Final Report

Accuracy Assessment of NOAA's Florida Keys Benthic Habitat Map

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EXECUTIVE SUMMARY

This report describes the methodologies, analyses, and results for an independent accuracy assessment of a thematic benthic habitat map produced by NOAA for the Florida Keys. It is an analysis of four regional accuracy assessments. Over the course of the Florida Keys mapping project, NOAA amended part of the classification scheme. The original scheme for mapping benthic cover was a tiered approach where certain benthic cover categories were given priority over others (e.g. coral was most important). Recently, this was modified to a dominant benthic cover scheme where the habitat is characterized by the single most dominant cover type and all habitats are characterized for percent cover of coral. The data and data analyses from Walker and Foster (2009 and 2010) were used to evaluate the accuracy of the reclassified map for Regions Of Interest (ROI) 1 and 2. New data were collected for ROIs 3 and 4 as part of this report. All four regions were combined and analyzed to determine total map accuracy.

Data were collected in January 2009 at ROI 1 (eastern Lower Keys), in June 2009 at ROI 2 (western Lower Keys), in September 2012 and February, March, and May 2013 at ROI 3 (back country), and in May 2013 at ROI 4 (Key Largo) (Figure 1). A total of 2029 sampling stations were visited, of which 1969 were used in the accuracy assessment. The sites were selected using a stratified random sampling protocol that equally distributed sampling points amongst the detailed structure categories. Most sites were sampled by deploying a weighted drop camera with the vessel drifting in idle and recording 30-120 seconds of dGPS-referenced video. The shallowest sites were sampled by snorkel, waverunner, or kayak, using a hand-held dGPS for navigation and a housed camera to record video. Each sampling station was given a Detailed Structure, Biological, and Coral Cover assignment in the field. These field classifications were reevaluated post-survey during a systematic review of video and photographic data, designed to ensure consistency within classifications. The efficacy of the benthic habitat map was assessed by a number of classification metrics derived from error matrices of the Major and Detailed levels of Geomorphological Structure and Biological Cover.

The overall, producer's, and user's accuracies were computed directly from the error matrices. The analyses of the combined ROIs 1 – 4 gave an overall accuracy of the benthic habitat map of 90.4% and 84.6% at the Major and Detailed levels of Structure respectively, and 85.1% and 76.5% at the Major and Detailed levels of cover. The known map proportions, i.e. relative areas of mapped classes, were used to remove the bias introduced to the producer's and user's accuracies by differential sampling intensity (points per unit area). The overall accuracy at the Major and Detailed levels of Structure changed to 92.6% and 85.9%. The overall accuracy at the Major and Detailed levels of cover changed to 83.9% and 77.5%. The overall accuracies were also adjusted to the number of map categories using the Tau coefficient. Tau is a measure of the improvement of the classification scheme over a random assignment of polygons to categories, bounded between -1 (0% overall accuracy for 2 map categories) and 1 (100% accuracy for any number of categories). The Tau coefficients were 0.807 ± 0.026 and 0.829 ± 0.018 at the Major and Detailed levels of Structure, and 0.814 ± 0.020 and 0.745 ± 0.020 at the Major and Detailed levels of cover.

Percent coral cover was classified for every polygon, thus coral cover was evaluated separately. Total accuracy for Coral in all habitats for all ROIs was 89.6% and 93.4% after adjusting for map marginal proportions. This calculation, however, was not realistic because it evaluated coral cover in non-coral habitat which inflated the number of correct sites. To account for this, coral cover was also evaluated at only those sites found to be Coral Reef and Hardbottom habitats. Total map accuracy for mapping coral cover on Coral Reef and Hardbottom habitats was 79.8%, and 82.7% after adjusting for habitat proportions. The accuracy varied greatly between the two coral categories present. User's and Producer's accuracies for Coral 0% - <10% were near or equal to 90%. Conversely, Coral 10% - <50% user's and producer's accuracies were 54.3% and 66.5% respectively. Adjusted producer's accuracy was reduced to 55.2%. The adjustment for map proportions was very relevant here due to the large disparity of area

between the two classes. The map contained 658.5 km^2 of Coral 0% - <10% and 39.8 km^2 of Coral 10% - <50%. Further 583 of AA points on Coral Reef and Hardbottom habitat were in Coral 0% - <10% and 219 were in Coral 10% - <50%. Interestingly, there were no mapped polygons of Coral 50% - <90% and 90% - 100%. There was confusion between coral classes where 88 locations mapped as Coral 10% - <50% were actually Coral 0% - <10% and 60 locations mapped as Coral 0% - <10% were found to be Coral 10% - <50%. Confusion between 11 locations that were mapped as Coral 10% - <50% were actually Coral 50% - <90% and 1 location mapped as Coral 10% - <50% was found to be Coral 90% - 100%. These sites were all located in the patch reefs of Hawk Channel. It is unknown if these sites met the minimum mapping unit criteria, but the field data indicated high coral cover at these locations. The relatively low adjusted producer’s accuracy for Coral 10% - <50% (55.2%) suggests that not all higher coral cover areas were captured in the map. Furthermore the relatively low user’s accuracy (54.3%) indicates that the areas of Coral 10% - <50% portrayed in the map are highly variable.

Combining all the results into a total map accuracy assessment gave a sense of how the overall map portrays the seascape. However, it should be noted that large gaps in map coverage exist, especially between Marathon and Key Largo, a 137 km stretch. The results given in the appendices are more representative of their specific regions. ROIs 1 and 2 covered most of the lower Keys and their results are a good representation of map accuracy for that region. ROI 3 covered the Backcountry which had higher accuracies, presumably due to a reduced diversity of habitats and lack of coral cover. ROI 4 is a good representation of the upper Keys map accuracy. It is difficult to know which assessment best represents the middle Keys. The landscape is more similar to the upper Keys, but Hawk Channel becomes deeper and more turbid.

INTRODUCTION

As part of a regional mapping and monitoring effort in the Florida Keys, NOAA required an independent accuracy assessment to statistically test the accuracy of the GIS-based benthic habitat map recently produced for the Florida Keys. Resources, budgets, and logistical constraints precluded a comprehensive assessment of the entire mapped area, thus biogeographically-representative corridors within the total benthic habitat map area were selected for performing the accuracy assessment (Congalton, 1991; Stehman and Czaplewski, 1998). The corridors, or Regions Of Interest (ROIs), not only captured a wide diversity of habitats, but were also characterized by frequent transitions between habitat types ensuring a well-distributed, representative set of survey locations (Figure 1).

Over the course of the Florida Keys mapping project which began in 2006, NOAA amended part of the classification scheme. The original scheme for mapping benthic cover was a tiered approach where certain benthic cover categories were given priority over others (e.g. coral was most important). Recently, this was modified to a dominant benthic cover scheme where the habitat is characterized by the single most dominant cover type and all habitats are characterized for percent cover of coral. Walker et al. (2013) reanalyzed the accuracy of ROIs 1 and 2 according to the new scheme using the data and data analyses from Walker and Foster (2009; 2010). As the Florida Keys benthic habitat mapping effort was nearing its completion, two new areas were chosen for evaluation: 1) ROI 3, a backcountry location, and 2) ROI 4, off Key Largo in the upper Keys. Here we provide an accuracy assessment of these new areas using the latest NOAA classification scheme (Appendices 3 & 4) and an assessment of all data (ROIs 1-4) to understand the accuracy of the entire NOAA habitat map.

Figure 1. Accuracy Assessment Area 1 (ROI-1) (yellow), Area 2 (ROI-2) (blue), Area 3 (ROI-3) (green), and Area 4 (ROI-4) (purple), within the overall NOAA mapped region of the FL Keys. Each area was assessed individually and all data were combined into one accuracy assessment to represent map accuracy for the entire mapped area.

This work directly relates to many of the NOAA Coral Reef Conservation Program's (CRCP) newly developed guiding principles in their roadmap for the future. It directly addresses coral reef management needs based on sound science, takes an ecosystem-level approach to coral reef conservation by capturing data across all mapped benthic habitats in the region at specific locations that can be used to qualitatively evaluate the different habitats, and implements its objectives through strong partnerships. Furthermore, it supports two of CRCP's new priorities by providing a baseline dataset that can be used for future studies identifying impacts of land-based sources of pollution and of climate change in the lower Keys.

METHODOLOGY

2.1 CLASSIFICATION SCHEME (FROM ZITELLO ET AL. 2009)

The classification scheme used herein was designed by NOAA and its partners for the benthic habitat mapping program initiated in 1999. A meeting was held on June 11 and 12, 2008 to update the Nova Southeastern University (NSU) scientists performing the AA on the sampling protocol and the map classification scheme. The two day workshop involved one day of discussions and presentations and one day of field demonstrations. The knowledge gained from this workshop helped calibrate the two teams (mapping and AA) and reduce confusion between habitat definitions. NSU scientists applied this knowledge with success during the AA for ROI-1 (Walker and Foster, 2009) and ROI-2 (Walker and Foster, 2010) which showed high agreement in many categories. Both AAs assessed two map attributes using the same assessment locations: one to assess geomorphological structure and one to assess biological cover. Since then, the map polygons were reclassified to a dominant cover classification scheme (Walker et al., 2013). The reclassified classification scheme used in the AA is listed below and more information can be found in Zitello et al. (2009).

Coral Ecosystem Geomorphological Structures

Unconsolidated Sediment: Areas of the seafloor consisting of small particles (<256 mm) with less than 10% cover of large stable substrate. Detailed structure classes of softbottom include *Sand, Mud,* and *Sand with Scattered Coral and Rock.*

Sand: Coarse sediment typically found in areas exposed to currents or wave energy. Particle sizes range from 1/16 mm – 256 mm, including pebbles and cobbles (Wentworth 1922).

Mud: Fine sediment often associated with river discharge and build-up of organic material in areas sheltered from high-energy waves and currents. Particle sizes range from < 1/256 mm – 1/16 mm (Wentworth 1922).

Coral Reef and Hardbottom: Areas of both shallow and deep-water seafloor with solid substrates including bedrock, boulders and deposition of calcium carbonate by reef building organisms. Substrates typically have no sediment cover, but a thin veneer of sediment may be present at times, especially on low relief hardbottoms. Detailed structure classes include *Rock Outcrop, Boulder, Spur and Groove, Individual Patch Reef, Aggregated Patch Reefs, Aggregate Reef, Reef Rubble, Pavement, Pavement with Sand Channels,* and *Rhodoliths*.

Spur and Groove: Structure having alternating sand and coral formations that are oriented perpendicular to the shore or reef crest. The coral formations (spurs) of this feature typically have a high vertical relief (approximately 1 meter or more) relative to pavement with sand channels and are separated from each other by 1-5 meters of sand or hardbottom (grooves), although the height and width of these elements may vary considerably. This habitat type typically occurs in the *Fore Reef* zone.

Individual Patch Reef: Patch reefs are coral formations that are isolated from other coral reef formations by bare sand, seagrass, or other habitats and that have no organized structural axis relative to the contours of the shore or shelf edge. They are characterized by a roughly circular or oblong shape with a vertical relief of one meter or more in relation to the surrounding seafloor. *Individual Patch Reefs* are larger than or equal to the minimum mapping unit.

Aggregate Patch Reefs: Having the same defining characteristics as an *Individual Patch Reef*. This class refers to clustered patch reefs that individually are too small (less than the MMU) or are too close together to map separately. Where aggregated patch reefs share sand halos, the halo is included in the polygon.

Aggregate Reef: Continuous, high-relief coral formation of variable shapes lacking sand channels of *Spur and Groove*. Includes linear reef formations that are oriented parallel to shore or the shelf edge. This class is used for commonly referred to terms such as linear reef, fore reef or fringing reef.

Scattered Coral/Rock in Unconsolidated Sediment: Primarily sand bottom with scattered rocks or small, isolated coral heads that are too small to be delineated individually (i.e., smaller than individual patch reef). If the density of small coral heads is greater than 10% of the entire polygon, this structure type is described as *Aggregated Patch Reefs*.

Pavement: Flat, low-relief, solid carbonate rock with coverage of algae, hard coral, gorgonians, zooanthids or other sessile vertebrates that are dense enough to partially obscure the underlying surface. On less colonized Pavement features, rock may be covered by a thin sand veneer or turf algae.

Rock/Boulder: Aggregation of loose carbonate or volcanic rock fragments that have been detached and transported from their native beds. Individual boulders range in diameter from 0.25 – 3 m as defined by the Wentworth scale (Wentworth 1922).

Reef Rubble: Dead, unstable coral rubble often colonized with filamentous or other macroalgae. This habitat often occurs landward of well-developed reef formations in the *Reef Crest*, *Back Reef* or *Reef Flat* zones. Less often, *Reef Rubble* can occur in low density aggregations on broad offshore sand areas.

Pavement with Sand Channels: Habitats of pavement with alternating sand/surge channel formations that are oriented perpendicular to the *Reef Crest* or *Bank/Shelf Escarpment*. The sand/surge channels of this feature have low vertical relief (approximately less than 1 meter) relative to *Spur and Groove* formations and are typically erosional in origin. This habitat type occurs in areas exposed to moderate wave surge such as the *Bank/Shelf* zone.

Other Delineations

Artificial: Man-made habitats such as submerged wrecks, large piers, submerged portions of rip-rap jetties, and the shoreline of islands created from dredge spoil.

Land: Terrestrial features above the spring high tide line.

Unknown: Zone, Cover, and Structural feature that is not interpretable due to turbidity, cloud cover, water depth, or other interference.

Florida Classification Hierarchical Biological Cover Component

Cover classes refer only to the dominant biological component colonizing the surface of the feature and do not address location (e.g., on the shelf or in the lagoon) or structure type. Habitats or features that cover areas smaller than the MMU were not considered. The cover types are defined in a collapsible hierarchy ranging from eight major classes (*Algae, Seagrass, Live Coral, Mangrove, Coralline Algae, No Cover, Unclassified* and *Unknown*), combined with a modifier describing the distribution of the dominant cover type throughout the polygon (*10% - <50%, 50% - <90%,* and *90% - 100%*). It is important to reinforce that the modifier represents a measure of the level of patchiness of the biological cover at the scale of delineation and not the density observed by divers in the water. For example, a seagrass bed can be described as covering 90% - 100% of a given polygon, but may have sparse densities of shoots when observed by divers.

Algae: Substrates with 10% or greater distribution of any combination of numerous species of red, green, or brown algae. It may be turf, fleshy or filamentous species and occurs throughout many zones, especially on hardbottoms with low coral densities and softbottoms in deeper waters of the *Bank/Shelf* zone.

Seagrass: Habitat with 10% or more of the mapping unit dominated by any single species of seagrass (e.g. *Syringodium* sp., *Thalassia* sp., and *Halophila* sp.) or a combination of several species.

Live Coral: Substrates colonized with 10% or greater live reef building corals and other organisms including scleractinian corals (e.g., *Acropora* sp.) and octocorals (e.g., *Briareum* sp.).

Mangrove: This habitat is comprised of semi-permanently, seasonally or tidally flooded coastal areas occupied by any species of mangrove. Mangrove trees are halophytes; plants that thrive in and are especially adapted to salty conditions.

Coralline Algae: An area with 10% or greater coverage of any combination of numerous species of encrusting or coralline algae. May occur along reef crest, in shallow back reef, relatively shallow waters on the bank/shelf zone, and at depth. Broad enough coverage to constitute dominant biological cover in a MMU is particularly rare in the U.S. Caribbean.

No Cover: Substrates not covered with a minimum of 10% of any of the other biological cover types. This habitat is usually found on sand or mud bottoms. Overall, *No Cover* is estimated at 90% - 100% of the bottom with the possibility of some very low density biological cover.

Unclassified: A different biological cover type, such as upland, deciduous forest, that is not included in this habitat classification scheme dominates the area. Most often used on polygons defined as *Land* with terrestrial vegetation.

Unknown: Biological cover is indistinguishable due to turbidity, cloud cover, water depth, or other interference with an optical signature of the seafloor.

<u>**Percent Cover**</u>

10% - <50%

Discontinuous cover of the major biological type with breaks in coverage that are too diffuse to delineate or result in isolated patches of a different, dominant biological cover that are too small (smaller than the MMU) to be mapped as a different feature. Overall cover of the major biological type is estimated at 10% - <50% of the polygon feature.

50% - <90%
Discontinuous cover of the major biological type with breaks in coverage that are too diffuse to delineate or result in isolated patches of a different dominant biological cover that are too small (smaller than the MMU) to be mapped as a different feature. Overall cover of the major biological type is estimated at 50% - <90% of the polygon feature.

90% - 100%
Major biological cover type with nearly continuous (90% - 100%) coverage of the substrate. May include areas of less than 90% major cover on 10% or less of the total area that are too small to be mapped independently (less than the MMU).

<u>Live coral cover classes</u>
Four distinct and non-overlapping percent live coral classes were identified that can be mapped through visual interpretation of remotely sensed imagery. This attribute is an additional biological cover modifier used to maintain information on the percent cover of live coral, both scleractinian and octocorals, even when it is not the dominant cover type. In order to provide resource managers with additional information on this cover type of critical concern, four range classes were used (*0% - <10%, 10% - <50%, 50% - <90%,* and *90% - 100%*). Hardbottom features are classified into these range classes based on the amount of combined scleractinian and octocoral present in a polygon. Distinction of scleractinian coral versus octocoral was limited by the current state of remote sensing technology and could not be separated in the *Live Coral Cover* modifier.

0% - <10%: Live coral cover of less than 10% of hardbottom substrate at a scale several meters above the seafloor.

