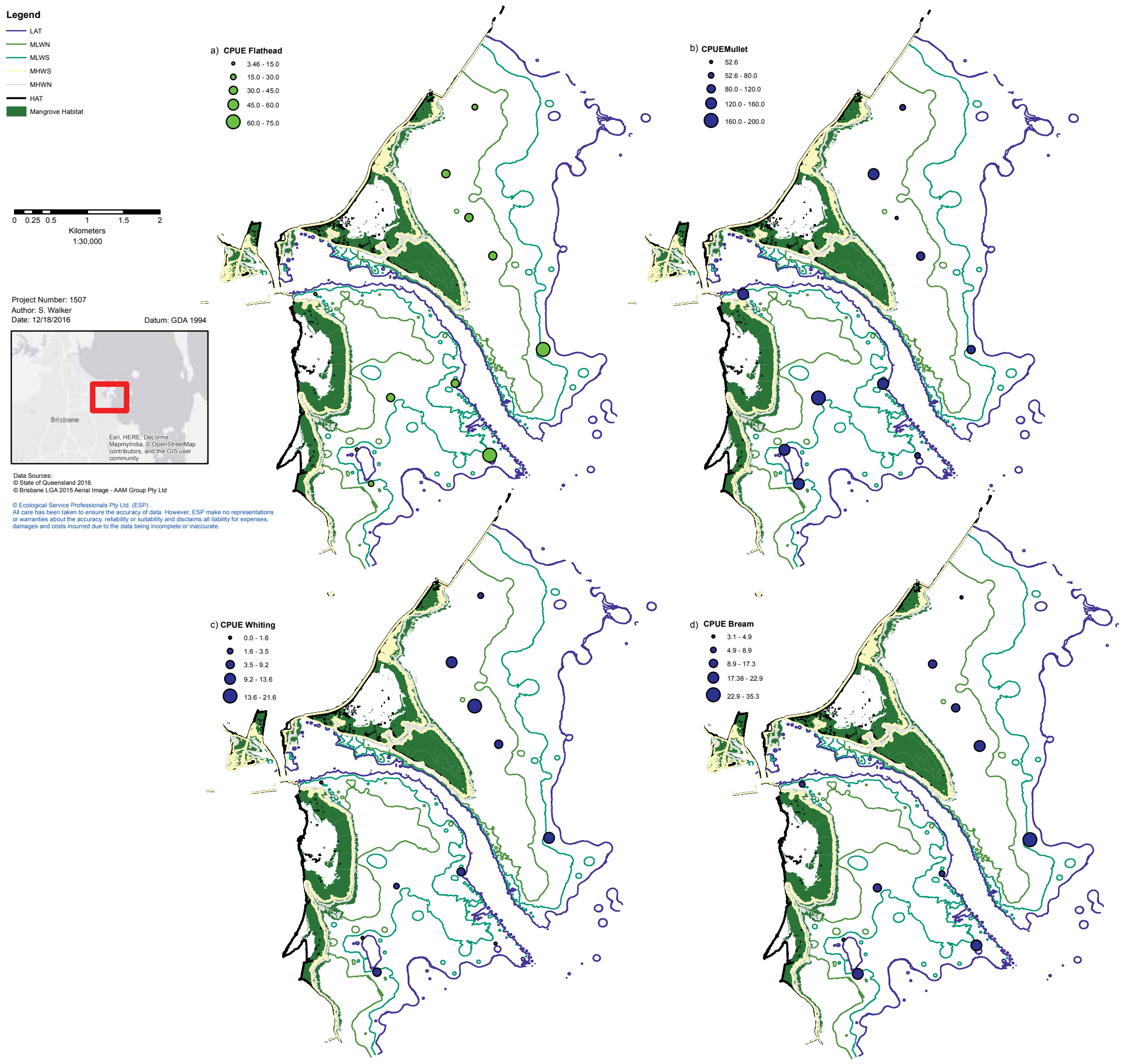

Figure 11 CPUE at each shot location for (a) flathead, (b) mullet, (c) whiting, and (d) bream.

4.4 Mapping Commercial Fisheries Value

Based on the key characteristics assessed in the field, the CPUE and overall value of habitat, we determined that there are several key areas adjacent to the Port of Brisbane that are essential to commercial fishing operations in the local area. These areas are fished more frequently than other areas due to: (1) the consistent presence of commercial sized fish; and (2) the high CPUE and therefore monetary value that they yield for commercial fishers. Based on the outcomes of the spatial assessment and expert fish habitat assessment, we created a modified method (extending on previous assessment methods i.e. DEEDI 2011) to measure the value of intertidal seascapes for commercial fish species. This approach might be suitable for other coastal seascapes in Queensland, but its predictive power remains to be tested.

The value of intertidal habitat for commercial fisheries in the study area was assessed using:

- the desktop review of the available fisheries literature linking habitat features with fish populations and commercial fish catches;
- a spatial assessment of the links between seascape and habitat features and catch value; and,
- mapping of dominant habitat features and value to the tunnel net fishery using the criteria adapted from the spatial analysis, existing literature, and expert knowledge of habitat features used by commercial fish.

4.4.1 Wholesale Value of Seagrass Habitat

Seagrasses are highly sensitive to changes in environmental conditions and declines in water quality (particularly high turbidity or increased total suspended solids (Heck et al. 2008). The spatial distribution is therefore highly dynamic, and large inter-annual changes in the extent of seagrass habitats and community structure resulting from disturbances (e.g. flood events, changes in rainfall) have been documented in the Moreton Bay region (Lyons et al. 2015).

Seagrass provides food and shelter for a diverse range of marine fauna; they also support benthic macroinvertebrate communities that are part of a food chain for many larger, commercially important species of crustacean, mollusc and finfish (Coles et al. 1993; Carruthers et al. 2002; McKenzie et al. 2014). Epibenthic and infaunal invertebrate communities associated with seagrass meadows are diverse, and are typically dominated by high abundances of polychaetes (and other worms, such as sipunculids), molluscs (including bivalves and gastropods), and crustaceans (particularly amphipods and decapods) (Blomfield & Gillanders 2005). Although marine plant communities provide particularly high value habitat for marine fauna, areas of non-vegetated soft-substrates (including sandy beaches, mudflats and subtidal soft sediments) are also important (Pittman et al. 2004). Infaunal communities in this region are often dominated by molluscs (such as the mollusc families Mitridae, Mactridae and Tellinidae), polychaetes (such as the families Sigalionidae, Capitellidae, Phyllodocidae and Maldanidae), echinoderms (Amphiuridae and Loveniidae), amphipods, isopods and crustaceans (family Callianassidae), many of which are distributed throughout the area in small patches (Skilleter et al. 2006a, b). These communities provide a food source for larger crustaceans, molluscs and finfish, many of which are commercially important (e.g. flathead) (Coles et al. 1993; Carruthers et al. 2002; McKenzie et al. 2014). Soft sediment habitats in shallow areas (where suspended sediment loads are low enough to allow sufficient sunlight penetration through the water column for photosynthesis) also contain benthic microalgae (BMA) assemblages, which can be an important driver in coastal food chains and macroalgal communities (Ferguson & Eyre 2013).

Table 6 Criteria used to determine the fisheries habitat value of seagrass based on review of available literature and current spatial assessment[1]

Fisheries Value	Poor	Fair	Good	Very Good	References
Bed extent at high tide	Small bed area (>930 m^2) available for fish at high tide	Small bed area (930-2300 m^2) available for fish at high tide	Moderate bed area (3000 – 5000 m^2) available for fish at high tide	Large bed area (>5000m^2) available for fish at high tide	Jelbart et al. 2007 Boström & Bonsdorff 1997 Heck et al. 1995
Bed extent continuous or patchy	Patchy <10m^2 of seagrass bed surrounded by bare substrate	Patchy bed either intertidal or subtidal areas only	Continuous bed extending from intertidal to subtidal areas	Continuous bed extending from intertidal to subtidal areas	Boström & Bonsdorff 1997 Heck et al. 1995
Maximum depth of seagrass in subtidal areas		Deepest edge of seagrass bed is <0.3 m	Deepest edge is 0.3 to 2 m. Seagrass growing to deepest point in estuary, lake or lagoon	Deepest edge of seagrass >2m depth OR Water is < 2m deep at deepest point, with seagrass growing to deepest points of estuary, lake or lagoon	Abal & Dennison 1996
Seagrass condition	Seagrass in poor condition	Seagrass in moderate to poor condition	Seagrass in good to moderate condition	Seagrass in good condition	Price et al. 2007
Presence of cyanobacterial mats	Presence of dense cyanobacterial mats (*Lyngbya*).	Sparse coverage of cyanobacterial mats (*Lyngbya*).		cyanobacterial mats essentially absent	
Coverage of seagrass	Sparse coverage of seagrass (<10%)	Sparse coverage of seagrass (30%)	Moderately dense coverage of seagrass (40-60%)	Dense coverage of seagrass (>60%)	Price et al. 2007

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[1] Bell & Westoby 1986a,b; Edgar & Robertson 1992; Boström & Bonsdorff 1997; Heck et al. 1995; Webster et al 1998; Skilleter et al. 2005; Vanderklift & Jacoby 2003; Boström et a. 2006a,b; Jelbart et al. 2007; Price et al. 2007; Shoji et al. 2007

Structural complexity	Low structural complexity (i.e. max length of seagrass blades <10cm, depending on dominant species present)	Moderate structural complexity (i.e. max length of seagrass blades 10 to 20cm; depending on dominant species present)	High structural complexity (i.e. max length of seagrass blades 20 to 30cm depending on dominant species present)	High structural complexity (i.e. max length of seagrass blades >40cm depending on dominant species present)	Bell & Westoby 1986a,b; Edgar & Robertson 1992
Coverage of epiphytic algae	Low or high cover of epiphytic algae (<20% or >80%)	high cover of epiphytic algae >60% of seagrass blades OR low cover of epiphytic (<20%)	Moderate cover of epiphytic algae (20-40%)	Moderate cover of epiphytic algae (20-40%)	Price et al. 2007; McKenzie et al. 2003
Connectivity with other habitat types	Not well connected to other structural fish habitat (Intertidal seagrass proximal to mangroves, subtidal seagrass, macroalgae rocky reef, coral reef, or another structured habitat)	Moderately connected to other structural fish habitat (Intertidal seagrass proximal to mangroves, subtidal seagrass, macroalgae rocky reef, coral reef, or another structured habitat)	Well connected to other structural fish habitat (Intertidal seagrass proximal to mangroves, subtidal seagrass, macroalgae rocky reef, coral reef, or another structured habitat)	Well connected up- and down-shore to other known structural fish habitats (Intertidal seagrass proximal to mangroves, subtidal seagrass, macroalgae rocky reef, coral reef, or another structured habitat)	Skilleter et al. 2005; Dorenbosch et al. 2005 Yeager et al. 2011

