2

LOCATIONS AND CLASSIFICATIONS

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Introduction: definitions

There is a continuum of geographic entities that can fit the definition of 'a piece of land surrounded by water': from the continent of Eurasia to the rock on a beach lapped by the waves that becomes a child's imaginary island. Nevertheless, drawing two lines between something that is too large to be an island and something too small to be an island is, ultimately, an arbitrary decision. In this chapter, we explore the geographic realities behind our concept of islands. We develop a terminology for islands that corresponds to scientific observations gleaned from geological, biological and human perspectives.

The tools of remote sensing satellite imagery (e.g. NASA 2017a) now provide data sets with globally consistent measurements of the 'world archipelago' made up of all those pieces of land surrounded by water. At the same time, our understanding of geotectonic movements, sea level changes and island-building processes allows us to see the islands of today not as eternal entities but as one static image captured from ongoing processes of islands growing and shrinking, joining and being separated, appearing and disappearing through time. In looking across the spectrum of continents, islands and other bodies, we can start with a purely geographic definition of an island as any piece of land surrounded by water, whatever its size or its distance to the closest mainland. Using criteria from physical geography, the number of oceanic islands in any particular size range can be counted, and details concerning their distribution explored.

From this platform, one can explore more functional definitions of 'islandness', or various scales and forms of isolation, as expressed for instance in the processes underlying island biogeography and the amazing diversity of species for which many islands are famous (MacArthur and Wilson 1967). Similar processes lie behind the human populations of islands, the history of their settlement and the unique island cultures they have generated. Today, islandness also finds economic, social and political expressions that are significant in addressing the challenges of sustainable development.

While the concept of an island may seem simple in theory, the many variations on the theme of islandness raise puzzling questions. What happens to an island if it is not surrounded by water all the time, or the channel that separates it fills in, or a causeway is constructed? Does a piece of land become an island if it is artificially cut off from surrounding land? The study of islands on their own terms has also acquired its own name: nissology (Depraetere 1991a, 1991b; McCall

1994, 1996). Understanding the deeper significance of islands means considering such issues as isolation and the resulting creation of diversity, the effects of fragmentation and the influence of marginality. Each of these would, in turn, affect various geographic, evolutionary and cultural processes in different ways.

