The morphology and structure of the Hannibal Bank fisheries management zone, Pacific Panama using acoustic seabed mapping

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Abstract: Morfología y estructura de la zona especial de manejo de Banco Hannibal, Pacífico de Panamá mediante el uso de sensores remotos acústicos. The Hannibal Bank sits within the Coiba UNESCO World Heritage Site in Pacific Panama and is also a fisheries management zone. Despite the protected status of the area and the importance of the Bank for commercial fish species such as snapper and tuna, the seamount has received no detailed survey except some collection of organisms. This study mapped the major topographic features and complexity of the Hannibal Bank seamount using acoustic remote sensing. A survey area of around 125km^2 was defined using existing charts and side-scan sonar data were collected during July 2008. A bathymetric output was imported to ArcGIS where a digital bathymetric model and slope map were created. The Benthic Terrain Modeler (BTM) extension for ArcGIS was used to calculate bathymetric position index and rugosity, and used to create a map of zones representing the various seabed morphology zones. The Hannibal bank is an elongated, triangular guyot (flat topped seamount), which ranges in depth from 53m to 416m, covers an area of 76km^2 and is 14.4km long and 7.1km wide. Hannibal bank is composed of steep slopes, more gentle slopes, top of the seamount, crests (elevated ridges at the top of the pinnacles), rugose areas (on crests, top of seamount and slope), gullies and pinnacles. The bank is asymmetric in nature with the Northerly side having a relatively gentle slope with gullies across the surface compared to the SouthWest side which is far steeper and more rugose. There are two pinnacles to the North and South East of the bank that range in depth from 180 to 333m. Rocky substrate makes up 22.6km^2 of the bank and sediment 37.8km^2. The bank and its steeply sided, rugose areas and pinnacles provide upright structures which can disrupt and topographically enhance currents, increasing productivity. The rugose areas of Hannibal Bank should be primary targets for further research efforts as they may contain corals and their rugosity indicates that these should be some of the highest faunal diversity areas of the bank. Hannibal Bank is likely to come increasing pressure in the future through climate change and fishing and this study has produced valuable information to assist in the future mapping and management of habitats, associated species and fisheries. Rev. Biol. Trop. 61 (4): 1967-1979. Epub 2013 December 01.

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Increasing concern over anthropogenic pressure on the marine environment has driven managers and policy makers to seek out effective tools for mapping, monitoring and protecting vulnerable habitats. To effectively manage the marine environment and its resources requires knowledge of the spatial distribution of species and habitats (Freeman & Rogers, 2003). It has previously been difficult to undertake on a wide scale because traditional marine survey techniques such as trawls and grabs sample at discrete locations that then need to be extrapolated between (Brown & Collier, 2008). This method only provides a snapshot of the environment, covering only a small proportion of the seafloor. Advances in remote sensing during the last 10 to 15 years have produced a notable improvement in our knowledge of the location of small-scale geological features and the distribution of marine habitats. Acoustic remote sensing such as side-scan sonar and multi-beam sonar now allows researchers improve coverage, to go beyond shallow depths and produce detailed maps of seafloor regions (Greene et al., 1999; Pickrill & Todd, 2003; Prada, Appeldoom & Rivera, 2008). Modern multi-beam bathymetric and side-scan sonar systems are capable of surveying wide areas of the seafloor, mapping benthic features and identifying vulnerable or sensitive habitats (Kostylev, Todd, Fader, Courtney, Cameron & Pickkrill, 2001; Prada et al., 2008). These improved acoustic techniques have increased the opportunity to research the biological and physical characteristics of deep-sea marine geological features, such as seamounts (Fornari, Garcia, Tyce & Gallo, 1988; Koppers & Staudigel, 2005; Mitchell & Lofi, 2008).

Seamounts are found in oceans worldwide and are primarily composed of basalt but their exact form depends on water depth, chemistry of the magma source, age of the seafloor, and the origin of the magma intrusion in to the water column (spreading zone, mid plate hotspot or subduction zones) (Wessel, 2007). They are normally isolated, cone-shaped seabed features but there are also flat-topped seamounts, or guyots (Wessel, 2007). Seamounts project upwards into shallower zones and as isolated structures they create a point of interest and suitable rocky habitat for species of corals and sessile communities. The diversity of life and unique communities on seamounts provide excellent areas for improving our understanding of marine biodiversity (Klimley, Richert & Jorgensen, 2005; Pitcher & Bulman, 2007). The physical presence of seamounts modifies local hydrographic conditions by interacting with deep water currents creating areas of upwelling. This process brings cooler nutrient rich water from deeper areas towards the surface and the photosynthetic zone, producing an area of high primary and secondary productivity around the seamount compared to the surrounding area (Boehlert & Genin, 1987; Genin, Haury& Greenblatt, 1988; Rogers, 1994; Koslow, 1997; Koslow, Gowlett-Holmes, Lowry, O'Hara, Poore & Williams, 2001; White, Bashmachnikov, Arístegui & Martins, 2007). This leads to an increased biodiversity and supports large feeding and/or spawning aggregations of fish, including large predators like billfish, tuna and sharks and marine mammals. Seamounts are also of commercial interest due to their association with higher concentrations of commercially and recreational valuable species.

