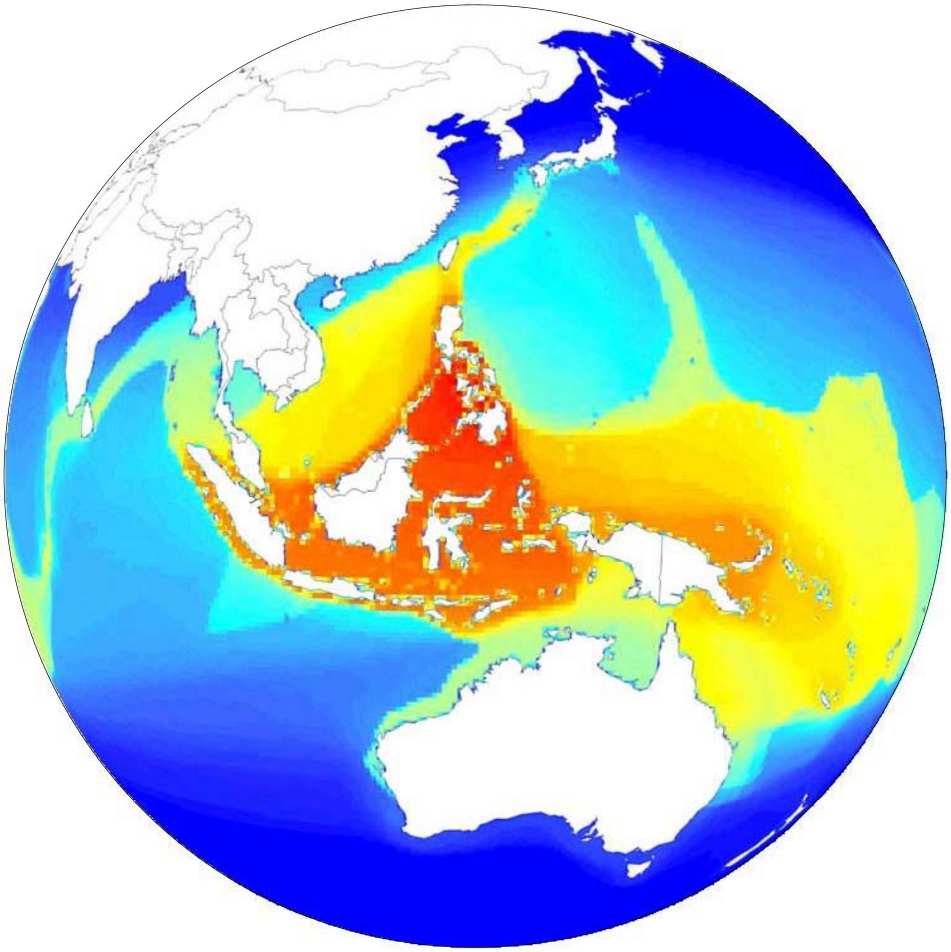

Mapping Marine Invertebrate Biodiversity Hotspots in the Indo-Pacific Ocean Using GIS

Final Report September 2004

Mapping Marine Invertebrate Biodiversity Hotspots in the Indo-Pacific Ocean Using GIS

Final report prepared for The John D. and Catherine T. MacArthur Foundation

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Executive Summary

As an aid to set policies and priorities for conservation of marine organisms in the Indo-Pacific region, the Bishop Museum studied the distribution of 2,249 marine invertebrates. Distributional data were obtained from museum collections and from taxonomic literature.

Over 29,000 locality records representing more than 1,100 species were gathered and georeferenced to plot species distributions on maps using a GIS program (ESRI ArcGIS 8.3). Maps for additional 1,100 species were obtained from the literature, digitized, rasterized, and added up to reveal patterns of biodiversity. The taxonomic coverage included all 794 coral species, 1,166 mollusks, and 289 crustaceans, totaling 2,249 species in the Indo-Pacific.

Composite maps of biodiversity revealed patterns of species richness that were concordant with a few exceptions. The region between the Philippines, the Malay Peninsula and New Guinea has the highest diversity of corals and is known as the "coral triangle." From this center of diversity in the tropics there are latitudinal and longitudinal gradients, decreasing rapidly with distance from the center. Mollusks and crustaceans studied showed similar patterns of diversity, although the region of highest diversity was slightly wider than the coral triangle.

Data on threats to coral reefs were used to rank the biodiversity hotspots according to species richness and threat risk, to preserve the largest number of species concentrated in small areas. The top biodiversity hotspots are: coral triangle, Vietnam, Thailand, Micronesia, Fiji, Okinawa, Sri Lanka, Seychelles, Madagascar, Comoro and Mascarene Islands, Tanzania, Red Sea, among others.

Additional data for other organisms should be analyzed to verify if patterns are concordant in different groups and identify gaps of knowledge and ecologically important regions currently without protection.

MAPPING MARINE INVERTEBRATE BIODIVERSITY HOTSPOTS IN THE INDO-PACIFIC OCEAN USING GIS

Introduction

Since the influential article by Myers *et al.* (2000), the concept of "biodiversity hotspots" has been widely touted as the best strategy to prioritize conservation funds to maximize the preservation of the largest number of species. Although the "hotspot" strategy has been extremely effective at generating funding for conservation, resources are limited. Despite some recent criticism (e.g. biodiversity "coldspots" by Kareiva and Marvier, 2003), the "hotspot" strategy still seems the most sensible, because of its cost-effective measures (Myers *et al.*, 2000). Rodrigues *et al.* (2004) evaluated the effectiveness of the global protected area network and suggested that it is far from ideal, but it could be enhanced if there were an expansion of protected areas where urgency for conservation action is greatest, i.e., in biodiversity hotspots not yet protected.

Coral reefs have been compared to tropical rain forests as areas of high diversity and in desperate need for conservation (Bryant *et al.*, 1998). Roberts *et al.* (2002) used corals, fishes, gastropods, and lobsters to identify marine biodiversity hotspots, and concluded that about half of the species studied are concentrated in 15.8% of the world's coral reefs. Many of these reefs are threatened, and conservation action is urgently needed.

The Tropical Indo-Pacific Ocean is the widest of all marine regions and recognized as the most diverse, particularly in the region known as "the coral triangle" or the "East Indies Triangle" (Briggs, 1996). This region is formed by the Philippines, Malay Peninsula, and New Guinea. Patterns of biodiversity both on terrestrial and marine organisms are coincident, and the peak of diversity is inside the coral triangle (Briggs, 1999). Biodiversity drops rapidly in any direction away from the triangle in longitudinal and latitudinal gradients. There is no consensus on the explanation of how this megadiversity was achieved, either by a process of accumulation of species, overlap of different biogeographic provinces, center of origin, center of refuge, or a combination of any of the above (Bellwood and Wainwright, 2002).

The goals of this study are to produce maps of distribution of marine species using GIS to study the patterns of biodiversity in the Indo-Pacific invertebrates and then compare the patterns of distribution and diversity to identify biodiversity hotspots, as well as gaps of knowledge. Ultimately, the results from this study could provide useful information to set conservation policies.

Materials and Methods

Detailed distributional data were collected from the taxonomic literature (monographs and revisions of families or genera) and museum specimens. More than 29,000 records were gathered and georeferenced (see *Georeferencing*). In addition, more than 1,100 species distributions reported as maps (as opposed to points) were used for the gastropod families Cypraeidae and Olividae and all scleractinian coral species.

Taxonomic sampling

The coral distributional data were obtained from J.E.N. Veron through Conservation International, consisting of maps of distribution for 794 species of scleractinian corals, virtually all known species (as recognized by Veron, 2000), from 18 families. Crustacean data representing 289 species from 19 families were collected, including coral-associated crabs in the family Trapeziidae, as well as other crabs (e.g. Homolidae, Portunidae), hermit crabs, and stomatopods. Molluscan distribution was studied for 1,166 species from 28 families, including well-known families such as the cowries (Cypraeidae), Cassidae, Cerithiidae, Haliotidae, Littorinidae, Mitridae, Strombidae, Tridacnidae, and others (Table 1). A total of 2,249 species of marine invertebrates were used in the analysis of biodiversity hotspots in the Indo-Pacific.

Georeferencing

Localities obtained from specimen data labels or from the literature were georeferenced, i.e., latitude and longitude coordinates were found and transformed into decimal degrees. The main source for coordinates for non-U.S. localities was the GEOnet Names Server (GNS) (http://earth-info.nga.mil/gns/html/), maintained by NGA (National Geospatial-Intelligence Agency, formerly National Imagery and Mapping Agency (NIMA)). The database is continually updated; name files for countries and territories were downloaded between May and June 2003. For localities in the United States and U.S. territories, coordinates were obtained from the U.S. Geological Survey (USGS) Geographic Names Information System (GNIS) (http://geonames.usgs.gov/). Several other electronic gazetteers were also used, including a mapping tool from the Alexandria Digital Library Gazetteer Server (http://fat-albert.alexandria.ucsb.edu:8827/gazetteer/), which plots locality maps in a user-friendly interface. Additionally, maps and atlases were also used for georeferencing. Google (www.google.com) was useful in tracking down localities not found in the gazetteers mentioned above.

A few historical names were found through Google in pre-World War II documents posted on the Internet, or through the help of people familiar with historical localities in Papua New Guinea (Allen Allison (Bishop Museum) and Mary LeCroy (AMNH)). Despite our best efforts, about one thousand records (circa 3.4 % of the records) could not be used in the analysis either because of too broad locality data (e.g., Pacific Ocean or Australia), wrong or no locality data, or because the locality could not be found in maps or gazetteers.

The coordinates for more than 5,500 localities were found, in addition to some 4,800 records with coordinates from the literature and specimen labels (actual number of different localities from the literature not counted, but likely to be more than 2,000). Georeferenced records were plotted onto maps using ESRI ArcGIS 8.3 suite (Fig. 55).

Making distribution maps

For distributions reported as points (records for each collection locality, Fig. 1), a minimum-bounding polygon ("shrink-wrapping" or concave hull) was drawn by hand in ArcMap encompassing all collection points for the species (Fig. 2). When large distances separated points, e.g. a few points in East Africa and others in the Central Pacific, separate polygons were created, assuming disjunct populations (but still analyzed as one species). Ranges for subspecies were added up (as the sum of the ranges for all subspecies) to obtain the distribution of the species. Data reported as distribution maps were digitized by hand into ArcMap. Maps were represented in "unprojected" coordinate system, using the WGS1984 datum, which is close in appearance to the Plate Carree projection used in the maps in this report.

A mask of the Indo-Pacific ocean with landmasses and islands was used as a "cookie cutter" to remove landmasses from the distribution maps. The ocean mask was made using ESRI's world basemap for continents and adding the coordinates for approximately 65,000 islands in the Indo-Pacific (coordinates obtained from all sea-bordering countries in the region, from the GEOnet Names Server website). The resulting complex polygon (Fig. 3) was then saved with the species name as an ArcGIS shapefile (e.g. marginatus.shp) and arranged in folders per family. A shapefile is a metafile composed of polygons (or points), map projection and coordinate system. Each polygon, in this case, represents the distribution of a single species.

Another ocean mask, the 200 m bathymetric mask, was made to clip out regions with depths greater than 200 m, to represent only the "shallow" water parts of the distribution. This was done because most of the species analyzed were "shallow" water benthic species. Bathymetric data was obtained from Smith and Sandwell (1977), WORLDBATH (2000), and atlases.

Upon completion of a distribution map, it was rasterized (i.e., converted from a vector-based map to a bitmap) using a 0.5° grid (circa 55 x 55 km, or about 3,000 km^2). Rasters for each species (Appendix Figs. 1-01 to 3-2249) were then added up to calculate the species diversity per family (Figs. 4-45), and then added up to identify global hotspots of species diversity in the Indo-Pacific (Figs. 46-54).

Species areas

The minimum-bounding polygons (maps of distributions) were projected in World Cylindrical Equal Area projection, to produce distributions of comparable areas despite latitude. The species area was calculated in this projection, so that areas could be meaningfully compared. The minimum and maximum latitude and longitude of each species distribution were recorded, as well as the center of distribution. Species areas were ranked per family to identify the species with the most widely and most restricted distributions, or pandemics and endemics (*sensu* Hughes *et al.*, 2002), respectively. The average area per species per family was also calculated.

Results

Maps of species richness for each family are presented in Figs. 4-45, and maps of composite biodiversity (species richness) are shown in Figs. 46-54. The maps for the following families with few species (three or less) are not shown: Actinocyclidae and Phasianellidae (Mollusca: Gastropoda), Caryophyllidae, Rhizangiidae, and Trachyphylliidae (Cnidaria: Scleractinia). Additionally, five families of polyplacophoran mollusks (Chitonidae, Choriplacidae, Hanleyidae, Ischnochitonidae, and Leptochitonidae) were combined into a single map (Fig. 24), since three of these families had only four or fewer species represented. And finally, eleven families of stomatopod crustaceans (Eurysquillidae, Gonodactylidae, Harpiosquillidae, Heterosquillidae, Lysiosquillidae, Nannosquillidae, Odontodactylidae, Protosquillidae, Pseudosquillidae, Squillidae, Takuidae) were combined into a single map (Fig. 31) also because most of these families are represented by a small number of species.

Not surprisingly, the center of highest marine biodiversity was found in the “coral triangle” region, between the Philippines, Malay Peninsula, and New Guinea, and latitudinal and longitudinal gradients decreasing with distance from the region.

There was an overall concordance between the patterns of species diversity between corals, mollusks, and crustaceans, although the latter two taxa had the area with the highest diversity slightly wider than corals. A few families or taxa (e.g. chitons (Polyplacophora), Fig. 24) had centers of diversity in different areas (southern Australia, Northwest coast of North America, and Japan), but most families or taxa analyzed had the highest diversity in or near the coral triangle.

Table 2 shows the average area per species per family. It is notable that most crustacean families have smaller average areas than the molluscan families. The chitons (families Chitonidae, Choriplacidae, Hanleyidae, and Leptochitonidae) studied had small distributions because many species are known from few specimens. On the other hand, some families of gastropods had wide distributions, in some cases ranging from East Africa through the Indian and Pacific Oceans, and even reaching the west coast of Central America.

Biodiversity Hotspots

Most biodiversity hotspots, as defined here as regions with high species richness that are under threat by human activities (Myers *et al*., 2000), are located in the coral triangle (Table 3). In this analysis, the Philippines had the highest species richness, with 1,047 species (46.6% of 2,249 species) around Cebu, but high species richness occurs in most central Philippines and in islands around the deep Sulu Sea. The whole coral triangle had an average of more than 800 species (35-45% of the total number of species analyzed). This is a result of the highest biodiversity in a myriad of islands in the tropics, with highly diverse habitats, and densely populated by humans (Indonesia has the world's fourth largest population). In addition, threats to coral reefs include widespread dynamite fishing, heavy ornamental fish collection, and pollution from human settlements.

Other hotspots near the coral triangle include Vietnam, Hainan Island (South China Sea), and Thailand (Phuket Island, Bangkok, Andaman Islands). These hotspots are also located in areas with dense human populations and anthropogenic disturbances.

Moving away from the coral triangle, other hotspots include Taiwan (especially the west coast) and Okinawa in the West Pacific, and in towards the Central Pacific there are Palau and Micronesia, Fiji, Western Samoa, and Christmas Island (Line islands, Kiribati), which has a high diversity, considering its distance from the coral triangle.

In the Western Indian Ocean, the biodiversity hotspots include Tanzania, Comoro Islands, Northern Madagascar, Mascarene Islands, and Seychelles. In the Northern Indian Ocean the biodiversity hotspots are Sri Lanka and southern India, and the Red Sea. Qatar is less diverse, but its reefs are at risk, so it was included as a hotspot.

Discussion

Taxonomic issues

No taxonomic judgment was attempted because it was beyond the scope of this project (therefore taxonomic revisions were used because they were assumed to be the most current). However, some monographs may be outdated, as evidenced by Reid (pers. comm., July 2004) in the Littorinidae. In some cases, current knowledge using molecular markers indicate that what were once considered species with wide Indo-Pacific distributions may actually consist of a number of species with narrower distributions. One difficulty is that such updated classifications are very recent or may not have been published yet, as in the case of the Littorinidae.

The validity of this model of biodiversity hotspots is not necessarily invalidated by taxonomic changes. The patterns of distribution of species may vary with the splitting or lumping of species, or discovery of new ones, but the overall patterns of diversity may change only slightly. The model can, and should, be updated and expanded to include more species to avoid bias in the distribution of certain taxa, and to become more comprehensive.

The pronounced taxonomic bias in the number of molluscan species in relation to the crustacean species is explained by one of us (F. Moretzsohn) being trained as a malacologist, and being more familiar with the molluscan than the crustacean literature.

Species areas

Species areas were overestimated because of a few factors: 1) species ranges were drawn wider than actual for visual effect. If points were represented as a point (and not a dot with a certain diameter), and minimum-bounding polygons were drawn without a buffer, some distributions would not be visible in a computer screen. 2) The suitable habitat for shallow water benthic marine invertebrates is not available in all of the range because of depth (especially in oceanic islands, where depth increases rapidly with distance from shore) and other physical and environmental factors (e.g. substrate, thermoclynes, etc).

On the other hand, however, the lack of knowledge of the real distribution may underestimate the potential range of the species. One example is shallow water species that once were believed to be endemic to certain areas may also occur in deeper waters elsewhere (e.g. *Luria tessellata*, a gastropod, once considered endemic to Hawaii, has recently been found in deeper waters in Taiwan and the Philippines). Another instance where species ranges can be underestimated is the poor knowledge of the fauna (and flora) in some locations that have not been well studied. The usefulness of biodiversity models depends on the accuracy of species distribution. The inclusion of additional records and correction of errors will improve the model.

Ocean masks

ESRI ArcGIS comes with a number of basemaps (in different formats, as layers, shapefiles and rasters), such as countries and continents, elevation and bathymetry, world cities, etc., but no ocean layer was found among the datasets provided with ArcGIS 8.3. Since this project dealt with marine species, we had to build our own ocean mask, starting with a continents layer, and adding some 65,000 points for oceanic islands in the Indo-Pacific. This ocean mask was used to clip out landmasses from maps of distribution, to represent only the distribution of marine species.

Another mask, a 200 m bathymetric mask, was made to clip out from a distribution map the areas representing depths greater than 200 m. This depth was chosen because it is approximately 100 fathoms, usually the first depth reported in world bathymetric maps (although some maps report depths of 50 fms). The contour of the 200 m isobath corresponds closely the continental shelf. Also, 200 m is deep enough to encompass most of the "shallow" water benthic species. Some species that occur in shallower waters may also occur in depths deeper than 200 m.

When making the bathymetric mask, an arbitrary buffer of 20 km was added to oceanic islands, so that distributions clipped with the mask could be seen in oceanic islands. The 200 m isobath in oceanic islands is so close to the shore that is would not show up in a global scale map. In reality, the depth at a distance of 20 km from shore in most oceanic islands is probably the bottom of the ocean.

Georeferencing

Assigning geographic coordinates to old museum records is increasingly receiving a lot of attention from many museums around the world. The task is daunting because of the enormous amount of data involved--in the order of billions of natural history specimens worldwide (Krishtalka and Humphrey, 2000). Currently, georeferencing has to be done manually in most cases because of inconsistencies in recording geographical information associated with museum specimens. New tools are being developed to automate the process, but as Murphey *et al.* (2004) reviewed, we are still in the infancy of the field of "Biodiversity Informatics."

One common problem in georeferencing of museum collections (retrospective georeferencing) is the "homonym problem," when multiple places with the same name are found (see Murphey *et al.*, 2004). This problem was particularly common in Indonesia, Malaysia, and the Philippines, and it may be time-consuming to resolve. In one extreme case, 178 entries for San Jose village were found in the Philippines, but with additional information, the search was narrowed down to the village closest to the

Mindoro Strait. Another problem is that of synonyms, which means that a different name for the same place can be used in a database.

Another georeferencing caveat is that the coordinates reported for localities in electronic gazetteers usually refer to the center of an island, village, or geographic feature. In many cases in this study, only the island or village name was available, and it was not possible to determine the associated error to properly georeference the locality. However, because of the global scale of the patterns of biodiversity in this project, errors of a few kilometers are not important when the final maps were rasterized with a 0.5° grid (circa 55 km x 55 km grid cell). This grid cell size provided better resolution than the 2° grid cells used in Roberts *et al.* (2002). A finer grid could be used to reveal even more details, but because some of the distributions (especially those reported as maps, not points) may be less accurate than the grid, we decided to use a 0.5° to avoid introducing a false sense of accuracy. As field collectors increasingly use more GPS (Global Satellite Positioning) devices and record named localities more accurately, biodiversity data can be explored and analyzed with much greater resolution.

Biases and caveats

The bias in geographic sampling can be evidenced in Fig. 55, where a high density of data points is seen around Australia, New Caledonia, Japan, and the Philippines, whereas the northern Indian Ocean, and the Pacific coast of Central and South America are poorly sampled. Some of the sampling effort may be explained by the presence of centers with long research tradition (e.g. Pacific coast of North America, Japan, New Caledonia) and intense commercial fisheries (e.g. New Zealand, Japan, Peru), but biodiversity hotspots do not necessarily coincide with sampling effort. If some areas that are currently under-sampled were equally sampled for biodiversity, biodiversity patterns might show a different picture and even higher diversity than currently recognized. There are gaps in the knowledge of marine diversity, and they may bias the model in the direction of areas that are well sampled. What may be seen as a weakness of the model is also one of its strengths, since the model is also useful in identifying those gaps.

An effort was made to include only data from global taxonomic reviews of families and genera. However, a few more localized works were also included, such as the stomatopod crustaceans from Vietnam (Fig. 31), or the personid gastropods with an emphasis on New Caledonia (Fig. 19), but in both cases the species reviewed had records from other regions as well. When these more localized studies were not included in the global analysis, the overall patterns of biodiversity were not changed (not shown).

ArcGIS

The GIS program used, ESRI ArcGIS is the most widely used GIS software. It is a powerful suite of programs (called extensions) that cater to a wide range of professionals. It is possible to do complex analyses, graphical representations, customizations and programming. However, the program is not user-friendly, and has a steep learning curve, despite the good technical support and online courses available. The program is also very expensive and may be out of reach for many institutions; each “extension” has to be purchased separately to obtain the appropriate functionality.

We had a long learning process to get the program to do the necessary calculations, rasterizations, and other steps involved in the analyses. Fortunately we had help from other people more familiar with the program and technical support from ESRI. Despite all the help and tips from technical support and a user forum, we could not perform a few functions, such as changing the projection of a raster, or making a raster of the world map to be represented with the Indo-Pacific in the center. For this reason, the species richness maps (Figs. 4-51), made from rasters, are shown with Greenwich as the central meridian, while the species distribution maps (see appendices), made from shapefiles, could be represented with the Indo-Pacific in the center.

Another problem encountered was the coral dataset, which was produced by another group (Conservation International). Until very late, we had problems with the projection and extension (coordinates of the bounding box of the map), and we could not project the coral layers and rasters in the same map with other layers (mollusks and crustaceans).

Finally, one of us (M. McShane) learned how to manipulate the coral data in a way that we were able analyze them together with the other datasets.

Biodiversity Hotspots

Based on the data used in this study, the region of overall highest diversity in mollusks and crustaceans extends slightly beyond the coral triangle. The implications of these patterns include a concern to also protect areas outside of the coral triangle, since other animals (and plants) may also have similar broader hotspots than corals. Each group analyzed has slight variations in the patterns of biodiversity, but overall there is a good concordance with the global patterns of global biodiversity (Fig. 46; Veron, 2000), therefore it is useful to refer to the coral triangle as the main hotspot of marine invertebrate biodiversity.

A few groups, such as the chitons (mostly families Ischnochitonidae and Leptochitonidae, Fig. 24), have a different pattern of biodiversity, and the highest species richness were found in Southern Australia, Pacific coast of North America, Japan, and South Africa, which bears similarities with marine algae (A. Kerswell, pers. comm., July 2004). This could be explained by some families or groups having a more temperate distribution, in contrast with the predominantly tropical distribution in most groups studied here.

The term “biodiversity hotspots” was coined by Myers in 1988 and became very common since the important article by Myers *et al*. (2000). The original meaning of biodiversity hotspot is a combination of both an area with high species endemism and degree of threat. The latter is difficult to measure, because of the subjective component on how to evaluate the hazards (Kareiva and Marvier, 2003). To compound the problem, marine biodiversity and the threats are even less understood in than in terrestrial habitats. Since there seems to be a good correlation between coral reef and invertebrate biodiversity, and the threats to corals are better documented (Bryant *et al*., 1998) than threats to other invertebrates, we followed a similar approach as Roberts *et al.* (2002) and used the mapped coral threats of Bryant *et al*. (1998) to assess threats to invertebrates in general.

In general, biodiversity hotspots correspond to regions with high species richness in the tropics, which are usually more densely populated by humans and associated anthropogenic problems.

Kareiva and Marvier (2003) coined the term biodiversity “coldspots”, to represent the vast majority of places which are not biodiversity hotspots. The authors present good arguments for not investing only in the hotspot strategy, but rather also protect certain regions with low species diversity but which have special ecological significance, such as the Artic, the Serengeti, or wetlands. In the case of marine species, based on this study we could list some places like the Galapagos Island, Easter Island, and New Zealand, all of which have relatively low species richness, but have high proportion of endemic species, and should be considered among the priorities for conservation. Some regions with high biodiversity were not included in Table 3 because they are either not under threat or are properly protected (e.g. the Great Barrier Reef in Australia).

A recent study by Rodrigues *et al.* (2004) based on terrestrial and freshwater vertebrates (mammals, birds, turtles, and amphibians) reviewed the effectiveness of the global protected area network. Despite the fact that 11.5% of the world’s landmasses are protected, gap analysis suggests that at least 12% of the species studied are not represented in any protected areas. Expansion of the protected area network should cover biodiversity hotspots not currently protected, such as montane or insular regions in the tropics. The study also recognizes that the analysis was done only with vertebrates, and invertebrates may have different patterns of endemism. The study did not mention, however, marine protected areas (MPAs) and the need for conservation, especially in coral reefs and other biodiversity hotspots. We suggest that a similar study in the marine protected areas would be a worthy endeavor to review their efficiency and to identify gaps.

Conclusions

More than half of the world's reefs are at risk from anthropogenic activities (Bryant *et al.*, 1998), and many crustacean and molluscan biodiversity hotspots coincide with coral reef hotspots, usually in tropical areas near highly concentrated humans.

Benthic marine invertebrates with restricted ranges are potentially more vulnerable to habitat degradation than widely spread species. Biodiversity hotspots should be urgently protected, but areas with high incidence of restricted-range species should also receive high priority to preserve unique genotypes.

Additional data (for example on fish distributions, more crustaceans and other groups) would provide valuable information and contribute to make more sound analyses. Also, a gap analysis of marine species and evaluation of the efficiency of the marine protected area network should be done to identify areas currently not protected.

