Chapter 2
7107 Islands

Abstract The fact that it is made up of 7107 islands defines the character of the Philippines as a terraqueous country where maritime activities, issues and concerns are central to the life of people, most of them having settled on or near the coasts, some even living on water (the Badjao "sea gypsies" of Sulu archipelago). The 7107 number is used as a symbol of the nation. The Philippine archipelago, as part of the "Pacific ring of fire", shares characteristics with Japan and Indonesia in terms of geological origin and the risks of earthquakes, volcanic eruptions and tsunamis. The chapter gives a summary presentation of the main physiographic features of the country (mountains and plains, lakes and rivers, peninsulas and inter-island seas) and its geophysical origin within the general scheme of plate tectonics. It also includes statistical comparisons with other island or archipelagic countries and raises some questions about the effects of the split of the country between many islands big and small.

Keywords Islands • Sea • Volcanoes • Plate tectonics • Coasts

The Philippine archipelago is located between Taiwan and Borneo, about 800 km from the Asian mainland (1100 km from Hong Kong to Manila, 1400 km from Da Nang). It is much more isolated from the Asian landmass than Indonesia or Japan. On the east side lies the immense Pacific Ocean, with the Philippine Sea extending more than 2000 km to the Carolines (Palau, Yap, Ulithi) and the Mariannas (Guam, Saipan, Tinian). On the west side, a hotly contested body of water, the South China Sea (or West Philippine Sea) separates the Philippines from Vietnam and China. The closest foreign land to the Philippines lies to the southwest, with the northern tip of the island of Borneo, in the Malaysian province of Sabah. The sea therefore plays a major role in the life of the Philippines, just as it is also a link between Southeast Asia's countries (Nguyen 2016).

The complex shape of the islands gives the country an exceptionally long coastline in regard to its overall land size. The genesis of such a spatial configuration is linked to the interaction of three major tectonic plates and four smaller ones. The intertwining of land and sea gives a special importance to coastal areas, in terms of population settlement, urbanization and economic activities. The defining charac-

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teristic of this archipelago nation is that it has a far greater sea area under national jurisdictions than land territory. Being an archipelagic country with an extended huge coastline, the Philippines has a big potential in coastline-development projects that could generate a wide variety of economic activities: the Philippines may become a mecca for marine tourism, develop the country's boat-manufacturing industry, and protect its exceptional marine biodiversity for ecotourism.

However, the Philippines is an elongated and fragmented state, whose parts are poorly connected. From the economic, social, and political standpoint, such a shape of the Philippines may be a disadvantage due to the high costs and time required to link together the different elements. The fragmentary nature of the country is a source of the regional (parochial?) thinking of the Filipinos. The existence of many tribal, ethnic and linguistic groups is partly due to the archipelagic character of the nation. In matters of security, the numerous islands and the long coastline make it difficult to defend the country against foreign invasion, smuggling and the prevention of illegal entry of aliens.

The ocean is also the source of typhoons, a major component of Philippine life. The situation of the archipelago in the western part of the Pacific Ocean gives it a humid climate, marked by a seasonal inversion of wind and rain patterns, and the permanent threat of strong storms born from the warmest ocean waters on the planet (Fig. 2.1).

2.1 Sea and Land Intertwined: The Terraqueous Character of the Philippines

2.1.1 Islands, Seas and Lakes

Official Philippine statistics indicate that the country is made up of 7107 islands, with a total land area of 299.000 km^2, the 64th largest country in the world, a medium-size country roughly of the same dimension as Cuba, Norway, Italy or Vietnam, slightly smaller than Japan. The country stretches about 1850 km from Y'Ami Island (Batanes province), barely 78 miles from Taiwan, in the north, to Sitangkai (Tawi-Tawi province) in the south, only 34 miles from Borneo. It extends from 4°23 N to 21°25 N and is therefore entirely located within the tropical zone.

The exact number of islands has been subject to discussions (Bethge 2008). In 1663, Spanish priest Francisco Colin, in his "Labor Evangelica" (Colin and Chirino 1663) indicates the number of the Philippine Islands to be only 40, obviously disregarding many other smaller islands, that he says "to be impossible to count". According to a map from the 1700s, "The Philippine Isles are computed to be 11000"[1]. The 1913 Catholic Encyclopedia lists 3141 islands

[1] http://filipinolibrarian.blogspot.fr/2006/07/islands-philippines.html

of which 1668 are named (Finegan 1913). Today, 2773 islands have a name. In 1949, Erica Grupe Lörcher refers to the "about four thousand smaller and larger islands" of the Philippines (Grupe-Lörcher 1949). Philippine historian Antonio Molina finally puts the number at 7083 in his publication "The Philippines through the Centuries" (Molina 1960). According to historian Ambeth Ocampo (2007), the number "7107" used today comes from a 1939 counting by the Land Survey Office. It is not clear if this number came from a counting on maps or from systematic field visits. Recent publications always use this 7107 number, or a "more than 7000 islands" formulation. According to geographers and the international law of the sea (UNCLOS) convention, islands are defined as "naturally formed lands surrounded by water at high tide and protruding above the water level". Since many of the islands not named are in fact mostly small coral reefs, would sea-level rise reduce the number of Philippine islands by covering some coral reefs at high tide? A new survey has revealed, on the contrary, that the country may have about 7500 islands (Macaranas 2016), most of the additional ones being in Mindanao.

This 7107 number has become somehow synonymous with the Philippines, since it is widely used by a number of companies, such as *7107 Islands Placement and Promotion* (an overseas job placement agency, www.my7107.com), several restaurants (*7107 Islands* on Boracay Island, *Archipelago 7107* in Ortigas Center, Pasig, *Bistro 7107*, a Filipino Fusion restaurant in Arlington, Virginia, www.bistro7107.us, *7107 Flavours* in Singapore), some cruise lines (*7107 Island Cruise*, www.7107islandsmanagement.com and *7107 Islands Cruise*, www.7107islandscruise.net) and several travel agencies (*The 7107 Islands—Discover the Philippines*, http:/www.the7107islands.com, *7107 Magnificent Islands Tours,* 7107islandstours.com, Visit 7101 Islands, www.visit7107islands.com, *7107 Islands Tours*, https://twitter.com/7107islands, 7107 Adventure Travel & Tour, http://fun7000.com), a travel magazine (*7107 Islands Magazine*) and a music festival (*7107 International Music Festival* in Angeles City, https://twitter.com/7107imf), among others.

And there are "7107 reasons to visit the Philippines", "7107 reasons why the Philippines rock", "7107 reasons to love Pinas", "7107 reasons why I love Philippines", "7107 reasons why we choose Philippines", "7107 good reasons to retire in the Philippines", "7107 reasons to be happy", "7107 reasons to celebrate in the Philippines", "7107 ways to travel the Philippines", "7107 ways to enjoy the Philippines" or "7107 ways to celebrate with San Miguel beer", "7107 Philippine sunsets", "7107 islands proving it's more fun the Philippines", presented on numerous Facebook pages and blogs. It is "7107 times more fun in the Philippines"!

Fig. 2.1 The Philippines in Southeast Asia

7107 islands, but only 11 of them cover 94% of the land area, two of them, Luzon in the north (104.687 km^2, 35%) and Mindanao in the south (94.630 km^2, 32.6%), being each larger than the rest of the archipelago, where the central islands, around the central Visayan Sea, are called collectively the Visayas.