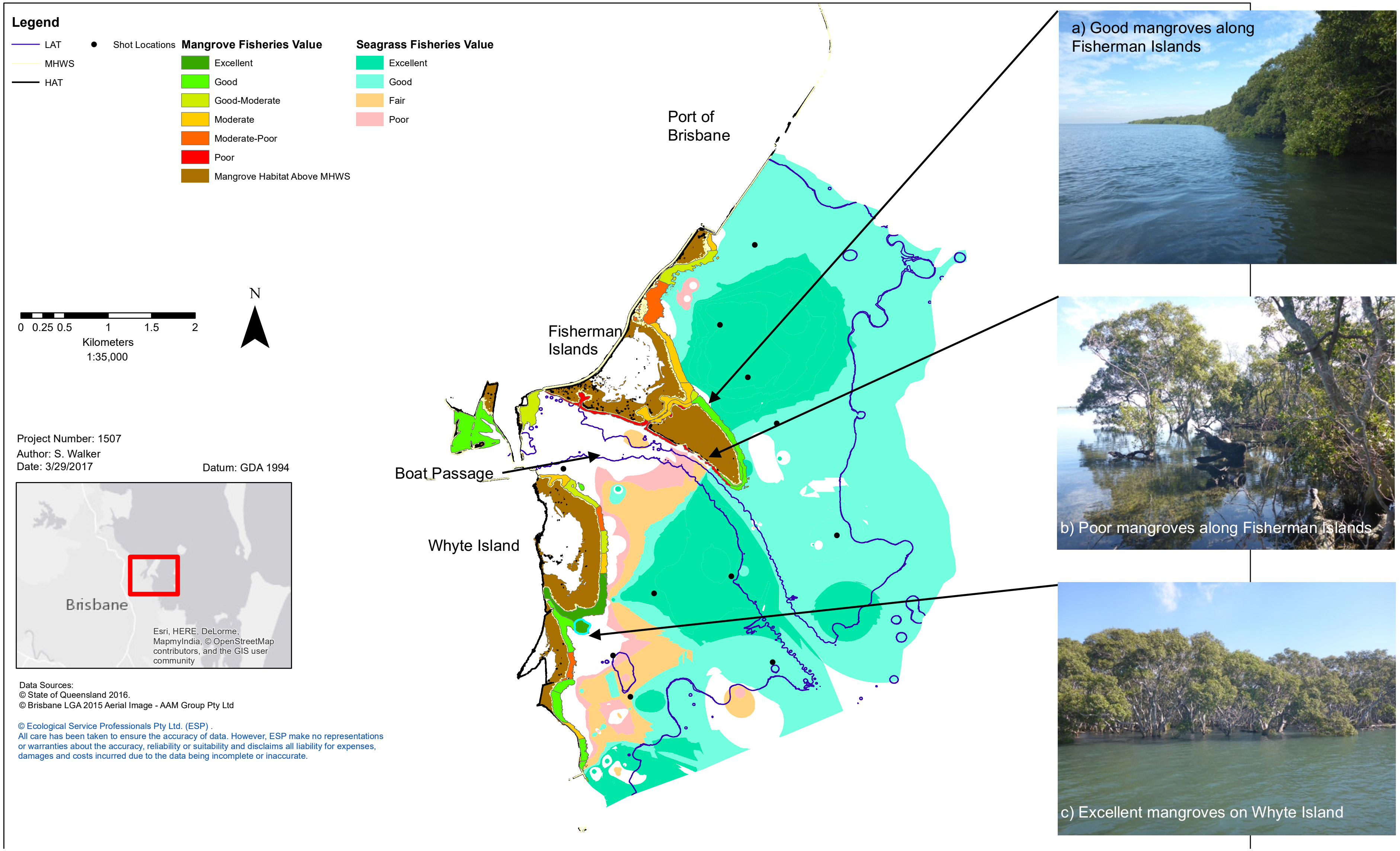

Figure 12 Value of seagrass and mangrove habitat to commercial fisheries and pictures of mangrove patches with (a) good, (b) poor, and (c) excellent value

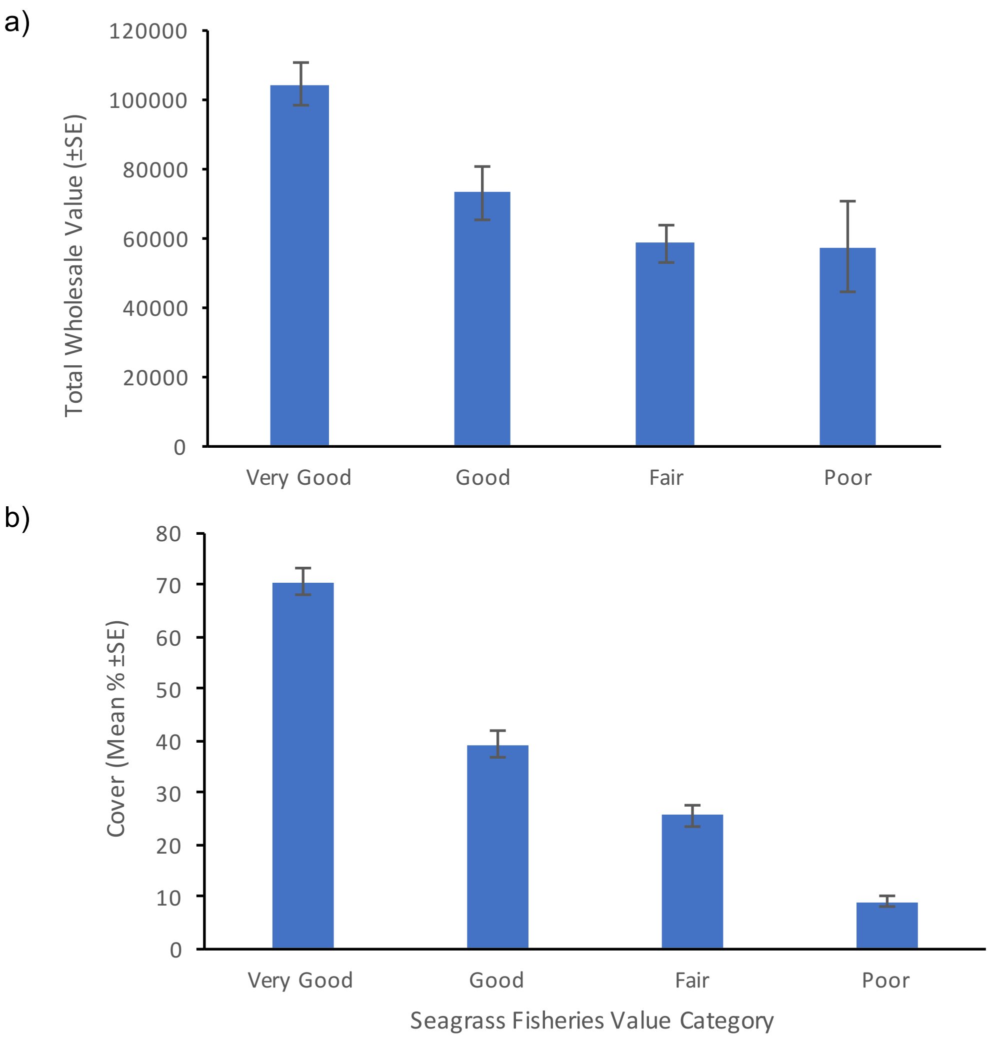

Figure 13 Annual wholesale value (AU$) and seagrass cover relative to commercial fisheries value categories[2]

The continuous seagrass beds in the study area extend for over 2 km in some areas, with a shallow gradient allowing for numerous small pools and channels for fish to seek refuge in (Figure 12). Several characteristics of seagrass beds were important predictors of the composition of the catch assemblage and individual species. Based on our assessment criteria, the seagrass was dominated by large areas of habitat that had good value for commercial fisheries (Figure 12). Lower quality habitat was typically found in areas adjacent to bare mud flat habitat with fine mud/clay sediments (Figure 12). The area of seagrass, length of edge and proximity of seagrass were all important environmental factors that were correlated with the composition of the catch assemblage. These large seagrass areas provided particularly high value habitat for species such as flathead and whiting that yield the highest wholesale value.

[2] Univariate PERMANOVA for differences in total wholesale value among seagrass fisheries value categories Pseudo-$F_{3,116}$ = 8.9, $p < 0.001$; Post-hoc pairwise comparisons, very good > good = fair = poor ($p < 0.001$). PERMANOVA results for differences in cover among seagrass fisheries value categories Pseudo-$F_{3,116}$ = 72.4, $p < 0.001$; Post-hoc pairwise comparisons, very good > good > fair > poor ($p < 0.001$).

A total of 1666 ha of seagrass habitat was within the 800 m radius around each of the 11 tunnel net shot locations. Of this habitat over 80% was characterised as either good (43%) or excellent (44%) fisheries value (Table 7), based on the habitat characterisation scheme outlined in Table 6. Less than 14% of the habitat was characterised as fair or poor. Seagrass habitat that was excellent yielded on average a much greater annual wholesale value to commercial fisheries than all other categories, and more than 10 times the value of habitat categorised as having poor value (Table 7).

Table 7 Fisheries valuation for seagrass habitat adjacent to the Port of Brisbane (wholesale commercial fisheries value AU$ 2015)

Mapped Fisheries Value Category	Area of Seagrass Habitat Fished (Ha)	Proportion of Total Seagrass Habitat Fished	Average Annual Wholesale Value (AU$ 2015)[1]
Excellent	727	44%	$72063
Good	716	43%	$55843
Fair	159	10%	$11845
Poor	63	4%	$5733
Total Area	1666		

[1] Based on the equivalent 2015 wholesale value of fish caught between 2010 to 2015 of a single commercial fishing operator around the Port of Brisbane. This valuation does not incorporate the value of other services and functions provided by mangroves such as nutrient cycling, coastal baffling and protection, nursery areas for fisheries.