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Table 1. Number of species analyzed per family

Phylum or Subphylum	Subclass or Order	Family	No. species	No. records
Mollusca	Bivalvia	Condylocardiidae	34	771
Mollusca	Bivalvia	Pinnidae	8	231
Mollusca	Bivalvia	Tridacnidae	7	451
Mollusca	Gastropoda	Actinocyclidae	2	14
Mollusca	Gastropoda	Bursidae	20	570
Mollusca	Gastropoda	Cassidae	26	705
Mollusca	Gastropoda	Cerithiidae	45	3,694
Mollusca	Gastropoda	Cypraeidae	209	552 + maps
Mollusca	Gastropoda	Dialidae	6	1,376
Mollusca	Gastropoda	Haliotidae	51	3,717
Mollusca	Gastropoda	Harpidae	15	529
Mollusca	Gastropoda	Littorinidae	49	2,332
Mollusca	Gastropoda	Mitridae	186	4,752
Mollusca	Gastropoda	Muricidae	9	825
Mollusca	Gastropoda	Olividae	115	Maps
Mollusca	Gastropoda	Patellidae	64	601
Mollusca	Gastropoda	Personidae	15	351
Mollusca	Gastropoda	Phasianellidae	3	21
Mollusca	Gastropoda	Ranellidae	48	1,518
Mollusca	Gastropoda	Strombidae	50	1,522
Mollusca	Gastropoda	Triviidae	20	242
Mollusca	Gastropoda	Trochidae	6	27
Mollusca	Gastropoda	Vasidae	14	114
Mollusca	Polyplacophora	Chitonidae	1	1
Mollusca	Polyplacophora	Choriplacidae	1	1
Mollusca	Polyplacophora	Hanleyidae	4	6
Mollusca	Polyplacophora	Ischnochitonidae	124	459
Mollusca	Polyplacophora	Leptochitonidae	34	114
Crustacea	Decapoda	Diogenidae	24	205
Crustacea	Decapoda	Dynomenidae	13	274
Crustacea	Decapoda	Homolidae	56	728
Crustacea	Decapoda	Homolodromiidae	20	48
Crustacea	Decapoda	Leucosiidae	27	105
Crustacea	Decapoda	Portunidae	35	656
Crustacea	Decapoda	Rhynchocinetidae	6	77
Crustacea	Decapoda	Trapeziidae	28	655
Crustacea	Stomatopoda	Eurysquillidae	5	41
Crustacea	Stomatopoda	Gonodactylidae	21	243
Crustacea	Stomatopoda	Harpiosquillidae	5	59
Crustacea	Stomatopoda	Heterosquillidae	1	3
Crustacea	Stomatopoda	Lysiosquillidae	3	30
Crustacea	Stomatopoda	Nannosquillidae	3	27
Crustacea	Stomatopoda	Odontodactylidae	2	39
Crustacea	Stomatopoda	Protosquillidae	6	74
Crustacea	Stomatopoda	Pseudosquillidae	2	20

Table 1 (cont.). Number of species analyzed per family

Phylum or Subphylum	Subclass or Order	Family	No. species	No. records
Crustacea	Stomatopoda	Squillidae	31	260
Crustacea	Stomatopoda	Takuidae	1	12
Cnidaria	Scleractinia	Acroporidae	262	Maps
Cnidaria	Scleractinia	Agariciidae	43	Maps
Cnidaria	Scleractinia	Astrocoenidae	13	Maps
Cnidaria	Scleractinia	Caryophyllidae	1	Map
Cnidaria	Scleractinia	Dendrophylliidae	14	Maps
Cnidaria	Scleractinia	Euphylliidae	14	Maps
Cnidaria	Scleractinia	Faviidae	126	Maps
Cnidaria	Scleractinia	Fungiidae	56	Maps
Cnidaria	Scleractinia	Merulinidae	13	Maps
Cnidaria	Scleractinia	Mussidae	50	Maps
Cnidaria	Scleractinia	Oculinidae	15	Maps
Cnidaria	Scleractinia	Pectiniidae	28	Maps
Cnidaria	Scleractinia	Pocilloporidae	30	Maps
Cnidaria	Scleractinia	Poritidae	92	Maps
Cnidaria	Scleractinia	Rhizangiidae	1	Map
Cnidaria	Scleractinia	Siderastreidae	28	Maps
Cnidaria	Scleractinia	Trachyphylliidae	1	Map

Table 2. Average area per species per family

Group	Family	No. species	Ave. area per family (km^2)
Mollusca	Choriplacidae	1	49,846
Mollusca	Phasianellidae	3	305,245
Crustacea	Harpiosquillidae	2	353,526
Mollusca	Trochidae	6	488,710
Mollusca	Leptochitonidae	34	564,019
Crustacea	Homolodromiidae	20	668,849
Mollusca	Ischnochitonidae	124	681,146
Mollusca	Condylocardiidae	34	712,616
Mollusca	Hanleyidae	4	785,638
Crustacea	Pseudosquillidae	2	899,823
Crustacea	Protosquillidae	6	1,174,057
Crustacea	Lysiosquillidae	3	1,438,894
Crustacea	Harpiosquillidae	4	1,540,088
Crustacea	Squillidae	31	1,569,187
Crustacea	Odontodactylidae	2	2,678,178
Crustacea	Eurysquillidae	5	3,412,059
Crustacea	Leucosiidae	27	3,839,367
Crustacea	Nannosquillidae	3	3,843,038
Mollusca	Triviidae	20	3,895,646
Crustacea	Gonodactylidae	21	4,129,435
Mollusca	Patellidae	64	4,607,442
Crustacea	Homolidae	56	5,162,797
Mollusca	Vasidae	14	9,181,469
Crustacea	Diogenidae	24	9,532,729
Mollusca	Haliotidae	51	11,646,896
Crustacea	Trapeziidae	28	13,373,022
Mollusca	Personidae	15	14,149,459
Mollusca	Olividae	115	15,153,911
Mollusca	Cassidae	26	16,422,949
Mollusca	Littorinidae	49	19,136,029
Mollusca	Harpidae	15	20,025,604
Mollusca	Bursidae	20	22,561,427
Mollusca	Cypraeidae	225	27,186,885
Mollusca	Actinocyclidae	2	27,286,979
Crustacea	Dynomenidae	13	28,472,084
Crustacea	Rhynchocinetidae	6	29,048,670
Mollusca	Mitridae	186	31,088,110
Mollusca	Strombidae	40	33,115,270
Crustacea	Portunidae	35	33,846,663
Mollusca	Ranellidae	48	34,053,758
Mollusca	Cerithiidae	46	40,429,466
Mollusca	Tridacnidae	6	45,670,473
Mollusca	Dialidae	6	46,763,142
Mollusca	Pinnidae	8	51,313,100
Mollusca	Muricidae	9	64,834,406

Table 3. Biodiversity hotspots ranked by species richness, with percentage of species analyzed

Biodiversity Hotspot location	**No. species**	**% species**
Philippines - Sulu Sea and central region	1047	46.6
Malaysia - NE Borneo	1000	44.5
Indonesia - Celebes, Ceram	985	43.8
Indonesia - Banda Sea	940	41.8
Indonesia - Java Sea, Timor, Bali	928	41.3
Indonesia - Mentawai Is.	889	39.5
Papua New Guinea - SE	800	35.6
East Vietnam	713	31.7
Micronesia	700	31.1
Fiji	697	31.0
Okinawa	684	30.4
Palau	614	27.3
Thailand - Phuket	597	26.5
Mascarene Is.	571	25.4
Comoro Is.	566	25.2
Sri Lanka - South India	560	24.9
Seychelles	550	24.5
Madagascar - North coast	550	24.5
Andaman Is.	535	23.8
Western Samoa	482	21.4
Tanzania	472	21.0
Southern Red Sea	450	20.0
West Taiwan	405	18.0
Thailand - Bangkok	395	17.6
China – Hainan Is.	335	14.9
Christmas Is.	192	8.5
Qatar	151	6.7

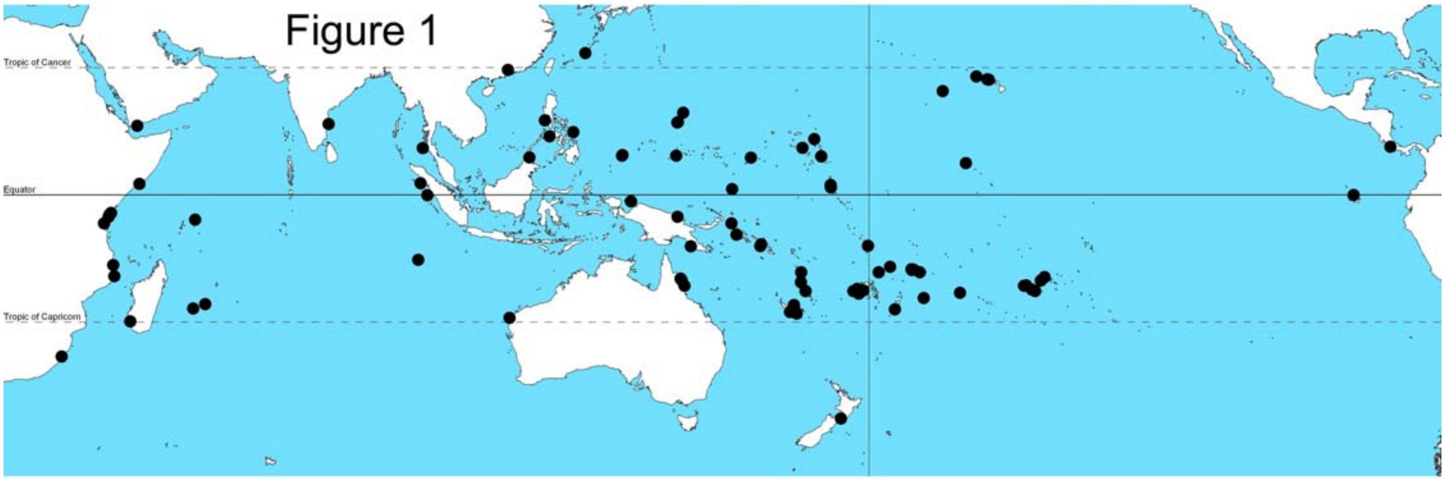


Figure 1
Tropic of Cancer
Equator
Tropic of Capricorn

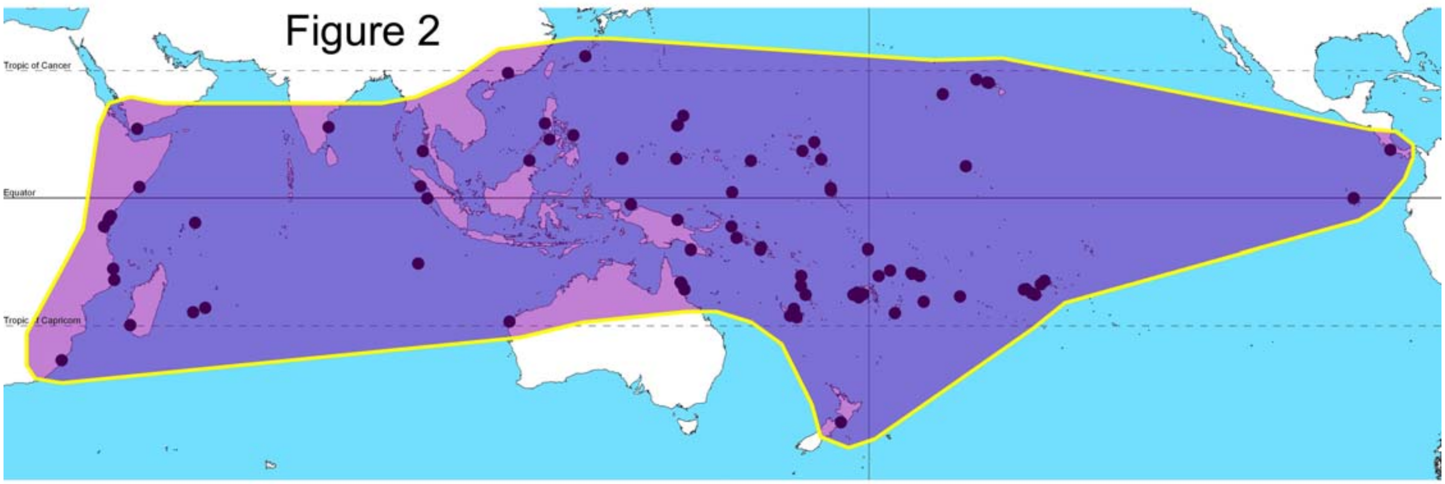


Figure 2
Tropic of Cancer
Equator


Figure 3
Tropic of Cancer
Equator
Tropic of Capricorn

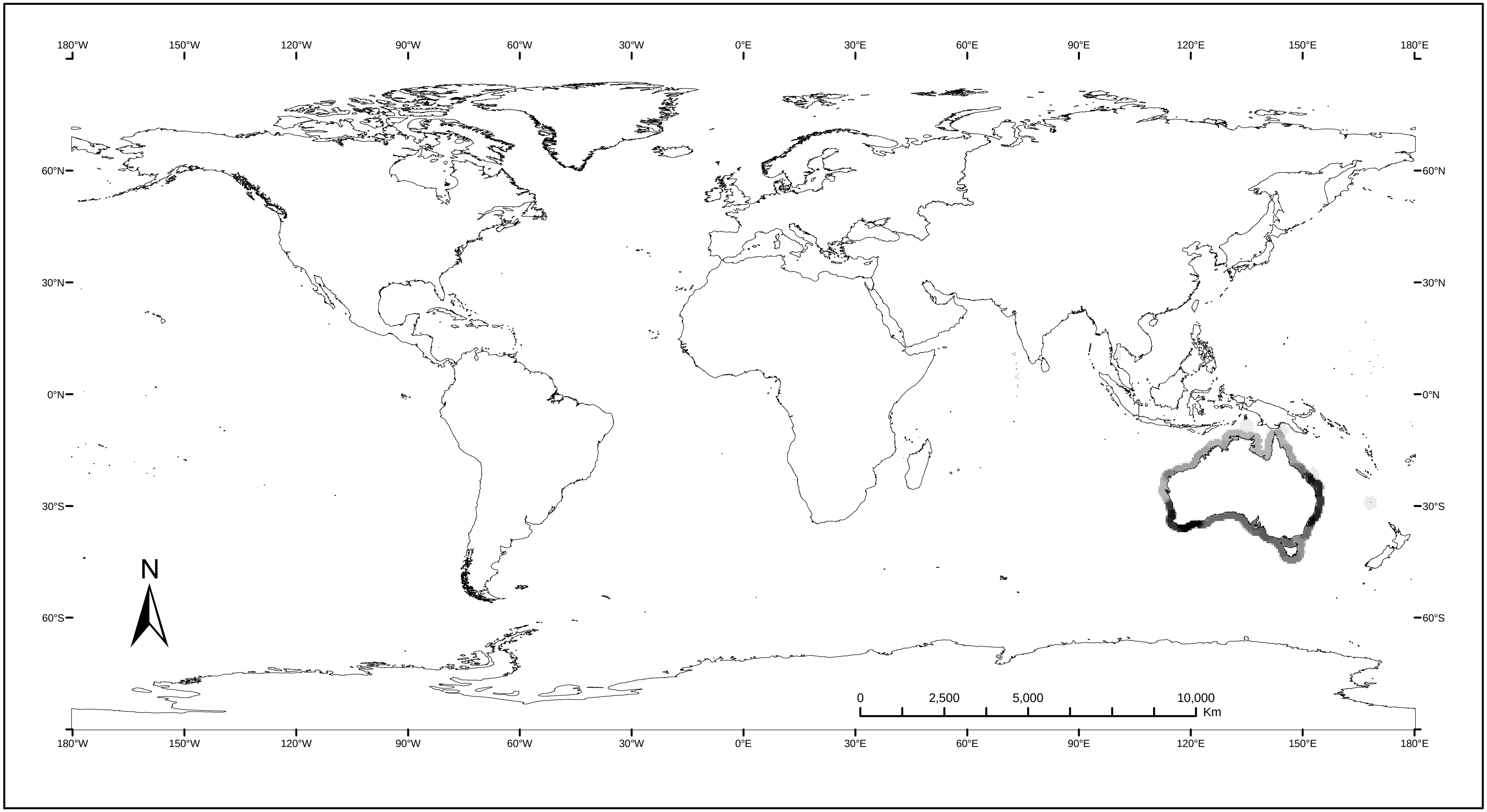
Figure 4

Phylum Mollusca, Class Bivalvia

Reference: modified from Middelfart, 2002A & B

Family Condylocardiidae

34 Australian species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5 6 7 8 9 10 11 12 13 14

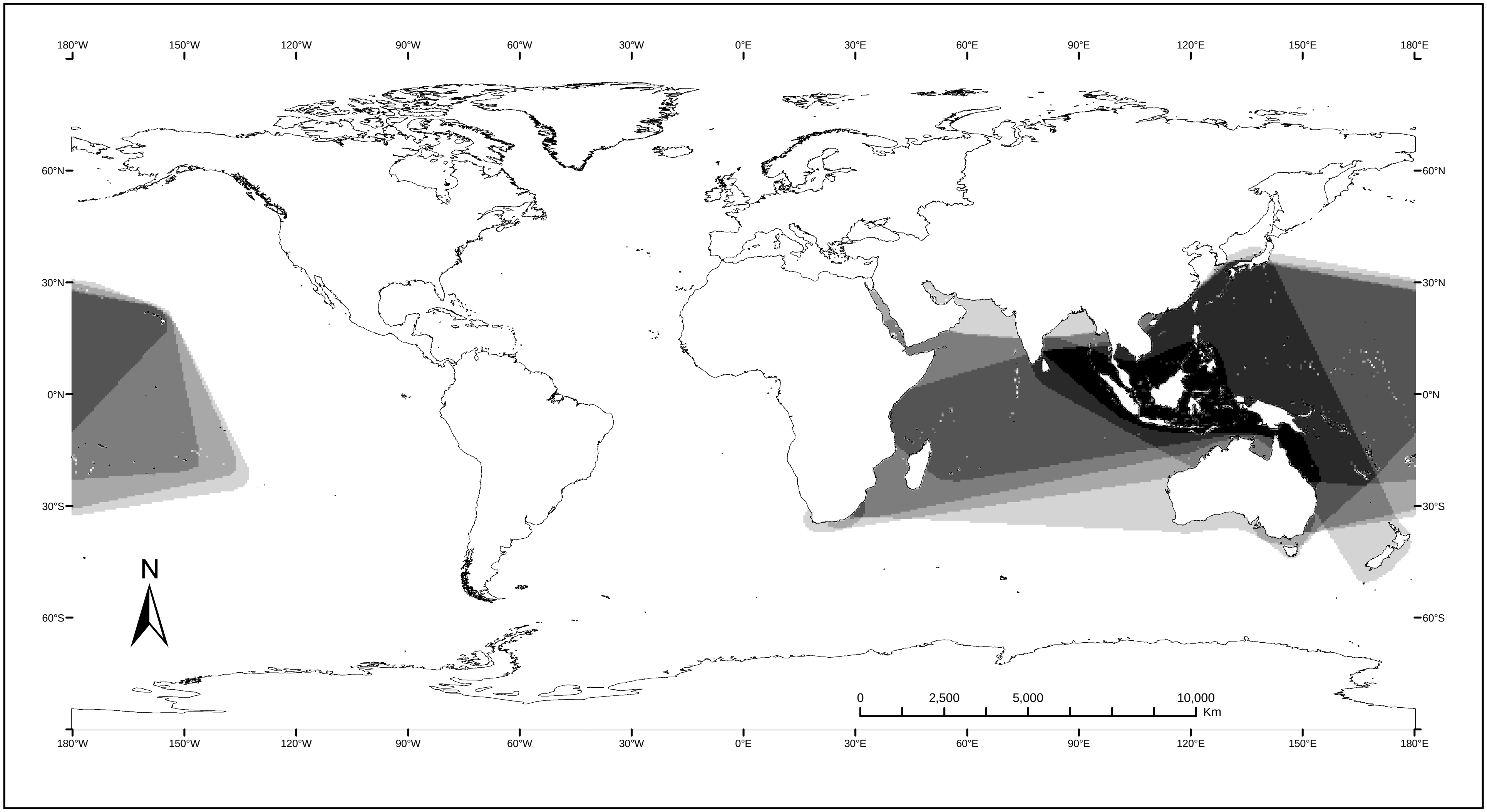
Figure 5

Phylum Mollusca, Class Bivalvia

Reference: modified from Rosewater, 1961

Family Pinnidae

8 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5 6

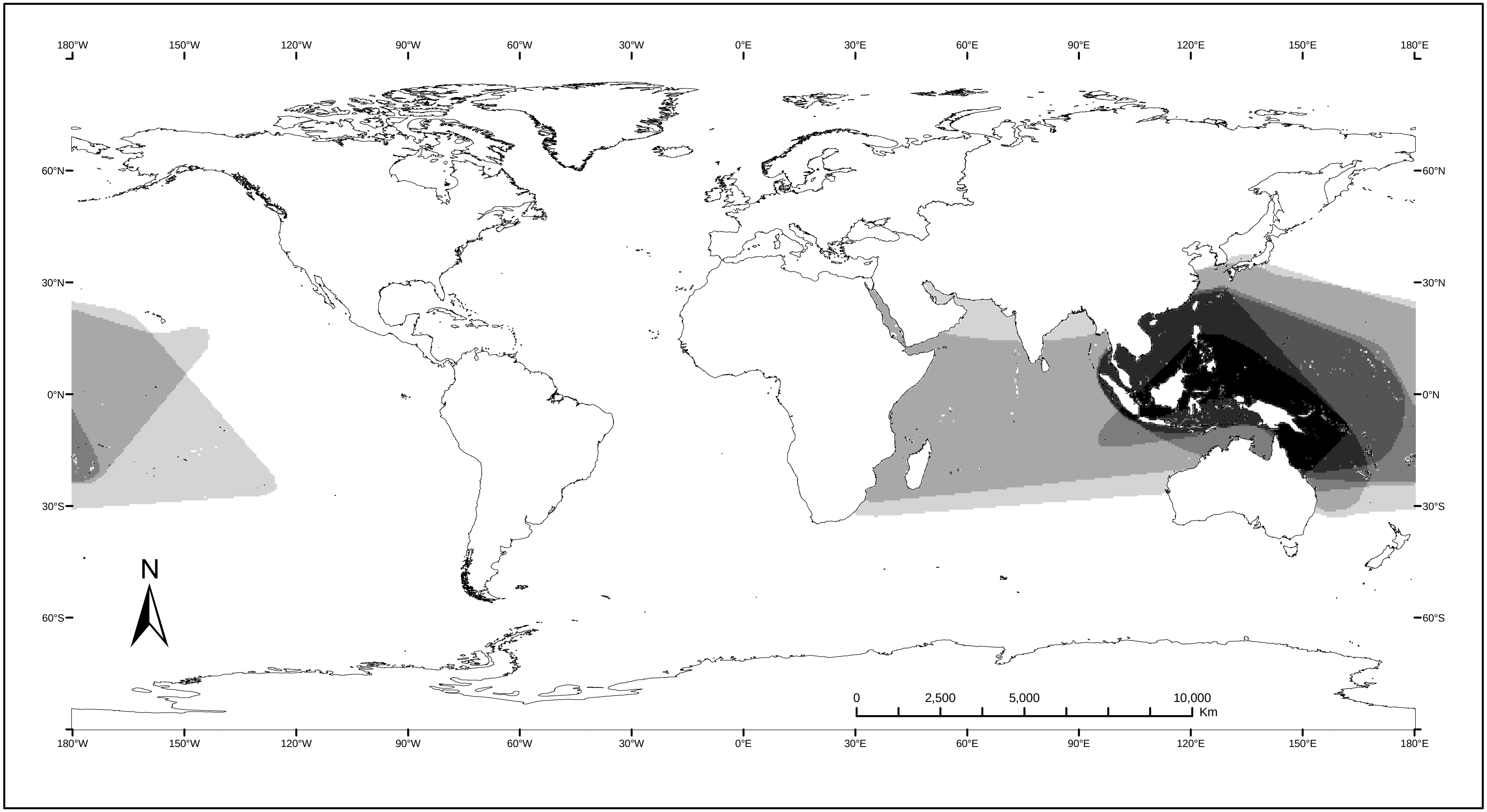
Figure 6

Phylum Mollusca, Class Bivalvia

Reference: modified from Rosewater, 1965

Family Tridacnidae

7 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

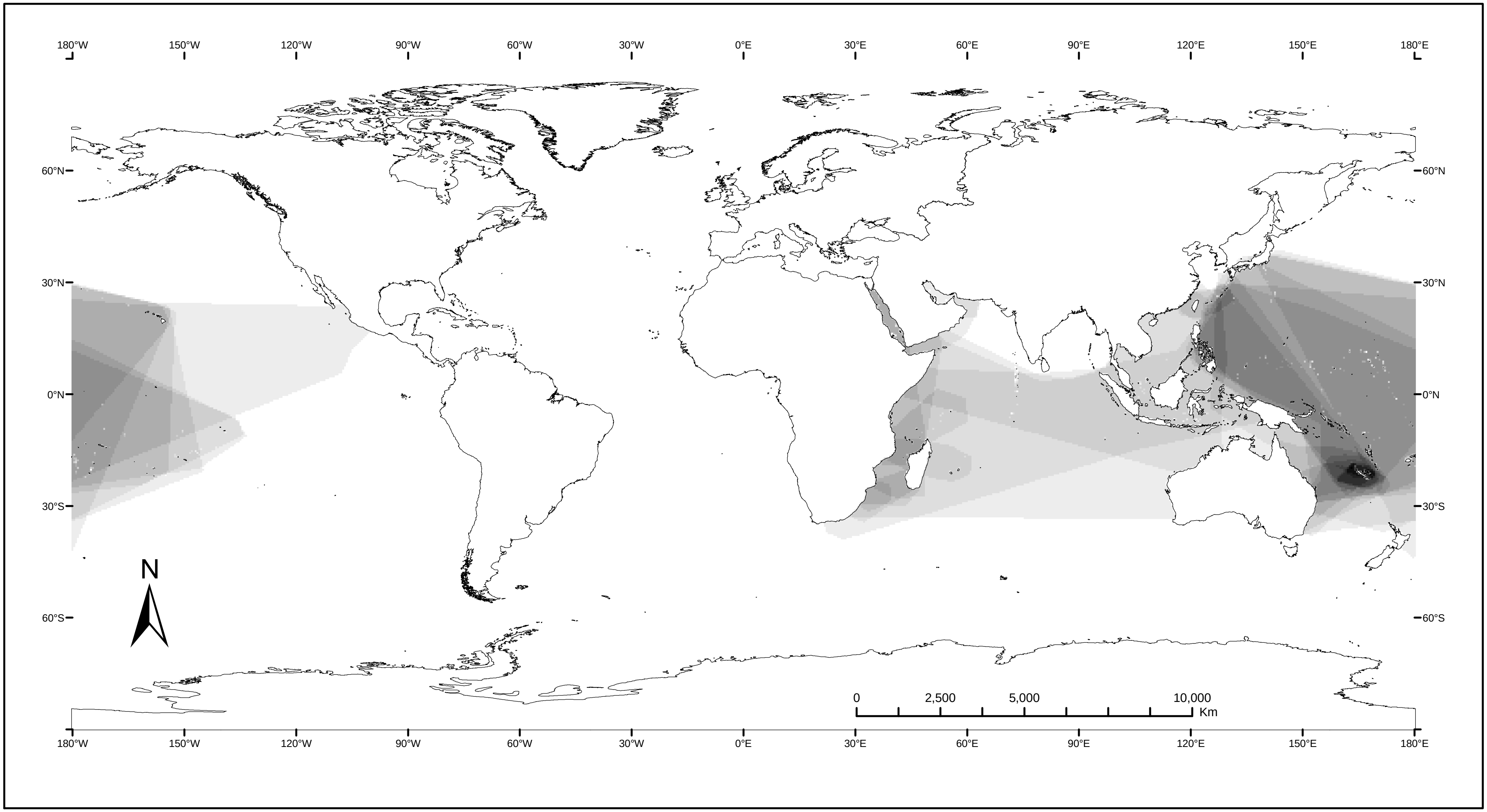
Figure 7

Phylum Mollusca, Class Gastropoda

Reference: modified from Beu, 1998

Family Bursidae

20 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

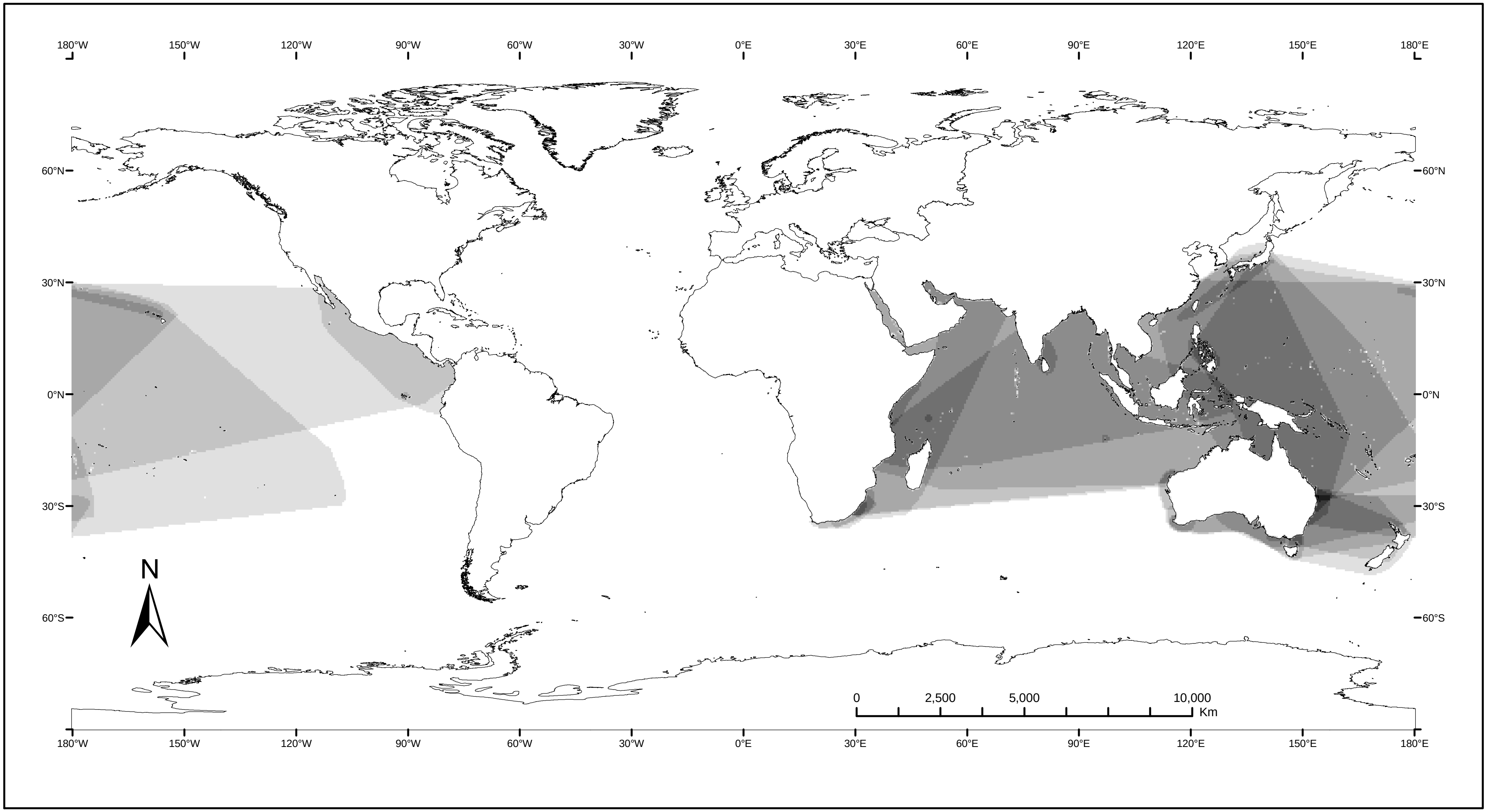
Figure 8

Phylum Mollusca, Class Gastropoda

Reference: modified from Abbott, 1968

Family Cassidae

26 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5 6 7 8 9

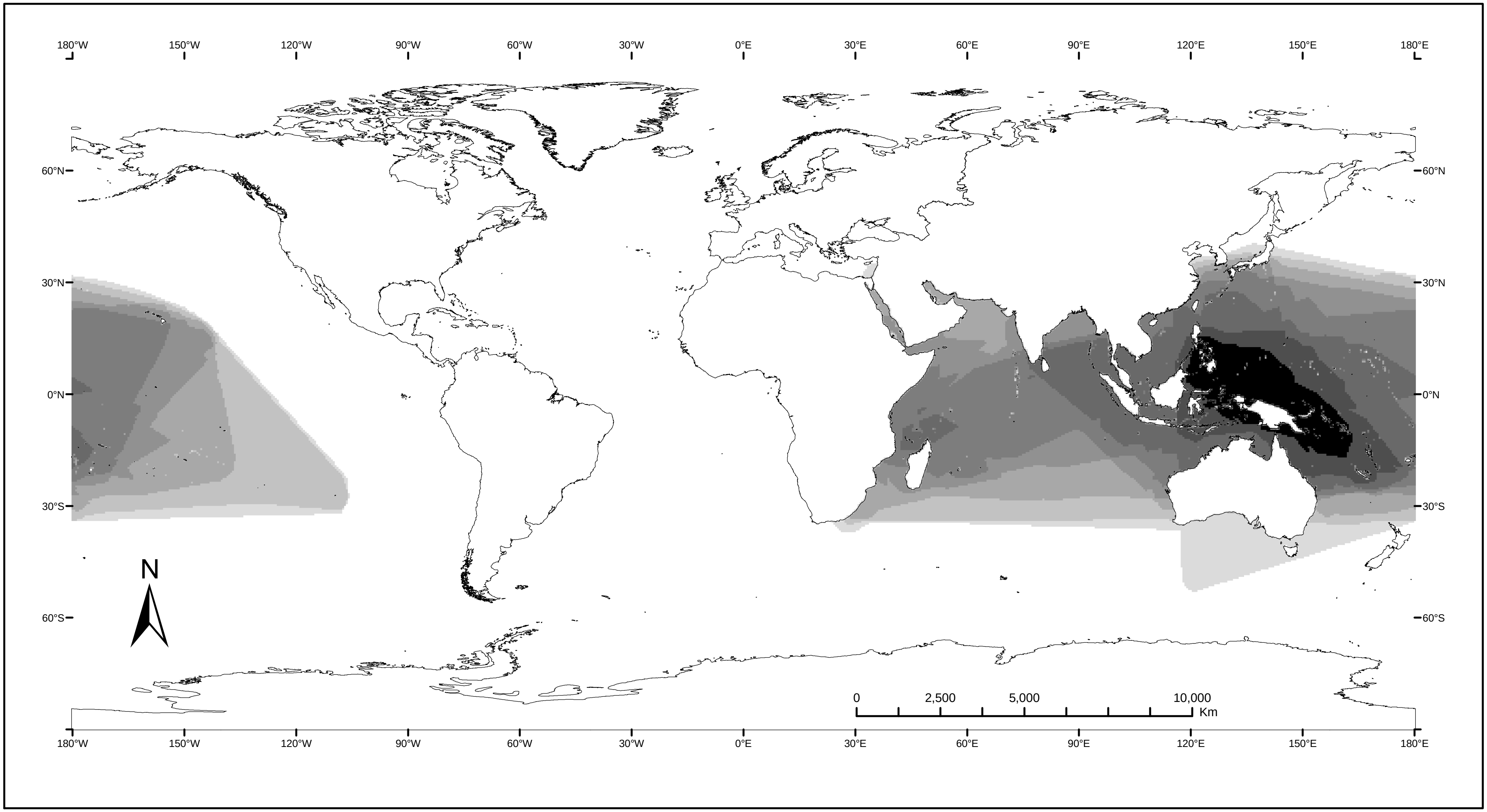
Figure 9

Phylum Mollusca, Class Gastropoda

Reference: modified from Houbrick, 1992

Family Cerithiidae

45 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1-3 | 4-7 | 8-11 | 12-14 | 15-18 | 19-22 | 23-26 | 27-31