10% - <50%: Live coral cover between 10% and 50% of hardbottom substrate at a scale several meters above the seafloor.

50% - <90%: Live coral cover between 50% and 90% of hardbottom substrate at a scale several meters above the seafloor.

90% - 100%: Continuous live coral consisting of 90% or greater cover of the hardbottom substrate at a scale several meters above the seafloor.

Not Applicable: An estimate of percent live coral cover is not appropriate for this particular feature. Only occurs in areas describing the terrestrial environment.

Unknown: Percent estimate of coral cover is indistinguishable due to turbidity, cloud cover, water depth, or other interference with an optical signature of the seafloor.

2.2 ACCURACY ASSESSMENT

Data Collection

For all Regions Of Interest (ROIs), target locations for the accuracy assessment (AA) procedure were determined by a GIS-based, stratified random sampling (StRS) technique. The draft benthic habitat polygons were merged by Detailed Biological Cover class so that there was one single part polygon group per class and target points were randomly placed within each Detailed Biological Cover classes in the map using Hawth's tools in ArcGIS at a minimum distance of 30 m apart. To accommodate a robust AA using Detailed Geomorphological Structure, locations were added or haphazardly moved to ensure each Detailed Structure category contained at least 20 samples. Between the four surveys, this yielded 2080 total target locations. Of those 2023 were visited in the field and 1969 were used in the assessment.

Data were collected in January 2009 at ROI 1 (eastern Lower Keys), in June 2009 at ROI 2 (western Lower Keys), in September 2012 and February, March, and May 2013 at ROI 3 (Backcountry), and in May 2013 at ROI 4 (Key Largo). Data collection procedures were consistent between each ROI. Underwater video from a drop camera was taken at each site, provided the location was safely accessible by the survey vessel. The data collection was initiated when the vessel positioned itself within 5 m of the target. A Sea Viewer 950 underwater color video drop camera with a Sea-trak GPS video overlay connected to a Magellan Mobile Mapper CX GPS with 2 SBAS (Satellite Based Augmentation Systems) (e.g. WAAS, EGNOS, etc.) channels and real-time accuracy of <1 m was lowered to the bottom. Color video was recorded over the side of the stationary/drifting vessel approximately 0.5-2 m from the seafloor. Fifteen second to two minute video clips were recorded directly to a digital video recorder in MPEG4 video format at 720x480 resolution and 30fps. Video length depended on the habitat type and vessel drift. Videos of large, homogeneous habitats were generally short while heterogeneous habitats, especially edges, were typically longer. While the video was being recorded, an observer categorized each site according to the video for Detailed Geomorphological Structure and Biological Cover into a database.

Not all sites were accessible by survey vessel. Sites that were too shallow were accessed using a two-seat ocean kayak. The kayak was launched from the survey vessel as close to the target as possible. The observers paddled to the target using a waterproof Garmin 76CSx GPS with WAAS correction (<3 m accuracy) as a guide. At the target, a digital camera in an underwater housing was used to take pictures and/or video of the site. Descriptive notes about the site were recorded on waterproof paper from the kayak.

Several widespread, shallow-water sites that were inaccessible by boat and not practical for kayaking were visited by wave runner. Navigation to these sites was the same as kayaking. At each site a short video clip from a digital camera was taken either at the surface or by snorkel. Bottom type was usually confirmed by free diving at these locations.

A few underwater targets were not practically accessible by any means. In these cases, the sites were moved to more easily accessible location within the same polygon if possible or to another polygon of the same category.

Aside from underwater targets, Emergent Vegetation (EV) was assessed in this effort as well. Hiking was performed to assess many of the EV sites. Accessible EV targets were visited and confirmed by still pictures. Many EV targets were practically inaccessible and were either moved to accessible areas or confirmed by getting as close to the target as possible either by survey vessel, car, or foot. In some cases the latest imagery was used in ArcGIS to confirm a lower cover EV site around islands.

Data Evaluation

The GPS location at the start and end of each video were entered into a database with the field notes and plotted in GIS resulting in a point layer. These data were then spatially joined to the benthic habitat layer to identify the map classification for each point. All sites were evaluated for structure, cover, and coral cover both in GIS and video/images to classify the habitat at each site. These were then statistically compared to the map classification to gauge accuracy.

Sampling locations that fell close to polygon boundaries were all included as it was assumed that the probability of error contributing to false negatives was equal to the probability of error contributing to false positives. However, negative points were moved if they were within 3 m of an edge and the video data justified the relocation (e.g. the video showed a transition to the next habitat). This was a rare occurrence.

Detailed Geomorphological Structure classes Artificial, Land, Rock/Boulder, Unclassified, and Unknown were excluded from the accuracy analysis. Furthermore the locations visited in Unknown habitat were not part of the error analyses, resulting in 1969 locations for statistical analysis.

Accuracy Assessment Analyses

A number of statistical analyses were used to characterize the thematic accuracy of each ROI and the entire benthic habitat map. In each analysis, a total of eight error matrices were prepared for the attributes of Geomorphological Structure and Biological Cover, at the Major and Detailed levels of classification. Overall accuracy, producer's accuracy, and user's accuracy were computed directly from the error matrices (Story and Congalton 1986). Direct interpretation of these producer's and overall accuracies can be problematic, as the stratified random sampling protocol can potentially introduce bias (Hay 1979, van Genderen 1978, van Genderen 1977). Stratification ensures adequate representation of all map categories, by assigning an equal number of accuracy assessment surveying locations to each map category, using the draft benthic habitat map as a guide. This caused rare map categories to be sampled at a greater rate (observations per unit area) than common map categories. The bias introduced by differential sampling rates was removed using the method of Card (1982), which utilizes the known map marginal proportions, i.e. the relative areas of map categories. The map marginal proportions were calculated as the area of each map category divided by the total area within the AA ROI boundaries. The map marginal proportions were also utilized in the computation of confidence intervals for the overall, producer's, and user's accuracies (Card 1982). The efficacy of the habitat map was further examined by computation of the Tau coefficient, which adjusted the overall accuracies based on the number of map categories, allowing for statistical comparison of error matrices of different sizes (Ma and Redmond 1995). As a classification metric, Tau is a measure of the improvement of the classification scheme over a random assignment of polygons to categories, bounded between -1 (0% overall accuracy for 2 map categories) and 1 (100% accuracy for any number of categories).

The error matrices were constructed as a square array of numbers arranged in rows (map classification) and columns (true, or ground-truthed classification). The overall accuracy (P_o) was calculated as the sum of the major diagonal, i.e. correct classifications, divided by the total number of accuracy assessment samples. The producer's and user's accuracies are both category-specific. Each diagonal element was divided by the column total to yield a producer's accuracy and by the row total to yield a user's accuracy. The producer's and user's accuracies provide different perspectives on the classification accuracy of a map. The producer's accuracy (omission/exclusion error) indicates how well the mapper classified a particular habitat, e.g. the percentage of times that substrate known to be sand was correctly mapped as sand. In this report, the most common producer's errors in detailed structure were mapping areas found to be sand as a coral reef habitat (Sand column in Table 3). The user's accuracy (commission/inclusion error) indicates how often map polygons of a certain habitat type were classified correctly, eg. the percentage of times that a polygon classified as sand was actually sand. In this report, the most common user's errors in detailed structure were mapping areas found to be something else as pavement (Pavement row in Table 3). The distinction between these two types of error is subtle. For example, the user's accuracy for the map category of sand is calculated as the number of accuracy assessment points that were mapped as sand and later verified to be sand, divided by the total number of accuracy assessment points that were mapped as sand. But this measure of user's accuracy for mapping sand does not account for points that were verified to be sand, but mapped as something else, i.e. producer's error.

Considering the uneven distribution of map category area, a simple random assignment of accuracy assessment points would have required an unrealistically large number of points to adequately cover all map categories. The stratified random sampling protocol was used to ensure that each habitat class would be adequately sampled, assigning an equal number of accuracy assessment points to each map category of Detailed Cover within the representative areas. As previously mentioned, this non-random sampling method introduced bias in the producer's and overall accuracies, as map categories with very large areal extents were sampled at the same rate as categories with very small extents. For example, the Detailed Structure category Sand accounted for 53.3% of the total area of known seafloor habitats mapped in the AA ROIs, but only 27.6% (544/1969) of the accuracy assessment points. Conversely, the Rubble category accounted for only 0.8% of the total mapped area of known seafloor habitats and 6.2% (122/1969) of the accuracy assessment points. This amounted to a sampling intensity of 1.4 sites per km^2 (544/392.7 km^2) for the very large Sand category versus 30.2 sites per km^2 (122/4.04 km^2) for Rubble.

To remove the bias introduced by the stratified random sampling procedure, the overall and producer's accuracies were adjusted to the known areal proportions of map categories (Card 1982). The known map marginal proportions (π_i) were computed from the GIS layer of the draft benthic habitat map for each of the four error matrices, by dividing the area of each category by the total map area. The map areas were calculated within the boundaries of the accuracy assessment corridor (ROIs 1 – 4) and were exclusive to categories present in the error matrix, which reduced total area from 628.1 to 527.2 km^2. For the example of Detailed Structure category Sand, π_i was 0.533 (280.8 km^2/527.2 km^2). The individual cell probabilities, i.e. the product of the original error matrix cell values and π_i, divided by the row marginal (total map classifications per category), were computed for the off-diagonal elements using the following equation:

$$\hat{P}_{ij} = \pi_i n_{ij} / n_{i-}$$

The relative proportions of the cell values within a row of the error matrix were unaffected by this operation, but the row marginals were forced to the known map marginal proportions, i.e. the row total of a particular habitat now equaled the fraction of map area occupied by that habitat, instead of the total number of accuracy assessment points. The estimated true marginal proportions were computed as the sum of individual cell probabilities down each column of the error matrix. The π_i-adjusted overall, producer's and user's accuracies were then computed from the new error matrix, now populated by individual cell probabilities. The values of the π_i-adjusted overall and producer's accuracies differ by design from those of the original error matrix, as they have been corrected for the areal bias introduced by the stratified random sampling protocol. The variances and confidence intervals of the overall, producer's and user's accuracies were then computed from the following set of equations:

Overall Variance = $V(\hat{P}_c) = \sum_{i=1}^{r} p_{ii}(\pi_i - p_{ii}) / n_{i-})$

Overall Confidence Interval = $\hat{P}_c \pm 2[V(\hat{P}_c)]^{1/2}$

Producer's Variance = $V(\hat{\theta}_{ii}) = p_{ii} p_i^{-4} [p_{ii} \sum_{j \neq 1}^{r} p_{ij}(\pi_i - p_{ij}) / n_{i-} + (\pi_i - p_{ii})(p_i - p_{ii})^2 / n_{i-j}]$

Producer's Confidence Interval = $\hat{\theta}_{ii} \pm 2[V(\hat{\theta}_{ii})]^{1/2}$

User's Variance = $V(\hat{\lambda}_{ii}) = p_{ii}(\pi_j - p_{ii}) / n_{i-}$

User's Confidence Interval = $\hat{\lambda}_{ii} \pm 2[V(\hat{\lambda}_{ii})]^{1/2}$

The Tau coefficient is a measure of the improvement of classification accuracy over a random assignment of map units to map categories (Ma and Redmond 1995). For a supervised classification scheme there are two possible forms of the Tau coefficient, differing only by the estimation of the probability of random agreement (P_r). In one case it is known *a priori* that the probability of class membership differs among map categories, e.g. a previous map that quantified the disproportionate areal extents of habitat classes. In this case, Tau (T_p) is an adjustment of overall accuracy (P_o) by the number of groups (r) and the *a priori* probabilities informing the classification. In the other case it is not possible to quantify the *a priori* disparities of group membership. In the case of the NOAA FL Keys benthic habitat map there was no *a priori* information available, and thus a Tau based on equal probability of group membership (T_e) was used to evaluate classification accuracy. In this case, the probability of random agreement simplifies to the reciprocal of the number of map categories ($1/r$), and T_e is simply an adjustment of P_o by the number of map categories. As the number of categories increases, the probability of random agreement diminishes, and T_e approaches P_o. Values of T_e were calculated as follows:

Tau coefficient for equal probability of group membership = $T_e = (P_o - 1/r) / (1 - 1/r)$

Because there are only two possible outcomes for each accuracy assessment point, i.e. correct or incorrect, the probability distribution of P_o follows a binomial distribution. But when the total number of accuracy assessment samples within the error matrix is large, i.e. $n > 100$, the probability distribution of P_o approximates a normal distribution (Steel and Torrie, 1960). Given that the distribution of P_o approximates normality, it can then be assumed that the distribution of T_e will also approximate normality (Cohen, 1960). And because the individual row values of P_r are fixed before the map is classified, i.e. equal to $1/r$, they can be treated as constants and a variance can be calculated for Tau (Ma and Redmond 1995):

Variance of Tau coefficient = $\sigma_r^2 = P_o(1 - P_o) / n(1 - P_r)^2$

Confidence intervals were then calculated for each Tau coefficient at the 95% confidence level (1-α), using the following generalized form:

95% CI = $T_e \pm Z_{\alpha/2}(\sigma_r^2)^{0.5}$

RESULTS

The results presented here are of the combined ROIs 1 - 4 accuracy assessment analyses to represent the entire mapped area. Accuracies of individual ROIs were different for each. The results for each ROI are presented in Appendices 1 - 4.

A total of 2029 ground validation stations were visited. The identity and number of planned targets differed from that of the targets (2080) as a result of the addition of opportunistic points of interest and inaccessible locations. Of the 2029 stations visited, 1969 were used for the accuracy assessment. The majority of excluded samples were due to intentionally visiting unknown areas (n = 45).

3.1 GEOMORPHOLOGICAL STRUCTURE

Major Geomorphological Structure

Error matrices for Major Geomorphological Structure are presented in Tables 1 and 2. The overall accuracy (P_o) was 90.4% at the Major Structure level (Table 1). The Tau coefficient for equal probability of group membership (T_e) was 0.807 ± 0.026 (α=0.05), i.e. the rate of misclassifications at the Major Structure level was 80.7% less than would be expected from random assignment of polygons to categories. Table 2 is populated by the individual cell probabilities ($\hat{P}_{ij}$), which are the product of the original error matrix cell values and the known map marginal proportions, divided by the row marginal of the original error matrix. The overall accuracy (P_o), corrected for bias using the known map marginal proportions, was 92.6% ± 1.1 (α=0.05) at the Major Structure level. The producer's accuracies, adjusted for known map marginal proportions, are shown for individual map categories. A 95% confidence interval was calculated for each value of producer's and user's accuracy.

The Major Structure error matrix clearly demonstrated the effect of adjusting producer's accuracy to the known map marginal proportions. In the original error matrix (Table 1), 1026 of 1969 ground-truthed Soft targets were correctly classified as Soft bottom habitats. The remaining 141 samples were incorrectly classified as Hard. The un-adjusted producer's accuracy was therefore equal to 1026/1167 = 87.9%. However, the known map marginal proportions of the Soft habitats were 74.5%, versus 25.5% for hard habitats (Table 2). Therefore, the producer's confusion between these two habitats was exaggerated by a disproportionately high sampling of hard habitats that had a disproportionately lower contribution to the total area. Discrimination between these two categories increased after the error matrix cell values were transformed from the original binomial observations to individual cell probabilities (141*0.255/894=0.040 and 1026*0.745/1075=0.711), increasing producer's accuracy from 87.9% to 94.6%.

Detailed Geomorphological Structure

Error matrices for Detailed Geomorphological Structure are presented in Tables 3 and 4. The overall accuracy (P_o) was 84.6% at the Detailed Structure level (Table 3). The Tau coefficient for equal probability of group membership (T_e) was 0.829 ± 0.018 (α=0.05), i.e. the rate of misclassifications at the Detailed Structure level was 82.9% less than would be expected from random assignment of polygons to categories. T_e more closely approached P_o at the Detailed level (r = 9) than at the Major level (r = 2), reflecting the diminishing probability of random agreement with increasing map categories. Table 4 is populated by the individual cell probabilities ($\hat{P}_{ij}$), which are the product of the original error matrix cell values and the known map marginal proportions, divided by the row marginal of the original error matrix. The overall accuracy (P_o), corrected for bias using the known map marginal proportions, was 85.9% ± 1.8

(α=0.05) at the Detailed Structure level. The producer's accuracies, adjusted for known map marginal proportions, are shown for individual map categories. A 95% confidence interval was calculated for each value of producer's and user's accuracy.

3.2 BIOLOGICAL COVER

Major Biological Cover

Error matrices for Major Biological Cover are presented in Tables 5 and 6. The overall accuracy (P_o) was 85.1% at the Major Cover level (Table 5). The Tau coefficient for equal probability of group membership (T_e) was 0.814 ± 0.020 (α=0.05), i.e. the rate of misclassifications at the Major Cover level was 81.4% less than would be expected from random assignment of polygons to categories. Table 6 is populated by the individual cell probabilities ($\hat{P}_{ij}$), which are the product of the original error matrix cell values and the known map marginal proportions, divided by the row marginal of the original error matrix. The overall accuracy (P_o), corrected for bias using the known map marginal proportions, was 83.9% ± 2% (α=0.05) at the Major Cover level. The producer's accuracies, adjusted for known map marginal proportions, are shown for individual map categories. A 95% confidence interval was calculated for each value of producer's and user's accuracy.