Bounded by the islands of Masbate (N), Cebu (SE), Negros (S) and Panay (W), the Visayan Sea covers an approximate area of 10,000 km^2, comparable to the Sibuyan Sea surrounded by Luzon (N), Mindoro (W), Panay (S) and Masbate (E). These two internal seas together are about the size of Japan's Seto Inland Sea. A third internal sea (20,000 km^2) is the Mindanao Sea, or Bohol Sea, separating Mindanao

Table 2.1 The 20 largest Philippine islands in area and resident population

	Area (km^2)	%	Aggregate %		Population 2010 (millions)		Aggregate %
Luzon	104.688	35.0%	35.0%	Luzon	48,520	52.5%	52.5%
Mindanao	97.530	32.6%	67.6%	Mindanao	20,365	22.1%	74.6%
Negros	13.328	4.4%	72.0%	Negros	4194	4.5%	79.1%
Samar	12.849	4.3%	76.3%	Panay	4031	4.4%	83.5%
Palawan	12.189	4.1%	80.4%	Cebu	3629	3.9%	87.4%
Panay	12.011	4%	84.4%	Leyte	2188	2.4%	89.8%
Mindoro	10.572	3.5%	87.9%	Samar	1751	1.9%	91.7%
Leyte	7368	2.5%	90.4%	Mindoro	1239	1.3%	93.0%
Cebu	4468	1.5%	91.9%	Bohol	1164	1.3%	94.3%
Bohol	3269	1.1%	93.0%	Palawan	0793	0.9%	952%
Masbate	3268	1.1%	94.1%	Masbate	0660	0.7%	95.9%
Catanduanes	1523	0.5%	94.6%	Jolo	0448	0.5%	96.4%
Basilan	1265	0.4%	95.0%	Basilan	0391	0.4%	96.8%
Marinduque	920	0.3%	95.3%	Mactan	0369	0.4%	97.2%
Busuanga	890	0.3%	95.6%	Tawi-Tawi	0366	0.4%	97.6%
Jolo	869	0.3%	95.9%	Marinduque	0228	0.3%	97.9%
Dinagat	769	0.3%	96.2%	Siargao	0200	0.2%	98.1%
Tablas	686	0.2%	96.4%	Guimaras	0163	0.2%	98.3%
Polillo	629	0.2%	96.6%	Tablas	0158	0.2%	98.5%
Guimaras	605	0.2%	96.8%	Biliran	0155	0.2%	98.7%
PHILIPPINES	299.000		100%	PHILIPPINES	92,337		100%

from the Visayas (Negros, Cebu, Bohol, Leyte). Finally the Sulu Sea (about 420,000 km^2, more than the entire landmass of the country) is much wider, between Palawan to the west, Mindoro, Panay, Negros to the northeast, Mindanao's Zamboanga peninsula to the southeast, the Sulu archipelago to the south and the northern shores of Malaysian Borneo to the southwest. It is also very deep in places (up to 7000 m). In the center of the Sulu Sea, a few atolls rise from the sea floor depths to within a few meters of the surface, such as the Tubbataha Reefs, a World Heritage site.

Only 154 islands are larger than 13 km^2 (5 sq. miles) and about 500 over 1 km^2. 5000 to 6000 have no permanent population[2]. The 20 largest islands make up 96.8% of the territory and the 20 most populated islands (a slightly different set) are home to 98.7% of the population (see Table 2.1).

This 7107 islands number (1768 of them for Palawan province alone) projects an image of extreme fragmentation. It also has some implications for service to the smallest inhabited islands, but in fact most of the population (95.9%) live on the 11 large islands of the country, and the archipelago resembles more Japan than Indonesia, whose West-to-East dimension is larger than the United States.

[2]The exact number of inhabited islands fluctuates widely, from 800 to 2000, while about 2500 islets are unnamed.

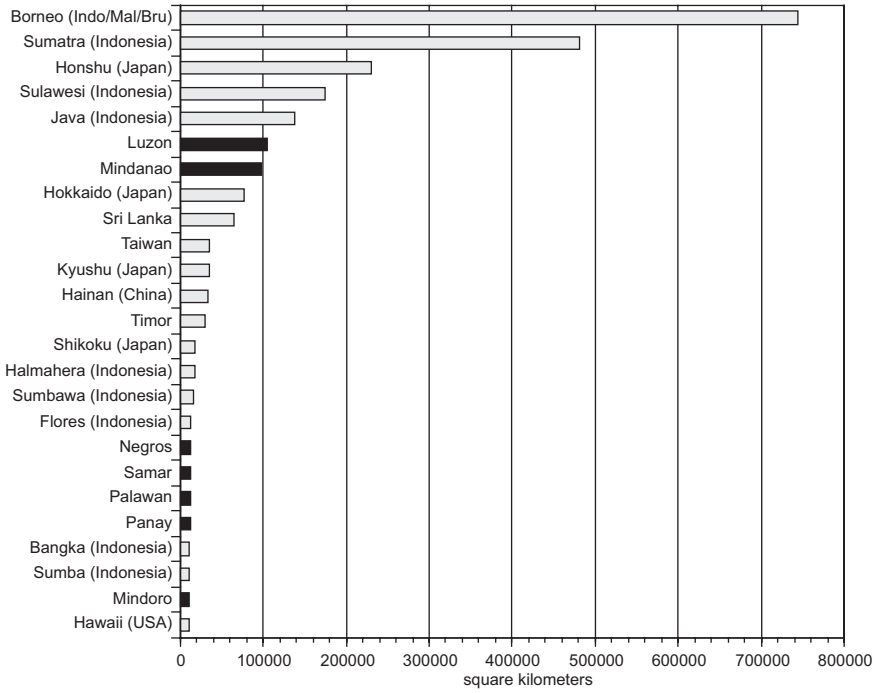

Fig. 2.2 Philippine islands among major Asia-Pacific islands

How do these Philippine islands compare to other islands in Asia and the Pacific? In terms of size, they are much smaller than their Indonesian counterparts. Four islands in Indonesia are much larger than Luzon: Borneo (7.1 times larger), Sumatra (4.6 times), Sulawesi (1.7 times) and Java (1.3 times). Negros, the third largest island in the Philippines, is slightly smaller than Flores, the 7th Indonesian island. In Japan, Honshu is 2.2 times the size of Luzon, however Mindanao is larger than Hokkaido, but Kyushu and Shikoku bigger than Negros. Japan has four large islands, and many tiny ones (Okinawa, the 5th one, is smaller than Basilan, ranked 13th, Awaji, the 6th one, is barely the size of Guimaras, 20th in the Philippines) (Fig. 2.2).

In terms of population, Luzon appears small compared to Java (139 million) and Honshu (104 million), and its population (48.5 million) is about the same as Sumatra (47 million). However, it has more than twice the population of Taiwan (23.2 million) or Sri Lanka (20.9 million). Luzon is much less dominant in the population of the Philippines (52.5%) than Java within Indonesia (57.5%) and Honshu in Japan (81.3%).

The Philippines' second island is relatively more populated than in the other countries (Mindanao 22.1% vs. Sumatra 19.3% and Kyushu 10.3%); Negros (4.5%) slightly more than Hokkaido (4.3%) but less than Sulawesi (7.1%); Panay (4.4%) more than Shikoku (3.1%) but less than Kalimantan-Borneo (5.7%) (Fig. 2.3).

