ANALYSIS OF AUSTRALIAN CONTINENTAL SHELF PROVINCES AND BIOMES BASED ON FISH DATA

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MARINE BIODIVERSITY RESEARCH
Prediction and Management of Australia's Marine Biodiversity

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Contents

List of Figures

Summary

To date, marine bioregionalisations of the Australian continental region (used in regional marine planning and the establishment of the NRSMPA) examined the provincial structuring of the shelf, and the biomic and provincial structuring of the slope. This study expands on the previous bioregionalisations by incorporating extensively updated data on continental shelf fishes to provide current biomic and preliminary provincial regionalisations of the continental shelf of Australia.

Analyses of all updated fish data available for species that occur at depths shallower than 200 m, regardless of BII (Biogeographic Information Index) scores, were conducted to determine the provincial and biomic structures. Distribution data consisting of depth and geographic start and end points, and quality control information, were recorded around the Australian continental margin for each species.

Extensive assimilation and updating of data resulted in 3687 of more than 5200 Australian fish species records having depth and string range information, and 2758 of these were recorded as occurring demersally at 200 m or shallower.

Jaccard analyses, following methods developed for the national slope bioregionalisation, were used to analyse the provincial structure for species occurring at depths shallower than 200 m. A gridded matrix analysis in string-depth space was also conducted to resolve the biomic structure.

Biomic structuring of the continental shelf is consistent, within uncertainties in species ranges and analysis resolution, around the whole coastline and shows an unresolved coastal biome from 0 to about 15 m and other biomes at approximate depth ranges of: 70–100 m; 120–145 m; 160–195 m, with transition zones between these. Of these transitions, the ones at 15–70 m and 195–235 m have the highest Jaccard implying strong inter-mixing of species at these depth ranges. While the magnitude of the Jaccard varied along the shelf, the pattern of this variation was consistent. This implies that both the provincial and biomic structures are important in determining the local rates of speciation and mixing.

The provincial structuring derived in this study is, in general, similar to that reported in the previous shelf bioregionalisation produced by CSIRO for the earliest IMCRA project (IMCRA, 1996). However, there were several significant differences, e.g. translocation of the Gulf Province off South Australia. The current study attempted to amalgamate the shelf and slope provincial analyses by mapping shelf species against the slope string based on the 500 m depth contour, as used in Last *et al.* (2005). Differences in provincial structuring reported here, may in part be a result of the loss of precision caused by use of the slope string. Thus future work requires additional analyses to produce a more robust shelf provincial bioregionalisation, and at this stage we recommend the continued use of shelf provinces as documented in the National Marine Bioregionalisation (NMB, 2005).

Background

The first provincial bioregionalisation of the Australian continental EEZ, based on the distributions of demersal fishes, was completed in 1996 (IMCRA, 1996). These analyses were synthesized with others based on bio-physical datasets, including oceanographic distributions, to produce regionalisations of the pelagic and demersal shelf and a preliminary offshore pelagic regionalisation of water masses, which were all part of the Interim Marine and Coastal Regionalisation for Australia, version 3.3 (IMCRA, 1998). This report identified demersal provinces comprising: 3 tropical provinces in the north, a subtropical province in the west, 3 warm-temperate provinces and one cold-temperate province in the south. The original study (IMCRA, 1996) followed an unpublished pilot study (Lyne *et al.*, 1995) that investigated the biomic structuring on the North West Shelf of Australia using a comprehensive database of fish caught during research voyages conducted in the late 70's and through the 80's. A key finding of that pilot study was a remarkable structuring of fish assemblages by depth (or depth-related variables such as temperature).

Following the first bioregionalisation study, a second study produced provincial and biomic regionalisations for the South-East Marine Region (SEMR) using continental slope fish data (CSIRO, 2001). This study found bathymetrically distinct faunal assemblages on the slope, representing four separate biomes, separated by transition zones or ecotones. It also highlighted the need for a national approach to develop an overarching framework for the whole Australian region. This national study was reported by Last *et al.* (2005) who produced provincial and biomic regionalisations of the whole of the Australian continental slope based on demersal fish fauna. This study found that there were strong patterns in the provincial distribution of Australian deepwater fishes with some obvious parallels to the inshore patterns, but with some marked differences. Eight deepwater provinces were identified and within each, strong patterns of bathymetric zoning of the fauna were also identified. In a companion study of biomic structures on the shelf, Lyne *et al.* (2007) revisited the earlier (Lyne *et al.*, 1994) unpublished study and demonstrated distinct depth zones (offshore of 20 m - the limiting depth for research ships in this high tide region) on the continental shelf of the North West Shelf which they classified into: inner shelf, mid-shelf and outer shelf units, matching the classification for the South East Shelf (Williams & Bax, 2001).

Collectively, these studies provided strong support for the notion that depth structuring exists within all provincial units along the Australian continental shelf, to complement the slope units found in Last *et al.* (2005). The major aim of the present study is to provide the first biomic regionalisation for the Australian continental shelf by updating the fish data used for the previous bioregionalisations. A further aim was to conduct provisional bioregionalisations of the continental shelf of Australia using these data and to compare with the previous shelf bioregionalisation.

Methods

The methods used in this study generally follow those used for the slope bioregionalisation (Last *et al.*, 2005) and are described in the following sections. In previous fish bioregionalisation studies, catch and collection data were utilised to determine species distributions, and in the case of the slope bioregionalisation study selected specimens were examined to validate identifications. Fishes existing on the shelf are relatively better known than those on the slope, and for this regionalisation species distributions were compiled from published literature.

To enable comparison between this study and the slope regionalisation (Last *et al.*, 2005) we used the same spatial reference "string" from the earlier slope study. Although in retrospect, change to this caused some problems for provincial regionalisation in the region around Bass Strait due to the string running around the slope of Tasmania. Also, a potential provincial unit in the Gulfs of South Australia (found in the IMCRA, 1996 study) was not adequately represented. Nonetheless, this study represents an important preliminary investigation of the shelf provincial units.

Data entry

A provisional list of fish species containing all fish taxa known to occur in the Australian EEZ was compiled by using the species list from CAAB (Codes for Australian Aquatic Biota, http://www.cmar.csiro.au/caab). Existing data (depth, geographic ranges and broad habitat type) are available in the Species Database for a large number of taxa from earlier bioregionalisations, i.e. IMCRA (1998), the South-east Marine Region (SEMR) study (CSIRO 2001) and the slope bioregionalisation study (Last *et al.*, 2005). For data entry purposes, the Species Database was exported as an Excel file to facilitate entry of data for this study, i.e. string position (geographic range), depth and broad habitat type occupied by each species.

Although a large number of species already had geographic range data added during previous shelf bioregionalisation studies, these typically did not have depth information included. Genera were prioritised based on their potential 'usefulness' to the study, i.e. occurring on the shelf, demersal, data available, etc. Focus was thus placed on adding depth ranges for those useful shelf species with string information already entered as well as adding in depth and string ranges for those species without previously entered data. For many species, and especially those treated in recent taxonomic revisions (e.g. sharks and rays), the geographic ranges were updated to reflect the new data available.

Entry of string data (start and end points of each geographic range) allowed for up to three disjunct distributions. For each string start and end point, the initials of the person entering the data, the confidence on a scale from 1–5 (where 1 = excellent, 2 = good, 3 = satisfactory, 4 = poor, 5 = doubtful), and the source of the information (e.g. museum specimen or specific literature record) were entered. An overall 'string completeness' score (where 1 = ready for analysis, 2 = minor upgrade still needed, 3 = incomplete, species potentially useful, 4 = data deficient, species probably not useful) was also recorded for each taxon. Grid references were added to reflect the distribution of those 'useful' species whose range started or ended within the Gulf of Carpentaria or Bass Strait (see next section for more details).

Minimum and maximum depths were also entered for each species in the same manner as the string data, *i.e.* data enterer, confidence and source for each depth data point. When available, a core (primary) depth range was also added, also with data enterer, confidence and source recorded. A level of completeness of depth information was also provided in the same manner as the string data.

The broad habitat types used were: F = freshwater, E = estuarine, C = coastal (0-40 m), SH = shelf demersal (40–200 m), SL = slope demersal (200–2000 m), A = abyssal (> 2000 m), PS = pelagic shelf (0–200 m), PE = epipelagic (0–200 m, oceanic), PM = mesopelagic (200–1000 m, oceanic), PB = bathypelagic (1000–2000 m, oceanic) and PA = abyssopelagic (>2000 m, oceanic).

In preparation for data analyses, the updated data entered during this phase was uploaded into the Species Database.

Modelled distributions based on string analysis

The geographic distributions of each fish species were converted to a 1-dimensional string (as described by Last *et al.*, 2005) along the 500 m depth contour (Figure 1).

For the purposes of the provincial and biomic analyses, a plot of points, ranging from 0 to 281, was used to identify locations equidistant along this string (as used by Last *et al.*, 2005). The starting point (0) of the string was near the northern tip of Queensland, slightly to the east of Cape York and from there moving clockwise around the coastline. For the slope bioregionalisation study by Last *et al.* (2005), a disjunction exists through the Gulf of Carpentaria which is shallower than 200 m (i.e. the upper limit of the continental slope).

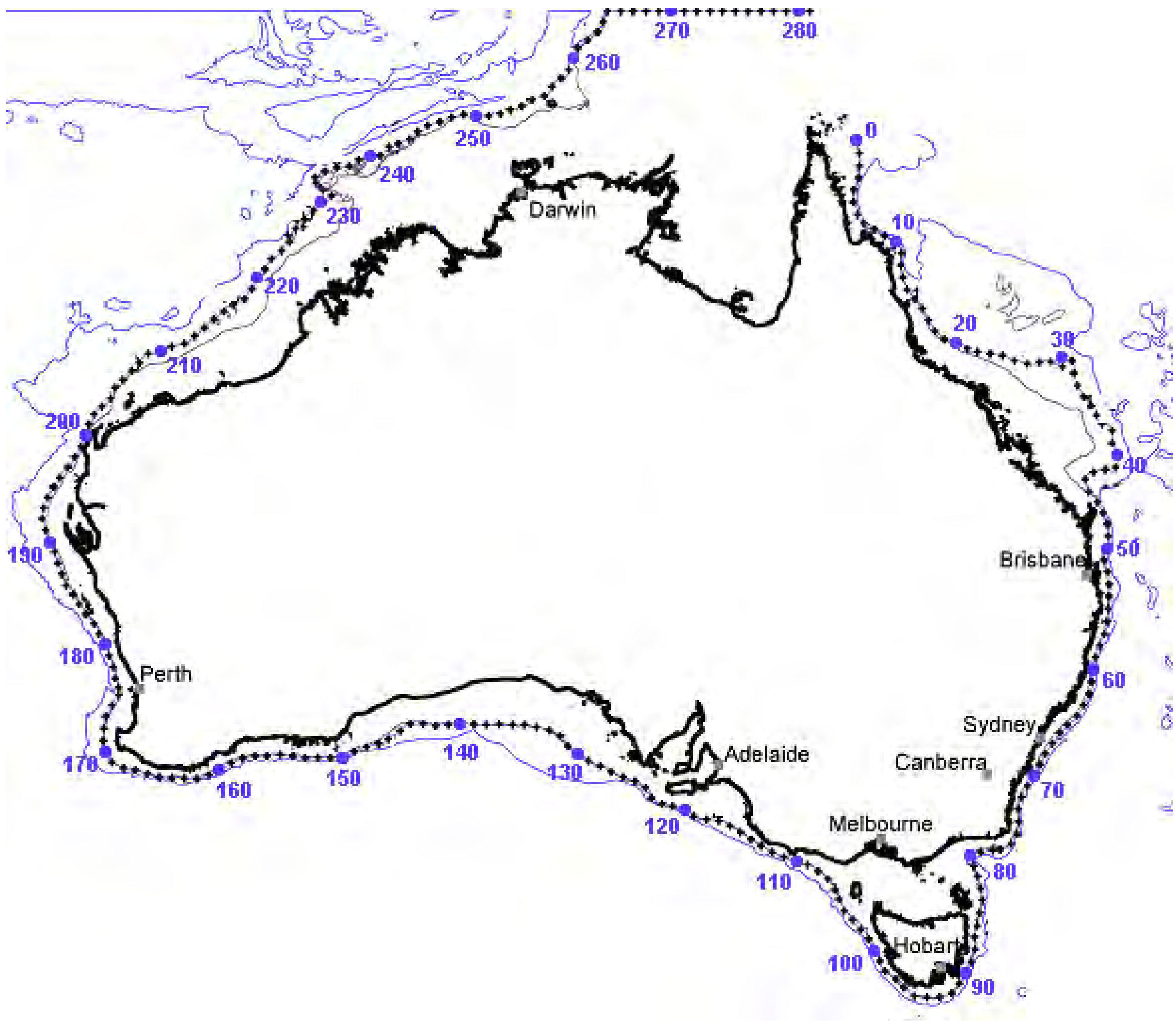


Figure 1 String route map based on the 500 m isobath.

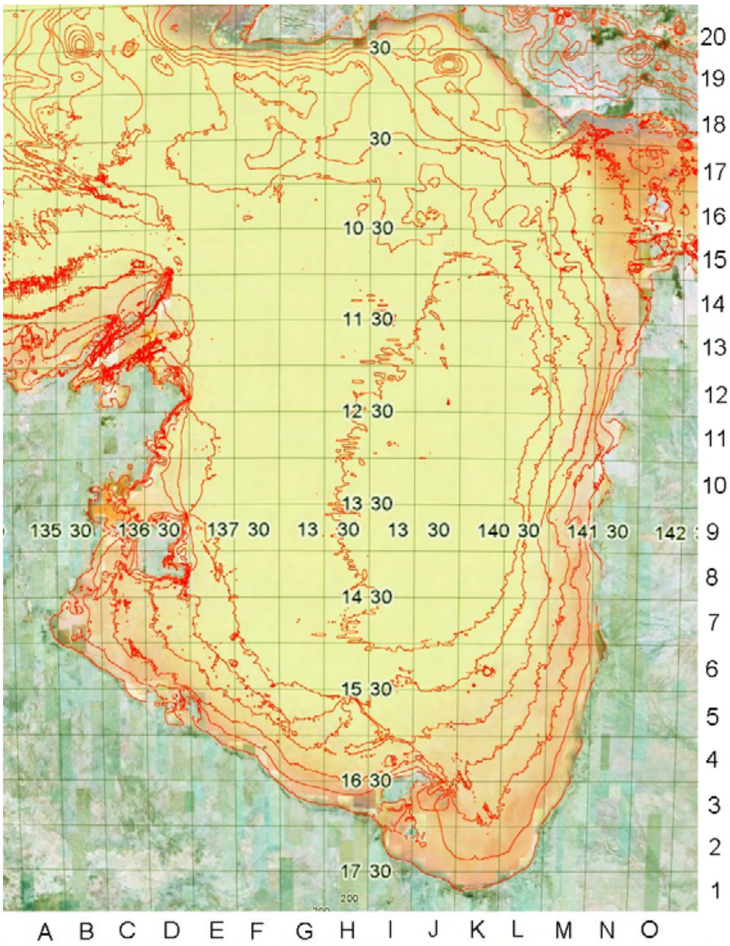


Figure 2 Gulf of Carpentaria grid reference points (0.5° squares).

Since this study is focusing on shelf species, more detailed information on the distribution of species through the Gulf of Carpentaria was required. String points were artificially diverted to run east for points 265–281 to simplify coding of distributional data in the Gulf of Carpentaria. Thus the area of the Gulf of Carpentaria (string point 265 to 281) was divided into a series of 0.5° grids (see Figure 2). For those species whose distributions start and/or end within this region, single or multiple grid reference points were recorded (e.g. A1–I8 or K7–U13) to best represent their distributions within the Gulf.

