

GIS derived spatial analysis as a tool to predict nearshore coral reef fish species presence in American Samoa

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Abstract. The U.S. National Park Service has undertaken a monumental task of inventorying species found within park boundaries. This is part of the Inventory & Monitoring program aimed to increase our management efforts in all the U.S. National Parks. In the National Park of American Samoa, the inventory of reef fish has helped to discover 47 new species records for the territory of American Samoa. This was done using both GIS polygons derived from known geographic distributions of marine fish as well as in-water surveys using SCUBA and technical diving procedures. Using ArcInfo GIS software, a distribution map was created for all known coral reef fish species from the central South Pacific. GIS benthic habitat maps were then used to locate suitable and likely locations for a given species. In-water surveys were then conducted to look for the predicted species. Using this technique 138 additional species were presumed to be located in American Samoa. To date the in-water surveys have found 47 new records, of these, 37 were assumed present from the GIS modeling but had never previously been found. Many of the remaining species are small and cryptic and are unlikely to be encountered without the use of ichthyocides.

Key words: GIS, predictive mapping, Samoa, coral reef, fish

Introduction

Though we often idealize the South Pacific as pristine and untouched, in reality many of the small tropical islands of the South Pacific have had significant alterations and anthropogenic influences. Increasing negative impacts on coral reef habitat and species abundance have been correlated with their proximity to greater population densities (Brainard et al 2008). As a result many governments, agencies, and private organizations have begun initiatives to identify, prioritize, and delineate areas of special importance so that we may mitigate anthropogenic influences (Pittman et al 2007, Allen 2008, Ward et al 1999).

In the United States one of the federal agencies that has begun this process is the U.S. National Park Service. It has undertaken the monumental task of inventorying and monitoring all species found within park boundaries both below water and on land. This is part of the Inventory & Monitoring program aimed at increasing management capabilities in all U.S. National Parks. As a part of this effort, a new fish species list for American Samoa was deemed necessary. Previous to this study the most recent list of fish presence data came from work completed 25 years ago. Researcher inventories, species lists, and museum collection records for Samoa were analyzed and it was noticed that they all emanated from similar, if not identical, collection locations and often from

similar depth strata. It was then hypothesized that key habitats and various depth profiles may have been undersampled and overlooked during these previous efforts.

Predictive mapping for species presence and abundance is relatively well developed and routinely used in terrestrial environments (Pittman et al 2007, Miller et al 2004, Guisan and Zimmerman 2000). Within the marine environment much less predictive mapping has been done until very recently (Pittman et al 2007, Friedlander et al 2007, Spens et al 2007). Many of these studies are theoretically based, using computer models and statistical variables to ascertain species data and few have little if any “groundtruthing” of the predicted species presence. In this study, we make fish species presence lists based on predictive modeling using GIS based methodologies as well as in water observations. We sought to sample both historical collection sites as well as additional undersampled areas based on habitat and depth to look for new species and new records of nearshore coral reef fish species.

Material and Methods

The study area used for this research was the nearshore waters of Tutuila, American Samoa (14°S, 170°W) a U.S. territory in the South Pacific (Fig. 1). Tutuila, the largest island in the territory, exhibits

more diversified habitat types (coral reefs, lagoon, sand, mangroves, etc.) with more varied depths and bathymetric complexity than the other islands in the archipelago due mostly to its much greater size (Brainard et al 2008). Given the diversity of available habitat types, the broadest range of fish species should occur around this island.



Figure 1: Study site location, Tutuila, American Samoa.

Adapting the methodology described by Allen (2008), known point collection records (California Academy of Sciences, Australian Museum, Western Australia Museum, and the Bishop Museum) and verified field sightings data (various colleagues and NOAA-CRED) were used to analyze distribution patterns of nearly 3,000 nearshore coral reef fishes throughout the Pacific using GIS mapping software (ESRI, ArcMap 9.2). All pertinent collection information such as benthic habitat and cover types was reviewed. From these point data, polygons were created to connect points into a generalized equal area range map for each species (Fig. 2).



Figure 2: A representative equal area range map, in this case for *Iniistius pavo*, used for nearshore coral reef fish species presence predictions.

