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Species groupings for management of the Gulf of Mexico reef fish fishery

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Abstract

The Magnuson-Stevens Reauthorization Act of 2006 requires regional fishery management councils to implement annual catch limits and accountability measures for all stocks under Federal management by 2011, to ensure overfishing does not occur. Many species are data-limited and have no formal stock assessment. One possible approach to managing these unassessed species is to assign them to assemblages that would be managed as units. The utility of this approach was evaluated using fishery-dependent and fishery-independent data from the Gulf of Mexico. Multivariate statistical analyses revealed several consistent assemblages among the 42 reef fish species managed by the Gulf of Mexico Fishery Management Council. Pearson correlation matrices and nodal analyses provided additional guidance regarding the placement of rare species. Identified stock complexes and sub-complexes may be useful for fisheries management, as a management measure implemented for any member of a complex might be expected to result in a similar trajectory of fishing mortality rate (F) for other members of the complex. Productivity-Susceptibility Analysis and life history were also considered, as differences in productivity, vulnerability, life history, and other population dynamic parameters for species within complexes might imply different population responses to a similar change in F. Identified linkages between species also provide guidance for ecosystem-based management considerations such as the impacts of regulations upon multi-species fisheries.

Introduction

The Magnuson-Stevens Reauthorization Act (MSRA 2006) requires regional fishery management councils to implement annual catch limits (ACLs) and accountability measures (AMs) to ensure overfishing does not occur. ACLs and AMs are required for all stocks under federal management, except stocks with annual life cycles and those managed by international agreement in which the United States participates. These ACL/AM provisions must be implemented in 2010 or earlier for stocks subject to overfishing, and in 2011 or earlier for all other federally-managed stocks. The Gulf of Mexico Fisheries Management Council (Gulf Council) currently manages 42 finfish species under its Reef Fish Fishery Management Plan (FMP). Traditionally, management measures have been implemented based upon species-specific stock assessment results. However, only 13 species managed by the Gulf Council Reef Fish FMP may have approved assessments by 2011 (e.g., red snapper, vermilion snapper, gray triggerfish, greater amberjack, black grouper, red grouper, goliath grouper, yellowedge grouper, mutton snapper, yellowtail snapper, golden tilefish, blueline tilefish, and gag grouper). Establishing ACLs for many of these assessed species, as well as the remaining 29 unassessed species, will be accomplished via the Gulf Council's Generic Comprehensive ACL/AM Amendment. This amendment may also revisit and adjust ACL/AM provisions previously adopted for greater amberjack and gray triggerfish if the Council finds it is necessary in order to be consistent with policies adopted in the generic comprehensive ACL/AM amendment. Gulf Reef Fish Amendment 32 will revise ACLs/AMs for gag, red grouper, and the shallow-water grouper complex.

One possible approach for developing ACLs for unassessed species would be to assign them to assemblages that would be managed as units. The NMFS ACL Final Rule states that "…the vulnerability of stocks to the fishery should be evaluated when determining if a particular stock complex should be established or reorganized, or if a particular stock should be included in a complex" (50 CFR 600.310(b)(8) in 74 FR 3205). National Standard 3 for fishery conservation and management (MSRA §301) states that "to the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination." A stock complex, as defined by the recently amended National Standard 1 guidance, is "a group of stocks that are sufficiently similar in geographic distribution, life history, and vulnerabilities to the fishery such that the impact of management actions on the stocks is similar" (74 FR 3178). Stocks may be grouped into complexes if: 1) they cannot be targeted independently of one another in a multispecies fishery; 2) there is not sufficient data to measure their status relative to established status determination criteria; or 3) when it is not feasible for fishermen to distinguish individual stocks among their catch (50 CFR 600.310(b)(8) in 74 FR 3178). A management unit is defined as "a fishery or that portion of a fishery identified in a FMP as relevant to the FMP's management objectives" (50 CFR 600.320(d)). Management units may be organized based on biological, geographic, economic, technical, social, or ecological considerations (50 CFR 600.320(d)(1)).

The objectives of this paper are threefold: (1) To determine whether species assemblages can be identified in the Gulf of Mexico among the 42 managed Reef Fish FMP species, (2) To determine if these assemblages are consistent between commercial and recreational fisheries, and (3) To develop species complexes that are "…sufficiently similar in geographic distribution, life history, and vulnerabilities to the fishery such that the impact of management actions on the stocks is similar" per National Standard 1. The results of these analyses should provide guidance for the Gulf Council in setting ACLs for reef fish species in the Generic Comprehensive ACL/AM Amendment.

Methods

Following Lee and Sampson (2000), multiple statistical techniques were used to identify species assemblages: (1) species life history and depth of occurrence, (2) percent landings and percent records by data matrix, (3) dimension reduction and hierarchical cluster analyses based on life history; abundance; and presence-absence, (4) correlation matrices, (5) nodal analyses, (6) weighted mean cluster association indices, and (7) maps of species distributions. These results were synthesized across analyses to develop potential species complexes for ACL management sufficiently similar in geographic distribution, life history, and vulnerabilities to the fishery such that the impact of management actions on the stocks would be similar.

Life History and Landings Data

Life history parameters were assembled from peer-reviewed literature, Southeast Data Assessment and Review (SEDAR) reports, unpublished data from the NMFS Panama City Laboratory, Stock Assessment and Fishery Evaluation (SAFE) reports, and from FishBase (Froese & Pauly 2009). Data from the Gulf of Mexico was used whenever possible. Depth of occurrence records were assimilated from FishBase, with minimum and maximum depths of occurrence recorded (Froese & Pauly 2009).

Commercial logbook, commercial observer, headboat logbook, recreational survey, and fishery-independent bottom longline data were used to evaluate similarities in spatial and temporal patterns of fisheries exploitation in the Gulf of Mexico for species in the Gulf Reef Fish FMP. Commercial logbook records (SEFSC logbook data, accessed 6 May 2010) summarize landings on a trip level, with information for each species encountered including landings (in lbs), primary gear used, and primary area and depth of capture. Depth of capture is an important consideration when evaluating similarities in fisheries vulnerability and is only available in logbook records from 2005 onward, reported as a mean depth of capture, by species captured. It should be noted that a single depth of fishing is reported for each species per trip, although they may be encountered at numerous depths during multiple sets, and even within a single drifting longline set.

For the purposes of these analyses, logbook landings were summarized by species, year, month, geartype, statistical area, and depth. Trip-level adjustments were made to black grouper and gag grouper landings to account for misidentification following recommendations from SEDAR-10 (2006). Year and month were defined by the date the fish were landed. Vertical line (e.g., handline and electric rig) and longline geartypes were evaluated separately. Area fished was based on the 21 Gulf of Mexico commercial logbook statistical areas. Depth of capture was aggregated into atmospheric pressure bins (e.g., 33 ft = 2 atm, 66 ft = 3 atm, etc.). Records with no reported depth or area of capture were removed from consideration; these represented approximately 9% of the total available records for both the longline and vertical line clusters. Overall, 27,566 longline and 121,767 vertical line commercial logbook records from 2005-2009 were evaluated.

For the commercial logbook data, separate analyses were conducted for commercial longline (CLL) and commercial vertical line (CVL) geartypes. Landings were aggregated by month to maximize the variety of species landed while still capturing temporal trends in abundance. Fishermen will typically make multiple sets on a trip, sometimes in geographically distant areas, targeting different species. Aggregating landings by area and depth reduced the probability of grouping species caught during the same time period that would likely not co-occur during any given set due to disparate geographic distributions.

In July 2006, NMFS implemented a mandatory reef fish observer program (RFOP) to characterize the reef fish fishery operating in the U.S. Gulf of Mexico. The mandatory RFOP provides general fishery landing and bycatch characterization, estimates managed finfish discard levels; dispositions; and size distributions, and provides observations of protected species takes. The RFOP provides set-level information on species encountered on trips using bottom longline, electric (bandit) reel, and handlines. Overall, 125,368 records representing encounters (e.g., landings plus discards) in numbers by species for 7,105 observed sets in the Gulf of Mexico from 2006-2009 were evaluated.

The recreational headboat sector of the reef fish fishery was evaluated using headboat survey (HBS) logbook data (Southeast Region Headboat Survey data, accessed 19 April 2010) reported by headboat operators. Headboats are large, for-hire vessels that typically accommodate 20 or more anglers on half- or full-day trips. Headboat records are arranged similar to commercial logbook records, and contain trip-level information on number of anglers, trip duration, date, area fished, and landings (number fish) and releases (number fish) of each species. Headboat landings and encounters (landings plus releases) were summarized by species, year, month, trip duration, and area fished. Trip duration was considered the best proxy for depth fished, as trips of longer duration are more likely to go farther offshore. Area fished was aggregated at the most common reporting level (1° latitude by 1° longitude). As with the commercial fishery data, area fished is self-reported and this introduces error into the analysis. Additionally, vessels fishing in multiple areas during a trip would be constrained by the current data form to select one area fished for the trip, which limits the spatial precision of the analysis. Records with no geographic area reported (~3%) were removed from consideration. Overall, 121,334 headboat records from 2004-2009 were evaluated.

The private, rental, and for-hire charter sectors were evaluated using data from the Marine Recreational Fisheries Statistics Survey (MRFSS) dockside intercept records. MRFSS intercepts collect data on port agent observed landings (‘A’ catch) and angler reported landings (‘B1’ catch) and discards (‘B2’ catch) in numbers by species, two-month wave (e.g., Wave 1 = Jan/Feb, … Wave 6 = Nov/Dec), area fished (inland, state, and federal waters), mode of fishing (charter, private/rental, shore), and state (west Florida, Alabama, Mississippi, and Louisiana). MRFSS intercepts from the Gulf of Mexico from 2000-2009 were aggregated by year, wave, mode, and area fished; computing a catch-per-angler-per-trip (CPAT) by species for the whole catch (e.g., ‘A’+’B1’+’B2’ catch). Overall, 64,782 dockside intercept records from 2000-2009 were evaluated.

Since 1995, NMFS has conducted fishery-independent shark bottom-longline (BLL) surveys throughout the Gulf of Mexico in depths from 9-55 m (Grace & Henwood 1997). In 1999, these surveys were expanded to survey an offshore snapper-grouper component (primarily red snapper) out to depths of 366 m (SEDAR7-DW7 2004). Study sites were randomly selected and longline sets were made parallel to depth contours. Gangion test and length varied between years. J-hooks were used prior to 1999, and circle hooks after 1999. Soak times were always one hour, using 100 #15/0 hooks baited with Atlantic mackerel (*Scomber scombrus*). Methods were standardized in 2001, with the survey expanded to cover the entire U.S. Gulf over depths ranging from 9-366 m. Effort was proportionally allocated based upon shelf width within 60 nautical mile statistical zones (81-82° W, 82-83° W, etc.) and stratified by depth (50%: 9-73 m, 40%: 73-183 m, 10%: 183-366 m). Data were recorded as catch per unit effort (CPUE=number of species per 100 hook hour). NMFS-BLL data was aggregated at the set level. Overall, 851 records of managed reef fish landings from 1995-2009 were evaluated.

Each data set was formatted as a matrix, with columns representing species (i) and rows representing aggregation bins (j). For commercial fisheries, aggregation bins were *year-month-area-depth* combinations, resulting in 5904 longline bins and 35,217 vertical line bins. For the RFOP, aggregation bins were *set-level*, resulting in 9031 bins. For headboat fisheries, aggregation bins were *year-month-area-trip duration* combinations, resulting in 10,893 bins. For MRFSS, aggregation bins were *year-wave-mode-area* combinations, resulting in 430 bins. For BLL, aggregation bins were *set-level*, resulting in 684 bins. Each element of the matrix (c_{ij}) quantified the amount (in units of pounds of fish for commercial and number of fish for all other sources) of a species (i) landed in a specific bin (j).

Initially, species were excluded from analyses if they appeared in <1% of bins, following Shertzer and Williams (2008). Rare species may distort inferred patterns (Koch 1987, Mueter and Norcross 2000). As a primary goal of these analyses was to assign less abundant species to species complexes, and preliminary examination suggested the inclusion of rare species did not impact inferred patterns in any of the cluster analyses, all species were included in the final analyses.

For hierarchical cluster analyses of landings data, prior to computing dissimilarities, data were transformed with a root-root transformation to moderate the influence of abundant species upon the resultant clusters:

$$c_{ij}^{*} = \sqrt[4]{c_{ij}} \qquad (1)$$

This transformation is recommended for density and biomass data (Field et al. 1982) and was applied in a similar clustering approach described by Shertzer and Williams (2008).

Because the fishing effort that generates the landings data does not represent a consistent sampling program, reported landings data might not be quantitatively comparable between collections. Additionally, many species are heavily targeted, whereas the catch of others is incidental. Boesch (1977) suggests a binary index (e.g., 'presence-absence') may be a more appropriate measure of similarity with fisheries-dependent data. A binary index also reduces distortions caused by super-abundant (headboat and commercial) and heavier (commercial) species. For analyses of presence-absence data, landings data matrices were converted to binary, where a '1' was assigned to positive data elements (c_{ij}) and data elements with no landings were left as '0's.

Dimension Reduction and Hierarchical Cluster Analyses

Dimension reduction was conducted using PROC VARCLUS in SAS V9.2 (SAS Institute Inc., Cary, NC). PROC VARCLUS is a dimension reduction tool that clusters variables that are as correlated as possible among themselves and as uncorrelated as possible with variables in other clusters. The algorithm used by PROC VARCLUS is binary and divisive - all variables start in one cluster. A cluster is chosen for splitting and split into two clusters by performing an orthoblique rotation on the first two principal components. Each variable is assigned to the rotated component with which it has the higher squared correlation. The procedure is nonhierarchical; variables are iteratively reassigned to clusters to maximize the variance accounted for by the cluster components. Clusters are split until 95% of the variance is explained.

Hierarchical cluster analyses were conducted using PASW V17.0.3 (SPSS Inc., Chicago, Illinois). Hierarchical cluster analysis identifies relatively homogeneous groups of cases (or variables) based on selected characteristics. It is an agglomerative method which optimizes a route between individual entities to the entire set of entities through progressive fusion (Boesch 1977).

Life history parameters in Tables 1 and 2 plus a categorical variable denoting Family were clustered using hierarchical cluster analysis with Ward's minimum-variance linkage method (Sneath & Sokal 1973), a Euclidean distance measure, and a Z-score transformation by variable. Ward's minimum-variance linkage method minimizes within-group dispersion. This method agglomerates clusters when the increase in variance is less than it would be if either of the two clusters were joined with any other cluster (Sneath & Sokal 1973). Minimum-variance fusion is similar to average-linkage fusion, except that it minimizes a squared distance weighted by cluster size. Minimum-variance linkage is a space-dilating strategy because penalty by squared-distance results in tighter clusters than average-linkage.

The Euclidean distance (*ED*) measure is the square root of the sum of the squared differences between two entities (*j* and *k*) based on *P* variables:

$$ED_{jk} = \sqrt{\sum_{i=1}^{P}(x_{ij} - x_{ik})^2} \quad (3)$$

The Z-score transformation normalized the data by parameter, facilitating comparisons between species. An additional life history cluster was developed without the dummy variable for Genus to evaluate sensitivity of the method to this variable, which was intended to capture aspects of body morphology and life history not described by the growth and maturity parameters in Table 1.

The method employed to hierarchically cluster the fisheries datasets (e.g., CLL, CVL, RFOP, HBS, MRFSS, and BLL) was slightly different. After root-root transformation of landings in numbers or pounds, a matrix of dissimilarities between two species (*a*, *b*) was computed using a Chi-square (χ^2) measure of distance:

$$\chi^2 = \sqrt{\frac{\sum_{i=1}^{A}\left(a_i - E(a_i)\right)^2}{E(a_i)} + \frac{\sum_{i=1}^{B}\left(b_i - E(b_i)\right)^2}{E(b_i)}} \quad (4)$$

The Chi-square measure is based on the chi-square test of equality for two sets of frequencies, and is the default measure in PASW for count (e.g., abundance or landings) data. The magnitude of this dissimilarity measure depends on the total frequencies of the two cases or variables whose dissimilarity is computed. Expected values (*E*) are from the model of independence of species *a* and *b*. The resultant dissimilarity matrix was clustered using Ward's minimum-variance linkage method.

Presence-absence of species in the commercial longline, commercial vertical line, and headboat fisheries were clustered using average linkage between groups with a Sørenson measure of dissimilarity:

$$D_{ih} = \sum_{j=1}^{J} \frac{\left|c'_{ij} - c'_{hj}\right|}{\left|c'_{ij} - c'_{hj}\right|} \quad (5)$$

where D_{ih} is the distance between species *i* and *h*, and *j* is the number of rows (bins). In an average linkage method, the linkage function specifies the distance between two clusters as the average distance between objects from the first cluster and objects from the second cluster. Averaging is performed over all pairs (x, y) of objects, where x is an object from the first cluster and y is an object from the second cluster.

The average linkage function is expressed as follows:

$$D(X,Y) = \frac{1}{N_X * N_Y} \sum_{i=1}^{N_X} \sum_{j=1}^{N_Y} d(x_i, y_i); \quad x_i \in X, y_i \in Y \quad (2)$$

where *d(x, y)* is the distance between objects $x \in X$ and $y \in Y$; *X* and *Y* are two sets of objects (clusters), and N_X and N_Y are the numbers of objects in clusters *X* and *Y*, respectively. Average-link clustering is less sensitive to outliers than complete-link clustering, and less likely to form long chains than single-link clustering. This method is also known as the 'unweighted pair-group method using arithmetic averages' (UPGMA), and is widely used in ecology (see Boesch

1977, McGarigal et al. 2000). This method is a space-conserving strategy that introduces little distortion to the relationships expressed in the similarity matrix (Boesch 1977).

The Sørenson (e.g. 'Dice', 'Bray-Curtis', 'Czekanowski') measure is an index in which joint absences are excluded from consideration, and matches are weighted double. The Sørenson measure has been found more robust in ecological studies (Beals 1973, Field et al. 1982, Faith et al. 1987). It is commonly used in studies of fish assemblages (e.g., Mueter & Norcross 2000, Gomes et al. 2001, Williams and Ralston 2002, Shertzer & Williams 2008, Shertzer et al. 2009).