Similarly, in the slope bioregionalisation, distributional information in central Bass Strait, also shallower than 200 m, was irrelevant. Hence, more detailed information on geographic ranges of species whose distribution started or ended in the Bass Strait were required. To overcome this, the Bass Strait region was divided into a series of 0.25° grids (Figure 3) and distributions recorded in a similar way to that recorded for the Gulf of Carpentaria.

Generally, four end points, demarcated as polygons (two grid and two depth points), were used to represent the boundaries of these (2-dimensional) modelled distributions. In some instances, additional polygons were required to represent the geographic range of species within these regions.

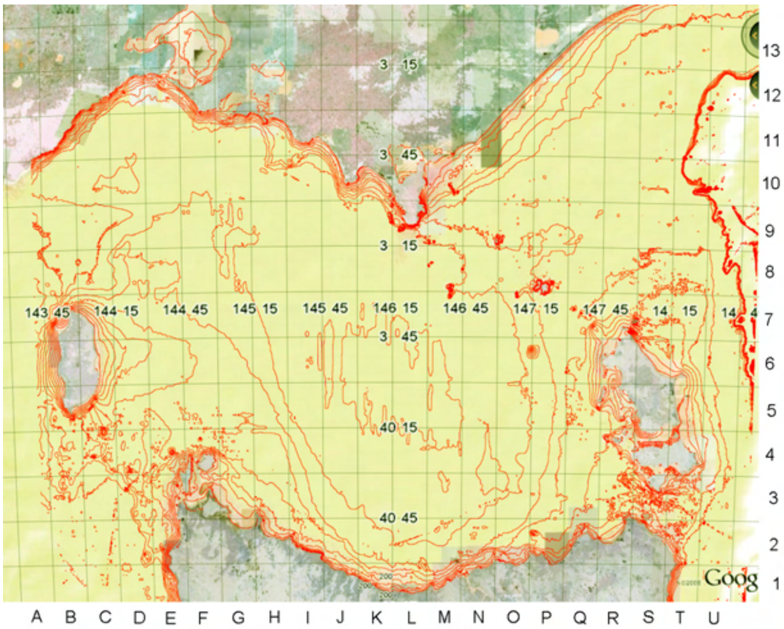


Figure 3 Bass Strait grid reference points (0.25° squares).

Prioritisation of important genera

Taxa vary in their usefulness for biogeographic analysis, depending on factors such as their geographic range, taxonomic complexity, and the quality and availability of data. Due to the species richness of fishes in Australian waters, not all local fishes could be included and it was necessary to identify a subset of the fish fauna for analysis. Genera within this subset would then be given priority in the validation of taxonomic and distributional information.

The Biogeographic Information Index (BII), which was developed during the IMCRA project (IMCRA 1996), was used to identify genera for the priority fauna subset. Genera listed on the Species Database were first ordered based on their biogeographic usefulness, using the following formula:

$$BII = C\,(2A + B) / \log (n + 1)$$

where: A = biogeographic potential; B = information content qualifier; C = value within each ecosystem and n = number of species in the genus.

The genera in the Species Database were then ranked by the resulting BII score. A low BII score (less than 30) indicates a genus providing significant biogeographic information, *i.e.* a genus with a high proportion of narrow-ranging endemic species.

Of the ca. 1700 genera in the database, about 1500 were coded as having demersal species occurring on the coastal or continental shelf regions. The BII for the top 50% (~250) of genera, based on BII's calculated in IMCRA (1996), were recalculated in this study and these genera had BII's ranging from 2.44 to 132.04. The project focused on examining specimens of genera with high potential for identifying bioregions (i.e. with a BII score less than 30). The most informative genera defined from this for the coastal zone and continental shelf are listed in Appendices 2 and 3.

Data analyses

The analyses undertaken from the updated Species Database follow those outlined in Last *et al.* (2005) and are described again below.

Analytical strategy

The hierarchical biodiversity framework that underpins this project (see Last *et al.*, 2009 *in review*) demonstrates that provinces are the most important biological unit for spatial structuring and bioregionalisation. Biomes are also important biological units that are nested within each province. In this study the boundaries of the shelf provinces and biomes were determined through multiple analyses, with the biomes defined (partitioned) at different depths within each province.

The primary determinants of the spatial scale equating to the provincial level (a major bioregion spanning hundreds or thousands of km), are past evolutionary processes associated with speciation, and modified by the contemporary environment. At the biomic level, species are keyed to depth-related processes (speciation and adaptation to different depth-related environments). Thus, the analyses of fish distribution data are aimed first at the provincial level, describing the largest scale spatial structures inherent in the data. At the biomic level, data analyses are aimed at partitioning the depth-related structures that are nested within the provinces at a lower level.

A variety of analytical methods could have been adopted and the governing considerations used in selecting the most appropriate one for this project included:

1. Recognising that insufficient information on deepwater-fish distributions is available to undertake an integrated 3-dimensional analysis. This is obvious from considering the amount of data required to populate a 3-dimensional grid in latitude/longitude/depth space.

2. At the provincial scale, the biogeographic evolutionary processes in Australian seas (where the continental shelf is generally narrow) are more related to dispersal in geographical space (latitude/longitude) rather than depth. This does not necessarily imply that depth is not important in biogeographic structuring, rather it implicitly assumes that the depth structures at this level are nested within the provinces.

3. Distributional information contained in the data is limited to range information along the string route and depth, and also to presence/absence data.

4. Given the paucity of geographic spatial information in certain regions, geographic range information is characterised along a string running at the arbitrary 500 m isobath contour along the continental slope. Each species is also characterised by a depth range (which will remain invariant along its string range).

5. Quality criteria from biogeographic potential and confidence classifications on ranges are available. The chosen analytical approach was to derive the provincial structures from a string analysis that combined data from a number of depth ranges. This provided the broadscale structure within which more detailed biomic analyses of the depth structuring were conducted for each derived province.

Four main analyses were used to investigate patterns in the distribution of demersal fish:

1. A summary of the raw data together with range of quality and biogeographic information content indices as described above.

2. Two-dimensional analysis of string data and depth information to identify major patterns in the data.

3. String range scaling—calculation of Jaccard Indices, combined with novel 'Mexican-hat' analyses based on normalised string data, using species within specified depth ranges (see next point 4). This identified provinces.

4. Depth range scaling—calculation of Jaccard Indices by depth using species within specified string ranges representative of provinces derived from (2). This identified biomes at different depths within the provinces.

Each of these approaches was iterated, using different subsets of the data to either investigate broad-scale patterns, or trends within sections of strings or depth intervals. All the information was then integrated to produce a national bioregionalisation of demersal units on the continental slope.

Summarising the raw data—data formats

Patterns in the data were investigated using various subsets of the raw data. For the biomic analyses, all species data of confidence scores of 1 or 2 were used with no restrictions on string range or BII. For the provincial analyses, three subsets of data were used comprising:

Entire Shelf Analysis

A1. 'All Shelf - Uniform' uses all available data for species with a maximum depth range of 200 m or less and confidence score of 1 or 2. A Uniform presence/absence was encoded for each species along its route.

A2. All Shelf - Uniform - Short' uses all available data for species with a maximum depth range of 200 m or less, string ranges of 100 or less, and confidence score of 1 or 2. A Uniform presence/absence was encoded for each species along its route.

A3. 'All Shelf - Normal - Short' uses all available data for species with a maximum depth range of 200 m or less, string ranges of 100 or less, and confidence score of 1 or 2. A Normal distribution was imposed for each species along the range of its route.

Coastal Analysis

The coastal datasets mirror those for the entire shelf and comprise datasets C1, C2 and C3 which correspond to A1, A2 and A3 respectively but with the maximum depth restricted to 40 m or less.

Shelf Analysis

The shelf datasets mirror those for the entire shelf and comprise datasets S1, S2 and S3 which correspond to A1, A2 and A3 respectively but with the maximum depth restricted to be greater than 40 m but less than 200 m.

These analyses mirror those conducted for the national slope study in Last *et al.* (2005) but time restrictions prevented application of the weighted string range analyses used to investigate narrow provincial units - as for example the Gulf Province (which would have been more easily discriminated with such an analysis).

Jaccard analyses

The initial provincial structures reported here are based on exploratory analyses using the Jaccard analysis as a basis to determine local species composition changes and species richness. These analyses were used to analyse the variations of the Jaccard Index against the string route/index.

The Jaccard Index is a measure of the species dissimilarity in adjacent areas. It is the ratio of the number of shared species to the number of distinct species in units that are being compared - which in this case equates to adjacent string units.

Given two adjacent string units (A, B) that record the presence/absence of species, the Jaccard Index is defined as:

$$JI = (n10 + n01)/(n10 + n01 + n11)$$

where: n10 is the number of species present in A but not in B,

n01 is the number of species present in B but not in A,

n11 is the number of species common to both A and B.

Thus, in the case where no species are unique to string units A or B (n10 = n01 = 0), JI is equal to zero and correspondingly, where the species are completely different (n11 = 0), JI is equal to one.

A version of the Jaccard Index based on non-integer numbers can also be used to characterise species distributional changes (other than presence/absence). For the moment we note that such an index based on adjacent units (e, w, where 'e' and 'w' are abundance sums of species) that record distributional information on species, can be defined as:

$$ji = (abxor)/(abxor + aband)$$

where: abxor = sum(abs(e – w))

aband = sum(e * w)

This version of the Jaccard is useful in investigating changes in species composition. A high Jaccard indicates faunal changeover, whereas uniformly low indices across a sequence of string points will flag the existence of regions of faunal consistency typical of major faunal units such as biogeographic provinces. Hence, these areas of evenness and change on a Jaccard plot are important in interpreting distributional patterns. Similarly, several analyses using different data combinations are needed to bring out the full complement of patterns existing in the data. For the work reported here, changes of JI are displayed along the string route using the various formats of the data discussed here. For the purposes of this project both JI and ji give the same results with presence/absence data and assuming a uniform distribution across the species string range. For a "Mexican Hat" or Normal distribution, the ji formulation is used as the distribution is no longer presence/absence but probability of presence along the species string range.

Species richness analyses

While the Jaccard Index is useful in showing relative changes in species composition between adjacent cells/grids (in the maps), it is independent of species numbers and does not indicate species richness.

One option in calculating species richness is to simply sum the number of other species that occur in each cell/grid over the range of the target species—we refer to this as a ‘top-hat’ distribution. This approach gives equal weight to each species, regardless of the location within the range of that species. In most cases, a species is less common at the extremities of its range than near the centre of its range. An alternative approach is to postulate a distribution which gives more weighting to positions away from these extremes. For the analyses reported here, a normalised distribution was used where it was assumed that the extremities of the range were two standard deviations away from the peak (centred at the middle of the range, but we did develop a two-sided distribution profile to allow for biasing of the ‘core range’ of the species towards one end of its range, when known).

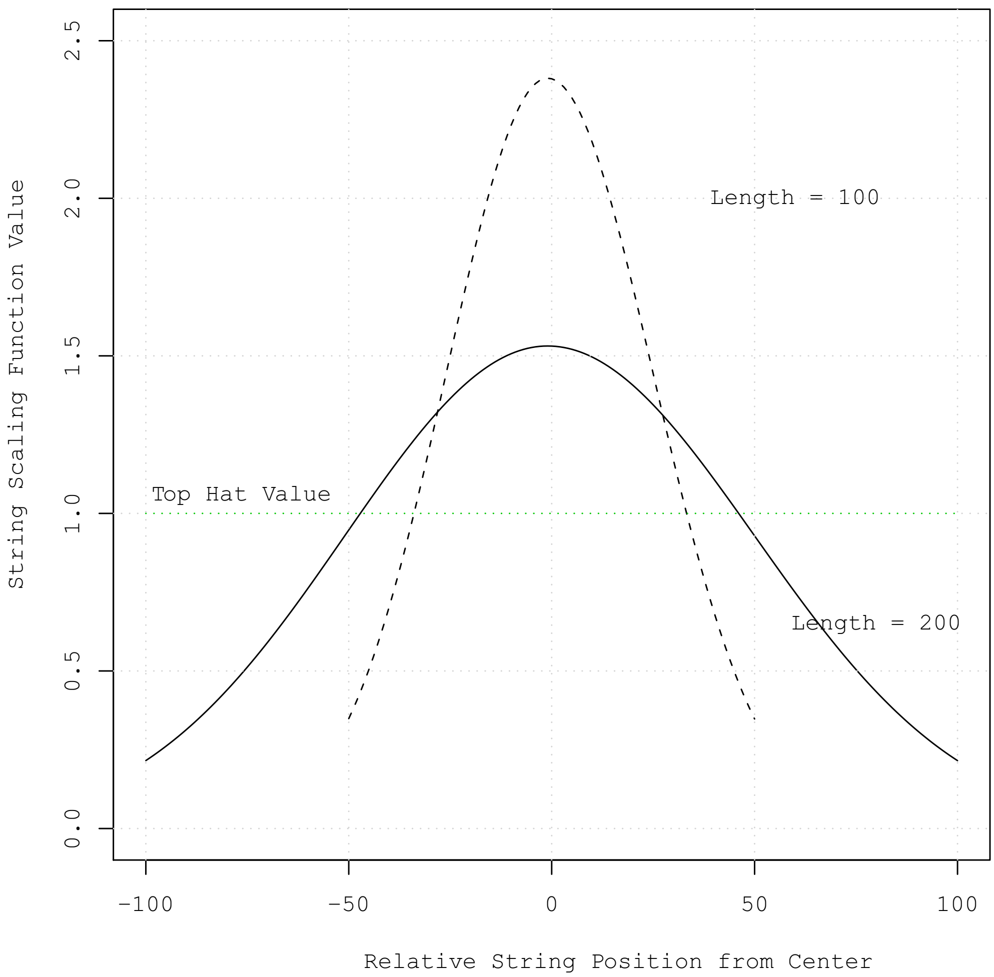


Figure 4 Diagrammatic plot of the string scaling function for three scenarios demonstrating the concept of ‘Mexican Hat’. weighting toward more biogeographically informative, narrow-ranging species: 1) ‘Top-Hat Value’ shows the equal scaling of 1.0 applied to all string positions; 2) ‘Length = 200’ shows the normalised amplitude ‘Bowler-hat‘ scaling for a string that is 200 units long, and 3) ‘Length = 100’ show the normalised amplitude ‘Mexican Hat‘ scaling for a string that is 100 units long. Note that the centre of the string has been placed at ‘0’ for illustrative purposes.

To emphasise the importance of more narrow-ranging, endemic species, this normalised distribution can be scaled in an inverse relation to the length of the distributional range. A demonstration of this method, which is termed the 'Mexican-hat' string scaling function, is presented in Figure 4.

Provinces are the evolutionary products of palaeohistorical events modified by the contemporary environment. Therefore, strong provinces would be expected to have high numbers of endemics and/or a broad geographic range within the Australian region. Weak provinces have few endemics, which are often narrowly distributed. A data confidence level exceeding 3 was considered to indicate a well-defined or strong province.

With these depth range index scalings, there is then no direct relationship between mean depth and the range of a species, and there are also discontinuities between the depth range scaling relationships. These need to be borne in mind when analysing Mexican-hat distributions that use the depth-range-based weightings. For a given depth range change, this scaling increases the weighting to shallower depth species.