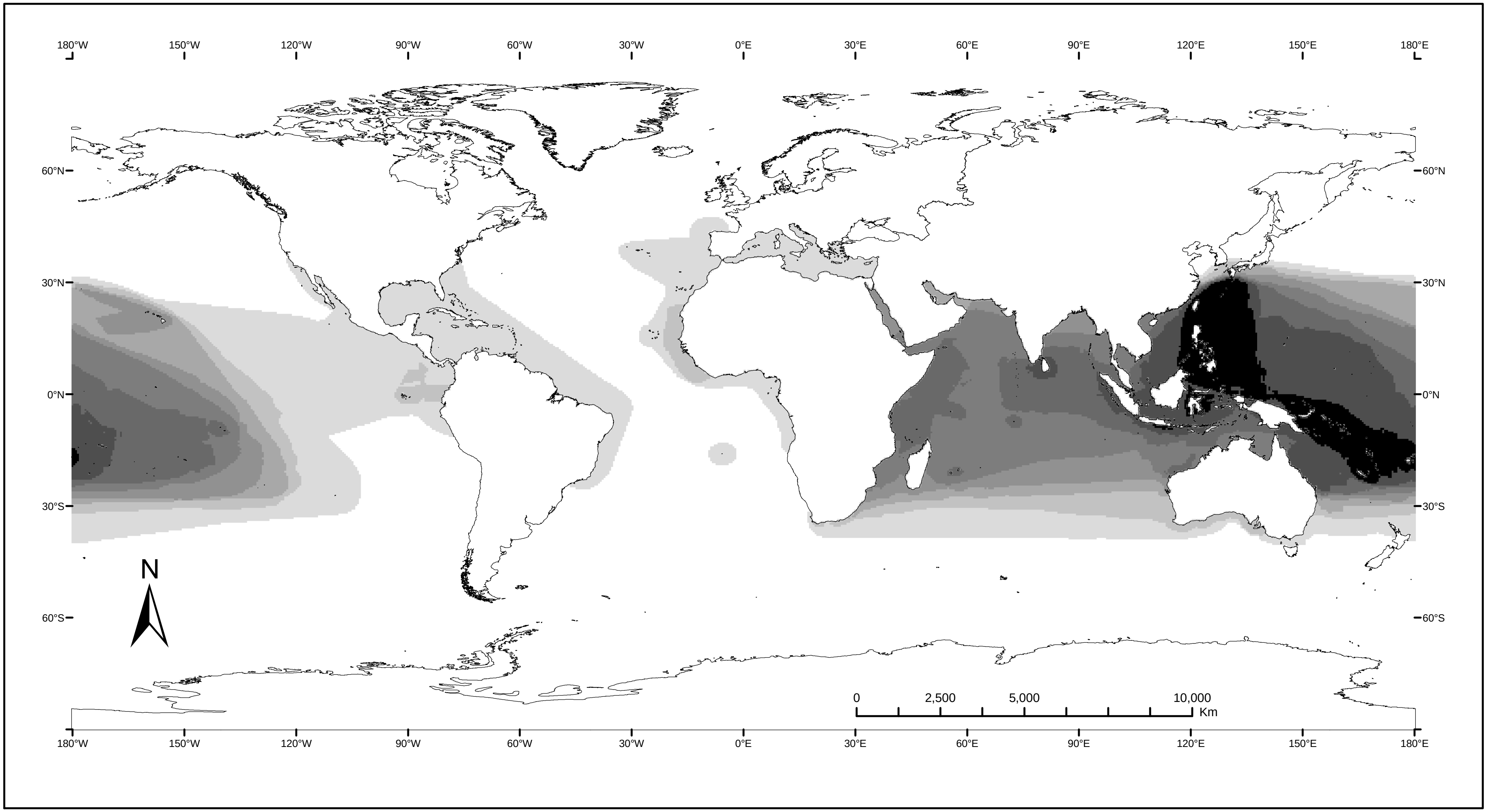
Figure 10

Phylum Mollusca, Class Gastropoda

References: Burgess, 1985; Lorenz & Hubert, 2000

Family Cypraeidae

209 Indo-Pacific species



World Plate Carree, WGS 1984 ESRI ArcMap 8.3 F. Moretzsohn, Bishop Museum, 2004

Species Richness

1-7 | 8-19 | 20-33 | 34-45 | 46-55 | 56-62 | 63-70 | 71-87

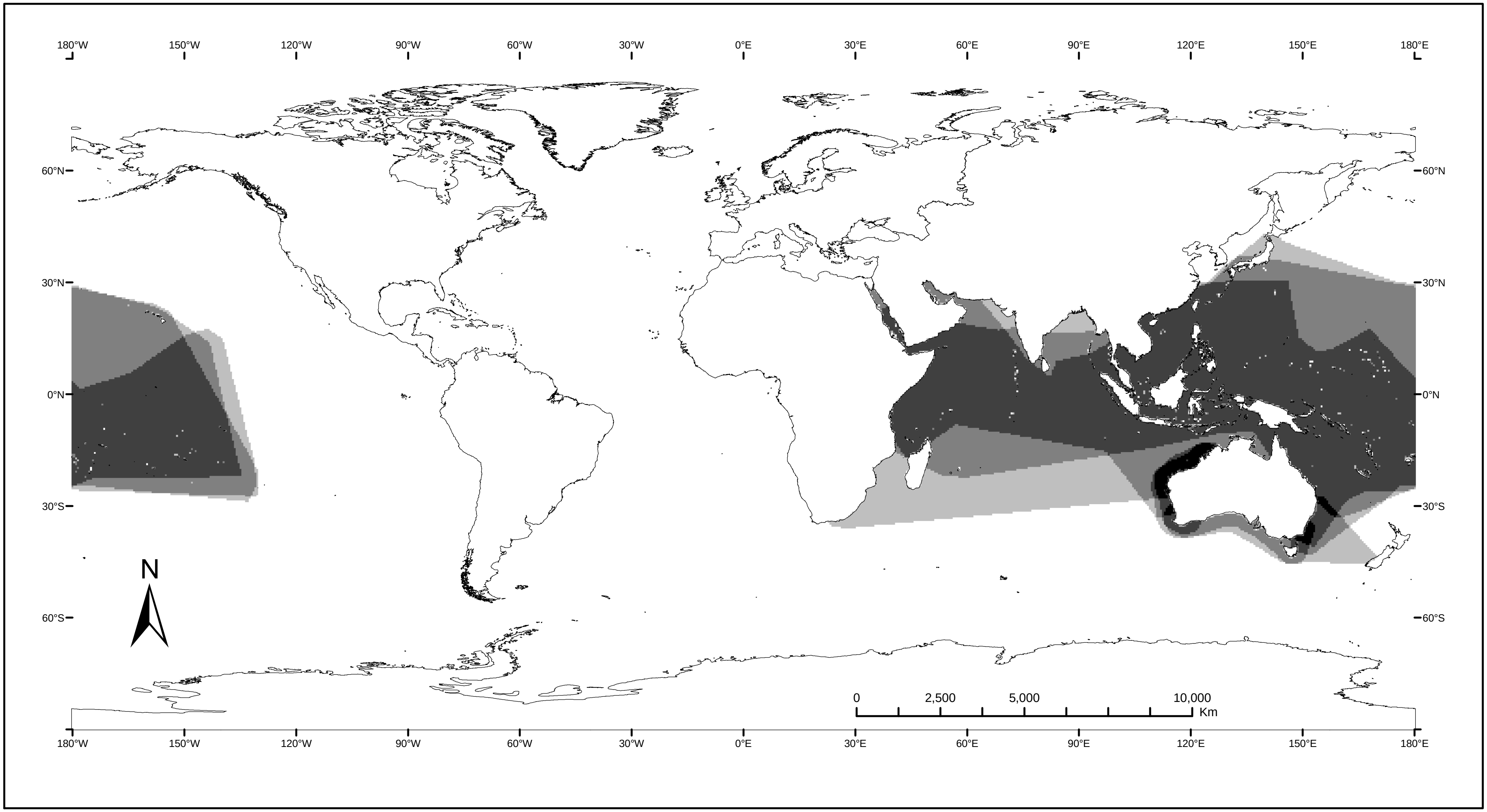
Figure 11

Phylum Mollusca, Class Gastropoda

Family Dialidae

References: modified from Ponder & Keyser, 1992

6 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4

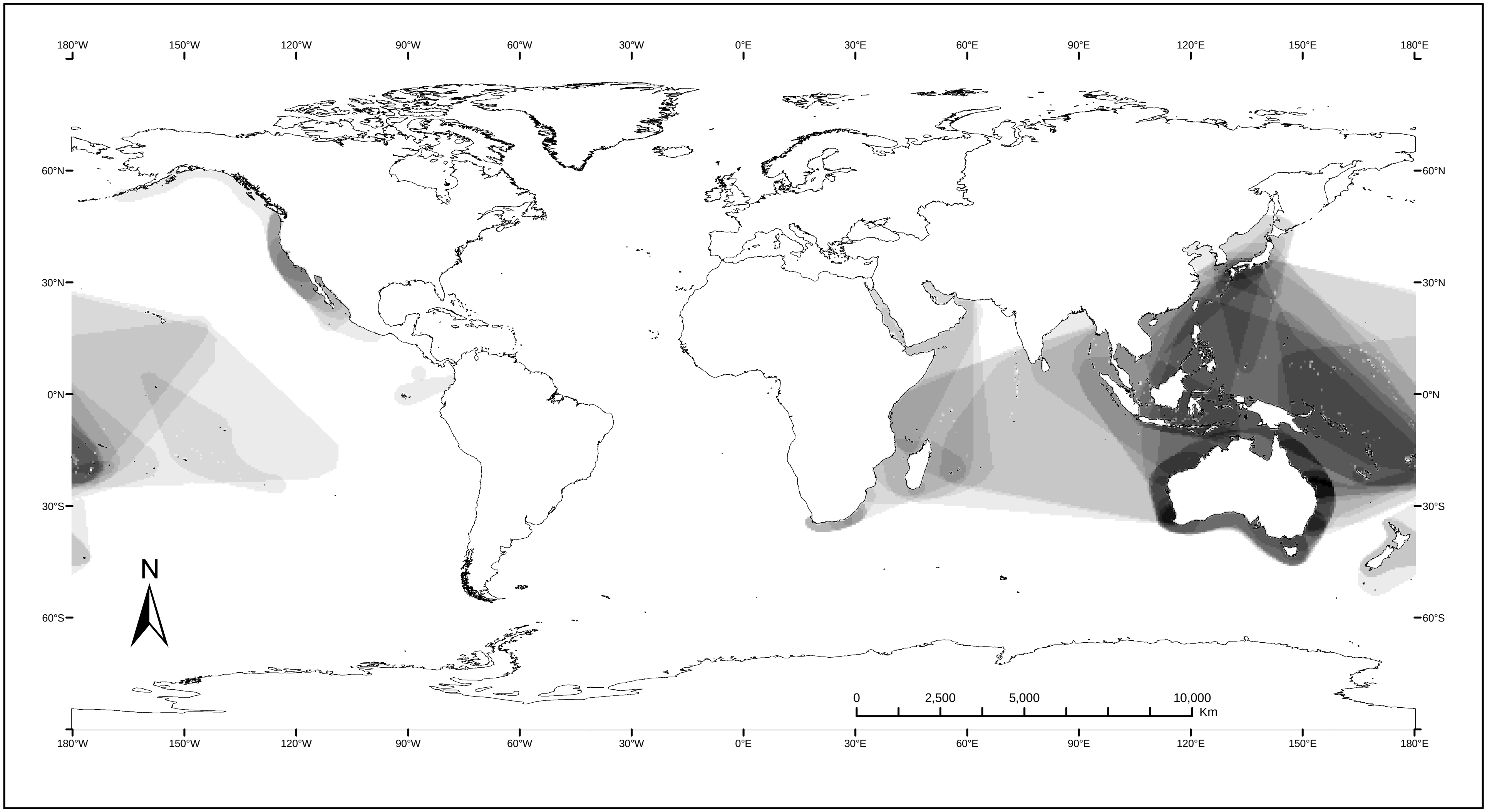
Figure 12

Phylum Mollusca, Class Gastropoda

Family Haliotidae

References: modified from Geiger, 2000

51 Indo-Pacific species



World Plate Carree, WGS 1984 ESRI ArcMap 8.3 F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5 6 7 8 9 10 11 12 13 14

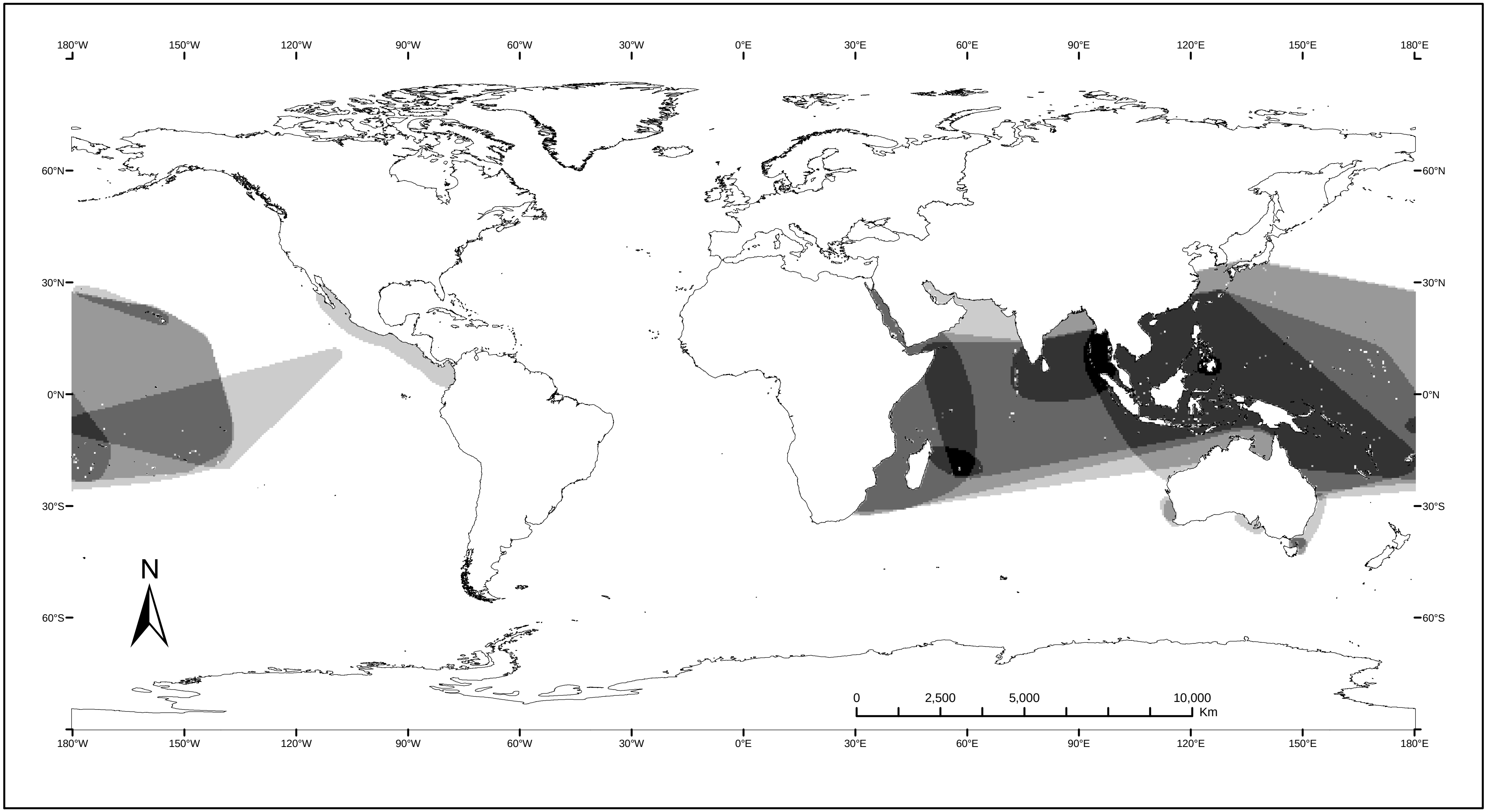
Figure 13

Phylum Mollusca, Class Gastropoda

Family Harpidae

References: modified from Rehder, 1973

15 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5

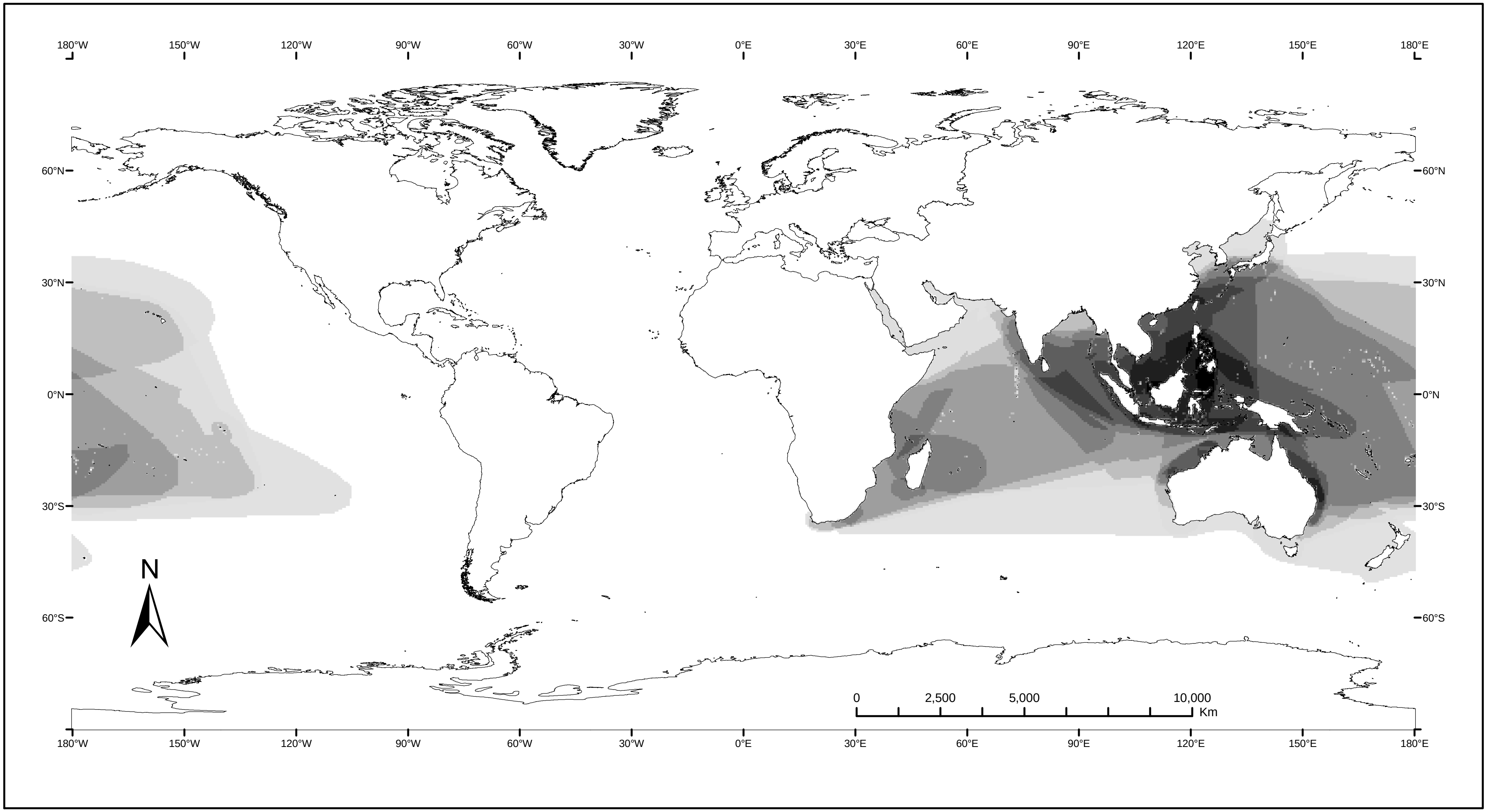
Figure 14

Phylum Mollusca, Class Gastropoda

Family Littorinidae

References: Rosewater 1970, 1972; Reid, 1986

49 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1-2 | 3-4 | 5-6 | 7-8 | 9-10 | 11-12 | 13-14 | 15-16 | 17-18

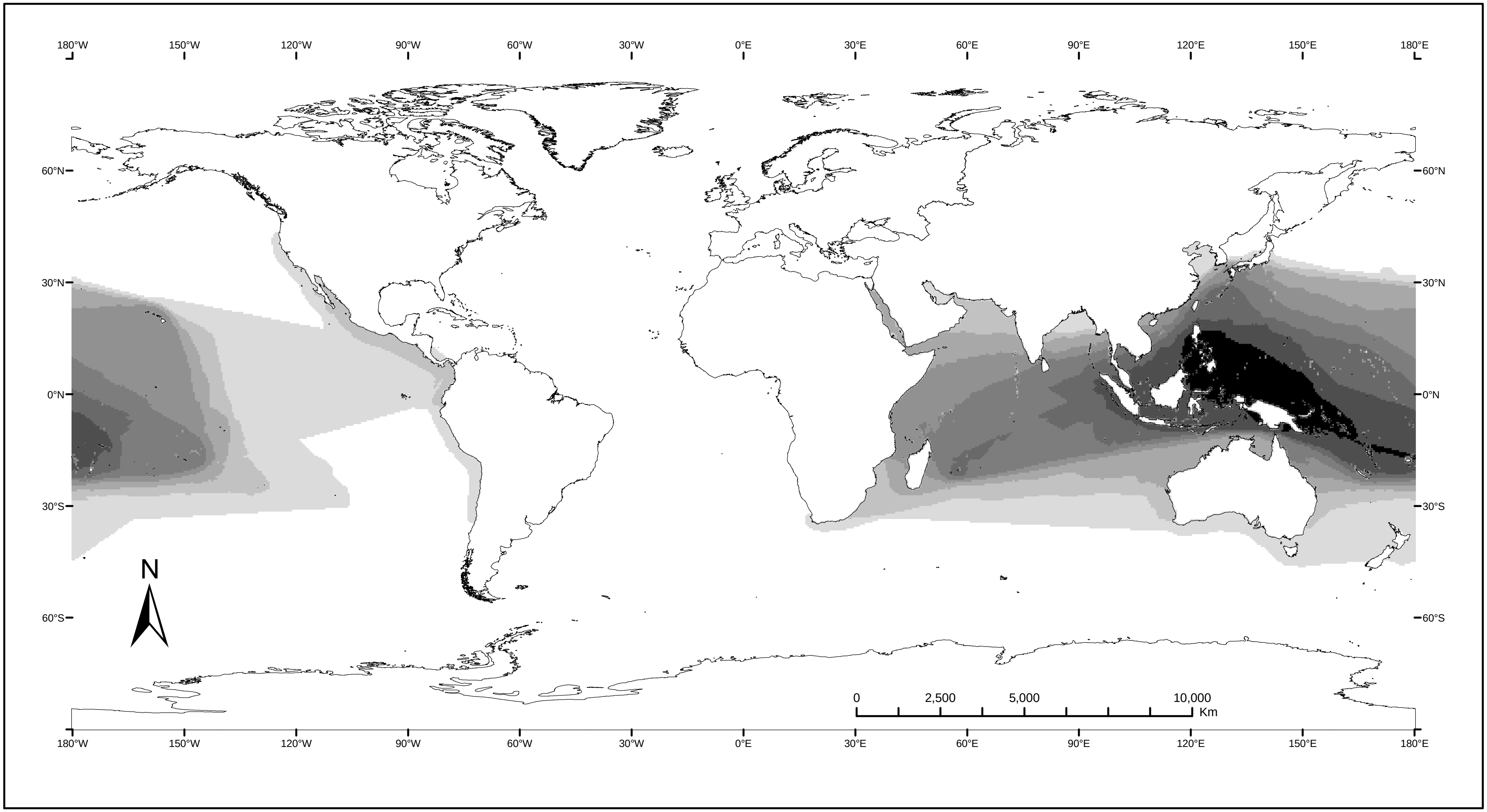
Figure 15

Phylum Mollusca, Class Gastropoda

Family Mitridae

References: modified from Cernohorsky, 1976, 1991

186 Indo-Pacific species



World Plate Carree, WGS 1984 ESRI ArcMap 8.3 F. Moretzsohn, Bishop Museum, 2004

Species Richness

1-9 | 10-22 | 23-37 | 38-52 | 53-64 | 65-75 | 76-88 | 89-106

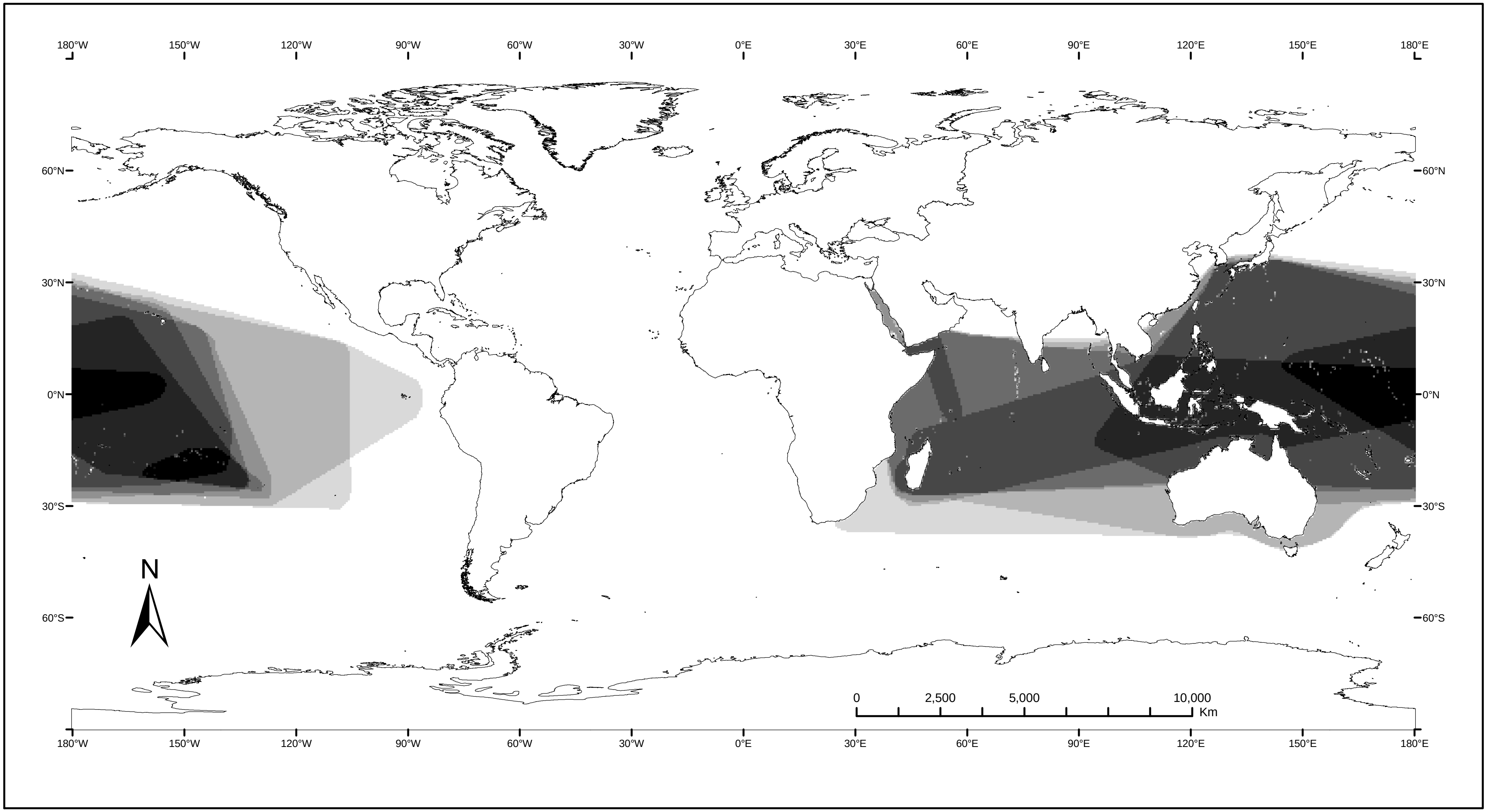
Figure 16

Phylum Mollusca, Class Gastropoda

Family Muricidae (Genus Drupa only)

