A habitat classification scheme for seamount landscapes: assessing the functional role of deep-water corals as fish habitat

Peter J. Auster[1], Jon Moore[2], Kari B. Heinonen[1], Les Watling[3]

[1] National Undersea Research Center, Department of Marine Sciences, University of Connecticut, Groton, CT 06340, USA
(auster@uconn.edu)
[2] Florida Atlantic University, Honors College, Jupiter, FL 33458, USA
[3] Darling Marine Center, University of Maine, Walpole, ME 04573, USA

Abstract. Seamounts are drowned volcanoes rising from abyssal depths. Fishes on seamounts exploit a range of landscape features that likely enhance probabilities of prey capture and reduce predator success. The epifaunal community on seamounts is dominated by suspension-feeders of which deep-water corals are a dominant element. Such taxa are widespread components of seamount landscapes but their functional role in mediating the distribution and abundance of fishes remains unknown. Here we propose a hierarchical habitat classification matrix, which includes deep-water corals, as a foundation for partitioning seamount landscapes in which fishes are observed. This scheme is based on our observations of fish distributions from the New England Seamounts, as well as literature review. Features of an idealized seamount landscape were divided at multiple spatial scales and included features at habitat class, subclass and microhabitat levels. Habitat classes were divided by major sediment types (i.e., basalt, fine grained sediments). Habitat subclasses included pavement, ridges, walls, ledges and tubes for basalt substrates and flat sediment, ripples and waves for fine-grained sediments. Microhabitat features were classified as flow related features, emergent structures (i.e., geologic and biologic including deep-water corals), and other biogenic structures (e.g., coral debris, depressions, burrows). Variations in the distribution of structures at multiple spatial scales can influence boundary flows and the ability of fishes to search for prey (e.g., where active searching by swimming can occur, where pelagic prey delivery is sufficient when station-keeping) and avoid predators (e.g., the ability to efficiently exhibit various avoidance behaviors such as shelter seeking). Placing fish abundance data in such a matrix of habitat types enables a variety of statistical approaches for testing for non-random distributions of fishes on seamounts and quantifying the functional role of corals as fish habitat.

Keywords. Topographically induced flows, seafloor, microhabitat, slope, habitat classification

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Introduction

Seamounts are extinct volcanoes that rise from the abyssal plain and occur in all ocean basins. These major geologic features cross wide depth ranges, predominantly consist of hard substrata, exhibit complex topography, create topographically induced flow patterns, are bathed in clear oceanic waters, and are geographically isolated (Boehlert and Genin 1987; Rogers 1994). The invertebrate fauna of seamounts is dominated by suspension feeders (e.g., corals, sponges) and limited studies have shown variable degrees of endemism (Wilson and Kaufman 1987; de Forges et al. 2000) of the invertebrate fauna. Seamount corals, and deep-water corals in general, have been the focus of a renewed interest by both the scientific and conservation communities. Corals have been found to be of extreme age, have low recruitment rates, and are sensitive to human-mediated disturbances such as fishing (Willison et al. 2001). One of the rationales articulated for conserving deep-water corals is their role in supporting exploited populations of fishes. However, the functional role of deep-water corals in mediating the distribution and abundance of fishes is not well understood (Auster 2005). For seamount fishes, it is important to understand the role that variations in seamount landscape attributes, in which corals are nested, play in mediating their distribution and abundance. In this paper we present a hierarchical habitat classification scheme for partitioning seamount landscapes at multiple spatial scales. This classification scheme includes corals as structural attributes of the landscape and enables assessing the functional role of the full range of landscape attributes as habitat for fishes.

Our classification scheme is based on the direct observation of fishes and their surrounding habitat on Muir Seamount and the New England Seamount chain (i.e., Bear, Retriever, Balanus, Kelvin, and Manning seamounts) during 3 cruises in 2003-2004. The New England Seamounts rise from the Sohm Abyssal Plain and have summit depths that range from 900-3750 m. Our observations were primarily in the range of 2500-1100 m although we made limited observations as deep as 3900 m. Observations were made from DSV Alvin (18 dives), ROV Hercules (12 dives), the AUV Autonomous Benthic Explorer (7 dives), and a towed camera sled (3 deployments).