Results of the early analysis conducted in late 2008 pointed to possible influences from slope species dominating the pattern of provincial structures on the shelf based on a combined analysis of species with depth ranges down to 250 m. The emerging patterns were consistent with the slope analyses conducted by Last *et al.* (2005) suggesting the need to focus the analysis on key coastal and shelf species by giving these species greater emphasis in the analysis. As a result, the following additional information and analyses were conducted:

- Maximum species' depth range were limited to be no more than 200 m instead of 250 m, as species that descend to 250 m may dwell primarily on the upper slope.
- Additional species were added to the list of coastal and shelf species.
- Biogeographic Information Indices (see Appendix) were added to key coastal and shelf species in order to be able to focus the analysis on informative suites of species.
- Species' string range extents were used to restrict analyses to species with shorter ranges, hence more informative with respect to identifying provincial structures.
- The provincial analysis was separated out as a coastal analysis from 0 to 40 m, and a shelf analysis from 40 m out to 200 m. Ideally, analyses should have been conducted for each biome but, apart from the time constraints on the project, the datasets need to be further refined and qualified (accuracy, information content and biogeographic importance) to facilitate such a detailed analysis.
- To make the process of identifying the province boundaries more objective, a new procedure was introduced to analyse the Jaccard variations (by route) that equated to the more subjective process used previously.
- The selection of indicator species was also formalised by developing an algorithm that ranked species in relation to how strongly they "adhered" to each province.

In order to focus the analyses on the informative species, BII scores were compiled for what were considered to be the most informative genera. Genera were also scored independently as to whether they were informative for a coastal analysis or a shelf analysis. The resulting list is summarised in Table 1. It shows that the scoring substantially reduces the number of species from over 4000 to less than 1000, and restricts informative genera for the shelf much more than the coast.

Table 1 Families, genera and species with BII scores.

Zone	Families	Genera	Species
Coast	118	312	807
Shelf	94	181	695
Total	124	332	976

While the reduction in the number of species focuses the analysis on the most informative species, it also reduces overall coverage with consequent implications for calculations of spatial species turnovers. To investigate these effects, analyses were conducted with just the informative species (species with BII scores under 30) as well as all available species (of confidence scores of 1 or 2). In addition, alternative analyses using string range, and fitting a Normal distribution, were trialled as per the analyses conducted for the slope analyses (Last *et al.*, 2005).

Based on the histogram of BII for the coast and shelf displayed in the following figures, we chose a score of 30 as the threshold for informative species. The analyses using BII scores were severely restricted by the number of genera available and by the number of informative species, in addition to the other constraints (depth, confidence) before even going to the analyses on species with restricted ranges and use of the Normal distribution. In the following section we examine some of these issues before detailing the final set of analyses used to demarcate the provincial structures.

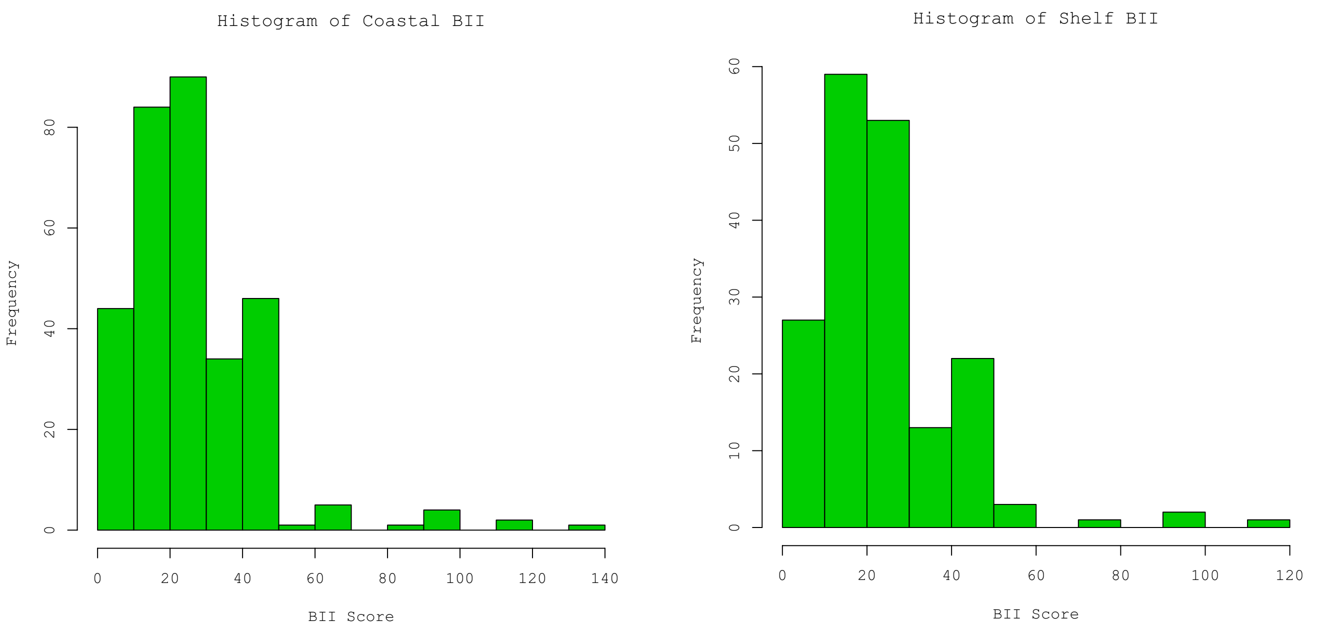


Figure 5 Histogram of BII scores for genera for the coastal zone defined as depths of 0-40 m (left figure) and the shelf defined as depths of 40–200 m (right figure). A BII score of 30 was used to demarcate the boundary between informative and less informative genera.

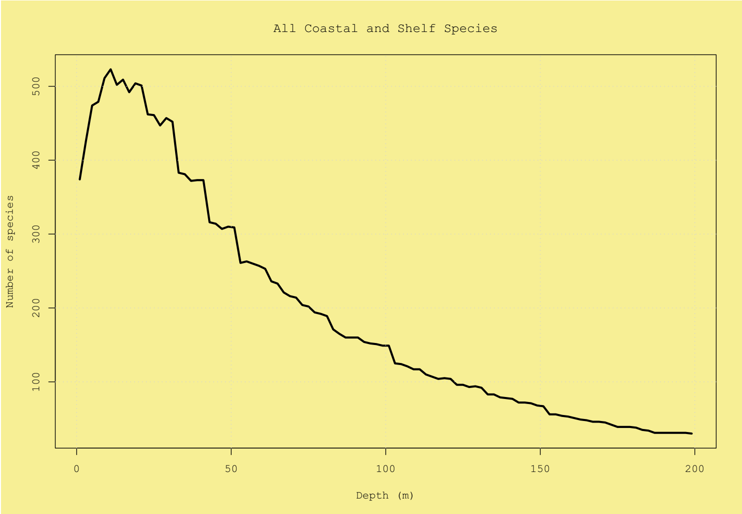
Results and discussion

In this section we examine the variation of species numbers by depth for the whole shelf (0–200 m) and separately for the coast and shelf, subject to constraints on a number of attributes. The intent here is to gain an understanding of how these various restrictions affect (or not affect) the number of species that are selected and how those numbers vary by depth.

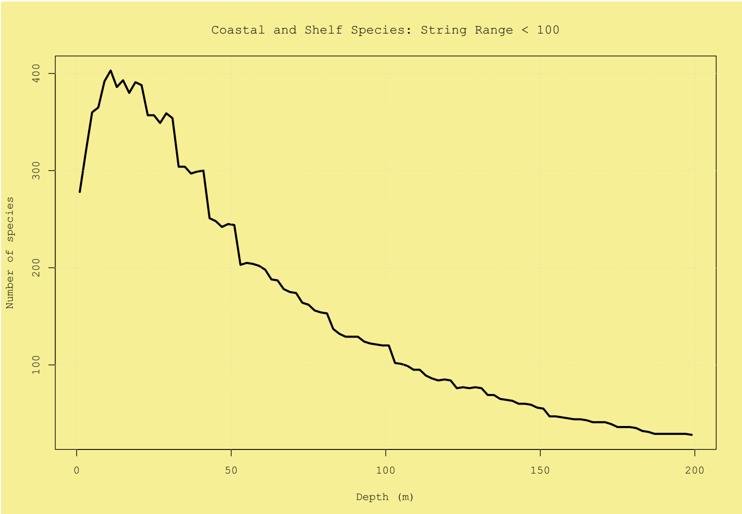
Depth Distributions of Coastal and Shelf Species

The plots below show the distribution of the number of species by depth for the coastal and shelf species. Three plots are shown: one for all species with depths less than 200 m (and species with confidence scores of 1 or 2); the second plot for species with string ranges of under 100 string units; and a third plot for string ranges less than 100 units and BII scores of 30 or less. A 2 m bin size was used to generate the plots.

- The depth distribution for all species shows:
- a rapid increase from the coast up to a peak near 12 m or so, with over 500 species occuring at the peak.
- a decline from the peak, punctuated by rapid drops (possibly at intervals of 10's of metres - due to data coding resolution) up to about 50 m.
- beyond about 50 m, the decline asymptotes to very low species levels at the 200 m mark (due to restricting the species to those occuring in less than 200 m)

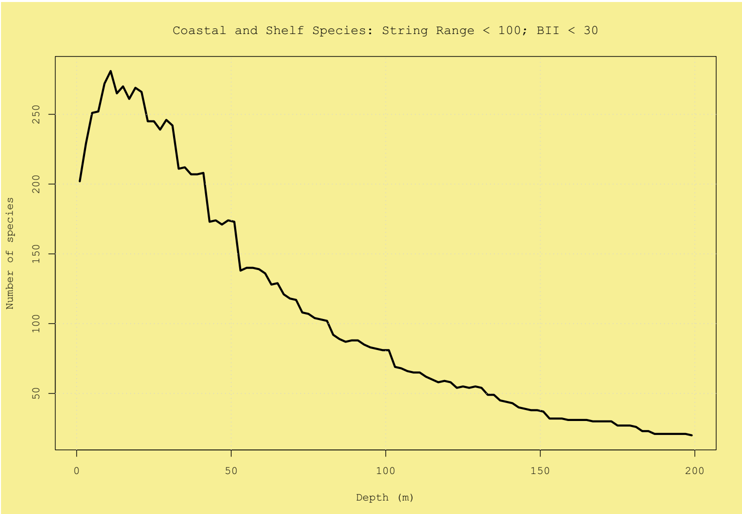


- With the string range being restricted to 100 string units or less, the notable changes are:
- a reduction in the number of species at the peak (which is in about the same position) to about 400.
- a similar punctuated decline beyond the peak and smooth trend to the 200 m mark as the previous plot.



- With the BII restriction of 30 or less (in addition to the previous restrictions), the pattern of increase and decline is similar but the number of species at the peak has declined to about 280.

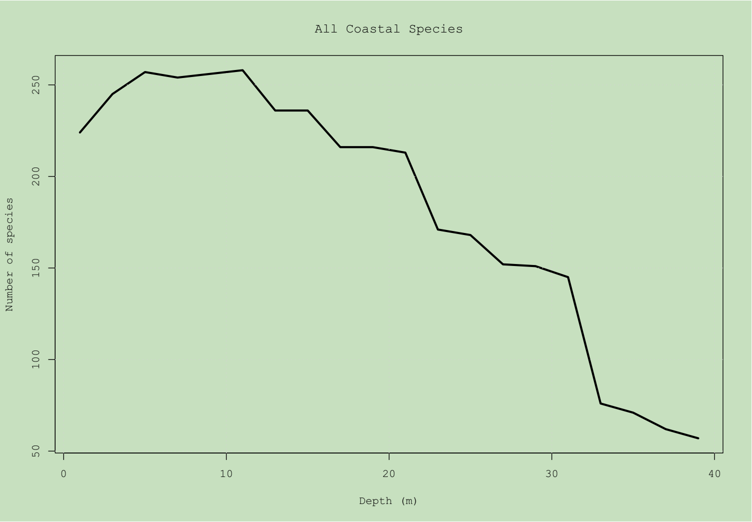
In summary, in this case, species numbers at the peak decline to 80% with the string range restriction and reach down to 56% with the additional BII restriction. In all cases, there is a gradual decline to no species at the 200 m depth mark, and a peak near the 12 m mark.



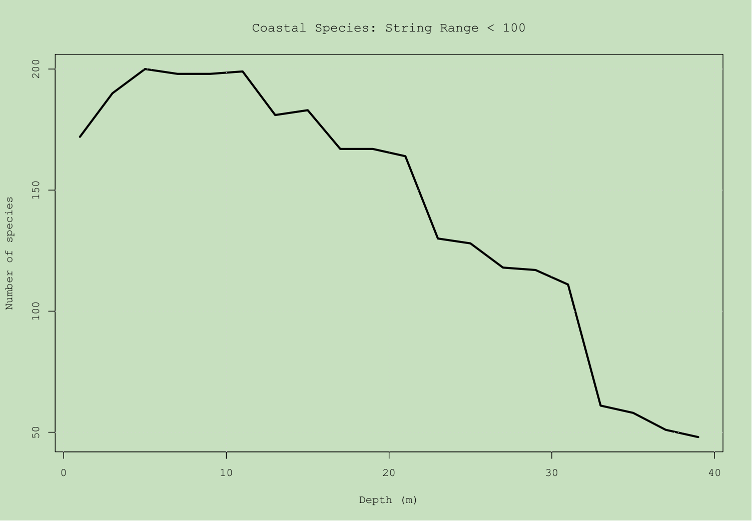
Depth Distributions of Coastal Species

The plots below show the distribution of the number of coastal species by depth. Three plots are shown: one for all coastal species (with maximum depth less than 40 m, and species with confidence scores of 1 or 2); the second plot for species with string ranges of under 100 string units; and a third plot for string ranges less than 100 units and BII scores of 30 or less. A 2 m bin size was used to generate the plots.

- The depth distribution for all coastal species shows:
- the characteristic peak from the coast up to a peak around 10 m an increase from the coast up to a peak of over 250 species.
- an almost linear decline from the peak that drops off most sharply at about 30 m.

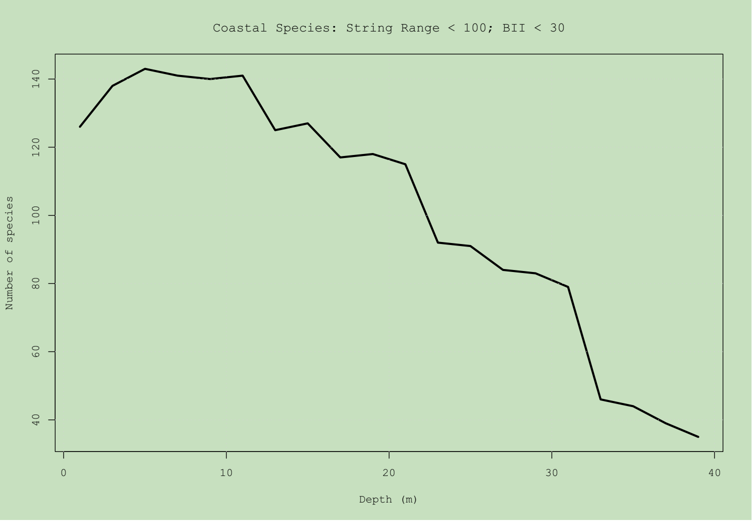


- With the string range being restricted to 100 string units or less, the notable changes are:
- a similar pattern is evident with the string range restriction in place. Maximum species count decreases to about 200.



- With the BII restriction of 30 or less (in addition to the previous restrictions), the pattern is similar but the number of species at the peak has declined to about 140 (about half the level of that for the coastal and shelf species combined).