Reference: modified from Emerson and Cernohorsky, 1973

9 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5 6 7

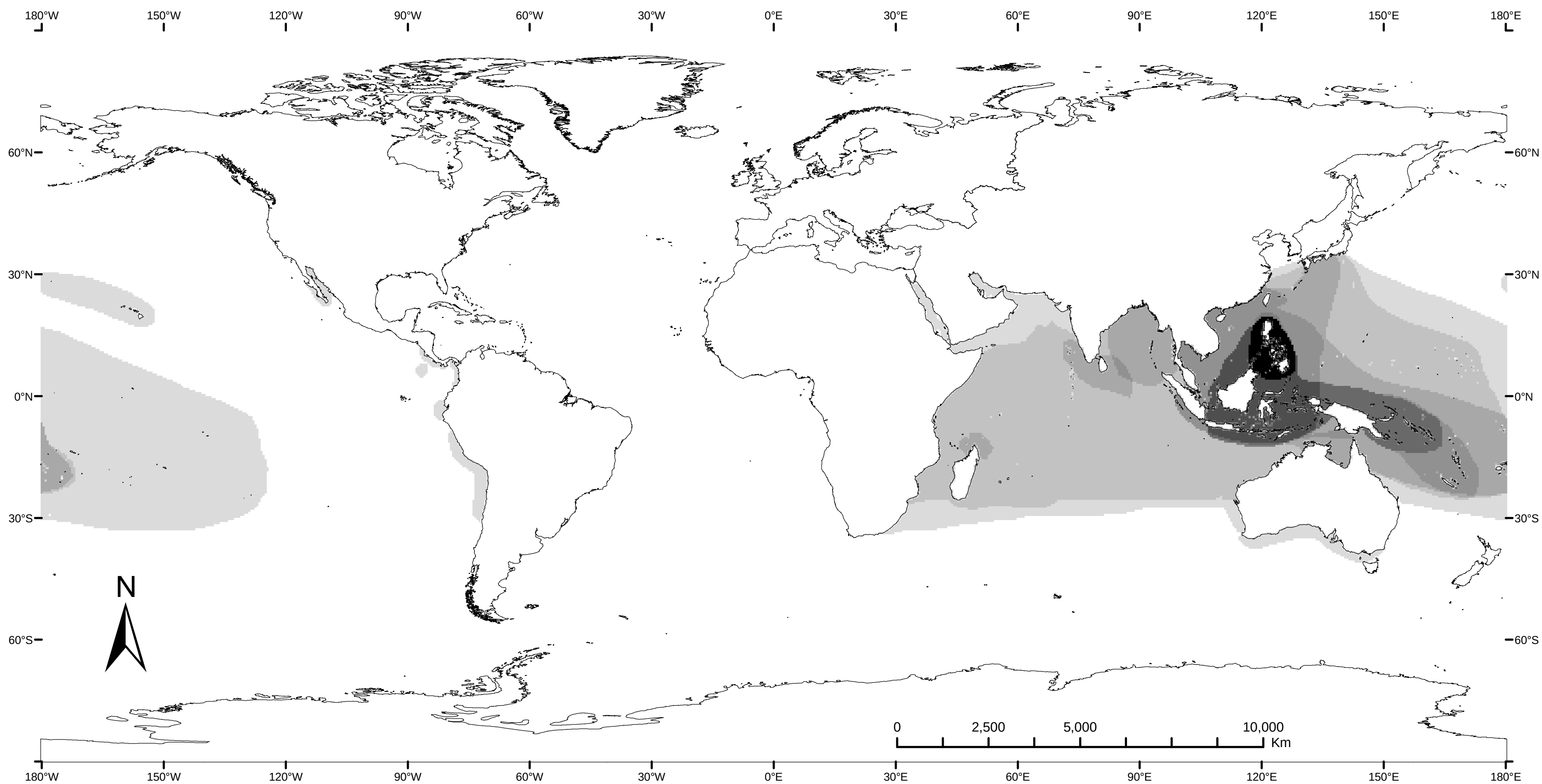
Figure 17

Phylum Mollusca, Class Gastropoda

Reference: modified from Petuch & Sargent, 1986

Family Olividae

115 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1-10 11-17 18-23 24-33 34-45 46-54 55-63 64-71

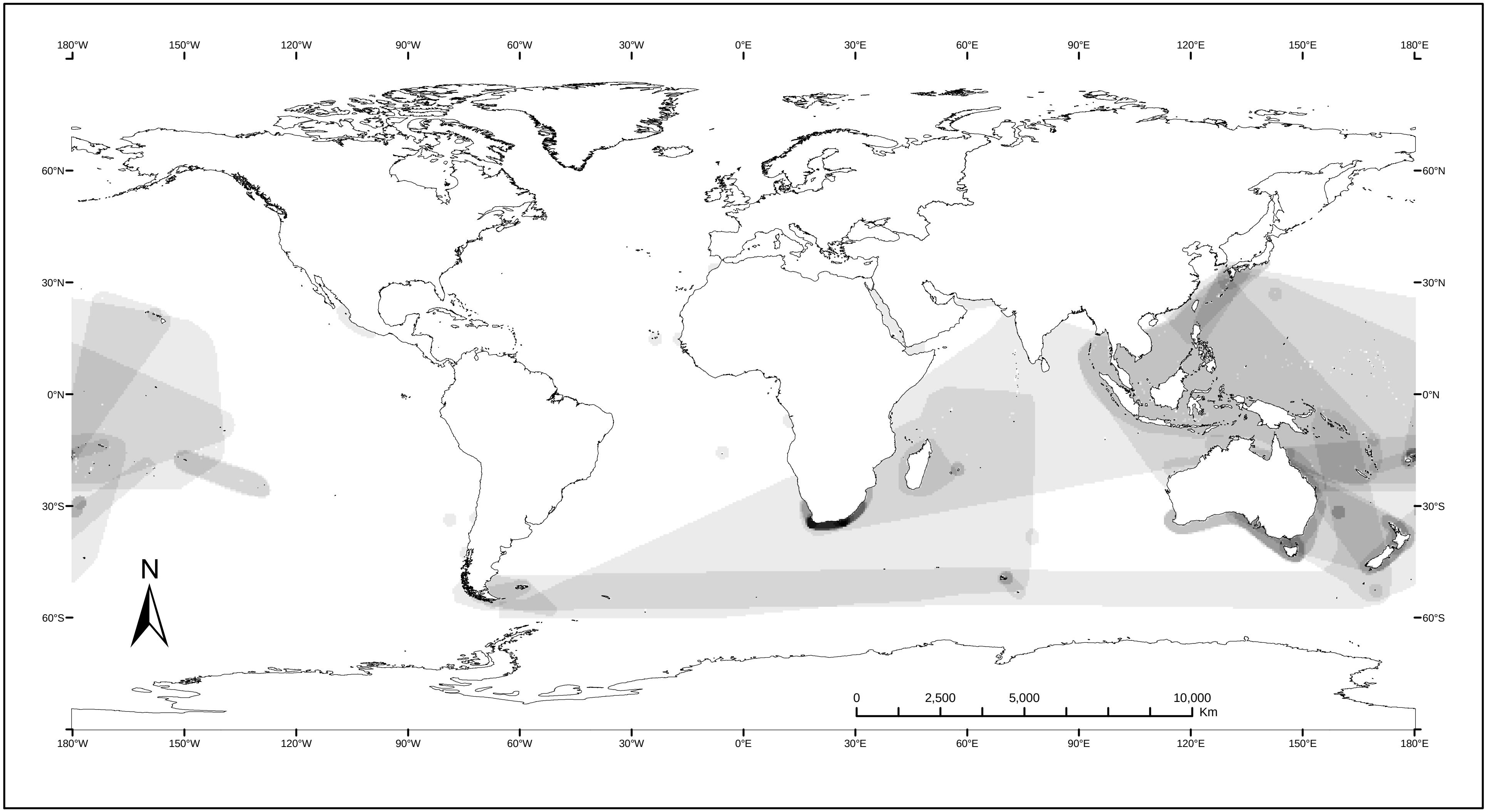
Figure 18

Phylum Mollusca, Class Gastropoda

Family Patellidae

Reference: modified from Powell, 1973

64 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5 6 7 8 9 10 11 12 13

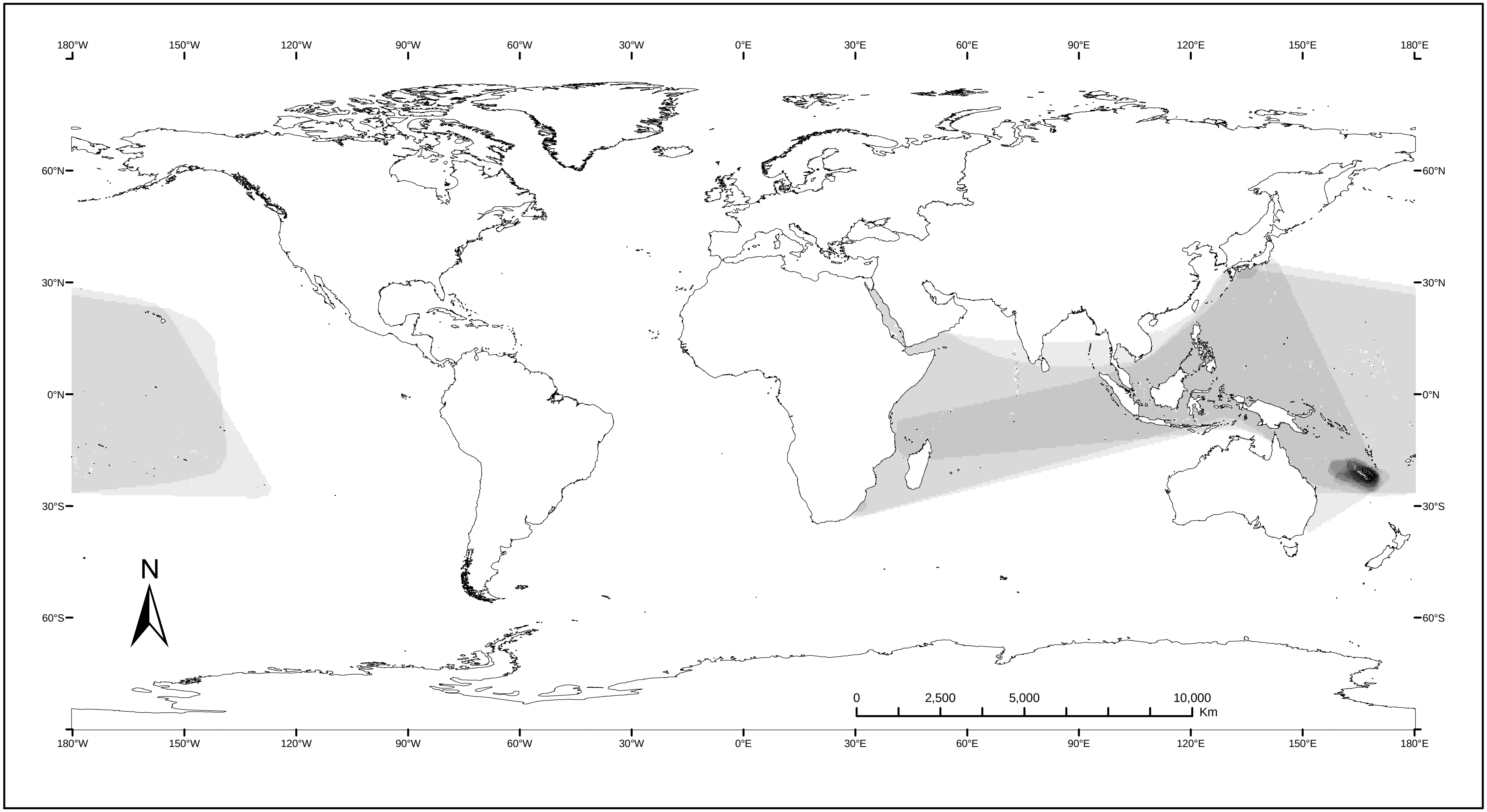
Figure 19

Phylum Mollusca, Class Gastropoda

Family Personidae

Reference: modified from Beu, 1998

15 Indo-Pacific species



World Plate Carree, WGS 1984 ESRI ArcMap 8.3 F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5 6 7 8 9 10 11 12 13 14

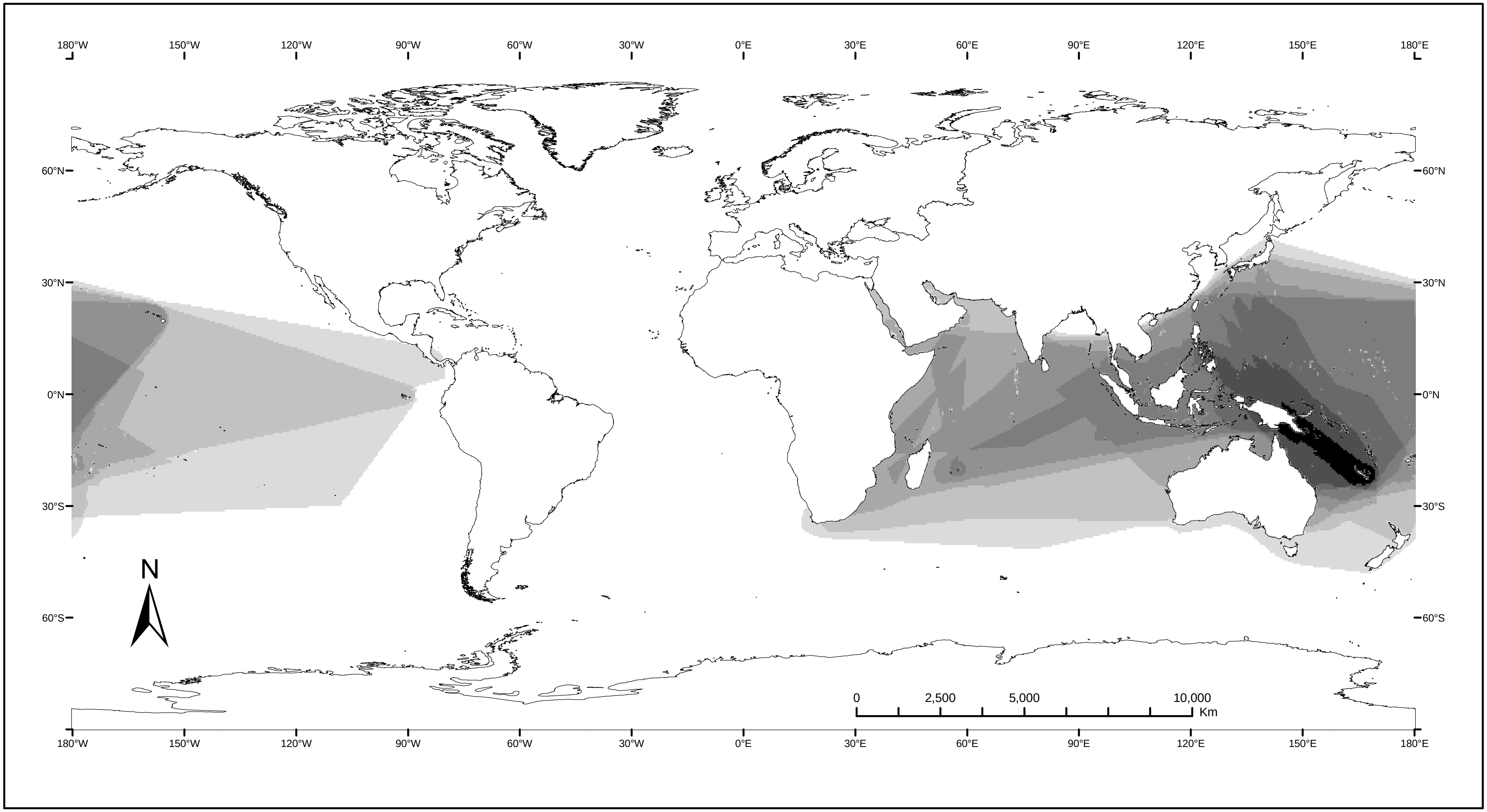
Figure 20

Phylum Mollusca, Class Gastropoda

Family Ranellidae

Reference: modified from Beu, 1998

48 Indo-Pacific species



World Plate Carree, WGS 1984 ESRI ArcMap 8.3 F. Moretzsohn, Bishop Museum, 2004

Species Richness

1-3 4-8 9-12 13-16 17-20 21-24 25-29 30-36

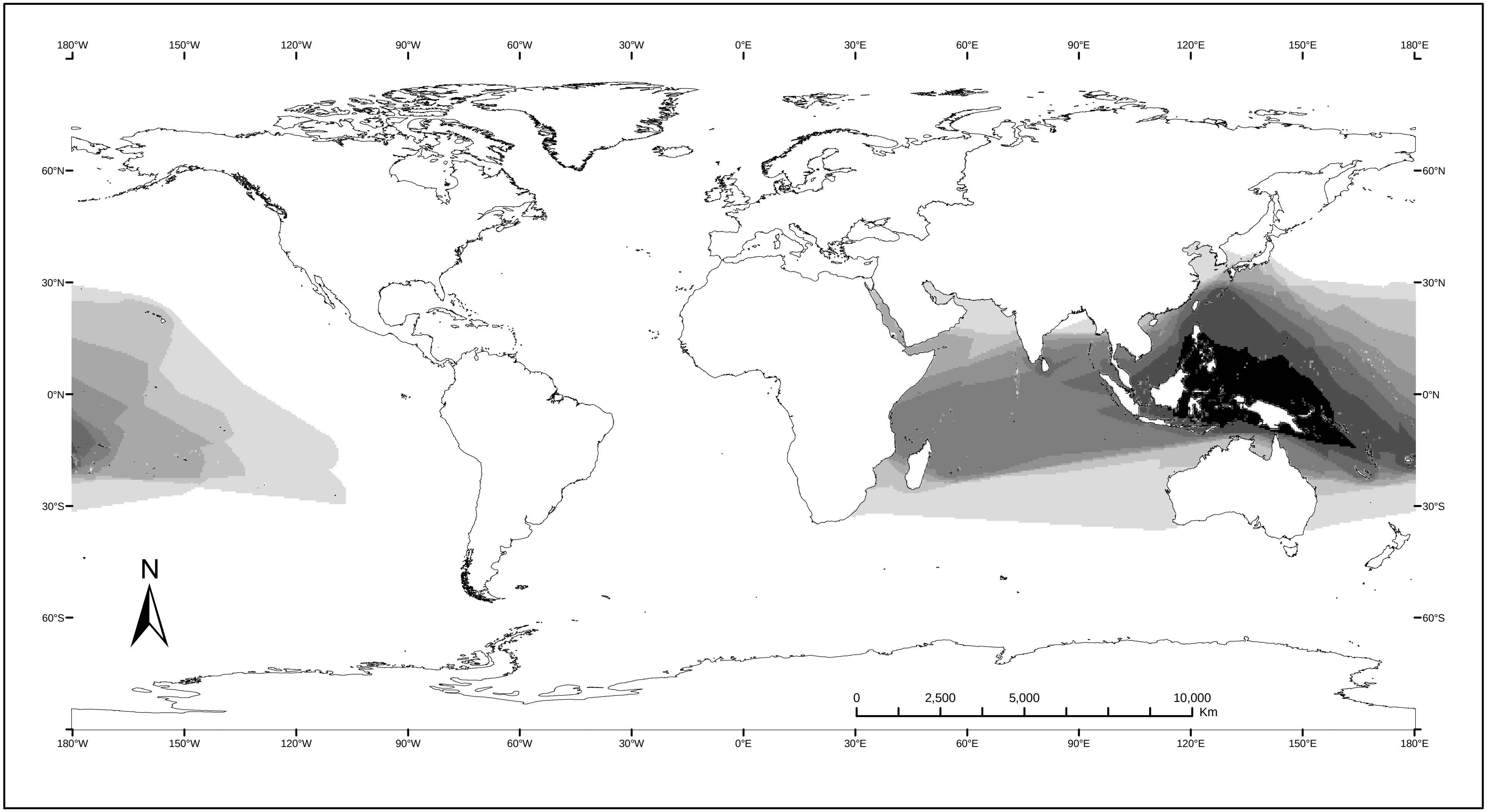
Figure 21

Phylum Mollusca, Class Gastropoda

Family Strombidae

Reference: modified from Abbott, 1961

50 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1-3 | 4-6 | 7-10 | 11-14 | 15-17 | 18-20 | 21-24 | 25-29

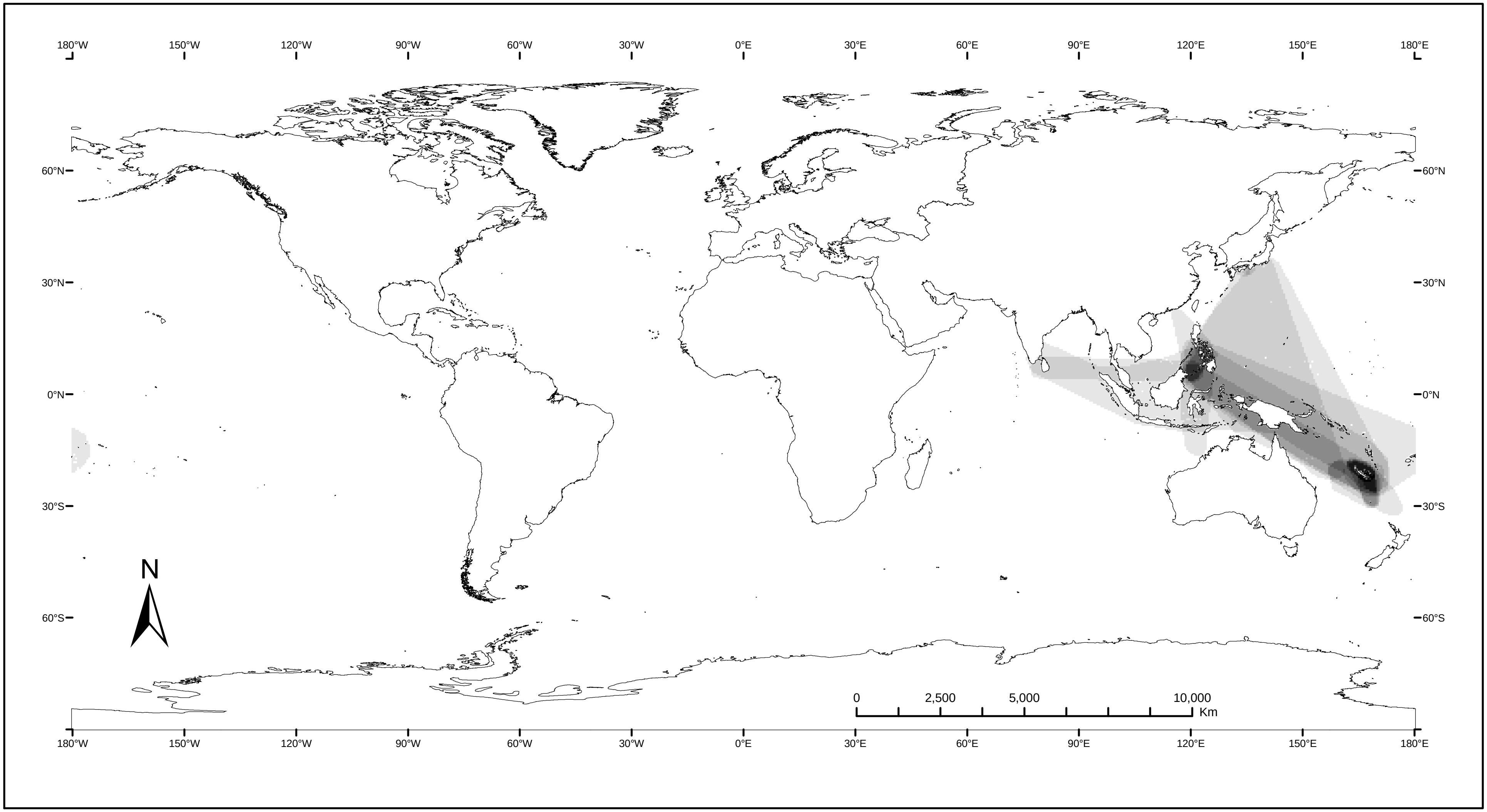
Figure 22

Phylum Mollusca, Class Gastropoda

Family Triviidae

Reference: modified from Dolin, 2001

20 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5 6 7 8 9 10 11

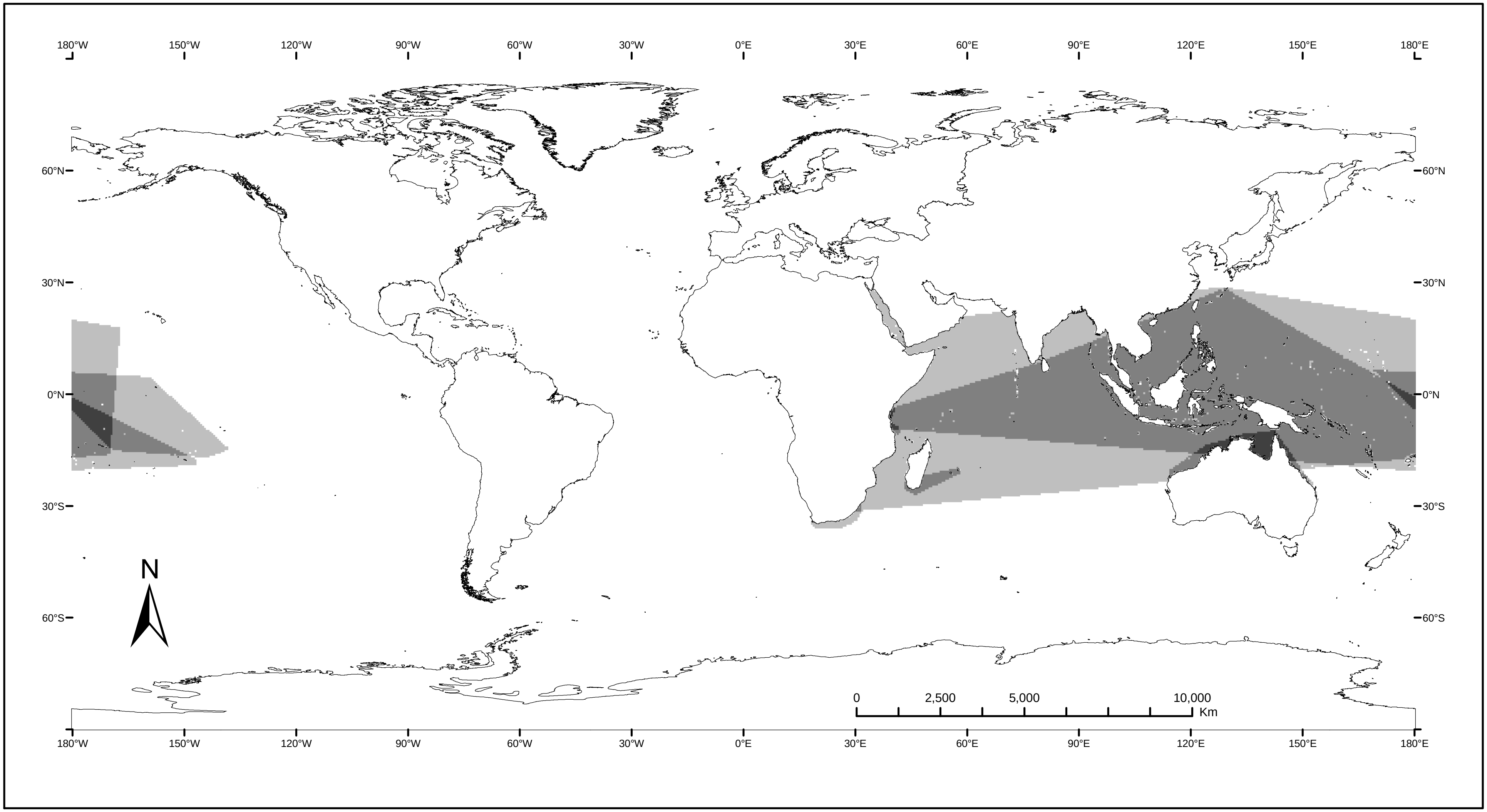
Figure 23

Phylum Mollusca, Class Gastropoda

Family Vasidae

Reference: modified from Abbott, 1959

14 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4

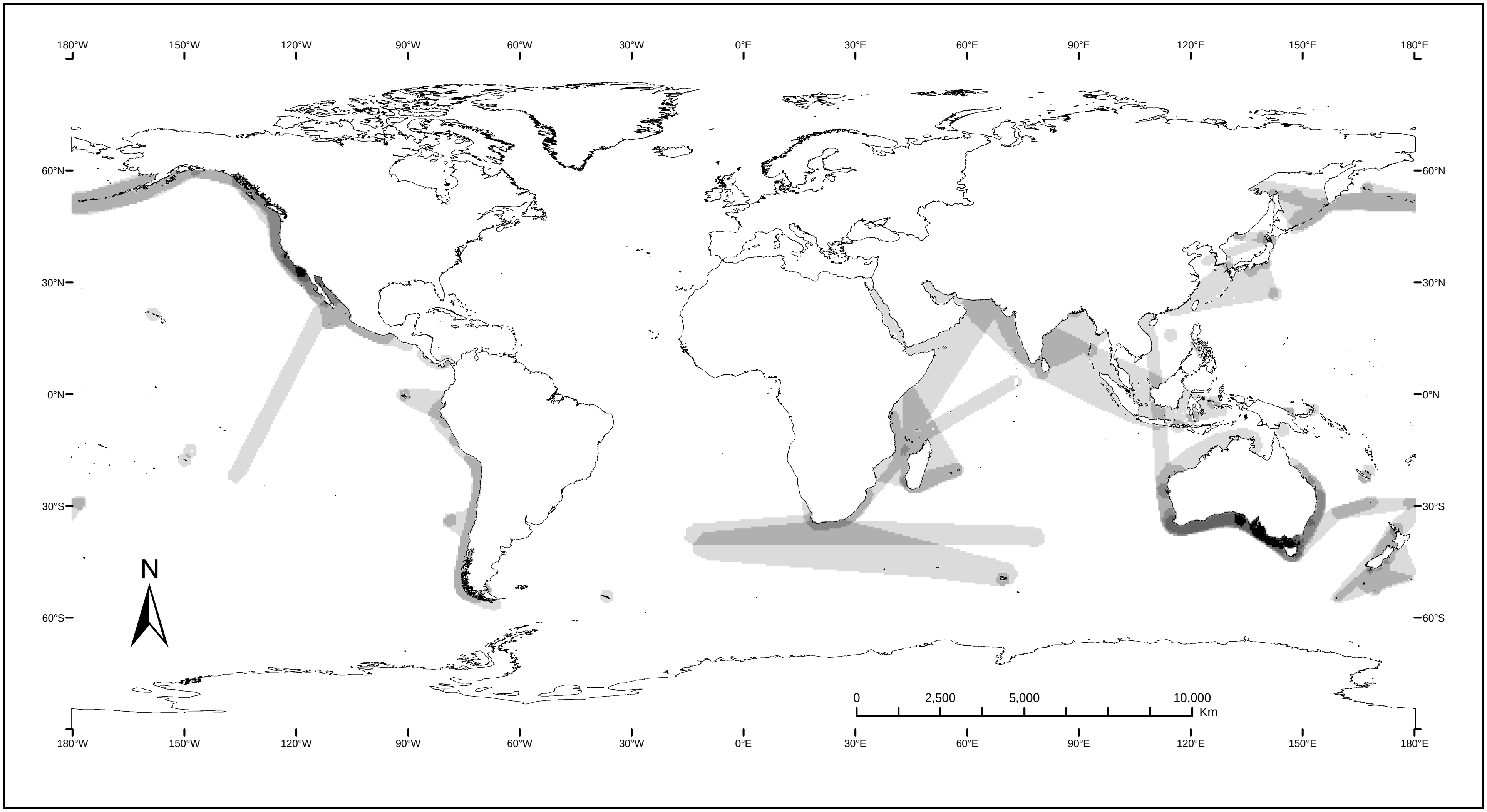
Figure 24

Phylum Mollusca, Class Polyplacophora

Families Ischnochitonidae and Leptochitonidae

Reference: Kaas & Van Belle, 1985A & B

164 Indo-Pacific species



World Plate Carree, WGS 1984 ESRI ArcMap 8.3 F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2-4 5-9 10-14 15-22