Overall, two life history and 24 fishery-data clusters were generated. For each of the six input datasets (e.g., CLL, CVL, RFOP, HBS, MRFSS, and BLL), a dimension reduction and a Ward's cluster were generated on root-root transformed landings, and a dimension reduction and a UPGMA cluster were generated on presence-absence. Dendrograms were generated for each cluster, based upon the agglomeration schedule. The dendrogram is read from left to right, with vertical lines indicating joined clusters. The position of the line on the scale indicates the distance at which clusters are joined. In SPSS, observed distances are rescaled to fall into the range of 1 to 25; the ratio of the rescaled distances within the dendrogram is the same as the ratio of the original distances. In SAS, Proc TREE was used to plot the dimension reductions with the proportion of variability explained as the height variable. Species joined closer to the left of the dendrogram would be considered more associated.

Nodal Analysis, Correlation, and Weighted Mean Cluster Association

As the CVL dataset high relatively high data resolution and high species richness, it was selected for further sensitivity analyses. Percent landings by species by logbook statistical reporting area were tabulated for the CVL, then sorted by the CVL presence-absence dendrogram. This nodal analysis facilitated a more detailed investigation into how the distribution of the stock impacted the overall cluster output.

Pearson correlation matrices were generated for the six fisheries input datasets. The table resulting from the co-occurrence analysis was subsequently sorted by columns according to the dendrogram from the commercial vertical line binary cluster output, and by rows according to the dendrogram from the MRFSS binary cluster output. The CVL dataset was selected due to its high species richness, and the MRFSS dataset was selected because it represented the most contrasting sector. The cells were next conditionally formatted to facilitate visual identification of the dense cells or 'nodes' within the data matrix where groups of species and groups of collections coincide between the two fisheries clusters and also co-occur with high frequency between species (Williams and Lambert 1961, Lambert and Williams 1962). This nodal analysis was used to identify species clusters that were often caught together, and also to suggest cluster assignment for rare species by providing a visual reference for vulnerability and co-occurrence with more ubiquitous or heavily-exploited species.

A weighted mean cluster association index was developed to synthesize results across the two life history and 24 fishery-data clusters (see Appendicx: Figs. A1-A26). The goal of the method was to provide a quantitative measure of cluster association across multiple dendrograms. Figure 1 illustrates a hypothetical cluster and cluster association table. The cluster association matrix for each dendrogram was completed on a species by species basis. For a given species on row *r*, the association level (α) with species in column *c* was computed as:

$$\alpha_{r\rightarrow c} = \frac{1}{\sum \eta_r} \quad , \tag{6}$$

where η is the number of species lower than the species on row *r* on the branches of the dendrogram. For example, species D and E are both below species F on the branch; thus $\alpha_{F\rightarrow D} = 0.5$ and $\alpha_{F\rightarrow E} = 0.5$ in the association matrix.

Unique cluster association matrices were assembled for each of the 26 dendrograms, and a weighted mean cluster association index matrix was computed. For a given species on row *r*, the weighted mean association level ($\overline{\alpha_{r\rightarrow c}}$) with species in column *c* was computed as:

$$\overline{\alpha_{r\rightarrow c}} = \frac{\sum_{D=1}^{6}\left(\omega_D \sum_{m=1}^{4} \alpha_{Dm(r\rightarrow c)}\right)}{\sum_{D=1}^{6}\sum_{m=1}^{4} \omega_D}, \tag{7}$$

where D is the dataset under examination, m is the clustering method, and w_D is the weighting term for the dataset. Weighting terms were computed by dataset, and were based upon the proportional representation of species within bins, and were scaled to 1 as a proportion of the maximum representation of that species across the 7 datasets, with life history given the maximal default value of 1 (Table 5). For example, if a species appeared in 80% of bins in the CLL and 40% of bins in the other datasets, its weighting term would be 1.0 for CLL (e.g., ω_{CLL}=1.0) and 0.5 for the other datasets. This weighted mean approach was employed for two reasons: (1) clusters are generally considered more reliable for species that frequently appear in the bins (Koch 1987, Mueter and Norcross 2000), and (2) management measures upon a species complex would typically be expected to have a higher proportional impact upon the sector that encounters the species most frequently. A sensitivity run was performed with life history removed from consideration (see Appendix).

Maps of Stock Distributions

The RFOP and NMFS-BLL survey provide spatially-explicit information regarding encounters with managed species in the Gulf of Mexico. These datasets were imported into ArcGIS (ESRI Inc., Redlands, CA) and displayed for presence-absence on bathymetric maps of the Gulf of Mexico. Trends in species distributions were used to explain inconsistencies between cluster analyses and to evaluate the MSRA '[similar] geographic distribution' requirement for stock complexes. Some points were removed to protect confidentiality of the RFOP dataset.

Results

Life History and Landings Data

Table 1 provides life history parameters for managed Gulf reef fish species. It should be noted that life history may be influenced by time (Shertzer et al. 2009), geography, habitat (Hoss & Engel 1996), exploitation (Hughes 1994), and climate (Holbrook et al. 1997); therefore these point estimates for species may not accurately express the life history dynamics of the unexploited population or of all stock subpopulations. Additionally, life history data may be less reliable for data-poor species, lending uncertainty to the resultant clusters. The data in Table 1 are clustered in Figure 2.

Table 2 provides ranges for depth of occurrence for managed species. For visualization purposes, species were placed into 'shallow' (yellow), 'mid' (pink), 'mid/deep' (pink/blue), and 'deep-water' (blue) groups, based upon median depth of occurrence. Red grouper and gag grouper have a broader depth range of occurrence than other 'shallow-water' groupers (Table 2). Banded rudderfish and almaco jack have a more constricted depth range than greater amberjack (Table 2). Red snapper, silk snapper, blackfin snapper, vermilion snapper, lane snapper, wenchman, and gray triggerfish all occur in mid-to-deep water (Table 2). Blueline tilefish and speckled hind have a shallower range than the other 'deep-water' groupers and tilefish (Table 2).

Dimension Reduction and Hierarchical Cluster Analyses

In general, dimension reduction and hierarchical cluster analysis outputs should be considered more reliable for species that are more prevalent in the input data matrices (Table 3). For example, shallow water grouper, deep-water grouper, and tilefish were well-represented in the CLL matrix. Species diversity refers to the variety of living species within a geographic area. It may be measured by species richness; the number of species within a particular sample, and species evenness; the evenness in the number of each species encountered in the sample. Of the six datasets, the RFOP and CVL had the highest number of species, but CLL had the most balanced representation among its species (Table 4). CLL bins were dominated by shallow- and deep-water grouper (Table 3). CVL bins were dominated by shallow-water grouper, greater amberjack, and mid-water snapper and triggerfish (Table 3). RFOP bins were dominated by red grouper, red snapper, gag, and vermilion snapper (Table 3). HBS and MRFSS bins were dominated by shallow-water grouper, greater amberjack, gray snapper, sand perch, mid-water snapper and triggerfish (Table 3). BLL survey bins were dominated by red snapper, red grouper, yellowedge grouper, and golden tilefish (Table 3). The high species richness observed in the CVL and RFOP are probably attributable to their broad depth ranges covered and high levels of effort.

The NMFS-BLL survey was the only fishery-independent dataset examined. Unfortunately, the selectivity of the longline gear led to low encounter rates with most reef fish species (Table 4). Only red snapper, red grouper, golden tilefish, and yellowedge grouper were encountered in >5% of sets. It is noteworthy that blueline tilefish were landed on both sets landing queen snapper. Similarly, golden tilefish was the only species landed on the only set landing a goldface tilefish. Red snapper, yellowedge grouper, warsaw grouper, and golden tilefish were all landed on sets landing wenchman.

Many species had much higher encounters in one dataset relative to the others (Table 3). The CLL fishery records were dominated by red grouper, yellowedge grouper, gag, golden tilefish, and snowy grouper. The CVL reported predominantly red snapper, vermilion snapper, red grouper, and gag. The RFOP reported predominantly red grouper, red snapper, and vermilion snapper landings. The HBS reported predominantly vermilion snapper, red snapper, gray triggerfish, and lane snapper landings. MRFSS reported predominantly red snapper and gray snapper. The BLL survey reported predominantly red snapper, red grouper, yellowedge grouper, and golden tilefish. In general, landings of goldface tilefish, yellowmouth grouper, hogfish, cubera snapper, dog snapper, anchor tilefish, schoolmaster, Nassau grouper, blackline tilefish, and mahogany snapper were extremely low, suggesting potential issues for clustering associated with rare species.

Not surprisingly, a hierarchical cluster analysis of the life history and depth of occurrence parameters in Tables 1 and 2 showed clustering by genus and depth of occurrence, although maximum size appeared to be the dominant factor (Figure 2). This is perhaps because maximum size was captured by L_{inf} and W_{inf}, and was also probably correlated to a_{λ}, l_m, a_m, and depth of occurrence.

A cursory examination of Tables 1 and 2 and Figure 2 supports many general trends observed in fisheries. Species of the same genus often exhibit similar growth patterns. Larger organisms tend to live longer and grow more slowly (e.g., ‘K-selected’ species), as do organisms that live in deeper water. Many species live up to 25-30 years, and some live to be older than 50.

Cluster analyses of Gulf CLL landings were unable to assign many shallow-water species to meaningful clusters because reef fish bottom longline fishing is prohibited in <20 fathoms; therefore landings of many of these species are extremely rare (Figures 3-4, also Table 2). Major clusters were formed by ‘shallow-water’, ‘mid-water’, and ‘deep-water’ complexes. The most apparent cluster was formed by the four dominant ‘shallow-water’ grouper species (e.g., red and black grouper, gag, and scamp). The relative lack of separation between black and gag in this cluster originated from the adjustment of the landings data for misidentification, which inflated the co-occurrence of these species. Within the ‘deep-water’ group, golden tilefish was somewhat distinct, and the deeper-water snowy grouper and yellowedge grouper were separated from the shallower-occurring blueline tilefish and speckled hind (Figure 4). Within the ‘mid-water’ group, gray triggerfish and vermilion snapper were often caught together in high numbers. Queen snapper and wenchman both clustered with ‘deep-water’ grouper and tilefish species (Figure 3).

Cluster analyses of Gulf commercial vertical line landings (Figures 5-6) provided similar results to the commercial longline. Both approaches produced clusters of ‘shallow-water’ grouper (red and black grouper, and gag), with scamp clustering with other ‘shallow-water’ grouper in Figure 6 and with ‘mid-water’ snapper in Figure 5. Both Figures 5 and 6 contain ‘mid-water’ complexes (silk and blackfin snapper; gray triggerfish with vermilion, red and lane snapper). Clusters for 'deep-water' (yellowedge, snowy, and warsaw grouper) and 'mid-water' species were less separated for the vertical line fishery as compared to the longline, perhaps due to shallower average operating depths (mean = 289 ft LL, 164 ft VL) and less selective gears. The jack species (greater amberjack, almaco jack, banded rudderfish, and lesser amberjack) clustered with (Figure 5) or nearby each other (Figure 6). As with the commercial longline clusters (Figures 3-4), placement of 'shallow-water' snapper species was less intuitive. Gray snapper clustered with the 'shallow-water' grouper species (Figures 5-6). Dog snapper and schoolmaster clustered together, as did mutton snapper, yellowtail snapper, and hogfish (Figures 5-6). Speckled hind, queen snapper and wenchman all clustered with 'deep-water' grouper and tilefish species (Figure 5). Geographic differences in the distribution of landings by the CVL sector explain many of the patterns observed in Figures 5 and 6. For example, mutton snapper, yellowtail snapper, and hogfish were all most frequently landed in the Florida Keys (Figure 7).

As the RFOP represents an aggregated, high-resolution sub-sample of the CLL and CVL datasets, it is not surprising that many of the trends observed in their clusters are repeated in the RFOP cluster (Figure 8). For example, 'deep-water' grouper, snapper and tilefish cluster together (e.g., yellowedge grouper, blueline tilefish, snowy grouper, speckled hind, anchor tilefish, queen snapper, and goldface tilefish). Red snapper and lane snapper cluster together, as do scamp and gag, almaco jack and greater amberjack (Figure 8). Additional clusters were formed by the hinds (e.g., red hind and rock hind), as well as by mutton and cubera snapper. It should also be noted that a cluster was formed between red grouper and vermilion snapper, and that sand perch clustered with scamp and gag.

Cluster analysis of species presence-absence in Gulf HBS landings (Figures 9-10) provided similar results to the CLL and CVL. Clusters of red grouper and gag (Figure 9-10) along with scamp and gray snapper (Figure 10) were formed. 'Mid-water' species (gray triggerfish with vermilion, red and lane snapper), and 'deep-water' species (yellowedge and snowy grouper) tended to cluster together. Greater amberjack and almaco jack clustered with each other (Figures 9-10). Dog snapper and silk snapper also clustered (Figures 9-10). More tropical species such as black grouper and mutton snapper (Figures 9-10), and yellowtail snapper (Figure 10) also clustered. Misidentification issues may have led to the clustering of yellowedge, yellowfin, and yellowmouth grouper in Figure 10 (see SEDAR-22-DW-13 2010).

Cluster analysis of species presence-absence in MRFSS-reported landings (Figure 11) identified a few apparent groups. Of the 'deep-water' species, warsaw grouper and snowy grouper clustered, as did yellowedge grouper and golden tilefish (Figure 11). A 'mid-water' group comprised of gray triggerfish, red snapper, lane snapper, vermilion snapper, scamp, banded rudderfish, greater amberjack, misty grouper, and speckled hind was also identified (Figure 11). As with other analyses, gag and red grouper clustered strongly, with gray snapper and black grouper nearby (Figure 11). Yellowtail snapper and mutton snapper also clustered together (Figure 11).

Cluster analysis of species presence-absence in the NMFS-BLL survey identified a few apparent groups (Figure 12). Mutton snapper grouped strongly with gray snapper (Figure 12). Red grouper and gag again clustered tightly (Figure 12). Two 'deep-water complexes' were identified; one containing blueline tilefish, speckled hind, snowy grouper, and queen snapper; and a second containing yellowedge grouper, golden tilefish, warsaw grouper, and wenchman (Figure 12). Red snapper was also loosely associated with this second 'deep-water' complex.

Nodal Analysis and Correlation

A nodal analysis of median Pearson correlation values aggregated across the 6 fishery datasets provided additional validation of observed clusters along with guidance in the placement of rare species into complexes (Figure 13). Apparent 'nodes' were formed by 'mid-water' snapper species and jacks, 'deep-water' snapper species and tilefish, 'deep-water' grouper, 'shallow-water' snapper and grouper (Figure 13). High median correlation values are noted between almaco jack and banded rudderfish, queen snapper with blueline tilefish and snowy grouper, between blackfin and silk snapper, anchor tilefish with blueline tilefish and snowy grouper, blackline tilefish and yellowedge grouper, cubera snapper and mutton snapper, dog snapper and schoolmaster, goldface tilefish with misty grouper and rock hind, red hind and rock hind, and wenchman with warsaw and yellowedge grouper (Figure 13).

The weighted mean cluster association index matrix (Table 6) provided a quantitative approach to synthesizing information contained in the 24 unique cluster analyses performed (see Appendix). This matrix was used to determine the top five most associated species with each managed species in the Gulf (Table 7). The results presented in Table 7 are explored further in the Discussion.

Maps of Stock Distributions

Maps of the distribution of observed NMFS-BLL and RFOP interactions with managed Gulf species provided insight into the outcomes of the cluster analyses described above. Figure 14A depicts the distribution of 'deep-water' snapper and grouper stocks. The broad, overlapping distributions of snowy and yellowedge grouper help explain the consistency observed in the clustering of these stocks across analyses. The broader depth distributions of speckled hind, warsaw grouper, and wenchman are also apparent, and probably explains the occasional clustering of these stocks with 'mid-water' stocks. Speckled hind was most commonly encountered off West Florida. Queen snapper was rarely encountered, but co-occurred with snowy grouper when observed.

Figure 14B depicts the distribution of tilefish stocks. Golden tilefish were encountered in the deepest waters, and was broadly distributed across the Gulf. By contrast, blueline tilefish co-occured with golden tilefish off Florida, but also were also encountered in shallower waters. Anchor, blackline, and goldface tilefish were all very rare, but were observed co-occurring with both blueline and golden tilefish.

Figure 15A depicts the distribution of jack stocks, which were encountered throughout the Gulf, but less frequently off Texas. Greater amberjack encounters were broadly distributed, overlapping all the other species and extending into much deeper waters off the West Florida coast. Lesser amberjack and almaco jack have overlapping distributions. Banded rudderfish were less commonly encountered outside of Florida.

Figure 15B depicts the distribution of 'mid-water' snapper and triggerfish stocks. Of these, the most commonly encountered were red snapper and vermilion snapper, which appeared ubiquitously throughout the Gulf at a broad range of depths. Red snapper co-occurred with vermilion but also appeared inshore of the vermilion snapper distribution. Silk snapper were rarely encountered, but occurred on the deeper portion of the red and vermilion snapper distributions. Gray triggerfish and lane snapper co-occurred with red and vermilion snapper, with gray triggerfish most common off West Florida and the Panhandle, and lane snapper most common off West Florida and Louisiana.

Figure 16A depicts the distribution of 'shallow-water' grouper stocks. The bulk of 'shallow-water' grouper encounters were with red grouper and gag, which were heavily concentrated off the West Florida coast over a broad range of depths. By contrast, scamp occurred predominantly along the deeper portion of the red grouper and gag distribution in West Florida, and appeared ubiquitously distributed throughout the Gulf, typically at depths between 50-180 fathoms. The tendency of scamp to occasionally cluster with 'mid-water' species was probably due to its high concentration off the coast of Louisiana, where large fisheries exist for almaco jack; red and vermilion snapper, other 'shallow-water' grouper species are less common, and longline fishing is prohibited within 50 fathoms. Other trends revealed by Figure 16A include: black grouper were most commonly encountered off southwest Florida, red hind and rock hind occurred on the inshore portion of the red grouper and gag distribution, and yellowmouth grouper co-occurred with red grouper and scamp.