Detailed Biological Cover

Error matrices for Detailed Biological Cover are presented in Tables 7 and 8. The overall accuracy (P_o) was 76.5% at the Detailed Cover level (Table 7). The Tau coefficient for equal probability of group membership (T_e) was 0.745 ± 0.020 (α=0.05), i.e. the rate of misclassifications at the Detailed Cover level was 74.5% less than would be expected from random assignment of polygons to categories. T_e more closely approached P_o at the Detailed level (r = 13) than at the Major level (r = 5), reflecting the diminishing probability of random agreement with increasing map categories. Table 8 is populated by the individual cell probabilities ($\hat{P}_{ij}$), which are the product of the original error matrix cell values and the known map marginal proportions, divided by the row marginal of the original error matrix. The overall accuracy (P_o), corrected for bias using the known map marginal proportions, was 77.5% ± 2.0 (α=0.05) at the Detailed Cover level. The producer's accuracies, adjusted for known map marginal proportions, are shown for individual map categories (user's accuracies are unaffected). A 95% confidence interval was calculated for each value of producer's and user's accuracy.

Detailed Coral Cover on all habitats

Error matrices for Detailed Coral Cover on all mapped habitats are presented in Tables 9 and 10. The overall accuracy (P_o) was 89.6% at the Detailed Cover level (Table 9). The Tau coefficient for equal probability of group membership (T_e) was 0.861 ± 0.018 (α=0.05), i.e. the rate of misclassifications at the Detailed Cover level was 88.3% less than would be expected from random assignment of polygons to categories. Table 10 is populated by the individual cell probabilities ($\hat{P}_{ij}$), which are the product of the original error matrix cell values and the known map marginal proportions, divided by the row marginal of the original error matrix. The overall accuracy (P_o), corrected for bias using the known map marginal proportions, was 93.4% ± 0.9% (α=0.05) at the Detailed Cover level. The producer's accuracies, adjusted for known map marginal proportions, are shown for individual map categories (user's accuracies are unaffected). A 95% confidence interval was calculated for each value of producer's and user's accuracy.

Detailed Coral Cover on Coral Reef and Hardbottom habitats only

Error matrices for Detailed Coral Cover on Coral Reef and Hardbottom habitats are presented in Tables 11 and 12. The overall accuracy (P_o) was 79.8% at the Detailed Cover level (Table 11). The Tau coefficient for equal probability of group membership (T_e) was 0.731 ± 0.037 (α=0.05), i.e. the rate of misclassifications at the Detailed Cover level was 73.1% less than would be expected from random assignment of polygons to categories. Table 12 is populated by the individual cell probabilities ($\hat{P}_{ij}$), which are the product of the original error matrix cell values and the known map marginal proportions, divided by the row marginal of the original error matrix. The overall accuracy (P_o), corrected for bias using the known map marginal proportions, was 82.7% ± 2.4% (α=0.05) at the Detailed Cover level. The producer's accuracies, adjusted for known map marginal proportions, are shown for individual map categories (user's accuracies are unaffected). A 95% confidence interval was calculated for each value of producer's and user's accuracy.

Table 1. Error matrix for Major Geomorphological Structure. The overall accuracy (P_o) was 90.4%. The Tau coefficient for equal probability of group membership (T_e) was 0.807, with a 95% Confidence Interval of 0.781 – 0.833.

MAP (i)	MAJOR STRUCTURE	TRUE (GROUND-TRUTHED) (j): hard	soft	n_{i-}	USERS Accuracy (%)
	hard	**753**	141	894	**84.2**
	soft	49	**1026**	1075	**95.4**
	n_{-j}	802	1167	**1969** <= n	
	PRODUCERS Accuracy (%)	**93.9**	**87.9**	P_o **90.4%**	

$T_e = 0.807 \pm 0.026$

Table 2. Error matrix for Major Geomorphological Structure (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 92.6% with a 95% Confidence Interval of 91.5% – 93.7%.

MAP (i)	MAJOR STRUCTURE	TRUE (GROUND-TRUTHED) (j): hard	soft	π_i	USERS Accuracy (%)	USERS CI (± %)
	hard	**0.2149**	0.0402	0.255	**84.2**	**2.4**
	soft	0.0340	**0.7110**	0.745	**95.4**	**1.3**
	n_{-j}	0.249	0.751	**1.000** <= n		
	PRODUCERS Accuracy (%)	**86.4**	**94.6**	P_o **92.6%**		
	PRODUCERS CI (± %)	**3.3**	**0.8**	CI (±) **1.1%**		

Table 3. Error matrix for Detailed Geomorphological Structure. The overall accuracy (P_o) was 84.6%. The Tau coefficient for equal probability of group membership (T_e) was 0.829, with a 95% Confidence Interval of 0.811 – 0.847. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

MAP DATA (i)

DETAILED STRUCTURE	Aggregate Reef	Aggregated Patch Reef	Individual Patch Reef	Spur and Groove	Rubble	Pavement	Pav w/ Sand Channels	Sand	Mud	n_{i-}	USERS Accuracy (%)
Aggregate Reef	**86**		1		1	8		23		119	**72.3**
Aggregated Patch Reef		**34**				2		24		60	**56.7**
Individual Patch Reef			**42**					3	2	47	**89.4**
Spur and Groove	1			**92**	1		3			97	**94.8**
Rubble	12				**98**	4		8		122	**80.3**
Pavement	10	3	2	3	1	**312**		50	30	411	**75.9**
Pav w/ Sand Channels							**37**	1		38	**97.4**
Sand	4	4	7	1	1	8		**476**	43	544	**87.5**
Mud			2			22		18	**489**	531	**92.1**
n_{-j}	113	41	54	96	102	356	40	603	564	**1969 <= *n***	
PRODUCERS Accuracy (%)	**76.1**	**82.9**	**77.8**	**95.8**	**96.1**	**87.6**	**92.5**	**78.9**	**86.7**	**P_o 84.6%**	

T_e = 0.829 ± 0.018

Table 4. Error matrix for Detailed Geomorphological Structure (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 85.9% with a 95% Confidence Interval of 84.1% - 87.7%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

MAP DATA (i)

DETAILED STRUCTURE	Aggregate Reef	Aggregated Patch Reef	Individual Patch Reef	Spur and Groove	Rubble	Pavement	Pav w/ Sand Channels	Sand	Mud	π_i	USERS Accuracy (%)	USERS CI (± %)
Aggregate Reef	**0.0203**		0.0002		0.0002	0.0019		0.0054		0.028	**72.3**	**8.2**
Aggregated Patch Reef		**0.0094**				0.0006		0.0067		0.017	**56.7**	**12.8**
Individual Patch Reef			**0.0106**					0.0008	0.0005	0.012	**89.4**	**9.0**
Spur and Groove	0.0002			**0.0195**	0.0002		0.0006			0.021	**94.8**	**4.5**
Rubble	0.0008				**0.0062**	0.0003		0.0005		0.008	**80.3**	**7.2**
Pavement	0.0039	0.0012	0.0008	0.0012	0.0004	**0.1206**		0.0193	0.0116	0.159	**75.9**	**4.2**
Pav w/ Sand Channels							**0.0111**	0.0003		0.011	**97.4**	**5.2**
Sand	0.0039	0.0039	0.0069	0.0010	0.0010	0.0078		**0.4661**	0.0421	0.533	**87.5**	**2.8**
Mud			0.0008			0.0088		0.0072	**0.1955**	0.212	**92.1**	**2.3**
n_{-j}	0.029	0.014	0.019	0.022	0.008	0.140	0.012	0.506	0.250	**1.000 <= *n***		
PRODUCERS Accuracy (%)	**69.9**	**65.0**	**55.0**	**90.1**	**77.3**	**86.2**	**94.6**	**92.1**	**78.3**	**P_o 85.9%**		
PRODUCERS CI (± %)	**11.4**	**19.2**	**15.6**	**9.9**	**21.3**	**4.2**	**7.5**	**1.3**	**4.1**	**CI (±) 1.8%**		

Table 5. Error matrix for Major Biological Cover. The overall accuracy (P_o) was 85.1%. The Tau coefficient for equal probability of group membership (T_e) was 0.814, with a 95% Confidence Interval of 0.794 – 0.834. Blank cells indicate 0 occurrences.

	MAJOR COVER	TRUE (GROUND-TRUTHED) (j) Coral	Sea Grass	Algae	Emerg Veg	No Cover	n_{i-}	USERS Accuracy (%)
MAP DATA (i)	Coral	**0**					0	**n/a**
	Seagrass		**614**	55	5	35	709	**86.6**
	Algae	6	119	**746**	1	29	901	**82.8**
	Emerg Veg				**161**		161	**100.0**
	No Cover		19	24		**157**	200	**78.5**
	n_{-j}	6	752	825	167	221	**1971** <= n	
	PRODUCERS Accuracy (%)	**0.0**	**81.6**	**90.4**	**96.4**	**71.0**	P_o **85.1%**	

T_e = **0.814 ± 0.020**

Table 6. Error matrix for Major Biological Cover (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 83.9% with a 95% Confidence Interval of 81.9% - 85.9%. Blank cells indicate 0 occurrences.

	MAJOR COVER	TRUE (GROUND-TRUTHED) (j) Coral	Sea Grass	Algae	Emerg Veg	No Cover	π_i	USERS Accuracy (%)	USERS CI (± %)
MAP DATA (i)	Coral	**0**					0.000	**n/a**	**n/a**
	Seagrass		**0.4334**	0.0388	0.0035	0.0247	0.500	**86.6**	**2.6**
	Algae	0.0017	0.0334	**0.2093**	0.0003	0.0081	0.253	**82.8**	**2.5**
	Emerg Veg				**0.0143**		0.014	**100.0**	**0.0**
	No Cover		0.0221	0.0279		**0.1825**	0.233	**78.5**	**5.8**
	n_{-j}	0.002	0.489	0.276	0.018	0.215	**1.000** <= n		
	PRODUCERS Accuracy (%)	**0.0**	**88.7**	**75.8**	**78.9**	**84.8**	P_o **83.9%**		
	PRODUCERS CI (± %)	**n/a**	**2.1**	**4.1**	**14.0**	**3.5**	**CI (±) 2.0%**		

Table 7. Error matrix for Detailed Biological Cover, L = 10-<50%, M = 50-<90%, H = 90-100%. The overall accuracy (P_o) was 76.5%. The Tau coefficient for equal probability of group membership (T_e) was 0.745, with a 95% Confidence Interval of 0.725 – 0.765. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

MAP DATA (i) — DETAILED COVER		Coral L	Coral M	Coral H	Seagrass L	Seagrass M	Seagrass H	Algae L	Algae M	Algae H	Emergent Vegetation L	Emergent Vegetation M	Emergent Vegetation H	No Cover	n_{i-}	USERS Accuracy (%)
Coral	L	**0**													0	**n/a**
Coral	M		**0**												0	**n/a**
Coral	H			**0**											0	**n/a**
Seagrass	L				**58**	12	2	8	15				1	25	121	**47.9**
Seagrass	M				6	**160**	7	5	11	1			2	7	199	**80.4**
Seagrass	H				3	15	**351**	4	10	1			2	3	389	**90.2**
Algae	L				1	13	1	**12**	26	5				6	64	**18.8**
Algae	M	2	4		11	62	17	12	**522**	15			1	15	661	**79.0**
Algae	H				2	7	5	2	60	**92**				8	176	**52.3**
Emergent Vegetation	L										**36**	1	1		38	**94.7**
Emergent Vegetation	M										4	**19**			23	**82.6**
Emergent Vegetation	H												**100**		100	**100.0**
No Cover					5	14		7	15	2				**157**	200	**78.5**
n_{-j}		2	4	0	86	283	383	50	659	116	40	20	107	221	**1971** <= n	
PRODUCERS Accuracy (%)		**0.0**	**0.0**	**n/a**	**67.4**	**56.5**	**91.6**	**24.0**	**79.2**	**79.3**	**90.0**	**95.0**	**93.5**	**71.0**	**P_o 76.5%**	

T_e = 0.745 ± 0.020

Table 8. Error matrix for Detailed Biological Cover (using individual cell probabilities P_{ij}); L = 10-<50%, M = 50-<90%, H = 90-100%. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 77.5% with a 95% Confidence Interval of 75.5% - 79.5%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

DETAILED COVER		Coral			Seagrass			Algae			Emergent Vegetation			No Cover	π_i	USERS Accuracy (%)	USERS CI (± %)
MAP DATA (i)		L	M	H	L	M	H	L	M	H	L	M	H				
Coral	L	**0.000**													0.0000	**n/a**	**n/a**
Coral	M		**0.000**												0.0000	**n/a**	**n/a**
Coral	H			**0.000**											0.0000	**n/a**	**n/a**
Seagrass	L				**0.022**	0.004	0.001	0.003	0.006				0.000	0.009	0.0450	**47.9**	**9.1**
Seagrass	M				0.003	**0.074**	0.003	0.002	0.005	0.000			0.001	0.003	0.0917	**80.4**	**5.6**
Seagrass	H				0.003	0.014	**0.328**	0.004	0.009	0.001			0.002	0.003	0.3637	**90.2**	**3.0**
Algae	L				0.000	0.001	0.000	**0.001**	0.002	0.000				0.000	0.0040	**18.8**	**9.8**
Algae	M	0.001	0.001		0.003	0.018	0.005	0.004	**0.154**	0.004			0.000	0.004	0.1948	**79.0**	**3.2**
Algae	H				0.001	0.002	0.002	0.001	0.018	0.028				0.002	0.0540	**52.3**	**7.5**
Emergent Vegetation	L										**0.000**	0.000	0.000		0.0000	**94.7**	**7.2**
Emergent Vegetation	M										0.000	**0.000**			0.0000	**82.6**	**15.8**
Emergent Vegetation	H												**0.014**		0.0142	**100.0**	**0.0**
No Cover					0.006	0.016		0.008	0.017	0.002				**0.183**	0.2325	**78.5**	**5.8**
$n_{\cdot j}$		0.001	0.001	0.000	0.037	0.130	0.339	0.022	0.211	0.037	0.000	0.000	0.018	0.205	**1.000 <= *n***		
PRODUCERS Accuracy (%)		**0.0**	**0.0**	**n/a**	**58.5**	**56.8**	**96.9**	**3.4**	**72.8**	**77.0**	**97.7**	**80.1**	**80.4**	**89.0**	**P_o**	**77.5%**	
PRODUCERS CI (± %)		**n/a**	**n/a**	**n/a**	**11.7**	**5.6**	**1.1**	**2.1**	**4.2**	**9.8**	**2.1**	**31.6**	**14.1**	**2.7**	**CI (±)**	**2.0%**	

Table 9. Error matrix for Detailed Coral Cover of all habitats. The overall accuracy (P_o) was 89.6%. The Tau coefficient for equal probability of group membership (T_e) was 0.861, with a 95% Confidence Interval of 0.843 – 0.879. Blank cells indicate 0 occurrences.

		TRUE (GROUND-TRUTHED) (j)					
CORAL COVER		Coral				n_{i-}	USERS Accuracy (%)
		0-<10%	10-<50%	50-<90%	>90%		
MAP DATA (i) Coral	0-<10%	**1647**	62	2		1711	**96.3**
	10-<50%	129	**119**	11	1	260	**45.8**
	50-<90%			**0**		0	**n/a**
	>90%				**0**	0	**n/a**
n_{-j}		1776	181	13	1	**1971 <= *n***	
PRODUCERS Accuracy (%)		**92.7**	**65.7**	**0.0**	**0.0**	**P_o 89.6%**	

T_e = 0.861 ± 0.018

Table 10. Error matrix for Detailed Coral Cover (using individual cell probabilities P_{ij}) of all habitats. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 93.4% with a 95% Confidence Interval of 92.5% - 94.3%. Blank cells indicate 0 occurrences.

		TRUE (GROUND-TRUTHED) (j)						
CORAL COVER		Coral				π_i	USERS Accuracy (%)	USERS CI (± %)
		0-<10%	10-<50%	50-<90%	>90%			
MAP DATA (i) Coral	0-<10%	**0.908**	0.034	0.001		0.9430	**96.3**	**0.9**
	10-<50%	0.028	**0.026**	0.002	0.000	0.0570	**45.8**	**6.2**
	50-<90%			**0.000**		0.0000	**n/a**	**n/a**
	>90%				**0.000**	0.0000	**n/a**	**n/a**
n_{-j}		0.936	0.060	0.004	0.000	**1.000 <= *n***		
PRODUCERS Accuracy (%)		**97.0**	**43.3**	**0.0**	**0.0**	**P_o 93.4%**		
PRODUCERS CI (± %)		**0.4**	**7.0**	**n/a**	**n/a**	**CI (±) 0.9%**		

Table 11. Error matrix for Detailed Coral Cover of Coral Reef and Hardbottom habitats only. The overall accuracy (P_o) was 79.8%. The Tau coefficient for equal probability of group membership (T_e) was 0.731, with a 95% Confidence Interval of 0.694 – 0.768. Blank cells indicate 0 occurrences.

		TRUE (GROUND-TRUTHED) (j)					
CORAL COVER		**Coral**				**n_{i-}**	**USERS Accuracy (%)**
		0-<10%	**10-<50%**	**50-<90%**	**>90%**		
MAP DATA (i) — **Coral**	**0-<10%**	**521**	60	2		583	**89.4**
	10-<50%	88	**119**	11	1	219	**54.3**
	50-<90%			**0**		0	**n/a**
	>90%				**0**	0	**n/a**
n_{-j}		609	179	13	1	**802**	**<= *n***
PRODUCERS Accuracy (%)		**85.6**	**66.5**	**0.0**	**0.0**	**P_o**	**79.8%**

T_e = 0.731 ± 0.037

Table 12. Error matrix for Detailed Coral Cover (using individual cell probabilities P_{ij}) of Coral Reef and Hardbottom habitats only. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 82.7% with a 95% Confidence Interval of 80.3% - 85.1%. Blank cells indicate 0 occurrences.