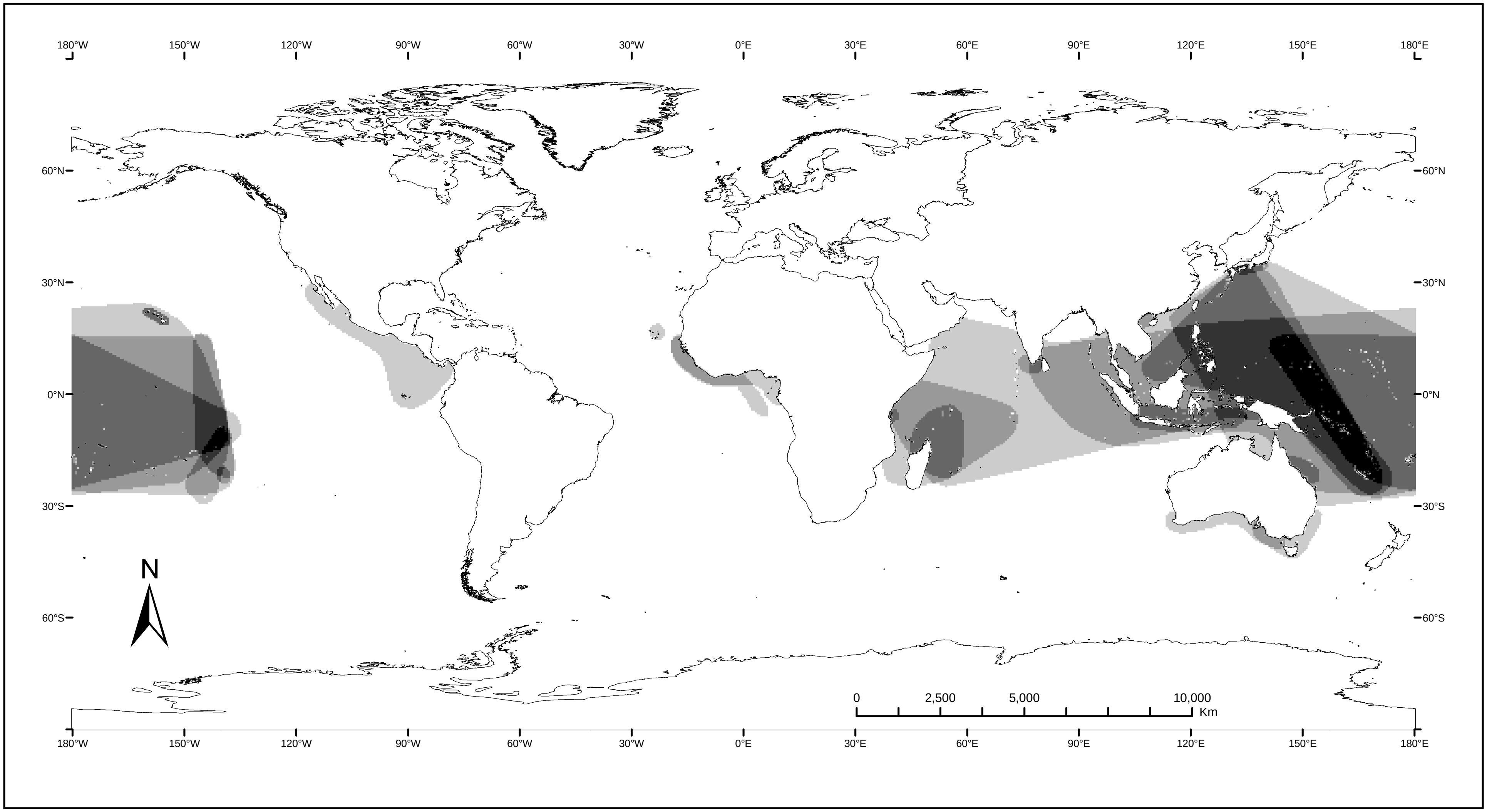
Figure 25

Subphylum Crustacea, Order Decapoda

Family Diogenidae

Reference: modified from Forest, 1995

24 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5

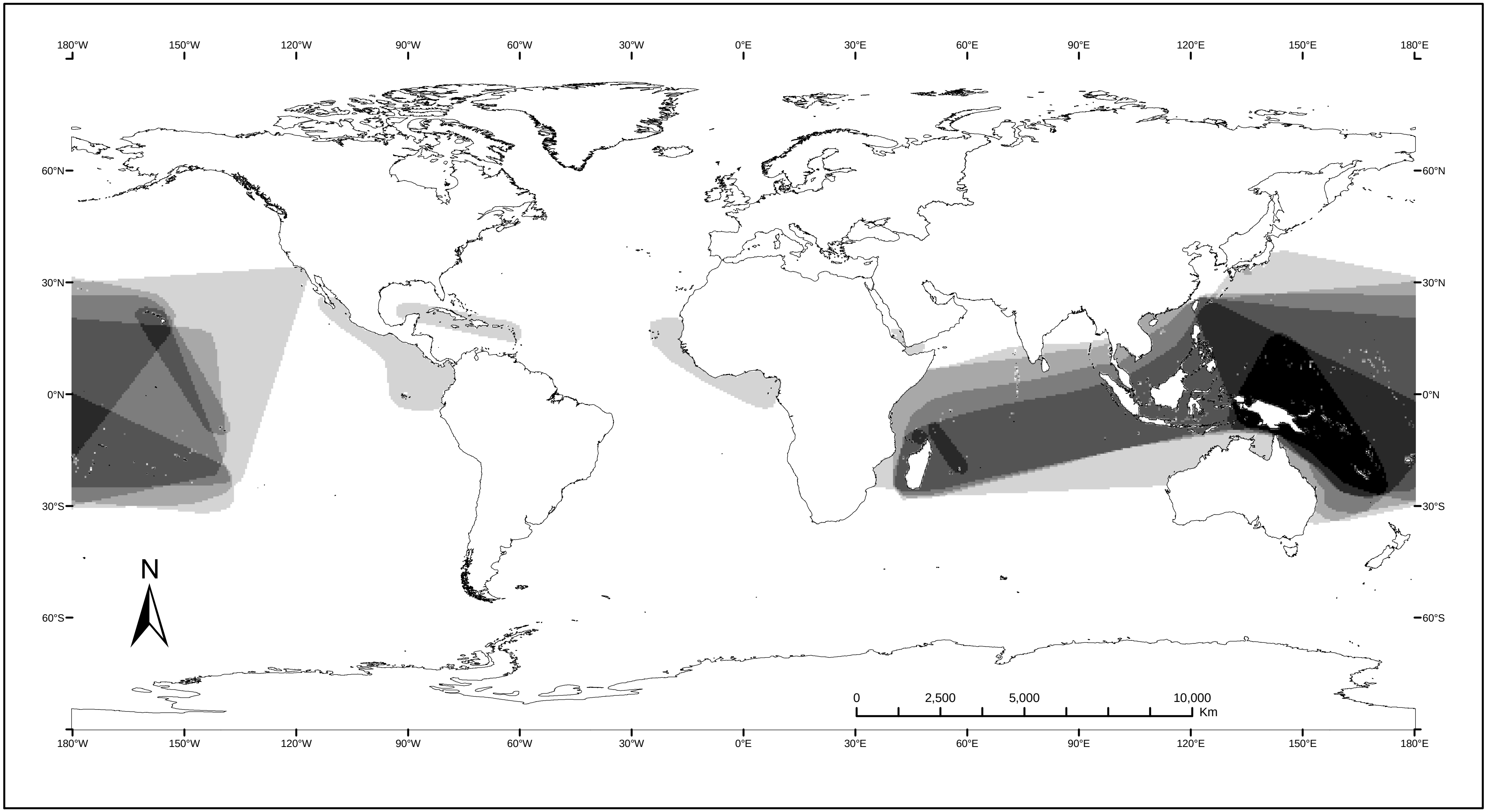
Figure 26

Subphylum Crustacea, Order Decapoda

Family Dynomenidae

Reference: modified from McLay, 1999

13 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5 6

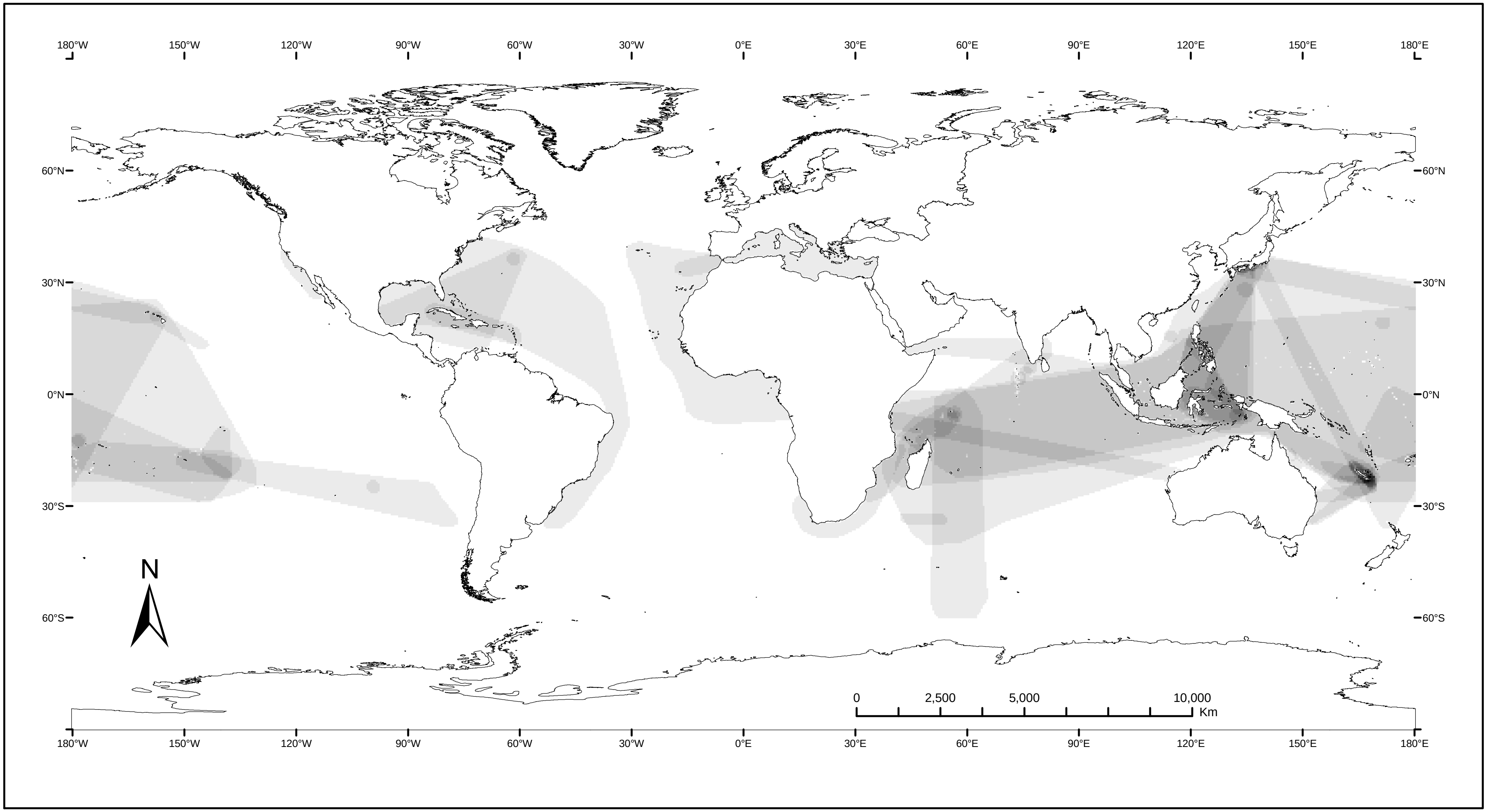
Figure 27

Subphylum Crustacea, Order Decapoda

Family Homolidae

Reference: Guinot & Richer de Forges, 1995

56 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5 6 7 8 9 10 11 12 13 14

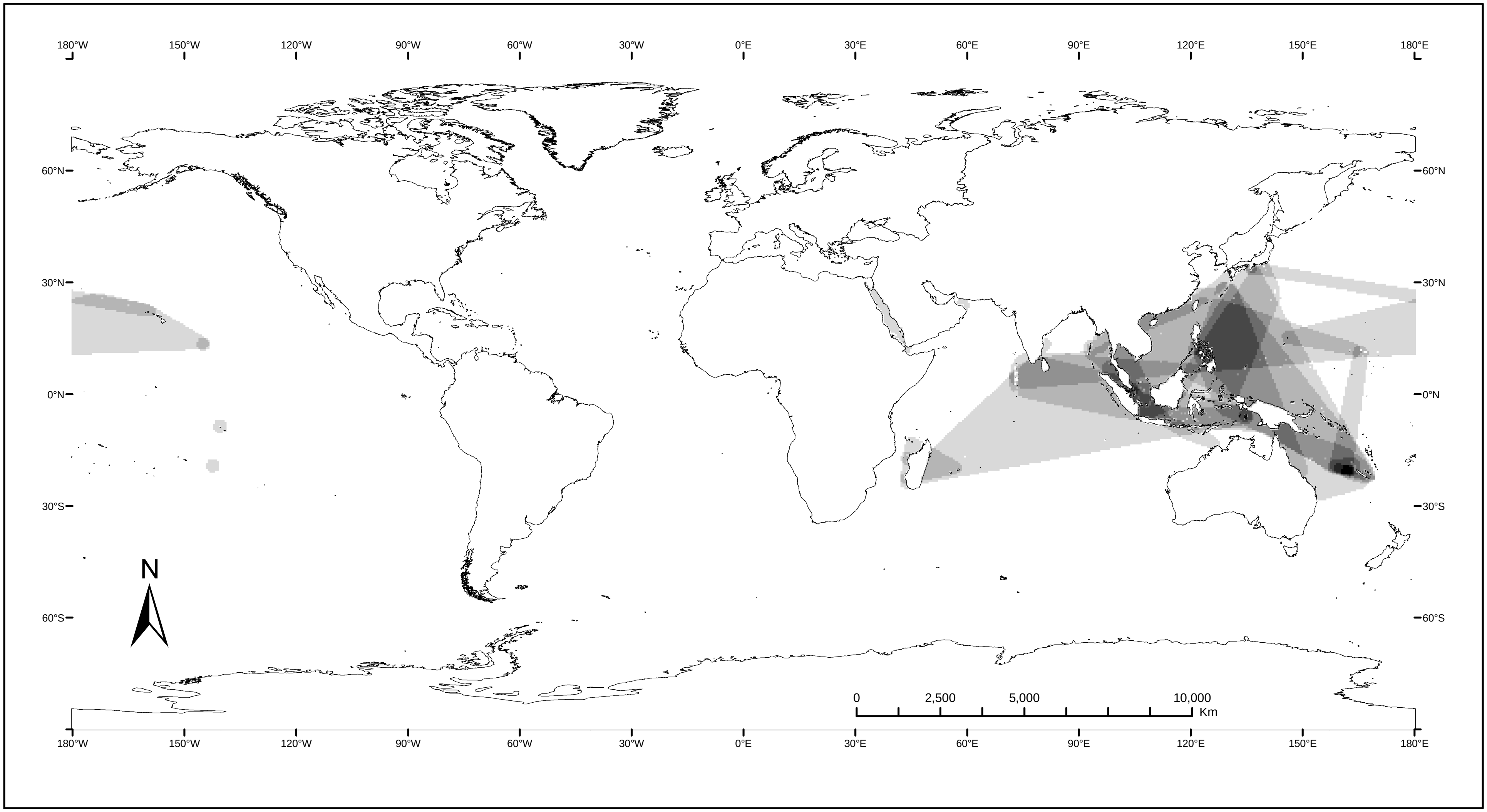
Figure 28

Subphylum Crustacea, Order Decapoda

Family Leucosiidae

Reference: modified from Tan and Ng, 1995

27 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1 2 3 4 5 6 7

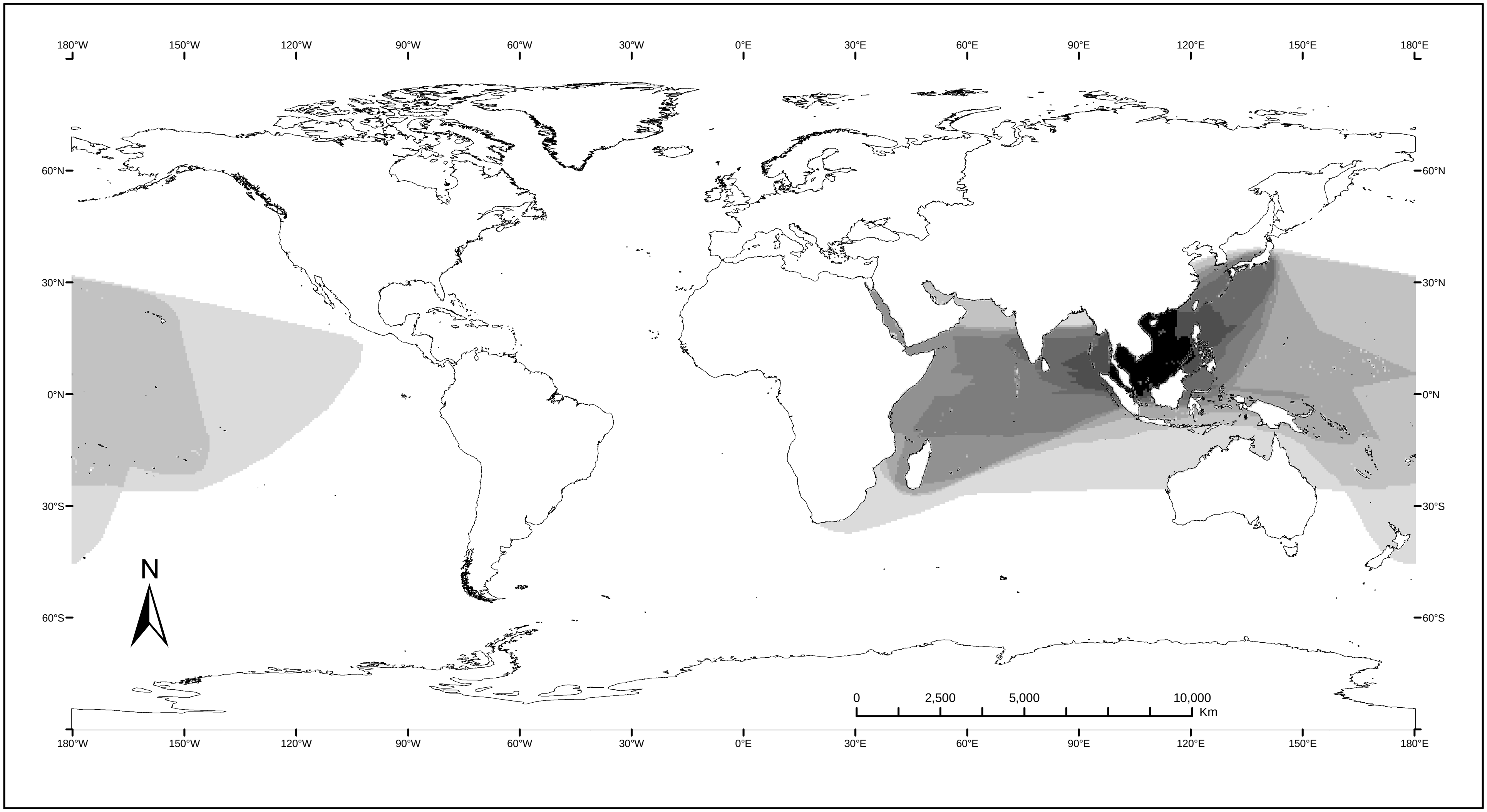
Figure 29

Subphylum Crustacea, Order Decapoda

Family Portunidae

Reference: modified from Wee and Ng, 1995

35 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1-4 | 5-9 | 10-13 | 14-17 | 18-21 | 22-24 | 25-28 | 29-35

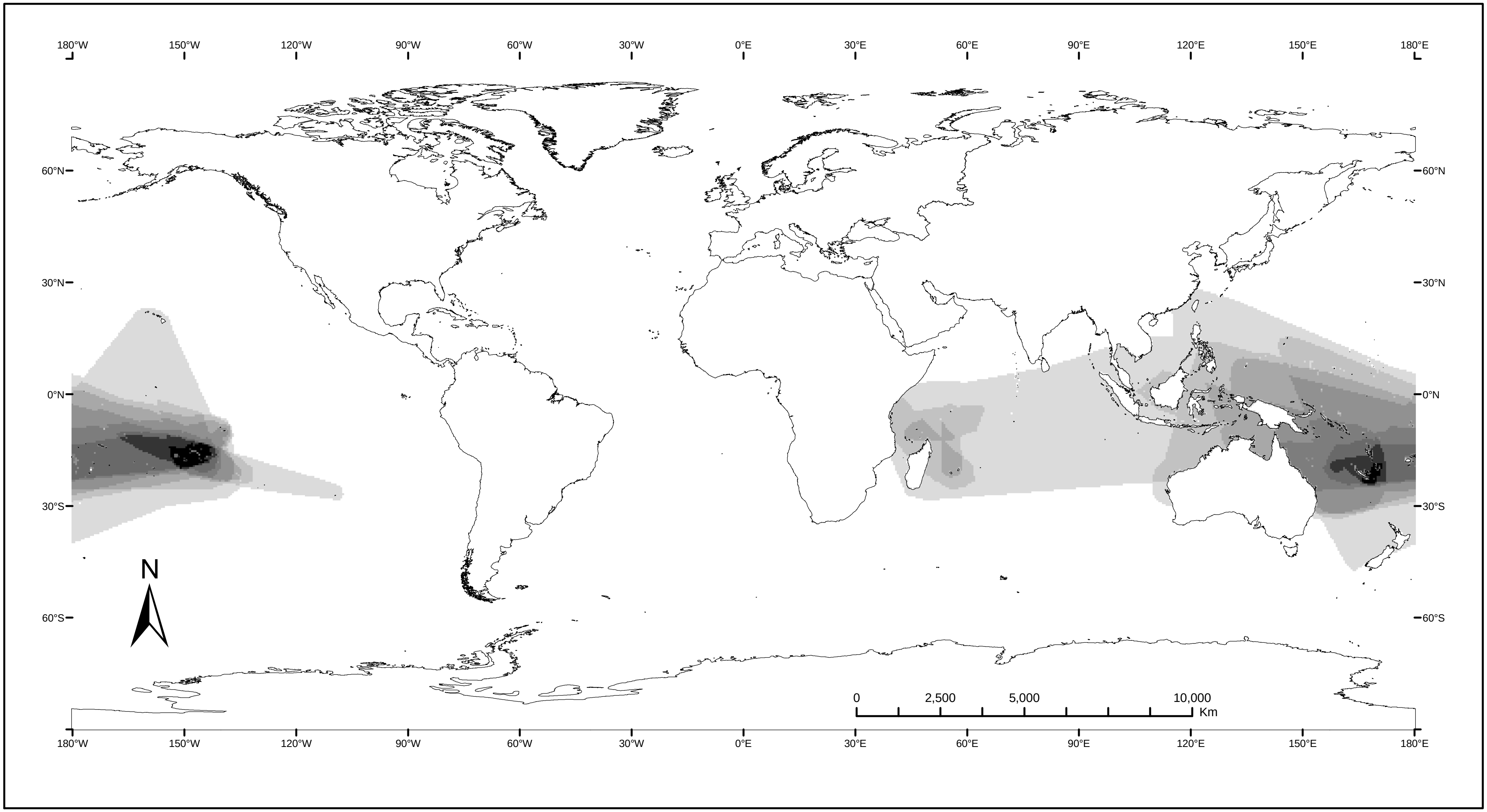
Figure 30

Subphylum Crustacea, Order Decapoda

Family Trapeziidae

Reference: modified from Castro, 1997

28 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1-2 | 3-4 | 5-6 | 7-9 | 10-12 | 13-14 | 15-16 | 17-20

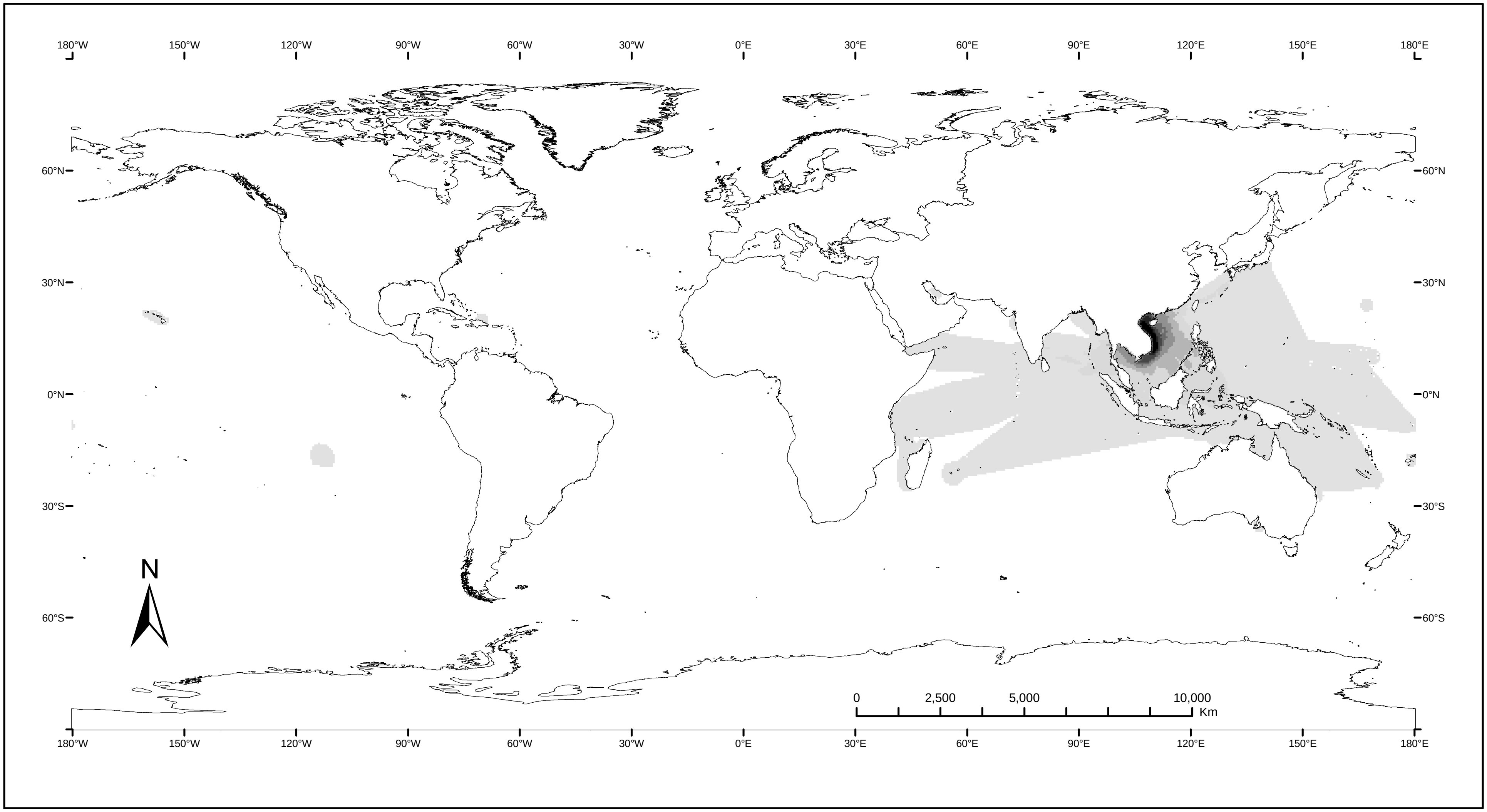
Figure 31

Subphylum Crustacea, Order Stomatopoda

11 Families (incl. Squillidae and Gonodactylidae)

Reference: modified from Manning, 1995

80 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

1-8 | 9-15 | 16-22 | 23-30 | 31-37 | 38-44 | 45-51 | 52-59

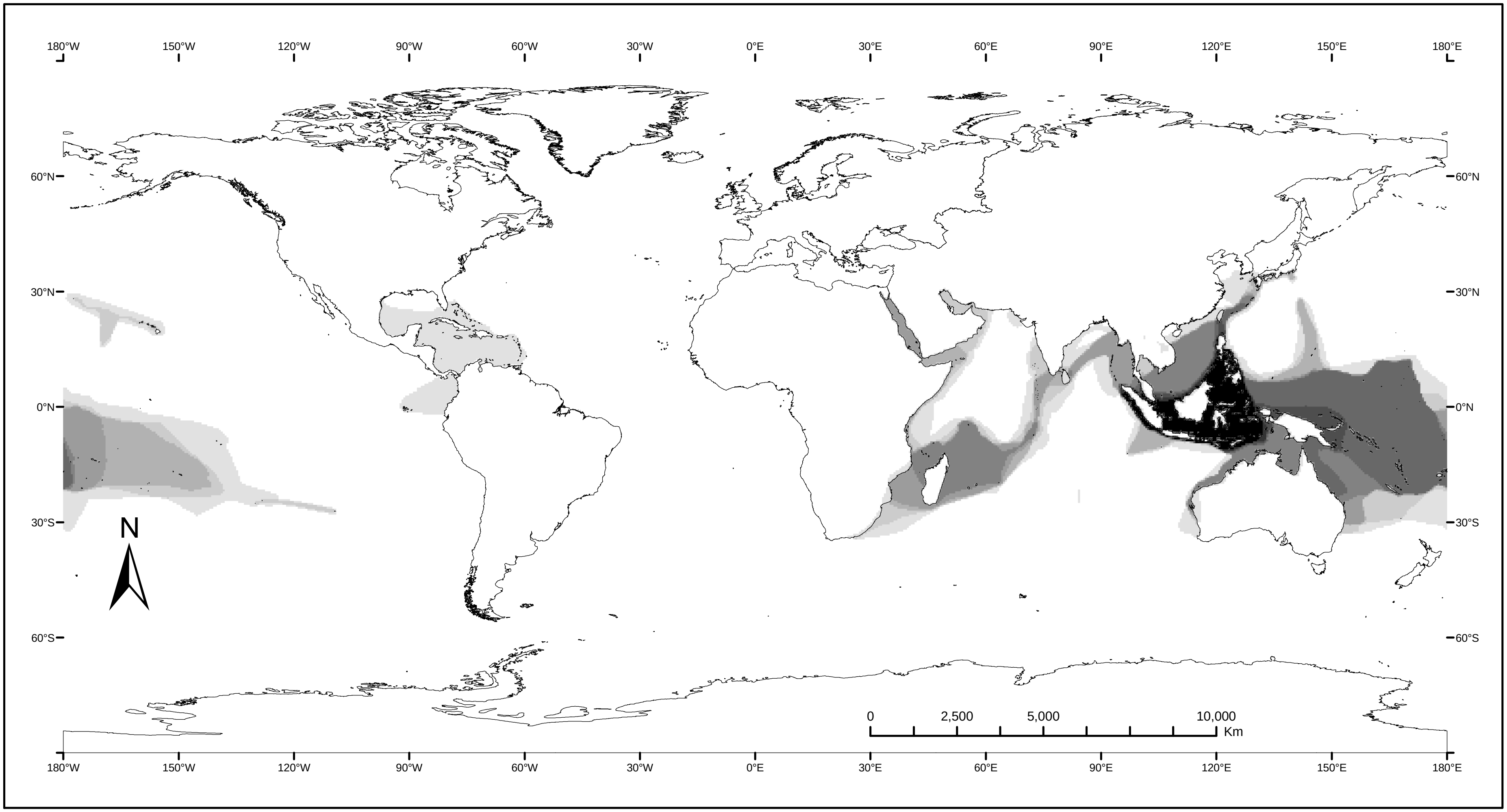
Figure 32

Phylum Cnidaria, Order Scleractinia

Reference: modified from Veron, 2000

Family Acroporidae

262 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

Species Richness

1 - 13 | 14 - 35 | 36 - 59 | 60 - 83 | 84 - 107 | 108 - 130 | 131 - 157 | 158 - 182 | 183 - 196