Figure 16B depicts the distribution of 'shallow-water' snapper stocks. Gray snapper was most commonly encountered in shallow to mid-depth waters from central Florida to the Big Bend, with some landings off Louisiana and Texas. Cubera, dog, mutton, and yellowtail snapper were most commonly encountered off southwest Florida.

Discussion

The MSRA requires fishery management plans to "establish a mechanism for specifying annual catch limits…at a level such that overfishing does not occur in the fishery" (MSRA §303(a)(15)). Traditionally, a formal stock assessment, such as those conducted by the SEDAR process, will specify an overfishing limit (OFL) corresponding with yield at the maximum fishing mortality threshold (MFMT) or the fishing mortality rate that will allow the stock to rebuild by a target year ($F_{rebuild}$). Next, the Council's Scientific and Statistical Committee (SSC) sets an acceptable biological catch level (ABC) that cannot be set higher than OFL, as it accounts for scientific uncertainty in the estimate of OFL. Finally, an ACL is set by the Council. The ACL is the level of

annual catch of the stock or stock complex that serves as the basis for invoking AMs. The ACL cannot be set higher than ABC, as it accounts for management uncertainty in ABC.
The Gulf Council currently has ACLs specified for red and gag grouper, the commercial shallow-water grouper complex, gray triggerfish, and greater amberjack. Additional ACLs may be specified for black grouper, yellowedge grouper, golden tilefish, and possibly blueline tilefish following SEDAR assessments in 2010. By 2011, the Gulf Council will need to establish ACLs for numerous unassessed reef fish stocks. Setting stock-specific ACLs for many of these stocks may be unrealistic due to inadequate data to determine stock status relative to established status determination criteria (SDC). Many of these stocks suffer from issues with species identification (i.e., jacks, anchor; blackline; and goldface tilefish) and/or extreme fluctuations in relative landings through time due to rarity or lack of targeted fishing effort (i.e., schoolmaster and mahogany snapper). Thus, specifying a single-species ACL based on average catch for these stocks might result in periodic overages that would require AM implementation, creating additional burdens on science and enforcement. Grouping unassessed stocks into complexes may help avoid implementing AMs for species whose landings fluctuate due to rarity or species identification issues.

The primary goal of a stock complex in the context of the Gulf Comprehensive ACL/AM Amendment is to determine how to best aggregate unassessed stocks in order to establish an ACL. Unfortunately, unassessed stocks are often rarely caught, and are difficult to cluster. Additionally, using assessed stocks as indicators may be the only practical way to set an ACL, but assessed stocks may not be the most vulnerable stocks in the complex. In fact, examination of Table 7 suggests that only the shallow-water grouper complex has an indicator stock (gag) that is the most vulnerable member of the complex per PSA scores. Using an assessed stock as an indicator may not facilitate detection of changes in the status of less abundant or less studied species, and may not prevent overfishing of more vulnerable stocks in the complex (Brown & Parrack 1985, Fahrig 1993, Shertzer & Williams 2008).

Indicator species have been used in management of both terrestrial and marine systems (Simberloff 1998, Zacharias & Roff 2001). The National Standard Guidelines of U.S. Federal fishery management state that where maximum sustainable yield (MSY) cannot be specified for each stock of a mixed-stock fishery, then “MSY may be specified on the basis of one or more species as an indicator for the mixed stock as a whole or for the fishery as a whole” (50 CFR 600.310(c)(1)(iii). An implicit assumption of the use of an indicator species for management is that population trends of the indicator species reflect those of others in the assemblage. As such, assemblages should account for interspecies similarities in the context of biological characteristics, fisheries exploitation patterns, and stock dynamics. Biological assemblages may be defined by similarities in life history, trophic behavior, and geographic distribution. For fisheries management purposes, species that are caught together should be grouped, so that regulations similarly influence all assemblage members. If trends with an indicator species truly represent those of the assemblage as a whole, the catch-per-unit-effort (CPUE) for the indicator species should exhibit synchrony with the CPUE patterns of the other members of the assemblage.

For an assessed stock to be an appropriate indicator stock for a stock complex, assessed stocks and unassessed stocks in the complex should show similar trends in population abundance in response to environmental forcing, fishing pressure, and fisheries management regulations. Unfortunately, it is extremely difficult to separate out these signals without a full benchmark assessment. In a resource-limited environment, niche theory (May & MacArthur 1972, Landres et al. 1988, Leibold 1995) predicts that coexisting species would differ in their life history (e.g., reproductive dynamics, foraging behavior, habitat requirements) and population dynamics (e.g., responses to competition, predation, disease, and environmental variation). If these differences are substantial enough, population trends for one stock may not readily extrapolate to others in the complex (e.g, Niemi et al. 1997, Shaul et al. 2007, Shertzer & Williams 2008). The use of indicator species is not recommended unless supported by strong evidence from the system in question (Landres et al. 1988, Niemi et al. 1997). Even closely related species may have dissimilarities in their population structures and dispersal patterns that lead to different responses to exploitation (Bird et al. 2007).

Fishery-independent data is preferable for inferring patterns of biodiversity (e.g., Jay 1996, Collie et al. 2008), but is extremely limited for the majority of the stocks managed by the Gulf Council. Using fishery-dependent data as a proxy for trends in population abundance would introduce several layers of bias (e.g. gear, spatial, temporal, depth) into any evaluation of indices of abundance. These biases might generate spurious correlations that would be difficult to separate out from actual population trends.

A comprehensive understanding of concurrent stock vulnerabilities to various fisheries is critical to achieve the goal of ACL/AM management. The myriad of statistical approaches explored in this study tell a relatively consistent story regarding what stocks might be impacted by similar management measures. By considering some fishery and ecosystem variables such as life history, vulnerability, sector, gear, area, and depth fished, these analyses provide insights that may facilitate multispecies or ecosystem-based management.

Of the cluster analysis input variables, depth appeared the most important, with apparent shallow-water, mid-water, and deep-water assemblages frequently appearing in most analyses. A similar approach by Bortone et al. (1979) also found community association was influenced predominantly by depth, and to a lesser extent by substrate, latitude, and season. The species composition of apparent assemblages varied slightly by dataset. Headboat was less likely to catch deep-water stocks because deep-water stocks are farther offshore and not often targeted by limited duration headboat trips. Commercial bottom longline was less likely to catch shallow-water stocks because commercial bottom longline is prohibited within 20 fathoms in the eastern Gulf of Mexico and within 50 fathoms in the western Gulf of Mexico (e.g., west of Cape San Blas, Florida). Subtle spatial trends were also observed in assemblages. For example, in the commercial vertical line sector, mutton snapper, red hind, yellowtail snapper, and hogfish formed a ‘tropical’ assemblage, due to their high landings in the Florida Keys. Genus was also important; for example, snappers and groupers were often separated. This is possibly due to differences in vulnerability to gears and fishing methods as well as differences in geographic and depth distributions. Caution should be taken when interpreting our results, as years of overexploitation may have altered community structure and species composition (Hughes 1994).

Stock complexes for ACL/AM management "may be comprised of: (1) one or more indicator stocks, each of which has SDC and ACLs, and several other stocks; (2) several stocks without an indicator stock, with SDC and an ACL for the complex as a whole; or (3) one of more indicator stocks, each of which has SDC and management objectives, with an ACL for the complex as a whole…" (50 CFR 600.310(b)(8) in 74 FR 3205). These approaches are not mutually exclusive. For example, a broad complex might be formed with an overall ACL, which, if exceeded, would trigger AMs. Within this broader complex, one or several sub-complexes might be designated. Each sub-complex could have an ACL either based on all species in the complex or on one or more indicator species. If this sub-complex ACL were exceeded, AMs might be implemented that impact all or some of the members of the sub-complex. Finally, some sub-complexes might contain only one species, and would require a species-specific ACL.

Setting an ACL for a stock complex containing a highly productive, targeted species might expose less productive, more vulnerable species to overfishing. One approach might be a multi-faceted approach to ACL management: (1) set species-specific ACLs for productive stocks; (2) set sub-complex ACLs for sub-complexes of related, less productive stocks; and (3) set complex ACLs that aggregate the single-species and sub-complex ACLs. This would provide multiple handles of control in the AMs that would help prevent overfishing of all species in the complex. If the single-species ACLs (e.g., '1') were slightly exceeded, AMs would be implemented for that stock without necessarily impacting the stocks in the sub-complex (e.g., '2'), allowing the fishery to obtain optimum yield (OY) for the productive stock. This might be favorable, since most productive stocks in the Gulf are assessed. If the sub-complex ACLs (e.g., '2') were exceeded, AMs would be implemented for the sub-complex without necessarily impacting the most productive stock (e.g., '1'). Finally, if the ACL for the targeted stock were grossly exceeded, the complex ACL (e.g., '3') might also be exceeded, resulting in implementation of AMs for the whole complex. This multi-faceted approach promotes attaining OY for the productive stocks while providing two mechanisms to prevent overfishing of the less productive—often more vulnerable—stocks. Grouping less productive, vulnerable, and/or data-poor stocks into sub-complexes helps mitigate uncertainty in individual landings histories, mitigates issues with species identification, and provides buffers against the unnecessary implementation of AMs. The use of an ACL for an overall complex containing one or more productive stocks plus other less productive stocks from the sub-complex helps protect the sub-complex stocks from overfishing because even if their sub-complex ACL is not exceeded according to the existent data collection program, undetected overfishing of these stocks may be taking place during overharvesting of a productive stock with which they are often incidentally or deliberately harvested.

Although the cluster analyses were based upon vulnerabilities to selective fishing gear, the major controlling factors included season, area, and depth; thus, some aspects of life history were *de facto* included in the analyses. These analyses mostly supported the current 'deep-water grouper' assemblage of yellowedge grouper, snowy grouper, warsaw grouper, speckled hind, and misty grouper (Table 7). Due to their distance from shore and the specialized gears required to capture the 'deep-water' component of these stocks, there was a low relative percentage of encounters of these species in all datasets save CLL and BLL (Table 3). Yellowedge and snowy grouper stocks had extremely high weighted mean cluster association index values and have overlapping geographic distributions (Table 6, Figure 14A). It should be noted that yellowedge grouper is extremely long-lived and highly productive relative to the other members of this complex (Table 3), although its life history is similar (Figure 2). Warsaw grouper is the most vulnerable member of this complex, and was most highly associated with misty and snowy grouper (Table 7). As with speckled hind, there is a substantial inshore fishery for warsaw grouper in addition to the core 'deep-water' component of the stock (Figure 14A). Misty grouper and speckled hind encounters were rare, but were associated other 'deep-water' stocks such as warsaw grouper and various tilefish species (Table 7). This placement is consistent with their depth distributions (Table 2).

A mid-to-deep-water snapper assemblage comprised of blackfin snapper, silk snapper, wenchman, and queen snapper was identified. Hogfish was loosely associated with queen snapper in the life history cluster (Figure 2), but was also associated with a variety of shallow-water grouper and snapper species. Blackfin and silk snapper often clustered strongly together. Queen snapper and wenchman landings were relatively rare, but their depth distributions are consistent with their observed loose associations with each other and other deep-water grouper and tilefish species (Table 2).

Our analyses supported the current 'tilefish' assemblage, although there were moderately high levels of association with several 'deep-water' groupers that suggested management regulations upon stocks in either assemblage might impact stocks in the other (Table 9). The weighted mean cluster association index matrix suggested high levels of association between all the tilefish species (Table 7). Golden tilefish occurs at similar depths as yellowedge grouper and is occasionally caught on the same set, but is less structure-affiliated than the grouper, preferring soft bottom habitats on the upper continental slope (Harris et al. 2001, Sedberry et al. 2006). It clustered with other 'deep-water' species, but was often separated from the other members of the complex (see Figure 4). Blueline tilefish frequently clustered with speckled hind, along with other 'deep-water' stocks (Table 7). Both blueline tilefish and speckled hind have distributions that extend further inshore along with the West Florida shelf than the other 'deep-water' stocks (Figure 14B). Blueline tilefish prefers irregular, rocky bottom from the outer shelf edge to the upper slope (Struhsaker 1969, Ross 1978, Ross and Huntsman 1982, Parker and Mays 1998). Blueline tilefish, snowy grouper, warsaw grouper, speckled hind, yellowedge grouper, and greater amberjack have all been documented to co-occur on the top edge of sinkholes (Reed et al. 2005). Little is known about anchor, blackline, and goldface tilefish; however, they may co-occur and even share burrows with blueline and golden tilefish (Able et al. 1987).

The four managed jack species (e.g., greater amberjack, lesser amberjack, banded rudderfish, and almaco jack), were most frequently encountered by the HBS and CLL sectors (Table 3). In the HBS, almaco jack and greater amberjack clustered tightly with each other (Figures 9-10). In the CLL, no strong associations between jacks were observed (Figures 3-4). Data from trained observers in the RFOP suggested a strong association between greater amberjack and almaco jack (Figure 8). A cluster of the CVL data suggested associations between all the jack species (Figure 5). Table 7 suggests high levels of cluster association between the jack species. SEDAR 15 (2009) concluded that lesser amberjack and almaco jack were correctly identified in most instances, but smaller greater amberjack and banded rudderfish were often misidentified. Issues with misidentification might lead to issues computing single-species ACLs for these species unless the rate of misidentification is quantifiable or has been (and remains) constant through time. It is noteworthy that encounters off the West Florida shelf beyond 130 fathoms were almost exclusively greater amberjack; thus, regulatory changes on the 'deep-water' component of any 'Jacks' complex might only impact greater amberjack (Figure 15A). The use of a 'Jacks' complex would mitigate issues with species identification by regulating misidentified species together.

Although there was some overlap with some of the more broadly distributed 'shallow-water' species such as gray snapper, scamp, red grouper, and mutton snapper, several species occurring at moderate depths (e.g., 'mid-water') consistently clustered together: gray triggerfish, vermilion; red; and lane snapper (Table 7). These species were most consistently encountered in the HBS data (Table 3). Clusters of the HBS data suggested a strong association between all four species. Among the snappers, the strongest association was between red and vermilion snapper (Figures 9-10). Although gray triggerfish clustered with 'mid-water' snapper species, it may be desirable to manage it separately due to differences in life history (Table 1). Red and vermilion snapper are both highly productive stocks and are ubiquitously distributed throughout the Gulf (Figure 15B).

Our analyses partially supported the current 'shallow-water grouper complex' of red; black; yellowmouth; and yellowfin grouper, red and rock hind, scamp, and gag (Table 7). Red grouper and gag consistently clustered together, and were often clustered with scamp and black grouper (Table 7). Black grouper and gag were highly associated in the CLL and CVL clusters, but this is likely an artifact of the misidentification adjustment applied, which ensures that some percentage of black grouper will be caught on every trip landing gag and vice versa. These species were separated in the HBS clusters (Figures 9-10). Although these species overlap in their distributions and are vulnerable to the same gears and fishing techniques, the core of the black grouper distribution is focused in the Florida Keys, whereas the gag is more ubiquitously distributed across the eastern Gulf (Figure 16A). Red hind and rock hind and yellowfin and yellowmouth grouper were rarely encountered, but had high weighted mean cluster association index values (Table 7). An assessed species (gag) is the most vulnerable species in the complex per PSA score (see Table 9). Currently, dwarf sand perch and sand perch are designated as 'Research Only' species in the Gulf Reef Fish FMP. These species could be designated as Ecosystem Component species or removed from the FMU, in which case no ACL would need to be specified.

The clustering for 'shallow-water' snappers (e.g., gray, mutton, yellowtail, cubera, dog, mahogany, and schoolmaster snapper) was reasonably tight (Table 7). These stocks are primarily distributed off the West Florida shelf (Figure 16B). Of these, gray, mutton, and yellowtail snapper are abundant, but encounters with other 'shallow-water' snapper species are rare (Table 3). Gray snapper was most commonly encountered in MRFSS, and formed a somewhat distinct cluster (Table 3, Figure 11). The gray snapper has a substantial fishery in Florida state waters, especially the Florida Keys, where it co-occurs to some extent with mutton snapper; however, it also has a sizeable fishery on the offshore reefs and oil rigs in the western Gulf of Mexico. This perhaps explains why gray snapper sometimes clustered with 'shallow-water' grouper (e.g., gag and scamp) and 'mid-water' snapper species (e.g., lane and red snapper).

Yellowtail snapper was most common in the CVL dataset, where it clustered with mutton snapper and hogfish. Yellowtail snapper was most highly correlated and associated with dog and mutton snapper (Figure 13, Table 7). Mutton snapper was associated with schoolmaster, yellowtail and gray snapper. Gulf landings of hogfish, mutton snapper, and yellowtail snapper are predominantly concentrated in southwest Florida and the Florida Keys (Figure 16B). The unique fishing techniques used to land yellowtail snapper and hogfish may make them good candidates for species-specific ACLs.

Clustering the rare snapper species was driven primarily through an examination of the nodal analysis and weighted mean cluster association index output (Figure 13, Table 7). Schoolmaster snapper was highly correlated with dog and mutton snapper, and highly associated with mutton, dog, yellowtail, and cubera snapper. Cubera snapper shares a similar life history with mutton snapper (Figure 2). Dog snapper was highly correlated and associated with yellowtail snapper (Table 7). Mahogany snapper were only recorded in the CVL dataset, and every trip landing a mahogany snapper also landed a gray snapper. Mahogany snapper was associated with cubera snapper (Table 7).

ACL management using stock complexes may be the best management option when formal stock assessments are unavailable, and the data requirements (e.g., stable catch for several years, reliable estimate of natural mortality) of other methods such as Depletion-Adjusted Average Catch (MacCall 2007) are not met. Using stock complexes for ACL/AM management reduces management burden for quota monitoring, and may help mitigate the impacts of uncertainty in landings data or species identification by pooling data-poor species. Additionally, the unnecessary implementation of AMs may be avoided by setting ACLs for complexes rather than rarely-encountered single species.