		TRUE (GROUND-TRUTHED) (j)						
CORAL COVER		**Coral**				**π_i**	**USERS Accuracy (%)**	**USERS CI (± %)**
		0-<10%	**10-<50%**	**50-<90%**	**>90%**			
MAP DATA (i) — **Coral**	**0-<10%**	**0.725**	0.083	0.003		0.8109	**89.4**	**2.6**
	10-<50%	0.076	**0.103**	0.009	0.001	0.1891	**54.3**	**6.7**
	50-<90%			**0.000**		0.0000	**n/a**	**n/a**
	>90%				**0.000**	0.0000	**n/a**	**n/a**
n_{-j}		0.801	0.186	0.012	0.001	**1.000**	**<= *n***	
PRODUCERS Accuracy (%)		**90.5**	**55.2**	**0.0**	**0.0**	**P_o**	**82.7%**	
PRODUCERS CI (± %)		**1.4**	**6.8**	**n/a**	**n/a**	**CI (±)**	**2.4%**	

DISCUSSION

Thus far, four accuracy assessments have been conducted for smaller regions of interest in the larger draft NOAA FL Keys benthic habitat map because resources, budgets, and logistical constraints precluded a comprehensive assessment of the entire mapped area. These areas were chosen as biogeographically-representative corridors within the total benthic habitat map area and not only captured a wide diversity of habitats, but were also characterized by frequent transitions between habitat types, ensuring a well-distributed, representative set of survey locations.

Since the assessments were conducted under the same methodologies, they are not only directly comparable, but combinable as well. Each assessment stands alone as a good measure of map accuracy for its given region; however, their combination is a better determination of the accuracy of the entire mapped area. Although the overall results might appear to be the average between ROIs, it was not so. Combining the data *a priori* and then analyzing them in a new error matrix gave values different from the mean of four error tables. This was especially obvious with the results from the tables adjusted for map marginal proportions. This analysis required the combination of the areas of each habitat type from all ROIs which changed their proportions to the total combined mapped area; therefore the combined analysis is not simply a mean of the two previous accuracy assessments. The results for each ROI are presented in Appendices 1 – 4.

4.1 COMBINED ROI 1 – 4 GEOMORPHOLOGICAL STRUCTURE

Major Geomorphological Structure

The Major Geomorphological Structure attributes in the combined ROIs were mapped with the greatest accuracy as indicated by the overall accuracy (90.4%), the overall accuracy adjusted for known map marginal proportions (92.6%), and the Tau coefficient (0.807), which adjusted for the number of map categories (Tables 1 and 2). Of the 190 classification errors, 141 were due to Unconsolidated Sediment being found in polygons classified as Coral Reef/Colonized Hardbottom. This overall accuracy was 0.4% lower than the combined accuracy assessment of ROI 1 and 2 (Walker et al. 2013).

The overall accuracy for Major Structure was similar to other NOAA mapping efforts, although recent changes to the NOAA classification scheme precluded a direct comparison to most. Kendall et al. (2001) reported a very similar overall Major Structure accuracy of 93.6% for the NOAA Puerto Rico and Virgin Island maps. The Hawaiian Islands AA used a similar classification scheme, but its distinctive geology and ecology confounded direct comparison to the Lower Keys AA. These issues aside, BAE Systems (2007) reported an overall accuracy of 98.1% for Major Structure, 7.7% higher, but only 5.5% higher after adjusting for known map marginal proportions. And finally, the NOAA St. John effort reported 96% total map accuracy for Major Geomorphologic Structure (Zitello et al., 2009). They adopted the methods reported in Walker and Foster (2009) to adjust for map marginal proportions, which increased the overall accuracy to 96.7%.

The overall accuracy was also consistent with other nearby regional mapping accuracies implementing similar classification schemes. Walker et al. (2008) reported an overall map accuracy of 89.6% for Broward County, FL; Riegl et al. (2005) reported an overall accuracy of 89.2% for Palm Beach County, FL; Miami-Dade County map overall accuracy was 93.0% (Walker 2009); and the adjusted accuracy in Martin County was 94.9% (Walker and Gilliam, 2013).

Detailed Geomorphological Structure

The combined ROI Detailed Geomorphological Structure attributes were mapped at the third highest level of accuracy, lower than Major Structure and Cover but higher Detailed Cover, as indicated by the overall accuracy (84.6%), the overall accuracy adjusted for known map marginal proportions (85.9%), and the Tau coefficient (0.829) (Tables 3 and 4). The overall accuracy was 5.4% less than the 90.0% reported for the Hawaiian Islands AA (BAE Systems, 2007). Twelve of the eighteen user's and producer's accuracies were greater than 80% and six of those were greater than 90%.

Pavement was the third most surveyed habitat (411), yet it had the third lowest user's accuracy (75.9%) of all classes. Areas mapped as Pavement were the most frequently confused with other habitats (Table 3). While the largest single error was mapping Sand habitat as Pavement, six other categories were found within mapped Pavement polygons. Of the 411 sites mapped as Pavement, 99 were found to be Sand (50), Mud (30), Aggregate Reef (10), Spur and Groove (3), Aggregated Patch Reefs (3), Individual Patch Reef (2), or Rubble (1). This demonstrates that Pavement was a difficult category to map and was much more variable than the other Detailed Structure Classes. Conversely, Pavement had a high adjusted producer's accuracy (86.2%). Of the 356 total field sites identified as Pavement, only 44 were misclassified as Mud (22), Sand (8), Aggregate Reef (8), Reef Rubble (4), or Aggregated Patch Reefs (2).

The producer's accuracies were fairly high (>73%) for all classes until adjusting for map marginal proportions. While most producer's accuracies remained high and some improved after adjustment, both Aggregated and Individual Patch Reefs dropped substantially (to 65% and 55% respectively). This indicates that these habitats were not mapped as well and many more likely exist that are not depicted in the maps. Of those depicted in the maps, 89.4% were correct for Individual Patch Reefs and 56.7% for Aggregated. These results are somewhat similar to previous analyses (Walker and Foster, 2010; Walker et al. 2103).

Sand was the second-most variable habitat mapped even though it had relatively high user accuracy (87.5%). Polygons mapped as Sand contained seven other categories; Aggregate Reef (4), Aggregated Patch Reef (4), Individual Patch Reef (7), Spur and Groove (1), Rubble (1), Pavement (8) and Mud (43). Discerning the difference between Sand and Mud was a challenge in the videos because the distinction ultimately depends on the Wentworth scale (*i.e.*, differences in grain size). Since sediment was not collected at each site, a judgment call was made based on how much turbidity was created by the camera hitting the bottom, the presence of certain flora and fauna, and occasionally, by direct inspection of the seabed. Given the difficulty of classifying the drop-video samples, it would seem that visually distinguishing sand and mud from satellite images would be very difficult, and that it would be necessary to rely on other information such as biogeographic zone or energy regime.

Sand had the most frequent and variable producer's errors in the map. One hundred and twenty-seven sites ground-truthed as Sand were mapped as one of seven other classes; Aggregate Reef (23), Aggregated Patch Reef (24), Individual Patch Reef (3), Rubble (8), Pavement (50), Mud (18), and Pavement with Sand Channels (1). This was a very similar outcome to the previous analyses (Walker et al, 2013; Walker and Foster, 2010). Sand and hardbottom can typically be distinguished with a high degree of success in shallow, clear water (Kendall et al. 2001, Zitello et al. 2009). Having lower than expected success in mapping sand may have come from several sources. First, the errors could have arisen from a scaling mismatch between the mapping and the accuracy assessment. The minimum mapping unit (mmu) for the mapping was 0.4 hectares (4046 m^2). It was neither practical nor feasible to survey each accuracy assessment point at that scale, however to account for some of the difference, the vessel was allowed to drift at each location to get a better understanding of the general area instead of one particular point. Since the accuracy assessment point was not surveyed at the mmu, it is unknown whether the point was smaller than the mmu and should not be included as an error. All videos were assumed to represent the habitat at each location, therefore, if only Sand was seen throughout the video, it was considered a Sand site. Sand patches smaller than the mmu may have been large enough to be deemed a Sand habitat in the video, which would unfairly increase the producer's error for Sand.

The second possible source of error for mapping sand comes from the mapping protocol. The images being used to map the Lower Keys were acquired over a time series between 2005 and 2006. NOAA's visual interpretation methodology is a time consuming process that can take up to a year or more for a given portion of the map to be drawn, groundtruthed and finalized, creating a lag time between image collection and map publication. For example, the ROI-1 map was created in 2007-2008 and assessed for accuracy in early 2009, but the data upon which the maps are based are from 2006 and earlier. Thus the maps being released in 2012 are based on six-year-old data. This time lag can have significant impact on the accuracy of the maps. Low relief habitats can often be covered and uncovered by sand movement during large storm events (Walker and Foster 2009, Walker 2009, Walker et al. 2008, Gilliam 2007) and the ephemeral nature of the system, especially in low relief pavement and seagrass habitats, likely contributed to some of the map errors. For example, the area in southern Miami-Dade is very dynamic and recent mapping showed large changes over a three year period, where large areas on the order of several thousand square meters that used to be dense seagrass were now sand (Walker 2009). Furthermore, Walker and Foster (2009) found large changes in satellite images in ROI-1 between 2005 and 2006. Some large-scale changes were noted in the 2006 imagery that were not reflected in the map nor the AA, presumably due to extreme storm conditions during hurricanes Katrina and Wilma indicating that large-scale changes have occurred in the recent past within the mapped area. These types of changes throughout the region affect the benthic habitat map accuracy and may degrade it over time. The longer the time lag between data collection and map creation, there is a greater probability for errors to be introduced into the map based on temporal changes in habitat through time and not actual mapping methodological errors. Nonetheless, they are errors in the map and are considered so in the accuracy assessment.

4.2 COMBINED ROI 1 – 4 BIOLOGICAL COVER

Major Biological Cover

As with previous analyses, the Major Biological Cover attributes were mapped at the second highest level of accuracy, lower than the Major Geomorphological Structure and higher than Detailed Structure and Cover, as indicated by the overall accuracy (85.1%), the overall accuracy adjusted for known map marginal proportions (83.9%), and the Tau coefficient (0.814) (Tables 5 and 6). Major Cover total accuracy was 0.5% lower than the combined ROI 1 and 2 analysis (Walker et al 2013).

Total map accuracy for Major Cover ranked low amongst other comparable recent studies. Zitello et al. (2009) reported a 93.7% total accuracy for St. John (93.0% adjusted for map marginal proportions); a 8.6% and 9.1% difference respectively. Similarly, BAE Systems (2007) reported an overall accuracy of 92.1% for Major Cover, 7.0% higher than the Florida Keys.

The allocation of sample points among Major Biological Cover categories was notably unbalanced. The reclassification of coral habitats to other types and the combination of Macroalgae and Turf algae into one category exacerbated the unequal sampling between Major Cover categories (Walker et al, 2013). Previous analyses separated these two categories and put about equal effort between Macroalgae and Turf algae sites. Combining these into one class caused 900 sites classified as Algae habitat, yet it only comprised 25.3% of the area. While this bias was ameliorated by adjusting for known map marginal proportions (Card 1982), the extreme disproportional sampling may have affected the assessment results.

Aside from Emergent Vegetation, almost every Major Cover class was confused with each other except Coral, which was only confused with Algae. The single largest confusion in the analysis was 119 points mapped as Algae that were found to be Seagrass (Table 5). The distinction between Algae and Seagrass was challenging. It is rare to find seagrass without algae interspersed. Seagrass and many types of algae often cohabitate, making them difficult to distinguish in imagery. Furthermore, Algae cover is highly variable, typically ephemeral, and can significantly change temporally and with large energy regimes or nutrient inputs into an area. Due to the time lag between data collection, mapping, and accuracy assessment, it is not surprising that Algae had high confusion.

No Cover producer's accuracy was 71.0%. Sixty-four locations found to be No Cover in the field data were mapped as one of two other habitats; Seagrass (35) and Algae (29). The low accuracy in this category was partly due to the large proportion of No Cover in the ROIs as evinced by correcting for map marginal proportions, which raised the accuracy to 84.8% (Table 6). This outcome indicates that there is likely less biological cover in the ROIs than was reflected in the maps. No Cover user's accuracy was higher (78.5%) indicating that the polygons outlined as No Cover were fairly realistic.

Detailed Biological Cover

Detailed Biological Cover attributes were mapped at the lowest level of accuracy as indicated by the overall accuracy (76.5%), the overall accuracy adjusted for known map marginal proportions (77.5%), and the Tau coefficient (0.745). These results were similar to those in the previous combined analysis (70.5% overall accuracy, 78.0% overall adjusted accuracy, and 0.688 Tau) and less than St. Johns (81.7%, Zitello et al. 2009) and Hawaii mapping where BAE Systems (2007) reported an 83.6% overall accuracy, 7.1% higher. Adjusting the data for the known map marginal proportions increased the overall accuracy by 1%.

Emergent Vegetation was mapped the best having 100% user's classification accuracy and 96.4% producer's. One hundred and sixty-one sites were verified by ground-truthed samples as having mangroves. Five were confused with Seagrass and one with Algae. The 10% - <50% and 50% - <90% sites were evaluated by satellite imagery because most sites were still too dense on a small spatial scale. Presumably, the lack of an overlying water column accounted for the high classification scores. The six errors may have been due to image rectification errors or landscape changes that occurred since the collection of the satellite images used for interpretation.

Algae cover contributed to most of the errors in the matrix. Algae were included in 76% (354) of the total 464 errors found in the assessment. One hundred and twenty errors occurred between Algae cover classes. The greatest single-class confusion existed between the Algae 50% - <90% and Algae 90% - 100% categories (Table 7). Sixty errors occurred where the habitat mapped as Algae 90 - 100% were found to be Algae 50% - <90%.

There was also high confusion between Algae and Seagrass cover. One hundred and nineteen errors accounted for Seagrass mapped as Algae and fifty-five errors were Algae mapped as Seagrass. There was confusion between almost every cover category, but the highest confusion (62) was Seagrass 50% - <90% mapped as Algae 50% - <90%.

The user's accuracy for Algae 90% - 100% (52.3%) and Algae 10% - <50% (18.8%) showed that these classes were very difficult to map. The worst accuracy was the adjusted Producer's for Algae 10% - <50% which equaled 3.4%. Other Algae producer's accuracy were adequate (79.2% and 79.3%) and did not change much after adjustment (72.8% and 77%).

These results indicate that the maps do not accurately depict low cover and very high cover dominated communities of algae. It must be noted, however, that as a result of the map reclassification which combined Turf and Macro Algae into one class, there is extreme disproportionate sampling between Algae classes that may have affected the assessment results. Of the 901 sites assessed mapped as Algae, 4.7% (43/901) were mapped as Low cover and 17.1% were mapped as High (154/901).

High (90% - 100%) and Medium (50% - <90%) Seagrass cover user's accuracies and High cover producer's accuracy were fairly high (>80%), however Low cover user's accuracy and Medium and Low cover producer's accuracy were low. Confusion within the Seagrass Detailed Cover classes was minimal (45 of 614). There were many instances where Seagrass polygons contained Algae (55) or No Cover (35) and Seagrass cover was found to dominate in 119 Algae polygons and 19 No Cover. These results are better than the previous combined analysis of ROIs 1 and 2 where Low and Medium Seagrass classes were found to be less than 70% for user's and producer's accuracy and High seagrass cover was 83% and 84% respectively.

Another source of Biological Cover confusion was revealed by the producer's accuracy of the No Cover category. While the adjusted producer's accuracy was high (89%), 64 sites found as No Cover were mapped as something else (Table 7). Six Detailed Cover habitat types contained No Cover groundtruthing sites, including 25 in Seagrass 10% - <50%. It is unknown if these areas were larger than the mmu and may have been small patches of unmapped sand within other habitats, however it is also possible that some of these areas have changed significantly since the satellite imagery was collected and the maps were created. Since the satellite imagery was collected, a number of large storms, including hurricanes Katrina and Wilma, have passed near the area and contributed to localized high energy conditions. These storms likely shifted large amounts of sand, burying pavement and seagrass and exposing previously buried substrate. This may help explain why so many communities mapped as other Cover types were found to be No Cover, however without recent imagery, the extent of these changes remains unknown.

Detailed Coral Cover

The percent of Coral Cover (a combination of both the soft coral canopy and live hard corals) was attributed to every polygon in the map, thus a separate analysis was required to evaluate Detailed Coral Cover accuracy. This yielded high total map accuracy (89.6%) (Table 9) and adjusted total map accuracy (93.4%) (Table 10). The accuracy varied greatly between the two categories. User's and Producer's accuracies for Coral 0% - <10% were over 92%. Conversely, Coral 10% - <50% user's and producer's accuracies were 45.8% and 65.7% respectively. The producer's accuracy dropped to 43.3% after adjusting to map marginal proportions. The adjustment for map proportions was relevant here due to the large disparity of area between the two classes. The map contained 658.5 km^2 of Coral 0% - <10% (94.3%) and 39.8 km^2 of Coral 10% - <50% (5.7%). Further 1711 of AA points were in Coral 0% - <10% and 260 were in Coral 10%-<50%. There were no mapped polygons of Coral 50% - <90% and 90% - 100% in any region, however field data indicated 13 Coral 50% - <90% and one Coral 90% - 100%. These sites were mostly located in the patch reefs of Hawk Channel. It is unknown if these sites met the minimum mapping unit criteria of the mapping, but the field data indicated high Coral cover at these locations.