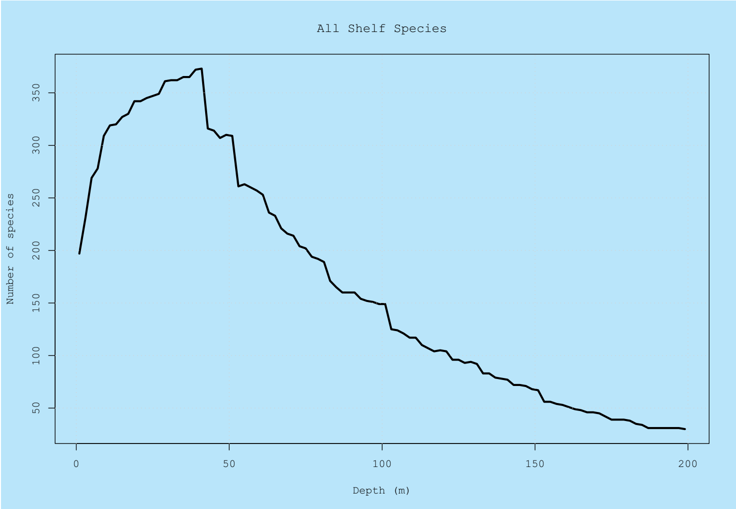
In summary, the reductions in the peak species numbers are in line with the overall reductions seen for the whole shelf (80% and 56%) but in this case, species numbers do not decline to zero at the edge of the zone.



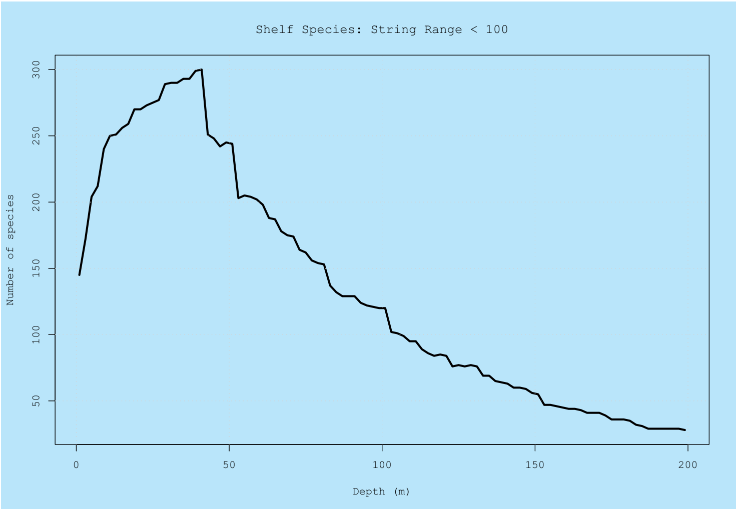
Depth Distributions of Shelf Species

The plots below show the distribution of the number of shelf species by depth. Three plots are shown: one for all shelf species (with maximum depth of greater than 40 m and less than 200 m, and species with confidence scores of 1 or 2); the second plot for species with string ranges of under 100 string units; and a third plot for string ranges less than 100 units and BII scores of 30 or less. A 2 m bin size was used to generate the plots.

- The depth distribution for all shelf species shows:
- despite the restrictions on maximum depth being in the 40 m to 200 m depth range, substantial numbers of species are found in the coastal zone (0 to 40 m). Within this zone, the species count increases up to a maximum, of about 370, to the edge of the coastal zone (40 m) and thereby drops off in an asymptotic manner with a couple of sharp dropoffs at the start.

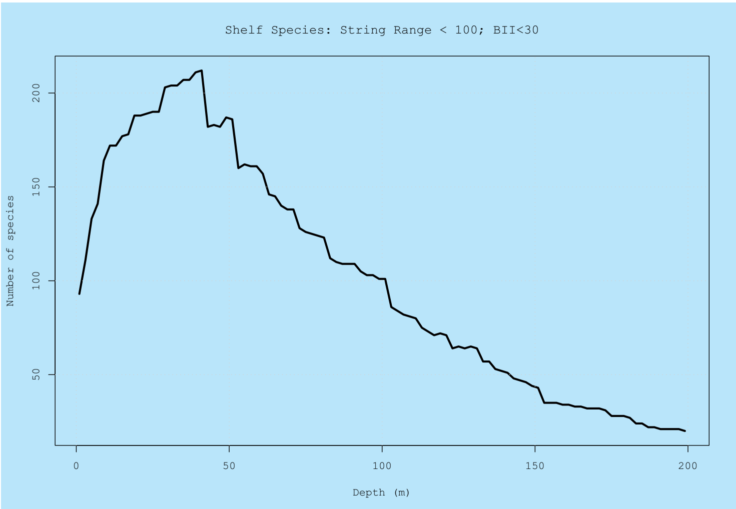


- With the string range being restricted to 100 string units or less, the notable changes are:
- a similar pattern is evident with the string range restriction in place. Maximum species count decreases to about 300.



- With the BII restriction of 30 or less (in addition to the previous restrictions), the pattern is similar but the number of species at the peak has declined to about 210.

In summary, the peak in species numbers shifts to the lower edge of this zone (around 40 m) and delines towards zero at the outer edge (200 m). Within the coastal band, species numbers increase towards the edge of this zone implying that some coastal species are contributing towards the species distributions that fall in this zone.



Demarcation of Provincial Units

Following the biomic analyses and investigation of species distributions by depth for the updated dataset, the final set of analyses were run to demarcate the provincial units. In these analyses, the coastal and shelf zones were analysed separately using the Uniform and Normal distributional profiles for species and string ranges to focus the analysis on the most informative species. Unfortunately, the severe constraints imposed by the BII restrictions prevented a more detailed analysis using BIIs to select informative species.

The analyses were based on the Jaccard approach used in previous analyses and detailed in this report. For the Uniform distribution, the Jaccard statistic based on the classic definition was used (sum of unique species in each comparison unit divided by the total number of unique species) whereas for the Normal distribution, the generic formulation was used.

In past analyses, the delineation of boundaries was based on expert assessment to define the transition point between peaks and troughs in the Jaccard curve along the string route. This process was not entirely repeatable and since the expert judgement relied upon examination of individual species that were most adherent to the unit under investigation, it was subject to some debate as to precisely how the boundary was chosen. In order to avoid such problems, and to make the process more objective, a smoothing filter was devised that "automatically" defined these endpoints.

The previous four analyses were used to provide the final demarcation of provincial units for the coast and the shelf. We gave initial precedence to the analyses which used the uniform distribution for species with string ranges of 100 units or less, confidence scores of 2 or less and maximum depth ranges of: 0-40 m for the coast and 0-200 m for the shelf. The analyses were not conducted for the biomic provincial units as the number of species would have been further reduced and because a number of preliminary analyses were showing consistent matching of units on the coast and shelf, with some exceptions. In future, as data quality improves it may be appropriate to investigate finer demarcations. The analyses using the Normal distribution for species was used to qualify the strength of the identified provincial units. Based on one of the authors experience with digital filters, a simple exponential filter was used. Both a forward and reverse pass of the filter was used (following the approach detailed in Lyne & Hollick, 1979) in order to preserve the location of peaks and troughs (a single forward pass will shift the locations because of the so-called "phase shift" effects of such filters).

The forward pass of the filter was described by the equation:

$$y(n) = a*y(n-1) + (1-a)*x(n)$$

where: y is the sequence of filtered outputs; x is in the input sequence of Jaccard statistics; n is the string location index under consideration; and "a" is the filter parameter that represents the memory effect of the filter ("a" ranges from 0 to 1, and larger values impart longer memory effects). The filter is run by stepping through "n" starting from some origin, n=0 say, up to the end of the sequence.

The reverse pass of the filter is conducted in the same way as the forward pass except that the output from the first pass (y) is now fed in as the input (i.e. it becomes (x) in this mode). By employing the reverse filter, the phase shift from the forward pass is cancelled (mostly) by the reverse pass, and hence peaks and trough positions are preserved enabling a more accurate demarcation of boundaries.

We experimented with a range of values of "a" and found that a filter value of 0.9 provided boundary demarcations consistent with a subjective expert assessment for the sort of Jaccard statistic variations resulting from the analyses. The results of applying the filter are presented in the following sections. The four analyses are presented on separate pages with a plot of the Jaccard variation, the results of the smoothing filter, an indication of the location of provincial units and a brief description of key features of the analysis.

Coastal Jaccard Analysis - Uniform Distribution

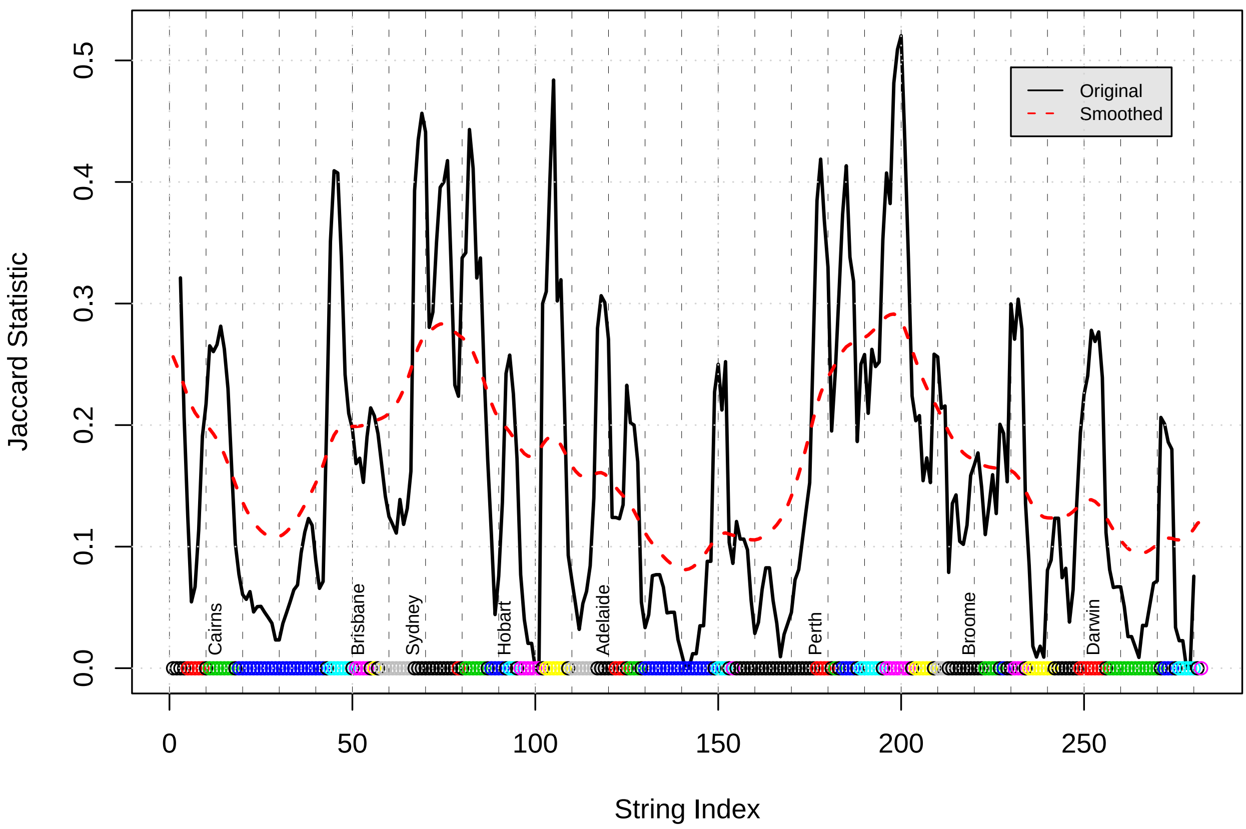


Figure 6 Variation of Jaccard statistic (black line) and a smoothed version (red dotted line) along the String route. The intersection of the smoothed curve with the original curve is used to define the boundaries of the provinces and transitions. Units defined this way of less than 2 string units are ignored or subsumed into neighbouring units. The approximate location of major cities is shown on the bottom along with points of different colour defining different provinces (units where the original curve is below the smoothed one) and transitions (units where the original curve is above the smoothed one). The plot shown is for the coastal analysis using species with confidence values of 1 or 2, strings of 100 units or less, depths from the coast to 40 m, no BII restrictions, a uniform distribution for each species (between the limits of their range) and a Jaccard analysis interval of 4 units.

Key Points of Interest:

- Large variations in the Jaccard statistic suggest relatively rapid turnover of species in keeping with the expectation that habitat variety and scales in the coastal zone are more diverse and restrictive than those offshore.
- A variety of minor structures are embedded within larger fluctuations. In some cases, the intersection of the smoothed curve with the original one does cut across these smaller structures. These smaller units were subsumed into adjoining units.
- For this analysis, a Jaccard interval of 4 string units were used to cope with the larger fluctuations. In the other plots that follow an interval of 6 units is used.

Shelf Jaccard Analysis - Uniform Distribution

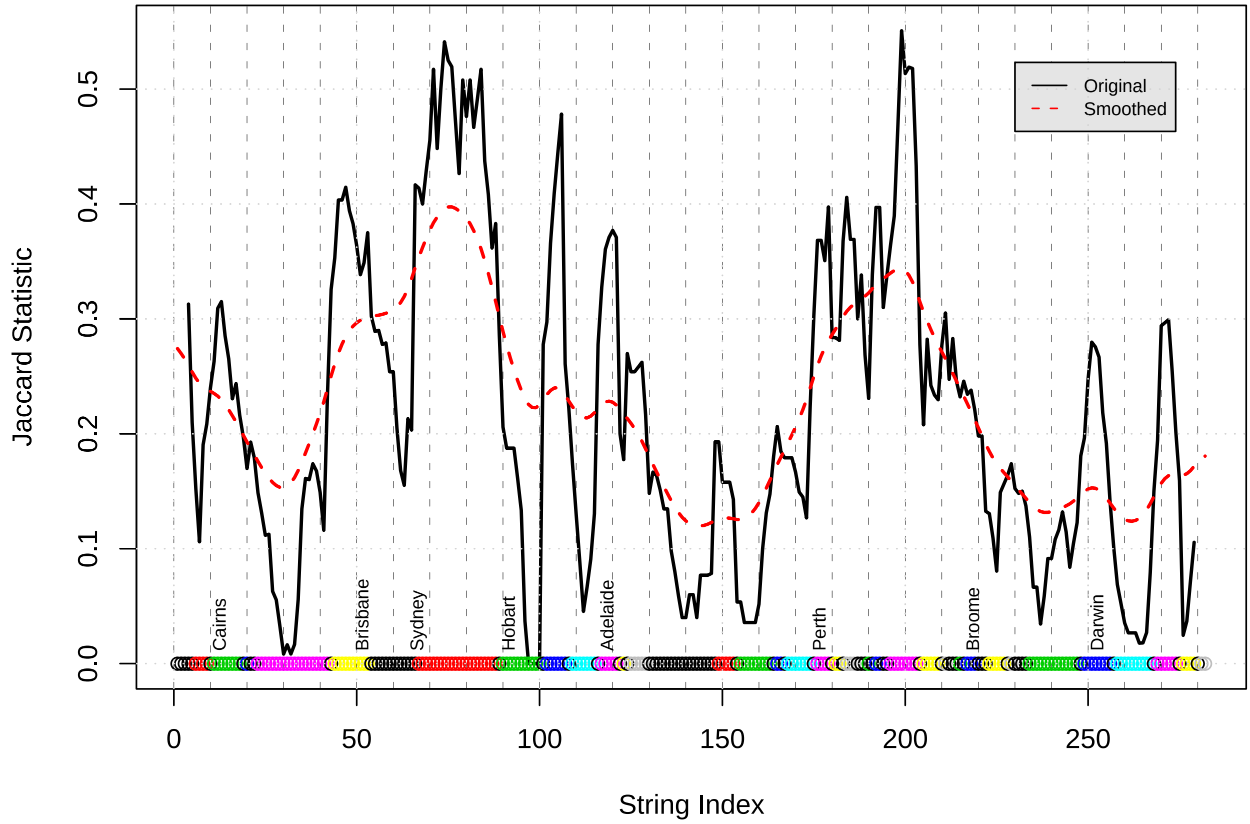


Figure 7 Variation of Jaccard statistic (annotations as per the first figure in this series) for the shelf analysis using species with confidence values of 1 or 2, strings of 100 units or less, depths from 40 m to 200 m, no BII restrictions, a Uniform distribution for each species (between the limits of their range) and a Jaccard analysis interval of 6 units.