Seamount landscapes

Seamount landscapes and habitat features, with modifiers specific to the New England Seamounts, were defined along a gradient of spatial scales (Table 1) based on a hierarchical classification system described by Greene et al. (1999). Here seamounts are the landscape unit, given that most deep-water fishes generally have wider distributions and occur across a range of landscape types (Auster et al. 1995; Moore et al. 2003; unpublished observations). Two broad classes of habitat occur on seamounts (i.e., basalt and fine-grained sediments) and are a function of the volcanic origin of seamounts and the accumulation of oceanic sediments. Habitat subclasses include pavement, ridges, walls, ledges and tubes for basalt substrates and flat sediment, sand ripples and sand waves for fine-grained sediments. Microhabitat

Table 1 Habitat classification scheme for seamount landscapes

Landscape
Seamount

- *Habitat Class*
  Basalt
  Water Mass
  - *Habitat Subclass*
    Pavement, Ridges, Walls, Ledges, Tubes
    Slope, exposure
    Fractures, rises, troughs
    - *Microhabitats*
      Flow-related features:
      Sediment draped basalt structure
      Thickness, exposure, grain size composition
    - **Emergent Structures**
      Geologic (boulders, cobble)
      Biologic (attached fauna i.e., corals and sponges)
      Exposure
    - **Biogenic Structures**
      (includes biogenic debris)
      Type of Debris
      Exposure
- *Habitat Class*
  Fine-Grained Sediment
  Water Mass
  - *Habitat Subclass*
    Flat, Ripples, Waves
    Slope, exposure
    Grain size, composition
    - *Microhabitats*
      Flow-related features:
      Erosional features
      Exposed cobble, pavement
      Exposure
    - **Emergent Structures**
      Geologic (boulders and cobble)
      Biologic (attached fauna i.e., corals and sponges)
      Exposure
    - **Biogenic Structures**
      (depressions, burrows, biogenic debris)
      Type of Debris
      Exposure

features were classified as flow related features (e.g., exposed patches of cobble or pavement in a predominantly sedimentary substrate), emergent structures (i.e., geologic and biologic including sponges, corals, other attached or emergent fauna), and other biogenic structures (e.g., coral debris, depressions, burrows). Figure 1 provides examples of a range of microhabitat types found within each habitat class.

Geologic attributes that are correlated with the distribution of fishes in other regions include sediment grain size, surface morphology or roughness, and slope (see Auster and Langton 1999 for a review). Grain size and roughness, from a fish habitat perspective, not only include the underlying geology but the biologic attributes of habitats that are composed of emergent fauna such a sponges and corals. These are grouped into a single microhabitat category in our classification scheme but can be divided where appropriate for classifying habitat use by fishes (e.g., boulders, boulders with attached corals). Coral debris, depressions, and burrows are grouped in a separate category (i.e., other biogenic structures) as they are neither static in size nor growing. In fact, coral debris degrades in complexity over time due to burial (and encrustation by manganese deposition). Depressions and burrows are physical alterations of sediment deposits created by individual organisms and are ephemeral habitats on the scale of days to years.

Applying this classification scheme in mixed basalt and sedimentary habitats will require decision rules for classifying habitats under threshold conditions. For example, a threshold is needed to decide if a habitat should be classified as ripples with exposed basalt pavement *versus* basalt pavement with a rippled sediment drape. Threshold values for sediment thickness and percent cover would be most easily applied in such cases. Here we suggest sediment thickness in excess 1 cm and greater than 50 % cover for classification as fine-grained sediment habitat. Less than either of these threshold values, at the scale of habitat class, subclass or microhabitat would require a classification of basalt habitat and associated sub-classes.

Similarly, the suspension feeders, in particular the gorgonians, present variable habitat aspects that could be used by different fish species. For example, deep on the seamount flanks the gorgonian assemblage is a mix of tall and whip-like species and short fans with low density branching (e.g., Fig. 1A). Here, the taller species can form moderately dense stands. In contrast, near and on the seamount summit, the gorgonians are more often large (~1 m wide) robust fans with high density