There are sharp contrasts in population densities. If Java and the adjacent islands of Madura and Bali are well known for their concentration of population (respectively

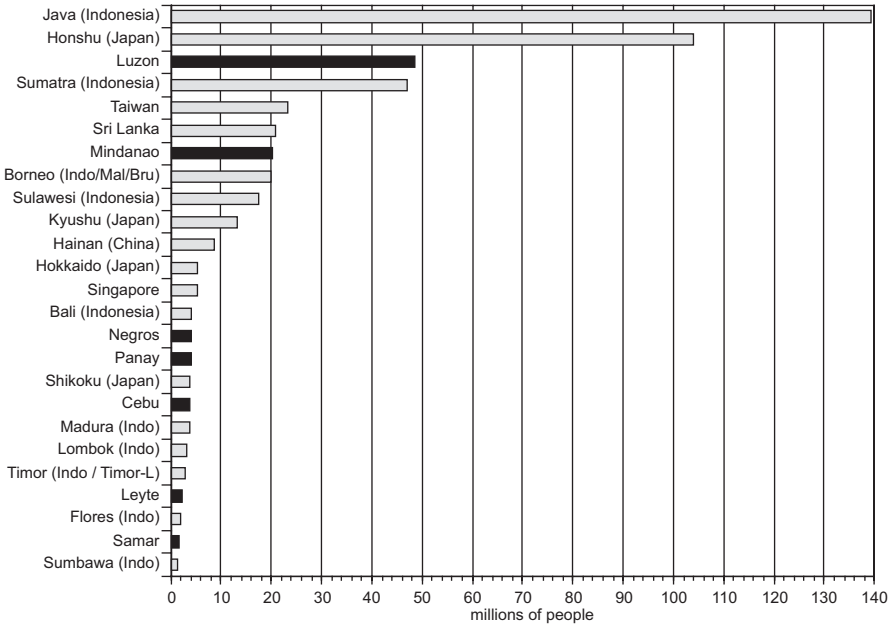

Fig. 2.3 The population of Philippine islands in comparison to other Asian islands

1004, 888 and 730 people/km^2), the same high densities are observed in Cebu (812 people/km^2). Luzon and Honshu are comparable (463 and 451 people/km^2). Many islands in the Visayas have densities around 300 (Bohol 356, Panay 336, Negros 315, Leyte 297). Mindanao and Masbate are at the 200 mark (209 and 202), but Mindoro is only at 117 (Sulawesi 99, Sumatra 98), and Palawan, at 65 people/km^2, has a lower density than Hokkaido (70), but still much higher than Borneo (27) or Halmahera (25).

The challenge of the Philippines may not be to tame the huge size of its territory like Indonesia, but rather the harmonious development of many medium-size, well populated, islands.

The archipelagic nature of the country is reinforced by the lack of fixed links and the fact that many areas are mountainous and difficult to access, with few roads and steep slopes despite the moderate altitudes, since there is no point above 3000 m in the Philippines.

The country's rivers are rather short, due to the lack of any major fluvial basin. Only four run for more than 200 km. They are the Cagayan River in northern Luzon (505 km for a watershed of barely 27,000 km^2), the Rio Grande de Mindanao (373 km), the Agusan River, also in Mindanao (350 km) and the Pampanga River in the central plains of Luzon (260 km). This limits the possibilities for major hydro-electric dams, despite the abundance of rain and the steep slopes observed in many parts of the country.

However, one of the largest Asian lakes[3] is located close to Manila. Laguna de Bay, which has a complex volcanic origin and used to be linked to the ocean (Vitales 2013), has an area of 930 km^2, the second largest plain lake in Southeast Asia after Cambodia's Tonle Sap (2700 km^2). Not far from Manila and Laguna de Bay, Lake Taal, the 3rd largest in the Philippines after Lake Lanao (Rabor 1971) in Mindanao (340 km^2), is a caldera lake (area 234 km^2, altitude 5 m, with an active volcano in its middle), second only to Lake Toba in Sumatra (1130 km^2, altitude 905 m). It is noted for having the only island of the world located in a lake on an island in a lake on an island (Vulcan point in Crater Lake on Volcano Island in Taal Lake on Luzon) (Ramos 2002). Taal Lake was formed by a series of catastrophic caldera-forming eruptions that created parts of Laguna de Bay and the smaller scale eruptions that formed the cones and volcanic peaks in the area. Taal Lake also presents biological oddities. It was once a salt-water bay; after it was separated from the sea, it turned fresh gradually, allowing a number of oceanic species time to adjust to freshwater conditions. Taal thus supports freshwater sardines as well as a freshwater sea snake. It once had bull sharks, but they were exterminated by local fishermen in the 1930s.

2.1.2 Shorelines

Shorelines of the Philippines are tortuous, with many peninsulas and bays, giving the country a very irregular shape. Drawing the Philippines by memory and by hand is quite a challenge!

The length of Luzon is about 1000 km and its width between 120 and 160 km, narrowing down to barely 13 km in Quezon province, at the mountainous Tayabas isthmus separating central Luzon and the Tagalog-speaking area from the long Bicol southeastern peninsula. Lingayen Gulf and the smaller Subic Bay indent Luzon's northwestern coast. Further south is Manila Bay, which is separated from the open sea by the Bataan Peninsula. Tayabas Bay and Ragay Gulf surround the Bondoc Peninsula of Luzon's southern coastline. Southeastern Luzon's Bicol peninsula has San Miguel Bay, Lagonoy Gulf and Albay Gulf on its eastern side, and Sorsogon Bay on the southwest. It ends in the Sorsogon Peninsula.

Mindanao's is also characterized by a number of sizable gulfs, bays and peninsulas. Its northernmost point is the Surigao Peninsula, with Butuan Bay to its west. Iligan Bay is extended inland from Ozamiz by a deep indentation, Panguil Bay, creating a narrow isthmus that connects the Zamboanga Peninsula to the rest of Mindanao. Sibuguey and Baganian Peninsulas protrude from the south coast of the Zamboanga Peninsula on Moro Gulf, with Pagadian Bay on the south of the isthmus and Illana Bay continuing the southwest coast. Sarangani Bay indents the coast near its southernmost part, Tinaca Point. North of that point is Davao Gulf, defined by Cape San Agustin.

[3] Lakes in the Philippines have not been the object of much study except for the mentioned ones (Brillo 2015).

In the Visayan Islands there are two large bays: Leyte Gulf, located south of Samar and east of Leyte. A peninsula leading towards Boracay Island protrudes in the northwestern part of Panay Island. Guian peninsula is a clearly delineated extension of Samar.

A number of smaller islands create further separations within water bodies. Northeast of the narrowest point of Luzon, the elongated Alabat Island separates Lamon Bay from Calauag Bay. In northern Leyte, Biliran Island creates a Biliran strait. The narrow San Juanico strait between Samar and Leyte appears as a little Bosphorus or Dardanelles, so is, on a smaller scale, the Gaboc Channel between Nonoc Island and the southern part of Dinagat Island. The Mactan Channel separates Lapu-Lapu, where the airport is located, from Cebu City on "mainland" Cebu.