Key Points of Interest:

- Variations in the Jaccard statistic are less than those for the coast but substantial small scale variability still exists particularly noticable between the Perth to Broome route.
- At a broadscale, the features in the shelf analysis mirror those for the coast.

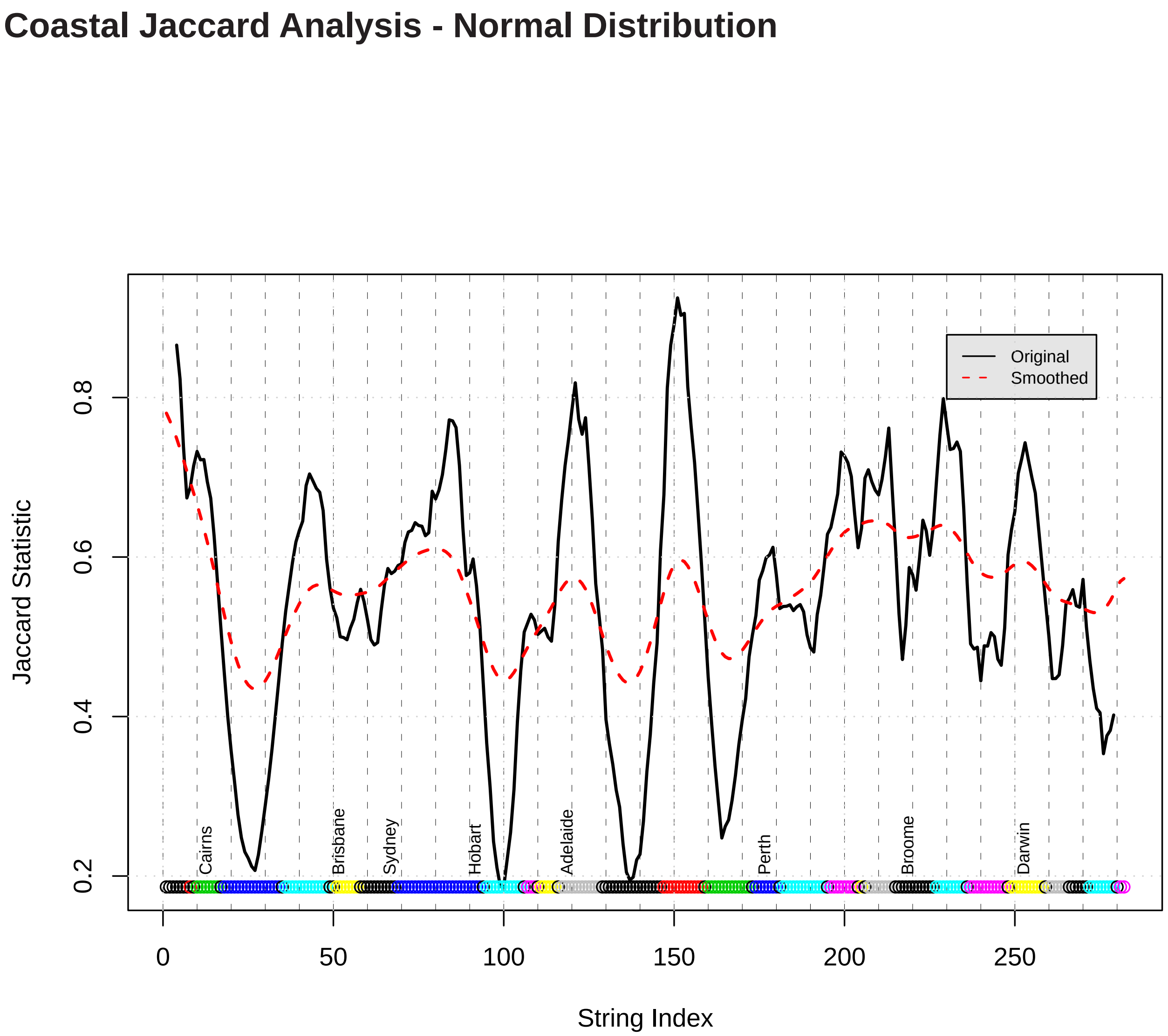


Figure 8 Variation of Jaccard statistic (annotations as per the first figure in this series) for the coastal analysis using species with confidence values of 1 or 2, strings of 100 units or less, depths from the coast to 40 m, no BII restrictions, a Normal distribution for each species (between the limits of their range) and a Jaccard analysis interval of 6 units.

Key Points of Interest:

- A much smoother variation in the Jaccard is produced by using a Normal distribution to represent the probability distribution of each species within its range. Whilst this analysis more clearly identifies the major provincial units, smaller scale units, even relatively strong ones, are now subsumed into neighbouring larger structures.

Shelf Jaccard Analysis - Normal Distribution

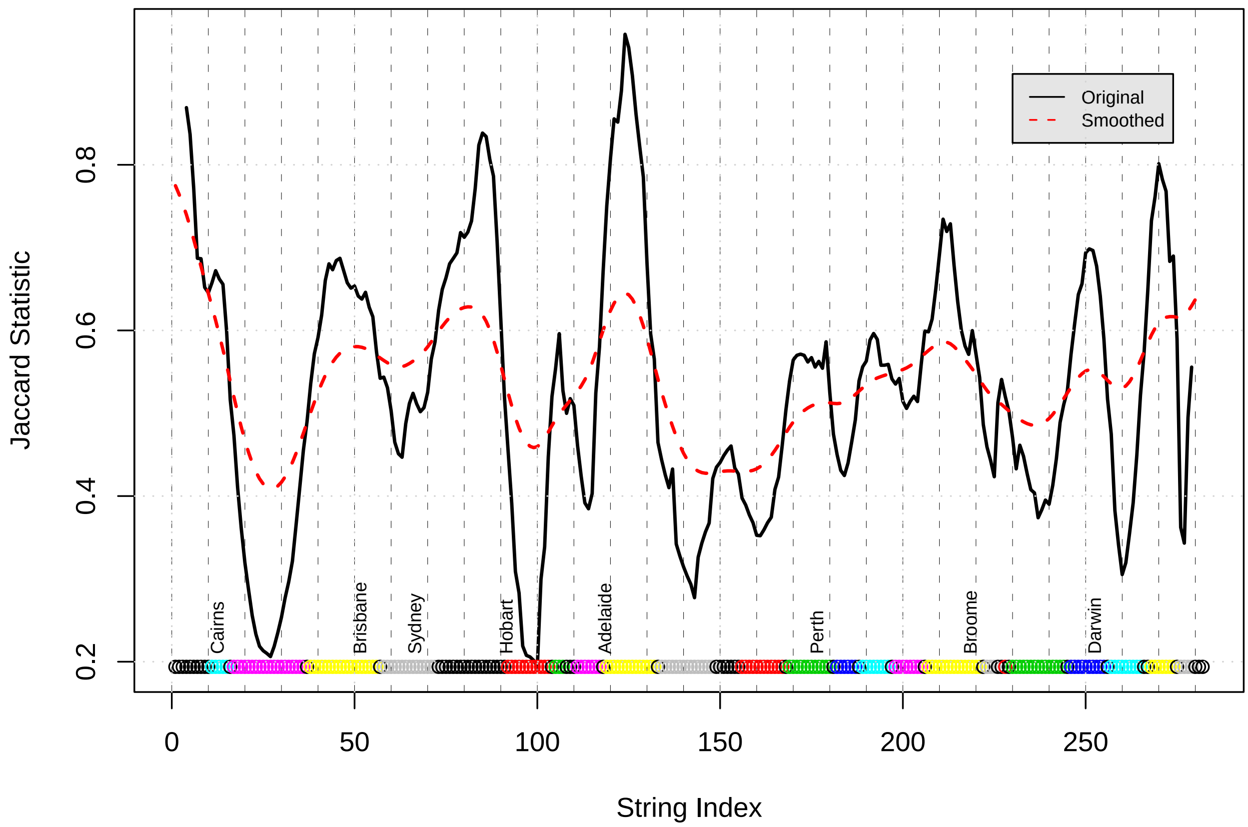


Figure 9 Variation of Jaccard statistic (annotations as per the first figure in this series) for the shelf analysis using species with confidence values of 1 or 2, strings of 100 units or less, depths from 40 m to 200 m, no BII restrictions, a Normal distribution for each species (between the limits of their range) and a Jaccard analysis interval of 6 units.

Key Points of Interest:

- As with the shelf analysis using Normal distributions across the species range, the analysis identifies much smoother and more clearly demarcated structures.
- The smoothed nature of the distribution is at the expense of less prominent, but possibly valid provincial units, being dominated by neighbouring units. For instance, at the String Index of 200, the first three plots (coast-uniform, shelf-uniform, coast-normal) suggest the presence of a transition unit whereas this plot shows a province (even though it is weak).

Description of the Provincial Units

The previous four analyses were used to provide the final demarcation of provincial units for the coast and the shelf. We gave initial precedence to the analyses which used the Uniform distribution for species with string ranges of 100 units or less, confidence scores of 2 or less and maximum depth ranges of: 0-40 m for the coast and 40-200 m for the shelf. The analyses were not conducted for the biomic provincial units as the number of species would have been further reduced and because a number of preliminary analyses were showing consistent matching of units on the coast and shelf, with some exceptions. In future, as data quality improves it may be appropriate to investigate finer demarcations. The analyses using the Normal distribution for species were used to qualify the strength of the identified provincial units; it was computed as the area formed by the intersection of the smooth filter curve with the original curve.

In all cases, we relied upon the intersection of the smoothed curve with the original to provide the boundaries of the units. Whilst this method is not ideal (particularly in situations where low signal units abut against stronger units), it does provide a repeatable and objective method for defining the boundaries.

Finally, we note that analyses using the weightings based on string range were not conducted - such analyses have the potential to resolve finer scale provincial structures - nor were the two dimensional analyses of the Gulf of Carpentaria and Bass Strait.

Lists of the Coastal and Shelf Provincial Units

The results of the analyses for the provincial units are listed in Tables 2 and 3. Units that were less than 2 string units in length were not included in the lists. In Table 4, the strengths of these units and a list of the top 5 adherents to the units are presented. The "adherents" were computed by ranking the percentages of the species range that were within the provincial unit, and selecting the top 5. While some of these objectively selected species have been vetted, the majority have not been, so this is a preliminary list awaiting further analysis and discussion.

Table 2 String route start and end indices for the COAST (0-40 m depth).

ID	Province	Start	End
1	Cape York Province	4	8
3	North East Province	17	42
5	Morton Coastal Province	49	54
7	Central East Province	56	66
9	Eden Coastal Province (weak)	77	79
11	Tasmanian Province	86	101
13	Bass Strait Province - West	108	116
15	Gulf Province	120	124
17	GAB Province	128	148
19	South West Province	152	175
21	Central West Province	187	194
23	North West Province	202	208
25	Kimberley Coastal Province	212	226
27	Timor Province	233	247
29	Northern Province - West	255	270
31	Northern Province - East	274	280

Table 3 String route start and end indices for the SHELF (40-200 m depth).

ID	Province	Start	End
1	Cape York Province	5	10
3	North East Province	19	42
5	Central East Province	53	65
7	Tasmanian Province	88	100
9	Bass Strait Province - West	107	115
11	Gulf Province	121	123
13	GAB Province	130	147
15	South West Province - East	153	161
17	South West Province - West	167	174
19	Central West Province	186	196
21	North West Province	203	210
23	Kimberley Province	219	226
25	Timor Province	229	247
27	Northern Province - West	256	267
29	Northern Province - East	274	279

Table 4 Description of the provincial units

Notes: "Strength" of the units are approximate qualifications based on the Jaccard analysis with meanings as follows: "S" - strong, "I" - intermediate, "W" - weak and "L" - low (very weak). Indicies refer to the string route index. Key species are based on species whose range is most adherent to the unit.

Unit Name	Strength: Coast	Strength: Shelf	Coast Indices		Shelf Indices		Description (Location and Key Species)
North East Province - 1	I	I	*4*	*8*	*5*	*10*	**Location:** A small province of intermdiate strength to the north of Cape Melville in Far North Queensland. **Key Species: Coastal:** *Micrognathus natans; Neocirrhites armatus; Enchelynassa canina; Istigobius rigilius; Naso minor.* **Shelf:** *Plectranthias nanus; Chromis delta; Lubbockichthys multisquamatus; Cirrhilabrus lineatus; Antennatus tuberosus*
North East Province - 2	S	S	*17*	*42*	*19*	*42*	**Location:** A strong core province both along the coast and shelf in Far North Queensland. **Key Species: Coastal:** *Rhabdoblennius rhabdotrachelus; Atherinomorus capricornensis; Eviota variola; Bathygobius cotticeps; Aporops bilinearis* **Shelf:** *Parapercis flavolabiata; Solegnathus sp. 1 [in Kuiter, 2000]; Labropsis australis; Pseudanthias fasciata; Plectropomus laevis*
Central East Province	S	S	*56*	*66*	*53*	*65*	**Location:** A strong province both on the coast and shelf, corresponding to the core of the so-called Peronian Province. **Key Species: Coastal:** *Gymnothorax annasona; Gymnothorax atolli; Acanthistius cinctus; Chaetodon tricinctus; Parma alboscapularis* **Shelf:** *Gymnothorax nubilus; Antennarius commerson; Amphiprion latezonatus; Amphiprion mccullochi; Cheilodactylus ephippium*
Tasmanian Province	I	S	*86*	*101*	*88*	*100*	**Location:** An intermediate coastal and a strong shelf province wrapping around southern Tasmania. **Key Species: Coastal:** *Halaphritis platycephala; Neochanna cleaveri; Mitotichthys semistriatus; Heteroclinus flavescens; Galaxias truttaceus* **Shelf:** *Nesogobius hinsbyi; Notolabrus fucicola; Heteroclinus johnstoni; Ammotretis lituratus; Latridopsis forsteri*
Bassian Province	I	S	*108*	*116*	*107*	*115*	**Location:** An intermediate to strong province that may be an artifact of problems with species distributions spanning the width of Bass Strait - this province is subject to further analyses. **Key Species: Coastal:** *Paraplesiops alisonae; Stipecampus cristatus; Hypselognathus rostratus; Tasmanogobius gloveri; Tasmanogobius lasti* **Shelf:** *Apopterygion alta; Trygonoptera imitata; Ammotretis macrolepis; Rhycherus filamentosus; Arnoglossus bassensis*
Gulf Province	L	L	*120*	*124*	*121*	*123*	**Location:** A very weak and narrow province limited to the South Australian Gulfs **Key Species: Coastal:** *Vanacampus vercoi; Kaupus costatus; Ophiclinops pardalis; Trinorfolkia cristata; Dactylosurculus gomoni* **Shelf:** *Epinephelus undulatostriatus; Rhycherus filamentosus; Thamnaconus degeni; Echinophryne mitchellii; Pataecus fronto*
South West Province - 1	S	I	*128*	*148*	*130*	*147*	**Location:** A core province that is strong on the coast and of intermediate strength on the shelf of the Great Australia Bight **Key Species: Coastal:** *Ophiclinus brevipinnis; Dipulus multiradiatus; Heteroclinus sp. 5 [in Gomon et al, 1994]; Peronedys anguillaris; Vincentia macrocauda* **Shelf:** *Ammotretis brevipinnis; Zebrias penescalaris; Arnoglossus muelleri; Rhycherus gloveri; Remora australis*
South West Province - 2	S	I	*152*	*175*	*153*	*174*	**Location:** A strong coastal and intermediate shelf strength province of the South West **Key Species: Coastal:** *Heteroclinus kuiteri; Heteroclinus sp. 8 [in Gomon et al, 1994]; Favonigobius punctatus; Cochleoceps viridis; Parma bicolor* **Shelf (East):** *Suezichthys bifurcatus; Batrachomoeus rubricephalus; Caprichthys gymnura; Arnoglossus micrommatus; Irolita waitii* **Shelf (West):** *Plectranthias alleni; Orectolobus floridus; Scorpaena sumptuosa; Epinephelides armatus; Coris auricularis*
Central West Province	W	W	*187*	*194*	*186*	*196*	**Location:** A weak province associated with Shark Bay **Key Species: Coastal:** *Notograptus gregoryi; Opistognathus alleni; Thalassoma septemfasciatum; Cirripectes hutchinsi; Entomacrodus striatus* **Shelf:** *Plectorhinchus chubbi; Pseudocaranx dinjerra; Sillago vittata; Siphamia cuneiceps; Batrachomoeus occidentalis*