4.4.2 Wholesale Value of Mangrove Habitat to Commercial Fisheries

Mangroves are known to provide important ecological function for a variety of commercial fisheries habitat, through provision of nursery habitat, protection from predators and contributing to food webs, among other functions (Nagelkerken et al. 2008). These intertidal habitats are also important for a range of species other than fish such as migratory shorebirds, waterbirds and crustaceans (Manson et al. 2005; Skilleter et al. 2005; Zharikov et al. 2005). Several parameters have previously been derived to assess the value of mangrove habitat for commercial fish species at a seascape scale, mostly centred on the value as nursery habitats (Faunce & Searfy 2006), connectivity and migration of different life history stages among habitats (Nagelkerken et al. 2008) and relative to commercial catch data (Manson et al. 2005); however, mangrove habitat parameters are often not well correlated with differences in fish assemblages (Pittman et al. 2004). Based on the desktop assessment and spatial assessment, there was also little correlation with the habitat parameters derived for mangrove habitats, especially relative to those for seagrass which were more strongly correlated. We therefore have provided some additional parameters based on extensive commercial fishing knowledge of the area and how commercial fish species use mangroves at high tide. The alternative habitat parameters provide a proxy for availability of habitat and structural complexity that are known to be important features of mangrove habitat for commercial species (Faunce & Searfy 2006). Each parameter was assigned into four key fisheries value categories and used to map the habitat around the Port of Brisbane. Differences in the scale of assessment versus the spatial and temporal scale at which fish are caught commercially make any correlation between commercial catch and habitat features used by commercial fish problematic. Therefore, additional comparative assessments of the general applicability of these methods for assessing commercial fisheries value elsewhere still need to be completed including a more direct assessment of mangrove habitat use by fish of commercial size using methods outlined in Sheaves et al. (2016).

The mangrove habitat down shore of the mean high water spring (MHWS) tide height was characterised in the field based on a variety of key factors (Table 8) and mapped (Figure 12). The average wholesale value of commercial catches was determined as the combined catch rate of shots within 800 m of each mangrove patch. Mangrove patches, assessed as having good or excellent fisheries value, supported greater CPUE at sites immediately offshore, than mangrove areas that were assessed to be of poorer fisheries value (Figure 12a). Areas where mangroves were assessed as moderate and moderate-poor also had relatively high CPUE, although this was due to high catches of fish such as mullet which are caught in high numbers but have low wholesale value. A small area of mangroves west of net shot D was assessed as having moderate to poor value due to a low dense canopy of trees below 3 m height, which act as a barrier to fish movement and reduce the available habitat for fish species of commercial size. However, the area fished at net shot D is over extensive continuous seagrass beds, which have a high precent cover (60-90%) and long blade lengths (>40 cm), that are frequently inundated for long periods of time and have small pools (most likely created by bait diggers) that hold water throughout the tide. These areas are still highly productive, despite the adjacent poor valued mangroves and the spatial assessment demonstrates seagrass habitat parameters were often more important than mangrove ones when predicting the value and CPUE of catches. We predict that that fish may remain in the dense seagrass beds in these areas rather than moving over bare mud to forage in the adjacent mangrove forest. Based on the commercial catch results, an area can continue to have high productivity in areas where there are seagrass beds in good condition is adjacent to mangroves. Catches decline in areas where mangrove quality is low and seagrass is absent (i.e. at net shot LI).

Another of the key parameters that was used to determine whether a mangrove patch was important for commercial fish was whether the area was frequently inundated at high tide (i.e. available for use by commercially sized fish). Based on the predicted frequency and height of high tides at the Brisbane Bar for 2016 and known height datum (MSQ 2016), 39% of all high tides per month (i.e. on average 29 out of 55 high tides) would reach the MHWS height, the remainder would reach mean high water neap (MHWN). Only 7 tides total per year would come close to highest astronomical tide (HAT) (allowing for ± 5 cm), which means that much of the intertidal habitat at the rear of the mangrove fringe in this area (including saltmarsh and claypan) is not available as habitat for commercial sized fin fish. The effects of inundation were particularly evident for mangroves along the northern bank of boat passage (southern Fisherman Islands). This area is not inundated regularly due to high sloping banks (the distance between MHWN & MHWS is less than 10 m in most areas and less than half this distance is mangroves). Mangroves in this area were in good physical condition, with good cover of healthy foliage and a high coverage of epiphytic macroalgae (based on previously used condition indices, DEEDI 2011), although the banks of the area are eroding due to proximity to the boat passage and little baffling of wave action by intertidal areas. Mangroves in this area were, however, considered to be of poor value to commercial fisheries and not suitable for commercial tunnel net fishing due to the low frequency of inundation and therefore lack of availability as a habitat for fish, and the lack of connectivity with intertidal seagrass meadows (Figure 12b).

By contrast, mangroves on the north-eastern side of Fisherman Islands and in the southern area of Whyte Island were assessed as having good to excellent value to commercial fisheries due to the mature open canopy, high proportion of trailing vegetation on the seaward edge and low density of large trees allowing fish to school behind the seaward fringe (Figure 12a,c). These areas are also close to large intertidal seagrass meadows, which is expected to provide substantial cover for fish as they move from up the shore with the flooding tide

The mangroves below mean high water spring (MHWS) were divided into fisheries value categories based on field assessments using the defined criteria (Table 8) and mapped (Figure 12). We calculated the average annual wholesale commercial value of mangrove habitat based on proportion of area within each of the net shot areas and the total value of shots over the past 5 years. The total value was divided by five to derive the average annual wholesale value to a single commercial fisherman working in the area adjacent to the Port. The mangrove patches characterised as good habitat for commercial fish accounted for the greatest proportion of fished mangrove habitat and contributed the greatest annual commercial value (Table 9). The annual value of mangroves to commercial catches was however, much lower than for seagrass (Table 7). The commercial value derived in Table 9 represents a minimum value as the frequency is only based off a single fishing operation and at least two operate in the area. Specific catch rates were unknown for additional operators and were therefore not assessed here. Other mangrove habitat classified as moderate value also contributed to the annual catch value, particularly where mangrove habitat was adjacent to dense seagrass beds, which appears to be a critical component of productive seascape mosaic. A cautious approach should be taken when calculating an average commercial fisheries value of mangrove habitat on a per hectare basis given that some areas can be considered in good condition, but are not accessed by commercial sized fish so would have limited value, while other areas are essential for commercial catches.

Table 8 Simplified criteria used to map the fisheries habitat value of mangroves based on review of available literature and current spatial assessment[3]

Habitat Proxy	Habitat Parameter ($100m^2$)	Poor	Moderate	Good	Excellent
Habitat availability and extent at high tide	Bank slope	High (>5°)	Moderate (2-5°)		Low (<2°)
	Average Water depth at fringe (m)	<0.24	0.25 – 0.49	0.50 – 0.75	>0.75
	Distance (m) from fringe - MHWS	<5	5-19	20-39	>40
	Distance (m) from fringe - MHWN	0	<5	5-19	>20
	Barriers to movement inshore	Presence of dense saplings ($>50/m^2$), dense shrubs, high bank or other barriers			Absence of dense saplings ($>50/m^2$), dense shrubs, high bank or other barriers
Structural complexity	Dominant Forest Structure	Shrubs <2 m	Immature trees or shrubs <3 m	Trees >3 m with shrubs	Mature trees >3 m
	Mangrove saplings (m^{-2})	dense >50	moderate dense 20-50	sparse 10-19	sparse <10
	Canopy cover & Understorey	Various / closed understorey	20-40% / closed understorey	40-60% / open understorey	>60% / open understorey
	Trailing canopy at high tide	Absent	<20%	20-60%	>60%
	Epiphytic algae cover (%)	<5% or >80%	5-20%	21-49%	50-80%

[3] References: Laegdssguaard & Johnston 1995; Faunce & Serafy 2006; Faunce & Serafy 2008; Johnson & Sheaves 2007; Baker et al. 2015; Dunbar et al. 2016; Sheaves et al. 2016

Example photo	

MHWN – Mean High Water Neap – tidal height of the average lowest high tide heights experienced during half-moon phases

MHWS – Mean High Water Spring - tidal height of the average highest high tide heights experienced during full and new moon phases

Table 9 Wholesale commercial fisheries valuation of mangrove habitat within 800m of each net shot location adjacent to the Port of Brisbane (AU$ 2015)

Mapped Fisheries Value Category	Total Area Mapped below MHWS	Area of Mangrove Habitat Fished (Ha)[1]	Proportion of Total Fished Mangrove Habitat	Average Annual Wholesale Value of Commercial Catch (AU$ 2015)[2]
Excellent	27.0	14.4	17%	$16713
Good	77.2	25.4	30%	$31919
Good-Moderate	35.8	15.4	18%	$18122
Moderate[3]	53.3	17.1	20%	$18600
Moderate-Poor[3]	22.7	11.6	14%	$8247
Poor	40.1	1.5	2%	$511
Total Area	256.0	85.4		

1 Based on the area within 800 m radius buffers around each net shot location.

2 Based on the 2015 equivalent wholesale value for fish caught between 2010 to 2015 by a single commercial fishing operator around the Port of Brisbane. This valuation does not incorporate the value of other services and functions provided by mangroves such as nutrient cycling, coastal baffling and protection, nursery areas for fisheries.

3 This habitat type is only productive due to the proximity to extensive and continuous intertidal seagrass meadows. Without this heterogeneous habitat, we would expect to see a more substantial decline in the fisheries productivity.

The wholesale value calculated represents only one of several components of the total value of mangroves and does not include the value to commercial crab or prawn fisheries, which are likely to be substantial based on previous assessments (Ronnback 1999), the value of habitat for productivity or as nurseries for commercially and recreationally important species, or for coastal protection. These additional ecological functions have been valued for ecological functions at approximately US$9990 $ha^{-1}yr^{-1}$ in 1997 (Costanza et al. 1997). Although, mangroves are likely to contribute substantially more value to coastal protection which is estimated on average to be US$33000 $ha^{-1}yr^{-1}$ (Costanza et al. 2008). Furthermore, the retail value of the fresh fish provided by these commercial operations could easily be 3-5 times the wholesale value depending on current market prices (which fluctuate more substantially than wholesale prices). This valuation also does not include the additional economic benefits provided by the fishing industry to maritime industries such as boat mechanics, fuel distributors, net manufacturers and fish distributors.

5 Conclusions

The intertidal areas around Fisherman Islands and Whyte Island are highly productive commercial fishing grounds that support a sustainable catch of commercial sized fish species (average annual catch of approximately 18 tonnes per year). Commercial sized fish are largely moving into the area from elsewhere in Moreton Bay or along the coast, with some species occurring throughout the year, while others are more abundant at certain times of year based on season and previous year recruitment patterns.