The result is that the overall length of the coastline[4] is comparable to the length of the Russian coastline (36.289 km vs. 37.653)! In fact, the Philippines have the 5th longest shoreline in the world, much longer than in bigger countries such as

Table 2.2 Longest coastlines and highest coastline/land area ratios

	Length of coastline (km)		Coastline/land area ratio (meters of coastline per km^2)
Canada	202.080	Denmark	172.36
Indonesia	54.716	**PHILIPPINES**	121.71
Greenland	44.087	Greece	104.68
Russia	37.653	Croatia	104.34
PHILIPPINES	36.289	Jamaica	94.36
Japan	29.751	Estonia	89.51
Australia	25.760	Norway	82.65
Norway	25.148	Japan	81.62
U.S.A.	19.924	Cyprus	70.12
Antarctica	17.968	Haiti	64.26
New Zealand	15.134	Fiji Islands	61.78
China	14.500	New Zealand	56.53
Greece	13.676	United Kingdom	51.37
United Kingdom	12.429	Iceland	49.58
Mexico	9.330	Qatar	48.59
Italy	7.600	Taiwan	48.55
Brazil	7.491	Timor-Leste	47.47
Turkey	7.200	Cuba	34.01
India	7.000	Panama	33.49
Chile	6.435	Indonesia	30.20

Source: http://world.bymap.org/Coastlines.html (CIA World Factbook data)

[4] Available data vary greatly due to the fractal nature of coastlines and the choices made to include—or not—major features such as fjords in the data (Mandelbrot 1983). If we include fjords, the length of the Norwegian coastline jumps from 25.148 km to 53.199 and the Chilean coastline from 6435 km to 78563. We will refer here to the most widely used data, drawn from the CIA World Factbook.

Australia, the United States, China or Brazil. When it is compared to the area of the country, the Philippines have the second longest ratio of coastline to land of any country of the world with more than 500 km of coastlines[5]. No point in the Philippines is located more than 120 km from the sea (Table 2.2).

The Philippines' diverse coastal zone consists of a variety of tropical ecosystems, including sandy beaches, rocky headlands, sand dunes, coral reefs, mangroves, sea-grass beds, wetlands, estuaries, and lagoons.

Many islands means also many sea passages between these islands. The current number of islands reflects a recent rise in sea levels, which tends both to diminish their number, by keeping permanently underwater some very low-lying coral reefs, but also to increase their number, in the cases a low altitude isthmus may be submerged and make two islands out of just one! Past reconstitutions of the physiognomy of the archipelago (Voris 2000; Robles 2013) indicate that the current major islands were not always separated one from another. It is well known that during the periods of lower sea levels associated with high latitude glaciations, the large Indonesian islands of Borneo, Sumatra, and Java were all connected to the Asian mainland, forming a landmass called "Sunda". Similarly, the Strait of Torres did not exist between Australia and Papua New Guinea, which were connected to form "Sahul". In the Philippines, which were for the most part separated from the Asian continent, Sunda and Sahul, the same interplay of sea level and islands has changed over time the linkages and separations. Throughout the Quaternary, land/sea distribution in the Philippine archipelago has fluctuated with the changes in the levels of seas and oceans.

At the Last Glacial Maximum value of –120 m for the sea level compared to today's level, the Philippines were much larger than they are now: 488,000 km^2 vs. 299,000. At that time, there was a greater Palawan including Culion, Busuanga, Balabac and Dumaran and other smaller islands. Jolo and Tawi-Tawi were just one. Cebu, Guimaras, Masbate, Negros and Panay were not separated, forming a large island of 56,000 km^2. Luzon was one island including the eastern Visayas (Leyte, Samar) as well as Bohol, Marinduque, Catanduanes, Polillo. However, some islands remained separate from others, even as the sea level was lowered by 200 m: Camiguin, Siquijor, Sibuyan, Tablas and Mindoro. This affected the sea crossing potential and migration routes for humans, animals and plants.

Rivers extending into now submerged maritime areas were merging, such as the Pampanga River and the Pasig River in what is now Manila Bay. The biogeographical zonation of the Philippine islands was mostly shaped by land exposures and connections during the glacial periods (Heaney 1985; Heaney et al. 1998).

[5] The calculated ratio is much higher, and loses much of its significance, for countries and territories mostly made up of multiple tiny atolls, such as Micronesia (aptly named "tiny islands", ratio of 8706!), the Bahamas (354) or French Polynesia (659).

Table 2.3 Largest EEZ in the world and coral reefs' share of world total

	EEZ area (km^2)	Country area (km^2)	EEZ/country	Share of world's coral reefs
United States (total)	11.351.000	9.600.000	118%	1.3%
France (total)	11.035.000	675.000	1635%	5.0%
Russia	8.095.881	17.098.242	47%	–
Australia	6.362.934	7.692.024	83%	17.2%
Indonesia	6.079.377	1.904.569	319%	17.9%
Canada	6.006.154	9.985.000	60%	–
French Polynesia	4.767.242	4167	114404%	2.5%
New Zealand	3.423.231	268.021	1277%	0.5%
Mexico	3.269.386	1.972.550	166%	0.9%
Brazil	3.179.693	8.515.767	37%	0.4%
Japan with outer islands	2.625.750	377.944	695%	1.0%
Papua New Guinea	2.396.214	462.840	518%	5.8%
Mainland China	2.285.872	9596961	24%	3.8%
PHILIPPINES	**2.265.684**	**298.170**	**759%**	**8.8%**
Greenland (Denmark)	2.184.254	2.166.086	101%	–
Chile	2.009.299	756.096	265%	–

Sources: Sea Around Us Project (http://www.seaaroundus.org/eez/), World Atlas of Coral Reefs (United Nations Environment Programme World Conservation Monitoring Centre, http://coral.unep.ch/Coral_Reefs_files/reef%20area%20by%20country%20.jpg)

2.1.3 Philippine Seas and EEZ

The EEZ of the Philippines, as the coastline length, compares favorably to other countries when measured in relation to the landmass of the country. The sea area theoretically under Philippine jurisdiction is eight times larger than the islands themselves, giving the archipelago the 13th place in the world. This EEZ includes, as in Indonesia, archipelagic waters between the islands (Table 2.3).

The Philippine archipelago is one of the three pillars of the "Coral Triangle" (Hoegh-Guldberg et al. 2008). With an estimated 25.000 km^2 of coral reefs within its EEZ, it ranks third in the world (8.8% of the total) behind Indonesia (17.9%) and Australia (17.2%), ahead of France (mostly Polynesia), Papua New Guinea and Fiji. These coral reefs represent, alongside the mangroves (19th in the world) (FAO 2007), a major marine biodiversity hotspot while also being very appealing for tourists (diving activities). However, the Philippine coral reefs appear today to be in a poor shape, possibly the most endangered of all major coral zones in the world, due to global warming combined with over-exploitation of the resources (Bryant et al. 1998; Burke et al. 2011; Alave 2012).

2.2 Mountainous Islands from the Ring of Fire

2.2.1 Physiography of the Philippines

The topography of the Philippines is quite diverse. Most of the major Philippine Islands are of volcanic origin. The country is therefore very mountainous. About 49% of the country is made up of slopes 18% or steeper (Espiritu et al. 2010), which makes large regions unsuitable for agriculture unless terraces are built, creates difficulties for circulation and heightens the risk of landslides.