Unequal surveying between classes was high yet it was somewhat proportional to the area of habitats. Coral 0% - 10% comprised 86.8% (1711) of the survey sites and only 13.2% (260) were Coral 10% - <50%. There was confusion between coral classes where 129 locations mapped as Coral 10% - <50% were actually Coral 0% - <10% and 62 locations mapped as Coral 0% - <10% were found to be Coral 10% -<50%. These were a lot of errors, however, they did not drastically affect the overall, user's, and producer's accuracy percentages due to the high number of samples in the Coral 0% - <10% class.

Although it is possible to analyze the data this way, it may not be a realistic reflection of accuracy because it evaluated coral cover in non-coral habitat which inflated the number of correct sites. Many of the habitats that exist in the map are not expected to contain coral. Locations in Unconsolidated Sediment (Sand and Mud) are not expected to have high coral cover and these habitats comprised 74.5% (392.7 km^2) of the mapped area and 45.4% (894) of the accuracy assessment locations. Including these areas in an evaluation of coral cover may not provide an accurate result because the number of correct points is increased by assessing habitats where coral does not reside. To account for this, Coral Cover was also evaluated at only those sites found to be Coral Reef and Hardbottom habitats (Tables 11 and 12).

Total map accuracy for mapping Coral Cover on Coral Reef and Hardbottom habitats was 79.8% and 82.7% after adjusting for habitat proportions. Unequal sampling remained in the analysis, yet it was somewhat proportional to the habitat area so adjusting for map proportions did not drastically differ. The producer's accuracy was relatively low for Coral 10% - <50% (66.5%) and worse after adjustment (55.2%). This suggests that substantial higher coral cover areas were not well depicted in the map. Furthermore the relatively low user's accuracy indicates that the areas of Coral 10% - <50% portrayed in the map are highly variable.

4.3 POINT V. TRANSECT

There are no strict rules as to which ground validation sampling methodology works best. Assessments at point locations and areal assessments are equally valid (Stehman and Czaplewski, 1998), but ideally the reference data should be collected at the mmu's scale (Stadelmann, 1994). The lower Keys mapping protocol dictated that the maps were drawn at a 1:6000 scale with a 625 sq m minimum mapping unit. It was neither practical nor economically feasible to assess the seafloor at this scale. However, assessment at a localized point wasn't ideal because it would not give a good representation of the area surrounding the sample point at the map scale. Localized point ground validation would have been problematic in mixed habitats like Aggregated Patch Reefs where patch reefs may be spread out and might not be visible at all discrete locations in the polygon. For example, a random point may be placed in the polygon such that the video would contain only Unconsolidated Sediments. This would be considered an error in the map, yet the error was caused by the difference in scale between the map and the assessment method rather than a true map error. This could also cause problems in the assessment of Biological Cover which can vary significantly on small spatial scales. In order to address this issue, AA samples in this effort were taken near the random sample location while drifting. The drift allowed for more of the surrounding area to be visited and recorded, thus giving more insight and confidence in the Geomorphological Structure and Biological Cover at a scale closer to the mmu. This also helped reduce the spatial errors associated with a precise GPS location.

The drifting assessment helped assess the transitions between habitats (i.e. the polygon borders) as well. A certain level of error is inherent in habitat transitions due to the scale of mapping (1:6000) and spatial errors in the imagery and GPS precision (Foody, 2002). Constraining sampling away from polygon boundaries to minimize spatial errors between the imagery and GPS is common practice (Dicks & Lo, 1990; Mickelson, Civco, & Silander, 1998; Richards, 1996; Wickham, O'Neill, Ritters, Wade, & Jones, 1997), however, this strategy may optimistically bias the results by not assessing the habitat transitions (Congalton & Plourde, 2000; Foody, 2002; Hammond & Verbyla, 1996; Muller et al., 1998; Yang et al., 2000; Zhu et al., 2000). Employing transect sampling and not constraining the samples from polygon edges allowed some component of the habitat transition errors to be captured. Although habitat transitions were not specifically targeted, assessed, or quantified, several occasions were encountered where the boat drifted from one habitat into another and the change was evident in the video. In these instances, the site location was considered the GPS coordinate from the point in the video where the targeted habitat was encountered.

4.4 ACCURACY REPRESENTATION FOR THE ENTIRE MAPPED AREA

Resources, budgets, and logistical constraints precluded a comprehensive assessment of the entire mapped area, thus biogeographically representative corridors within the total benthic habitat map area were selected for performing the accuracy assessment (Congalton, 1991; Stehman and Czaplewski, 1998). These corridors not only captured a wide diversity of habitats, but were also characterized by frequent transitions between habitat types. Biological Cover habitat and Geomorphological Structure in the entire Lower Keys map was represented in the sample area.

The true error of non-sampled portions of the map is ultimately unknown and further sampling in these areas of the map would allow for a better understanding of the entire map accuracy, however, the accuracy assessment ensured that a well-distributed, representative set of monitoring locations were surveyed that closely represented the entire mapped region. For this reason, it is thought to be a good measure of the map accuracies for the broader area. Many of the Biological Cover habitats were very small relative to the overall percentage of the entire mapped area; therefore the total map accuracy adjusted for marginal map proportions was likely a better gauge of the overall map accuracy than P_0. This, however, should not diminish the use of Tau as a metric to gauge map accuracy. Adjusting for marginal map proportions does not account for the probabilities of error due to increased number of classes, thus both metrics should be used as a gauge of the overall accuracy of the map products. Furthermore, removing the Unconsolidated Sediment habitat from the evaluation of Coral Cover proved useful and is recommended to provide a better understanding of the map accuracy of coral cover classes.

Table 13. Summary of adjusted accuracies for each habitat class in each ROI.

Habitat	ROI 1	ROI 2	ROI 3	ROI 4
Major Structure	96.5%	91.3%	90.9%	91.0%
Detailed Structure	82.4%	82.4%	89.6%	87.8%
Major Cover	79.3%	79.1%	86.4%	84.2%
Detailed Cover	76.5%	71.0%	85.9%	75.1%
Coral Cover	95.1%	92.5%	100.0%	86.4%
Coral Cover HB only	82.2%	87.0%	100.0%	57.7%

Some accuracy results varied drastically between ROIs while others did not. The ROIs refer to the following areas: ROIs 1 and 2 are considered lower Keys, ROI 3 was the Backcountry, and ROI 4 was off Key Largo (Figure 1). Table 13 shows a comparison of adjusted total map accuracies by habitat and ROI. Although Major Structure was the highest in ROI 1, over 5% higher than the others, it was mapped at a very high accuracy in all four regions. Detailed Structure and Major Cover were less accurate in the lower Keys than in the Backcountry and Key Largo area. Detailed Cover was most accurate in the Backcountry and about the same in other regions. Coral Cover was highest in the Backcountry and lowest in Key Largo.

There did not appear to be any pattern in overall accuracy declining over time. The maps were created in a similar order of the ROIs. As a new map section was created, a new ROI was selected and accuracy assessment performed. This is relevant in that although the time gap between image acquisition and mapping lengthen with each ROI, it does not appear to have impacted the total map accuracy results. In fact detailed Structure and Major Cover have higher accuracies in the most recent scenes versus the older ones of the lower Keys. Accuracy differences between regions are more likely due to regional image quality, water clarity, and habitat diversity and complexity.

For example the Backcountry (ROI 3) had the highest Detailed Structure accuracy (89.6%), however it only contained three of the nine available categories (Mud, Sand, and Pavement). All of the other categories were associated with different zones outside of the Backcountry, making it less confusing. Map accuracy is affected by the number of map categories, where higher accuracies are expected with fewer categories. ROI 3 was the only area missing the six reef structure categories. This was further exemplified in the ROI 3 Coral cover analyses. No areas were found in the Backcountry that had greater than 10% coral cover. Since none existed in the area, the map accuracy for coral cover was 100%. With only one cover category existing in the region, a very high accuracy is expected.

Conversely, regions with high habitat diversity (more categories) likely caused lower accuracies. For example Coral Cover on hardbottom habitats in ROI 4 was 57.7% accurate (Appendix 4.11). The ROI 4 coral cover analysis showed that three of the four cover categories were found in the field data, making it much harder to distinguish than in ROI 3. Of the 113 sites mapped as Coral 10% - <50%, 46% were correct. Fifty-five were found as Coral 0% - <10% and six were Coral 50% - <90%. The user's accuracy was also low (68.7%) for Coral 0% - <10% where 24 Coral 10% - <50% sites were mapped as Coral 0% - <10%.

Combining all results into a total map accuracy assessment gave a sense of how the overall map portrays the seascape, however it should be noted that large gaps in map coverage exist, especially between Marathon and Key Largo, a 137 km stretch. The results given in the appendices are more representative of their specific regions. ROIs 1 and 2 covered most of the lower Keys and their results are a good representation of map accuracy for that region. ROI 3 covered the Backcountry which had higher accuracies presumably due to a reduced diversity of habitats and lack of coral cover. ROI 4 is a good representation of the upper Keys map accuracy. It is difficult to know which assessment best represents the middle Keys. The landscape is more similar to the upper Keys, but Hawk Channel becomes deeper and more turbid.

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APPENDIX 1. Reclassified ROI 1 Accuracy Assessment Matrices

A.1.1. Error matrix for ROI 1 Major Geomorphological Structure. The overall accuracy (P_o) was 92.2%. The Tau coefficient for equal probability of group membership (T_e) was 0.845, with a 95% Confidence Interval of 0.798– 0. 892.

MAP (i)	*MAJOR STRUCTURE*	TRUE (GROUND-TRUTHED) (j) hard	soft	n_{i-}	USERS Accuracy (%)
	hard	**183**	36	219	**83.6**
	soft	3	**281**	284	**98.9**
	n_{-j}	186	317	**503**	**<= n**
	PRODUCERS Accuracy (%)	**98.4**	**88.6**	**P_o**	**92.2%**

T_e = 0.845 ± 0.047

A.1.2. Error matrix for ROI 1 Major Geomorphological Structure (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 96.5% with a 95% Confidence Interval of 95.2% – 97.8%.

MAP (i)	*MAJOR STRUCTURE*	TRUE (GROUND-TRUTHED) (j) hard	soft	π_i	USERS Accuracy (%)	USERS CI (± %)
	hard	**0.1354**	0.0266	0.162	**83.6**	**5.0**
	soft	0.0089	**0.8291**	0.838	**98.9**	**1.2**
	n_{-j}	0.144	0.856	**1.000**	**<= n**	
	PRODUCERS Accuracy (%)	**93.9**	**96.9**	**P_o**	**96.5%**	
	PRODUCERS CI (± %)	**6.6**	**0.9**	**CI (±)**	**1.3%**	

A.1.3. Error matrix for ROI 1 Detailed Geomorphological Structure. The overall accuracy (P_o) was 79.7%. The Tau coefficient for equal probability of group membership (T_e) was 0.775, with a 95% Confidence Interval of 0.736 – 0.814. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

MAP DATA (i) — ***DETAILED STRUCTURE***	Aggregate Reef	Aggregated Patch Reef	Individual Patch Reef	Spur and Groove	Rubble	Pavement	Pav w/ Sand Channels	Sand	Mud	n_{i-}	USERS Accuracy (%)
Aggregate Reef	**51**		1			1		3		56	**91.1**
Aggregated Patch Reef		**14**						4		18	**77.8**
Individual Patch Reef			**14**						1	15	**93.3**
Spur and Groove				**28**			3			31	**90.3**
Rubble	11				**17**	4		2		34	**50.0**
Pavement						**39**		11	15	65	**60.0**
Pav w/ Sand Channels							**0**			0	**n/a**
Sand			1			1		**113**	26	141	**80.1**
Mud			1					17	**125**	143	**87.4**
n_{-j}	62	14	17	28	17	45	3	150	167	**503 <= *n***	
PRODUCERS Accuracy (%)	**82.3**	**100.0**	**82.4**	**100.0**	**100.0**	**86.7**	**0.0**	**75.3**	**74.9**	**P_o 79.7%**	

T_e = 0.775 ± 0.039

A.1.4. Error matrix for ROI 1 Detailed Geomorphological Structure (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 82.4% with a 95% Confidence Interval of 78.5% – 86.3%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

MAP DATA (i) — ***DETAILED STRUCTURE***	Aggregate Reef	Aggregated Patch Reef	Individual Patch Reef	Spur and Groove	Rubble	Pavement	Pav w/ Sand Channels	Sand	Mud	π_i	USERS Accuracy (%)	USERS CI (± %)
Aggregate Reef	**0.0227**		0.0004			0.0004		0.0013		0.025	**91.1**	**7.6**
Aggregated Patch Reef		**0.0033**						0.0010		0.004	**77.8**	**19.6**
Individual Patch Reef			**0.0092**						0.0007	0.010	**93.3**	**12.9**
Spur and Groove				**0.0114**			0.0012			0.013	**90.3**	**10.6**
Rubble	0.0017				**0.0026**	0.0006		0.0003		0.005	**50.0**	**17.1**
Pavement						**0.0631**		0.0178	0.0243	0.105	**60.0**	**12.2**
Pav w/ Sand Channels							**0.0000**			0.000	**n/a**	**n/a**
Sand			0.0020			0.0020		**0.2238**	0.0515	0.279	**80.1**	**6.7**
Mud			0.0039					0.0664	**0.4883**	0.559	**87.4**	**5.5**
n_{-j}	0.024	0.003	0.016	0.011	0.003	0.066	0.001	0.311	0.565	**1.000 <= *n***		
PRODUCERS Accuracy (%)	**93.0**	**100.0**	**59.2**	**100.0**	**100.0**	**95.4**	**0.0**	**72.1**	**86.5**	**P_o 82.4%**		
PRODUCERS CI (± %)	**3.3**	**0.0**	**33.6**	**0.0**	**0.0**	**6.0**	**n/a**	**7.6**	**3.3**	**CI (±) 3.9%**		

A.1.5. Error matrix for ROI 1 Major Biological Cover. The overall accuracy (P_o) was 85.7%. The Tau coefficient for equal probability of group membership (T_e) was 0.821, with a 95% Confidence Interval of 0.783 – 0.859. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

MAP DATA (i) — MAJOR COVER	Coral	Sea Grass	Algae	Emerg Veg	No Cover	$n_{i\cdot}$	USERS Accuracy (%)
Coral	**0**					0	**n/a**
Seagrass		**87**	12		24	123	**70.7**
Algae	4	17	**188**		11	220	**85.5**
Emerg Veg				**66**		66	**100.0**
No Cover		2	2		**90**	94	**95.7**
$n_{\cdot j}$	4	106	202	66	125	**503** <= n	
PRODUCERS Accuracy (%)	**0.0**	**82.1**	**93.1**	**100.0**	**72.0**	P_o 85.7%	

T_e = 0.821 ± 0.038

A.1.6. Error matrix for ROI 1 Major Biological Cover (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 79.3% with a 95% Confidence Interval of 74.3% – 84.3%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

MAP DATA (i) — MAJOR COVER	Coral	Sea Grass	Algae	Emerg Veg	No Cover	π_i	USERS Accuracy (%)	USERS CI (± %)
Coral	**0**					0.000	**n/a**	**n/a**
Seagrass		**0.4193**	0.0578		0.1157	0.593	**70.7**	**8.2**
Algae	0.0030	0.0128	**0.1412**		0.0083	0.165	**85.5**	**4.8**
Emerg Veg				**0.0223**		0.022	**100.0**	**0.0**
No Cover		0.0047	0.0047		**0.2103**	0.220	**95.7**	**4.2**
$n_{\cdot j}$	0.003	0.437	0.204	0.022	0.334	**1.000** <= n		
PRODUCERS Accuracy (%)	**0.0**	**96.0**	**69.3**	**100.0**	**62.9**	P_o 79.3%		
PRODUCERS CI (± %)	**n/a**	**2.0**	**11.1**	**0.0**	**8.1**	CI (±) 5.0%		

A.1.7. Error matrix for ROI 1 Detailed Biological Cover, L = 10-<50%, M = 50-<90%, H = 90-100%. The overall accuracy (P_o) was 73.2%. The Tau coefficient for equal probability of group membership (T_e) was 0.709, with a 95% Confidence Interval of 0.667 – 0.751. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

MAP DATA (i)	DETAILED COVER	Coral L	Coral M	Coral H	Seagrass L	Seagrass M	Seagrass H	Algae L	Algae M	Algae H	Emergent Vegetation L	Emergent Vegetation M	Emergent Vegetation H	No Cover	n_{i-}	USERS Accuracy (%)
Coral	L	**0**													0	**n/a**
Coral	M		**0**												0	**n/a**
Coral	H			**0**											0	**n/a**
Seagrass	L				**12**	1	1	2	3					18	37	**32.4**
Seagrass	M				6	**22**	3	2	1					5	39	**56.4**
Seagrass	H				1	4	**37**	2	2					1	47	**78.7**
Algae	L				1			**1**	9					1	12	**8.3**
Algae	M	1	3		3	8	2	6	**130**	5				7	165	**78.8**
Algae	H				1	1	1	1	26	**10**				3	43	**23.3**
Emergent Vegetation	L										**24**				24	**100.0**
Emergent Vegetation	M											**8**			8	**100.0**
Emergent Vegetation	H												**34**		34	**100.0**
No Cover					1	1		2						**90**	94	**95.7**
n_{-j}		1	3	0	25	37	44	16	171	15	24	8	34	125	**503**	**<= *n***
PRODUCERS Accuracy (%)		**0.0**	**0.0**	**n/a**	**48.0**	**59.5**	**84.1**	**6.3**	**76.0**	**66.7**	**100.0**	**100.0**	**100.0**	**72.0**	**P_o**	**73.2%**