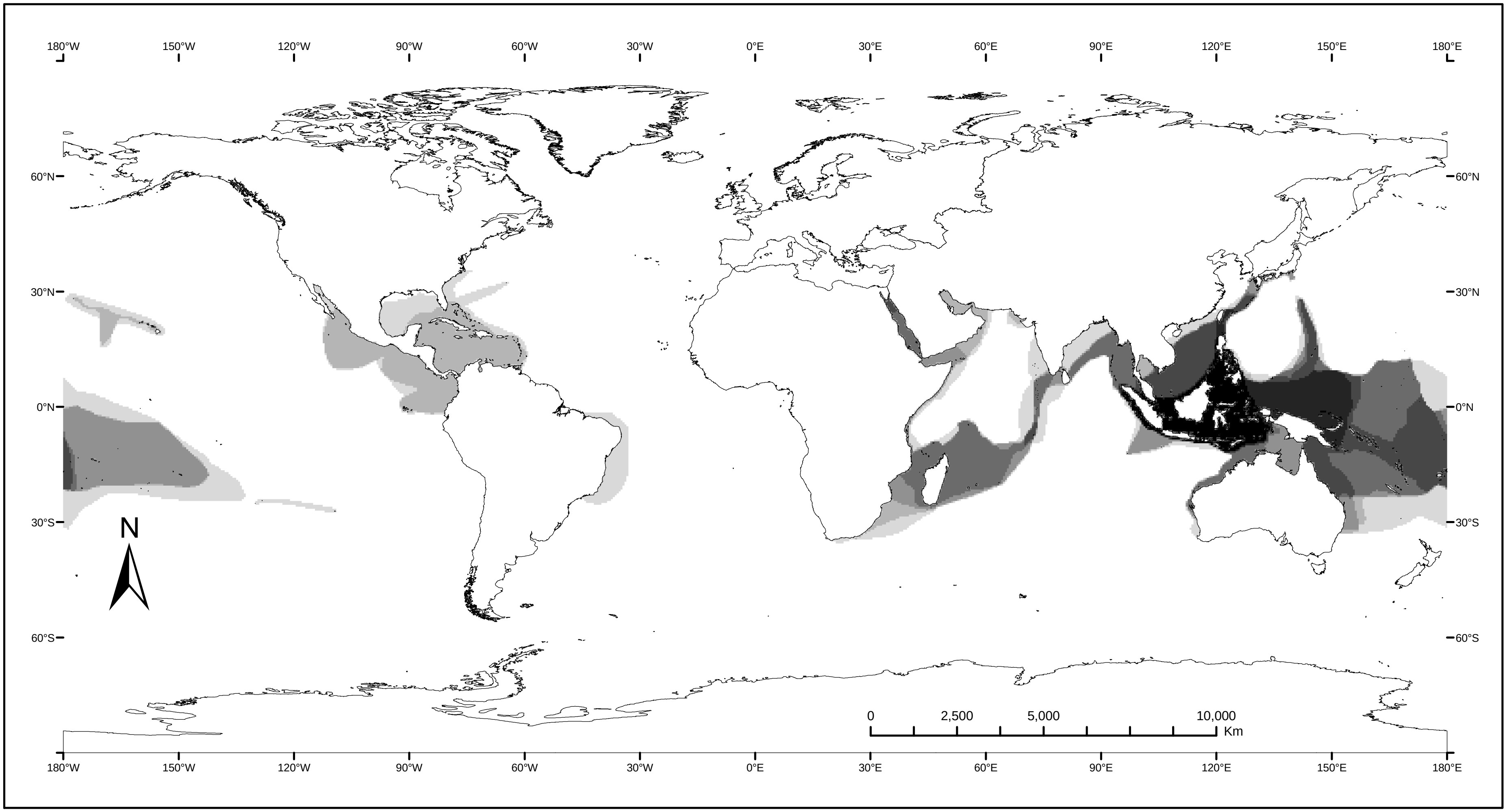
Figure 33

Phylum Cnidaria, Order Scleractinia

Reference: modified from Veron, 2000

Family Agariciidae

43 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

Species Richness

Value 1 - 6 | 7 - 12 | 13 - 18 | 19 - 21 | 22 - 24 | 25 - 28 | 29 - 32

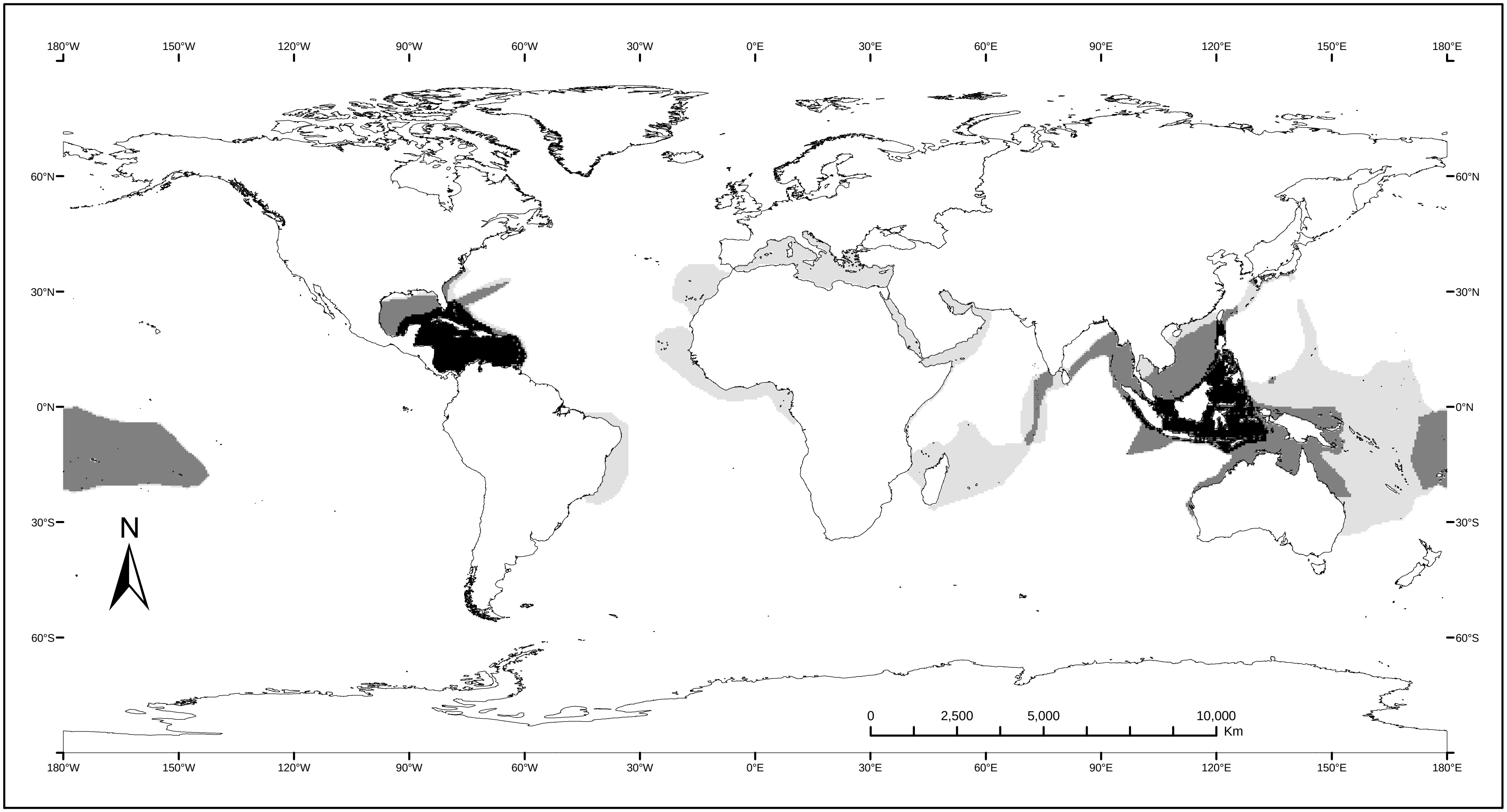
Figure 34

Phylum Cnidaria, Order Scleractinia

Reference: modified from Veron, 2000

Family Astrocoeniidae

13 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

Species Richness

1 - 2   3 - 4   5 - 7

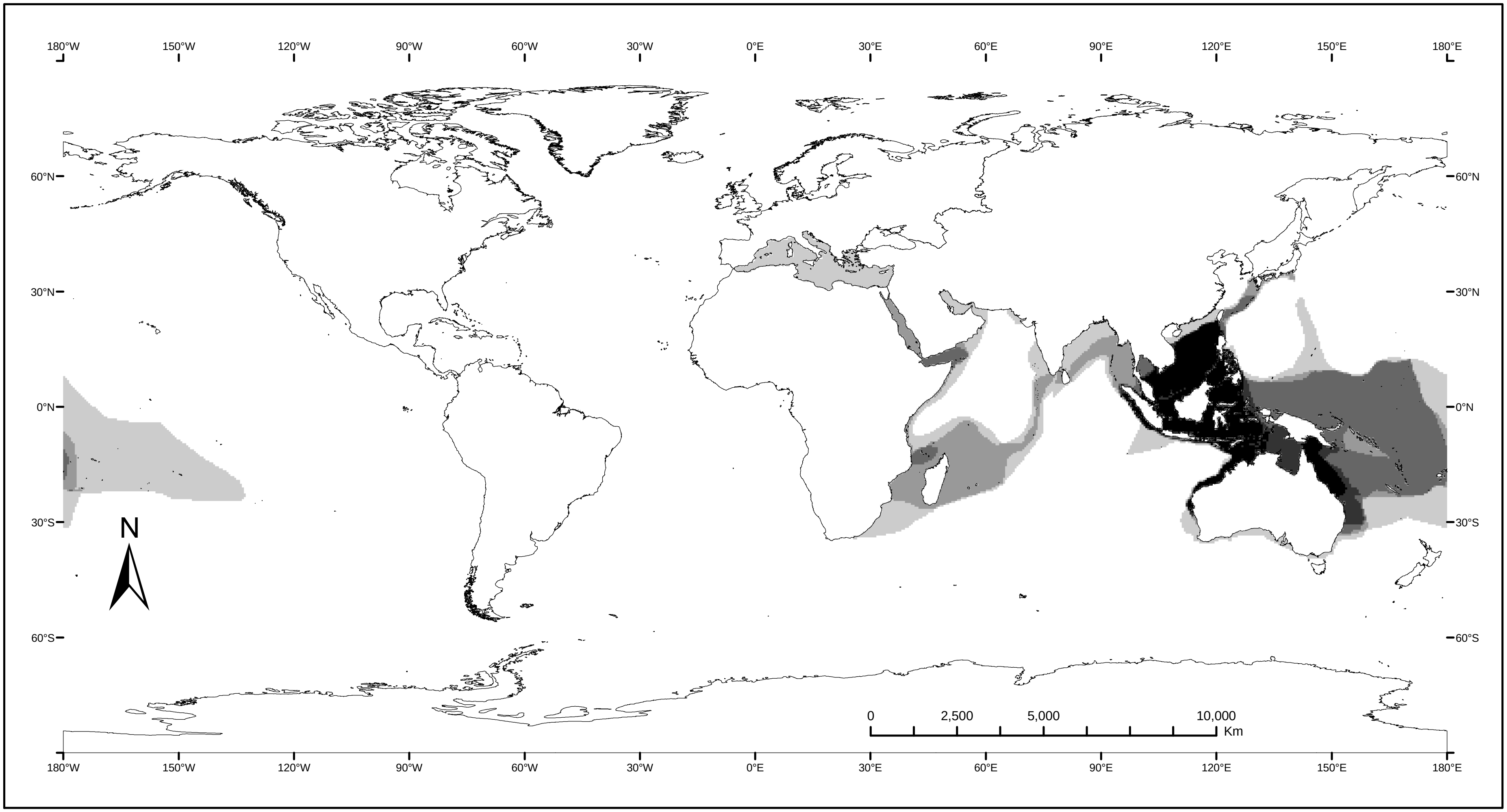
Figure 35

Phylum Cnidaria, Order Scleractinia

Reference: modified from Veron, 2000

Family Dendrophylliidae

14 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

Species Richness

1 - 4 | 5 - 6 | 7 - 8 | 9 - 10 | 11 - 12

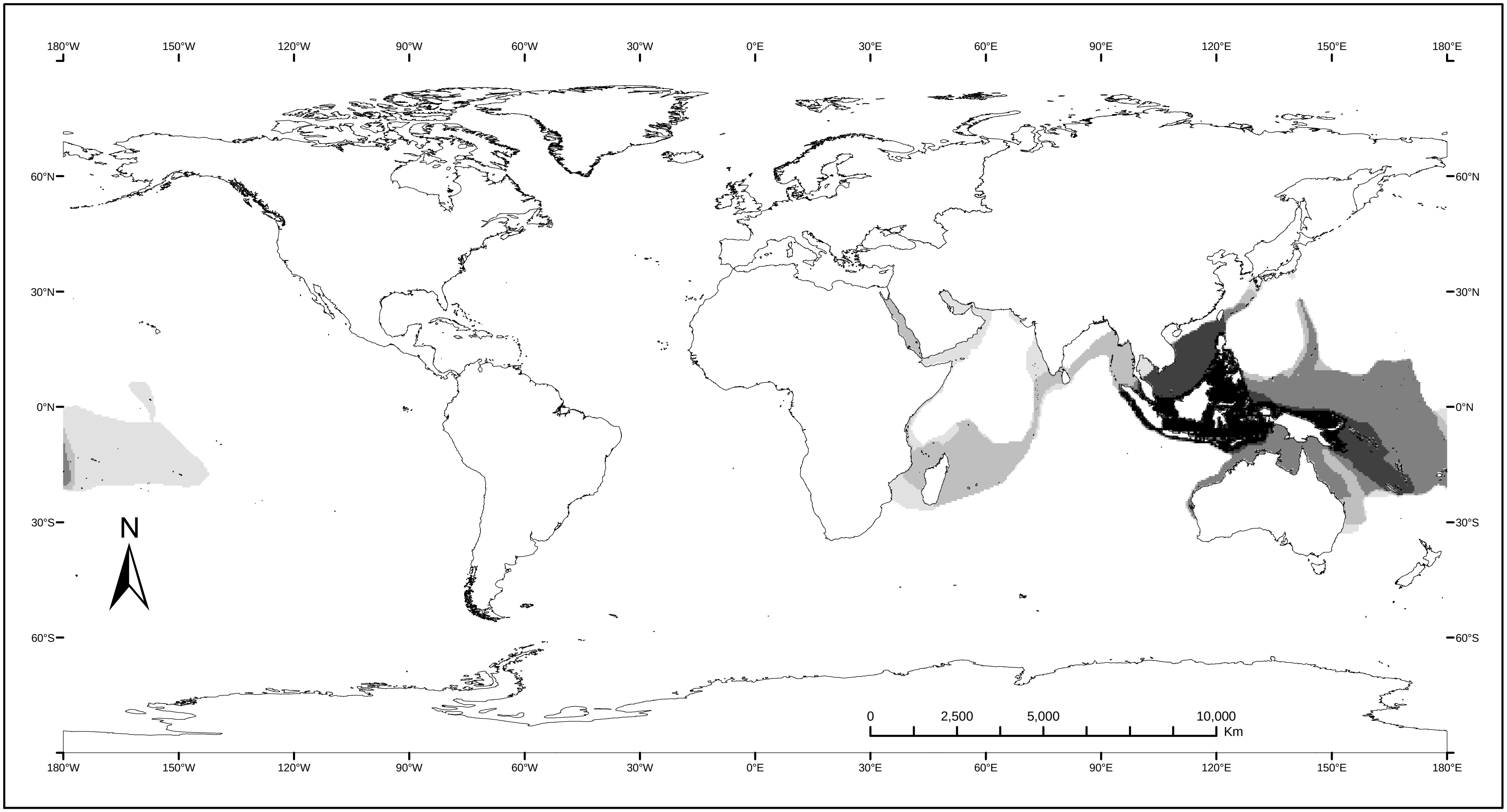
Figure 36

Phylum Cnidaria, Order Scleractinia

Reference: modified from Veron, 2000

Family Euphylliidae

14 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

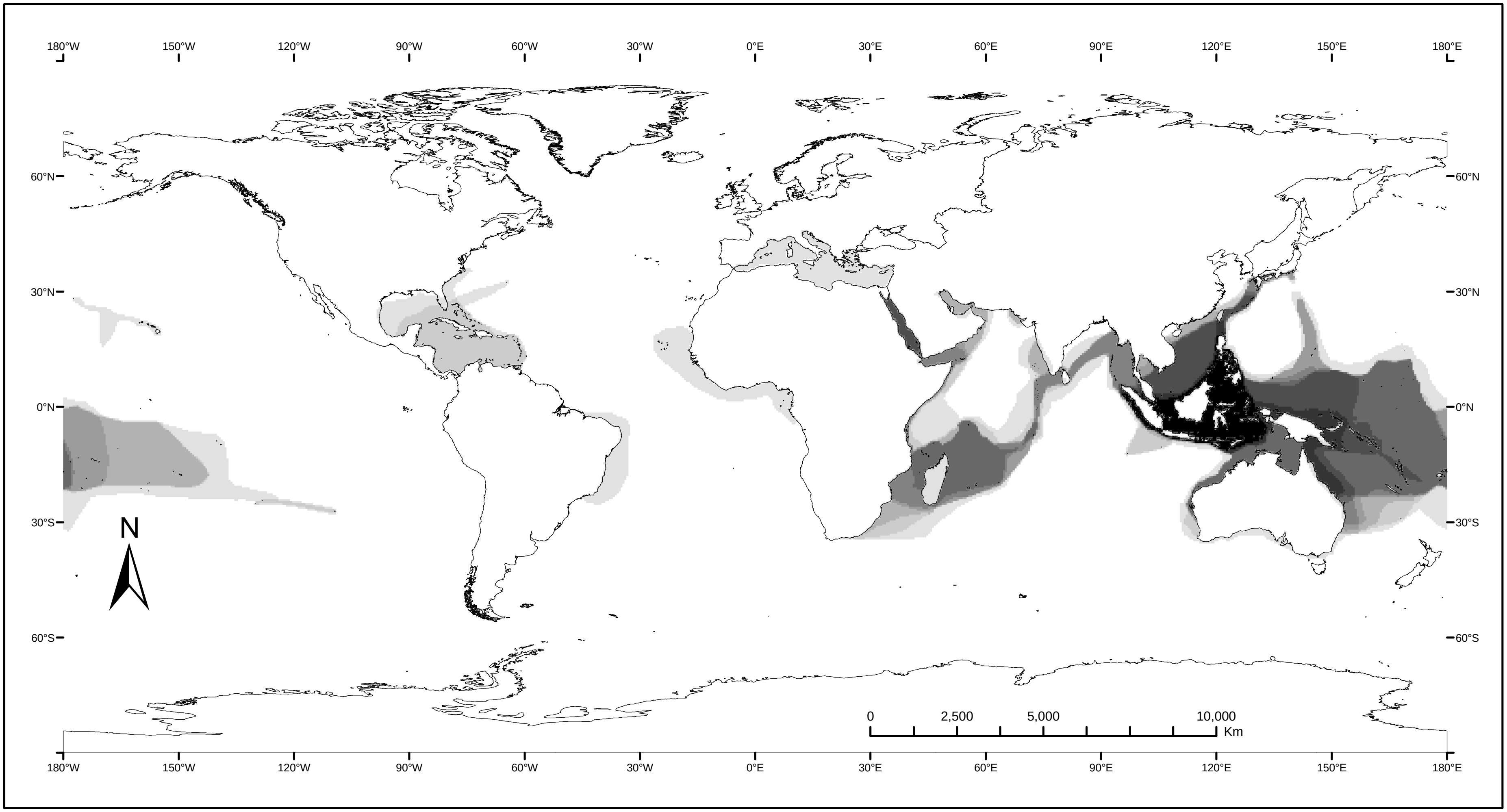
Species Richness

1 - 2 | 3 - 5 | 6 - 7 | 8 - 10 | 11 - 13

Figure 37

Phylum Cnidaria, Order Scleractinia — Reference: modified from Veron, 2000

Family Faviidae — 126 Indo-Pacific species



World Plate Carree, WGS 1984 — ESRI ArcMap 8.3 — M.K.K.McShane, Bishop Museum, 2004

Species Richness

1 - 7 | 8 - 18 | 19 - 30 | 31 - 42 | 43 - 54 | 55 - 64 | 65 - 72 | 73 - 84 | 85 - 93

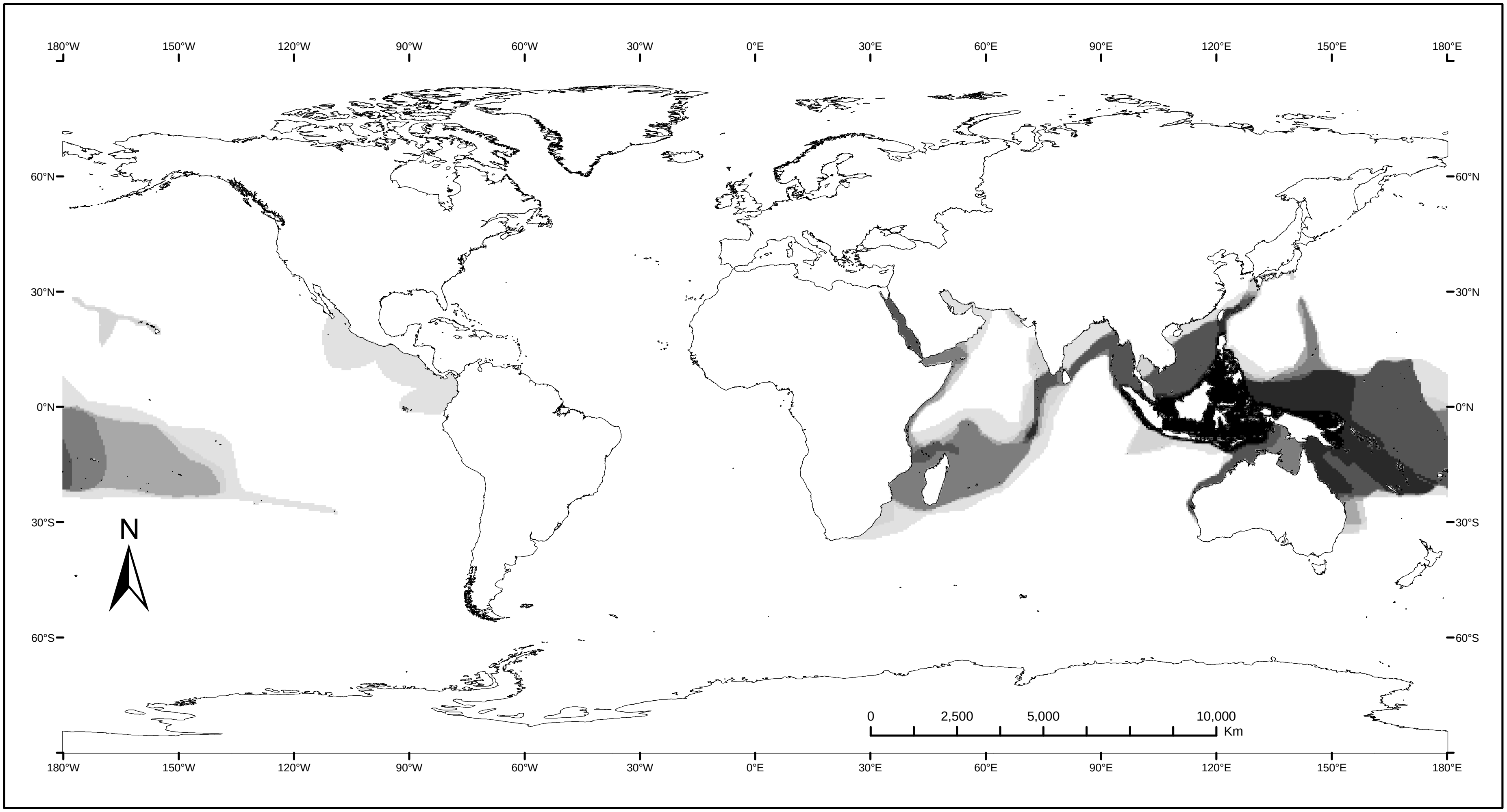
Figure 38

Phylum Cnidaria, Order Scleractinia

Reference: modified from Veron, 2000

Family Fungiidae

56 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

Species Richness

1 - 5 | 6 - 11 | 12 - 19 | 20 - 26 | 27 - 32 | 33 - 39 | 40 - 46

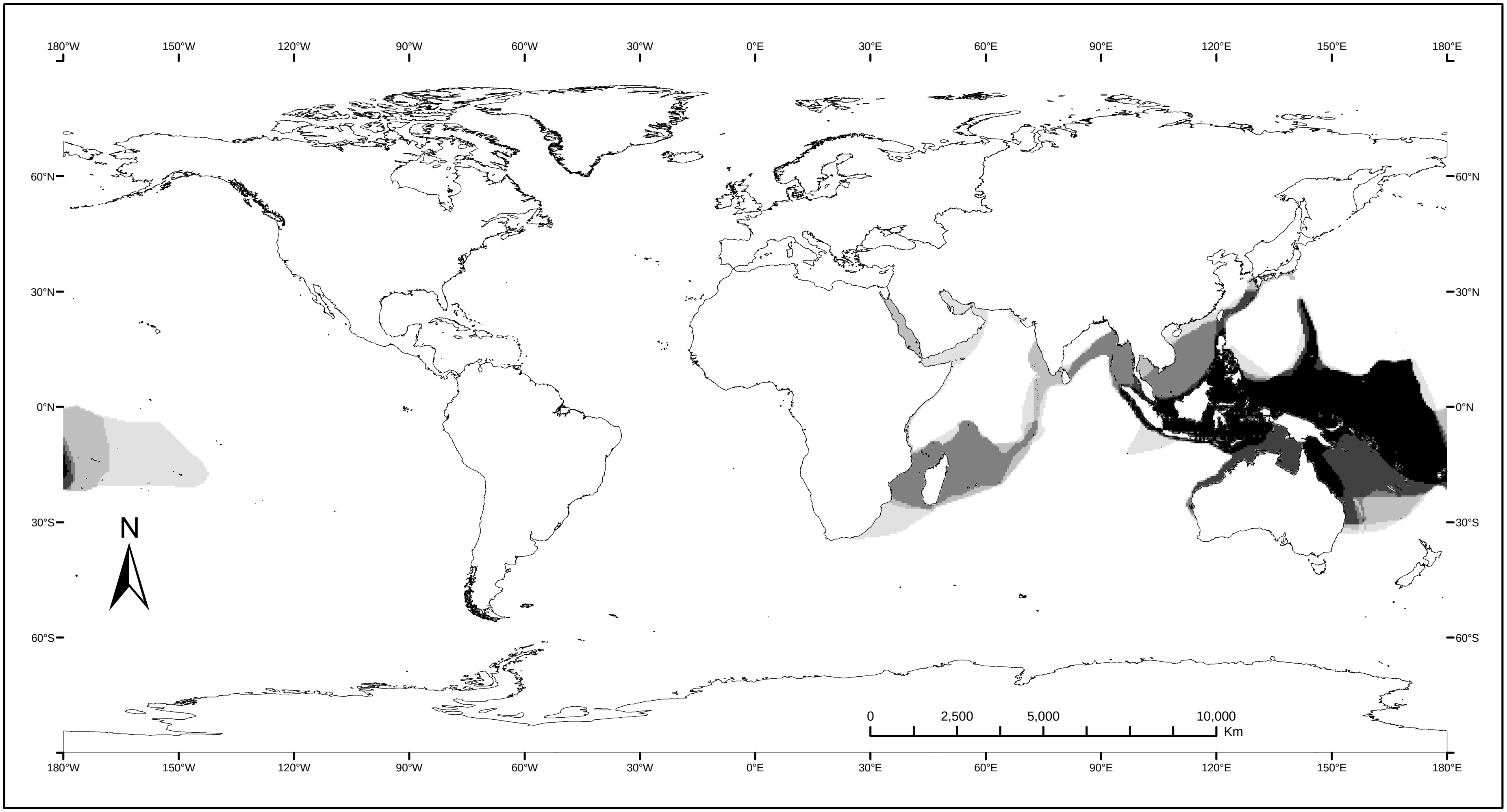
Figure 39

Phylum Cnidaria, Order Scleractinia

Reference: modified from Veron, 2000

Family Merulinidae

13 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

Species Richness

1 - 2 | 3 - 4 | 5 - 6 | 7 - 8 | 9 - 10

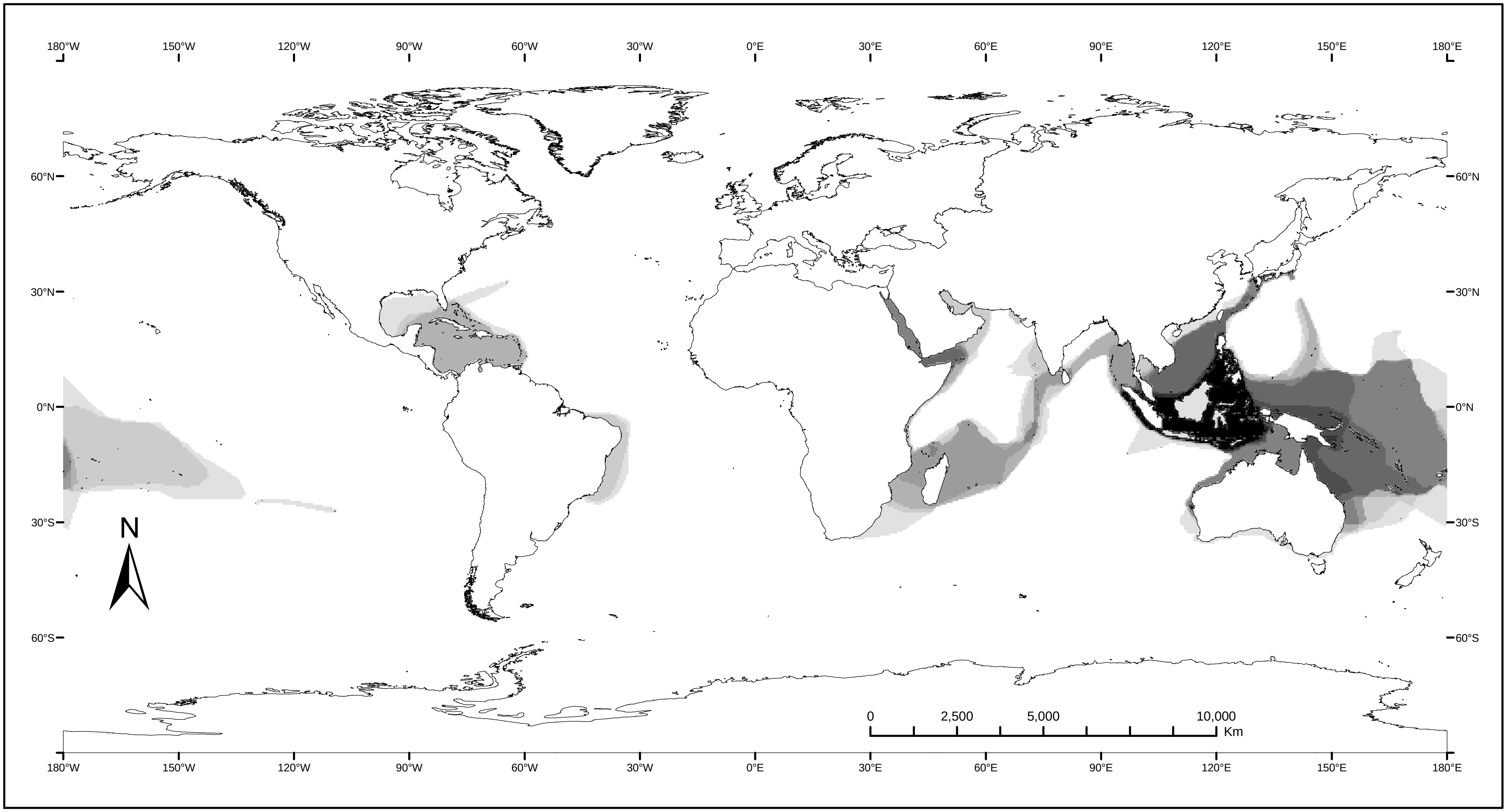
Figure 40

Phylum Cnidaria, Order Scleractinia

Reference: modified from Veron, 2000

Family Mussidae

50 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

Species Richness

1 - 3 | 4 - 7 | 8 - 11 | 12 - 14 | 15 - 18 | 19 - 22 | 23 - 26 | 27 - 30 | 31 - 34