The northern part of Luzon Island is extremely rugged. Luzon's highest peak, Mount Pulag, rises to 2934 m (9626 ft). The island has three mountain ranges that run roughly parallel in a north-south direction (Fig. 2.4).

The Sierra Madre runs so close to the island's eastern shore that there is hardly any coastal plain. The wide Cagayan River valley separates this eastern range from the Cordillera Central. On the west, the Zambales Mountains (Mt Tapulao 2037 m, Mt Pinatubo 1486 m today but 1745 m before its 1991 eruption) extend southward to Manila Bay. The central plain of Luzon (Pangasinan /Nueva Ecija/Tarlac / Pampanga / Bulacan provinces north of Manila, continuing south of the capital), mostly agricultural (64% in Pampanga), is in sharp contrast with the adjacent high mountains areas of the central and east Cordilleras and the Zambales mountains. Southeastern Luzon's Bicol peninsula is a mountainous and volcanic area containing the most active Philippine volcano, Mount Mayon (2420 m), a perfect cone rising above the plain like Mt Fuji in Japan. Legazpi City (Albay) and Fuefuki City (Yamanashi Prefecture) have developed a sisterhood accord for their respective volcanoes, Mayon and Fuji (Nuñez 2016).

Mindanao has five major mountain systems, some of which were formed by volcanic activity. The eastern edge of Mindanao is highly mountainous; this region includes the Diuata Mountains, with several elevations above 1800 m and the southeastern ranges, which reach a high point of 2800 m. In central Mindanao, a broad mass of rugged mountain ranges bisects the island from north to south. It includes Mt Apo (2954 m), the highest peak in the country, which overlooks Davao Gulf. In the eastern part of Mindanao, the Agusan River Valley lies between two mountain ranges. To the southwest of those ridges, several rivers meet in the Cotabato Basin and mountain peaks lead to the Bukidnon-Lanao Plateau. Further west, the island narrows to a fifteen-kilometer wide isthmus, from which the long Zamboanga Peninsula protrudes to the southwest. This peninsula is covered largely with mountains and possesses limited coastal lowlands.

Mindoro Island is mostly mountainous, rising above 2400 m, with narrow coastal lowlands to the east and northeast of the mountain zone.

In the Visayas, if Samar is a rather low-lying island, Leyte, Bohol, Cebu and Negros, as well as Palawan, show strong altitudinal contrasts, with mountain ridges separated by elongated valleys of tectonic origin (horst/graben combinations) or falling into the sea with basically no coastal plain (Cebu). Volcanoes have built the top peaks in Negros (Mt Canlaon or Kanlaon, 2465 m), while an interesting tropical karst (Teves 1954) has developed in Bohol, the tourist-drawing "Chocolate Hills".

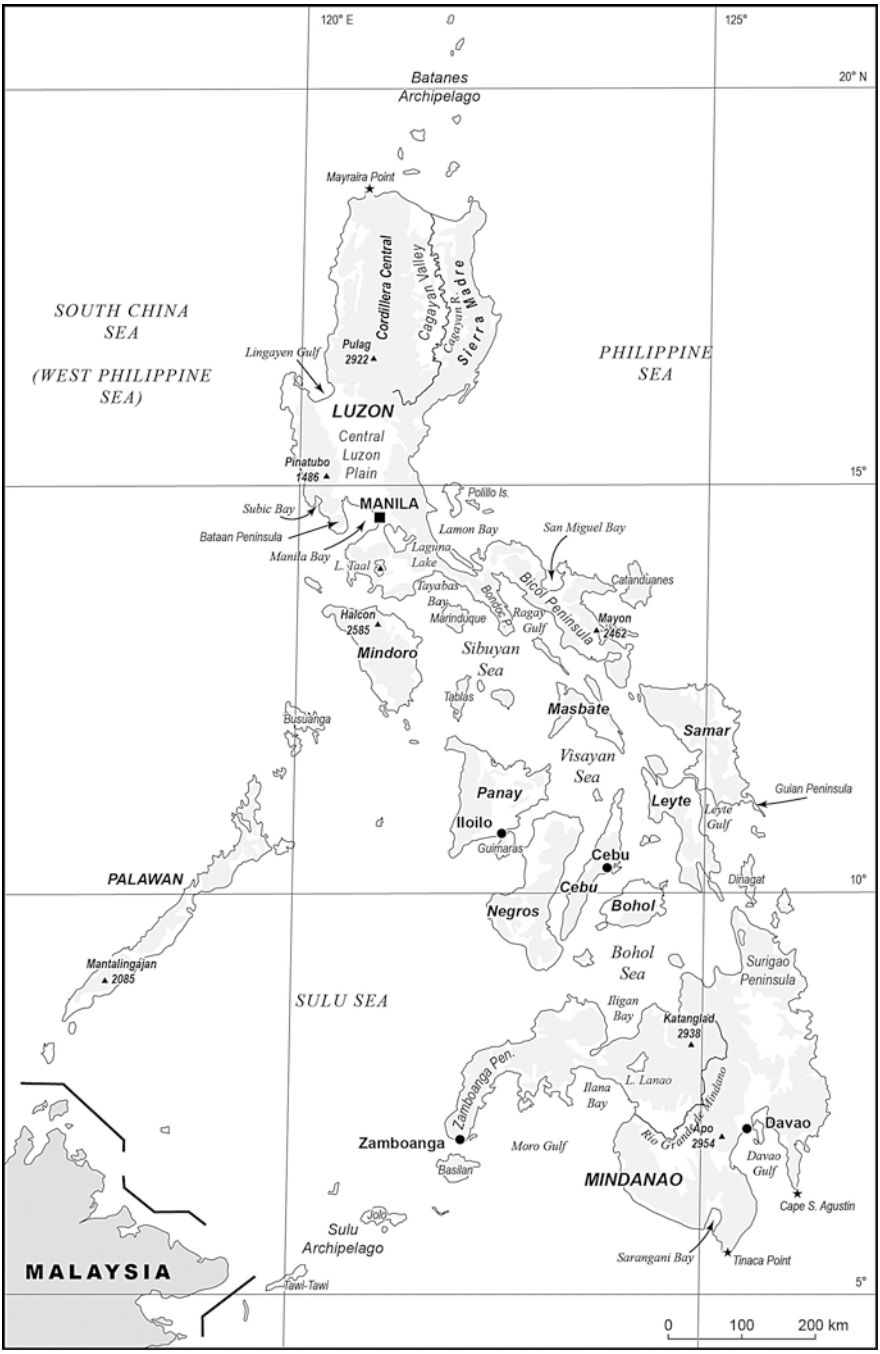

Fig. 2.4 Principal features of the physiography of the Philippines

Some of the mountains have acquired some spiritual value as sites of connection with God or gods, such as Mt Makiling in Laguna province and Mt Banahaw on the Laguna-Quezon border. Hot springs gave birth to a flourishing spa and resort industry (Calamba-Los Baños area near Mt Makiling, Laguna, and Mt Bulusan in the Sorsogon province of southeastern Luzon).

Several mountain sites are rich in minerals: gold (Paracale in Camarines Norte, Mt Diwalawal in Compostela Velley, Mindanao), copper (Zambales province, Rapu-Rapu in Albay, Mankayat in the Igorot country of northern Luzon,…), iron (Camarines Norte, Bulacan, Marinduque, Samar, Surigao), nickel (Nonoc island near Mindanao), marble (Romblon, Palawan, Cebu) and coal (Sorsogon, Cebu, Masbate).