Table 4 cont'd

Unit Name	Strength: Coast	Strength: Shelf	Coast Indices		Shelf Indices		Description (Location and Key Species)
North West Province	W	I	*202*	*247*	*203*	*247*	**Location:** A weak coastal and intermediate strength province of the North West Shelf of Australia. Contains northern and southern substructure. **Key Species: Coastal (South):** *Naso fageni; Craterocephalus pauciradiatus; Pterosynchiropus occidentalis; Congrogadus winterbottomi; Siganus trispilos* **Shelf (South):** *Pseudochromis howsoni; Parapercis biordinis; Euristhmus sandrae; Pleurosicya annandalei; Atelomycterus fasciatus* **Key Species: Coastal (North):** *Cirripectes alleni; Assiculoides desmonotus; Glyphis garricki; Parapolynemus verekeri; Plotosus canius* **Shelf (North):** *Epinephelus bleekeri; Chromis caudalis; Lethrinus amboinensis; Polydactylus nigripinnis; Antennarius rosaceus*
Northern Province - 1	I	S	*255*	*270*	*256*	*267*	**Location:** An intermediate coastal and strong shelf province of Arnhem Land **Key Species: Coastal:** *Hippichthys parvicarinatus; Hemiarius dioctes; Pandaka rouxi; Congrogadus amplimaculatus; Oxuderces wirzi* **Shelf:** *Amblyotrypauchen arctocephalus; Lethrinus erythracanthus; Cyclichthys hardenbergi; Sardinella brachysoma; Pholidichthys anguis*
Northern Province - 2t	I	L	*274*	*280*	*274*	*279*	**Location:** An intermediate coastal and a very weak shelf province in the eastern Gulf of Carpentaria. The warnings above with respect to string representation also apply here **Key Species: Coastal:** *Hippocampus grandiceps; Thryssa scratchleyi; Helcogramma gymnauchen; Siganus javus; Acentrogobius janthinopterus* **Shelf:** *Stolephorus brachycephalus; Pseudocalliurichthys pleurostictus; Xiphocheilus typus; Lethrinus harak; Centropyge aurantia*

Biomic analyses

For each province, the strings within that province range were subjected to a Jaccard analysis by depth. In addition a two-dimensional grid analysis, by depth and by string route, was conducted to determine the biomic structures. In conducting the biomic analyses we were conscious of the need to link these analyses with those from the national slope study and with this in mind, a maximum depth out to 200 m was used.

The overall structure along the route was obtained by analysing all relevant species using depth bins of 5 m and a Jaccard interval for analysis of 20 m (see Figure 10). This analysis indicated four biomes at the approximate depth ranges of 0–13; 70–97; 118–145 and 160–195 m; for practical purposes these can be rounded off as 0–15; 70–100; 120–145 and 160–195 m. For each province, variations about this overall profile were determined by conducting depth-structured Jaccard analyses within each of the provinces. The resulting depth biomes are shown in Table 5. Major transitions between the biomes were observed at the approximate depth ranges of 13–70 m and 195–235 m; which for purposes can be rounded off as 15–70 and 195–235 m.

Table 5 Depth ranges (to nearest 5 metres) for biomes within each of the provinces. Note that for the last 2 provinces in the table, the Outer Shelf and Shelf Break biomes merge together because of the weakening transition between them.

Name	Coastal Biome	Mid-Shelf Biome	Outer Shelf Biome	Shelf-Break Biome
North East Province - 1	0 – 15	70 – 95	120 – 145	160 – 195
Central Eastern Province	0 – 15	75 – 95	120 – 150	165 – 195
Tasmanian Province	0 – 15	75 – 100	130 – 150	165 – 195
South West Province - 1	0 – 15	70 – 95	120 – 150	165 – 190
Central West Province	0 – 15	70 – 95	120 – 150	165 – 190
North West Province	0 – 15	70 – 95	118 –	– 185
Northern Province - 1	0 – 15	70 – 95	117 –	– 195

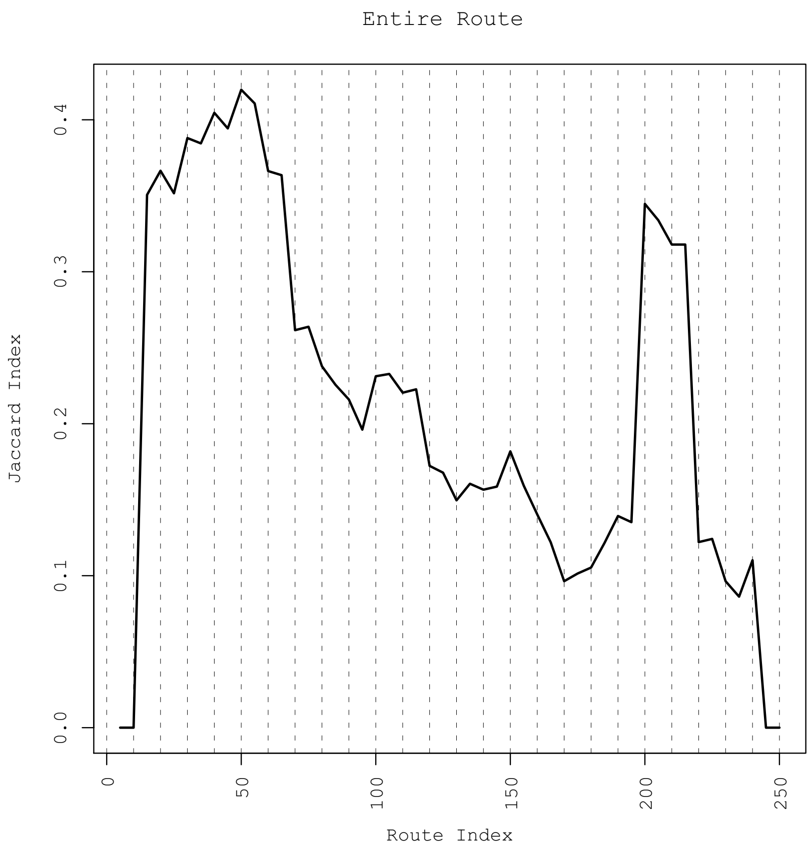


Figure 10 Variation of the Jaccard Index along the string route. All species occurring below 200 m depth were used. The Jaccard analysis interval was 20 m.

The two-dimensional plot of the Jaccard Index by string and depth is shown in Figure 11 to illustrate the persistent nature of the depth-related changes in the species turnover across the string route.

The results reported here are preliminary and more detailed analyses, including the grid analyses of Bass Strait and the Gulf of Carpentaria are required. As discussed previously, these results suggest that shelf and slope provinces will need to be analysed independently. The biomic structure appears to be consistent across the shelf in all provinces, with four distinct biomes recorded between 0 and 200 m depth, each with a transition zone between them (Figure 12). The first and last of these transition zones (approximately 15–70 and 195–235 m) were found to have the highest Jaccards which indicates a strong inter-mixing of species at these depth ranges. Thus, it is clear that both the provincial and biomic structures are important in determining the local rates of speciation and mixing of these species. A simplified depiction of the biomes is provided in Table 6 along with descriptions of the character of the biomes.

Table 6 Description of the shelf biomes defined in this study.

Biome	Depth Range	Description	Strength
Coastal	0–15 m	A well-defined and very shallow coastal province that has a consistent structure throughout Australia. A key concern with this biome is to what extent restriction on possible diving depth ranges are influencing the unit. Most ocean-going research vessels are limited to depths of 20 m or more. Nonetheless the biome is strongly defined. Note also depth range rounded to nearest 5 m. Within this depth range, a variety of near-shore and terrestrial influences are operating and it is also the most well-lit in terms of light penetration to the seafloor. Tidal stirring also has a strong influence on this unit.	Strong
Inner Shelf	70–100 m	Somewhat beyond the inner-shelf, this biome is of intermediate strength. Depths here are deep enough to form a surface photic zone and light penetration to the seafloor is weak. Tidal and wind stirring influences are also weak.	Medium
Mid Shelf	120–145 m	While not as strongly defined as the Coastal biome, this unit is better defined than the units to either side of it. Depths here are deep enough that influences from the slope and shelf-break may be influencing the environment in this unit. Thus edge effects from boundary currents and instabilities in currents at the shelf edge, along with breaking internal tides, may be forcing factors.	Strong to Medium
Outer Shelf	160–195 m	This unit is part of the classic “shelf-break” region. Influences from the slope are strengthening and so are the environmental factors from such processes as the shelf-break front, boundary currents, boundary instabilities, internal tides and topographic waves. The shelf-break is an area of enhanced mixing and productivity but it also highly dynamic.	Medium

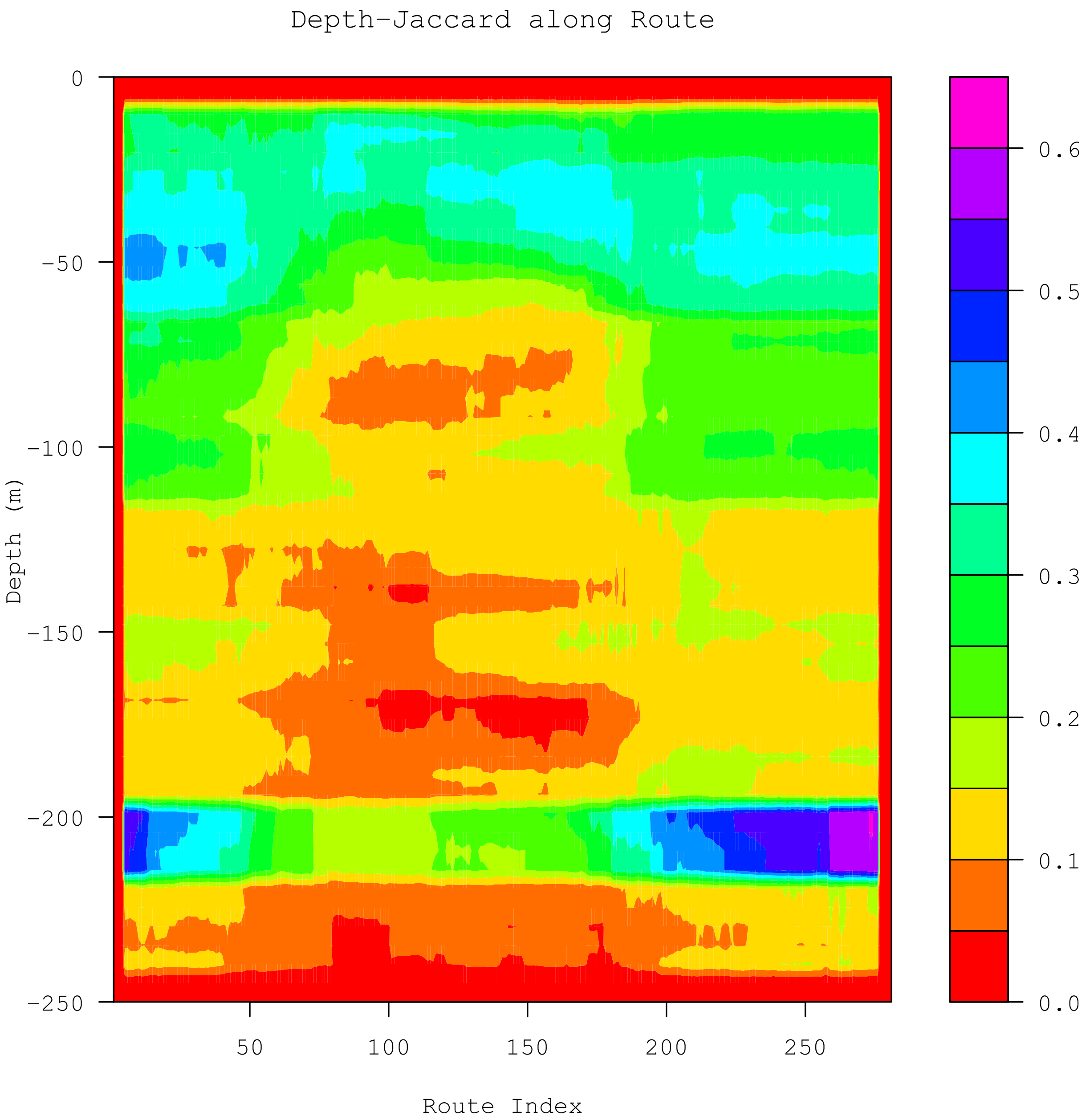


Figure 11 A two-dimensional plot showing the variation of the Jaccard Index by route (x-axis) and Depth (y-axis). Note the consistent depth band structure across the route

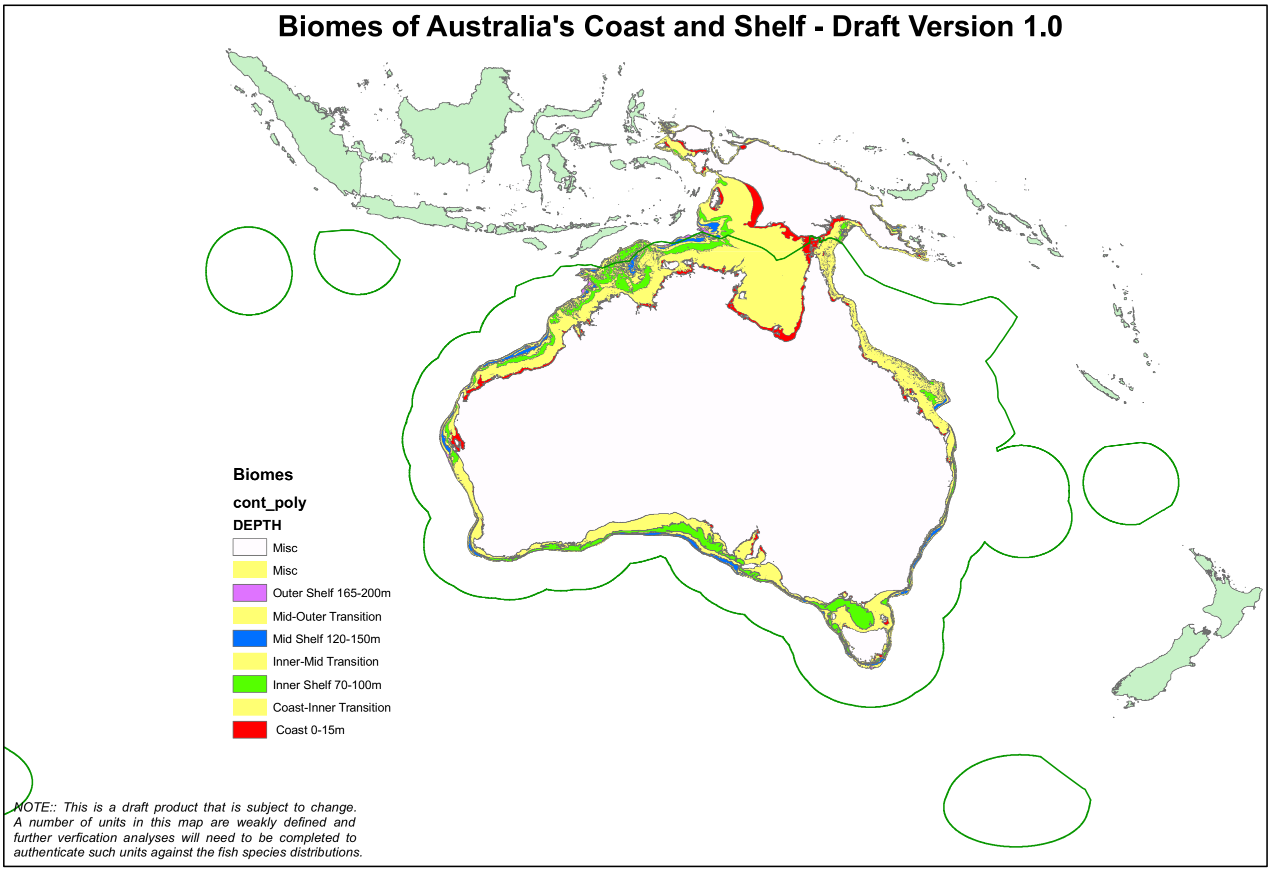


Figure 12 Preliminary mapping of the biomes of Australia's shelf based on the results of this study.