A key attribute of the use of intertidal habitat for commercial fishes is whether the habitat can be accessed at high tide, the length of time the habitat is submerged for, and if there is sufficient depth for commercial-sized fish to move around and forage. As such, the frequency of inundation should be a prime indicator of the potential for any habitat to be used by commercially viable numbers of fish. Using LIDAR data to determine the tidal height and frequency of recorded tidal heights, this study demonstrated a substantial area of mangrove habitat at the back of the forest was not accessible for commercial fisheries, as much of this habitat area was inundated infrequently (7 times per year) relative to the fringe, down shore of MHWS. The areas at the back of the forest may provide other functions such as nutrient cycling, coastal protection, and are certainly important foraging habitat for juvenile fish and shorebirds, an assessment of which was beyond the scope of this project.

The composition of catches, CPUE and total value were more highly correlated with habitat parameters associated with seagrass, such as the relative position in a seascape context, rather than habitat parameters associated with mangroves. Furthermore, the extent of seagrass beds and their and proximity to other structured habitat was particularly important for species that consistently yielded the greatest wholesale value (e.g. flathead and bream).

This raises an important question for fisheries management with respect to fish habitat in a seascape context and whether seagrass meadows are more important for commercial fisheries than adjacent mangroves, and just how the mosaic of different habitats affects commercial catches. An explicit comparative test of whether mangrove habitat with and without adjacent seagrass yields a greater number of commercially size fish is warranted to determine whether and how often commercially sized species use mangrove forest. Previous work has demonstrated that abundance of prawns was greater in dense seagrass close to mangroves than when seagrass beds are further away (Skilleter et al. 2005). When conserving areas for commercial fishing, it is essential to examine the characteristics of the broader seascape rather than individual habitats in isolation. This is particularly important when providing a valuation of the coastal habitat as some areas may be critical to the success of a fishery, while others may be much less important or not used at all.

Overall this fishing grounds around the Port of Brisbane provide a unique mix of habitat types with extensive intertidal flats (>2 km wide) that has supported a mesh and tunnel net fishery for many years. Given innovations in net design, understanding of when fish occur and sustainable “resting” of the various shot, using tunnel nets has emerged as a sustainable approach to the fishery, which has increased efficiency while decreasing the overall effort required to supply fresh fish to local markets making the operation more viable long term.

Based on the current assessment of the value of coastal habitat, an understanding the type of commercial fishery is essential, as in this case, seagrass attributes are more important than mangrove attributes for predicting commercial tunnel net catches from this area. In contrast, if the fishery was for prawns or crabs, the result may be quite different. This work also highlights that the valuation of areas must be considered at a local scale, with some areas being critical for sustaining commercial fish catches, while other areas are unimportant. Caution should be taken when providing an average or generic valuation for coastal habitat, because based on the results of this assessment, the value can be orders of magnitude higher for some areas and virtually worthless for others. Further work is required when assessing the value of coastal seascapes in the context of development and particularly the calculation of the value of biodiversity offsets, including “like for like” proposals (FHMOP005.2 Marine Fisheries Habitat Offset Policy, Fisheries Queensland, QLD Government), as patches of coastal habitat clearly support different fish assemblages and yield vastly different quantities and values of commercial fish depending on the specific habitat characteristics of the seascape.

5.1 Limitations

This assessment specifically assessed the value of habitat for commercial catches (i.e. fish of a size suitable for sale). It is well known in the scientific literature that mangroves and seagrass provide a range of important ecological services and functions such as being important nursery habitat, important links in food webs, productivity and coastal erosion protection, among others. Due to the limitations of the scope of this study, the value provided in this report does not include these important components and separate assessments should be completed to assess the value of these other important services in future.

This assessment does not consider the value of coastal seascapes for recreationally important species or the effort of recreational fishers on the area surrounding the Port.

This spatial assessment was a pilot study and is specific to the survey area adjacent to the Port of Brisbane. The predictive power of this methodology to determine the value of areas elsewhere in Moreton Bay and more broadly in Queensland remains to be tested. We plan to complete an expanded assessment in 2017.

This study was limited to finfish. The valuation would most likely be different for prawns and crabs as these species use the mangrove and seagrass habitat differently to finfish, including potentially burrowing into the sediment and remaining within the habitat at low tide.

The area is currently fished by at least two commercial operators; however, the catch data used in this report is based on a single operator who has been fishing the area for more than 44 years. The valuation of habitat for commercial fisheries is therefore a minimum valuation as frequency of fishing is likely to be higher than 40 days per year.

5.2 Recommendations

Additional information is required for this study including completing an assessment of:

- The connectivity of habitats and movement of fish between habitats using an acoustic tagging study and using unbaited remote underwater video stations at several points along the intertidal gradient to determine habitat use by different fish species at different stages of the tide.
- The correlation between current habitat characteristics and seascape complexity with the abundance and diversity of commercially important crustaceans (mud crabs, blue swimmer crabs and prawns – as mangrove and seagrass habitats are likely to be essential for these species (Coles et al. 1993)).
- Additional targeted assessment particularly in areas assessed as having poor value for fisheries are still required and may improve the confidence of these assessments, as currently we only have information from the shots that have historically yielded good catches over time.
- An assessment of the improvement in fisheries productivity following restoration of fish habitat (i.e. in areas of poor condition) or where connectivity among habitats for fish passage has been restored would also be useful to understand the impact of restoration on fish productivity.

6 References

Abal EG, & Dennison WC. 1996. Seagrass depth range and water quality in southern Moreton Bay, Queensland, Australia. *Marine and Freshwater Research, 47:* 763-771.

Anderson, MJ. 2004 *DISTLM: Distance-based multivariate analysis for a linear model*. pp. Department of Statistics, University of Auckland.

Beumer J, & Halliday I. 1994. *Effects of Habitat Disturbance on Coastal Fisheries Resources of Tin Can Bay/Great Sandy Strait.* Report to the Fisheries Research and Development Corporation FRDC No.91/41

Bell JD. & Westoby M. 1986a. Abundance of macrofauna in dense seagrass is due to habitat preference, not predation. *Oecologia, 68:* 205-209.

Bell JD. & Westoby M. 1986b. Variation in seagrass height and density over a wide spatial scale: effects on common fish and decapods. *Journal of Experimental Marine Biology and Ecology 104:* 275-295.

Boström, C., Pittman, S.J., Simenstad, C. & Kneib, R.T. (2011) Seascape ecology of coastal biogenic habitats: advances, gaps, and challenges. *Marine Ecology Progress Series*, 427: 191–217

Blomfield AL. & Gillanders BM. 2005, Fish and invertebrate assemblages in seagrass, mangrove, saltmarsh and non-vegetated habitats, *Estuaries*, 28: 63-77.

BMT WBM 2014. *Mangrove Health Assessment: 2014 Monitoring Results*. Report and spatial layers prepared for Port of Brisbane Pty Ltd. Brisbane, QLD pp. 72

BMT WBM 2015a. *Port of Brisbane – Seagrass Monitoring Report 2014*. Report and spatial layers prepared for Port of Brisbane Pty Ltd. Brisbane, QLD pp. 53

BMT WBM 2015b. *Assessment of marine sediments adjacent to Fisherman Islands 2015*. Report prepared for Port of Brisbane Pty Ltd. Brisbane, QLD pp. 87

Boström C. & Bonsdorff E. 1997. Community structure and spatial variation of benthic invertebrates associated with *Zostera marina* (L.) beds in the northern Baltic Sea. *Journal of Sea Research*, *37:* 153-166.

Bray DJ. 2011. Black Rabbitfish, *Siganus fuscescens*, in Fishes of Australia, accessed 01 May 2016, http://www.fishesofaustralia.net.au/home/species/4734

Burnham KP. & Anderson DR. 2002. *Model selection and multi-model inference*. Springer, New York, NY.

Cappo, M., Williams, D. M., & Duke, N. (1998). A review and synthesis of Australian fisheries habitat research. Major threats, issues and gaps in knowledge of coastal and marine fisheries habitats: a prospectus of opportunities for the FRDC "Ecosystem Protection Program".

Carruthers, T.J.B., Dennison, W.C., Longstaff, B.J., Waycott, M., Abal, E.G., McKenzie, L.J. and Lee Long, W.J. 2002, Seagrass habitats of north east Australia: models of key processes and controls, *Bulletin of marine Science,* 71(3):1153-1169.

Clarke KR. & Gorley RN. 2006. User manual/tutorial. *Primer-E Ltd., Plymouth*, pp. *93*.

Clarke KR, Somerfield PJ. & Gorley RN. 2008. Testing of null hypotheses in exploratory community analyses: similarity profiles and biota-environment linkage. *Journal of Experimental Marine Biology and Ecology*, 366: 56–69.

Coles, R.G., Lee Long, W.J., Watson, R.A. and Derbyshire, K.J. 1993, Distribution of seagrasses, and their fish and penaeid prawn communities, in Cairns Harbour, a tropical estuary, northern Queensland, Australia, *Australian Journal of Marine and Freshwater Research,* 44:193-210.

Connolly RM. & Butler AJ. 1996. The effects of altering seagrass canopy height on small, motile invertebrates of shallow Mediterranean embayments. *Marine Ecology*, *17:* 637-652.

DNPRS 2008 *Moreton Bay broad scale habitats 2008*. Queensland Spatial layer. Accessed 10 June 2016 http://qldspatial.information.qld.gov.au/catalogue/custom/search.page?q=%22Moreton%20Bay%20broadscale%20habitats%202008%22

DEEDI 201. *Data collection protocol for mapping and monitoring mangrove communities in Moreton Bay*. Department of Employment, Education, Economic Development and Innovation, Queensland Government, Brisbane. Accessed online https://www.daf.qld.gov.au/__data/assets/pdf_file/0006/63339/Data-collection-protocol.pdf

Dorenbosch M, Grol MGG, Christianen MJA, Nagelkerken I, & Van Der Velde G. 2005. Indo-Pacific seagrass beds and mangroves contribute to fish density and diversity on adjacent coral reefs. *Marine Ecology Progress Series*, *302*: 63-76.