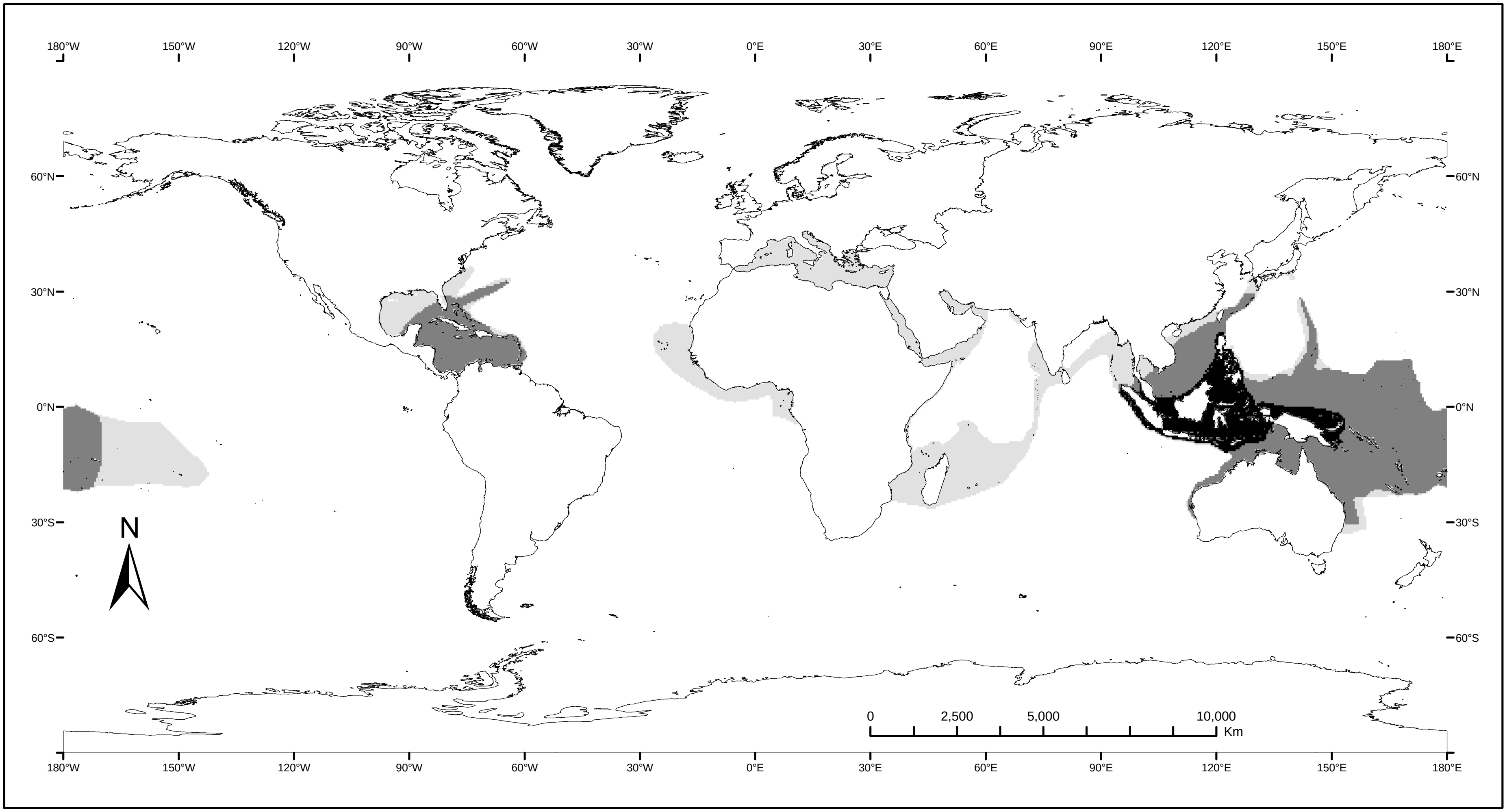
Figure 41

Phylum Cnidaria, Order Scleractinia

Reference: modified from Veron, 2000

Family Oculinidae

15 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

Species Richness

1 - 2 3 - 5 6 - 8

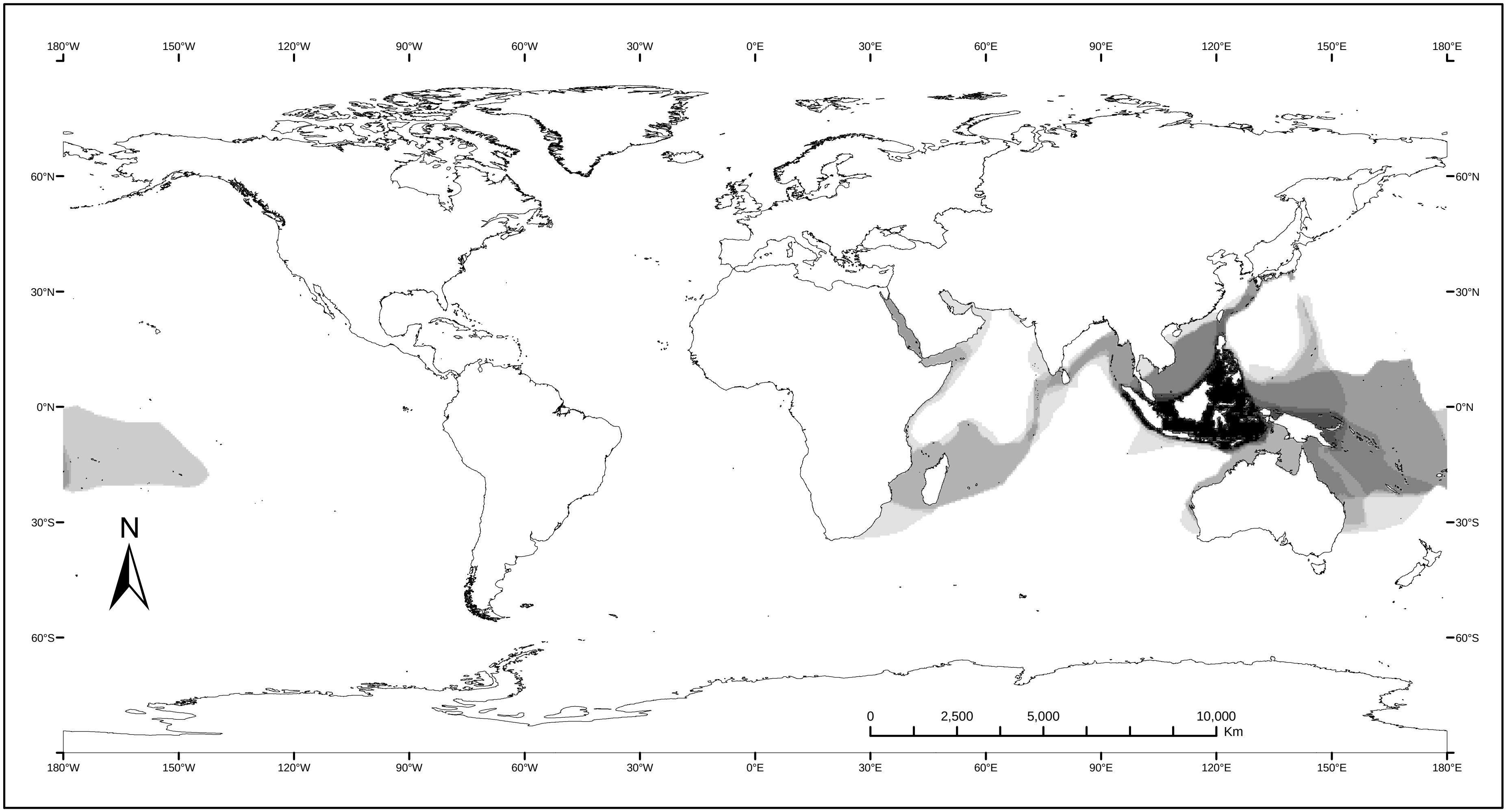
Figure 42

Phylum Cnidaria, Order Scleractinia

Reference: modified from Veron, 2000

Family Pectiniidae

28 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

Species Richness

1 - 2 | 3 - 5 | 6 - 8 | 9 - 10 | 11 - 13 | 14 - 16 | 17 - 19 | 20 - 21 | 22 - 24

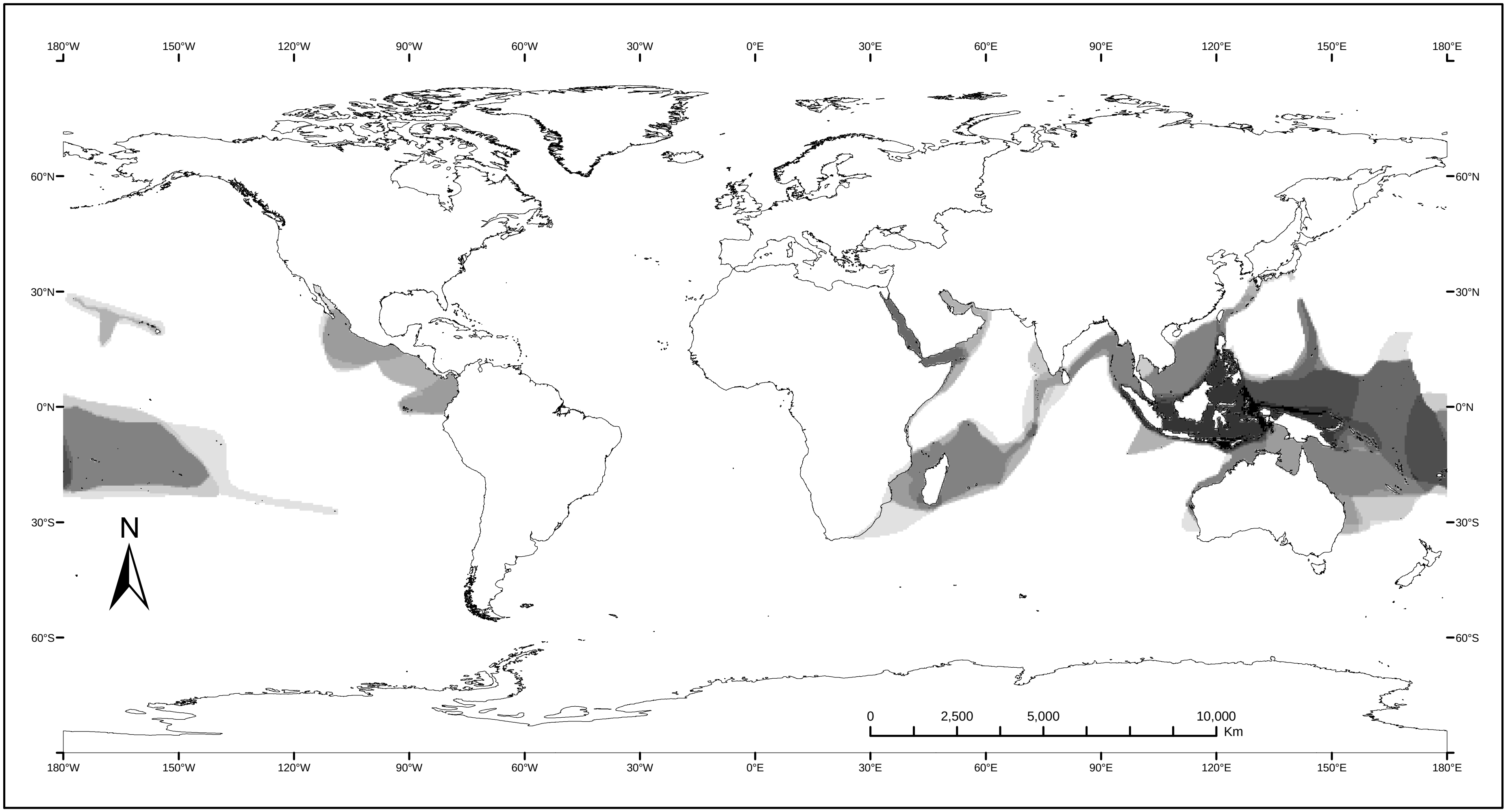
Figure 43

Phylum Cnidaria, Order Scleractinia

Reference: modified from Veron, 2000

Family Pocilloporidae

30 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

Species Richness

1 - 2 | 3 - 4 | 5 - 6 | 7 - 8 | 9 - 10 | 11 - 12 | 13 - 14 | 15 | 16 - 18

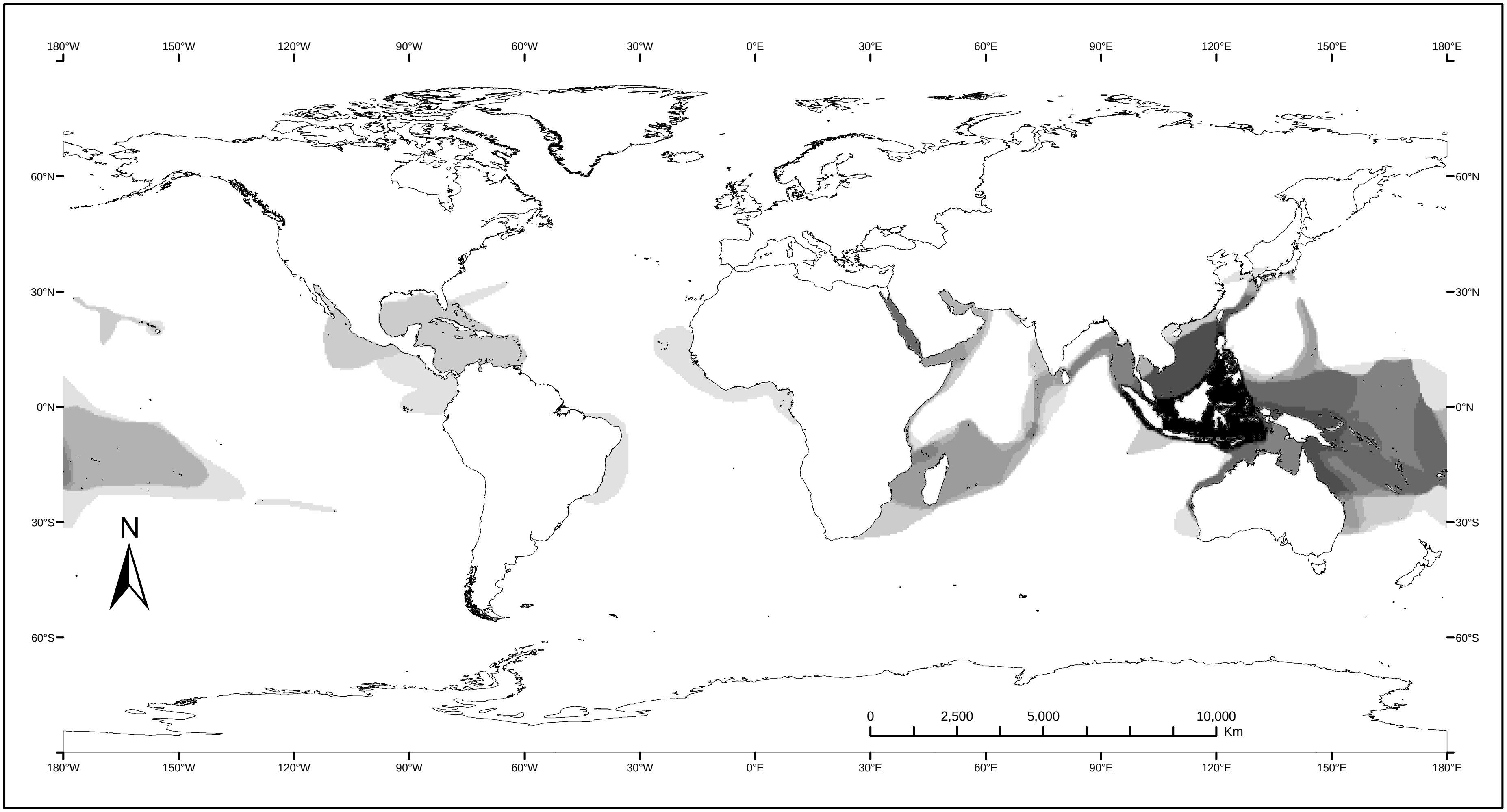
Figure 44

Phylum Cnidaria, Order Scleractinia

Reference: modified from Veron, 2000

Family Poritidae

92 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

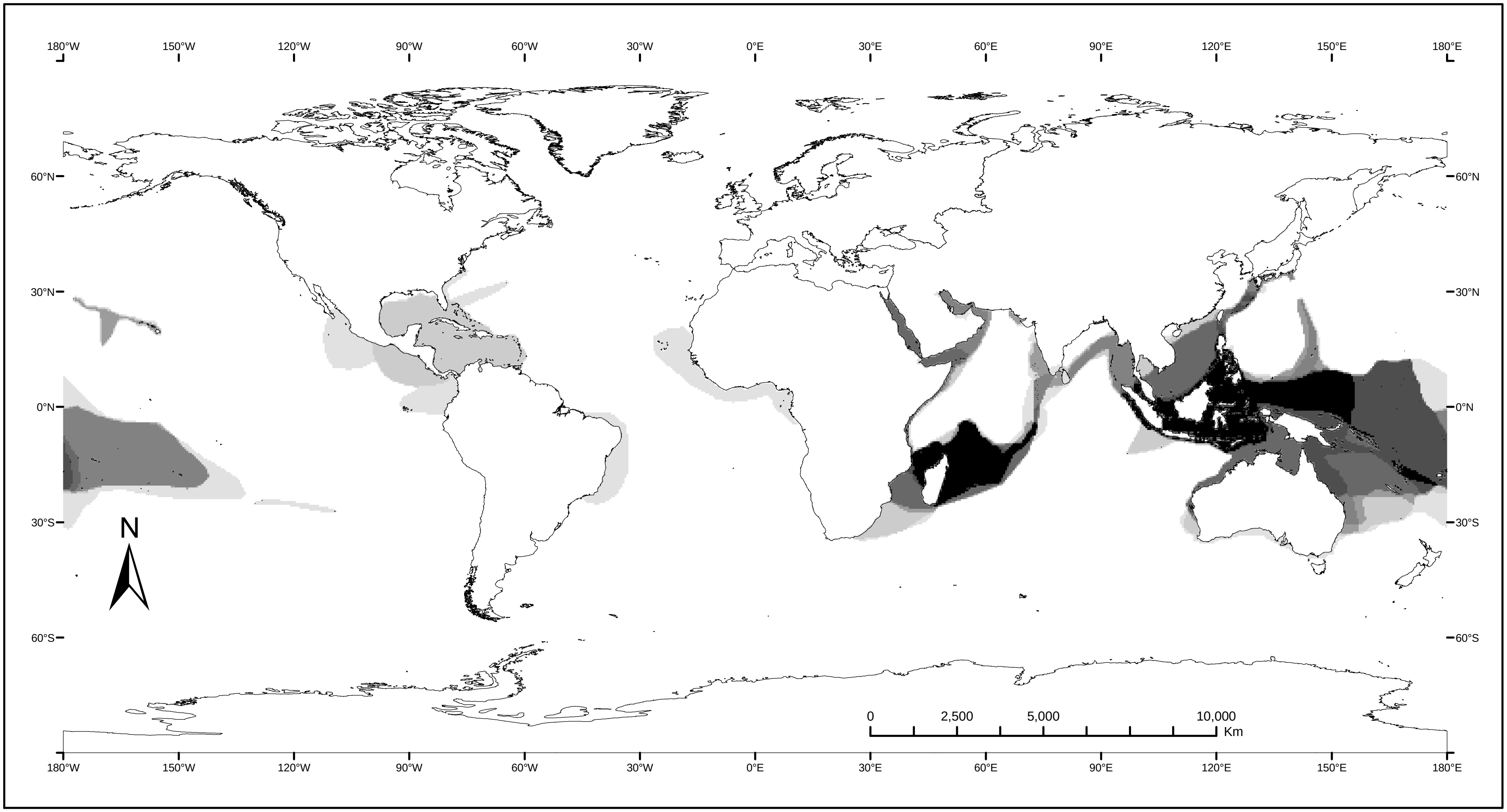
Species Richness

1 - 4 | 5 - 11 | 12 - 20 | 21 - 28 | 29 - 33 | 34 - 38 | 39 - 46 | 47 - 54 | 55 - 60

Figure 45

Phylum Cnidaria, Order Scleractinia — Reference: modified from Veron, 2000

Family Siderastreidae — 28 Indo-Pacific species



World Plate Carree, WGS 1984 — ESRI ArcMap 8.3 — M.K.K.McShane, Bishop Museum, 2004

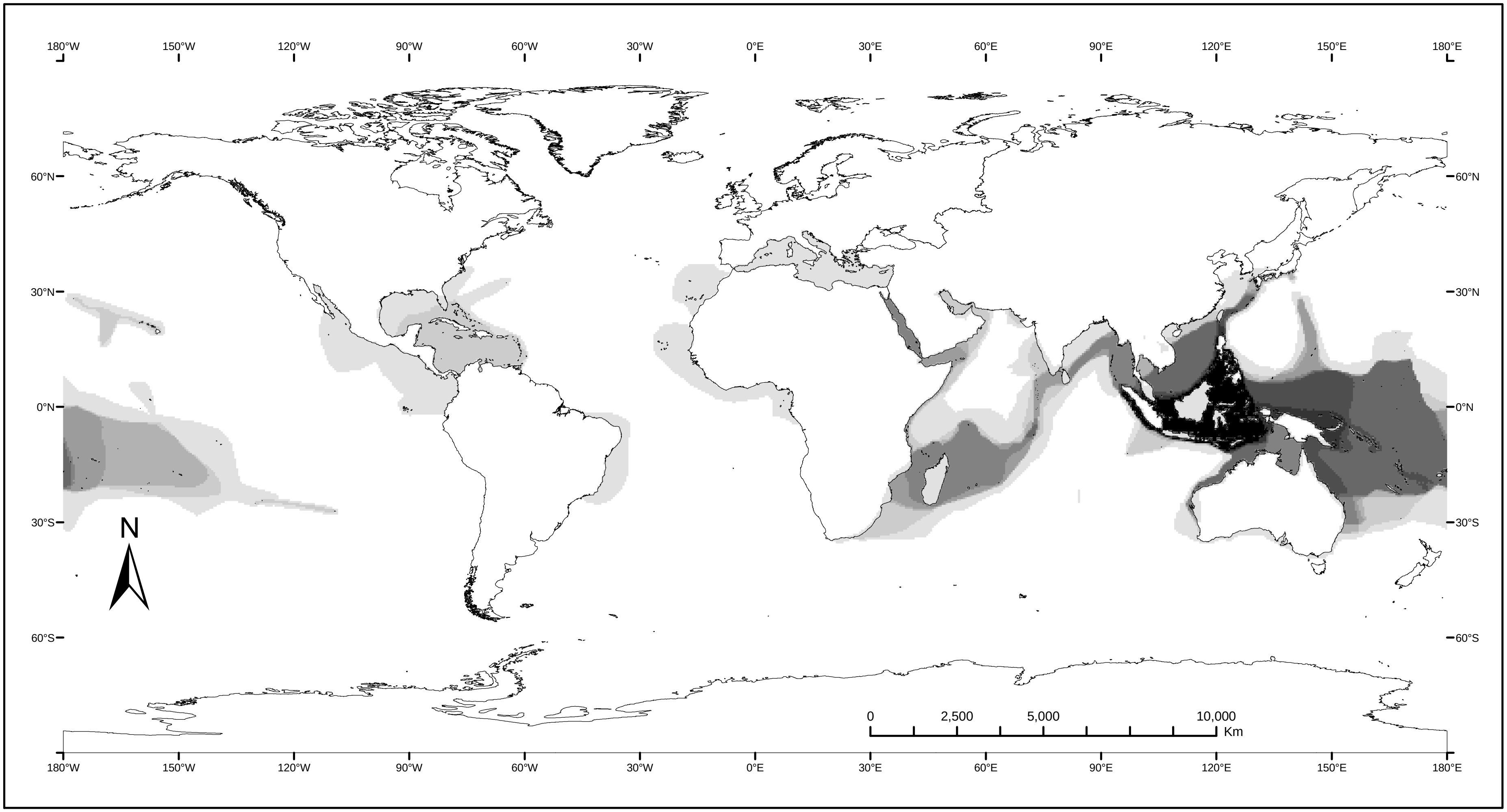
Species Richness

1 - 2 | 3 - 4 | 5 - 7 | 8 - 9 | 10 - 11 | 12 - 13 | 14 - 16

Figure 46

Phylum Cnidaria, Order Scleractinia

18 Families 794 Indo-Pacific species



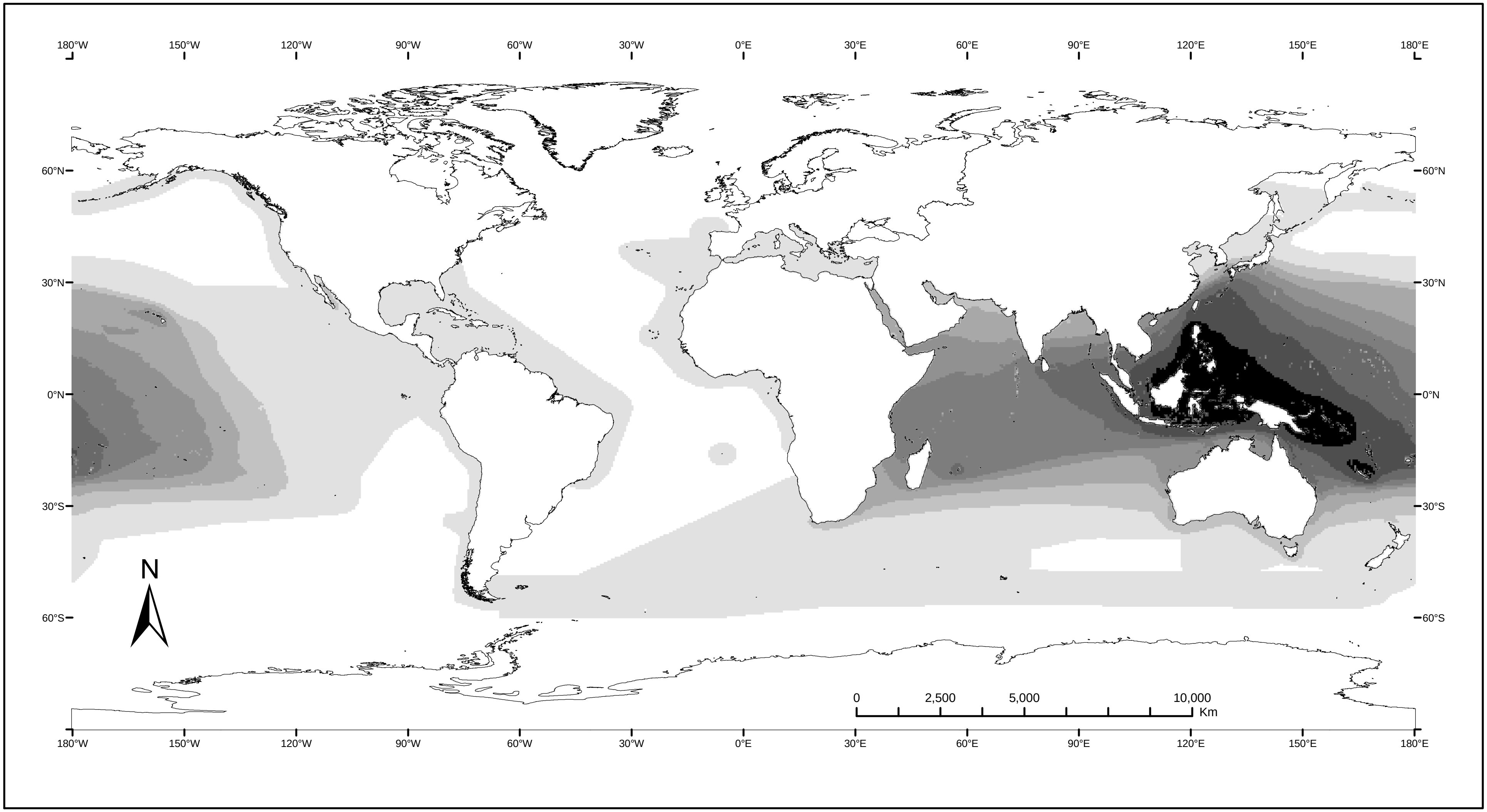
World Plate Carree, WGS 1984 ESRI ArcMap 8.3 M.K.K.McShane, Bishop Museum, 2004

Species Richness

1 - 36 | 37 - 108 | 109 - 182 | 183 - 245 | 246 - 311 | 312 - 361 | 362 - 415 | 416 - 500 | 501 - 561