Conclusions

- Investigation of the biomes, as well as preliminary provincial analyses, on Australia's continental shelf were conducted using updated fish distribution datasets. Over 1000 species were added to the database and used for analyses.
- Biomic structuring of the continental shelf are consistent, within uncertainties in species ranges and analysis resolution, around the whole coastline and show an unresolved coastal biome out to about 15 m and other biomes at approximate depth ranges of: 70–100 m; 120–145 m; 160–195 m, with transition zones between these. Of these transitions, the ones at 15–70 m and 195–235 m have the highest Jaccards implying strong inter-mixing of species at these depth ranges. While the magnitude of the Jaccard varied along the shelf, the pattern of this variation was consistent. This implies that both the provincial and biomic structures are important in determining the local rates of speciation and mixing. The depth structures within the Gulf of Carpentaria and Bass Strait also remain to be resolved.

- The provincial structuring derived in this study is, in general, similar to that produced in the previous shelf bioregionalisation produced by CSIRO for the earliest IMCRA project (IMCRA, 1996). However, there were several significant differences, e.g. translocation of the Gulfs Province off South Australia, and uncertainties are found in the North West, in the Great Australian Bight and to the west of Bass Strait.

- Differences detailed in provincial structure in this study may result in part from a potential loss of precision caused by using the slope string to map shelf species. Additional loss of precision may have resulted from the use of published literature to determine species distributions. In earlier regionalisations, distributions were determined by evaluating collection and survey data and by examination of specimens. Some published distributions may include generalised data, which would reduce the precision. Additional, more detailed analyses are required to validate the shelf provincial bioregionalisation, and at this stage we recommend the continued use of shelf provinces as documented in the National Marine Bioregionalisation (NMB, 2005).

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Acronyms and abbreviations

CAAB	Codes for Australian Aquatic Biota
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EEZ	Exclusive Economic Zone
IMCRA	Interim Marine and Coastal Regionalisation for Australia
NRSMPA	National Representative System of Marine Protected Areas
SEMR	South-east Marine Region

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Appendix 1. Biogeographic Information Index (BII)

The following definition of the Biogeographic Information Index (BII), and discussion relating to the scoring of genera, is taken from Last *et al.* (2005).

Biogeographic Information Index (BII):

$$BII = C\,(2A + B) / \log(n + 1)$$

where: BII = Biogeographic Information Index

A = biogeographic potential

B = information content qualifier

C = value within each ecosystem

n = number of species in the genus

The biogeographic potential (A) incorporates both the species richness of the genus and the extent of the species' distribution (*e.g.* very restricted within Australia, subregional endemics, about half the Australian coastline, through to international species). Endemics are considered to be more informative than widely distributed species in delineating intraregional biogeographic patterns. Similarly, highly restricted endemics are likely to be more useful than those that occur more widely through the region so the range extents were considered when formulating the criteria (see below). The information qualifier (B) serves to include an index of the reliability of the distributional information for the species within the genus. Collective relevance of the species to the continental slope is modified according to the variable 'C' – zero values of C result in zero BII values eliminating the genus from the candidate groups for the continental slope. The presence of the variable $\log_n$ enabled the size of the group concerned to be factored in or out. Consequently, genera with low BII scores are considered to be more informative than those with high values.

The biogeographical potential (A) of genera were assessed according to the following eight criteria:

1. High richness (10 or more species in the genus) and almost all members with very restricted distributions

2. Low/medium richness (9 or fewer species in the genus) and almost all members with very restricted distributions

3. High richness and mostly subregional species (diversity high to low) but not applying to 1 or 2

4. Low/medium richness and mostly subregional species (diversity high to low) but not applying to 1 or 2

5. Mixed genus, including endemics and international species, but a few species have very restricted Australian distributions

6. Mainly broadly distributed Australian endemics

7. Broad mix of international and Australian subregional endemics

8. Almost all species with international distributions

The information qualifier (B) takes into account the quality of distributional information available for each genus. Distributions were scored according to the following weightings:

1. Well defined for most species in the genus (*i.e.* easily determined or has been studied extensively)

2. Reasonably well known for most of the species in the genus (*i.e*. good baseline data exists but only general studies available)

5. An even mixture of both well defined and poorly known species within the genus

9. Poorly defined

0. Unknown

The relative value (C) of each genus was weighted according to the following criteria:

1. High potential value (*i.e.* most species occurring on the continental slope) Medium value (*i.e.* half or so of species occurring on the continental slope)

2. Low potential value (i.e. few species occurring on the continental slope)

5. Genus unlikely to occur on the continental slope.

Appendix 2. Biogeographic Information Index (BII) scores for the most informative genera in the coastal zone.

BII scores for informative 218 coastal genera (*i.e.* those with a BII of less than 30).

Genus	# species	BII score	Family	Family Common Name
Urolophus	16	2.44	Urolophidae	Stingarees
Sillago	12	2.69	Sillaginidae	Whitings
Dipturus	18	3.13	Rajidae	Skates
Heteroclinus	24	4.29	Clinidae	Weedfishes
Neosebastes	9	5.00	Neosebastidae	Gurnard Perches
Parma	9	5.00	Pomacentridae	Damselfishes
Asymbolus	8	5.24	Scyliorhinidae	Catsharks
Meuschenia	8	5.24	Monacanthidae	Leatherjackets
Orectolobus	8	5.24	Orectolobidae	Wobbegongs
Eubalichthys	6	5.92	Monacanthidae	Leatherjackets
Pavoraja	6	5.92	Rajidae	Skates
Siphonognathus	6	5.92	Odacidae	Rock Whitings
Trygonoptera	6	5.92	Urolophidae	Stingarees
Torquigener	13	6.11	Tetraodontidae	Toadfishes
Corythoichthys	8	6.29	Syngnathidae	Pipefishes
Ammotretis	5	6.43	Pleuronectidae	Righteye Flounders
Favonigobius	5	6.43	Gobiidae	Gobies
Girella	5	6.43	Kyphosidae	Drummers
Maxillicosta	5	6.43	Neosebastidae	Gurnard Perches
Parascyllium	5	6.43	Parascylliidae	Collared Carpet Sharks
Foetorepus	7	6.64	Callionymidae	Dragonets
Alabes	10	6.72	Gobiesocidae	Clingfishes
Repomucenus	13	6.98	Callionymidae	Dragonets
Vincentia	6	7.10	Apogonidae	Cardinalfishes
Scorpis	4	7.15	Scorpididae	Sweeps
Trachinops	4	7.15	Plesiopidae	Prettyfins
Platycephalus	12	7.18	Platycephalidae	Flatheads
Choeroichthys	5	7.71	Syngnathidae	Pipefishes
Paraplesiops	5	7.71	Plesiopidae	Prettyfins
Hippocampus	27	8.29	Syngnathidae	Pipefishes
Doryrhamphus	4	8.58	Syngnathidae	Pipefishes
Hypoatherina	4	8.58	Atherinidae	Hardyheads
Mitotichthys	4	8.58	Syngnathidae	Pipefishes
Vanacampus	4	8.58	Syngnathidae	Pipefishes
Thamnaconus	6	8.87	Monacanthidae	Leatherjackets
Lepidotrigla	19	9.22	Triglidae	Searobins
Notolabrus	5	9.64	Labridae	Wrasses
Brachiopsilus	3	9.97	Brachionichthyidae	Handfishes
Campichthys	3	9.97	Syngnathidae	Pipefishes
Echinophryne	3	9.97	Antennariidae	Frogfishes
Festucalex	3	9.97	Syngnathidae	Pipefishes
Lissocampus	3	9.97	Syngnathidae	Pipefishes
Nesogobius	7	9.97	Gobiidae	Gobies

Tasmanogobius	3	9.97	Gobiidae	Gobies
Atypichthys	2	10.48	Scorpididae	Sweeps
Brachaelurus	2	10.48	Brachaeluridae	Blind Sharks
Cephaloscyllium	8	10.48	Scyliorhinidae	Catsharks
Hypoplectrodes	6	10.65	Serranidae	Rockcods
Ophiclinus	6	10.65	Ophiclinidae	Snake Blennies
Cheilodactylus	8	11.53	Cheilodactylidae	Morwongs
Cochleoceps	5	11.57	Gobiesocidae	Clingfishes
Pezichthys	5	11.57	Brachionichthyidae	Handfishes
Notoraja	6	11.83	Rajidae	Skates
Atelomycterus	3	12.46	Scyliorhinidae	Catsharks
Pictilabrus	3	12.46	Labridae	Wrasses
Atherinosoma	2	12.58	Atherinidae	Hardyheads
Atherion	2	12.58	Atherinidae	Hardyheads
Bulbonaricus	2	12.58	Syngnathidae	Pipefishes
Heraldia	2	12.58	Syngnathidae	Pipefishes
Histiogamphelus	2	12.58	Syngnathidae	Pipefishes
Kestratherina	2	12.58	Atherinidae	Hardyheads
Rhycherus	2	12.58	Antennariidae	Frogfishes
Calliurichthys	5	12.85	Callionymidae	Dragonets
Helcogramma	5	12.85	Tripterygiidae	Triplefins
Aplodactylus	4	12.88	Aplodactylidae	Marblefishes
Aspasmogaster	4	12.88	Gobiesocidae	Clingfishes
Mustelus	4	12.88	Triakidae	Hound Sharks
Norfolkia	4	12.88	Tripterygiidae	Triplefins
Squatina	4	12.88	Squatinidae	Angelsharks
Mugilogobius	9	13.00	Gobiidae	Gobies
Siganus	16	13.00	Siganidae	Rabbitfishes
Scarus	21	13.41	Scaridae	Parrotfishes
Acanthurus	20	13.61	Acanthuridae	Surgeonfishes
Bodianus	18	14.08	Labridae	Wrasses
Choerodon	16	14.63	Labridae	Wrasses
Cynoglossus	12	14.81	Cynoglossidae	Tongue Soles
Parapercis	32	14.82	Pinguipedidae	Grubfishes
Acanthaluteres	3	14.95	Monacanthidae	Leatherjackets
Aptychotrema	3	14.95	Rhinobatidae	Guitarfishes
Arenigobius	3	14.95	Gobiidae	Gobies
Centropogon	3	14.95	Tetrarogidae	Fortesques
Chironemus	3	14.95	Chironemidae	Kelpfishes
Ophiclinops	3	14.95	Ophiclinidae	Snake Blennies
Trygonorrhina	3	14.95	Rhinobatidae	Guitarfishes
Hyporhamphus	7	14.95	Hemiramphidae	Garfishes
Plesiops	5	15.42	Plesiopidae	Prettyfins
Contusus	2	15.72	Tetraodontidae	Toadfishes
Liza	8	15.72	Mugilidae	Mullets
Chromis	30	16.09	Pomacentridae	Damselfishes
Sillaginodes	1	16.61	Sillaginidae	Whitings
Stenatherina	1	16.61	Atherinidae	Hardyheads

Sympterichthys	1	16.61	Brachionichthyidae	Handfishes
Centropyge	11	16.68	Pomacanthidae	Angelfishes
Pterygotrigla	11	16.68	Triglidae	Searobins
Epinephelus	47	16.95	Serranidae	Rockcods
Pempheris	10	17.28	Pempherididae	Bullseyes
Gymnothorax	43	17.34	Muraenidae	Moray Eels
Centroberyx	5	17.35	Berycidae	Alfonsinos
Valamugil	6	17.75	Mugilidae	Mullets
Squalus	12	18.85	Squalidae	Dogfishes
Brachionichthys	2	18.86	Brachionichthyidae	Handfishes
Hemitriakis	2	18.86	Triakidae	Hound Sharks
Lepidoblennius	2	18.86	Tripterygiidae	Triplefins
Omegophora	2	18.86	Tetraodontidae	Toadfishes
Arnoglossus	14	19.13	Bothidae	Lefteye Flounders
Acanthistius	5	19.28	Serranidae	Rockcods
Narcine	5	19.28	Narcinidae	Numbfishes
Neotrygon	5	19.28	Dasyatidae	Stingrays
Parascorpaena	5	19.28	Scorpaenidae	Scorpionfishes
Arripis	4	19.31	Arripidae	Australian Salmons
Nemipterus	16	19.51	Nemipteridae	Threadfin Breams
Dasyatis	6	19.52	Dasyatidae	Stingrays
Pleurosicya	13	19.63	Gobiidae	Gobies
Acentronura	1	19.93	Syngnathidae	Pipefishes
Atherinason	1	19.93	Atherinidae	Hardyheads
Crapatalus	1	19.93	Leptoscopidae	Sandfishes
Dentatherina	1	19.93	Atherinidae	Hardyheads
Eeyorius	1	19.93	Moridae	Morid Cods
Filicampus	1	19.93	Syngnathidae	Pipefishes
Kuiterichthys	1	19.93	Antennariidae	Frogfishes
Kyphosus	7	19.93	Kyphosidae	Drummers
Leptoichthys	1	19.93	Syngnathidae	Pipefishes
Maroubra	1	19.93	Syngnathidae	Pipefishes
Notiocampus	1	19.93	Syngnathidae	Pipefishes
Phycodurus	1	19.93	Syngnathidae	Pipefishes
Phyllophryne	1	19.93	Antennariidae	Frogfishes
Pugnaso	1	19.93	Syngnathidae	Pipefishes
Stipecampus	1	19.93	Syngnathidae	Pipefishes
Lethrinus	21	20.11	Lethrinidae	Emperors
Aseraggodes	12	20.20	Soleidae	Soles
Suezichthys	8	20.44	Labridae	Wrasses
Coris	11	20.85	Labridae	Wrasses
Lesueurina	2	20.96	Leptoscopidae	Sandfishes
Thymichthys	2	20.96	Brachionichthyidae	Handfishes
Acanthopagrus	5	21.20	Sparidae	Breams
Ichthyscopus	6	21.30	Uranoscopidae	Stargazers
Zebrias	6	21.30	Soleidae	Soles
Parablennius	4	21.46	Blenniidae	Blennies
Pseudolabrus	4	21.46	Labridae	Wrasses