The Hannibal Bank belongs to the Panamic Biogeographic Province, which extends from the Gulf of Guayaquil in Ecuador to the Gulf of Tehuantepec in Mexico (Glynn & Wellington, 1983; Cortés, 1997). The protected area of the CNP was created in 1991, and in 2002 it was included as part of a regional protected 'Pacific Biological Corridor' which includes the islands of Malpelo and Gorgona (Colombia), Galapagos and Cocos (Costa Rica). The CNP has a surface area of 270 125ha of which 216 543ha (80.2%) are marine environments (Cardiel, Castroviejo & Velayos, 1997). The coastline of Coiba and the Gulf of Chiriquí has already been the focus of coral reef research, having the highest coral diversity in the Tropical Eastern Pacific (TEP) (Guzman, Guevara & Breedy, 2004). The CNP and its Marine Protected Special Zone (Hannibal Bank) is also a UNESO World Heritage site because of their key ecological link in the Tropical Eastern Pacific (ANAM, 2009). It is a 1 781km^2 fisheries management zone within the World Heritage and is one of the most important fishery areas for species such as grouppers and snappers in the Gulf of Chiriqui (Vega, Robles & Cipriani, 2011). Hannibal Bank supports local fishing communities, larger long-line and gill-net fisheries and sport fishing vessels targeting species such as marlin, sailfish, dorado and tuna (ANAM, 2009).

Despite previous marine research in shallower coral reefs of the CNP and the commercial importance of Hannibal Bank as a fisheries area, the seamount has received no detailed bathymetry or ecological surveys, and the fishery is a priority to be evaluated (sensu

Harper, Bates, Guzman & Mair, 2010) There is significant potential for habitats to be physically damaged by increasing human pressures such as fishing (Koslow et al., 2001) and global climate change, and preliminary surveys in the area indicate well-developed mesophotic reefs down to 90m and deeper rocky habitats for snapper and groupers. Additionally, whilst the majority of seamounts globally are located in the Pacific Ocean, there have been no surveys conducted in Pacific Panama or along the majority of the Pacific Central American coast.

This study aimed to map the major topographic features and complexity of the Hannibal Bank seamount using acoustic remote sensing. The results of this survey were aimed at providing baseline analysis of the potential variety of substrates and topographic zones present on the Hannibal Bank, which could ultimately be used for drafting management recommendations for the habitats and fisheries of Hannibal Bank. The work described in this study also provides the first steps in research on seamounts for this region and assists the global research effort to improve our understanding of seamounts.

MATERIALS AND METHODS

Study area: The study area for this research was the Hannibal Bank, a seamount and fisheries management zone located between (07º 20’47’’N - 81º 59’17’’W and 07º 27’13” N - 82º 7’48” W) within the Coiba National Park (CNP), Gulf of Chiriquí, Panama (Fig. 1). The CNP is part of the Middle American Trench forearc-volcanic system on the Western coast of Panama that formed because of the subduction of the Cocos and Nazca plates under the Caribbean plate. The geology is complex with fragments of oceanic plate, spreading centres, hotspots traces such as the Cocos, Malpelo and Carnegie Ridges together with sedimentary units typical in near shore to continental shelfs. Areas including seamounts, islands and peninsulas occur as a series of Upper Cretaceous to Eocene accreted plateaus. The island of Coiba has been interpreted as an accreted piece of the subducted Galapagos hotspot track based on the geochemical signature and age of rocks (Geldmacher, Höfig, Hauff, Hoernle, Garbe-Schönberg & Wilson, 2012). Coiba and its surrounding islands combine volcanic rock