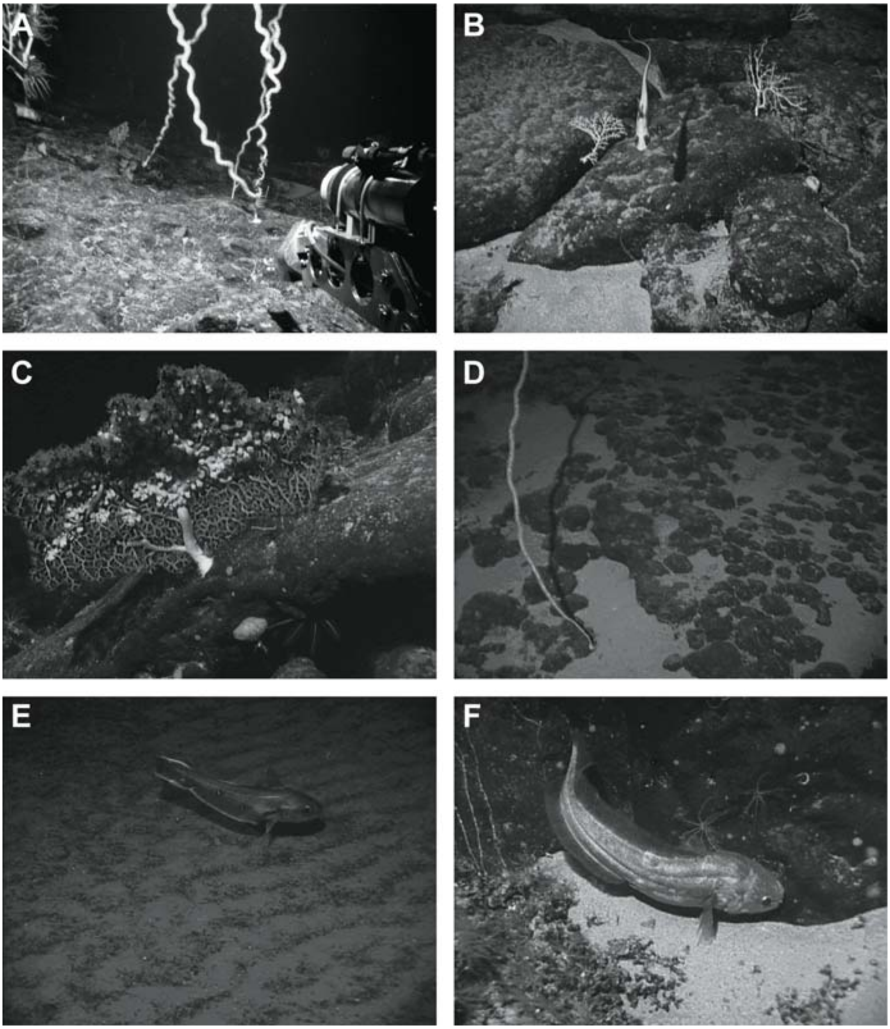

Fig. 1 Examples of microhabitat types found within each habitat class: **A** basalt pavement with tall, whip-like bamboo corals, **B** fractured basalt pavement with shelter sites and flow refuges in sediment-filled depressions between segments, **C** pavement with gorgonian fan with high density branching (i.e., *Paragorgia* sp.) as a shelter and flow refuge, **D** sediment draped basalt pavement, **E** rippled sediment, and **F** basalt-sediment ecotone. For scale, laser dots in images have 10 cm spacing

branching (Fig. 1C). These fans are spread much more widely across the landscape, and their form and density may have a different habitat value in terms of shelter or flow refuge.

Topographically induced flows occur at landscape, habitat class, habitat subclass and microhabitat levels. Water masses (with particular temperature and salinity characteristics) and currents impinging on seamounts produce different conditions despite similar substrate types and therefore are important attributes defining seamount landscape features as habitat for fishes. One or more water masses impinge on seamounts at different depth intervals with the consequence that physiological tolerances (as well as prey and shelter requirements) may determine how fishes are distributed at large spatial scales (ca. 100s - 1000s m). Flow characteristics around seamounts can be divided in a coarse fashion into regions of impingement, flow refuge and columnar flows (Figs. 2A-C). Variations in the distribution of structures at the scales of habitat subclasses (Fig. 2D) and microhabitats (Fig. 3) influence boundary flows and the ability of fishes to search for prey (e.g., where active searching by swimming can occur, where pelagic prey delivery is sufficient when station-keeping) and to avoid predators (e.g., the ability to exhibit efficiently various avoidance behaviors such as shelter seeking).