T_e = 0.709 ± 0.042

A.1.8. Error matrix for ROI 1 Detailed Biological Cover (using individual cell probabilities P_{ij}); L = 10-<50%, M = 50-<90%, H = 90-100%. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 76.5% with a 95% Confidence Interval of 70.9% - 82.1%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

MAP DATA (i)	DETAILED COVER	Coral L	Coral M	Coral H	Seagrass L	Seagrass M	Seagrass H	Algae L	Algae M	Algae H	Emergent Vegetation L	Emergent Vegetation M	Emergent Vegetation H	No Cover	π_i	USERS Accuracy (%)	USERS CI (± %)
Coral	L	**0.000**													0.0000	**n/a**	**n/a**
Coral	M		**0.000**												0.0000	**n/a**	**n/a**
Coral	H			**0.000**											0.0000	**n/a**	**n/a**
Seagrass	L				**0.021**	0.002	0.002	0.004	0.005					0.032	0.0652	**32.4**	**15.4**
Seagrass	M				0.016	**0.057**	0.008	0.005	0.003					0.013	0.1009	**56.4**	**15.9**
Seagrass	H				0.009	0.036	**0.336**	0.018	0.018					0.009	0.4267	**78.7**	**11.9**
Algae	L				0.001			**0.001**	0.005					0.001	0.0067	**8.3**	**16.0**
Algae	M	0.001	0.003		0.003	0.007	0.002	0.005	**0.118**	0.005				0.006	0.1497	**78.8**	**6.4**
Algae	H				0.000	0.000	0.000	0.000	0.005	0.002				0.001	0.0088	**23.3**	**12.9**
Emergent Vegetation	L										**0.000**				0.0001	**100.0**	**0.0**
Emergent Vegetation	M											**0.000**			0.0000	**100.0**	**0.0**
Emergent Vegetation	H												**0.022**		0.0221	**100.0**	**0.0**
No Cover					0.002	0.002		0.005						**0.210**	0.2196	**95.7**	**4.2**
n_{-j}		0.001	0.003	0.000	0.052	0.105	0.347	0.038	0.154	0.007	0.000	0.000	0.022	0.272	**1.000**	**<= *n***	
PRODUCERS Accuracy (%)		**0.0**	**0.0**	**n/a**	**41.0**	**54.3**	**96.7**	**1.5**	**76.4**	**31.1**	**100.0**	**100.0**	**100.0**	**77.4**	**P_o**	**76.5%**	
PRODUCERS CI (± %)		**n/a**	**n/a**	**n/a**	**21.0**	**19.7**	**2.7**	**3.0**	**13.1**	**22.3**	**0.0**	**0.0**	**0.0**	**6.9**	**CI (±)**	**5.6%**	

A.1.9. Error matrix for ROI 1 Detailed Coral Cover in all habitats. The overall accuracy (P_o) was 91.1%. The Tau coefficient for equal probability of group membership (T_e) was 0.881, with a 95% Confidence Interval of 0.848–0.914. Blank cells indicate 0 occurrences.

CORAL COVER		TRUE (GROUND-TRUTHED) (j) Coral 0-<10%	10-<50%	50-<90%	>90%	n_{i-}	USERS Accuracy (%)
MAP DATA (i) Coral	0-<10%	**428**	15			443	**96.6**
	10-<50%	24	**30**	5	1	60	**50.0**
	50-<90%			**0**		0	**n/a**
	>90%				**0**	0	**n/a**
n_{-j}		452	45	5	1	**503** <= n	
PRODUCERS Accuracy (%)		**94.7**	**66.7**	**0.0**	**0.0**	P_o **91.1%**	

T_e = **0.881 ± 0.033**

A.1.10. Error matrix for ROI 1 Detailed Coral Cover (using individual cell probabilities P_{ij}) in all habitats. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 95.1% with a 95% Confidence Interval of 93.4% - 96.8%. Blank cells indicate 0 occurrences.

CORAL COVER		TRUE (GROUND-TRUTHED) (j) Coral 0-<10%	10-<50%	50-<90%	>90%	π_i	USERS Accuracy (%)	USERS CI (± %)
MAP DATA (i) Coral	0-<10%	**0.936**	0.033			0.9684	**96.6**	**1.7**
	10-<50%	0.013	**0.016**	0.003	0.001	0.0316	**50.0**	**12.9**
	50-<90%			**0.000**		0.0000	**n/a**	**n/a**
	>90%				**0.000**	0.0000	**n/a**	**n/a**
n_{-j}		0.948	0.049	0.003	0.001	**1.000** <= n		
PRODUCERS Accuracy (%)		**98.7**	**32.5**	**0.0**	**0.0**	P_o **95.1%**		
PRODUCERS CI (± %)		**0.4**	**12.5**	**n/a**	**n/a**	CI (±) **1.7%**		

A.1.11. Error matrix for Detailed Coral Cover of Coral Reef and Hardbottom habitats only. The overall accuracy (P_o) was 77.4%. The Tau coefficient for equal probability of group membership (T_e) was 0.699, with a 95% Confidence Interval of 0.619 – 0.779. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

MAP DATA (i)	CORAL COVER	Coral 0-<10%	Coral 10-<50%	Coral 50-<90%	Coral >90%	n_{i-}	USERS Accuracy (%)
Coral	0-<10%	**114**	15			129	**88.4**
Coral	10-<50%	21	**30**	5	1	57	**52.6**
Coral	50-<90%			**0**		0	**n/a**
Coral	>90%				**0**	0	**n/a**
	n_{-j}	135	45	5	1	**186** <= n	
	PRODUCERS Accuracy (%)	**84.4**	**66.7**	**0.0**	**0.0**	P_o **77.4%**	

T_e = **0.699 ± 0.080**

A.1.12. Error matrix for Detailed Coral Cover (using individual cell probabilities P_{ij}) of Coral Reef and Hardbottom habitats only. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 82.2% with a 95% Confidence Interval of 77.0% - 87.4%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

MAP DATA (i)	CORAL COVER	Coral 0-<10%	Coral 10-<50%	Coral 50-<90%	Coral >90%	π_i	USERS Accuracy (%)	USERS CI (± %)
Coral	0-<10%	**0.732**	0.096			0.8281	**88.4**	**5.6**
Coral	10-<50%	0.063	**0.090**	0.015	0.003	0.1719	**52.6**	**13.2**
Coral	50-<90%			**0.000**		0.0000	**n/a**	**n/a**
Coral	>90%				**0.000**	0.0000	**n/a**	**n/a**
	n_{-j}	0.795	0.187	0.015	0.003	**1.000** <= n		
	PRODUCERS Accuracy (%)	**92.0**	**48.4**	**0.0**	**0.0**	P_o **82.2%**		
	PRODUCERS CI (± %)	**2.6**	**13.7**	**n/a**	**n/a**	CI (±) **5.2%**		

APPENDIX 2. Reclassified ROI 2 Accuracy Assessment Matrices

A.2.1. Error matrix for ROI 2 Major Geomorphological Structure. The overall accuracy (P_o) was 89.3%. The Tau coefficient for equal probability of group membership (T_e) was 0.786, with a 95% Confidence Interval of 0.730– 0. 842.

	MAJOR STRUCTURE	**TRUE (GROUND-TRUTHED) (j)** hard	soft	n_{i-}	**USERS Accuracy (%)**
MAP (i)	**hard**	**245**	42	287	**85.4**
	soft	9	**180**	189	**95.2**
	n_{-j}	254	222	**476**	**<=** n
	PRODUCERS Accuracy (%)	**96.5**	**81.1**	P_o	**89.3%**

$T_e = 0.786 \pm 0.056$

A.2.2. Error matrix for ROI 2 Major Geomorphological Structure (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 91.3% with a 95% Confidence Interval of 88.8% – 93.8%.

	MAJOR STRUCTURE	**TRUE (GROUND-TRUTHED) (j)** hard	soft	π_i	**USERS Accuracy (%)**	**USERS CI (± %)**
MAP (i)	**hard**	**0.3372**	0.0578	0.395	**85.4**	**4.2**
	soft	0.0288	**0.5762**	0.605	**95.2**	**3.1**
	n_{-j}	0.366	0.634	**1.000**	**<=** n	
	PRODUCERS Accuracy (%)	**92.1**	**90.9**	P_o	**91.3%**	
	PRODUCERS CI (± %)	**4.7**	**2.4**	**CI (±)**	**2.5%**	

A.2.3. Error matrix for ROI 2 Detailed Geomorphological Structure. The overall accuracy (P_o) was 83.2%. The Tau coefficient for equal probability of group membership (T_e) was 0.813, with a 95% Confidence Interval of 0.776 – 0.850. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

DETAILED STRUCTURE — **MAP DATA (i)**	Aggregate Reef	Aggregated Patch Reef	Individual Patch Reef	Spur and Groove	Rubble	Pavement	Pav w/ Sand Channels	Sand	Mud	n_{i-}	USERS Accuracy (%)
Aggregate Reef	**14**				1	4		9		28	**50.0**
Aggregated Patch Reef		**8**				1		3		12	**66.7**
Individual Patch Reef			**15**					1	1	17	**88.2**
Spur and Groove	1			**42**						43	**97.7**
Rubble	1				**72**			6		79	**91.1**
Pavement	5	3	2	3	1	**72**		16	6	108	**66.7**
Pav w/ Sand Channels							**0**			0	**n/a**
Sand	1	2	3		1	1		**128**	7	143	**89.5**
Mud			1						**45**	46	**97.8**
n_{-j}	22	13	21	45	75	78	0	163	59	**476 <= *n***	
PRODUCERS Accuracy (%)	**63.6**	**61.5**	**71.4**	**93.3**	**96.0**	**92.3**	**n/a**	**78.5**	**76.3**	**P_o 83.2%**	

T_e = 0.813 ± 0.037

A.2.4. Error matrix for ROI 2 Detailed Geomorphological Structure (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 82.4% with a 95% Confidence Interval of 78.6% – 86.2%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

DETAILED STRUCTURE — **MAP DATA (i)**	Aggregate Reef	Aggregated Patch Reef	Individual Patch Reef	Spur and Groove	Rubble	Pavement	Pav w/ Sand Channels	Sand	Mud	π_i	USERS Accuracy (%)	USERS CI (± %)
Aggregate Reef	**0.0202**				0.0014	0.0058		0.0130		0.040	**50.0**	**18.9**
Aggregated Patch Reef		**0.0129**				0.0016		0.0048		0.019	**66.7**	**27.2**
Individual Patch Reef			**0.0159**					0.0011	0.0011	0.018	**88.2**	**15.6**
Spur and Groove	0.0009			**0.0367**						0.038	**97.7**	**4.6**
Rubble	0.0002				**0.0167**			0.0014		0.018	**91.1**	**6.4**
Pavement	0.0121	0.0073	0.0048	0.0073	0.0024	**0.1742**		0.0387	0.0145	0.261	**66.7**	**9.1**
Pav w/ Sand Channels							**0.0000**			0.000	**n/a**	**n/a**
Sand	0.0037	0.0074	0.0112		0.0037	0.0037		**0.4763**	0.0260	0.532	**89.5**	**5.1**
Mud			0.0016						**0.0713**	0.073	**97.8**	**4.3**
n_{-j}	0.037	0.028	0.034	0.044	0.024	0.185	0.000	0.535	0.113	**1.000 <= *n***		
PRODUCERS Accuracy (%)	**54.4**	**46.8**	**47.5**	**83.5**	**68.7**	**94.0**	**n/a**	**89.0**	**63.1**	**P_o 82.4%**		
PRODUCERS CI (± %)	**21.3**	**24.7**	**21.4**	**15.7**	**26.4**	**5.0**	**n/a**	**3.4**	**12.6**	**CI (±) 3.8%**		

A.2.5. Error matrix for ROI 2 Major Biological Cover. The overall accuracy (P_o) was 85.5%. The Tau coefficient for equal probability of group membership (T_e) was 0.819, with a 95% Confidence Interval of 0.779 – 0.859. Blank cells indicate 0 occurrences.

MAP DATA (i) — MAJOR COVER	TRUE (GROUND-TRUTHED) (j): Coral	Sea Grass	Algae	Emerg Veg	No Cover	n_{i-}	USERS Accuracy (%)
Coral	**0**					0	**n/a**
Seagrass		**96**	11		9	116	**82.8**
Algae	1	19	**247**		15	282	**87.6**
Emerg Veg				**37**		37	**100.0**
No Cover		5	9		**27**	41	**65.9**
n_{-j}	1	120	267	37	51	**476 <= n**	
PRODUCERS Accuracy (%)	**0.0**	**80.0**	**92.5**	**100.0**	**52.9**	**P_o 85.5%**	

T_e = 0.819 ± 0.040

A.2.6. Error matrix for ROI 2 Major Biological Cover (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 79.1% with a 95% Confidence Interval of 73.6% – 84.6%. Blank cells indicate 0 occurrences.

MAP DATA (i) — MAJOR COVER	TRUE (GROUND-TRUTHED) (j): Coral	Sea Grass	Algae	Emerg Veg	No Cover	π_i	USERS Accuracy (%)	USERS CI (± %)
Coral	**0**					0.000	**n/a**	**n/a**
Seagrass		**0.2363**	0.0271		0.0222	0.286	**82.8**	**7.0**
Algae	0.0014	0.0258	**0.3354**		0.0204	0.383	**87.6**	**3.9**
Emerg Veg				**0.0024**		0.002	**100.0**	**0.0**
No Cover		0.0401	0.0723		**0.2168**	0.329	**65.9**	**14.8**
n_{-j}	0.001	0.302	0.435	0.002	0.259	**1.000 <= n**		
PRODUCERS Accuracy (%)	**0.0**	**78.2**	**77.1**	**100.0**	**83.6**	**P_o 79.1%**		
PRODUCERS CI (± %)	**n/a**	**9.3**	**8.1**	**0.0**	**6.4**	**CI (±) 5.5%**		

A.2.7. Error matrix for ROI 2 Detailed Biological Cover, L = 10-<50%, M = 50-<90%, H = 90-100%. The overall accuracy (P_o) was 73.1%. The Tau coefficient for equal probability of group membership (T_e) was 0.709, with a 95% Confidence Interval of 0.666 – 0.752. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

DETAILED COVER (MAP DATA (i))		Coral			Seagrass			Algae			Emergent Vegetation			No Cover	n_{i-}	USERS Accuracy
		L	M	H	L	M	H	L	M	H	L	M	H			(%)
Coral	L	**0**													0	**n/a**
	M		**0**												0	**n/a**
	H			**0**											0	**n/a**
Seagrass	L				**25**				4					7	36	**69.4**
	M					**33**		2	4					1	40	**82.5**
	H				1	1	**36**		1					1	40	**90.0**
Algae	L							**4**	10	2				4	20	**20.0**
	M	1			4	6	4	3	**162**	9				6	195	**83.1**
	H					1	4		33	**24**				5	67	**35.8**
Emergent Vegetation	L										**0**				0	**n/a**
	M											**0**			0	**n/a**
	H												**37**		37	**100.0**
No Cover					3	2		1	6	2				**27**	41	**65.9**
n_{-j}		1	0	0	33	43	44	10	220	37	0	0	37	51	**476 <= *n***	
PRODUCERS Accuracy (%)		**0.0**	**n/a**	**n/a**	**75.8**	**76.7**	**81.8**	**40.0**	**73.6**	**64.9**	**n/a**	**n/a**	**100.0**	**52.9**	**P_o 73.1%**	

T_e = 0.709 ± 0.043

A.2.8. Error matrix for ROI 2 Detailed Biological Cover (using individual cell probabilities P_{ij}); L = 10-<50%, M = 50-<90%, H = 90-100%. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 71.0% with a 95% Confidence Interval of 65.5% - 76.5%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

DETAILED COVER (MAP DATA (i))		Coral			Seagrass			Algae			Emergent Vegetation			No Cover	π_i	USERS Accuracy	USERS CI
		L	M	H	L	M	H	L	M	H	L	M	H			(%)	(± %)
Coral	L	**0.000**													0.0000	**n/a**	**n/a**
	M		**0.000**												0.0000	**n/a**	**n/a**
	H			**0.000**											0.0000	**n/a**	**n/a**
Seagrass	L				**0.042**				0.007					0.012	0.0605	**69.4**	**15.4**
	M					**0.057**		0.003	0.007					0.002	0.0691	**82.5**	**12.0**
	H				0.004	0.004	**0.140**		0.004					0.004	0.1560	**90.0**	**9.5**
Algae	L							**0.001**	0.002	0.000				0.001	0.0039	**20.0**	**17.9**
	M	0.002			0.006	0.009	0.006	0.005	**0.250**	0.014				0.009	0.3014	**83.1**	**5.4**
	H					0.001	0.005		0.038	0.028				0.006	0.0776	**35.8**	**11.7**
Emergent Vegetation	L										**0.000**				0.0000	**n/a**	**n/a**
	M											**0.000**			0.0000	**n/a**	**n/a**
	H												**0.002**		0.0024	**100.0**	**0.0**
No Cover					0.024	0.016		0.008	0.048	0.016				**0.217**	0.3292	**65.9**	**14.8**
n_{-j}		0.002	0.000	0.000	0.076	0.087	0.151	0.017	0.356	0.058	0.000	0.000	0.002	0.250	**1.000 <= *n***		
PRODUCERS Accuracy (%)		**0.0**	**n/a**	**n/a**	**55.1**	**65.2**	**92.8**	**4.7**	**70.3**	**47.8**	**n/a**	**n/a**	**100.0**	**86.7**	**P_o 71.0%**		
PRODUCERS CI (± %)		**n/a**	**n/a**	**n/a**	**21.4**	**18.7**	**4.7**	**6.2**	**7.9**	**21.3**	**n/a**	**n/a**	**0.0**	**5.7**	**CI (±) 5.5%**		

A.2.9. Error matrix for ROI 2 Detailed Coral Cover in all habitats. The overall accuracy (P_o) was 91.4%. The Tau coefficient for equal probability of group membership (T_e) was 0.885, with a 95% Confidence Interval of 0.851 – 0.919. Blank cells indicate 0 occurrences.