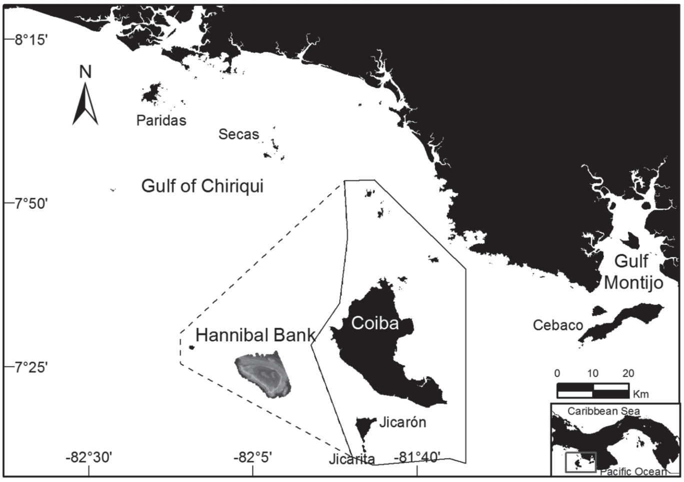

Fig. 1. Hannibal Bank inside the Marine Protected Special Zone (dashed line) and Coiba National Park (solid line), both part of the UNESCO World Heritage, Gulf of Chiriquí, Pacific Panama.

and limestone and therefore it is likely that the Hannibal Bank is of similar geological composition. Backarc tectonic uplift resulted in final closing of the Panama Isthmus at 3.0-2.5Ma (Bartoli, Sarnthein, Weinelt, Erlenkeuser, Garbe-Schönberg & Lea, 2005). This feature caused a fundamental change in both local and global ocean current circulation patterns and associated climate. Numerous islands along the Western coast also became isolated from the mainland. The isolation was periodically compromised by the lowering of global sea levels during glacial cold phases, the last of which was experienced at approximately 20Ka to 18Ka (Castroviejo & Ibáñez, 2001).

The Pacific Biological Corridor, of which the CNP and Hannibal Bank are a part, is an area strongly influenced by the convergence of warm and cool currents. The dominant currents in the area are the North Equatorial counter-current bringing moderately warm sub-tropical waters from the North via the South-flowing Panama current; and the North-flowing Colombia current reinforced by the Panamanian Cyclonic counter-current bringing cooler low salinity water from the Southwest (Rodriguez-Rubio & Schneider, 2003). In addition, the equatorial undercurrent that flows along the equator from the West, producing upwelling of cool water rich in nutrients when they interact with the underwater base of islands and features such as the Hannibal Bank, causing these areas to be particularly productive. Between December and April, the Gulf of Chiriquí is sheltered from the prevailing North Easterly winds by the mountains of the mainland. This protects it from the accompanying cold upwelling currents and from the worst effects of El Niño (Longhurst, 2007). The climate of the region is humid-tropical monsoonal, with a rainfall of up to 3 500mm/yr, an average temperature of 26ºC and a marked seasonality (a dry season from December to mid April and a rainy season for the rest of the year).

The acoustic survey was made between the 20th and 27th of July 2008 the Smithsonian Tropical Research Institute's research vessel, R/V Urraca, was deployed to survey the topographical structure of the Hannibal Bank. The study area was defined using available Admiralty bathymetric charts of the region to set the bearings and lengths of the sonar transects following the shape of the bank, covering a total area of around 125km^2.

Acoustic data were collected using a SEA SwathPlus 117kHz side-scan sonar system together with a TSS motion reference unit and navigation using an Omnistar solution. Side-scan sonar systems work by emitting an acoustic signal that interacts with the seafloor and returns a signal that is interpreted based on its strength. The strength of the backscatter provides information on superficial features of the seabed (e.g. sand waves, rock outcrops and biogenic structures) and characteristics of the sediment (Brown, Hewer, Meadows, Limpenny, Cooper & Rees, 2004). The interpretation of side-scan images normally involves the identification of acoustic classes describing habitats based on ground-truth data (Collier & Brown, 2005; Bartholoma, 2006; Lathrop, Cole, Senyk & Butman, 2006).

Our sonar system consisted of a pair of underwater transducers that were fixed to the side of the vessel, 2m below the surface. The system was connected by cable to a shipboard recording device and computer for the acquisition, display and storage of data. The sonar frequency and water depths resulted in swath widths of 70-300m to port and starboard (Harper et al., 2010). The average tow speed was four knots with signals being emitted at a minimum ping rate of between five and ten pings per second.