Equal area range maps were utilized in order to represent a true geographic relationship between collection points and theoretical range maps. It is very likely that there is a wider dispersal zone for each

species around a given collection point, but for added conservatism, only exact locations were used to derive polygons without any type of buffer zone around individual point data. These range map polygons for individual species cover vast areas of the Pacific, most of which is deepsea/pelagic habitat. The distribution of individual reef species is assumed only to occur in areas with suitable habitat (e.g. nearshore shallow-water coral reefs and associated habitats). Species that were already known to occur (Wass 1984), were then removed from the dataset and the remaining species were examined. There were 138 species not previously recorded that had predicted ranges that included American Samoa or came within 400km of the Samoan Archipelago.

Using existing natural history data, habitat preferences for these species were identified. Taking species thought to occur in the territory from the data provided in the range maps, predictive habitat maps were then created for each of these species and their likely locations plotted using specific habitat parameters. Habitat parameters were derived for each species from the published literature utilizing known natural history and habitat useage (e.g. *Acanthurus olivaceus* occurs over coral and rubble bottoms, *Acanthurus lineatus* is most frequently encountered on shallow reef flats, while *Acanthurus thompsoni* is found near steep drop-offs). Habitat maps were created using orthorectified aerial photographs as well as IKONOS and Quickbird satellite data, following methodology developed by NOAA (Coyne et al 2003). The panchromatic visual imagery was first interpreted and reef zones delineated to classify major sub-types of reef (reef flat, slope, backreef, crest, and lagoon). Next Quickbird and IKONOS multispectral color imagery was used to delineate the nearshore area into broad classes of habitat (coral reef, plant, rock, sand). Each of these was then subdivided into narrower categories (i.e. emergent vegetation, macroalgae, seagrass, etc.). Output from the process of delineating the broad reef zones and habitat classes and their corresponding subclasses was a series of digital GIS layers. These polygons were then overlaid to produce a highly accurate and delineated thematic map of the nearshore benthic habitat. The overlay process involved adjusting the relative opacity for each individual map and then projecting each into the same plane so that multiple features could be viewed simultaneously. It was determined that an intersect operation did not identify subtle differences in the various layers and was therefore carried out visually to ensure accuracy of the interpretation. This process was repeated for each of the 138 predicted fish species. For example, *Iniistius pavo*, is known to occur at depths from 20-100m in areas with high sand near coral reefs with high rugosity. Bathymetric data

collected by the NOAA coral reef ecosystem division (Brainard et al 2008) was used to stratify the available habitats by depth. Given the size of the study location groundtruthing was not possible at all locations, therefore random sites were chosen and groundtruthed using scuba. An accuracy rate of >90% was found at each of the 15 random sites. Exploratory dives were then made during the day and night into those likely habitats to look for the presence of predicted fish species. Additional survey dives were also carried out at historical collection sites and at various depths in these locations.

Results

Many fish species were found in American Samoa that were previously unrecorded. Most of these fish were species that are small, cryptic and/or nocturnal. There were however several species, including two stingrays, which attain significant sizes of 1m or more. These rays were found in sand flat habitats that have historically been undersampled (Fig. 3). Of the 138 fish predicted that had not been previously seen in American Samoa, 37 were located during this study, including one new family record. A further 10 fish species were located during the in-water survey dives which were unexpected (e.g. not predicted by the mapping procedures and previously unrecorded from Samoa). Of the 37 new species records, 34 were located in habitats previously poorly documented or searched. At least 3 species have been discovered which may be new to science including a Pomacentrid, Apogonid, and a Gobiid.