Edgar GJ, & Robertson AI. 1992. The influence of seagrass structure on the distribution and abundance of mobile epifauna: Pattern and process in a Western Australian *Amphibolis* bed, *Journal of Experimental Marine Biology and Ecology,* 160:13-31

Elliott M, Whitfield AK, Potter IC, et al. (2007) The guild approach to categorizing estuarine fish assemblages: A global review. *Fish and Fisheries*, 8: 241-268

Faunce CH, & Serafy JE. 2008. Selective use of mangrove shorelines by snappers, grunts, and great barracuda. *Marine Ecology Progress Series,* 356:153–162

Ferguson A. & Eyre B. 2013. Interaction of benthic microalgae and macrofauna in the control of benthic metabolism, nutrient fluxes and denitrification in a shallow sub-tropical coastal embayment (western Moreton Bay, Australia). *Biogeochemistry*, *112*(1-3): 423-440.

Gillanders, B., Able, K., Brown, J., Eggleston, D., & Sheridan, P. (2003). Evidence of connectivity between juvenile and adult habitats for mobile marine fauna: an important component of nurseries. *Marine Ecology Progress Series*, *247:* 281-295.

Gomon MF. 2011. Striped Scat, *Selenotoca multifasciata*, in Fishes of Australia, accessed 01 May 2016, http://www.fishesofaustralia.net.au/home/species/2213

Gray CA, & Barnes LM. 2008. *Reproduction and growth of dusky flathead (Platycephalus fuscus) in NSW estuaries*. NSW Department of Primary Industries.

Gray CA, & Barnes LM. 2015. Spawning, maturity, growth and movement of *Platycephalus fuscus* (Cuvier, 1829) (Platycephalidae): fishery management considerations. *Journal of Applied Ichthyology*, *31*(3): 442-450.

Hadwen WL, Russell GL, & Arthington AH. 2007. Gut content-and stable isotope-derived diets of four commercially and recreationally important fish species in two intermittently open estuaries. *Marine and Freshwater Research*, *58*(4): 363-375.

Halliday IA, & Young WR. 1996. Density, biomass and species composition of fish in a subtropical Rhizophora *stylosa* mangrove forest. *Marine and Freshwater Research*, *47*(4): 609-615.

Hastie T. & Tibshirani R. 1986. Generalized additive models. *Statistical Science*, 1: 297–318.

Heck KL, Able KW, Roman CT, & Fahay MP. 1995, Composition, abundance, biomass, and production of macrofauna in a New England Estuary: Comparisons among eelgrass meadows and other nursery habitats, *Estuaries,* 18:379-389.

Heck KLJ, Carruthers TJB, Duarte CM, Hughes AR, Kendrick G, Orth RJ. & Williams WS. 2008, Trophic transfers from seagrass meadows subsidize diverse marine and terrestrial consumers, *Ecosystems,* 11(7):1198-1210.

Hindell JS, & Jenkins GP. 2005. Assessing patterns of fish zonation in temperate mangroves, with emphasis on evaluating sampling artefacts. *Marine Ecology Progress Series*, *290:* 193-205.

Jelbart, J.E., Ross, P.M. and Connolly, R.M. 2007, Patterns of small fish distributions in seagrass beds in a temperate Australian estuary, *Journal of the Marine Biological Association of the United Kingdom,* 87:1297-1307.

Johnson R, Sheaves M (2007) Small fish and crustaceans demonstrate a preference for particular small-scale habitats when mangrove forests are not accessible. *Journal of Experimental Marine Biology and Ecology,* 353: 164–179.

Kohler, K.E. and Gill, S.M. 2006, Coral Point Count with Excel Extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology, *Computers and Geosciences,* 32(9):1259-1269.

Laegdsgaard, P, & Johnson, C. (2001). Why do juvenile fish utilise mangrove habitats? *Journal of experimental marine biology and ecology*, *257*(2): 229-253

Melville, A. J., & Connolly, R. M. (2003). Spatial analysis of stable isotope data to determine primary sources of nutrition for fish. *Oecologia*, *136*(4): 499-507.

Lyons M, Roelfsema C, Kovacs E, Samper-Villarreal J, Saunders M, Maxwell P, Phinn S. 2015. Rapid monitoring of seagrass biomass using a simple linear modelling approach, in the field and from space. *Marine Ecology Progress Series*, 530: 1-14.

Manson, F. J., Loneragan, N. R., Skilleter, G. A., & Phinn, S. R. (2005). An evaluation of the evidence for linkages between mangroves and fisheries: a synthesis of the literature and identification of research directions. *Oceanography and marine biology*, *43:* 483.

McIvor, C. C., & Odum, W. E. (1988). Food, predation risk, and microhabitat selection in a marsh fish assemblage. *Ecology*, *69*(5): 1341-1351.

McKenzie, L.J., Campbell, S.J. & Roder, C.A. (2003) *Seagrass-Watch: Manual for Mapping & Monitoring Seagrass Resources by Community (citizen) volunteers*. 2nd Edition. (QFS, NFC, Cairns) 100pp.

McKenzie, L., Smith, N., Johns, L., Yoshida, R. and Coles, R. 2014, *Development of Wet Tropics WQIP elements – seagrass monitoring,* A report to Terrain NRM, Innisfail, Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) report 14/37, James Cook University, Cairns.

Meynecke, J. O., Lee, S. Y., & Duke, N. C. (2008). Linking spatial metrics and fish catch reveals the importance of coastal wetland connectivity to inshore fisheries in Queensland, Australia. *Biological Conservation*, *141*(4): 981-996.

Morton RM, Halliday I. & Cameron D. 1993. Movement of tagged juvenile Tailor (*Pomatomus saltatrix*) in Moreton Bay, Queensland. *Australian Journal of Marine & Freshwater Research,* 44: 811-816

Nagelkerken, I., Blaber, S.J.M., Bouillon, S., Green, P., Haywood, M., Kirton, L.G., Meynecke, J.-O., Pawlik, J., Penrose, H.M., Sasekumar, A. and Somerfield, P.J. 2008, The habitat function of mangroves for terrestrial and marine fauna: A review, *Aquatic Botany,* 89: 155-185.

Nagelkerken, I., Sheaves, M., Baker, R., Connolly, R.M. (2015) The seascape nursery: a novel spatial approach to identify and manage nurseries for coastal marine fauna. *Fish and Fisheries,* 16: 362-371.

Olds AD, Connolly RM, Pitt KA, & Maxwell PS. 2012. Primacy of seascape connectivity effects in structuring coral reef fish assemblages. *Marine Ecology Progress Series*, *462:* 191-203.

Olds AD, Connolly RM, Pitt KA, Maxwell PS, Aswani S, & Albert S. 2014. Incorporating surrogate species and seascape connectivity to improve marine conservation outcomes. *Conservation Biology*, *28*(4): 982-991.

Olds, A.D., Connolly, R.M., Pitt, K.A., et al. 2016. Quantifying the conservation value of seascape connectivity: A global synthesis. *Global Ecology and Biogeography,* 25: 3-15.

Pittman, S.J., McAlpine, C.A. and Pittman, K.M. 2004, Linking fish and prawns to their environment: a hierarchical landscape approach, *Marine Ecology Progress Series,* 283: 233-254.

Price, C., Gosling, A., Golus, C. and Weslake, M. 2007, *Wetland Assessment Techniques Manual for Australian Wetlands,* WetlandCare Australia, Ballina.

Rempel, R.S., D. Kaukinen., and A.P. Carr. 2012. *Patch Analyst and Patch Grid*. Ontario Ministry of Natural Resources. Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario. Accessed online 01 May 2016 http://www.cnfer.on.ca/SEP/patchanalyst/Patch5_2_Install.htm

Roelfsema, C.M. and Phinn, S.R. 2009, *A manual for conducting georeferenced photo transect surveys to assess the benthos of coral reef and seagrass habitats version 3.0,* Centre for Remote Sensing and Spatial Information Science, The University of Queensland, Brisbane.

Rönnbäck P (1999) The ecological basis for economic valuation of seafood production supported by mangrove ecosystems. *Ecological Economics,* 29: 235-252.

Rönnbäck P, Troell M, Kautsky N, Primavera JH (1999) Distribution pattern of shrimps and fish among *Avicennia* and *Rhizophora* microhabitats in the Pagbilao mangroves, Philippines. *Estuarine Coastal and Shelf Science,* 48: 223–234.

Sheaves MJ. 1996. Habitat-specific distributions of some fishes in a tropical estuary. *Marine and Freshwater Research*, *47*(6): 827-830.

Sheaves, M. 2009. Consequences of ecological connectivity: the coastal ecosystem mosaic. *Marine Ecology Progress Series,* 391: 107-115.

Sheaves, M., Abrantes, K., Johnston, R., Owens, R., Read, M., Saunders, T. and Wulf, P. 2013, *The life-cycle habitat requirements of coastal fisheries species; identifying key knowledge gaps and research needs,* FDRC Project No. 2012/37, James Cook University.

Skilleter GA, Olds A, Loneragan NR, & Zharikov Y. 2005. The value of patches of intertidal seagrass to prawns depends on their proximity to mangroves. *Marine Biology*, *147*(2): 353-365.

Skilleter GA, Cameron B, Zharikov Y, Boland D, & McPhee DP. 2006a. Effects of physical disturbance on infaunal and epifaunal assemblages in subtropical, intertidal seagrass beds. *Marine Ecology Progress Series*, *308:* 61-78.

Skilleter GA, Pryor A, Miller S, & Cameron B. 2006b. Detecting the effects of physical disturbance on benthic assemblages in a subtropical estuary: a beyond BACI approach. *Journal of Experimental Marine Biology and Ecology*, *338*(2): 271-287.

Smith TM, & Hindell JS. 2005. Assessing effects of diel period, gear selectivity and predation on patterns of microhabitat use by fish in a mangrove dominated system in SE Australia. *Marine Ecology Progress Series*, *294:* 257-270.

Travers MJ, & Potter IC. 2002. Factors influencing the characteristics of fish assemblages in a large subtropical marine embayment. *Journal of Fish Biology*, *61*(3): 764-784.

Waltham NJ, & Connolly RM. 2006. Trophic strategies of garfish, *Arrhamphus sclerolepis*, in natural coastal wetlands and artificial urban waterways. *Marine biology*, *148*(5): 1135-1141.

Webster, P.J., Rowden, A.A. and Attrill, M.J. 1998, Effect of Shoot Density on the infaunal macro-invertebrate community within a *Zostera marina* seagrass bed, *Estuarine, Coastal and Shelf Science*, *47*(3): 351-357.

Wedding LM, Lepczyk CA, Pittman SJ, Friedlander AM, & Jorgensen S. 2011. Quantifying seascape structure: extending terrestrial spatial pattern metrics to the marine realm. *Marine Ecology Progress Series*, *427:* 219-232.