2.2.2 The Complex Origin of the Philippine Archipelago

The birth of the Philippine archipelago, in the midst of the West Pacific Region, is the result of a complex series of geological events (Aurelio 2000a, b; Aurelio et al. 2012) that have involved continental rifting, oceanic spreading, subduction, ophiolite obduction, arc-continent collision, intra-arc basin formation and strike-slip faulting (Lallemand et al. 2001; Yumul et al. 2003a, b). As part of the western-Pacific "Ring of Fire," the Philippine archipelago contains thirty-seven volcanoes, of which eighteen are active.

Located at the juncture of the large India-Australia plate, Eurasia Plate and Pacific Plate, the West Pacific Region is currently the region of the world with the most active and complex tectonic activities (Acharya and Aggarwal 1980). Since late Mesozoic, a northward movement of the India-Australia Plate has resulted in collision/subduction with the Eurasia Plate, as well as the westward subduction of the Pacific Plate under the Eurasia Plate. This has resulted in the formation of a series of volcanic activity zones, in Pacific Siberia, Japan, the Ryukyu, the Philippines, Indonesia, the Mariannas and New Zealand, among others, and the opening of marginal seas with young oceanic lithosphere (Xu et al. 2014). Several micro-plates are getting squeezed between convergent plate margins. These oceanic lithospheres, whose limits are still revisited by researchers (Lagmay and Tejeda 2009), formed at different times and opened through different mechanisms (Hall et al. 1995; Aurelio 2000a, b). The Philippine Sea plate, proposed as a distinct plate at the early stage of plate motion theory, plays a special role in the tectonic history of the western Pacific and eastern Eurasian continent and represents a challenge for geophysicists, because its motion relative to the surrounding plates is difficult to determine since its limits consist primarily of subduction zones rather than accreting boundaries.

The plate under the Philippine Sea (Fang et al. 2011) subducts under the Eurasia Plate at the Ryukyu Trench to the northwest and along the 100 km long west-dipping East Luzon Trough—Philippine Trench System to the Southwest. At the "Galathea Depth" (−10.540 m), this Philippine trench (or Mindanao trench, extending towards Halmahera in Indonesia) is the third deepest in the world after "Challenger Deep" in the Marianna trench near Guam (−11.033 m) and "Horizon Deep" in the Tonga trench (−10.880 m).

The Sunda/Sulu Sea micro-plate subducts along the east-dipping Negros Trench, the South China Sea subducts along the 1200 km east-dipping Manila Trench beneath Luzon (Hayes and Lewis 1984) and the Celebes Sea subducts along the east-dipping Cotabato Trench in western Mindanao.

Two tectono-stratigraphic blocks underlying the Philippine islands have been identified: PCB and PMB. The Palawan–Mindoro Continental Block (PCB) was originally a part of the Asian mainland that was rifted away during the Mesozoic and drifted in the course of the opening of the South China Sea (SCS) during Late Paleogene. The Philippine Mobile Belt (PMB) (Rangin 1991a, b) has developed mainly from island arcs and ophiolite terranes that started to form during the Cretaceous. Since the Miocene, the PMB has been colliding with the PCB in the Visayas in the central-western Philippines.

This PCB/PMB collision has significantly influenced the geological evolution of the Philippines through space and time, resulting into the collage of terranes of varying origin exposed in the central Philippines (Yumul et al. 2008) and the counterclockwise rotation of Mindoro–Marinduque and the clockwise rotation of Panay, northeastern Negros, Cebu, northwestern Masbate and Bohol (collectively called the Western Visayan block), resulting into their present-day northeast–southwest trend (Yumul et al. 2003a, b). The collision boundary is located from the northern part of Mindoro through the central mountain range swinging east of Sibuyan Island in the Romblon Island Group and finally threading along the Buruanga Peninsula and eastern side of the Antique Ophiolite Complex in Northwest Panay (Zamoras et al. 2008; Yumul et al. 2013) before exiting and connecting with the Negros Trench (Yumul et al. 2009).

The north–south-trending Philippines archipelago is composed of several rigid rotating crustal blocks (platelets), hence the high number of earthquakes and the complex geology (Rangin 2015). Basement rocks, originated from mainland Asia before the rifting and eventual opening of the South China Sea between 32 and 17 Ma, are found in Palawan, Mindoro, western Panay and the Romblon Islands group (Romblon, Sibuyan, Tablas). They include clastic, carbonate and igneous rocks. Karstic (Wagner 2013) seaside formations and grottoes are tourist attractions in two areas of Palawan: El Nido and near Puerto Princesa (Underground River) (de Vivo et al. 2009), as well as in Bohol ("Chocolate Hills", a typical cone karst) (Urich et al. 2001; Waltham 2008; Salomon 2011). The Sagada caves (Mouret et al. 1984) in the mountains of North Luzon are also karstic. Ophiolite and ophiolitic basement rocks are widely distributed in the Philippines. They originated from several oceanic rifts, in at least five episodes of oceanic crust generation since the Jurassic period (Encarnacion 2004). Likewise, arc basement rocks can be found throughout the archipelago, particularly in the magmatic arcs of the Cordillera and Sierra Madre Range in Luzon Island, the Antique Range and Negros Arc in the Visayas, and in the East Pacific Cordillera and Daguma Range in Mindanao. Philvolcs (the Philippine Institute of Volcanology and Seismology) is currently listing 22 active volcanoes in the Philippine Mobile Belt Volcanic activity and igneous intrusions have been active since Cretaceous. Most of these arc sequences are related to subduction events.

The Philippines islands have therefore long been recognized as a natural laboratory for studying biodiversity and biogeographic limits, transitions and fine local

scale endemisms (Jones and Kennedy 2008; Vallejo 2011). The archipelago is somewhat of an oddity, having fauna and flora features from all major biogeographic provinces of the western Pacific, Melanesia, Wallacea and Sundaland. However, the island of Palawan and its satellites have more affinities with Sundaland (all Indonesian islands west of Lombok, including Borneo and Malaysia), whereas the rest of the Philippines are more Wallacean (Indonesian islands east of Bali, including Sulawesi) in flora and fauna (Persoon and Van Weerd 2006).

The Philippines is also a laboratory for the study of arc evolution and continent growth (Angelier 1984; Florendo 1994). A number of authors have developed the paradigm, though not universally accepted, that the Philippines is a collage of exotic terranes assembled by accretion, convergence and wrench tectonics (Karig 1983). There is strong evidence that the Philippines are in the process of becoming a part of the continental margin of Southeast Asia. As the subduction of South China Sea and Sulu Sea lithosphere continues, the Philippines, as well as Taiwan, will be completely accreted to Asia and constitute new continental crust (Dilek and Harris 2004).

Tectonic deformations are therefore very complex in the Philippines (Yoshida et al. 2016) and create a permanent risk of violent volcanic eruptions and major earthquakes with a potential for powerful tsunamis all over the archipelago.