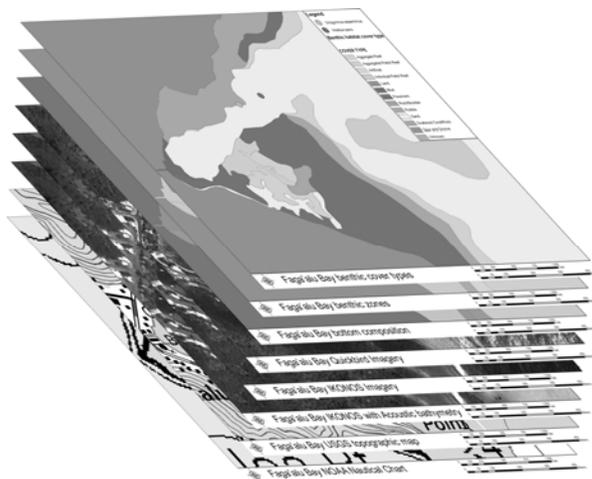


Figure 3: Multiple layers of benthic habitat maps, bathymetric data, and satellite imagery used to predict locations of predicted fish species.

Discussion

Many researchers, like recreational divers, often go to established sites. Given the limited time often available for studies, maximizing results by going to

known locations is often prudent. This approach does however ignore certain habitats that may then get undersampled, if at all. Part of this study was focused on looking in those locations other researchers have deemed unfit or unworthy of limited research time. For example, Faga'alu Bay, within Pago Pago Harbor is often considered too degraded and impacted to be of any scientific value. Yet it is within this bay that many of the new species records were found.

Some new species records, like the two stingray species, are large and non-cryptic in nature and thus it is unlikely that they were present in previous years surveys and seem to indicate a recent colonization. While many species which were predicted were discovered, several others were found that were unexpected. This emphasizes the need for groundtruthing, as this was an important component of this study, not only to validate benthic habitat maps, but also to verify theoretical species presence and more significantly yielded 10 new unexpected records.

Given the small size, cryptic nature, and often nocturnal habits of the remaining predicted fish species, it is unlikely that using non-destructive sampling methods like those employed in the present study will uncover many additional species records from the predicted list. This study shows that using GIS based predictive modeling and non-destructive methods in novel habitats can yield advances in our knowledge of fish species in remote locations.

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References

- Allen GR (2008) Conservation hotspots of biodiversity and endemism for Indo-Pacific coral reef fishes. *Aquatic Conserv: Mar Freshw Ecosyst* 18:541-556
- Brainard R, Asher J, Grove J, Helyer J, Kenyon J, Mancini F, Miller J, Myhre S, Nadon M, Rooney J, Schroeder R, Smith E, Vargas-Angel B, Vogt S, Vroom P (2008) Coral reef ecosystem monitoring report for American Samoa 2002-2006. NOAA Special report NMFS PIFSC, US Dept of Commerce, p472
- Coyne MS, Monaco ME, Battista TA, Anderson M, Waddell J, Smith W, Jokiel P, Kendall MS (2003) Benthic habitats of the main Hawaiian Islands. NOAA Technical Memorandum NOS/NCCOS/CCMA 152. US Dept of Commerce, National Ocean Service, Silver Spring, MD
- Friedlander AM, Brown EK, Monaco ME (2007) Coupling ecology and GIS to evaluate efficacy of marine protected areas in Hawaii. *Ecol App* 17(3):715-730
- Guisan A, Zimmermann NE (2000) Predictive habitat distribution models in ecology. *Ecol Model* 135:147-186
- Miller JR, Turner MG, Smithwick EAH, Dent CL, Stanley EH (2004) Spatial extrapolation: the science of predicting ecological patterns and processes. *BioSci* 54(4):310-320
- Patternson W, DeVore K (2008) California lake threatened by pike. *ArcUser* 11(1):28-31

- Pittman SJ, Christensen JD, Caldwell C, Menza C, Monaco ME (2007) Predictive mapping of fish species richness across shallow water seascapes in the Caribbean. *Ecol Model* 204:9-21
- Spens J, Englund G, Lundqvist H (2007) Network connectivity and dispersal barriers: using geographical information systems (GIS) tools to predict landscape scale distribution of a key predator (*Esox lucius*) among lakes. *J App Ecol* 44:1127-1137
- Ward TJ, Vanderklift MA, Nicholls AO, Kenchington RA(1999) Selecting marine reserves using habitats and species Assemblages as surrogates for biological diversity. *Ecol Appl* 9:691-698
- Wass RC (1984) An annotated checklist of the fishes of Samoa. NOAA technical report NMFS SSRF-781, US Dept of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, MD, p43