Proprietary SEA software was used in the initial acquisition and processing of the bathymetric side-scan data. SEA Grid 2000 and Fledermaus (IVS) were then used for further processing of the bathymetric data to produce a mosaic of depth on a 10m-bin size. Water column and beam angle corrections for the amplitude (backscatter) data were made using SonarWiz Map (Chesapeake Inc.) with appropriate adjustments made to the images for color and contrast in display of the final mosaic image. The bathymetry output (a file containing x-y-z coordinates, where z was the bathymetric data corrected to depth at chart datum) was imported into ArcMap version 9.2 for further spatial analysis. A digital bathymetric model (DBM) was created using a triangulated irregular network (TIN) to represent the area of the bank. From the DBM a secondary map was created for slope using the spatial analyst extension of ArcMap. Slope, aspect and depth are useful in predicting the distribution of benthic communities (Roberts, Brown, Long & Bates, 2005). The Benthic Terrain Modeler (BTM) extension for ArcGIS was used for further data analysis. The DBM was used to calculate bathymetric position index (BPI), which is an evaluation of the slope of each cell relative to neighboring cells. Cell size (10m) was determined from the raw DBM based on bathymetry bin size and the predicted variability in the spatial sea floor data. BPI calculations were made at a broad and a fine scale in order to detect both large and smaller-scale topographic features (Lundblad et al., 2006). The scale factors for both broad and fine scale BPIs were chosen based on evaluating the bathymetric data sets and determining the distance between features of interest. After some trial and error examining what best represented the visual patterns recognizable, e.g. rugose areas, changes in form, scale factors of 500m for the broad scale and 200m for the fine scale were chosen. The classification scheme used for the BPI zones was adapted from an existing scheme designed for the classification of reefs in American Samoa (Lundblad et al., 2006). Rugosity was calculated as a measure of topographic complexity using the BTM extension. Rugosity values represent the surface area to planar area ratio, with high values indicating areas of greater relief or complexity and low to near zero values indicating flat/smooth regions (Lundblad et al., 2006). The resulting classified maps were then used for delineating zone boundaries.

The BPI raster map was converted to a vector shapefile, interpreted with respect to the DBM, BPI, rugosity and slope images, and modified to represent zones of physically distinct seabed areas. The final parameters (DBM, slope and rugosity) used to define the zones are outlined in Table 1. A shapefile was produced representing the various seabed morphology zones and an estimation of substrate type (rocky or sediment) based on the rugosity and slope data.

RESULTS

The survey revealed that the Hannibal bank forms an elongated, triangular, raised guyot above the surrounding seafloor. The Hannibal Bank ranges in depth from 53m on

TABLE 1
Range of values for variables used in defining zones of Hannibal Bank and predicted substrate type

Zone	DBM range (m)	Rugosity range	Slope range (degrees)	Predicted substrate type	Area classified (km^2)
Steep slope	99.82 – 416.39	0-6.03	0-65.49	Rock	17.97 (16.02)
Slope	84.58 – 383.45	0-5.83	0-40.66	Sediment	10.48 (10.24)
Top of seamount (excluding rugose areas)	71.15 – 276.16	1-2.49	0.01-20.39	Sediment	26.83
Crest	180.18-333.02	1-4.86	0.06-35.75	Rock	1.13 (0.95)
Rugose area	53.71-394.67	1-15.01	0.01-48.66	Rock	21.40
Gullies	194.43-307.16	1-1.75	0.12-12.84	Sediment	0.69
Sea floor	148.19-428.38	1-11.04	0-58.44	Sediment	40.31
TOTAL (excluding seafloor)					116.44 (76.13)

DBM = Digital Bathymetric Model. Areas for steep slope, slope and crest in brackets exclude the rugose areas.

rugose areas at the top of the seamount, to 416m at the bottom of the steep slope. The deepest location mapped was 428m located on the seafloor area. The bank covers an area of 76km^2 excluding the seafloor area surrounding the seamount (Table 1). It is 14.4km long and 7.1km wide. Seven zones were determined from the DBM, BPI, rugosity and slope information (Fig. 2). These zones are illustrated in figure 3a and comprise:

- steep slope;
- slopes (shallower sloping areas compared to the steep slope);
- top of seamount;
- crests (an elevated ridge);
- rugose areas (high rugosity areas on slopes and top of seamount);
- gullies (deep channel/valley potentially eroded away); and
- pinnacles (small seamounts neighbouring the bank being comprised of crests, slopes and rugose areas).

The seafloor area around the seamount and pinnacles is mapped in figure 3a. The Hannibal Bank has a relatively flat top, with slopes that include rugose areas and gullies. The top of the seamount ranges from 53-276m deep which appears to be rugose in nature. Its Northern side is composed of a gentle slope that is smoothly textured and has apparent interesting 'creases' that appears to be gullies (Fig. 2a, 3a and 4). On the Eastern and Southern sides of the bank, there are steep, rugose slopes which are far more rugose than the Northern side and do not possess gullies. The Western side of the bank is similar in nature to the Southern side, although less steeply sloping and less rugose as it joins the Northerly side of the bank.