There are 23 volcanoes currently active in the archipelago (Ozawa et al. 2004; de la Cruz 2015a): Mt Mayon has erupted 48 times since its first recorded eruption in 1616, the second most active volcano is Taal Volcano in Batangas province (33 recorded eruptions, including a cataclysmic one in 1754) (Moore et al. 1966; Ranada 2015c). The next most active volcanoes are Mount Kanlaon on Negros island with 27 recorded eruptions (Espina 2015; Corrales 2016) and Mt Bulusan in Sorsogon (17 eruptions since 1852) (de la Cruz 2015b, 2016; Ranada 2015a). These volcanoes may be tricky to predict since they can produce phreatic eruptions, ash eruptions, lave flows or deadly explosions and pyroclastic flows with major caldeira collapses (Fontijn and Newhall 2013). Sometimes they emit toxic ashes than can be deadly for the visitors and residents nearby. The 1814 eruption of Mt Mayon killed 1200 people, and 350 more died in 1897 (Olan 2015). Taal and Mayon have the potential to erupt again with great force. The proximity of Metro Manila and its dynamic southern periphery (Cavite, Batangas and Laguna provinces) is quite worrisome in case of a major Taal eruption (Torres et al. 1995; Bartel et al. 2003; Alanis et al. 2013; Galgana et al. 2014; Ranada 2015d).

The 1991 eruption of Mt Pinatubo (Wolfe 1992; de la Cruz 2015c) is considered as the most powerful volcanic event of the twentieth century. For months and years after the volcano blew off its top and released huge amounts of pyroclastic flows that buried parts of Pampanga and Zambales provinces, including the US-controlled military bases of Clark and Subic Bay and a now famous church in Bacolor, the remaining ashes on its sloped are still threatening to trigger more lahars (Tayag and Punongbayan 1994; Newhall and Punongbayan 1995; Bardintzeff 1999; Crittenden and Rodolfo 2003; Orejas 2015). Pinatubo's lahar flows (Umbal 1997; Van Westen and Daag 2005; Carranza and Castro 2006) and their consequences on local residents, especially the Aeta aborigene population (Rodolfo 1995; Seitz 1998; Leone and Gaillard 1999; Gaillard and Leone 2000; Crittenden 2001; Gaillard 2002, 2006a, b, 2008; Gaillard et al. 2005; Gaillard and Le Masson 2007) have been

abundantly studied, due to the magnitude of the 1991 eruption, but lahar flows have also affected other Philippine volcanoes such as Mt Mayon. (Rodolfo 1989; Arguden and Rodolfo 1990; Rodolfo and Arguden 1991) on the days after the eruption but also in times of heavy rainfall (Paguican et al. 2009).

Earthquakes of damaging intensity have occurred all over the archipelago, except in Palawan, which is geologically different from most of the country, since it is part of the more stable Sunda plate. Fault lines of a generally meridian direction have been identified (Molas and Yamazaki 1994) including in the Manila metropolitan area, with the Marikina river running alongside the "West Valley" fault line (Rimando and Knuepfer 2006). Detailed maps have been drawn distributed to local officials for a better assessment of risk. (Pazzibugan 2015; Ranada 2015b). Strong earthquakes have occurred recently in Bohol (magnitude 7.2 in 2013), and geophysicists agree that a catastrophic earthquake of a magnitude much greater than 8 is expected soon in the Philippine archipelago (Galgana et al. 2007; Yu et al. 2013; Diola 2014), as they have happened in Indonesia and Japan. Past earthquakes already reached that level (possibly 8.6 and 8.7 in 1897 in Basilan, 8.3 in 1948 in Aklan, 8.3 in 1924 in Davao oriental and four others above 8…) (Bautista and Oike 2000; Bautista and Bautista 2004; Romulo et al. 2015). Such a "big one" would create havoc if it happens in Metro Manila (Miura et al. 2008), already hit by an estimated 8.0 tremor in Las Piñas in 1645 when the area was thinly settled (Solidum 2014).

Major earthquakes have the potential to trigger tsunamis (Nakamura 1978). The most devastating tsunami in the history of the Philippines (Lovholt et al. 2012; Suppasri et al. 2012) hit the Moro Gulf region in August 1976, after a magnitude 8.0 earthquake centered in Cotabato, and killed around 8000 people (Badillo 1978; de la Cruz 2015d). Another one hit the northern coast of Mindoro in November 1994 after a 7.0 magnitude quake (Imamura 1995), killing 71 people, and one in Bohol in 1990 with 41 casualties (Besana-Ostman et al. 2011). Manila Bay and Metro Manila could suffer immensely from a tsunami generated by an earthquake alongside the Manila Trench thrust fault in the South China Sea (which could also devastate the coastlines of Vietnam and southern China) (Megawati et al. 2009; Okal et al. 2011; Nguyen et al. 2014).

This tectonic activity is a factor in the high frequency of landslides (Lagmay et al. 2006), alongside abundant rainfall (see Chap. 3) and excessive deforestation. It explains the complexity of the islands contours, the exceptional length of their shoreline and the extreme terraqueousness of the country.

2.3 The High Level of Maritimity of the Archipelago

2.3.1 Coastal Population

67 of the 81 Philippine provinces have a seashore. Only Luzon and Mindanao, the two largest islands, have inland provinces (11 in Luzon, mostly north of Manila, the lone exception being Laguna province, named for the largest lake in the country, Laguna de Bay, and 3 in Mindanao).

Inland provinces of northern Luzon are mountainous and their population densities dip well below the national average: 62 people/km^2 in Kalinga, 56 in Abra and 26 in Apayao, the least densely populated province of the Philippines.

915 of the 1616 Philippine cities and municipalities are in the coastal area, and they house 62% of the country's population. 301 of them include small offshore islands (Baguilat 2004). In Quezon province, which has 1066 km of shorelines, 34 out of 42 municipalities are coastal. On many islands, coastal municipalities have a much higher population density than inland ones, for example in Bohol (average 337 for coastal municipalities vs. 173 inland), or in the coastal villages of Marinduque vs. the inland villages (Salvacion and Magcale-Macandog 2015). This however does not appear to be true when the inland side of provinces is made up of rich farmland, such as Pangasinan, northern Luzon (504 inland density vs. 523 coastal density), where the inland areas are home to 67% of the provincial population, quite an exception.

Most large cities of the country are either on the coast, or near the coast (in the Greater Manila area: Quezon City, Makati, Caloocan, Pasig, Taguig, Valenzuela, Muntinlupa). The main cities away from the sea are either on the outskirts of Manila (Antipolo, San Jose del Monte, Rodriguez) or in the northern Luzon central plain (Angeles City, Tarlac, Cabanatuan). Only Baguio is clearly a city away from the sea, in a mountainous region. In all other islands, the main population centers are in a coastal position: Davao, Cagayan de Oro, General Santos, Iligan, Cotabato (Mindanao), Cebu (Cebu Island), Bacolod, Dumaguete (Negros), Iloilo (Panay), Tacloban (Leyte), Puerto Princesa (Palawan)… Most of these cities are ports: ports of commerce, fishing ports and ferry terminals for inter-island travel. Fisheries and aquaculture are major activities in coastal farm communities. It is also well known that Filipinos are possibly the largest nationality onboard commercial ships, cruises ships and cargo ships alike.

Some minority populations even have a seaborne lifestyle.