		TRUE (GROUND-TRUTHED) (j)					
CORAL COVER		**Coral**					
		0-<10%	**10-<50%**	**50-<90%**	**>90%**	**n_{i-}**	**USERS Accuracy (%)**
MAP DATA (i) Coral	**0-<10%**	**398**	23			421	**94.5**
	10-<50%	18	**37**			55	**67.3**
	50-<90%			**0**		0	**n/a**
	>90%				**0**	0	**n/a**
n_{-j}		416	60	0	0	**476 <= n**	
PRODUCERS Accuracy (%)		**95.7**	**61.7**	**n/a**	**n/a**	**P_o 91.4%**	

T_e = 0.885 ± 0.034

A.2.10. Error matrix for ROI 2 Detailed Coral Cover (using individual cell probabilities P_{ij}) in all habitats. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 92.5% with a 95% Confidence Interval of 90.2% - 94.8%. Blank cells indicate 0 occurrences.

		TRUE (GROUND-TRUTHED) (j)						
CORAL COVER		**Coral**						
		0-<10%	**10-<50%**	**50-<90%**	**>90%**	**π_i**	**USERS Accuracy (%)**	**USERS CI (± %)**
MAP DATA (i) Coral	**0-<10%**	**0.873**	0.050			0.9237	**94.5**	**2.2**
	10-<50%	0.025	**0.051**			0.0763	**67.3**	**12.7**
	50-<90%			**0.000**		0.0000	**n/a**	**n/a**
	>90%				**0.000**	0.0000	**n/a**	**n/a**
n_{-j}		0.898	0.102	0.000	0.000	**1.000 <= n**		
PRODUCERS Accuracy (%)		**97.2**	**50.4**	**n/a**	**n/a**	**P_o 92.5%**		
PRODUCERS CI (± %)		**1.0**	**11.2**	**n/a**	**n/a**	**CI (±) 2.3%**		

A.2.11. Error matrix for Detailed Coral Cover of Coral Reef and Hardbottom habitats only. The overall accuracy (P_o) was 87.0%. The Tau coefficient for equal probability of group membership (T_e) was 0.827, with a 95% Confidence Interval of 0.772 – 0.882. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

CORAL COVER		Coral 0-<10%	Coral 10-<50%	Coral 50-<90%	Coral >90%	n_{i-}	USERS Accuracy (%)
MAP DATA (i) Coral	0-<10%	**184**	21			205	**89.8**
	10-<50%	12	**37**			49	**75.5**
	50-<90%			**0**		0	**n/a**
	>90%				**0**	0	**n/a**
n_{-j}		196	58	0	0	**254**	<= *n*
PRODUCERS Accuracy (%)		**93.9**	**63.8**	**n/a**	**n/a**	P_o	**87.0%**

T_e = 0.827 ± 0.055

A.2.12. Error matrix for Detailed Coral Cover (using individual cell probabilities P_{ij}) of Coral Reef and Hardbottom habitats only. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 87.0% with a 95% Confidence Interval of 82.8% - 91.2%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

CORAL COVER		Coral 0-<10%	Coral 10-<50%	Coral 50-<90%	Coral >90%	π_i	USERS Accuracy (%)	USERS CI (± %)
MAP DATA (i) Coral	0-<10%	**0.724**	0.083			0.8068	**89.8**	**4.2**
	10-<50%	0.047	**0.146**			0.1932	**75.5**	**12.3**
	50-<90%			**0.000**		0.0000	**n/a**	**n/a**
	>90%				**0.000**	0.0000	**n/a**	**n/a**
n_{-j}		0.771	0.229	0.000	0.000	**1.000**	<= *n*	
PRODUCERS Accuracy (%)		**93.9**	**63.8**	**n/a**	**n/a**	P_o	**87.0%**	
PRODUCERS CI (± %)		**2.9**	**10.3**	**n/a**	**n/a**	CI (±)	**4.2%**	

APPENDIX 3. ROI 3 Accuracy Assessment Matrices

A.3.1. Error matrix for ROI 3 Major Geomorphological Structure. The overall accuracy (P_o) was 91.1%. The Tau coefficient for equal probability of group membership (T_e) was 0.823, with a 95% Confidence Interval of 0.774– 0. 872.

	MAJOR STRUCTURE	TRUE (GROUND-TRUTHED) (j) hard	soft	n_{i-}	USERS Accuracy (%)
MAP (i)	hard	**142**	21	163	**87.1**
	soft	24	**321**	345	**93.0**
	n_{-j}	166	342	**508**	<= n
	PRODUCERS Accuracy (%)	**85.5**	**93.9**	P_o	**91.1%**

T_e = **0.823 ± 0.049**

A.3.2. Error matrix for ROI 3 Major Geomorphological Structure (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 90.9% with a 95% Confidence Interval of 88.2% – 93.4%.

	MAJOR STRUCTURE	TRUE (GROUND-TRUTHED) (j) hard	soft	π_i	USERS Accuracy (%)	USERS CI (± %)
MAP (i)	hard	**0.3222**	0.0476	0.370	**87.1**	**5.2**
	soft	0.0438	**0.5863**	0.630	**93.0**	**2.7**
	n_{-j}	0.366	0.634	**1.000**	<= n	
	PRODUCERS Accuracy (%)	**88.0**	**92.5**	P_o	**90.9%**	
	PRODUCERS CI (± %)	**4.2**	**2.8**	CI (±)	**2.6%**	

A.3.3. Error matrix for ROI 3 Detailed Geomorphological Structure. The overall accuracy (P_o) was 89.4%. The Tau coefficient for equal probability of group membership (T_e) was 0.882, with a 95% Confidence Interval of 0.852 – 0.912. Blank cells indicate 0 occurrences.

DETAILED STRUCTURE — MAP DATA (i) / TRUE (GROUND-TRUTHED) (j)	Aggregate Reef	Aggregated Patch Reef	Individual Patch Reef	Spur and Groove	Rubble	Pavement	Pav w/ Sand Channels	Sand	Mud	n_{i-}	USERS Accuracy (%)
Aggregate Reef	**0**									0	**n/a**
Aggregated Patch Reef		**0**								0	**n/a**
Individual Patch Reef			**0**							0	**n/a**
Spur and Groove				**0**						0	**n/a**
Rubble					**0**					0	**n/a**
Pavement						**142**		15	6	163	**87.1**
Pav w/ Sand Channels							**0**			0	**n/a**
Sand						2		**47**	8	57	**82.5**
Mud						22		1	**265**	288	**92.0**
n_{-j}	0	0	0	0	0	166	0	63	279	**508 <= *n***	
PRODUCERS Accuracy (%)	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**85.5**	**n/a**	**74.6**	**95.0**	**P_o 89.4%**	

T_e = 0.882 ± 0.030

A.3.4. Error matrix for ROI 3 Detailed Geomorphological Structure (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 89.6% with a 95% Confidence Interval of 86.9% – 92.3%. Blank cells indicate 0 occurrences.

DETAILED STRUCTURE — MAP DATA (i) / TRUE (GROUND-TRUTHED) (j)	Aggregate Reef	Aggregated Patch Reef	Individual Patch Reef	Spur and Groove	Rubble	Pavement	Pav w/ Sand Channels	Sand	Mud	π_i	USERS Accuracy (%)	USERS CI (± %)
Aggregate Reef	**0.0000**									0.000	**n/a**	**n/a**
Aggregated Patch Reef		**0.0000**								0.000	**n/a**	**n/a**
Individual Patch Reef			**0.0000**							0.000	**n/a**	**n/a**
Spur and Groove				**0.0000**						0.000	**n/a**	**n/a**
Rubble					**0.0000**					0.000	**n/a**	**n/a**
Pavement						**0.3222**		0.0340	0.0136	0.370	**87.1**	**5.2**
Pav w/ Sand Channels							**0.0000**			0.000	**n/a**	**n/a**
Sand						0.0023		**0.0551**	0.0094	0.067	**82.5**	**10.1**
Mud						0.0430		0.0020	**0.5183**	0.563	**92.0**	**3.2**
n_{-j}	0.000	0.000	0.000	0.000	0.000	0.368	0.000	0.091	0.541	**1.000 <= *n***		
PRODUCERS Accuracy (%)	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**87.7**	**n/a**	**60.5**	**95.8**	**P_o 89.6%**		
PRODUCERS CI (± %)	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**4.3**	**n/a**	**11.8**	**2.2**	**CI (±) 2.7%**		

A.3.5. Error matrix for ROI 3 Major Biological Cover. The overall accuracy (P_o) was 86.0%. The Tau coefficient for equal probability of group membership (T_e) was 0.825, with a 95% Confidence Interval of 0.788 – 0.863. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

MAP DATA (i)	MAJOR COVER	Coral	Sea Grass	Algae	Emerg Veg	No Cover	n_{i-}	USERS Accuracy (%)
	Coral	**0**					0	**n/a**
	Seagrass		**270**	21	2		293	**92.2**
	Algae		38	**124**		1	163	**76.1**
	Emerg Veg				**43**		43	**100.0**
	No Cover		9			**0**	9	**0.0**
	n_{-j}	0	317	145	45	1	**508** <= n	
	PRODUCERS Accuracy (%)	**n/a**	**85.2**	**85.5**	**95.6**	**0.0**	P_o **86.0%**	

T_e = **0.825 ± 0.038**

A.3.6. Error matrix for ROI 3 Major Biological Cover (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 86.4% with a 95% Confidence Interval of 83.3% – 89.5%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

MAP DATA (i)	MAJOR COVER	Coral	Sea Grass	Algae	Emerg Veg	No Cover	π_i	USERS Accuracy (%)	USERS CI (± %)
	Coral	**0**					0.000	**n/a**	**n/a**
	Seagrass		**0.5665**	0.0441	0.0042		0.615	**92.2**	**3.1**
	Algae		0.0848	**0.2766**		0.0022	0.364	**76.1**	**6.7**
	Emerg Veg				**0.0208**		0.021	**100.0**	**0.0**
	No Cover		0.0008			**0**	0.001	**0.0**	**0.0**
	n_{-j}	0.000	0.652	0.321	0.025	0.002	**1.000** <= n		
	PRODUCERS Accuracy (%)	**n/a**	**86.9**	**86.3**	**83.2**	**0.0**	P_o **86.4%**		
	PRODUCERS CI (± %)	**n/a**	**3.2**	**5.1**	**19.7**	**n/a**	**CI (±) 3.1%**		

A.3.7. Error matrix for ROI 3 Detailed Biological Cover, L = 10-<50%, M = 50-<90%, H = 90-100%. The overall accuracy (P_o) was 82.1%. The Tau coefficient for equal probability of group membership (T_e) was 0.806, with a 95% Confidence Interval of 0.770 – 0.842. Blank cells indicate 0 occurrences.

MAP DATA (i)	DETAILED COVER	TRUE (GROUND-TRUTHED) (j): Coral			Seagrass			Algae			Emergent Vegetation			No Cover	n_{i-}	USERS Accuracy
		L	M	H	L	M	H	L	M	H	L	M	H			(%)
Coral	L	**0**													0	**n/a**
Coral	M		**0**												0	**n/a**
Coral	H			**0**											0	**n/a**
Seagrass	L				**14**	3		2	7						26	**53.8**
Seagrass	M					**67**	1	1	6						75	**89.3**
Seagrass	H				1	4	**180**		5				2		192	**93.8**
Algae	L					6		**5**	2					1	14	**35.7**
Algae	M					25	7	3	**114**						149	**76.5**
Algae	H									**0**					0	**n/a**
Emergent Vegetation	L										**12**	1	1		14	**85.7**
Emergent Vegetation	M										4	**11**			15	**73.3**
Emergent Vegetation	H												**14**		14	**100.0**
No Cover					1	8								**0**	9	**0.0**
	n_{-j}	0	0	0	16	113	188	11	134	0	16	12	17	1	**508**	**<= *n***
	PRODUCERS Accuracy (%)	**n/a**	**n/a**	**n/a**	**87.5**	**59.3**	**95.7**	**45.5**	**85.1**	**n/a**	**75.0**	**91.7**	**82.4**	**0.0**	**P_o**	**82.1%**

T_e = 0.806 ± 0.036

A.3.8. Error matrix for ROI 3 Detailed Biological Cover (using individual cell probabilities P_{ij}); L = 10-<50%, M = 50-<90%, H = 90-100%. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 85.9% with a 95% Confidence Interval of 82.8% - 89.0%. Blank cells indicate 0 occurrences.

MAP DATA (i)	DETAILED COVER	TRUE (GROUND-TRUTHED) (j): Coral			Seagrass			Algae			Emergent Vegetation			No Cover	π_i	USERS Accuracy	USERS CI
		L	M	H	L	M	H	L	M	H	L	M	H			(%)	(± %)
Coral	L	**0.000**													0.0000	**n/a**	**n/a**
Coral	M		**0.000**												0.0000	**n/a**	**n/a**
Coral	H			**0.000**											0.0000	**n/a**	**n/a**
Seagrass	L				**0.009**	0.002		0.001	0.005						0.0176	**53.8**	**19.6**
Seagrass	M					**0.132**	0.002	0.002	0.012						0.1473	**89.3**	**7.1**
Seagrass	H				0.002	0.009	**0.422**		0.012				0.005		0.4499	**93.8**	**3.5**
Algae	L					0.002		**0.002**	0.001					0.000	0.0056	**35.7**	**25.6**
Algae	M					0.060	0.017	0.007	**0.274**						0.3580	**76.5**	**6.9**
Algae	H									0.000					0.0000	**n/a**	**n/a**
Emergent Vegetation	L										**0.002**	0.000	0.000		0.0024	**85.7**	**18.7**
Emergent Vegetation	M										0.000	**0.001**			0.0014	**73.3**	**22.8**
Emergent Vegetation	H												**0.017**		0.0170	**100.0**	**0.0**
No Cover					0.000	0.001								**0.000**	0.0008	**0.0**	**0.0**
	n_{-j}	0.000	0.000	0.000	0.012	0.206	0.441	0.013	0.303	0.000	0.002	0.001	0.022	0.000	**1.000**	**<= *n***	
	PRODUCERS Accuracy (%)	**n/a**	**n/a**	**n/a**	**79.6**	**63.8**	**95.7**	**15.9**	**90.4**	**n/a**	**84.5**	**85.8**	**77.8**	**0.0**	**P_o**	**85.9%**	
	PRODUCERS CI (± %)	**n/a**	**n/a**	**n/a**	**31.8**	**7.6**	**2.8**	**15.2**	**4.3**	**n/a**	**11.6**	**23.8**	**23.5**	**n/a**	**CI (±)**	**3.1%**	

A.3.9. Error matrix for ROI 3 Detailed Coral Cover in all habitats. The overall accuracy (P_o) was 100%. The Tau coefficient for equal probability of group membership (T_e) was 1.0. Blank cells indicate 0 occurrences.

CORAL COVER		TRUE (GROUND-TRUTHED) (j) Coral 0-<10%	10-<50%	50-<90%	>90%	n_{i-}	USERS Accuracy (%)
MAP DATA (i) Coral	0-<10%	**508**				508	**100.0**
	10-<50%		**0**			0	**n/a**
	50-<90%			**0**		0	**n/a**
	>90%				**0**	0	**n/a**
n_{-j}		508	0	0	0	**508 <= n**	
PRODUCERS Accuracy (%)		**100.0**	**n/a**	**n/a**	**n/a**	**P_o 100.0%**	

$T_e = 1 \pm 0.0$

A.3.10. Error matrix for ROI 3 Detailed Coral Cover (using individual cell probabilities P_{ij}) in all habitats. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 100%. Blank cells indicate 0 occurrences.

CORAL COVER		TRUE (GROUND-TRUTHED) (j) Coral 0-<10%	10-<50%	50-<90%	>90%	π_i	USERS Accuracy (%)	USERS CI (± %)
MAP DATA (i) Coral	0-<10%	**1.000**				1.0000	**100.0**	**0.0**
	10-<50%		**0.000**			0.0000	**n/a**	**n/a**
	50-<90%			**0.000**		0.0000	**n/a**	**n/a**
	>90%				**0.000**	0.0000	**n/a**	**n/a**
n_{-j}		1.000	0.000	0.000	0.000	**1.000 <= n**		
PRODUCERS Accuracy (%)		**100.0**	**n/a**	**n/a**	**n/a**	**P_o 100.0%**		
PRODUCERS CI (± %)		**0.0**	**n/a**	**n/a**	**n/a**	**CI (±) 0**		

A.3.11. Error matrix for ROI 3 Detailed Coral Cover of Coral Reef and Hardbottom habitats only. The overall accuracy (P_o) was 100.0%. The Tau coefficient for equal probability of group membership (T_e) was 1.0. Blank cells indicate 0 occurrences.