This habitat classification system was developed for initial application at the spatial scale of where individual organisms are located. The higher-level

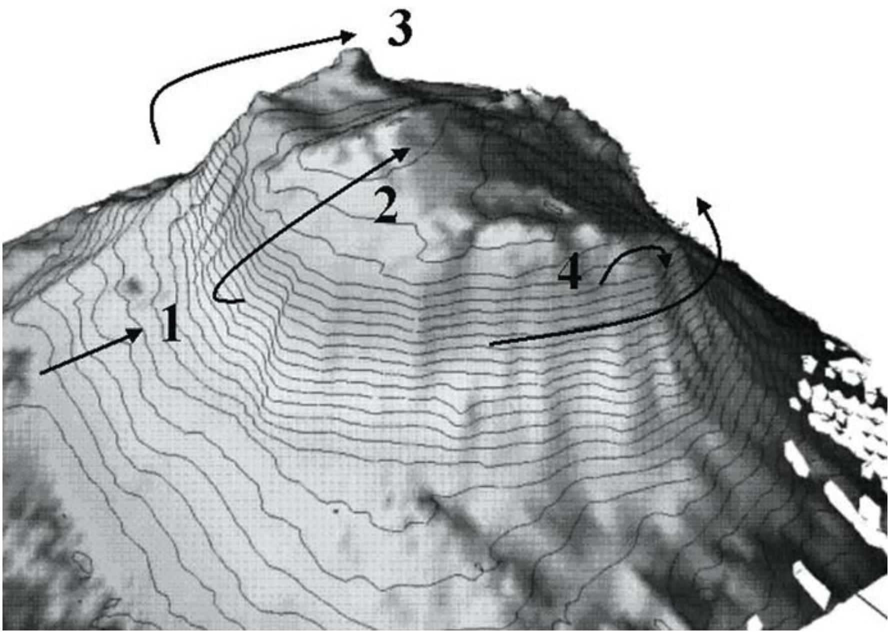

Fig. 2 Examples of variable flow regimes at the spatial scale of habitat classes include regions of (1) impinging flows, (2) flow induced upwellings, and (3) flow refuge or back-eddy. At the spatial scale of habitat subclasses, flows are influenced by features such as ridges and walls (4). (Figure is based on a preliminary multibeam sonar map of Bear Seamount)