Although ecosystem-based or single-species ACLs may be desirable for many species, stock complexes may provide a temporary solution for setting ACLs for species lacking stock assessments. In establishing stock complexes, managers should consider the geographic and depth distribution of species, life history characteristics, exploitation patterns, and vulnerabilities. Managers should then adapt their management strategies as new information and understanding of species linkages and complexes arises. This will allow for proactive management that accounts for ecosystem-based management considerations such as temporal fluctuations in stock abundance due to environmental forcing or multispecies interactions, as well as comprehensive assessments of the impacts of regulations on associated species. For this approach to succeed, data collection will need to be targeted at gaining a high-resolution map of the biogeographic distribution of fish stocks and the spatial distribution of fishing effort, as well as improved estimation of life history parameters and trophic linkages between species. This approach is especially relevant given that community structure may change through time (Shertzer et al. 2009) due to heavy exploitation (Hughes 1994, McClenachan 2009), invasive species (Albins & Hixon 2008), habitat degradation (Hoss & Engel 1996, Anderson et al. 2008), and climate change (Holbrook et al. 1997, Attrill & Power 2002, Genner et al. 2004, Perry et al. 2005, Collie et al. 2008). Similarly, the structure of stock complexes may change through time if the fishery begins operating more heavily in different areas, using different gears, or targeting different species.

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Table 1. Life history parameters for managed reef fish species in Gulf of Mexico (see Appendix for references).

Common Name	Species Name	a_λ	K	L_{inf}	a_0	W_{inf}	L_m	a_m	REF
Almaco Jack	*Seriola rivoliana*	22.2	0.13	163.3	-0.83	6	811	53	19
Anchor Tilefish	*Caulolatilus intermedius*	16.0	0.18	62.2	0.77	11	341	42	16
Banded Rudderfish	*Seriola zonata*	10.3	0.28	77.5	-0.46	5	415	27	19
Black Grouper	*Mycteroperca bonaci*	33.0	0.14	133.4	-0.90	41	826	62	13
Blackfin Snapper	*Lutjanus buccanella*	8.2	0.35	62.0	-0.39	14	250	21	19
Blackline Tilefish	*Caulolatilus cyanops*	16.0	0.18	62.2	0.77	11	341	42	16
Blueline Tilefish (female)	*Caulolatilus microps*	32.0	0.15	86.7	-2.09	6	338	36	17, 18
Blueline Tilefish (male)	*Caulolatilus microps*	32.0	0.09	122.2	-1.84	17	363	36	17, 18
Cubera Snapper	*Lutjanus cyanopterus*	22.1	0.13	105.0	-0.94	57	546	55	19
Dog Snapper	*Lutjanus jocu*	12.0	0.10	85.4	-1.28	10	300	74	32/19
Dwarf Sand Perch	*Diplectrum bivittatum*	7.0	0.41	26.3	-0.42	1	157	20	16, 20
Gag	*Mycteroperca microlepis*	31.0	0.14	130.0	-0.39	37	656	43	11, 19
Golden Tilefish (female)	*Lopholatilus chamaeleonticeps*	50.0	0.13	112.0	-4.56	23	613	60	23
Golden Tilefish (male)	*Lopholatilus chamaeleonticeps*	50.0	0.15	141.5	-1.46	50	767	66	22
Goldface Tilefish	*Caulolatilus chrysops*	16.0	0.18	62.2	0.77	11	341	42	16
Goliath Grouper	*Epinephelus itajara*	37.0	0.13	201.0	-0.78	455	1100	48	3, 19
Gray Snapper	*Lutjanus griseus*	26.0	0.17	559.0	-2.23	5	233	24	33
Gray Triggerfish	*Balistes capriscus*	12.0	0.38	46.6	-0.33	6	142	12	5, 19
Greater Amberjack	*Seriola dumerilli*	17.0	0.23	111.0	-0.79	81	788	27	6, 19, 21
Hogfish	*Lachnolaimus maximus*	23.0	0.13	85.1	-0.45	9	169	24	24, 35
Lane Snapper	*Lutjanus syngaris*	10.0	0.10	61.8	-1.73	3	205	12	32
Lesser Amberjack	*Seriola fasciata*	10.2	0.28	69.9	-0.47	5	379	27	16
Mahogany Snapper	*Lutjanus mahogoni*	28.5	0.10	49.9	-1.51	13	130	55	19
Misty Grouper	*Epinephelus mystacinus*	41.0	0.07	163.3	-1.58	107	811	98	19
Mutton Snapper	*Lutjanus analis*	14.5	0.16	86.9	-0.94	9	330	37	9
Nassau Grouper	*Epinephelus striatus*	29.0	0.13	76.0	-1.12	27	400	60	31
Queen Snapper	*Etelis oculatus*	30.0	0.61	103.0	-0.19	53	536	12	19
Red Grouper	*Epinephelus morio*	29.0	0.13	88.4	-0.19	23	572	36	12, 19
Red Hind	*Epinephelus guttatus*	11.0	0.09	47.1	-0.75	25	266	41	25
Red Snapper	*Lutjanus campechanus*	57.0	0.35	100.0	-0.50	23	230	43	8
Rock Hind	*Epinephelus adscensionis*	12.0	0.16	60.1	-2.50	4	280	28	25
Sand Perch	*Diplectrum formosum*	2.0	0.27	27.7	0.11	1	165	72	16, 15
Scamp	*Mycteroperca phenax*	30.0	0.09	108.0	-1.36	13	353	15	26
Schoolmaster	*Lutjanus apodus*	12.0	0.18	57.0	-0.45	3	148	24	32/19
Silk Snapper	*Lutjnaus vivanus*	29.0	0.10	81.2	-1.32	8	434	63	19
Snowy Grouper	*Epinephelus niveatus*	28.0	0.09	132.0	-1.01	30	670	60	2, 19
Speckled Hind	*Epinephelus drummondhayi*	25.0	0.13	110.0	-0.98	30	503	53	29
Vermilion Snapper	*Rhomboplites aurorubens*	26.0	0.12	50.6	-3.09	3	320	24	10, 19
Warsaw Grouper	*Epinephelus nigritus*	41.0	0.14	239.0	0.12	190	810	49	30
Wenchman	*Pristipomoides aquilonaris*	11.0	0.27	58.1	-0.52	5	321	29	16
Yellowedge Grouper	*Epinephelus flavolimbatus*	85.0	0.06	100.5	-4.75	19	815	264	20
Yellowfin Grouper	*Mycteroperca venenosa*	15.0	0.09	89.5	-0.75	19	540	44	7, 19
Yellowmouth Grouper	*Mycteroperca interstitalis*	28.0	0.06	85.4	-2.21	9	453	36	19
Yellowtail Snapper	*Ocyurus chrysurus*	17.0	0.17	60.0	-0.53	4	224	75	4, 34

Note: a_λ denotes maximum age in years, K denotes Brody growth coefficient, L_{inf} denotes asymptotic length coefficient for von Bertalanffy growth equation, $a_\circ$ denotes theoretical age at length zero scaling parameter for von Bertlanffy growth equation, W_{inf} denotes theoretical maximum weight in kilograms, L_m denotes length (in mm) at maturity, a_m denotes age (in months) at maturity.

Table 2. Depth of occurrence for managed reef fish species in Gulf of Mexico, sorted by median depth (Source: Fishbase). Colors denote categorizations of 'shallow' (yellow), 'mid' (pink), 'mid/deep' (blue/pink), and 'deep-water' (blue).

Depth (m)	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420+
hogfish	■	■													
black grouper	■	■													
dog snapper	■	■													
schoolmaster	■	■	■												
cubera snapper		■													
sand perch	■	■	■												
Nassau grouper	■	■	■	■											
mahogany snapper	■	■	■	■											
goliath grouper	■	■	■	■											
dwarf sand perch	■	■	■	■											
red hind	■	■	■	■											
mutton snapper		■	■	■											
scamp		■	■	■											
rock hind	■	■	■	■	■										
yellowfin grouper	■	■	■	■	■										
yellowmouth grouper	■	■	■	■	■	■									
banded rudderfish		■	■	■	■										
almaco jack	■	■	■	■	■	■									
yellowtail snapper	■	■	■	■	■	■	■								
gray snapper	■	■	■	■	■	■	■								
lesser amberjack			■	■	■										
gag		■	■	■	■	■									
red snapper	■	■	■	■	■	■	■								
speckled hind		■	■	■	■	■	■								
blackfin snapper		■	■	■	■	■	■								
blueline tilefish		■	■	■	■	■	■	■							
goldface tilefish				■	■	■	■	■	■						
silk snapper				■	■	■	■	■	■						
anchor tilefish			■	■	■	■	■	■	■	■					
red grouper	■	■	■	■	■	■	■	■	■	■	■	■			
yellowedge grouper			■	■	■	■	■	■	■	■					
vermilion snapper		■	■	■	■	■	■	■	■	■	■				
gray triggerfish	■	■	■	■	■	■	■	■	■	■	■	■	■		
greater amberjack	■	■	■	■	■	■	■	■	■	■	■	■	■		
wenchman		■	■	■	■	■	■	■	■	■	■	■	■		
black snapper				■	■	■	■	■	■	■	■				
lane snapper	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
misty grouper					■	■	■	■	■	■	■	■	■	■	
blackline tilefish			■	■	■	■	■	■	■	■	■	■	■	■	■
queen snapper				■	■	■	■	■	■	■	■	■	■	■	■
snowy grouper		■	■	■	■	■	■	■	■	■	■	■	■	■	■
warsaw grouper			■	■	■	■	■	■	■	■	■	■	■	■	■
golden tilefish				■	■	■	■	■	■	■	■	■	■	■	■

Table 3. Percent of commercial bottom longline (CLL), vertical line (CVL), reef fish observer (RFOP), headboat (HBS), MRFSS, and NMFS Bottom Longline (BLL) aggregated records in Gulf of Mexico with landings of species.

COMMON NAME	CLL	CVL	RFOP	HBS	MRFSS	BLL	MEAN	MEDIAN
red grouper	54%	44%	57%	59%	29%	28%	**52%**	**55%**
gag	50%	44%	17%	70%	75%	4%	**49%**	**63%**
red snapper	16%	58%	43%	63%	60%	33%	**45%**	**41%**
gray snapper	26%	42%	6%	59%	84%	1%	**35%**	**31%**
gray triggerfish	17%	45%	6%	73%	42%	0%	**32%**	**24%**
vermilion snapper	13%	54%	20%	61%	30%	1%	**28%**	**25%**
sand perch	0%	0%	1%	27%	30%	0%	**25%**	**30%**
scamp	52%	50%	12%	49%	18%	2%	**25%**	**23%**
lane snapper	10%	32%	5%	60%	43%	0%	**24%**	**14%**
black grouper	28%	27%	1%	9%	5%	0%	**23%**	**5%**
greater amberjack	29%	32%	6%	43%	31%	2%	**18%**	**18%**
yellowedge grouper	39%	11%	7%	2%	2%	24%	**11%**	**5%**
golden tilefish	25%	3%	2%	0%	0%	14%	**8%**	**8%**
almaco jack	2%	18%	3%	25%	13%	0%	**7%**	**5%**
snowy grouper	34%	12%	4%	6%	3%	3%	**7%**	**3%**
goliath grouper	0%	0%	0%	0%	24%	0%	**6%**	**0%**
yellowtail snapper	4%	10%	0%	16%	4%	0%	**6%**	**4%**
warsaw grouper	13%	12%	1%	14%	7%	3%	**5%**	**5%**
mutton snapper	23%	10%	1%	5%	3%	0%	**5%**	**2%**
blueline tilefish	17%	10%	4%	1%	0%	4%	**5%**	**4%**
banded rudderfish	1%	7%	1%	21%	4%	0%	**4%**	**2%**
speckled hind	19%	6%	3%	6%	0%	1%	**4%**	**2%**
rock hind	0%	0%	0%	16%	2%	0%	**4%**	**2%**
silk snapper	12%	7%	0%	1%	0%	0%	**2%**	**1%**
blackfin snapper	8%	4%	0%	1%	0%	0%	**2%**	**1%**
hogfish	0%	3%	0%	6%	3%	0%	**2%**	**2%**
lesser amberjack	6%	9%	1%	3%	1%	0%	**2%**	**1%**
red hind	2%	4%	0%	4%	2%	0%	**1%**	**1%**
queen snapper	5%	5%	0%	0%	0%	0%	**1%**	**0%**
misty grouper	3%	1%	0%	0%	0%	0%	**1%**	**0%**
dwarf sand perch	0%	0%	0%	0%	0%	1%	**1%**	**1%**
dog snapper	1%	0%	0%	0%	2%	0%	**1%**	**0%**
cubera snapper	1%	0%	0%	2%	0%	0%	**0%**	**0%**
wenchman	0%	0%	0%	0%	0%	1%	**0%**	**0%**
yellowmouth grouper	0%	0%	0%	2%	0%	0%	**0%**	**0%**
Nassau grouper	0%	0%	0%	0%	0%	0%	**0%**	**0%**
yellowfin grouper	1%	1%	0%	1%	0%	0%	**0%**	**0%**
goldface tilefish	0%	0%	0%	0%	0%	0%	**0%**	**0%**
schoolmaster snapper	0%	0%	0%	0%	0%	0%	**0%**	**0%**
anchor tilefish	0%	0%	0%	0%	0%	0%	**0%**	**0%**
blackline tilefish	0%	0%	0%	0%	0%	0%	**0%**	**0%**
mahogany snapper	0%	0%	0%	0%	0%	0%	**0%**	**0%**

Table 4. Species diversity metrics for presence of managed species in the Gulf in binned commercial longline (CLL), vertical line (CVL), reef fish observer (RFOP), headboat (HBS), MRFSS, and NMFS Bottom Longline (BLL) datasets.

%BINS WITH SPECIES	CLL	CVL	RFOP	HBS	MRFSS	NMFSBLL
>0%	**32**	**35**	**35**	**32**	**30**	**24**
>1%	25	24	21	21	23	12
>5%	19	12	9	15	14	4

Table 5. Weighting terms for mean cluster strength matrix.

COMMON NAME	CLL	CVL	HBS	MRFSS	BLL	RFOP	LH
almaco jack	0.54	0.44	0.57	0.59	0.29	0.28	1.00
anchor tilefish	0.50	0.44	0.17	0.70	0.75	0.04	1.00
banded rudderfish	0.16	0.58	0.43	0.63	0.60	0.33	1.00
black grouper	0.26	0.42	0.06	0.59	0.84	0.01	1.00
blackfin snapper	0.17	0.45	0.06	0.73	0.42	0.00	1.00
blackline tilefish	0.13	0.54	0.20	0.61	0.30	0.01	1.00
blueline tilefish	0.00	0.00	0.01	0.27	0.30	0.00	1.00
cubera snapper	0.52	0.50	0.12	0.49	0.18	0.02	1.00
dog snapper	0.10	0.32	0.05	0.60	0.43	0.00	1.00
dwarf sand perch	0.28	0.27	0.01	0.09	0.05	0.00	1.00
gag	0.29	0.32	0.06	0.43	0.31	0.02	1.00
golden tilefish	0.39	0.11	0.07	0.02	0.02	0.24	1.00
goldface tilefish	0.25	0.03	0.02	0.00	0.00	0.14	1.00
goliath grouper	0.02	0.18	0.03	0.25	0.13	0.00	1.00
gray snapper	0.34	0.12	0.04	0.06	0.03	0.03	1.00
gray triggerfish	0.00	0.00	0.00	0.00	0.24	0.00	1.00
greater amberjack	0.04	0.10	0.00	0.16	0.04	0.00	1.00
hogfish	0.13	0.12	0.01	0.14	0.07	0.03	1.00
lane snapper	0.23	0.10	0.01	0.05	0.03	0.00	1.00
lesser amberjack	0.17	0.10	0.04	0.01	0.00	0.04	1.00
mahogany snapper	0.01	0.07	0.01	0.21	0.04	0.00	1.00
misty grouper	0.19	0.06	0.03	0.06	0.00	0.01	1.00
mutton snapper	0.00	0.00	0.00	0.16	0.02	0.00	1.00
Nassau grouper	0.12	0.07	0.00	0.01	0.00	0.00	1.00
queen snapper	0.08	0.04	0.00	0.01	0.00	0.00	1.00
red grouper	0.00	0.03	0.00	0.06	0.03	0.00	1.00
red hind	0.06	0.09	0.01	0.03	0.01	0.00	1.00
red snapper	0.02	0.04	0.00	0.04	0.02	0.00	1.00
rock hind	0.05	0.05	0.00	0.00	0.00	0.00	1.00
sand perch	0.03	0.01	0.00	0.00	0.00	0.00	1.00
scamp	0.00	0.00	0.00	0.00	0.00	0.01	1.00
schoolmaster snapper	0.01	0.00	0.00	0.00	0.02	0.00	1.00
silk snapper	0.01	0.00	0.00	0.02	0.00	0.00	1.00
snowy grouper	0.00	0.00	0.00	0.00	0.00	0.01	1.00
speckled hind	0.00	0.00	0.00	0.02	0.00	0.00	1.00
vermilion snapper	0.00	0.00	0.00	0.00	0.00	0.00	1.00
warsaw grouper	0.01	0.01	0.00	0.01	0.00	0.00	1.00
wenchman	0.00	0.00	0.00	0.00	0.00	0.00	1.00
yellowedge grouper	0.00	0.00	0.00	0.00	0.00	0.00	1.00
yellowfin grouper	0.00	0.00	0.00	0.00	0.00	0.00	1.00
yellowmouth grouper	0.00	0.00	0.00	0.00	0.00	0.00	1.00
yellowtail snapper	0.00	0.00	0.00	0.00	0.00	0.00	1.00

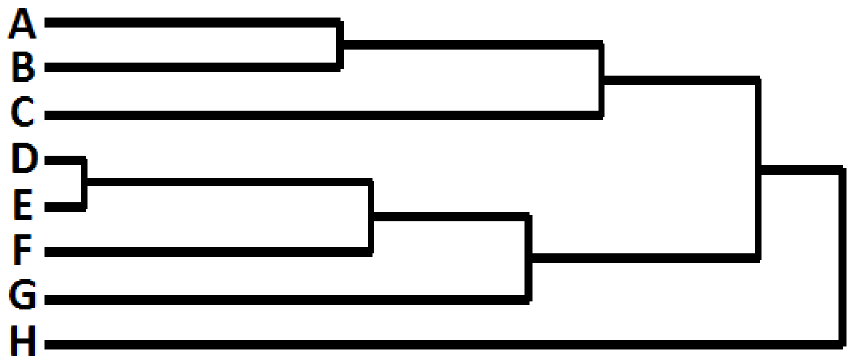
Table 6. Aggregated cluster analysis matrix generated from the 2 LH and 24 CLL, CVL, HBS, MRFSS, NMFS-BLL, and RFOP clusters (see Appendix).