Figure 47
Phylum Mollusca
28 Families

1166 species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

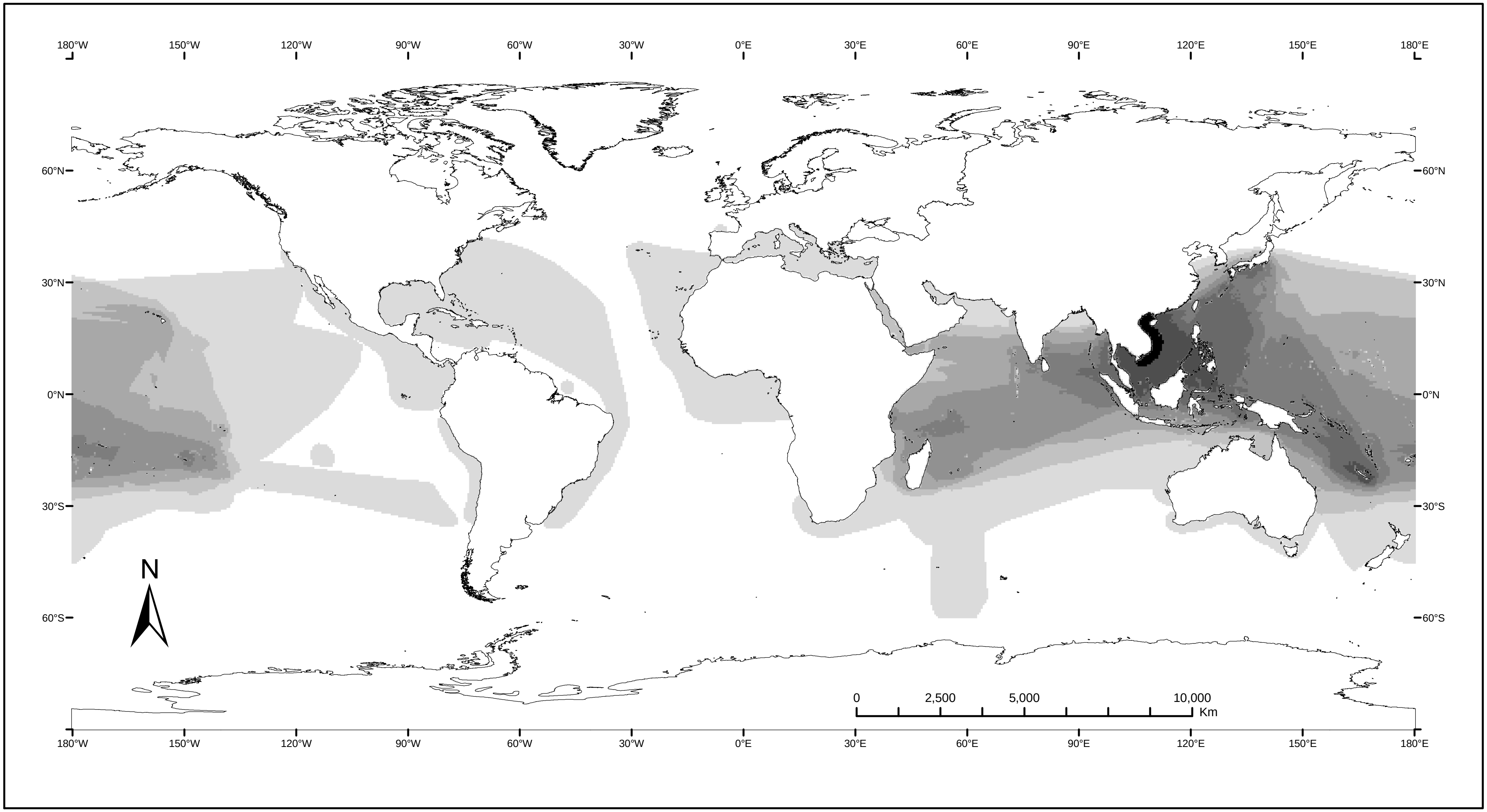
1-34 | 35-93 | 94-150 | 151-196 | 197-238 | 239-283 | 284-334 | 335-426

Figure 48

Subphylum Crustacea

19 Families

289 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

F. Moretzsohn, Bishop Museum, 2004

Species Richness

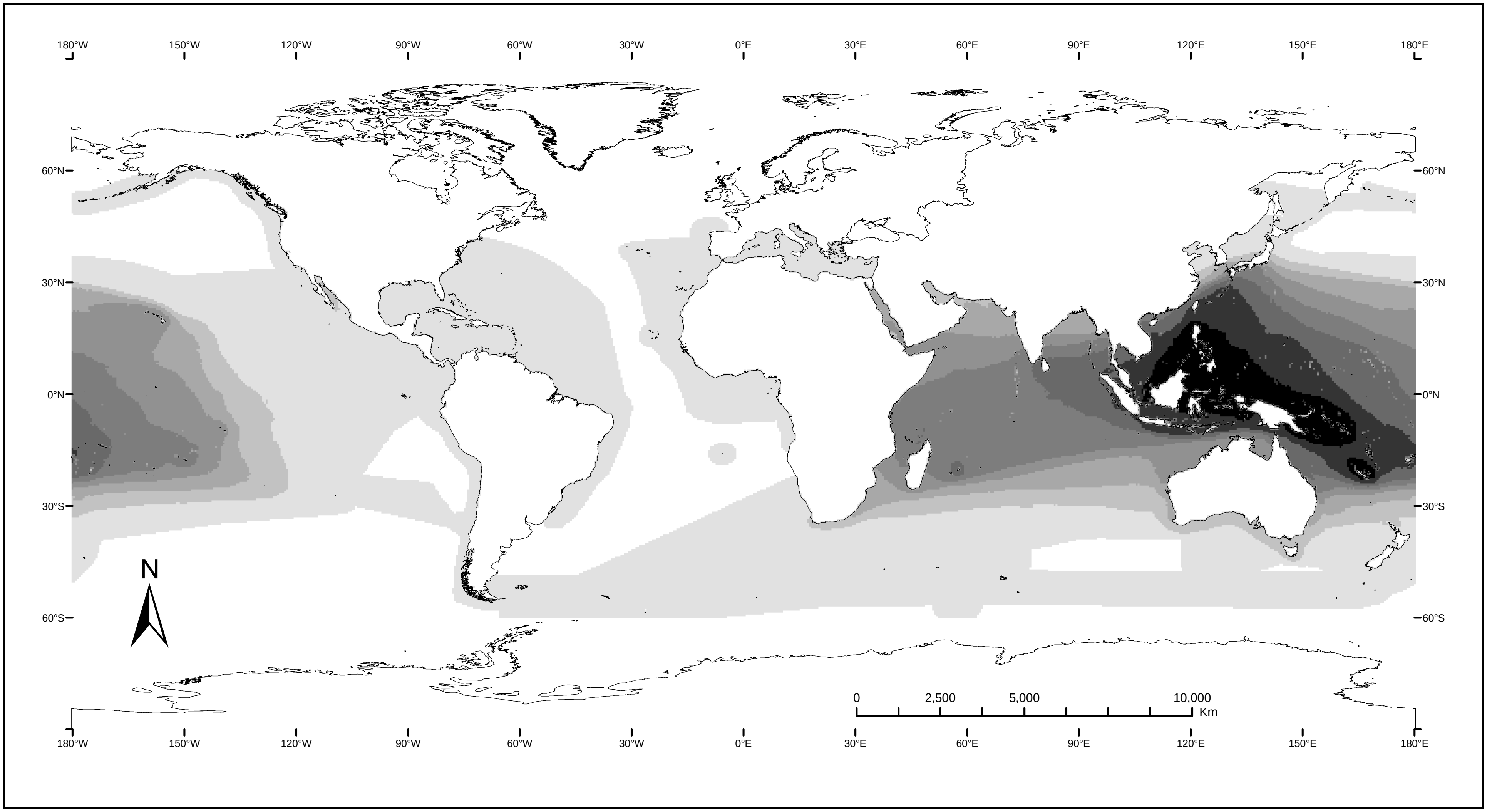
1-8 | 9-18 | 19-27 | 28-36 | 27-44 | 45-55 | 56-72 | 73-95

Figure 49

Mollusca + Crustacea

47 Families

1455 Indo-Pacific species



World Plate Carree, WGS 1984 ESRI ArcMap 8.3 F. Moretzsohn, Bishop Museum, 2004

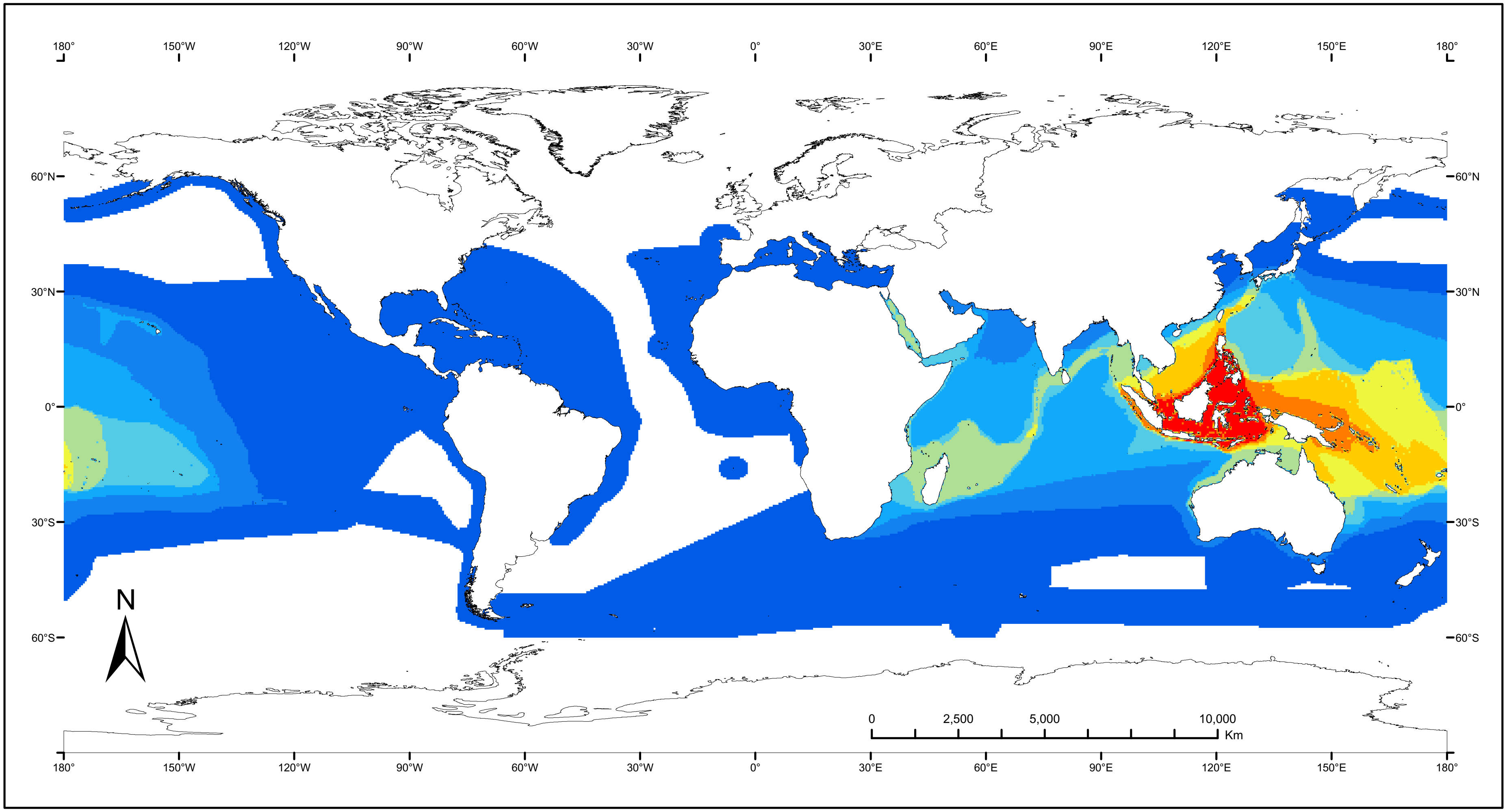
Species Richness

1-33 34-92 93-154 155-213 214-267 268-321 322-380 381-489

Figure 50 - Composite map of biodiversity
Mollusks, Crustaceans, and Corals

65 Families

2249 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

Species Richness

1 - 71 | 72-184 | 185-302 | 303-435 | 436-573 | 574-682 | 683-774 | 775-889 | 890-1,047

Figure 51 - Hotspots of biodiversity in the Indian Ocean
Mollusks, Crustaceans, and Corals

65 Families 2249 Indo-Pacific species

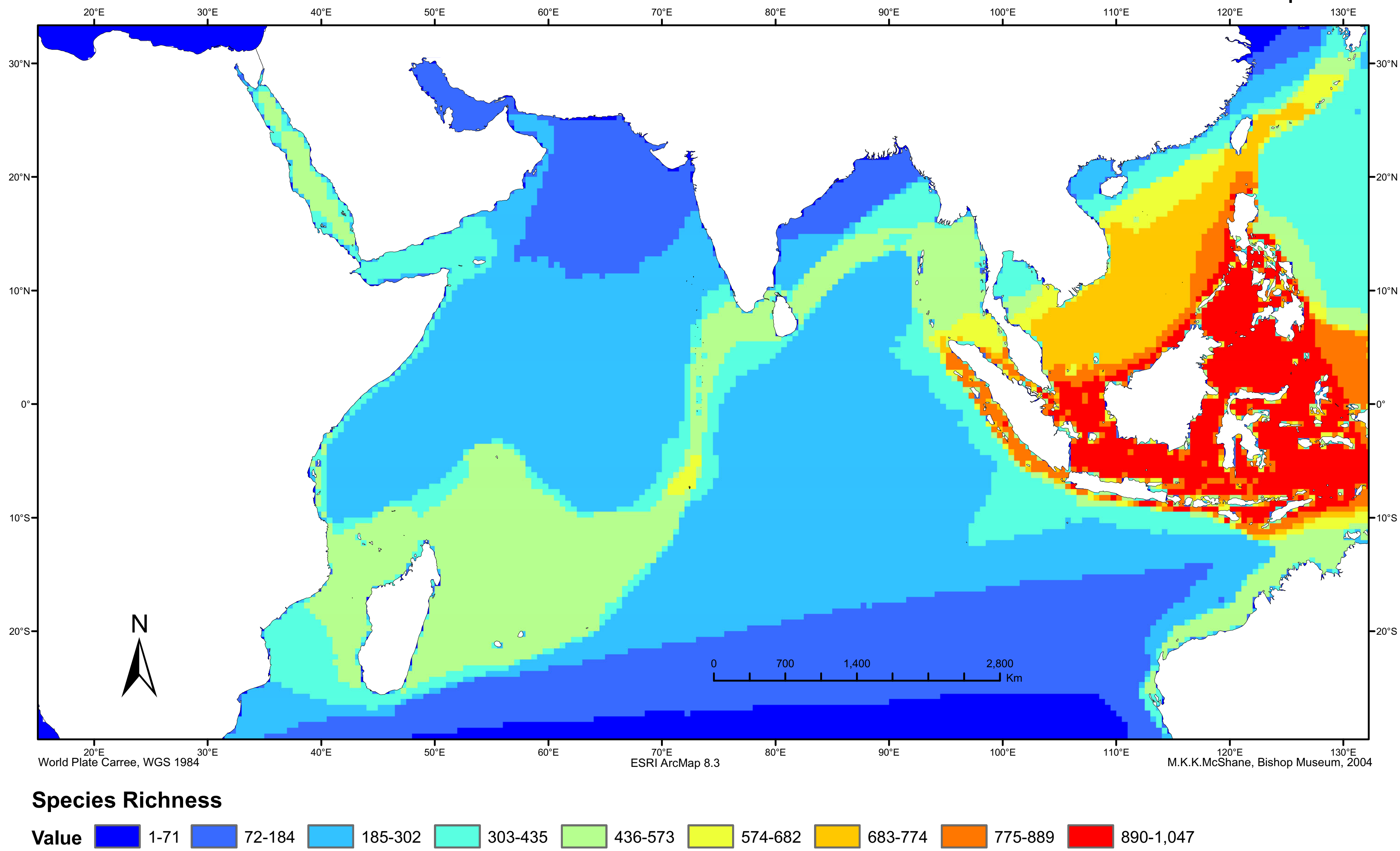


Figure 52 - Hotspots of biodiversity in the Indo-West Pacific
Mollusks, Crustaceans, and Corals

65 Families

2249 Indo-Pacific species

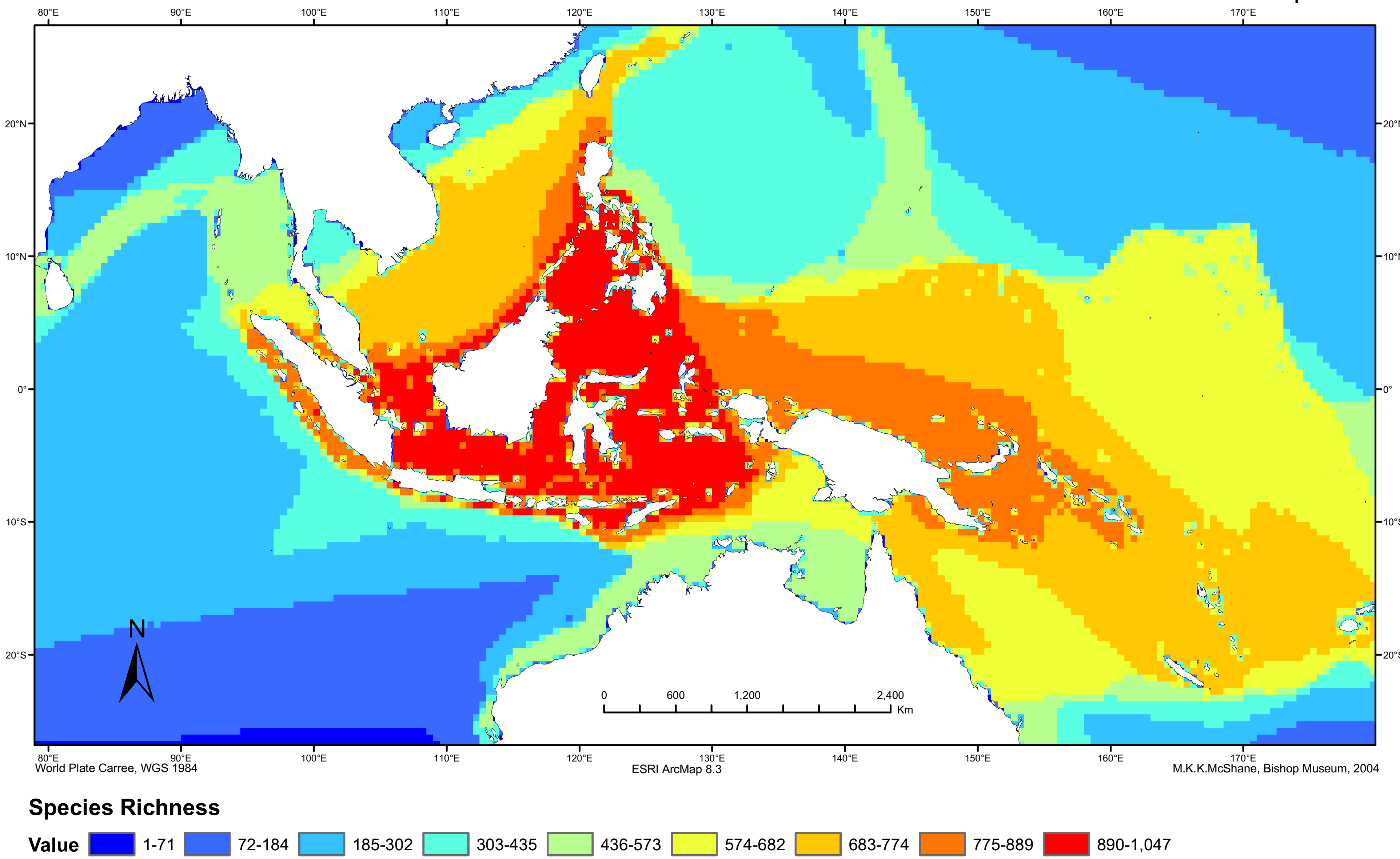
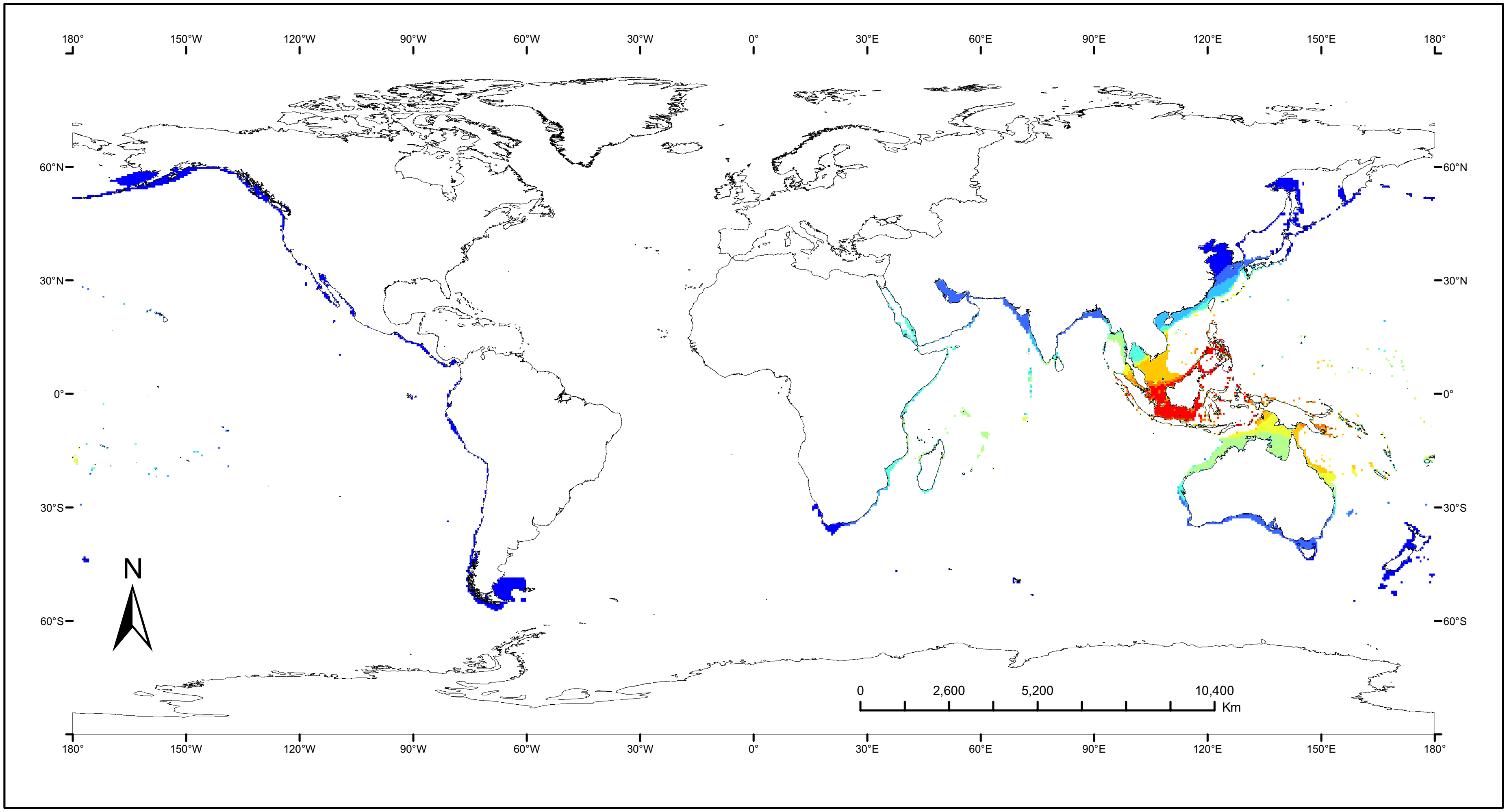


Figure 53 - Composite map of biodiversity up to 200 m

Mollusks, Crustaceans, and Corals

65 Families

2249 Indo-Pacific species



World Plate Carree, WGS 1984

ESRI ArcMap 8.3

M.K.K.McShane, Bishop Museum, 2004

Species Richness

1-64 | 65-193 | 194-336 | 337-454 | 455-563 | 564-665 | 666-772 | 773-885 | 886-1,040

Figure 54 - Detail of composite biodiversity up to 200 m
Mollusks, Crustaceans, and Corals

65 Families 2249 Indo-Pacific species

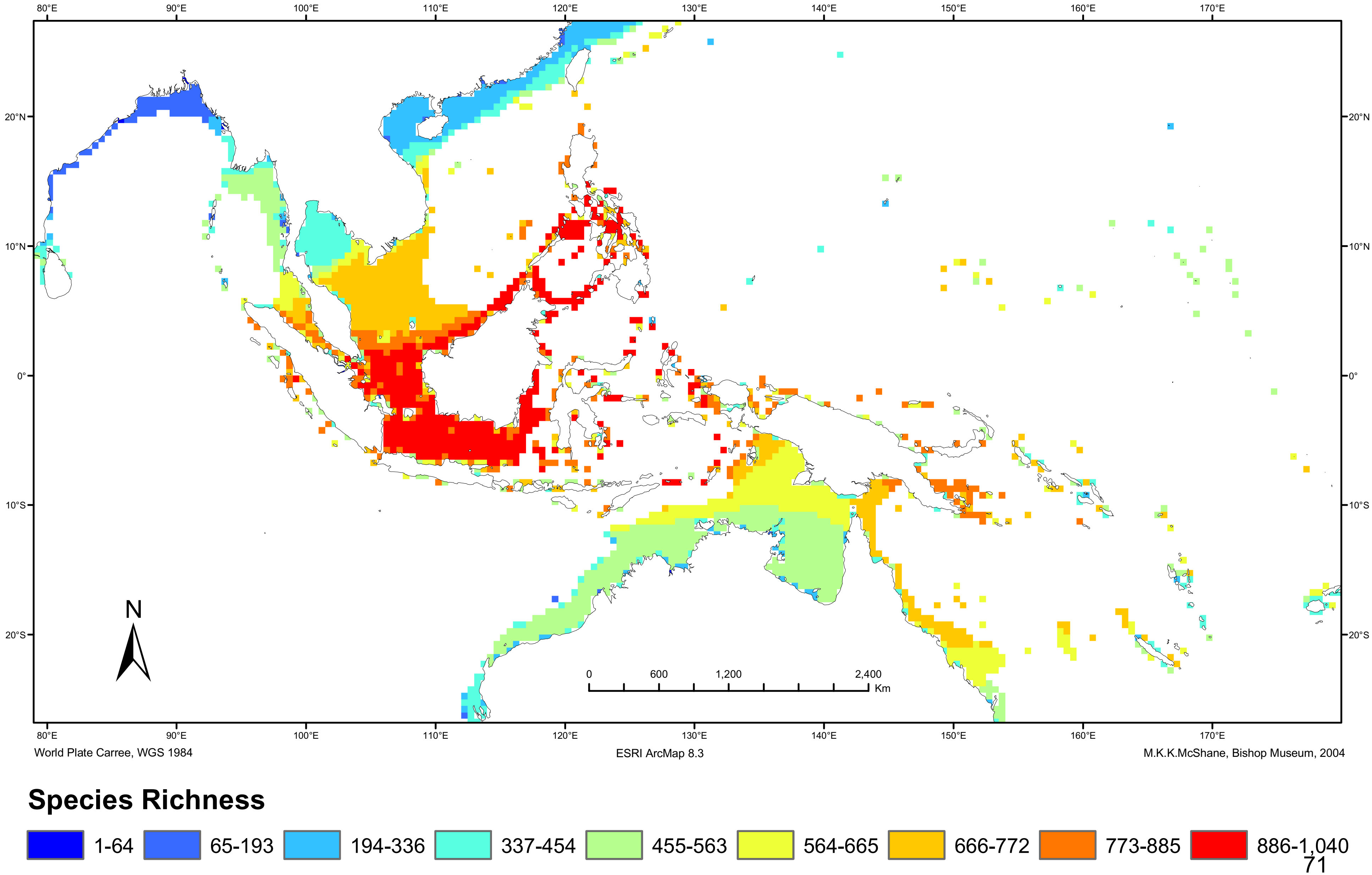
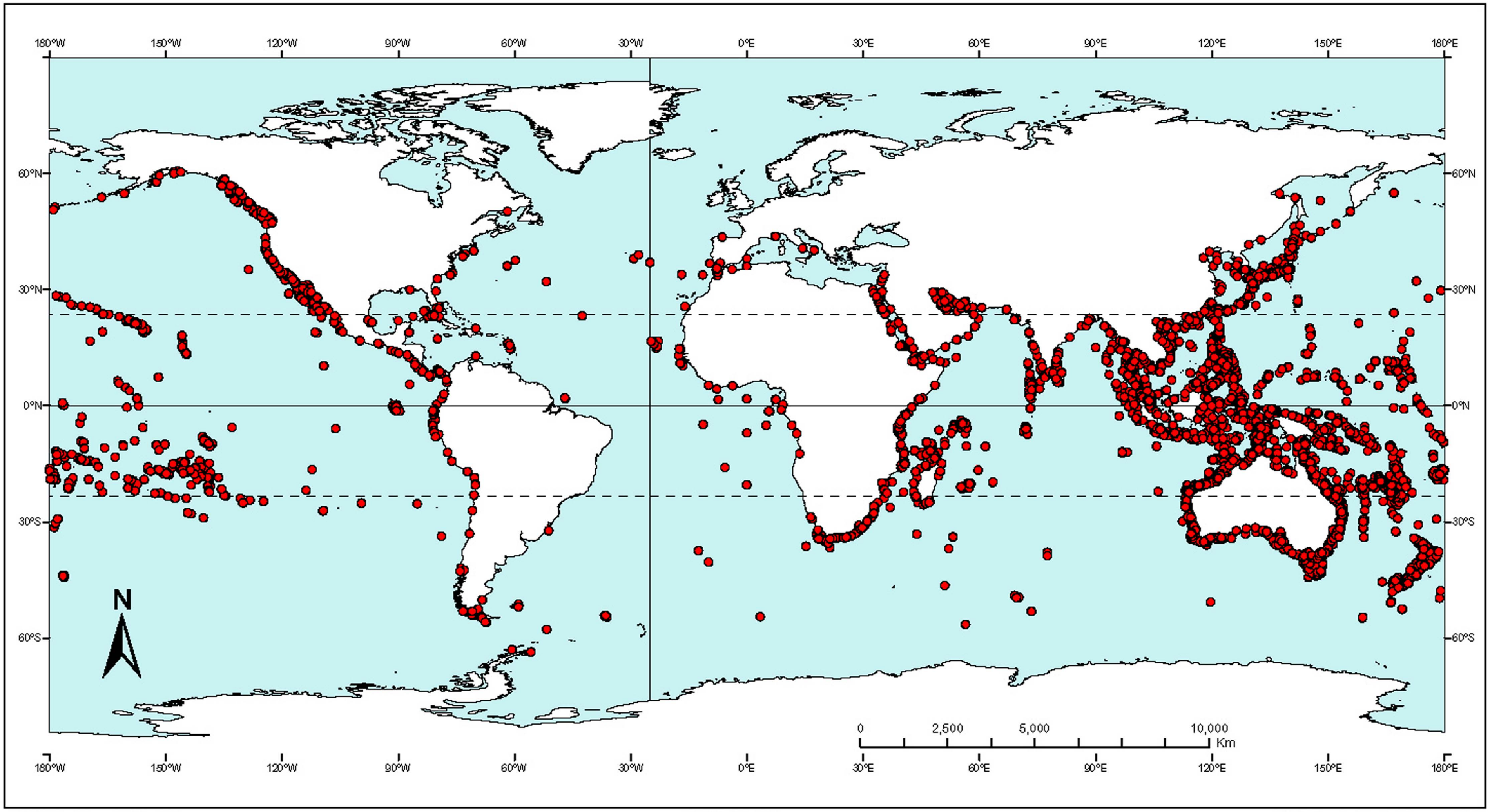


Figure 55 - Mollusk and crustacean georeferenced records (28,060)



World Plate Carree, WGS 1984 ESRI ArcMap 8.3 F. Moretzsohn, Bishop Museum, 2004

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