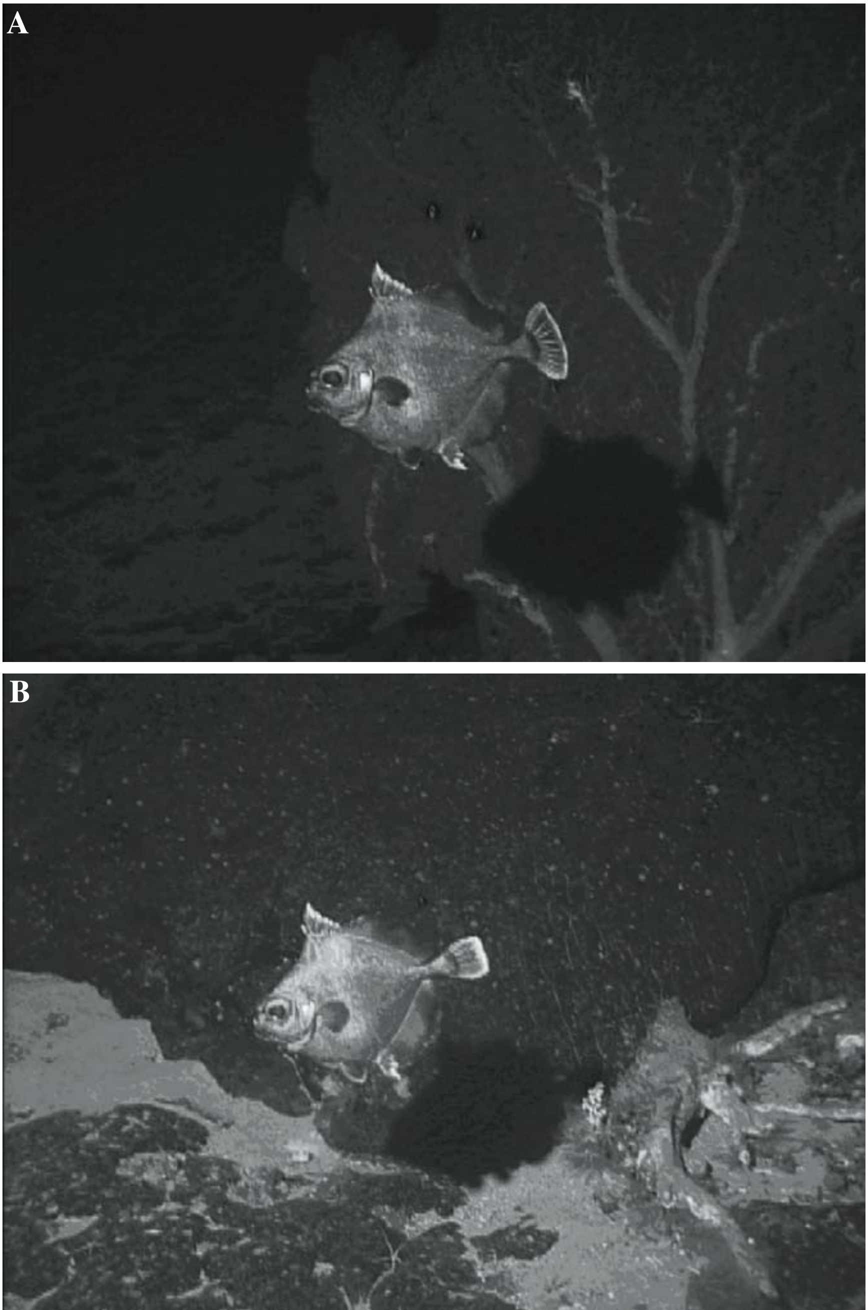

Fig. 3 *Neocyttus helgae* were observed to use (**A)** *Paragorgia* sp. coral and (**B**) depressions in the fractures of basalt pavements as shelter and flow refuge. For scale: fish length approximately 25 cm

classifications were therefore applied in a bottom up fashion. Our approach to delineating categorical habitat types was not designed to produce maps of seamount landscapes *per se* (although it is possible with this approach) but will be used to aid in quantification of the patterns of habitat use by fishes. Placing abundance data for individual species of fish within two different types of data matrices will allow quantitative approaches for assessing the role of particular landscape features in general, and corals in particular. A matrix composed of habitat subclasses *versus* microhabitat type will allow use of a chi-square test of homogeneity of distribution. Here expected values for each cell must be weighted based on the overall occurrence of each cell type along a transect or set of transects (e.g., Auster et al. 1995). A second matrix of sample (or species) abundances *versus* habitat subclass/microhabitat types (e.g., basalt pavement-coral, fine-grained sediment ripples-scattered boulders) can be analyzed using multi-dimensional scaling to ascertain relationships of groups of samples or species with particular microhabitat types.

Preliminary observations suggest that seamount fishes can be divided into four groups. The members of the first group are generalists and occur in all habitat types. These include halosaurids (i.e., *Aldrovandia* spp.), macrourids (i.e., *Caelorinchus* spp., *Nezumia* spp.) and *Synaphobranchus kaupii*. The second group, which occurs primarily in basalt habitats, includes an oreosomatid. Taxa that make up the third group occur in fine-grained sediment habitats, including macrourids (*Coryphaenoides* spp.), chimaerids (*Hydrolagus* spp.), rajids, alepocephalids, ipnopids (*Bathypterois* spp.), and synodontids (*Bathysaurus* spp.). One final group appears to be specialized in living along the ecotone of ledges and sediment and includes morids (*Antimora rostrata* and *Laemonema* spp.), ophidiid cusk-eels and other synaphobranchids besides *S. kaupii*.

Small-scale geologic and biotic components of the landscape include the organisms that are attached to or emerge from different substrate types as well as crests and depressions that influence flow patterns at local scales. Flow refuging by fishes, using depressions below the seafloor horizon and the down-current sides of epi- and emergent fauna can reduce the physiological requirements of station-keeping while enhancing the delivery of prey such as macrozooplankton and small nekton (Hobson 1991). The density of fishes on the New England Seamounts is low when compared to shelf and upper slope habitats (unpublished observations) and predation pressure may be widely dispersed, a hypothesis supported by the lack of most species to exhibit shelter-seeking behaviors (Auster et al. 1995). The exception to this observation is the behavior of *Neocyttus helgae* (family Oreosomatidae) that appears to be associated with *Paragorgia* sp., depressions within fractured basalt, and along depressed edges of pavements (Fig. 3). Their behavior appears to be related to some form of central place foraging and flow refuging. Individuals were observed holding station in the near-bottom water column behind or slightly above corals and small-scale topographic rises, apparently to encounter drifting zooplankton. Additional observations showed individuals picking at coral and sponge surfaces, apparently exploiting prey species associated with coral colonies or the polyps themselves.