Weng HT. 1983. Identification, habitats and seasonal occurrence of juvenile whiting (Sillaginidae) in Moreton Bay, Queensland. *Journal of Fish Biology*, *23*(2): 195-200.

Weng HT. 1990. Fish in shallow areas in Moreton Bay, Queensland and factors affecting their distribution. *Estuarine, Coastal and Shelf Science*, *30*(6): 569-578.

Zharikov, Y., Skilleter, G. A., Loneragan, N. R., Taranto, T., & Cameron, B. E. (2005). Mapping and characterising subtropical estuarine landscapes using aerial photography and GIS for potential application in wildlife conservation and management. *Biological Conservation*, *125*(1): 87-100.

Zuur AF, Ieno N, Walker N, Saveliev AA. & Smith GM. 2009. *Mixed effects models and extensions in ecology with R*. Springer, Berlin.

Appendix A SIMPER Analysis Tables

Species	Average Weight (kg)		Average Dissimilarity	Dissimilarity / Standard Deviation	Contribution (%)
	Net Shot CCC	**Net Shot CDO**	**Average dissimilarity = 71.42**		
Sea mullet	94.0	63.6	16.7	0.95	23
Flathead	45.2	58.0	10.6	1.00	15
Flat tail mullet	24.4	62.0	10.2	0.53	14
Dory	35.6	28.8	8.0	0.52	11
Whiting	6.8	21.6	5.4	0.64	8
Bream	17.6	26.8	5.2	0.67	7
Tailor	2.8	10.0	2.3	0.75	3
Eel pike	5.6	2.8	2.1	0.52	3
Catfish	17.6	0.0	1.8	0.29	2
Shark	9.0	1.2	1.7	0.62	2
	Shot CCC	**Shot D**	**Average dissimilarity = 78.55**		
Mullet	94.0	117.8	23.4	1.11	30
Flathead	45.2	24.8	11.9	0.88	15
Tailor	2.8	28.4	8.6	0.60	11
Bream	17.6	29.8	5.8	0.63	7
Dory	35.6	0.5	4.7	0.37	6
Flat tail mullet	24.4	4.0	4.6	0.43	6
Shark	9.0	10.3	4.6	0.64	6
Whiting	6.8	9.1	3.2	0.41	4
Catfish	17.6	0.9	2.0	0.31	3
	Net Shot CDO	**Net Shot D**	**Average dissimilarity = 79.28**		
Mullet	63.6	117.8	20.5	1.02	26
Flathead	58.0	24.8	13.1	1.04	17
Flat tail mullet	62.0	4.0	8.6	0.45	11
Tailor	10.0	28.4	8.2	0.65	10
Bream	26.8	29.8	7.3	0.67	9
Whiting	21.6	9.1	5.5	0.74	7
Dory	28.8	0.5	4.5	0.37	6
Shark	1.2	10.3	3.7	0.55	5
Silver Biddy	8.0	0.2	1.7	0.37	2
	Net Shot CCC	**Net Shot LI**	**Average dissimilarity = 66.20**		
Mullet	94.0	50.0	15.4	1.13	23
Bream	17.6	50.0	12.3	1.62	19
Dory	35.6	30.0	11.0	1.09	17
Flathead	45.2	30.0	7.6	1.13	11
Flat tail mullet	24.4	0.0	3.7	0.37	6

Species	Average Weight (kg)		Average Dissimilarity	Dissimilarity / Standard Deviation	Contribution (%)
Whiting	6.8	10.0	3.5	0.74	5
Mixed Fish	0.4	10.0	2.7	2.01	4
Catfish	17.6	0.0	1.8	0.29	3
	Net Shot CDO	**Net Shot LI**	**Average dissimilarity = 67.78**		
Mullet	63.6	50.0	13.4	1.29	20
Bream	26.8	50.0	12.1	1.83	18
Dory	28.8	30.0	11.2	1.39	16
Flathead	58.0	30.0	9.7	1.39	14
Flat tail mullet	62.0	0.0	7.6	0.41	11
Whiting	21.6	10.0	5.0	0.98	7
Mixed Fish	0.8	10.0	2.5	2.03	4
	Net Shot D	**Net Shot LI**	**Average dissimilarity = 74.36**		
Mullet	117.8	50.0	21.3	1.49	29
Bream	29.8	50.0	15.1	2.03	20
Dory	0.5	30.0	8.9	2.50	12
Tailor	28.4	0.0	8.1	0.67	11
Flathead	24.8	30.0	6.1	1.38	8
Shark	10.3	0.0	3.6	0.62	5
Whiting	9.1	10.0	3.5	1.23	5
Mixed Fish	0.5	10.0	2.9	2.43	4
	Net Shot CCC	**Net Shot MB**	**Average dissimilarity = 77.45**		
Bream	17.6	90.0	21.1	1.16	27
Mullet	94.0	23.3	14.6	0.91	19
Flathead	45.2	16.7	10.8	1.11	14
Dory	35.6	6.7	5.6	0.45	7
Tailor	2.8	16.7	3.9	1.16	5
Flat tail mullet	24.4	0.0	3.8	0.37	5
Squid	0.4	13.3	3.3	1.06	4
Whiting	6.8	6.7	2.6	0.41	3
garfish	5.6	10.0	2.3	0.78	3
	Net Shot CDO	**Net Shot MB**	**Average dissimilarity = 76.70**		
Bream	26.8	90.0	20.9	1.30	27
Flathead	58.0	16.7	12.5	1.29	16
Mullet	63.6	23.3	11.1	0.85	14
Flat tail mullet	62.0	0.0	7.8	0.41	10
Dory	28.8	6.7	5.5	0.47	7
Whiting	21.6	6.7	5.1	0.75	7
Tailor	10.0	16.7	3.7	1.10	5
Squid	0.4	13.3	3.2	1.11	4

Species	Average Weight (kg)		Average Dissimilarity	Dissimilarity / Standard Deviation	Contribution (%)
	Net Shot D	**Net Shot MB**	**Average dissimilarity = 76.76**		
Bream	29.8	90.0	23.2	1.22	30
Mullet	117.8	23.3	19.6	1.04	26
Tailor	28.4	16.7	9.1	0.73	12
Flathead	24.8	16.7	7.7	0.96	10
Shark	10.3	3.5	4.1	0.60	5
Squid	5.0	13.3	3.6	1.12	5
Garfish	7.9	10.0	2.9	0.81	4
	Net Shot LI	**Net Shot MB**	**Average dissimilarity = 56.28**		
Bream	50.0	90.0	19.7	12.76	35
Mullet	50.0	23.3	7.6	1.31	14
Dory	30.0	6.7	7.5	1.69	13
Flathead	30.0	16.7	5.6	2.09	10
Tailor	0.0	16.7	4.0	1.29	7
Squid	0.0	13.3	3.3	1.21	6
Whiting	10.0	6.7	3.0	3.48	5
	Net Shot CCC	**Net Shot MBF**	**Average dissimilarity = 85.74**		
Mullet	94.0	61.0	20.6	1.08	24
Tailor	2.8	54.6	14.5	0.78	17
Flathead	45.2	13.0	13.5	0.89	16
Shark	9.0	27.9	8.8	0.55	10
Dory	35.6	3.0	5.1	0.41	6
Flat tail mullet	24.4	7.0	5.0	0.47	6
Mackerel	0.0	6.0	3.0	0.50	3
Bream	17.6	5.0	2.9	0.78	3
Catfish	17.6	0.0	1.9	0.29	2
	Net Shot CDO	**Net Shot MBF**	**Average dissimilarity = 86.61**		
Mullet	63.6	61.0	17.4	1.03	20
Flathead	58.0	13.0	14.7	1.06	17
Tailor	10.0	54.6	13.6	0.82	16
Flat tail	62.0	7.0	9.0	0.47	10
Shark	1.2	27.9	8.0	0.52	9
Dory	28.8	3.0	4.9	0.41	6
Whiting	21.6	0.0	4.9	0.67	6
Bream	26.8	5.0	4.6	0.58	5
Mackerel	0.0	6.0	2.7	0.51	3
	Net Shot D	**Net Shot MBF**	**Average dissimilarity = 79.04**		
Sea mullet	117.8	61.0	24.0	1.12	30
Tailor	28.4	54.6	17.4	0.92	22
Shark	10.3	27.9	10.1	0.61	13
Flathead	24.8	13.0	7.4	0.86	9

Species	Average Weight (kg)		Average Dissimilarity	Dissimilarity / Standard Deviation	Contribution (%)
Bream	29.8	5.0	5.2	0.55	7
Mackerel	1.4	6.0	3.5	0.53	4
Flat tail mullet	4.0	7.0	2.7	0.38	3
garfish	7.9	4.0	2.2	0.57	3
	Net Shot LI	**Net Shot MBF**	**Average dissimilarity = 83.72**		
Sea mullet	50.0	61.0	19.1	2.54	23
Tailor	0.0	54.6	14.5	0.89	17
Bream	50.0	5.0	13.9	2.25	17
Dory	30.0	3.0	8.4	2.12	10
Shark	0.0	27.9	8.1	0.55	10
Flathead	30.0	13.0	7.3	1.75	9
Whiting	10.0	0.0	3.0	3.08	4
Mixed Fish	10.0	0.0	3.0	3.08	4
	Net Shot MB	**Net Shot MBF**	**Average dissimilarity = 85.46**		
Bream	90.0	5.0	22.7	1.25	27
Sea mullet	23.3	61.0	16.9	1.17	20
Tailor	16.7	54.6	14.7	0.88	17
Shark	3.5	27.9	8.7	0.53	10
Flathead	16.7	13.0	6.9	0.76	8
Squid	13.3	0.0	3.6	1.13	4
Mackerel	0.0	6.0	2.9	0.55	3
garfish	10.0	4.0	2.6	0.72	3
	Net Shot CCC	**Net Shot MBT**	**Average dissimilarity = 69.01**		
Sea mullet	94.0	54.2	16.6	1.03	24
Flathead	45.2	41.1	10.2	0.92	15
Flat tail	24.4	30.5	7.9	0.55	11
Bream	17.6	51.6	7.9	0.69	11
Dory	35.6	21.6	5.9	0.43	8
Eel pike	5.6	9.5	3.4	0.70	5
Whiting	6.8	9.5	3.3	0.43	5
Catfish	17.6	4.7	2.7	0.40	4
Shark	9.0	4.0	2.2	0.70	3
	Net Shot CDO	**Net Shot MBT**	**Average dissimilarity = 70.38**		
Mullet	63.6	54.2	13.5	1.04	19
Flat tail	62.0	30.5	11.5	0.56	16
Flathead	58.0	41.1	11.3	1.06	16
Bream	26.8	51.6	9.3	0.74	13
Dory	28.8	21.6	5.7	0.44	8
Whiting	21.6	9.5	5.6	0.76	8
Eel pike	2.8	9.5	2.8	0.81	4
Tailor	10.0	3.7	2.6	0.82	4
Silver Biddy	8.0	0.5	1.7	0.37	2