There are also two pinnacles to the North and South East of the bank that range in depth from 180 to 333m (Fig. 2a, 3a). The Northern pinnacle is 2.6km long by 1.3km wide. It appears steep and rugose on its Southern side but less on its Northern side and is rugose on its crest (Fig. 2 and 3). The pinnacle in the South

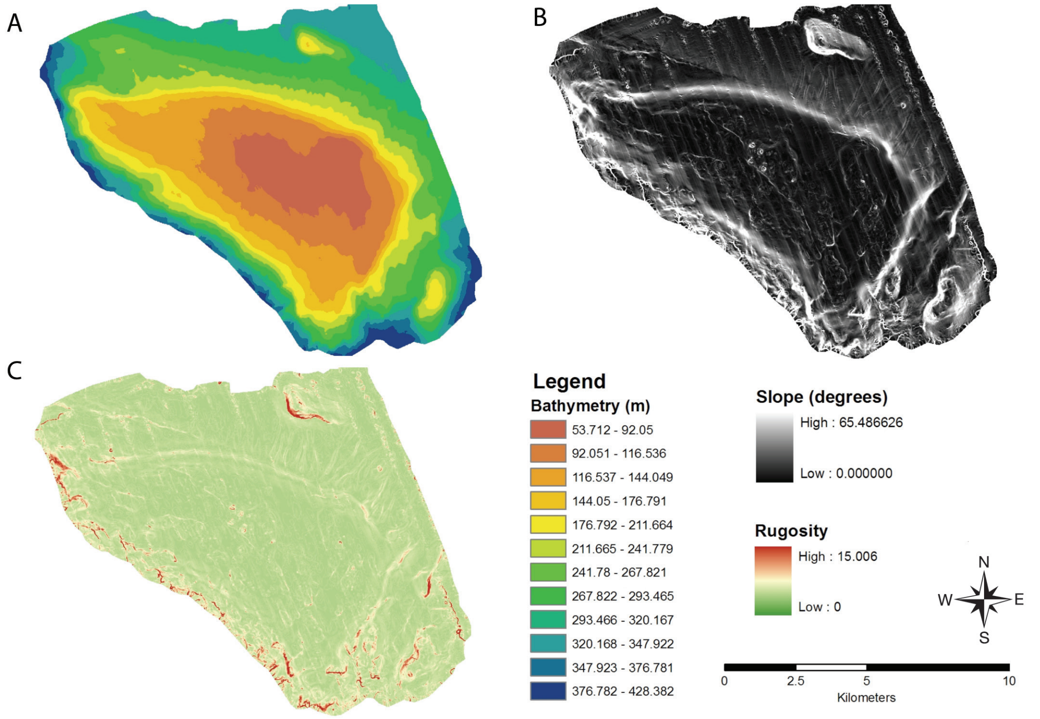

Fig. 2. Hannibal Bank survey site; (a) Bathymetry profile; (b) Slope; (c) Rugosity.