	almaco jack	anchor tilefish	banded rudderfish	black grouper	blackfin snapper	blackline tilefish	blueline tilefish	cubera snapper	dog snapper	dwarf sand perch	gag	golden tilefish	goldface tilefish	goliath grouper	gray snapper	gray triggerfish	greater amberjack	hogfish	lane snapper	lesser amberjack	mahogany snapper	misty grouper	mutton snapper	Nassau grouper	queen snapper	red grouper	red hind	red snapper	rock hind	sand perch	scamp	schoolmaster snapper	silk snapper	snowy grouper	speckled hind	vermilion snapper	warsaw grouper	wenchman	yellowedge grouper	yellowfin grouper	yellowmouth grouper	yellowtail snapper
almaco jack		0.00	0.05	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.28	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.07	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.05	0.00	0.00
anchor tilefish	0.00		0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
banded rudderfish	0.06	0.00		0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.03	0.01	0.01	0.01	0.19	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.13	0.05	0.01	0.01	0.02	0.11	0.02	0.02	0.01	0.00	0.00	0.00	0.00
black grouper	0.13	0.00	0.00		0.00	0.00	0.00	0.09	0.00	0.00	0.27	0.00	0.01	0.03	0.02	0.00	0.03	0.02	0.01	0.01	0.00	0.00	0.06	0.00	0.01	0.02	0.00	0.00	0.00	0.02	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05
blackfin snapper	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.11	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.01	0.00	0.00	0.11	0.00	0.00	0.00	0.00
blackline tilefish	0.00	0.11	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
blueline tilefish	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.01	0.23	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.07	0.23	0.01	0.00	0.01	0.00	0.00	0.00
cubera snapper	0.00	0.00	0.00	0.11	0.01	0.00	0.00		0.01	0.00	0.06	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.09	0.01	0.01	0.02	0.02	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.04	0.01	0.05	0.07	0.00	0.05	0.03	0.00	0.03	0.14	0.01
dog snapper	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.01		0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.08	0.00	0.01	0.05	0.01	0.00	0.13	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.12	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.18
dwarf sand perch	0.01	0.00	0.00	0.00	0.28	0.00	0.01	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00
gag	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.06	0.00	0.00		0.04	0.02	0.00	0.17	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.19	0.00	0.01	0.00	0.01	0.00	0.00	0.00
golden tilefish	0.00	0.00	0.00	0.04	0.00	0.00	0.22	0.00	0.00	0.00	0.04		0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.01	0.00	0.00	0.00	0.04	0.00	0.00	0.06	0.02	0.00	0.05	0.13	0.23	0.00	0.00	0.00
goldface tilefish	0.00	0.27	0.00	0.00	0.00	0.27	0.00	0.00	0.01	0.00	0.00	0.00		0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
goliath grouper	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.09	0.01		0.02	0.00	0.00	0.01	0.01	0.01	0.00	0.09	0.01	0.00	0.01	0.02	0.00	0.00	0.00	0.19	0.00	0.00	0.03	0.04	0.00	0.00	0.09	0.01	0.11	0.00	0.01	0.00
gray snapper	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.01	0.09	0.00	0.00	0.00		0.01	0.00	0.00	0.24	0.00	0.23	0.00	0.02	0.00	0.00	0.07	0.00	0.00	0.11	0.00	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.11	0.02
gray triggerfish	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00
greater amberjack	0.36	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01		0.00	0.01	0.03	0.00	0.00	0.01	0.00	0.00	0.30	0.00	0.05	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.01
hogfish	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01		0.00	0.00	0.00	0.00	0.07	0.10	0.50	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.07
lane snapper	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.20	0.21	0.01	0.00		0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.29	0.00	0.14	0.00	0.00	0.00	0.00
lesser amberjack	0.02	0.00	0.59	0.01	0.01	0.00	0.01	0.07	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.04	0.01	0.01		0.00	0.02	0.01	0.00	0.03	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.09	0.01	0.00	0.00	0.00	0.00	0.00
mahogany snapper	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.10	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.10
misty grouper	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00		0.00	0.01	0.06	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.15	0.15	0.01	0.01	0.38	0.01	0.01	0.03	0.00	0.00
mutton snapper	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.20
Nassau grouper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.12	0.01	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.18	0.18	0.12
queen snapper	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.00	0.00	0.00	0.03	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00
red grouper	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.01	0.00	0.02	0.01	0.00	0.40	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.02	0.13	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.03	0.00	0.00	0.00
red hind	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.04	0.01	0.03	0.00	0.00	0.03	0.00	0.01	0.00		0.01	0.36	0.00	0.01	0.36	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.03
red snapper	0.01	0.00	0.00	0.07	0.00	0.00	0.13	0.07	0.00	0.00	0.07	0.01	0.00	0.00	0.01	0.07	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00		0.00	0.00	0.07	0.00	0.13	0.01	0.07	0.16	0.01	0.00	0.01	0.00	0.00	0.00
rock hind	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.21	0.00
sand perch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34
scamp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.16	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.16	0.00		0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.16	0.00
schoolmaster snapper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
silk snapper	0.00	0.00	0.00	0.00	0.02	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.47	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00
snowy grouper	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.48		0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
speckled hind	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
vermilion snapper	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00
warsaw grouper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.18	0.01	0.00		0.00	0.01	0.00	0.00	0.00
wenchman	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
yellowedge grouper	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00		0.00	0.00	0.00
yellowfin grouper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.25	0.00
yellowmouth grouper	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25		0.00
yellowtail snapper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Table 7. Table of managed species in Gulf, indicating species with completed or pending assessments and top five most associated species, by species, per weighted mean cluster association index. Productivity-Susceptibility Analysis (PSA) scores of overall risk from MRAG Americas Gulf of Mexico Final Report provided when available (MRAG 2009a). Color-coding denotes associations; dashed lines denote distinct life histories between associated species.

COMMON NAME	1	2	3	4	5	ASSESSED?	PSA
misty grouper	warsaw grouper	snowy grouper	silk snapper	queen snapper	yellowfin grouper		3.66
warsaw grouper	misty grouper	snowy grouper	silk snapper	yellowedge grouper	speckled hind		3.89
snowy grouper	yellowedge grouper	silk snapper	greater amberjack	red grouper	warsaw grouper		3.54
yellowedge grouper	snowy grouper	golden tilefish	blueline tilefish	queen snapper	yellowmouth grouper	2010	3.64
speckled hind	gag	blueline tilefish	cubera snapper	banded rudderfish	warsaw grouper		3.42*
blueline tilefish	golden tilefish	vermilion snapper	speckled hind	yellowedge grouper	queen snapper	2010	3.4*
golden tilefish (tilefish)	blueline tilefish	yellowedge grouper	wenchman	snowy grouper	warsaw grouper	2010	3.33
goldface tilefish	anchor tilefish	blackline tilefish	queen snapper	dog snapper	goliath grouper		-
anchor tilefish	blackline tilefish	goldface tilefish	almaco jack	banded rudderfish	black grouper		-
blackline tilefish	anchor tilefish	goldface tilefish	almaco jack	banded rudderfish	black grouper		-
gray triggerfish	red snapper	vermilion snapper	wenchman	lane snapper	blackfin snapper	2006	2.46*
lane snapper	gray triggerfish	vermilion snapper	red grouper	gray snapper	wenchman		2.99
red snapper	gray triggerfish	vermilion snapper	red grouper	snowy grouper	greater amberjack	2010	3.37
vermilion snapper	gray triggerfish	greater amberjack	lane snapper	blueline tilefish	scamp	2006	3.07
lesser amberjack	banded rudderfish	greater amberjack	vermilion snapper	cubera snapper	red hind		3.64
banded rudderfish	lesser amberjack	speckled hind	almaco jack	snowy grouper	rock hind		3.26*
greater amberjack	almaco jack	vermilion snapper	red grouper	scamp	red snapper	2006	3.23
almaco jack	greater amberjack	scamp	black grouper	banded rudderfish	vermilion snapper		3.35*
scamp	almaco jack	gag	black grouper	red grouper	vermilion snapper		3.25
gag	black grouper	red grouper	gray snapper	speckled hind	golden tilefish	2006	3.52
black grouper	gag	almaco jack	cubera snapper	scamp	mutton snapper	2010	3.48
red grouper	gag	black grouper	greater amberjack	red snapper	yellowedge grouper	2007	3.28
red hind	schoolmaster	rock hind	lesser amberjack	hogfish	yellowtail snapper		3.05
rock hind	red hind	yellowmouth grouper	gray snapper	snowy grouper	warsaw grouper		3.23*
yellowfin grouper	mutton snapper	yellowmouth grouper	Nassau grouper	cubera snapper	warsaw grouper		3.39*
yellowmouth grouper	yellowfin grouper	Nassau grouper	gray snapper	rock hind	wenchman		3.2*
goliath grouper	yellowedge grouper	golden tilefish	warsaw grouper	misty grouper	red grouper	2004	3.42
Nassau grouper	yellowmouth grouper	yellowfin grouper	dog snapper	mahogany snapper	yellowtail snapper		3.3
sand perch	goliath grouper	yellowtail snapper	dog snapper	mahogany snapper	Nassau grouper		-
dwarf sand perch	blackfin snapper	gray triggerfish	wenchman	almaco jack	anchor tilefish		-
blackfin snapper	dwarf sand perch	wenchman	silk snapper	mutton snapper	golden tilefish		3.36*
silk snapper	snowy grouper	blackfin snapper	blueline tilefish	vermilion snapper	mutton snapper		3.52
wenchman	blackfin snapper	gray triggerfish	golden tilefish	warsaw grouper	queen snapper		-
queen snapper	hogfish	blueline tilefish	misty grouper	speckled hind	yellowedge grouper		3.08*
hogfish	queen snapper	Nassau grouper	mutton snapper	yellowtail snapper	black grouper	2004	3.05
mutton snapper	yellowfin grouper	schoolmaster	yellowtail snapper	silk snapper	gray snapper	2008	3.27
schoolmaster	#N/A	#N/A	#N/A	#N/A	#N/A		3.49*
dog snapper	yellowtail snapper	Nassau grouper	mahogany snapper	schoolmaster	hogfish		3.29*
yellowtail snapper	dog snapper	mutton snapper	mahogany snapper	Nassau grouper	hogfish	2003	2.84
mahogany snapper	cubera snapper	blackfin snapper	yellowmouth grouper	silk snapper	dog snapper		3.55*
cubera snapper	black grouper	speckled hind	gag	snowy grouper	warsaw grouper		3.92*
gray (mangrove) snapper	mutton snapper	gag	mahogany snapper	vermilion snapper	red grouper		3.17

(*) = from MRAG (2009b).



	A	B	C	D	E	F	G	H
A		1	0	0	0	0	0	0
B	1		0	0	0	0	0	0
C	0.5	0.5		0	0	0	0	0
D	0	0	0		1	0	0	0
E	0	0	0	1		0	0	0
F	0	0	0	0.5	0.5		0	0
G	0	0	0	0.33	0.33	0.33		0
H	0.14	0.14	0.14	0.14	0.14	0.14	0.14	

Figure 1. Example dendrogram and cluster association matrix.

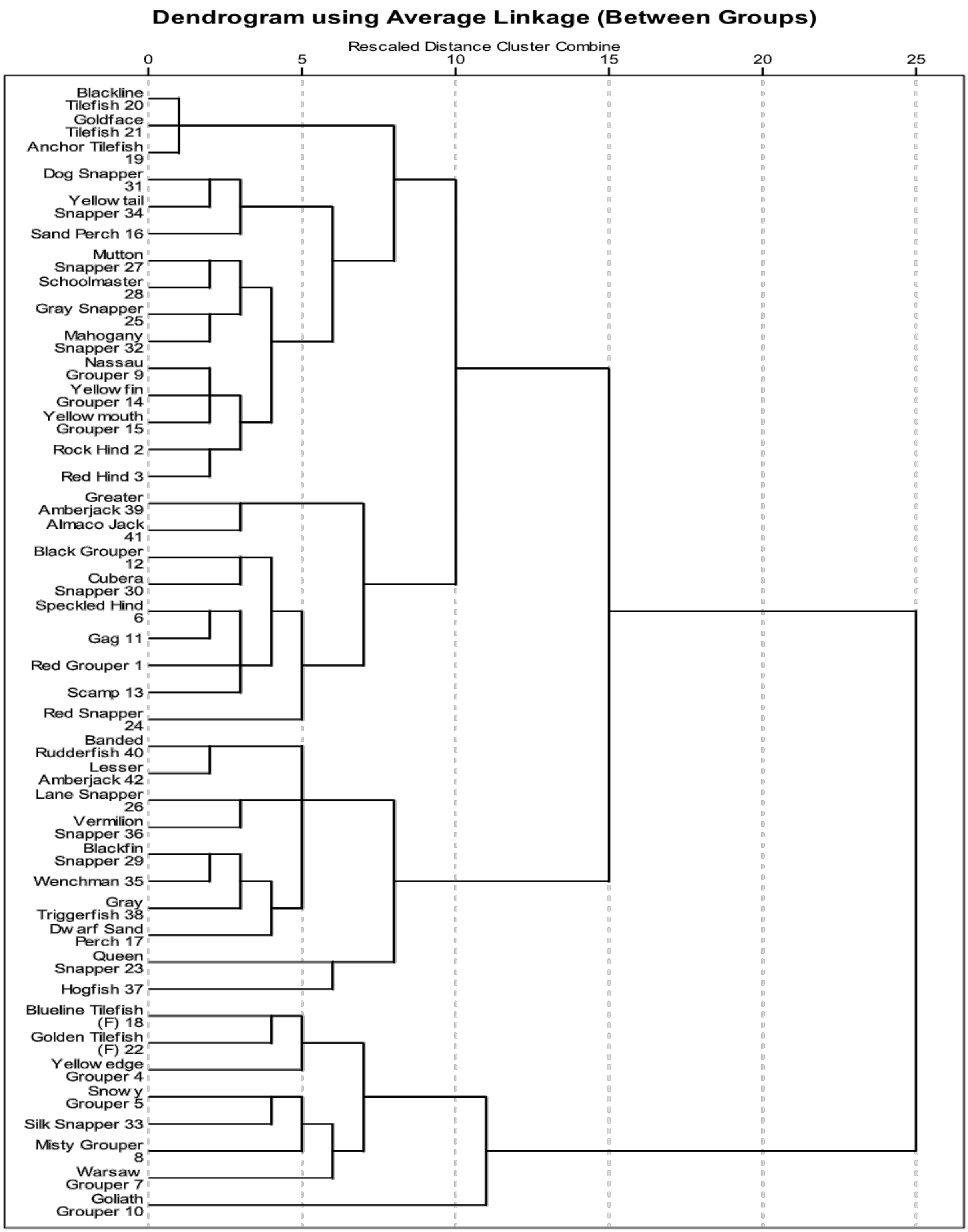


Figure 2. Hierarchical cluster analysis of life history parameters for managed Gulf reef fish species with dummy code for genus (Linkage Method: Ward's, Dissimilarity Measure: Euclidean Distance, Transformation: Z-Score by Variable). Note 'F' denotes female.

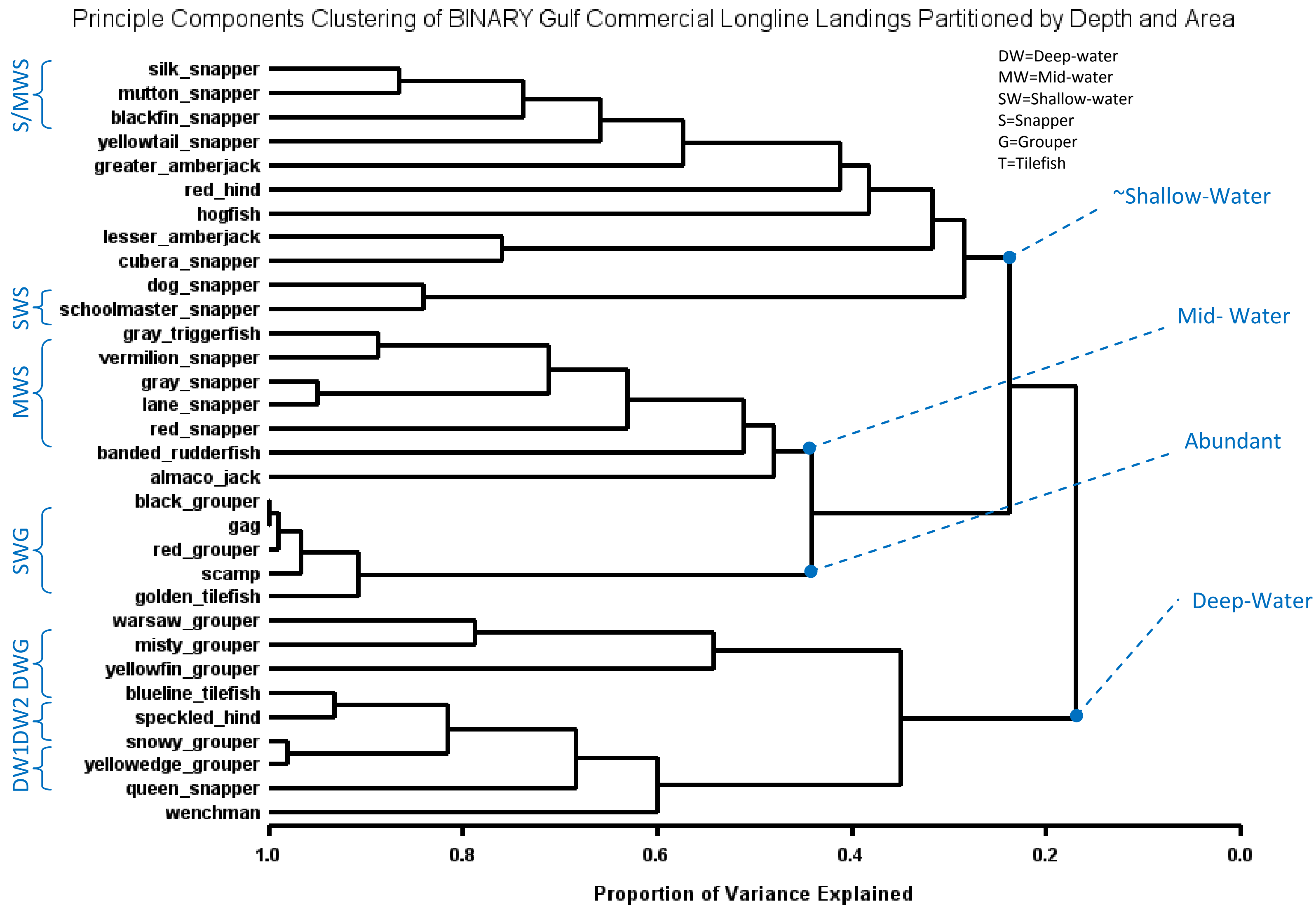


Figure 3. Dimension reduction cluster of presence-absence in Gulf reef fish commercial longline landings (2005-2009) aggregated by year, month, area, and depth (Linkage Method: VARCLUS, Height Measure: Proportion of Variance Explained, Transformation: Binary). Dendrogram shows deep-water (DW), mid-water (MW), and shallow-water (SW) assemblages for snapper (S) and grouper (G).