CORAL COVER		TRUE (GROUND-TRUTHED) (j) Coral 0-<10%	10-<50%	50-<90%	>90%	n_{i-}	USERS Accuracy (%)
MAP DATA (i) Coral	0-<10%	166				166	100.0
	10-<50%		0			0	n/a
	50-<90%			0		0	n/a
	>90%				0	0	n/a
n_{-j}		166	0	0	0	166 <= n	
PRODUCERS Accuracy (%)		100.0	n/a	n/a	n/a	P_o 100.0%	

$T_e = 1 \pm 0.0$

A.3.12. Error matrix for ROI 3 Detailed Coral Cover (using individual cell probabilities P_{ij}) of Coral Reef and Hardbottom habitats only. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 100.0% . Blank cells indicate 0 occurrences.

CORAL COVER		TRUE (GROUND-TRUTHED) (j) Coral 0-<10%	10-<50%	50-<90%	>90%	π_i	USERS Accuracy (%)	USERS CI (± %)
MAP DATA (i) Coral	0-<10%	1.000				1.0000	100.0	0.0
	10-<50%		0.000			0.0000	n/a	n/a
	50-<90%			0.000		0.0000	n/a	n/a
	>90%				0.000	0.0000	n/a	n/a
n_{-j}		1.000	0.000	0.000	0.000	1.000 <= n		
PRODUCERS Accuracy (%)		100.0	n/a	n/a	n/a	P_o 100.0%		
PRODUCERS CI (± %)		0.0	n/a	n/a	n/a	CI (±) 0.0%		

APPENDIX 3. ROI 4 Accuracy Assessment Matrices

A.4.1. Error matrix for ROI 4 Major Geomorphological Structure. The overall accuracy (P_o) was 88.2%. The Tau coefficient for equal probability of group membership (T_e) was 0.763, with a 95% Confidence Interval of 0.705– 0. 821.

	MAJOR STRUCTURE	TRUE (GROUND-TRUTHED) (j): hard	soft	n_{i-}	USERS Accuracy (%)
MAP (i)	hard	**185**	40	225	**82.2**
	soft	17	**240**	257	**93.4**
	n_{-j}	202	280	**482**	**<= n**
	PRODUCERS Accuracy (%)	**91.6**	**85.7**	**P_o**	**88.2%**

T_e = 0.763 ± 0.058

A.4.2. Error matrix for ROI 4 Major Geomorphological Structure (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 91.0% with a 95% Confidence Interval of 88.3% – 93.6%.

	MAJOR STRUCTURE	TRUE (GROUND-TRUTHED) (j): hard	soft	π_i	USERS Accuracy (%)	USERS CI (± %)
MAP (i)	hard	**0.1785**	0.0386	0.217	**82.2**	**5.1**
	soft	0.0518	**0.7311**	0.783	**93.4**	**3.1**
	n_{-j}	0.230	0.770	**1.000**	**<= n**	
	PRODUCERS Accuracy (%)	**77.5**	**95.0**	**P_o**	**91.0%**	
	PRODUCERS CI (± %)	**8.2**	**1.4**	**CI (±)**	**2.7%**	

A.4.3. Error matrix for ROI 4 Detailed Geomorphological Structure. The overall accuracy (P_o) was 85.5%. The Tau coefficient for equal probability of group membership (T_e) was 0.839, with a 95% Confidence Interval of 0.804 – 0.874. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j) / **MAP DATA (i)**

DETAILED STRUCTURE	**Aggregate Reef**	**Aggregated Patch Reef**	**Individual Patch Reef**	**Spur and Groove**	**Rubble**	**Pavement**	**Pav w/ Sand Channels**	**Sand**	**Mud**	**n_{i-}**	**USERS Accuracy (%)**
Aggregate Reef	**23**					3		9		35	**65.7**
Aggregated Patch Reef		**12**				1		17		30	**40.0**
Individual Patch Reef			**13**					2		15	**86.7**
Spur and Groove				**22**	1					23	**95.7**
Rubble					**9**					9	**100.0**
Pavement	5					**59**		8	3	75	**78.7**
Pav w/ Sand Channels						1	**36**	1		38	**94.7**
Sand	4	2	6	1		4		**184**	2	203	**90.6**
Mud									**54**	54	**100.0**
n_{-j}	32	14	19	23	10	68	36	221	59	**482 <= *n***	
PRODUCERS Accuracy (%)	**71.9**	**85.7**	**68.4**	**95.7**	**90.0**	**86.8**	**100.0**	**83.3**	**91.5**	**P_o 85.5%**	

T_e = 0.839 ± 0.035

A.4.4. Error matrix for ROI 4 Detailed Geomorphological Structure (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 87.8% with a 95% Confidence Interval of 84.5% – 91.2%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j) / **MAP DATA (i)**

DETAILED STRUCTURE	**Aggregate Reef**	**Aggregated Patch Reef**	**Individual Patch Reef**	**Spur and Groove**	**Rubble**	**Pavement**	**Pav w/ Sand Channels**	**Sand**	**Mud**	**π_i**	**USERS Accuracy (%)**	**USERS CI (± %)**
Aggregate Reef	**0.0134**					0.0017		0.0052		0.020	**65.7**	**16.0**
Aggregated Patch Reef		**0.0101**				0.0008		0.0143		0.025	**40.0**	**17.9**
Individual Patch Reef			**0.0072**					0.0011		0.008	**86.7**	**17.6**
Spur and Groove				**0.0123**	0.0006					0.013	**95.7**	**8.5**
Rubble					**0.0006**					0.001	**100.0**	**0.0**
Pavement	0.0079					**0.0931**		0.0126	0.0047	0.118	**78.7**	**9.5**
Pav w/ Sand Channels						0.0008	**0.0298**	0.0008		0.031	**94.7**	**7.2**
Sand	0.0150	0.0075	0.0225	0.0037		0.0150		**0.6888**	0.0075	0.760	**90.6**	**4.1**
Mud									**0.0230**	0.023	**100.0**	**0.0**
n_{-j}	0.036	0.018	0.030	0.016	0.001	0.111	0.030	0.723	0.035	**1.000 <= *n***		
PRODUCERS Accuracy (%)	**36.9**	**57.5**	**24.2**	**76.7**	**51.2**	**83.5**	**100.0**	**95.3**	**65.3**	**P_o 87.8%**		
PRODUCERS CI (± %)	**17.6**	**36.1**	**15.2**	**35.7**	**48.9**	**11.5**	**7.6**	**1.4**	**21.9**	**CI (±) 3.4%**		

A.4.5. Error matrix for ROI 4 Major Biological Cover. The overall accuracy (P_o) was 82.6%. The Tau coefficient for equal probability of group membership (T_e) was 0.783, with a 95% Confidence Interval of 0.741 – 0.825. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

	MAJOR COVER	Coral	Sea Grass	Algae	Emerg Veg	No Cover	n_{i-}	USERS Accuracy (%)
MAP DATA (i)	Coral	**0**					0	**n/a**
	Seagrass		**158**	14	3	2	177	**89.3**
	Algae	1	44	**188**	1	2	236	**79.7**
	Emerg Veg				**15**		15	**100.0**
	No Cover		3	14		**39**	56	**69.6**
	n_{-j}	1	205	216	19	43	**484**	**<= n**
	PRODUCERS Accuracy (%)	**0.0**	**77.1**	**87.0**	**78.9**	**90.7**	**P_o**	**82.6%**

T_e = 0.783 ± 0.042

A.4.6. Error matrix for ROI 4 Major Biological Cover (using individual cell probabilities P_{ij}). The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 84.2% with a 95% Confidence Interval of 80.6% – 87.8%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

	MAJOR COVER	Coral	Sea Grass	Algae	Emerg Veg	No Cover	π_i	USERS Accuracy (%)	USERS CI (± %)
MAP DATA (i)	Coral	**0**					0.000	**n/a**	**n/a**
	Seagrass		**0.5391**	0.0478	0.0102	0.0068	0.604	**89.3**	**4.7**
	Algae	0.0009	0.0407	**0.1740**	0.0009	0.0019	0.218	**79.7**	**5.2**
	Emerg Veg				**0.0174**		0.017	**100.0**	**0.0**
	No Cover		0.0086	0.0401		**0.1116**	0.160	**69.6**	**12.3**
	n_{-j}	0.001	0.588	0.262	0.029	0.120	**1.000**	**<= n**	
	PRODUCERS Accuracy (%)	**0.0**	**91.6**	**66.5**	**60.9**	**92.8**	**P_o**	**84.2%**	
	PRODUCERS CI (± %)	**n/a**	**2.3**	**7.9**	**25.3**	**7.8**	**CI (±)**	**3.6%**	

A.4.7. Error matrix for ROI 4 Detailed Biological Cover, L = 10-<50%, M = 50-<90%, H = 90-100%. The overall accuracy (P_o) was 76.7%. The Tau coefficient for equal probability of group membership (T_e) was 0.747, with a 95% Confidence Interval of 0.706 – 0.788. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

DETAILED COVER		**Coral**			**Seagrass**			**Algae**			**Emergent Vegetation**			**No Cover**	**n i -**	**USERS Accuracy**
		L	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**			**(%)**
MAP DATA (i) **Coral**	**L**	**0**													0	**n/a**
Coral	**M**		**0**												0	**n/a**
Coral	**H**			**0**											0	**n/a**
Seagrass	**L**				**7**	8	1	4	1				1		22	**31.8**
Seagrass	**M**					**38**	3			1			2	1	45	**84.4**
Seagrass	**H**					6	**95**	3	4	1				1	110	**86.4**
Algae	**L**					7	1	**2**	4	4					18	**11.1**
Algae	**M**		1		4	22	4		**117**	1			1	2	152	**77.0**
Algae	**H**				1	5		1	1	**58**					66	**87.9**
Emergent Vegetation	**L**										**0**				0	**n/a**
Emergent Vegetation	**M**											**0**			0	**n/a**
Emergent Vegetation	**H**												**15**		15	**100.0**
No Cover						3		4	10					**39**	56	**69.6**
n - j		0	1	0	12	89	104	14	137	65	0	0	19	43	**484**	**<= *n***
PRODUCERS Accuracy (%)		**n/a**	**0.0**	**n/a**	**58.3**	**42.7**	**91.3**	**14.3**	**85.4**	**89.2**	**n/a**	**n/a**	**78.9**	**90.7**	**P_o**	**76.7%**

T_e = 0.747 ± 0.041

A.4.8. Error matrix for ROI 4 Detailed Biological Cover (using individual cell probabilities P_{ij}); L = 10-<50%, M = 50-<90%, H = 90-100%. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 75.1% with a 95% Confidence Interval of 71.1% - 79.2%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

DETAILED COVER		**Coral**			**Seagrass**			**Algae**			**Emergent Vegetation**			**No Cover**	**π_i**	**USERS Accuracy**	**USERS CI**
		L	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**			**(%)**	**(± %)**
MAP DATA (i) **Coral**	**L**	**0.000**													0.0000	**n/a**	**n/a**
Coral	**M**		**0.000**												0.0000	**n/a**	**n/a**
Coral	**H**			**0.000**											0.0000	**n/a**	**n/a**
Seagrass	**L**				**0.004**	0.005	0.001	0.002	0.001				0.001		0.0136	**31.8**	**19.9**
Seagrass	**M**					**0.087**	0.007			0.002			0.005	0.002	0.1030	**84.4**	**10.8**
Seagrass	**H**					0.027	**0.421**	0.013	0.018	0.004				0.004	0.4873	**86.4**	**6.5**
Algae	**L**					0.001	0.000	**0.000**	0.000	0.000					0.0016	**11.1**	**14.8**
Algae	**M**		0.001		0.004	0.021	0.004		**0.110**	0.001			0.001	0.002	0.1427	**77.0**	**6.8**
Algae	**H**				0.001	0.006		0.001	0.001	0.065					0.0741	**87.9**	**8.0**
Emergent Vegetation	**L**										**0.000**				0.0000	**n/a**	**n/a**
Emergent Vegetation	**M**											**0.000**			0.0000	**n/a**	**n/a**
Emergent Vegetation	**H**												**0.017**		0.0174	**100.0**	**0.0**
No Cover						0.009		0.011	0.029					**0.112**	0.1602	**69.6**	**12.3**
n - j		0.000	0.001	0.000	0.009	0.154	0.432	0.029	0.158	0.073	0.000	0.000	0.024	0.120	**1.000**	**<= *n***	
PRODUCERS Accuracy (%)		**n/a**	**0.0**	**n/a**	**47.0**	**56.5**	**97.4**	**0.6**	**69.4**	**89.1**	**n/a**	**n/a**	**73.9**	**92.8**	**P_o**	**75.1%**	
PRODUCERS CI (± %)		**n/a**	**n/a**	**n/a**	**27.0**	**9.8**	**1.9**	**0.9**	**10.7**	**12.3**	**n/a**	**n/a**	**21.1**	**8.0**	**CI (±)**	**4.0%**	

A.4.9. Error matrix for ROI 4 Detailed Coral Cover in all habitats. The overall accuracy (P_o) was 75.4%. The Tau coefficient for equal probability of group membership (T_e) was 0.672, with a 95% Confidence Interval of 0.051. Blank cells indicate 0 occurrences.

		TRUE (GROUND-TRUTHED) (j)					
CORAL COVER		**Coral**				n_{i-}	**USERS Accuracy (%)**
		0-<10%	**10-<50%**	**50-<90%**	**>90%**		
MAP DATA (i) **Coral**	**0-<10%**	**313**	24	2		339	**92.3**
	10-<50%	87	**52**	6		145	**35.9**
	50-<90%			**0**		0	**n/a**
	>90%				**0**	0	**n/a**
n_{-j}		400	76	8	0	**484**	**<=** n
PRODUCERS Accuracy (%)		**78.3**	**68.4**	**0.0**	**n/a**	P_o	**75.4%**

$T_e = 0.672 \pm 0.051$

A.4.10. Error matrix for ROI 4 Detailed Coral Cover (using individual cell probabilities P_{ij}) in all habitats. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 86.4% with a 95% Confidence Interval of 83.7% - 89.1%. Blank cells indicate 0 occurrences.

		TRUE (GROUND-TRUTHED) (j)						
CORAL COVER		**Coral**				π_i	**USERS Accuracy (%)**	**USERS CI (± %)**
		0-<10%	**10-<50%**	**50-<90%**	**>90%**			
MAP DATA (i) **Coral**	**0-<10%**	**0.826**	0.063	0.005		0.8948	**92.3**	**2.9**
	10-<50%	0.063	**0.038**	0.004		0.1052	**35.9**	**8.0**
	50-<90%			**0.000**		0.0000	**n/a**	**n/a**
	>90%				**0.000**	0.0000	**n/a**	**n/a**
n_{-j}		0.889	0.101	0.010	0.000	**1.000**	**<=** n	
PRODUCERS Accuracy (%)		**92.9**	**37.3**	**0.0**	**n/a**	P_o	**86.4%**	
PRODUCERS CI (± %)		**0.9**	**10.6**	**n/a**	**n/a**	**CI (±)**	**2.7%**	

A.4.11. Error matrix for ROI 4 Detailed Coral Cover of Coral Reef and Hardbottom habitats only. The overall accuracy (P_o) was 55.6%. The Tau coefficient for equal probability of group membership (T_e) was 0.408, with a 95% Confidence Interval of 0.315– 0.501. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

CORAL COVER		Coral 0-<10%	Coral 10-<50%	Coral 50-<90%	Coral >90%	n_{i-}	USERS Accuracy (%)
MAP DATA (i) Coral	0-<10%	**57**	24	2		83	**68.7**
	10-<50%	55	**52**	6		113	**46.0**
	50-<90%			**0**		0	**n/a**
	>90%				**0**	0	**n/a**
n_{-j}		112	76	8	0	**196**	**<= n**
PRODUCERS Accuracy (%)		**50.9**	**68.4**	**0.0**	**n/a**	**P_o**	**55.6%**

T_e = 0.408 ± 0.093

A.4.12. Error matrix for ROI 4 Detailed Coral Cover (using individual cell probabilities P_{ij}) of Coral Reef and Hardbottom habitats only. The overall accuracy, corrected for bias using the known map marginal proportions (π_i), was 57.7% with a 95% Confidence Interval of 50.8% - 64.6%. Blank cells indicate 0 occurrences.

TRUE (GROUND-TRUTHED) (j)

CORAL COVER		Coral 0-<10%	Coral 10-<50%	Coral 50-<90%	Coral >90%	π_i	USERS Accuracy (%)	USERS CI (± %)
MAP DATA (i) Coral	0-<10%	**0.355**	0.149	0.012		0.5165	**68.7**	**10.2**
	10-<50%	0.235	**0.222**	0.026		0.4835	**46.0**	**9.4**
	50-<90%			**0.000**		0.0000	**n/a**	**n/a**
	>90%				**0.000**	0.0000	**n/a**	**n/a**
n_{-j}		0.590	0.372	0.038	0.000	**1.000**	**<= n**	
PRODUCERS Accuracy (%)		**60.1**	**59.8**	**0.0**	**n/a**	**P_o**	**57.7%**	
PRODUCERS CI (± %)		**5.8**	**9.6**	**n/a**	**n/a**	**CI (±)**	**6.9%**	