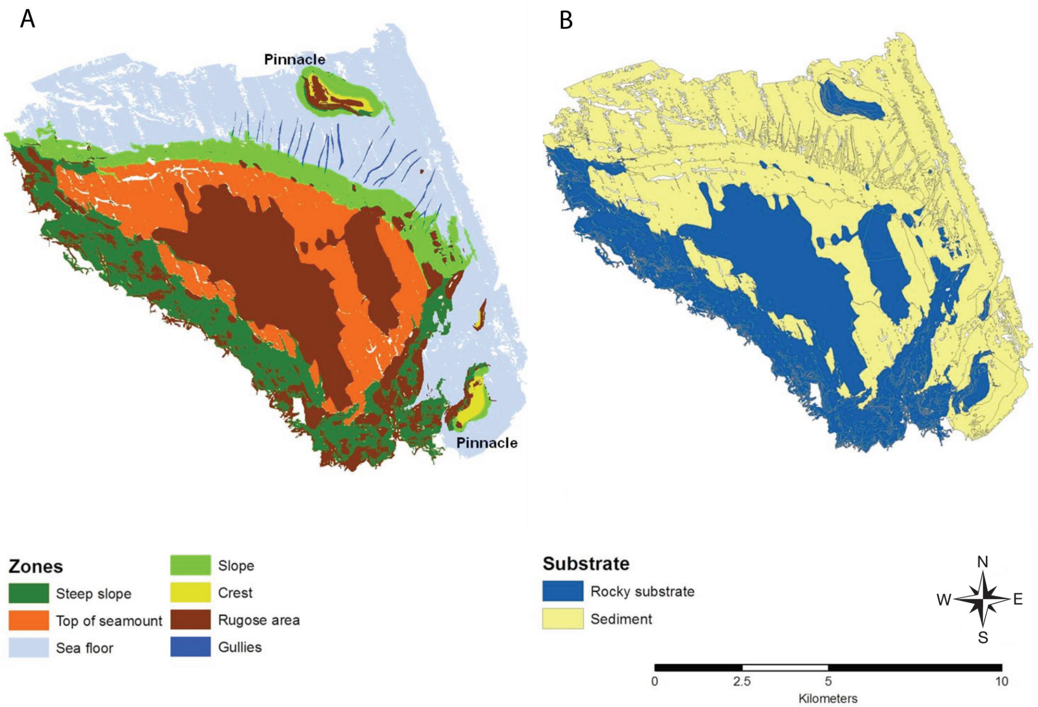

Fig. 3. Hannibal Bank survey site; (a) Zones classified using Bathymetric Position Index (BPI); (b) Substrate type classified from interpretation of BPI Zones, slope and rugosity.

East is 2.2km long and 1.1km wide and is steep and rugose on all sides and on its crest.

The South, West and Eastern sides of the bank have the highest rugosity (Fig. 2c) along with the crest areas of the pinnacles. There are also rugose areas present on the top of the Hannibal Bank. These rugose areas appear to correlate with areas of the highest slope (Fig. 2b), which were also present on the South, West and Eastern sides of the bank, the sides of the small pinnacles and in some areas on top of the Hannibal Bank. The Hannibal Bank is 29%

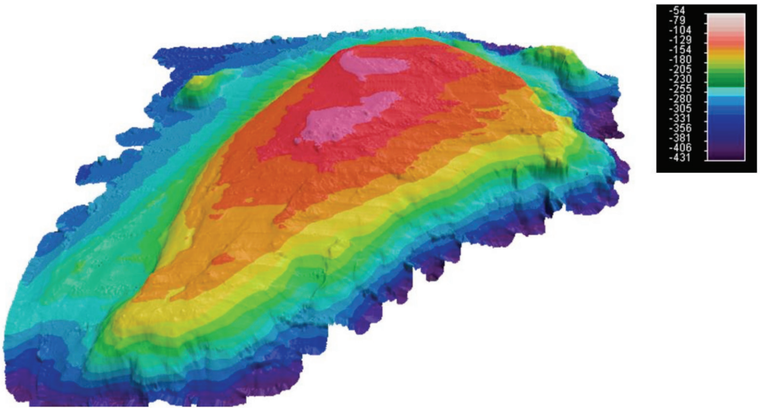

Fig. 4. Three dimensional profile of the Hannibal Bank derived from bathymetric information collected, showing the top of the bank the steep slope and rugose areas, the shallowly sloping Northern side with gullies and the two distinct pinnacles discovered.

rugose areas, 30% top of the seamount (relatively flat) and 21% steep slope. As no ground truth information was collected in conjunction with the side-scan sonar mapping, it is impossible to determine what sediment types and habitats are present. However, the estimation was made to define the dominant substrate type from the topography, slope and rugosity information. As shown in Table 1 steep slopes, crest and rugose areas are believed to be rocky in nature. Sediment dominated areas are believed to be the more gentle slopes, sea floor, top of seamount and the gullies. The zoned map presented in figure 3a was reclassified into substrate type (rock/sediment) and is presented in figure 3b. Rocky substrate makes up 22.6km^2 of the bank and sediment 37.8km^2 excluding the surrounding sea floor.

Therefore, the Hannibal Bank appears to be composed of the following main regions with their estimated substrate character: (1) steep slopes, that are rugose and probably rocky; (2) more gentle slopes with a smooth texture and probably sedimentary composition; (3) top of the seamount which is generally of lower rugosity and slope than the crests/rugose areas identified and is probably a mix of sediment and rocky; (4) crests forming elevated ridges at the top of the pinnacles with a rugose and probable rocky nature; (5) rugose areas on crests/top of seamount/slope which have high rugosity and slope and are probably rocky in nature; (6) gullies forming deep channels/valleys that may have been areas of erosion and are probably sedimentary in nature due to low rugosity and slope, and (7) pinnacles composed of both slopes, crest and rugose areas of rocky substrate previously referred to.

DISCUSSION

This study provided the first detailed bathymetric study of the Hannibal Bank and identified seven main zones, which include rugose, probably rocky areas of higher complexity that are worthy of further investigation. The products of this study are valuable tools to assist in the future mapping and management of sensitive habitats and associated species, which could ultimately be used for developing management recommendations for the habitats and fisheries of Hannibal Bank.