It is important to note that co-occurrence does not imply a mechanistic relationship between particular habitat types and demographic processes mediating fish populations. Furthermore, many shelf and slope species exhibit facultative *versus* obligate habitat use patterns (Auster et al. 1995; Auster and Langton 1999). However, precautionary management paradigms suggest that pattern data be interpreted in a conservative manner and decision-making to conserve habitat attributes includes such features.

From a conservation science perspective, we need to evaluate the ecological role of deep-water corals as habitat for fishes within the context of the overall seamount landscape. This does not negate the need to focus first on conservation of corals based on their intrinsic long life spans and sensitivity to human caused disturbance (Koslow et al. 2001; Auster 2005).

Our objective here is to describe a system for classifying habitats in relation to the distribution of fishes. A future paper will provide a quantitative analysis relating the distribution and abundance of fishes to the range of landscape attributes on the New England Seamounts. Moreover, there remains an interest by some nations in expanding deep-water fisheries as well as designating seamounts and other deep-water features as marine reserves. This classification system can be used by those involved in mapping and monitoring to determine the spatial extent of particular habitats and quantify the dynamics of habitat based on natural and antropogenic induced chances.

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References

Auster PJ (2005) Are deep-water corals important habitats for fishes? In: Freiwald A, Roberts JM (eds) Cold-water Corals and Ecosystems. Springer, Berlin Heidelberg, pp 747-760

Auster PJ, Langton RW (1999) The effects of fishing on fish habitat. In: Benaka L (ed) Fish Habitat: Essential Fish Habitat and Rehabilitation. Amer Fish Soc, Bethesda, Maryland, pp 150-187

Auster PJ, Malatesta RJ, LaRosa SC (1995) Patterns of microhabitat utilization by mobile megafauna on the southern New England (USA) continental shelf and slope. Mar Ecol Progr Ser 127: 77-85

Boehlert GW, Genin A (1987) A review of the effects of seamounts on biological processes. In: Keating BH, Fryer P, Batiza R, Boehlert G (eds) Seamounts, Islands, and Atolls. Amer Geophys Union, Geophys Monogr 43: 319-334

De Forges BR, Koslow JA, Poore GCB (2000) Diversity and endemism of the benthic seamount fauna in the southwest Pacific. Nature 405: 944-947

Greene HG, Yoklavich MM, Starr RM, O'Connell VM, Wakefield WW, Sullivan DE, McRea JE, Cailliet GM (1999) A classification scheme for deep seafloor habitats. Oceanol Acta 22: 663-678

Hobson ES (1991) Trophic relationships of fishes specialized to feed on zooplankters above coral reefs. In: Sale PF (ed) The Ecology of Fishes on Coral Reefs. Academic Press, New York, pp 69-74

Koslow JA, Gowlett-Holmes K, Lowry JK, O'Hara T, Poore GCB, Williams A (2001) Seamount benthic macrofauna off southern Tasmania: community structure and impacts of trawling. Mar Ecol Progr Ser 213: 111-125

Moore JA, Hartel KE, Craddock JE, Galbraith JK (2003) An annotated list of deepwater fishes from the New England region, with new area records. Northeast Natural 10: 159-248

Rogers AD (1994) The biology of seamounts. Adv Mar Biol 30: 305-350

Willison JHM, Hall J, Gass SE, Kenchington ELR, Butler M, Doherty P (2001) Proceedings of the First International Symposium on Deep-Sea Corals. Ecology Action Centre and Nova Scotia Museum Natural History, Halifax, 231 pp

Wilson RR, Kaufmann RS (1987) Seamount biota and biogeography. In: Keating BH, Fryer P, Batiza R, Boehlert G (eds) Seamounts, Islands, and Atolls. Amer Geophys Union, Geophys Monogr 43: 355-378