Species	Average Weight (kg)		Average Dissimilarity	Dissimilarity / Standard Deviation	Contribution (%)
	Net Shot D	**Net Shot MBT**	**Average dissimilarity = 76.93**		
Mullet	117.8	54.2	20.9	1.11	27
Flathead	24.8	41.1	10.5	0.96	14
Bream	29.8	51.6	10.1	0.73	13
Tailor	28.4	3.7	9.5	0.63	12
Flat tail	4.0	30.5	6.0	0.46	8
Shark	10.3	4.0	4.6	0.56	6
Whiting	9.1	9.5	3.4	0.63	4
Eel pike	0.3	9.5	2.9	0.76	4
garfish	7.9	5.3	2.3	0.59	3
	Net Shot LI	**Net Shot MBT**	**Average dissimilarity = 62.33**		
Bream	50.0	51.6	16.2	1.79	26
Mullet	50.0	54.2	11.8	1.63	19
Dory	30.0	21.6	10.3	2.18	17
Flathead	30.0	41.1	4.8	0.74	8
Flat tail	0.0	30.5	4.8	0.42	8
Whiting	10.0	9.5	3.2	1.31	5
Mixed Fish	10.0	1.1	3.1	2.56	5
Eel pike	0.0	9.5	2.6	0.88	4
	Net Shot MB	**Net Shot MBT**	**Average dissimilarity = 72.62**		
Bream	90.0	51.6	24.6	1.29	34
Mullet	23.3	54.2	11.0	1.27	15
Flathead	16.7	41.1	9.4	1.17	13
Flat tail	0.0	30.5	5.0	0.42	7
Tailor	16.7	3.7	4.3	1.27	6
Squid	13.3	2.1	3.6	1.05	5
Whiting	6.7	9.5	2.8	0.79	4
Eel pike	0.0	9.5	2.8	0.81	4
Dory	6.7	21.6	2.7	0.46	4
	Net Shot MBF	**Net Shot MBT**	**Average dissimilarity = 85.97**		
Mullet	61.0	54.2	18.0	1.21	21
Tailor	54.6	3.7	15.7	0.80	18
Flathead	13.0	41.1	12.1	1.01	14
Shark	27.9	4.0	9.3	0.53	11
Bream	5.0	51.6	7.5	0.63	9
Flat tail	7.0	30.5	6.3	0.50	7
Mackeral	6.0	0.0	3.4	0.49	4
Eel pike	0.0	9.5	2.8	0.77	3
Whiting	0.0	9.5	2.1	0.56	2
Dory	3.0	21.6	2.0	0.33	2

Species	Average Weight (kg)		Average Dissimilarity	Dissimilarity / Standard Deviation	Contribution (%)
	Net Shot CCC	**Net Shot PC**	**Average dissimilarity = 82.05**		
Mullet	94.0	86.3	20.4	0.99	25
Flathead	45.2	25.4	12.9	0.77	16
Bream	17.6	57.9	10.6	0.80	13
Dory	35.6	43.3	8.0	0.47	10
Tailor	2.8	20.3	7.0	0.57	9
Whiting	6.8	20.4	5.2	0.51	6
Flat tail	24.4	0.0	3.6	0.36	4
Shark	9.0	6.1	3.3	0.53	4
Eel pike	5.6	0.0	1.8	0.36	2
	Net Shot CDO	**Net Shot PC**	**Average dissimilarity = 80.65**		
Mullet	63.6	86.3	17.0	0.89	21
Flathead	58.0	25.4	13.7	0.91	17
Bream	26.8	57.9	11.5	0.87	14
Dory	28.8	43.3	7.8	0.47	10
Flat tail	62.0	0.0	7.7	0.41	10
Whiting	21.6	20.4	7.0	0.77	9
Tailor	10.0	20.3	6.4	0.58	8
Shark	1.2	6.1	2.2	0.40	3
	Net Shot D	**Net Shot PC**	**Average dissimilarity = 78.26**		
Mullet	117.8	86.3	23.6	1.03	30
Bream	29.8	57.9	12.7	0.85	16
Tailor	28.4	20.3	11.4	0.72	15
Flathead	24.8	25.4	8.2	0.83	10
Whiting	9.1	20.4	5.4	0.61	7
Shark	10.3	6.1	5.2	0.55	7
Dory	0.5	43.3	4.1	0.31	5
	Net Shot LI	**Net Shot PC**	**Average dissimilarity = 72.69**		
Mullet	50.0	86.3	18.8	1.36	26
Bream	50.0	57.9	15.0	1.67	21
Dory	30.0	43.3	12.0	1.06	17
Flathead	30.0	25.4	6.8	1.39	9
Tailor	0.0	20.3	6.6	0.65	9
Whiting	10.0	20.4	5.5	0.90	8
Mixed Fish	10.0	0.4	2.8	1.94	4
	Net Shot MB	**Net Shot PC**	**Average dissimilarity = 72.44**		
Bream	90.0	57.9	22.7	1.18	31
Mullet	23.3	86.3	16.1	0.90	22
Flathead	16.7	25.4	7.7	0.79	11
Tailor	16.7	20.3	7.0	0.65	10
Dory	6.7	43.3	5.3	0.39	7
Whiting	6.7	20.4	4.9	0.62	7

Species	Average Weight (kg)		Average Dissimilarity	Dissimilarity / Standard Deviation	Contribution (%)
Squid	13.3	7.5	3.4	0.92	5
	Net Shot MBF	**Net Shot PC**	**Average dissimilarity = 82.77**		
Mullet	61.0	86.3	20.2	0.96	24
Tailor	54.6	20.3	16.1	0.85	19
Bream	5.0	57.9	10.9	0.79	13
Shark	27.9	6.1	9.4	0.55	11
Flathead	13.0	25.4	6.3	1.00	8
Dory	3.0	43.3	4.7	0.34	6
Whiting	0.0	20.4	4.3	0.52	5
Mackeral	6.0	0.2	3.6	0.39	4
	Net Shot MBT	**Net Shot PC**	**Average dissimilarity = 80.04**		
Mullet	54.2	86.3	17.6	1.02	22
Bream	51.6	57.9	14.4	0.92	18
Flathead	41.1	25.4	11.7	0.86	15
Tailor	3.7	20.3	7.7	0.58	10
Whiting	9.5	20.4	5.4	0.64	7
Dory	21.6	43.3	5.4	0.37	7
Flat tail	30.5	0.0	5.0	0.40	6
Shark	4.0	6.1	3.0	0.44	4
Eel pike	9.5	0.0	2.8	0.71	4
	Net Shot CCC	**Net Shot RBB**	**Average dissimilarity = 75.13**		
Mullet	94.0	102.5	20.0	1.09	27
Bream	17.6	90.5	14.4	1.06	19
Flathead	45.2	53.0	11.4	0.76	15
Dory	35.6	21.0	6.0	0.49	8
Shark	9.0	10.7	4.7	0.43	6
Flat tail	24.4	0.0	3.3	0.36	4
Whiting	6.8	14.5	3.3	0.49	4
Squid	0.4	10.0	1.8	0.63	2
Catfish	17.6	0.0	1.7	0.28	2
	Net Shot CDO	**Net Shot RBB**	**Average dissimilarity = 74.99**		
Mullet	63.6	102.5	17.6	1.05	23
Bream	26.8	90.5	14.9	1.13	20
Flathead	58.0	53.0	11.7	0.87	16
Flat tail	62.0	0.0	7.0	0.40	9
Dory	28.8	21.0	5.9	0.51	8
Whiting	21.6	14.5	5.0	0.78	7
Shark	1.2	10.7	3.8	0.37	5
Tailor	10.0	7.5	2.4	0.77	3
	Net Shot D	**Net Shot RBB**	**Average dissimilarity = 77.31**		
Mullet	117.8	102.5	23.1	1.15	30
Bream	29.8	90.5	16.0	1.09	21

Species	Average Weight (kg)		Average Dissimilarity	Dissimilarity / Standard Deviation	Contribution (%)
Flathead	24.8	53.0	11.1	0.91	14
Tailor	28.4	7.5	8.0	0.57	10
Shark	10.3	10.7	6.1	0.51	8
Whiting	9.1	14.5	3.4	0.70	4
Dory	0.5	21.0	2.5	0.40	3
	Net Shot LI	**Net Shot RBB**	**Average dissimilarity = 63.25**		
Mullet	50.0	102.5	17.2	1.34	27
Bream	50.0	90.5	16.3	2.02	26
Flathead	30.0	53.0	8.7	1.23	14
Dory	30.0	21.0	7.7	1.28	12
Shark	0.0	10.7	3.6	0.41	6
Whiting	10.0	14.5	2.9	1.06	5
Mixed Fish	10.0	1.5	2.5	1.76	4
	Net Shot MB	**Net Shot RBB**	**Average dissimilarity = 67.50**		
Bream	90.0	90.5	20.3	1.10	30
Mullet	23.3	102.5	16.5	1.03	24
Flathead	16.7	53.0	10.8	1.01	16
Shark	3.5	10.7	4.2	0.40	6
Tailor	16.7	7.5	3.6	1.04	5
Squid	13.3	10.0	3.2	0.93	5
Dory	6.7	21.0	3.1	0.52	5
	Net Shot MBF	**Net Shot RBB**	**Average dissimilarity = 84.62**		
Mullet	61.0	102.5	20.3	1.14	24
Bream	5.0	90.5	15.3	1.11	18
Tailor	54.6	7.5	13.1	0.75	15
Flathead	13.0	53.0	11.1	0.95	13
Shark	27.9	10.7	9.6	0.57	11
Mackeral	6.0	0.0	3.0	0.34	3
Dory	3.0	21.0	2.8	0.45	3
Whiting	0.0	14.5	2.5	0.72	3
	Net Shot MBT	**Net Shot RBB**	**Average dissimilarity = 73.66**		
Mullet	54.2	102.5	17.7	1.15	24
Bream	51.6	90.5	17.3	1.15	23
Flathead	41.1	53.0	11.6	0.88	16
Shark	4.0	10.7	4.8	0.38	6
Flat tail	30.5	0.0	4.5	0.39	6
Dory	21.6	21.0	3.7	0.46	5
Whiting	9.5	14.5	3.3	0.82	5
Eel pike	9.5	0.5	2.5	0.71	3
Squid	2.1	10.0	2.1	0.67	3
	Net Shot PC	**Net Shot RBB**	**Average dissimilarity = 76.05**		
Mullet	86.3	102.5	20.2	1.04	27