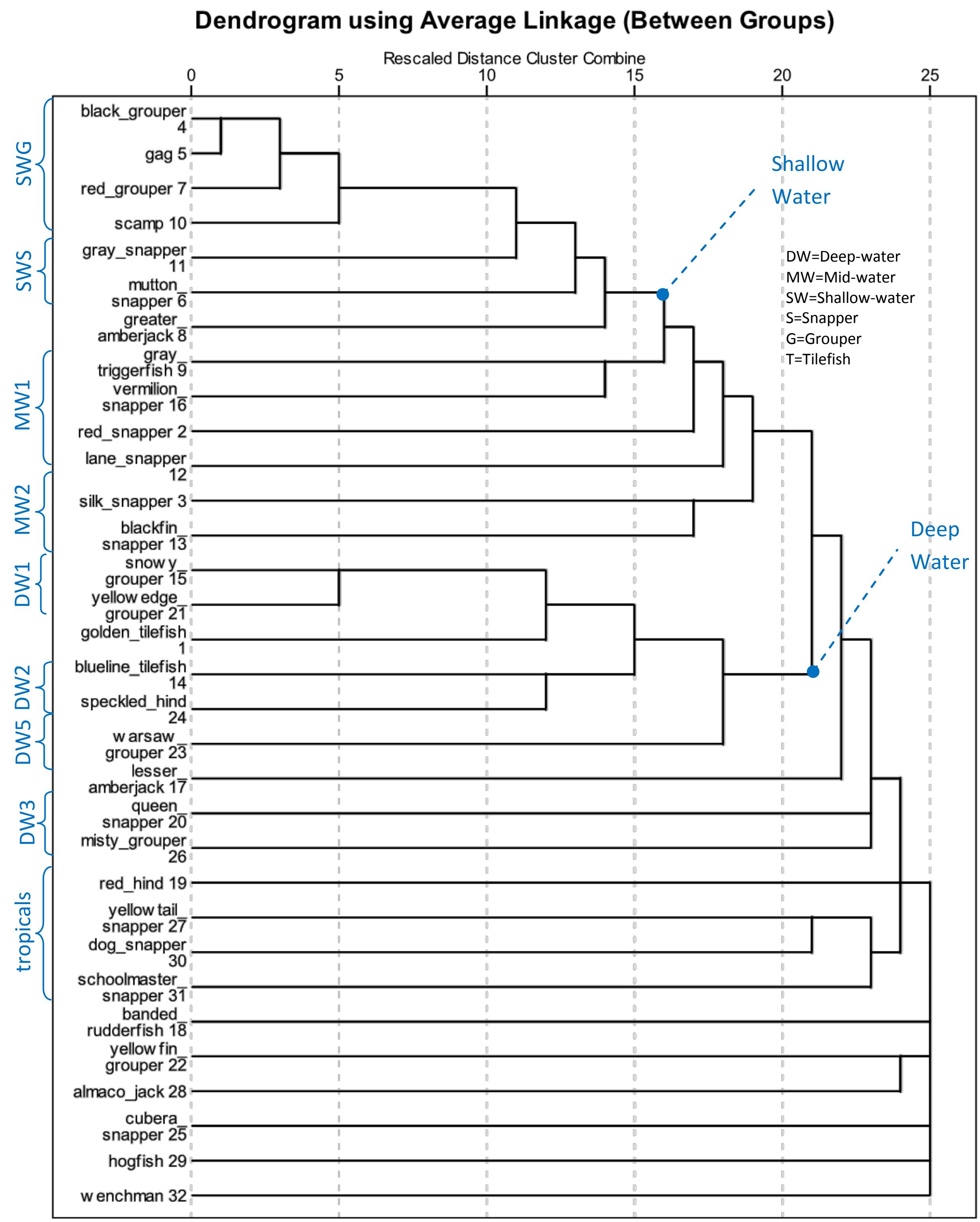


Figure 4. Hierarchical cluster analysis of species presence-absence in Gulf reef fish commercial longline landings (2005-2009) aggregated by year, month, area, and depth (Linkage Method: Between (Average), Dissimilarity Measure: Sørenson (Binary)).

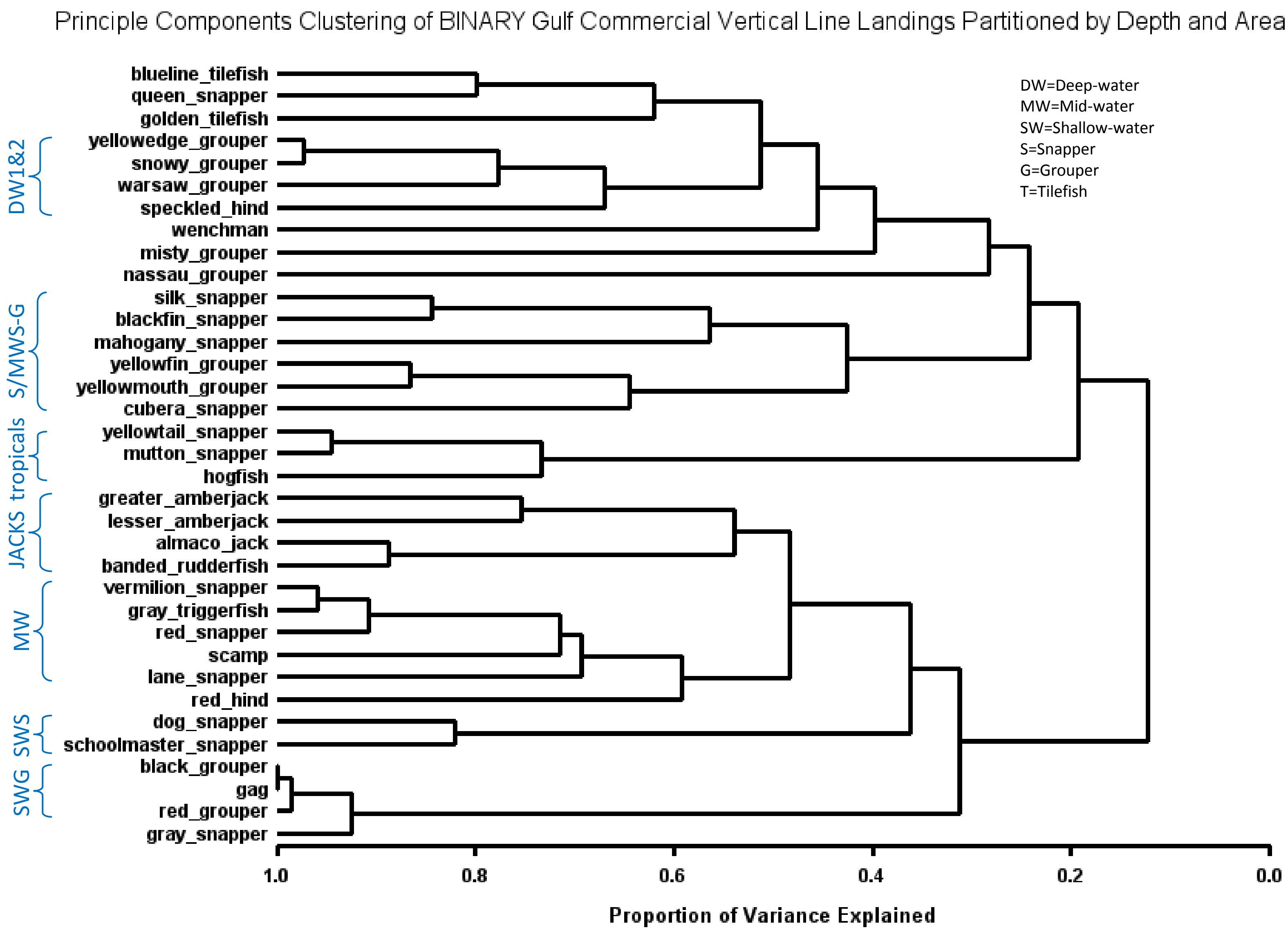


Figure 5. Dimension reduction cluster of Gulf reef fish commercial vertical line landings (2005-2009) aggregated by year, month, area, and depth (Linkage Method: VARCLUS, Height Measure: Proportion of Variance Explained, Transformation: Binary).

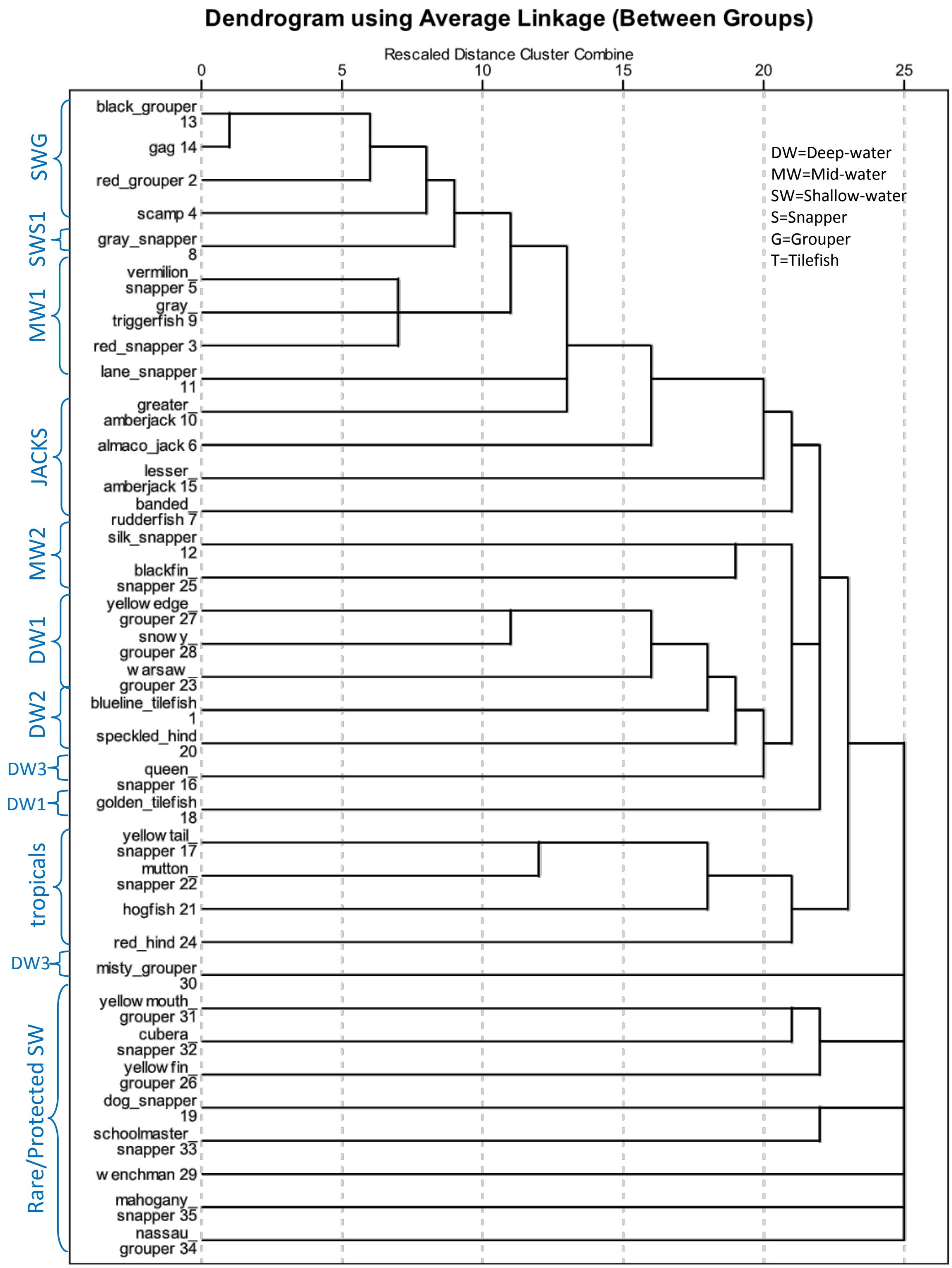


Figure 6. Hierarchical cluster analysis of species presence-absence in Gulf reef fish commercial vertical line landings aggregated by year, month, area, and depth (Linkage Method: Between (Average), Dissimilarity Measure: Sørenson (Binary)).

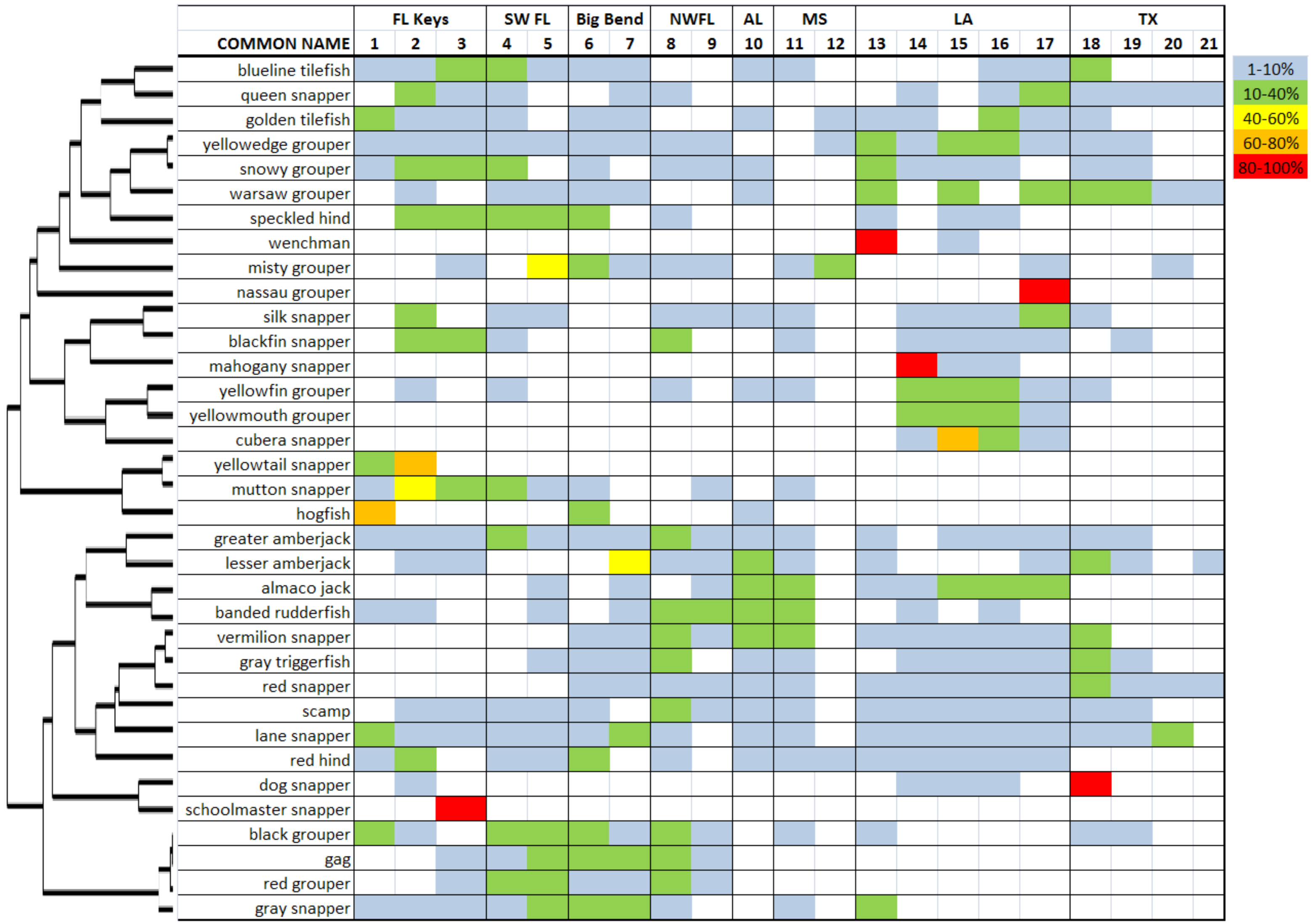


Figure 7. Plot of species presence-absence in Gulf reef fish commercial vertical line landings aggregated by year, month, area, and depth (Linkage Method: VARCLUS, Height Measure: Proportion of Variance Explained, Transformation: Binary) relative to percent of landings (2005-2009) originating from commercial logbook statistical areas 1-21. Similar color patterns between adjacent rows illustrate the importance of stock spatial distributions upon resultant clusters.