The Hannibal Bank would offer an extremely interesting location for further geological examination. The relatively flat top of this seamount indicates that it is a guyot and may be geologically significant as its depth indicates that the top of the bank was above sea level (125m shallower than present) at the last glacial minimum (Fleming, Johnston, Zwartz, Yokoyama, Lambeck & Chappell, 1998). This is important as it may indicate that habitats such as coral reefs may have been present on the bank. These two features and other geological research in the area indicate that Coiba and the neighboring Hannibal Bank were created via accretion of the subducted Galapagos hotspot track through the accumulation of magma and that the bank like Coiba was above sea level. It is hypothesised that when the active construction of the island waned the island that became the Hannibal Bank, could no longer regenerate to keep up with the forces of erosion and long-term subsidence of the seafloor as described by Wessel (2007). This allowed the summit to come back to sea level where wave erosion acted to flatten the summit of the seamount to produce the Hannibal Bank, a guyot as revealed in this study. Given the geological knowledge of the rest of the CNP and previous research on the formation of seamounts being volcanic in nature (Hoernle et al., 2002; Wessel, 2007; Geldmacher et al., 2012), it is probable that the rocky substrate of the bank (crest, steep slope, rugose areas) are volcanic in nature with some areas of limestone. These zones were also the areas of highest rugosity and slope, and rugosity in particular is an important indicator of habitat complexity (Friedlander, Brown, Jokiel, Smith & Rodgers, 2003; Lundblad et al., 2006; Kuffner, Brock, Grober-Dunsmore, Bonito, Hickey & Wright, 2007; Benfield, Baxter, Guzman & Mair, 2008; Purkis, Graham & Riegl, 2008). The potential presence of complex habitats on the bank is important because such habitats are valuable in conservation because their increased surface area, food and shelter foster higher species diversity and richness. These areas should be the priority of further research to determine the exact habitats and species presence in order to assess their vulnerability to human pressures such as fishing.

The whole bank itself but in particular its steeply sided, rugose areas of the seamount and the pinnacles provide a set of physically upright structures in an otherwise relatively flat area of seafloor. Therefore, it provides a physical presence on the seafloor to disrupt and topographically enhance currents, such as the South-flowing Panama current, the North-flowing Columbia current and the equatorial undercurrent from the West. This, it is hypothesised, produces a localised region of upwelling as these currents hit the comparably vertical faces of the Hannibal Bank and its surrounding pinnacles. This could explain the higher aggregations of fish e.g. anchovy, tuna, sailfish, marlin which are targeted by commercial fishing and sport fishing businesses, and predators such as sharks and whales.

Additionally, it can be hypothesized that areas of coral reef (patch and fringing) were once present on the top of the bank and its pinnacles. As previously discussed the Hannibal Bank may once have been above sea level and coral reefs have been found elsewhere in this region (Guzman et al., 2004). As described by Darwin (1842), coral growth tended to keep up with the subsidence rate of volcanic islands capping many with a thick coral reef layer before subsidence and wave erosion eventually drowned the seamount. The rugose areas of Hannibal Bank should be primary targets for further research efforts as they may still harbour corals and their rugose nature means that these should have some of the highest faunal diversity on the bank. However, the unusual gullies and more gently sloping Northerly side of the bank also warrant investigation, due to the striking difference in morphology and therefore potentially different ecological communities compared to the rest of the bank.

Whilst the bank provides an interesting location to undertake ecological research due to its high productivity and potential for harbouring sensitive coral habitats, there is an underlying need to study the area further to provide evidence for conservation management, using this research as a starting point. Hannibal Bank and its habitats are likely to come under more pressure in the future through climate change and fishing in particular. Hannibal Bank has previously experienced El Niño and La Niña events, which may become more severe and frequent with climate change. These events can be detrimental to important local processes such as upwelling and sensitive species such as corals. Additionally there is no knowledge of how current levels of fishing or any increases in activity are or could affect the bank's habitats and target and non-target species.

For further research, a more detailed habitat map and documentation of the fauna and communities of the bank would greatly assist in improving not only our understanding of seamount communities in Pacific Central America and their contribution to regional marine biodiversity. It is suggested that the specific objectives of further work should be to: a) describe the benthic habitats and map their distribution; (b) examine the composition and diversity of the communities (invertebrates and fish species) associated with the habitats identified; (c) make comparisons to shallower areas of Coiba and the Gulf of Chiriquí and examine the seamount's contribution to biodiversity of the TEP; (d) investigate relationships between bank associated fish and invertebrate species and habitat/environmental variables; and (e) examine the correlation between habitats and associated community distribution in relation to fishing grounds and suggest priority areas for conservation, with particular regard to fragile and diverse habitats.