2.3.2 People of the Sea: The Badjao "Sea Gypsies"

The archipelagic nature of the Philippines promoted a seafaring people who depended heavily on boats for livelihood and transportation. For centuries prior to the coming of the Spaniards, inhabitants of the islands satisfied their protein requirements by subsistence fishing from outriggered *barotos or paraws* within the lagoons and along the edges of reefs surrounding their islands. Some boats could carry many persons, while others carried one man (*isahan*) or two men (*duhahan*). A boat might be constructed with or without *katig* (outriggers: bamboo and wood floats attached to each side serving as a counterpoise to stabilize the boat and avoid its overturn). Boats were also used for riverine and inter-island trading activities. They were needed to conduct wars and raids (*mangayaw*). According to the Spaniards, war was part of the early Bisayans' lives, and Bisayan raiders were especially feared due to their fast boats. According to the accounts of the Spanish writers, the Ilonggos of

Panay particularly were skilled boat-builders. Popular due to its speed and maneuverability, their *paraw* had decorative edges and was powered by sails.. There was also the *barangay* or *balangay,* made of wooden planks put together with wooden nails, and worked by sails on two masts as well as by paddles. This maritime legacy may explain why Ilonggo sailors can be found in all shipping routes around the world (Scott 1982; Funtecha 2000).

Historians of the early settlement of the Philippines advance the idea of a society largely structured by small clans derived from the occupants of boats. The common term for "neighborhood" is *barangay*, a term derived from *balangay*. As in many southeastern Asian societies, there seems to be a strong social symbolism associated with ships (Abinion 1989; Mangin 2001).

Fishermen play a major role in the coastal society of the Philippines. many of them used to live a seasonal nomadic lifestyle, migrating alongside the concentration of fish (*pangayaw*), and returning rarely to the sedentary villages where sojourners (*tumandok*) lived. Several places served as sheltering ports in case of bad weather, among them the Gigantes islands, off the Panay coast in the Visayan sea, where fishermen from Panay, Masbate, Cebu, Negros, Samar, Leyte and Bohol could mix every year (Zayas 1994). In the southernmost municipality of the country, Sitangkai, boats are still the primary transportation mode, although footbridges connect one house from another. A simple "labuan" (moorage) in the mangroves and islets of the outer reaches of Borneo island, it has been for long time a place of maritime contacts, a hub for economic and population exchanges (Zayas 2014), one of the centers of the Bajau life on the water.

Scattered along the coastal areas of Tawi Tawi, Sulu, Basilan, and some coastal municipalities of Zamboanga del Sur, the Badjao[6] (or Bajau) of the Sulu and Celebes Seas use small wooden double outrigger sailing canoes (trimarans: *perahu*, *vinta*) (Spoehr 1971) first developed in Micronesia. Nicknamed "sea gypsies", they had developed over the centuries a nomadic lifestyle (Nimmo 1968, 1969; Martenot 2001) comparable to the Moken of the Mergui archipelago (Burmese-Thai coastland), the Bugis of eastern Sulawesi and the Orang Laut of southeastern Sumatra (Lenhart 1995; Lapian 2004). Their myths and legends are sea-based (Jubilado 2010). Their livelihood depended on the sea : spear fishing, fish trapping, seaweeds and shell gathering, both as their source of food or to sell/barter with sedentary populations or other necessities such as clothing, materials for boat construction, mats, fishing equipment as well as farm products such as fruits and cassava. Unique to their cultural rituals was the concept of life and their relationship to the sea : as a childbirth ritual, a newly born infant was thrown into the sea and members of the clan dived to save him and make it a new member of the community.

Today, their nomadic lifestyle as navigators and sea divers living on houseboats is receding quickly (Nimmo 1972; Lagsa 2015). Displaced by poverty[7], conflict and the death of their traditional fishing culture (Glionna 2009), most of the 200.000

[6] Amongst themselves, they're known as Sama Lau or Sama Dilaut (Sea Sama). Their group originated from the Samal tribe on Mindanao.

[7] Poverty compounded by high fertility rates, with many families of 10–12 children.

[8] http://www.philstar.com/cebu-news/2013/02/18/910267/badjaos-their-real-story

Badjao are settled in poor neighborhoods (Jumala 2011), living in ramshackle villages of wooden huts, built on stilts over the water, in cities such as Zamboanga (Mindanao) or Puerto Princesa (Palawan)[8], even in the seaside slums of Manila Bay or Cebu (Bracamonte et al. 2011). In Sulu, many have become beggars, waiting for tourists to throw a few coins in water next to their small boats. Due to the ongoing conflict in the region between revolutionary Muslim groups and the Philippine government (see Chap. 19), many Badjao have migrated to friendler Muslim areas, Sabah in Malaysia (Nagatsu 2001) and Sulawesi and Kalimantan in Indonesia (Saat 2003). They are now the second-largest ethnic group in Sabah, despite the fact that many of them are illegal immigrants. Many are stateless, feeling rejected by Filipinos but not really welcome in Malaysia, and their children remain largely unschooled (Lim 2012), which limits their hopes for rewarding employment in the future.

2.3.3 Dangers from the Sea

If the constant land-sea interaction and the circumvoluted shape of the Philippine islands provide some benefits, such as multiple harborage facilities and sea breezes, as well as the lack of any dry or arid area in the country, many dangers lurk from its oceanic environment. The sea is a major element of Filipinos' life and they have learned to live with threats coming from oceanic waters.

Four major "natural" threats and a political one can be identified.

Powerful typhoons (see Chap. 3) develop between the Mariannas and the Philippines many times every year, drenching the country under deluges of water accompanied by howling winds. Storm surges may become deadly. During heavy weather times, public advisories recommend a stop to all maritime activity, in the open ocean as well as within the archipelago. Islands are then temporarily isolated from each other when ferries stop.

The tectonic activity underlying the surrection of the Philippine islands may also trigger tsunamis, another deadly threat from the ocean.

A third category of risk is sea-level rise. As in all coastal areas of the world, this is a worrisome future, since a large part of the population lives alongside the coastline. The long-term threat presented by gradual sea-level rise may be accelerated short-term by storm surges and the sinking of alluvial materials. Seawater level rise is also a threat to fragile coral reefs already damaged by human use. Coastal erosion is seen as increasing (Bayani-Arias et al. 2012).

On a much smaller scale, the Philippine waters, part of tropical oceans, are visited by sharks, and the range of deadly dangerous estuarine crocodiles (*crocodylus porosus*) extends to the archipelago, as shown by the 2011 capture of "Lolong", a gigantic specimen, in Agusan Marsh (Mindanao).

Dangers may also come from human actions. Piracy has been frequent for many centuries in all maritime Southeast Asia. In the early nineteenth century, an entire ethnic group, the Samal Balangingi of the Sulu-Mindanao region, specialized in maritime raiding, attacking Southeast Asian coastal settlements and trading vessels (Warren 2003). Piracy seems to have increased in recent years (Frécon 2008). In the

Philippines, the Sulu archipelago is still known for harboring pirates hiding in numerous tiny islands close to the Malaysian waters. Also, the geopolitical situation of the Spratly Islands in the "South China Sea" (see Chap. 20) has led to acerbic verbal exchanges between China and the Philippines and of small-scale confrontations, which may escalate, hopefully not, towards military actions. Without terrestrial borders, the Philippine islands are threatened in their maritime geopolitical environment by the uncertain status of an archipelago of tiny atolls.

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