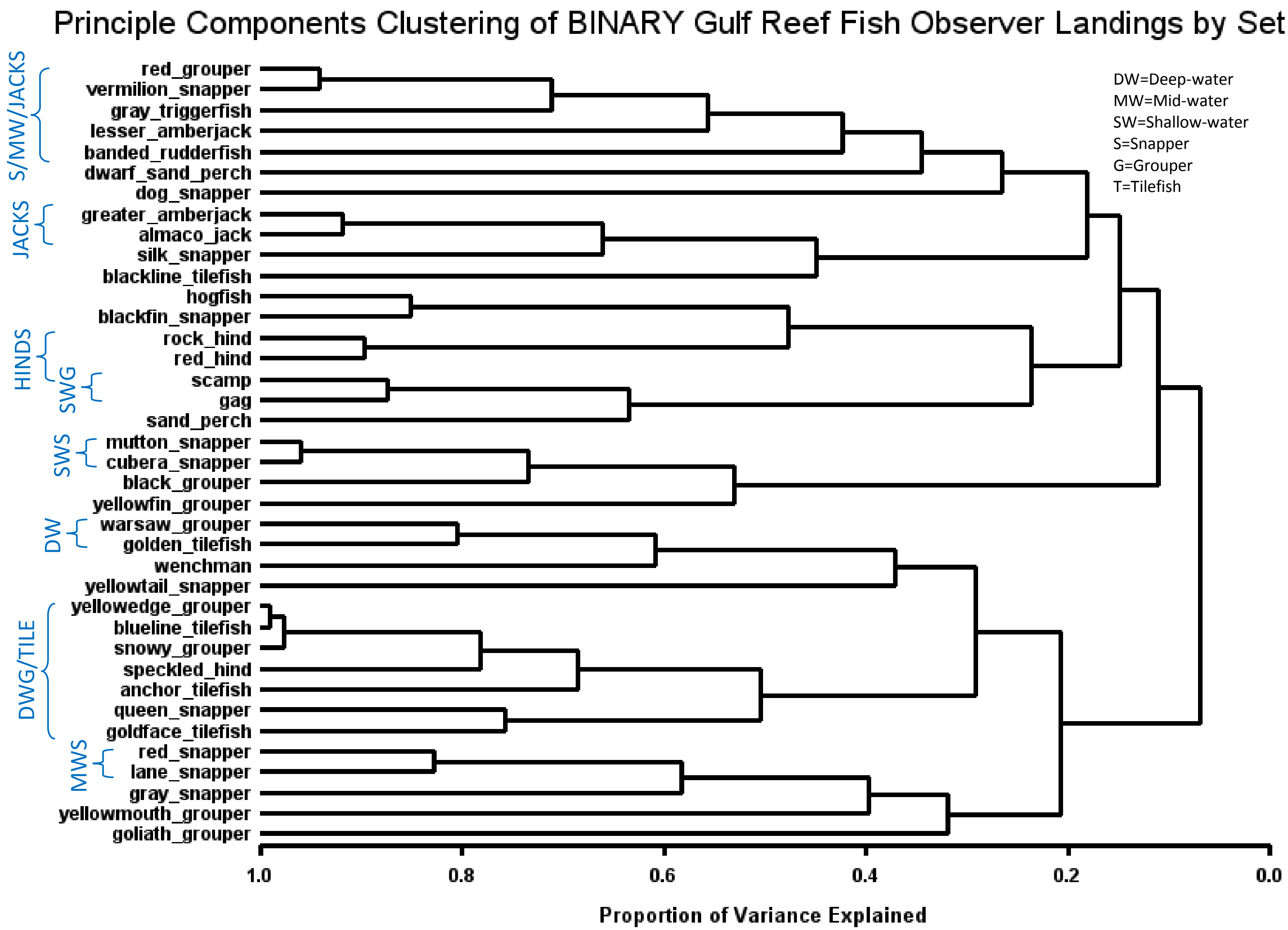


Figure 8. Dimension reduction cluster of species presence-absence in Gulf reef fish observer program landings aggregated at the individual set level (Linkage Method: VARCLUS, Measure: Proportion of Variance Explained).

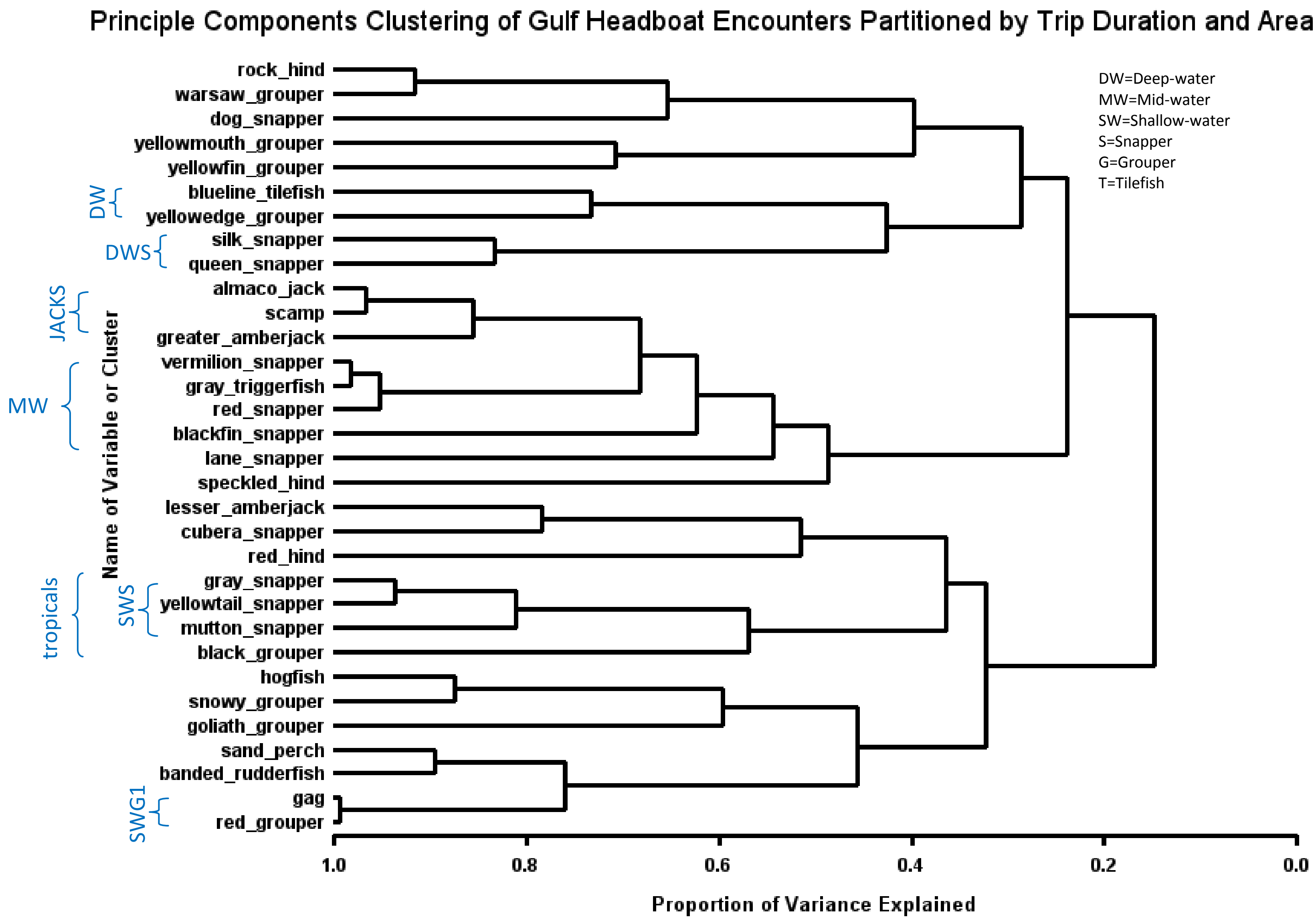


Figure 9. Dimension reduction cluster of Gulf reef fish recreational headboat landings (N) aggregated by year, month, area, and trip duration (Linkage Method: VARCLUS, Height Measure: Proportion of Variance Explained, Transformation: Root-Root).

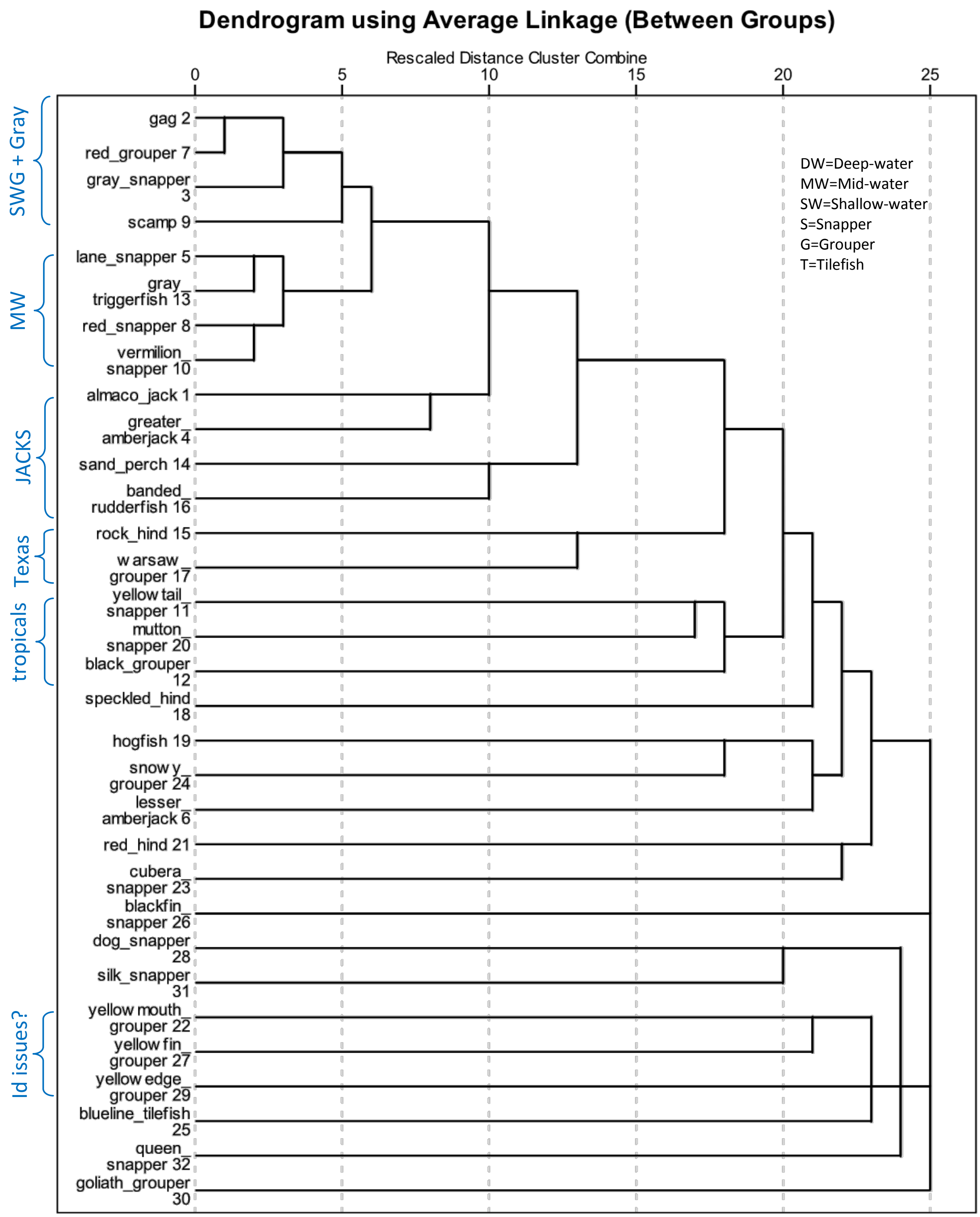


Figure 10. Hierarchical cluster analysis of species presence-absence in Gulf reef fish headboat landings aggregated by year, month, trip duration, and area fished (Linkage Method: Average (Between), Measure: Sørenson (Binary)).

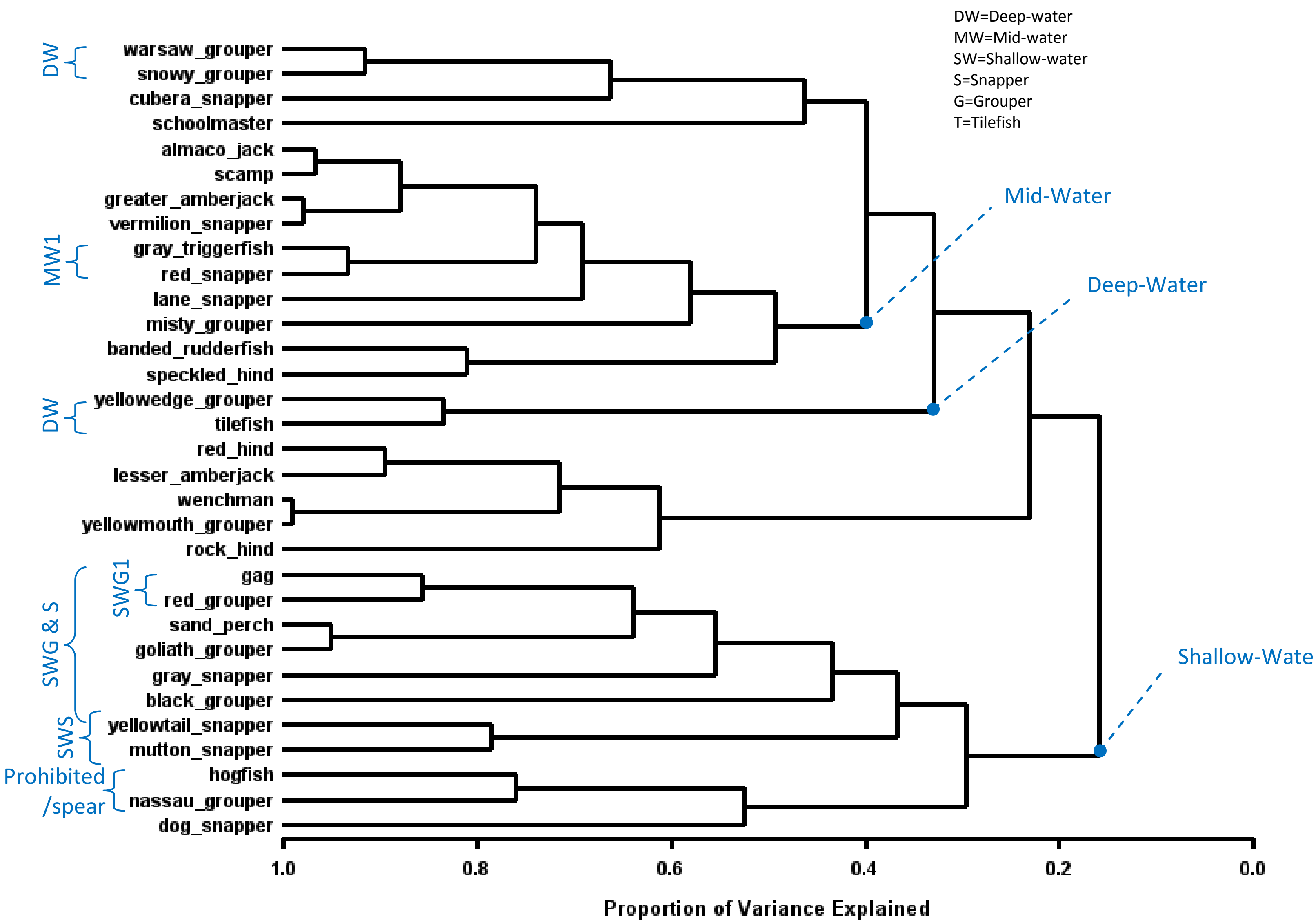


Figure 11. Dimension reduction cluster of species presence-absence in Gulf reef fish recreational MRFSS-reported landings aggregated by year, wave, mode of fishing, and area fished (Linkage Method: VARCLUS, Height Measure: Proportion of Variance Explained, Transformation: Binary).

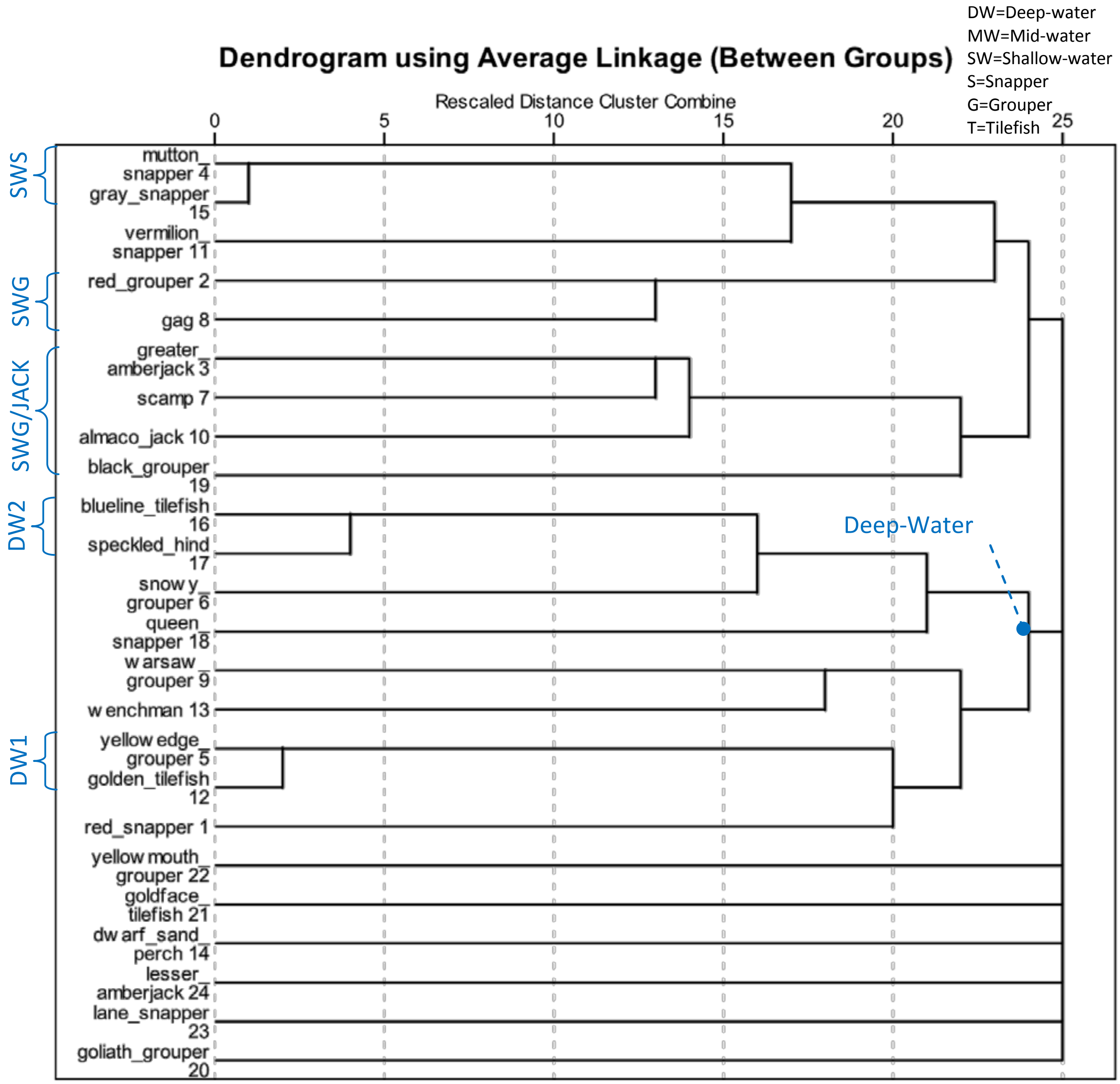


Figure 12. Hierarchical cluster analysis of species presence-absence in Gulf NMFS bottom longline survey landings aggregated by set (Linkage Method: Average (Between), Measure: Sørenson (Binary)).