Further work should utilise the output maps produced here to select station locations for ground-truthing to provide broad spatial coverage of the seamount and its acoustic signatures at a range of depths. This would enable a supervised classification of the acoustic information from the side scan in conjunction with the derived DBM, BPI, rugosity and slope layers to create a habitat map. To gather data to describe the benthic habitats and associated macrofauna a submarine and/or a remotely operated vehicle (ROV) with on-board digital video camera and collection capability would be the most suitable method. The majority of the Hannibal Bank is greater than 50m in depth, beyond that which can be reached by scuba divers. An ROV would offer a suitable sampling non-invasive tool compared to dredging and trawling and hence reduces the impact of surveying on the habitats of interest, and it can cover a wide area (Fossa et al., 2005; Roberts et al., 2005). The data collected can also allow relatively detailed taxonomic identification to be made, with resulting qualitative and quantitative ecological discrimination possible (sensu Mortensen, Buhl-Mortensen, Gebruk & Krylova, 2008).

This study is the first step in providing robust scientific information that is urgently required to assist the government, research and conservation organizations in Panama in managing the habitats, communities and fisheries of Hannibal Bank fisheries management zone. It also has initiated seamount research in this region, as whilst the majority of seamounts globally are located in the Pacific Ocean and offshore (deForges, Koslow & Poore, 2000; Fernandez & Castilla, 2005), there have been no seamount surveys conducted in Pacific Panama or along the majority of the Pacific Central American coast with the exception of Costa Rica (Lizano, 2012; Starr et al., 2012). If the research on the Hannibal Bank proceeds as outlined under further research, this work will also contribute to assist the global research effort on seamounts and their ecology, and help provide recommendations for improved sustainable management and protection of such areas that could be useful elsewhere.

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RESUMEN

El Banco Hannibal se encuentra en Coiba que es Patrimonio de la Humanidad de UNESCO en el Pacífico de Panamá y es una importante zona de pesca. Este estudio evaluó las principales características topográficas y la complejidad de la montaña submarina Banco Hannibal mediante el uso de sensores remotos acústicos. A pesar del estado de protección de la zona y la importancia para las especies comerciales de peces como el pargo y el atún, la montaña submarina no ha tenido ningún estudio detallado salvo alguna colección de organismos. El área de estudio de alrededor de 125km^2 identificada usando cartas de navegación fue definida usando datos de sonar de barrido lateral durante julio 2008. La información batimétrica fue importada a ArcGIS donde se creó un modelo digital batimétrico (DBM) y mapa de pendientes. La extensión del ArcGIS Benthic Terrain Modeler (BTM) se utilizó para calcular el índice de posición batimétrica o BPI (pendiente de cada celda relativa a las celdas vecinas) y rugosidad. El banco Hannibal es un guyot alargado, triangular (montaña submarina plana en parte superior), que se extiende en profundidad desde 53m hasta 416m, tiene una superficie de 76km^2 y es de 14.4km de largo y 7.1km de ancho. El Banco Hannibal está compuesto por pendientes pronunciadas, pendientes más suaves, parte superior de la montaña submarina, crestas (altos relieves en la parte superior), zonas rugosas (en las crestas, parte superior de los montes submarinos y pendiente), barrancos y crestas. El banco es asimétrico, con una pendiente relativamente suave y con surcos a través de la superficie en el lado norte en comparación con el lado suroeste que es mucho más pronunciado y más rugoso. Hay dos cumbres al norte y al sureste de la orilla, que varían en profundidad de 180 a 333m. El sustrato rocoso comprende unos 22.6km^2 del banco y sedimentos 37.8km^2. El banco y sus caras abruptas, áreas rugosas y pináculos proporcionan estructuras verticales que pueden alterar y mejorar topográficamente las corrientes.

Esto se cree produce un afloramiento local que explicaría las mayores agregaciones de peces que son el objetivo de la pesca comercial y deportiva. Es probable que el Banco Hannibal tenga una presión cada vez mayor en el futuro debido al cambio climático y la pesca y este estudio ha producido información valiosa que permite la clasificación de los hábitats para el manejo de las especies asociadas y su pesca, así como la iniciación de la investigación sobre montañas submarinas de Panamá.

Palabras clave: exploración acústica, montaña submarina, banco, lecho marino, topografía, batimetría.

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