Species	Average Weight (kg)		Average Dissimilarity	Dissimilarity / Standard Deviation	Contribution (%)
Bream	57.9	90.5	17.0	1.11	22
Flathead	25.4	53.0	10.9	0.86	14
Tailor	20.3	7.5	6.5	0.51	9
Dory	43.3	21.0	5.9	0.44	8
Shark	6.1	10.7	5.3	0.41	7
Whiting	20.4	14.5	5.1	0.69	7
	Net Shot CCC	**Net Shot RMB**	**Average dissimilarity = 56.87**		
Mullet	94.0	100.0	25.0	1.68	44
Flathead	45.2	70.0	7.9	1.06	14
Dory	35.6	0.0	4.7	0.37	8
Bream	17.6	10.0	3.8	1.99	7
Flat tail	24.4	0.0	3.7	0.37	6
Catfish	17.6	0.0	1.8	0.29	3
Shark	9.0	0.0	1.7	0.57	3
Whiting	6.8	0.0	1.6	0.28	3
	Net Shot CDO	**Net Shot RMB**	**Average dissimilarity = 60.67**		
Mullet	63.6	100.0	23.5	1.81	39
Flathead	58.0	70.0	9.1	1.36	15
Flat tail	62.0	0.0	7.6	0.41	12
Bream	26.8	10.0	4.9	0.83	8
Whiting	21.6	0.0	4.6	0.69	8
Dory	28.8	0.0	4.4	0.37	7
Tailor	10.0	0.0	2.1	0.79	3
	Net Shot D	**Net Shot RMB**	**Average dissimilarity = 69.81**		
Mullet	117.8	100.0	30.7	2.28	44
Flathead	24.8	70.0	14.8	1.56	21
Tailor	28.4	0.0	8.1	0.67	12
Bream	29.8	10.0	5.9	0.72	8
Shark	10.3	0.0	3.6	0.62	5
	Net Shot LI	**Net Shot RMB**	**Average dissimilarity = 50.00**		
Mullet	50.0	100.0	13.9		28
Flathead	30.0	70.0	11.1		22
Bream	50.0	10.0	11.1		22
Dory	30.0	0.0	8.3		17
Whiting	10.0	0.0	2.8		6
	Net Shot MB	**Net Shot RMB**	**Average dissimilarity = 70.94**		
Mullet	23.3	100.0	22.4	2.69	32
Bream	90.0	10.0	21.2	1.41	30
Flathead	16.7	70.0	14.8	2.69	21
Tailor	16.7	0.0	4.0	1.15	6
Squid	13.3	0.0	3.3	1.08	5

Species	Average Weight (kg)		Average Dissimilarity	Dissimilarity / Standard Deviation	Contribution (%)
	Net Shot MBF	**Net Shot RMB**	**Average dissimilarity = 77.31**		
Mullet	61.0	100.0	26.5	1.84	34
Flathead	13.0	70.0	17.9	1.87	23
Tailor	54.6	0.0	14.5	0.87	19
Shark	27.9	0.0	8.1	0.53	11
Bream	5.0	10.0	3.2	3.30	4
	Net Shot MBT	**Net Shot RMB**	**Average dissimilarity = 59.41**		
Mullet	54.2	100.0	23.2	1.52	39
Flathead	41.1	70.0	11.2	1.68	19
Bream	51.6	10.0	8.6	0.83	14
Flat tail	30.5	0.0	4.8	0.41	8
Eel pike	9.5	0.0	2.6	0.87	4
Whiting	9.5	0.0	2.0	0.57	3
Dory	21.6	0.0	1.5	0.24	2
	Net Shot PC	**Net Shot RMB**	**Average dissimilarity = 76.31**		
Mullet	86.3	100.0	29.7	1.91	39
Flathead	25.4	70.0	15.8	1.37	21
Bream	57.9	10.0	10.7	0.97	14
Tailor	20.3	0.0	6.6	0.64	9
Dory	43.3	0.0	4.2	0.30	5
Whiting	20.4	0.0	4.1	0.52	5
	Net Shot RBB	**Net Shot RMB**	**Average dissimilarity = 63.03**		
Mullet	102.5	100.0	24.1	1.53	38
Bream	90.5	10.0	15.2	1.35	24
Flathead	53.0	70.0	10.7	0.95	17
Shark	10.7	0.0	3.6	0.40	6
Whiting	14.5	0.0	2.4	0.73	4
Dory	21.0	0.0	2.4	0.38	4
	Net Shot CCC	**Net Shot WD**	**Average dissimilarity = 89.49**		
Flathead	45.2	9.2	19.3	0.95	22
Mullet	94.0	21.5	18.9	0.97	21
Tailor	2.8	37.1	14.4	0.91	16
Flat tail	24.4	13.9	5.8	0.46	6
Dory	35.6	1.5	5.4	0.38	6
Shark	9.0	10.1	5.1	0.68	6
Bream	17.6	14.6	4.6	0.74	5
Whiting	6.8	8.5	3.3	0.34	4
Eel pike	5.6	1.5	2.5	0.41	3
	Net Shot CDO	**Net Shot WD**	**Average dissimilarity = 87.87**		
Flathead	58.0	9.2	19.8	1.11	23
Mullet	63.6	21.5	13.7	0.85	16

Species	Average Weight (kg)		Average Dissimilarity	Dissimilarity / Standard Deviation	Contribution (%)
Tailor	10.0	37.1	12.6	0.89	14
Flat tail	62.0	13.9	10.8	0.50	12
Bream	26.8	14.6	6.7	0.64	8
Whiting	21.6	8.5	6.5	0.75	7
Dory	28.8	1.5	5.2	0.38	6
Shark	1.2	10.1	3.9	0.56	4
	Net Shot D	**Net Shot WD**	**Average dissimilarity = 80.24**		
Mullet	117.8	21.5	22.1	0.94	28
Tailor	28.4	37.1	17.7	0.98	22
Flathead	24.8	9.2	10.4	0.78	13
Shark	10.3	10.1	7.5	0.69	9
Bream	29.8	14.6	7.0	0.61	9
Whiting	9.1	8.5	3.4	0.54	4
Flat tail	4.0	13.9	3.4	0.36	4
garfish	7.9	2.3	1.9	0.54	2
	Net Shot LI	**Net Shot WD**	**Average dissimilarity = 89.51**		
Mullet	50.0	21.5	19.8	4.60	22
Bream	50.0	14.6	18.7	3.19	21
Tailor	0.0	37.1	13.4	1.11	15
Dory	30.0	1.5	11.1	2.86	12
Flathead	30.0	9.2	10.3	2.12	11
Whiting	10.0	8.5	4.5	2.86	5
Shark	0.0	10.1	3.8	0.60	4
	Net Shot MB	**Net Shot WD**	**Average dissimilarity = 84.52**		
Bream	90.0	14.6	27.7	1.20	33
Mullet	23.3	21.5	13.4	1.04	16
Tailor	16.7	37.1	13.0	0.93	15
Flathead	16.7	9.2	10.0	0.76	12
Squid	13.3	0.8	4.4	1.12	5
Shark	3.5	10.1	4.3	0.60	5
Whiting	6.7	8.5	2.6	0.76	3
garfish	10.0	2.3	2.5	0.74	3
	Net Shot MBF	**Net Shot WD**	**Average dissimilarity = 78.83**		
Tailor	54.6	37.1	22.3	1.06	28
Mullet	61.0	21.5	16.8	0.81	21
Shark	27.9	10.1	12.6	0.63	16
Flathead	13.0	9.2	6.1	0.64	8
Mackeral	6.0	2.3	5.3	0.53	7
Flat tail	7.0	13.9	3.7	0.44	5
Bream	5.0	14.6	3.4	0.59	4
Spotted Ray	5.0	0.0	2.3	0.31	3

Species	Average Weight (kg)		Average Dissimilarity	Dissimilarity / Standard Deviation	Contribution (%)
	Net Shot MBT	**Net Shot WD**	**Average dissimilarity = 88.61**		
Flathead	41.1	9.2	17.9	1.14	20
Tailor	3.7	37.1	16.0	0.93	18
Mullet	54.2	21.5	14.8	1.31	17
Bream	51.6	14.6	9.5	0.68	11
Flat tail	30.5	13.9	7.8	0.52	9
Shark	4.0	10.1	5.1	0.61	6
Eel pike	9.5	1.5	3.7	0.78	4
Whiting	9.5	8.5	3.5	0.70	4
Dory	21.6	1.5	1.7	0.28	2
	Net Shot PC	**Net Shot WD**	**Average dissimilarity = 80.95**		
Tailor	20.3	37.1	16.1	0.85	20
Mullet	86.3	21.5	16.1	0.75	20
Bream	57.9	14.6	13.6	0.82	17
Flathead	25.4	9.2	8.5	0.73	11
Shark	6.1	10.1	6.2	0.58	8
Whiting	20.4	8.5	5.9	0.60	7
Dory	43.3	1.5	4.6	0.32	6
Squid	7.5	0.8	2.3	0.63	3
	Net Shot RBB	**Net Shot WD**	**Average dissimilarity = 87.39**		
Mullet	102.5	21.5	18.8	1.02	22
Bream	90.5	14.6	17.7	1.07	20
Flathead	53.0	9.2	14.5	0.89	17
Tailor	7.5	37.1	13.1	0.75	15
Shark	10.7	10.1	7.8	0.49	9
Whiting	14.5	8.5	3.6	0.85	4
Dory	21.0	1.5	2.8	0.43	3
Squid	10.0	0.8	2.3	0.65	3
	Net Shot RMB	**Net Shot WD**	**Average dissimilarity = 88.78**		
Mullet	100.0	21.5	36.1	2.49	41
Flathead	70.0	9.2	23.4	2.13	26
Tailor	0.0	37.1	13.4	1.08	15
Bream	10.0	14.6	5.6	1.47	6
Shark	0.0	10.1	3.8	0.59	4