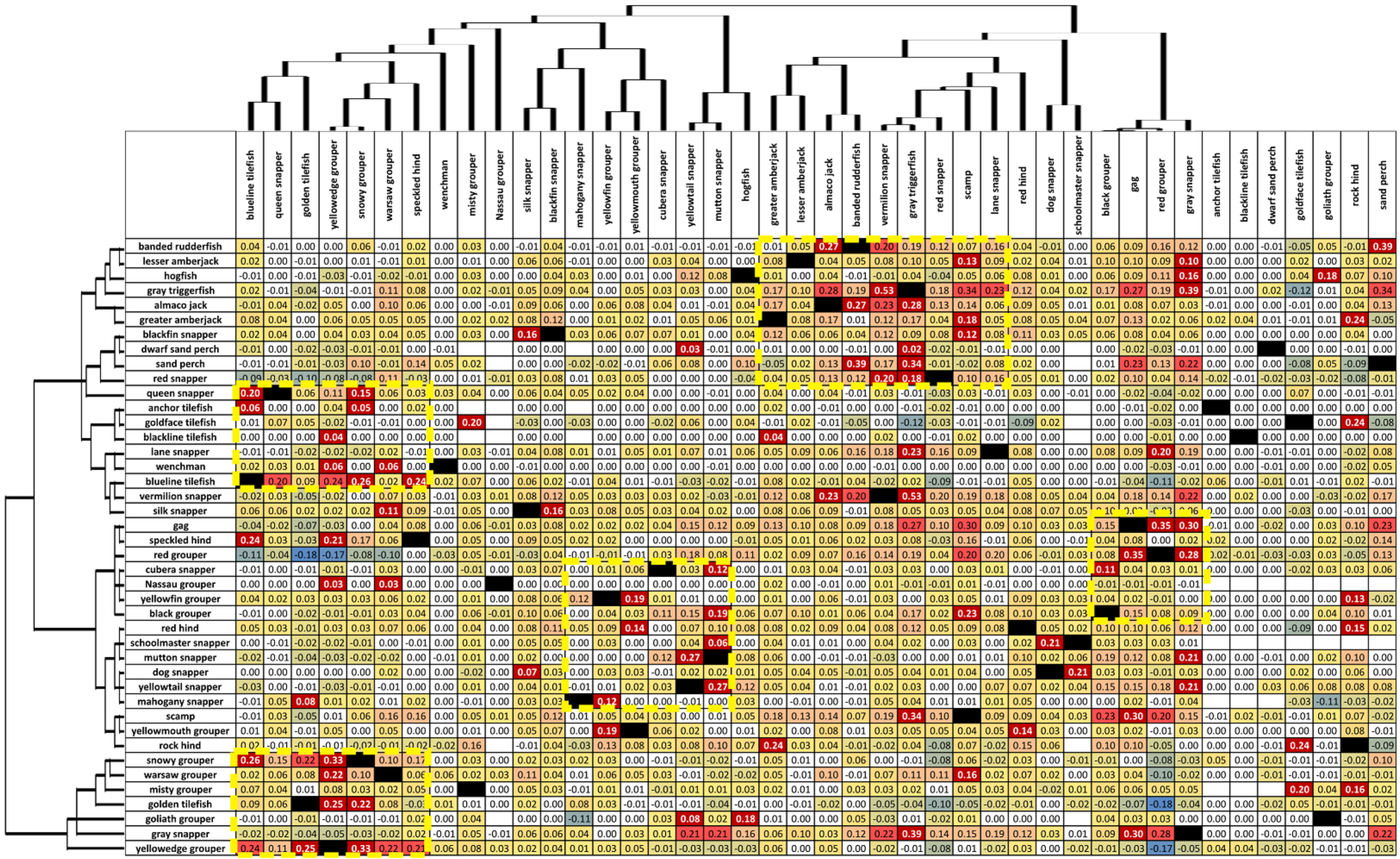


Figure 13. Nodal analysis of median correlation values from Pearson correlation matrices for CLL, CVL, HBS, MRFSS, NMFS-BLL, and RFOP. Columns are sorted by binary CVL dendrogram (Fig. 5) and rows are sorted by Life History dendrogram (Fig. 2). Nodes of warmer tones denote concurrence between the two clustering approaches, suggesting species with similar life histories are similarly susceptible to CVL sector.

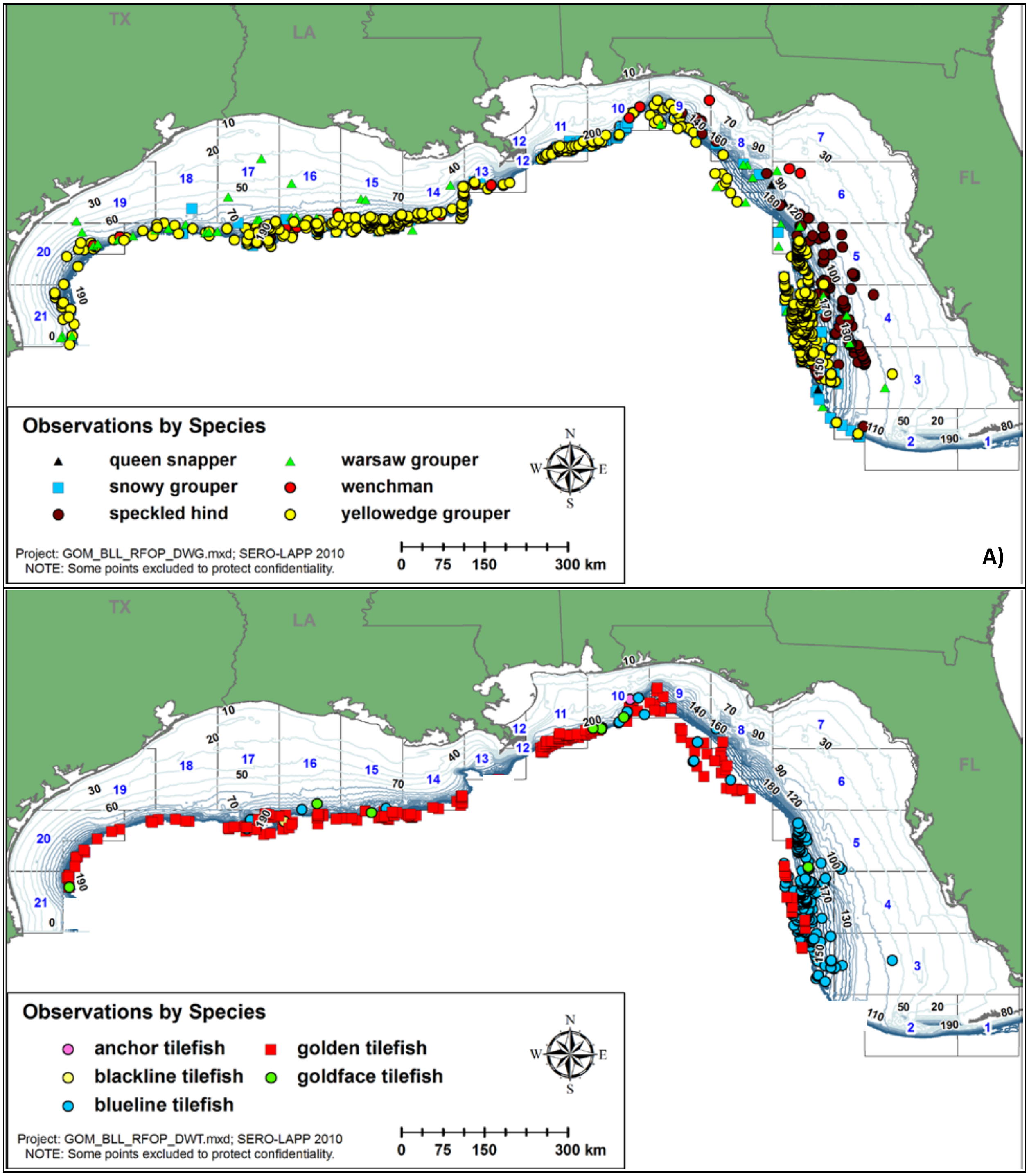


Figure 14. Map of A) deep-water grouper and snapper and B) tilefish observations from aggregated NMFS Bottom Longline Survey and Reef Fish Observer Program datasets relative to bathymetry and commercial fishery statistical reporting areas in Gulf of Mexico. Some observations removed to protect confidentiality.

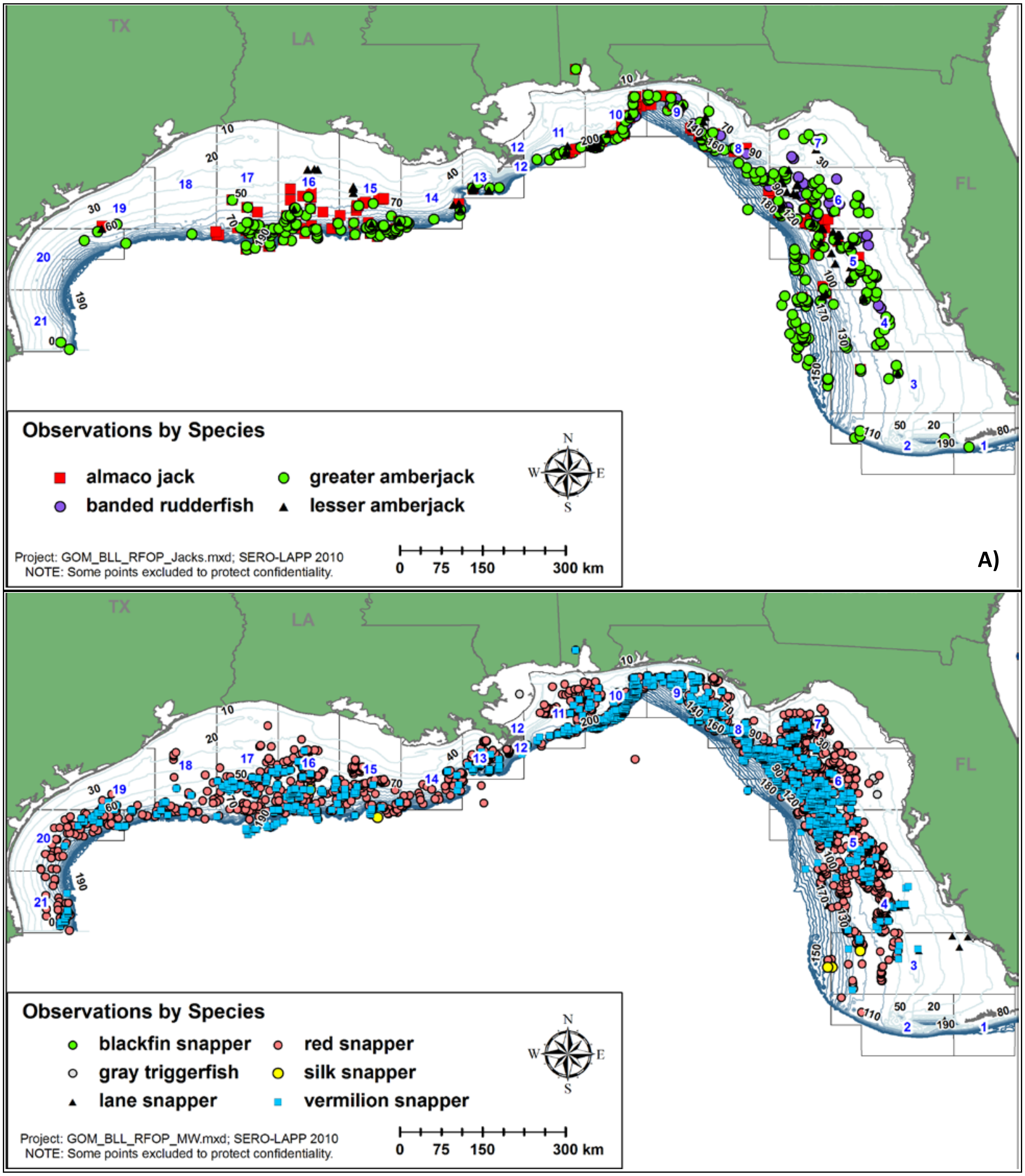


Figure 15. Map of A) jacks and B) mid-water species observations from aggregated NMFS Bottom Longline Survey and Reef Fish Observer Program datasets relative to bathymetry and commercial fishery statistical reporting areas in Gulf of Mexico.

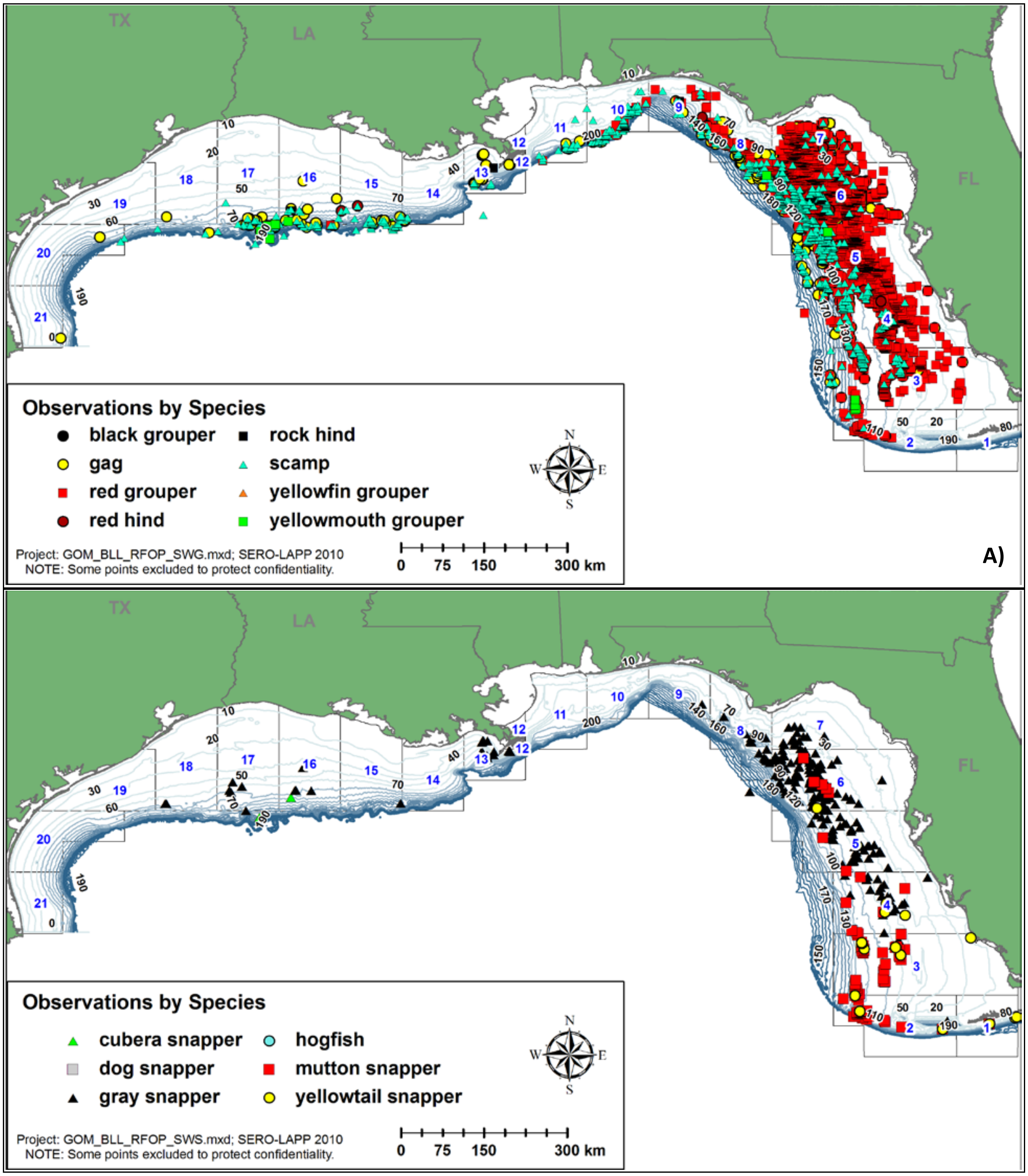


Figure 16. Map of A) shallow-water grouper and B) shallow-water snapper and wrasse observations from aggregated NMFS Bottom Longline Survey and Reef Fish Observer Program datasets relative to bathymetry and commercial fishery statistical reporting areas in Gulf of Mexico.