Parupeneus	12	21.55	Mullidae	Goatfishes
Beaglichthys	3	21.59	Bythitidae	Live-bearing Cusks
Diancistrus	7	21.59	Bythitidae	Live-bearing Cusks
Dinematichthys	3	21.59	Bythitidae	Live-bearing Cusks
Enneapterygius	19	21.91	Tripterygiidae	Triplefins
Scorpaena	11	22.24	Scorpaenidae	Scorpionfishes
Upeneus	11	22.24	Mullidae	Goatfishes
Caesioperca	3	22.42	Serranidae	Rockcods
Carangoides	15	22.42	Carangidae	Trevallies
Chrysiptera	15	22.42	Pomacentridae	Damselfishes
Pristiophorus	3	22.42	Pristiophoridae	Sawsharks
Pseudophycis	3	22.42	Moridae	Morid Cods
Upeneichthys	3	22.42	Mullidae	Goatfishes
Uranoscopus	9	22.50	Uranoscopidae	Stargazers
Eviota	31	22.92	Gobiidae	Gobies
Leiognathus	10	23.05	Leiognathidae	Ponyfishes
Batrachomoeus	6	23.07	Batrachoididae	Frogfishes
Pervagor	5	23.13	Monacanthidae	Leatherjackets
Opistognathus	16	23.16	Opisthognathidae	Jawfishes
Plectorhinchus	13	23.56	Haemulidae	Grunter Breams
Himantura	8	23.58	Dasyatidae	Stingrays
Nemadactylus	4	23.61	Cheilodactylidae	Morwongs
Synodus	15	23.67	Synodontidae	Lizardfishes
Pseudorhombus	14	24.23	Paralichthyidae	Sand Flounders
Anoplocapros	3	24.91	Ostraciidae	Box Fishes
Cristiceps	3	24.91	Clinidae	Weedfishes
Galaxias	1	24.91	Lepidogalaxiidae	Salamanderfishes
Kathetostoma	3	24.91	Uranoscopidae	Stargazers
Lovettia	1	24.91	Aplochitonidae	Galaxiids
Nematalosa	3	24.91	Clupeidae	Herrings
Paraplotosus	3	24.91	Plotosidae	Eeltail Catfishes
Pseudaphritis	1	24.91	Bovichthyidae	Thornfishes
Seriolella	3	24.91	Centrolophidae	Trevallas
Sutorectus	1	24.91	Orectolobidae	Wobbegongs
Taratretis	1	24.91	Pleuronectidae	Righteye Flounders
Lepidoperca	7	24.91	Serranidae	Rockcods
Cryptocentrus	12	25.58	Gobiidae	Gobies
Pseudochromis	12	25.58	Pseudochromidae	Dottybacks
Cirrhilabrus	11	26.41	Labridae	Wrasses
Saurida	11	26.41	Bathysauridae	Deepsea Lizardfishes
Scorpaenodes	11	26.41	Scorpaenidae	Scorpionfishes
Herklotsichthys	7	26.58	Clupeidae	Herrings
Dermatopsis	2	27.25	Bythitidae	Live-bearing Cusks
Sticharium	2	27.25	Ophiclinidae	Snake Blennies
Heterodontus	3	27.41	Heterodontidae	Hornsharks
Dipulus	4	27.90	Bythitidae	Live-bearing Cusks
Achoerodus	2	28.29	Labridae	Wrasses
Aracana	2	28.29	Ostraciidae	Box Fishes

Callanthias	2	28.29	Serranidae	Rockcods
Dotalabrus	2	28.29	Labridae	Wrasses
Hemiramphus	2	28.29	Hemiramphidae	Garfishes
Myliobatis	2	28.29	Myliobatidae	Eagle Rays
Odax	2	28.29	Odacidae	Rock Whitings
Anampses	9	28.50	Labridae	Wrasses
Cirripectes	9	28.50	Blenniidae	Blennies
Omobranchus	9	28.50	Blenniidae	Blennies
Siphamia	9	28.50	Apogonidae	Cardinalfishes
Callogobius	8	29.87	Gobiidae	Gobies
Gerres	8	29.87	Gerreidae	Silverbiddies
Aldrichetta	1	29.90	Mugilidae	Mullets
Austrolabrus	1	29.90	Labridae	Wrasses
Bovichtus	1	29.90	Bovichthyidae	Thornfishes
Cnidoglanis	1	29.90	Plotosidae	Eeltail Catfishes
Creocele	1	29.90	Gobiesocidae	Clingfishes
Dinolestes	1	29.90	Dinolestidae	Longfin Pike
Enoplosus	1	29.90	Enoplosidae	Old Wives
Gymnapistes	1	29.90	Tetrarogidae	Fortesques
Haletta	1	29.90	Odacidae	Rock Whitings
Leviprora	1	29.90	Platycephalidae	Flatheads
Myxus	1	29.90	Mugilidae	Mullets
Neoodax	1	29.90	Odacidae	Rock Whitings
Ophthalmolepis	1	29.90	Labridae	Wrasses
Othos	1	29.90	Serranidae	Rockcods
Parequula	1	29.90	Gerreidae	Silverbiddies
Pentaceropsis	1	29.90	Pentacerotidae	Boarfishes
Phyllopteryx	1	29.90	Syngnathidae	Pipefishes
Polyspina	1	29.90	Tetraodontidae	Toadfishes
Reicheltia	1	29.90	Tetraodontidae	Toadfishes
Scobinichthys	1	29.90	Monacanthidae	Leatherjackets

Appendix 3. Biogeographic Information Index (BII) scores for the most informative genera in the continental shelf zone.

Biogeographic Information Index (BII) scores for the most informative 139 shelf genera (*i.e.* those with a BII of less than 30).

Genus	# species	BII score	Family	Family Common Name
Urolophus	16	2.44	Urolophidae	Stingarees
Sillago	12	4.04	Sillaginidae	Whitings
Neosebastes	9	5.00	Neosebastidae	Gurnard Perches
Asymbolus	8	5.24	Scyliorhinidae	Catsharks
Hippocampus	27	5.53	Syngnathidae	Pipefishes
Lepidotrigla	19	6.15	Triglidae	Searobins
Maxillicosta	5	6.43	Neosebastidae	Gurnard Perches
Solegnathus	6	7.10	Syngnathidae	Pipefishes
Platycephalus	12	7.18	Platycephalidae	Flatheads
Scorpaena	11	7.41	Scorpaenidae	Scorpionfishes
Parma	9	7.50	Pomacentridae	Damselfishes
Pezichthys	5	7.71	Brachionichthyidae	Handfishes
Meuschenia	8	7.86	Monacanthidae	Leatherjackets
Orectolobus	8	7.86	Orectolobidae	Wobbegongs
Atelomycterus	3	8.30	Scyliorhinidae	Catsharks
Hypoatherina	4	8.58	Atherinidae	Hardyheads
Eubalichthys	6	8.87	Monacanthidae	Leatherjackets
Thamnaconus	6	8.87	Monacanthidae	Leatherjackets
Siphonognathus	6	8.87	Odacidae	Rock Whitings
Pavoraja	6	8.87	Rajidae	Skates
Trygonoptera	6	8.87	Urolophidae	Stingarees
Squalus	12	9.43	Squalidae	Dogfishes
Corythoichthys	8	9.43	Syngnathidae	Pipefishes
Girella	5	9.64	Kyphosidae	Drummers
Notolabrus	5	9.64	Labridae	Wrasses
Parascyllium	5	9.64	Parascylliidae	Collared Carpet Sharks
Brachiopsilus	3	9.97	Brachionichthyidae	Handfishes
Irolita	2	10.48	Rajidae	Skates
Scorpis	4	10.73	Scorpididae	Sweeps
Epinephelus	47	11.30	Serranidae	Rockcods
Cheilodactylus	8	11.53	Cheilodactylidae	Morwongs
Centroberyx	5	11.57	Berycidae	Alfonsinos
Choeroichthys	5	11.57	Syngnathidae	Pipefishes
Lutjanus	27	12.44	Lutjanidae	Snappers
Pictilabrus	3	12.46	Labridae	Wrasses
Thymichthys	2	12.58	Brachionichthyidae	Handfishes
Arnoglossus	14	12.75	Bothidae	Lefteye Flounders
Pseudorhombus	14	12.75	Paralichthyidae	Sand Flounders
Narcine	5	12.85	Narcinidae	Numbfishes
Squatina	4	12.88	Squatinidae	Angelsharks
Mitotichthys	4	12.88	Syngnathidae	Pipefishes
Vanacampus	4	12.88	Syngnathidae	Pipefishes
Mustelus	4	12.88	Triakidae	Hound Sharks

Aseraggodes	12	13.47	Soleidae	Soles
Bodianus	18	14.08	Labridae	Wrasses
Zebrias	6	14.20	Soleidae	Soles
Ichthyscopus	6	14.20	Uranoscopidae	Stargazers
Choerodon	17	14.34	Labridae	Wrasses
Parapercis	32	14.82	Pinguipedidae	Grubfishes
Pristiophorus	3	14.95	Pristiophoridae	Sawsharks
Aptychotrema	3	14.95	Rhinobatidae	Guitarfishes
Trygonorrhina	3	14.95	Rhinobatidae	Guitarfishes
Caesioperca	3	14.95	Serranidae	Rockcods
Campichthys	3	14.95	Syngnathidae	Pipefishes
Lissocampus	3	14.95	Syngnathidae	Pipefishes
Uranoscopus	9	15.00	Uranoscopidae	Stargazers
Caelorinchus	35	15.42	Macrouridae	Whiptails
Opistognathus	16	15.44	Opisthognathidae	Jawfishes
Brachaelurus	2	15.72	Brachaeluridae	Blind Sharks
Brachionichthys	2	15.72	Brachionichthyidae	Handfishes
Sympterichthys	2	15.72	Brachionichthyidae	Handfishes
Cephaloscyllium	8	15.72	Scyliorhinidae	Catsharks
Nemadactylus	4	15.74	Cheilodactylidae	Morwongs
Synodus	15	15.78	Synodontidae	Lizardfishes
Hypoplectrodes	6	15.97	Serranidae	Rockcods
Anoplocapros	3	16.61	Ostraciidae	Box Fishes
Kathetostoma	3	16.61	Uranoscopidae	Stargazers
Pterygotrigla	11	16.68	Triglidae	Searobins
Pempheris	10	17.28	Pempherididae	Bullseyes
Gymnothorax	43	17.34	Muraenidae	Moray Eels
Chaetodon	35	17.35	Chaetodontidae	Butterflyfishes
Neotrygon	5	17.35	Dasyatidae	Stingrays
Saurida	11	17.61	Bathysauridae	Deepsea Lizardfishes
Batrachomoeus	6	17.75	Batrachoididae	Frogfishes
Siganus	16	18.29	Siganidae	Rabbitfishes
Dipulus	4	18.60	Bythitidae	Live-bearing Cusks
Callanthias	2	18.86	Serranidae	Rockcods
Histiogamphelus	2	18.86	Syngnathidae	Pipefishes
Hypselognathus	2	18.86	Syngnathidae	Pipefishes
Hemitriakis	2	18.86	Triakidae	Hound Sharks
Onigocia	6	18.93	Platycephalidae	Flatheads
Bembrops	9	19.00	Percophidae	Duckbills
Arripis	4	19.31	Arripidae	Australian Salmons
Nemipterus	16	19.51	Nemipteridae	Threadfin Breams
Dasyatis	6	19.52	Dasyatidae	Stingrays
Pleurosicya	13	19.63	Gobiidae	Gobies
Lethrinus	21	20.11	Lethrinidae	Emperors
Cynoglossus	12	20.20	Cynoglossidae	Tongue Soles
Suezichthys	8	20.44	Labridae	Wrasses
Aulopus	2	20.96	Aulopidae	Threadsails
Engyprosopon	7	21.04	Bothidae	Lefteye Flounders

Hydrolagus	6	21.30	Chimaeridae	Shortnose Chimaeras
Chaetodontoplus	6	21.30	Pomacanthidae	Angelfishes
Pseudolabrus	4	21.46	Labridae	Wrasses
Parupeneus	12	21.55	Mullidae	Goatfishes
Beaglichthys	3	21.59	Bythitidae	Live-bearing Cusks
Enneapterygius	19	21.91	Tripterygiidae	Triplefins
Upeneus	11	22.24	Mullidae	Goatfishes
Pseudophycis	3	22.42	Moridae	Morid Cods
Glaucosoma	4	22.89	Glaucosomatidae	Pearl Perches
Leiognathus	10	23.05	Leiognathidae	Ponyfishes
Genypterus	2	23.05	Ophidiidae	Cuskeels
Pervagor	5	23.13	Monacanthidae	Leatherjackets
Plectorhinchus	13	23.56	Haemulidae	Grunter Breams
Himantura	8	23.58	Dasyatidae	Stingrays
Seriolella	3	24.91	Centrolophidae	Trevallas
Sutorectus	1	24.91	Orectolobidae	Wobbegongs
Parapriacanthus	3	24.91	Pempherididae	Bullseyes
Aulohalaelurus	1	24.91	Scyliorhinidae	Catsharks
Trachichthys	3	24.91	Trachichthyidae	Roughies
Lepidoperca	7	24.91	Serranidae	Rockcods
Centropyge	11	25.02	Pomacanthidae	Angelfishes
Scorpaenodes	11	26.41	Scorpaenidae	Scorpionfishes
Rhizoprionodon	3	26.58	Carcharhinidae	Whaler Sharks
Minous	3	26.58	Synanceiidae	Stonefishes
Polydactylus	4	27.18	Polynemidae	Threadfin Salmons
Enigmapercis	2	27.25	Percophidae	Duckbills
Helicolenus	2	27.25	Sebastidae	Ocean Perches
Myliobatis	2	28.29	Myliobatidae	Eagle Rays
Aracana	2	28.29	Ostraciidae	Box Fishes
Cirripectes	9	28.50	Blenniidae	Blennies
Gerres	8	29.87	Gerreidae	Silverbiddies
Allomycterus	1	29.90	Diodontidae	Porcupinefishes
Heterodontus	3	29.90	Heterodontidae	Hornsharks
Hypnos	1	29.90	Hypnidae	Coffin Rays
Crapatalus	1	29.90	Leptoscopidae	Sandfishes
Nelusetta	1	29.90	Monacanthidae	Leatherjackets
Caprichthys	1	29.90	Ostraciidae	Box Fishes
Capropygia	1	29.90	Ostraciidae	Box Fishes
Kentrocapros	1	29.90	Ostraciidae	Box Fishes
Acentronura	1	29.90	Syngnathidae	Pipefishes
Filicampus	1	29.90	Syngnathidae	Pipefishes
Kaupus	1	29.90	Syngnathidae	Pipefishes
Leptoichthys	1	29.90	Syngnathidae	Pipefishes
Notiocampus	1	29.90	Syngnathidae	Pipefishes
Phycodurus	1	29.90	Syngnathidae	Pipefishes
Pugnaso	1	29.90	Syngnathidae	Pipefishes
Reicheltia	1	29.90	Tetraodontidae	Toadfishes
Paratrachichthys	1	29.90	Trachichthyidae	Roughies

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