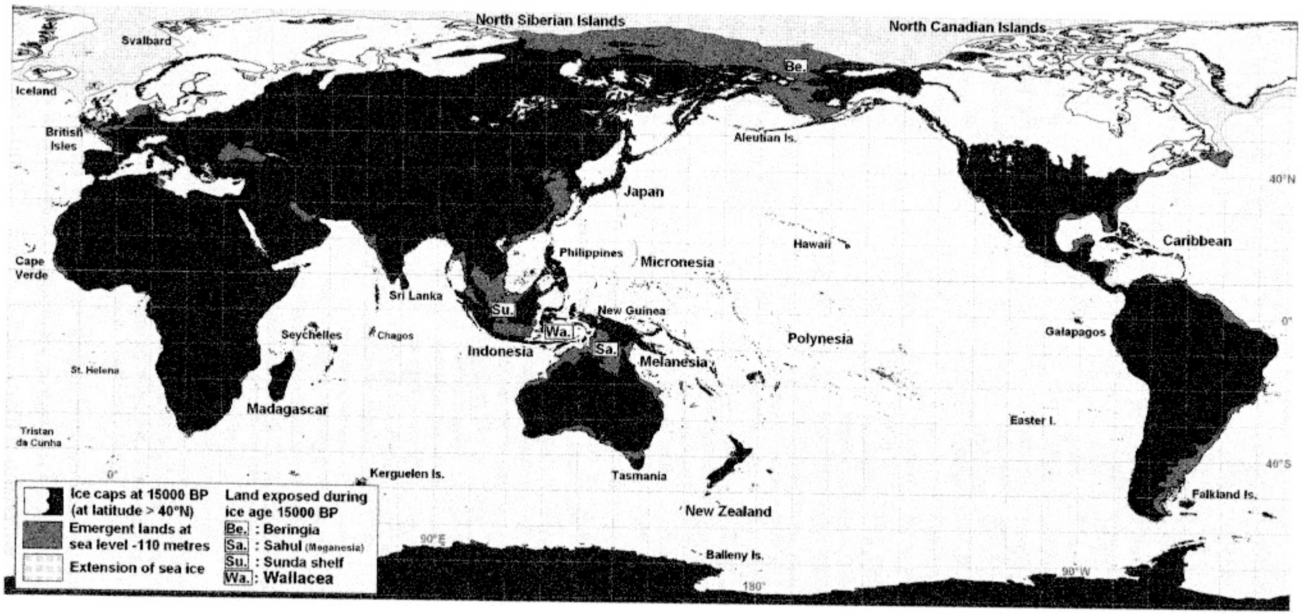
The world archipelago

When looking at a globe or world map, the emerged lands of our blue planet constitute a sort of 'world archipelago' (see Map 2.1). The general description of this archipelago as it is today supposes no *a priori* definition of pieces and bits of land: continents, islands, islets, atolls, motus, reefs, keys and rocks are inherited from a rather imprecise usage in the past (see Royle and Brinklow, this volume). In any case, they present an obvious hierarchy according to their size (see Table 2.1). There are mainlands surrounded by smaller units, whatever the scale considered.

The two mainlands of the world archipelago are the Old World (including Eurasia with its southern peninsula of Africa) and the New World of North America (with its southern peninsula). Both Antarctica and Greenland are mostly ice caps with a large proportion of their bedrock below sea level. They are thus not, strictly speaking, emergent land and will not be considered as mainlands, even though they form an emergent part of the Earth. The next ranked mainland is Australia, sometimes referred to as a 'continental island'. This small continent represents only 43 per cent of the surface of South America but is ten times larger than the next ranked land, New Guinea. This appears to be the major size gap between two land areas according to their surface proportion (see Figure 2.1). This basic and robust relative surface proportion method provides an objective definition of what are the mainlands of the world archipelago compared to other land that usage tends to consider as islands *per se*. This method is also useful in describing smaller archipelagos (like Japan, British Isles and the Caribbean).

Are there any other size gaps among lands below 1 billion km^2? The surface proportion of tenth-ranking Honshu (the main island of Japan, R_{10}=227,899km^2) relative to ninth-ranking Sumatra (Indonesia, R_9=430,802km^2) is 53 per cent. This threshold occurs just after a class of five islands: New Guinea (as part of the Sahul plate), Borneo and Sumatra (as parts of the Sunda Shelf), Baffin within the northern Canadian Shield, and Madagascar, off East Africa, as a microplate on its own. These reflect various tectonic and geomorphologic contexts (see Nunn and Kumar, this volume). Another size gap occurs between 23rd-ranked Mindanao (Philippines, R_{23}=94,550km^2) and 24th-ranked Ireland (R_{24}=83,577km^2), though the proportion of 88 per cent is not as sharp.

What is the significance of this pattern of land areas? Various processes with specific time and geographical scales are responsible for the structure of the world archipelago as it is today. The combination of processes involved in the formation of an island depends on its size: the smaller the size, the better the chance there is only one dominant process. Major mainlands and large islands are directly derived from the break-up of the ancient continents of Gondwana and Laurasia. Smaller islands may also be fragments of tectonic plates more or less submerged at the present sea level such as the Seychelles. They also come from processes related to volcanism (Galápagos, Iceland, Mauritius), coral reef formation (Bahamas, Micronesia, Tuamotous) or the carving of coastlines by glaciers (Norway, Chile). All these endogenous, exogenous and biological processes interact with worldwide sea level changes to define the land pattern in space and time. Each process tends to produce islands of different size ranges, which may explain some of the size gaps and peaks observable in the distribution of lands by area at global, regional and local scales. Timing may also be important. Since small islands erode faster than large ones because of their higher coastline-to-area ratio, the many small islands created by the retreat of glaciers



Map 2.1 The evolution of the 'world archipelago' between 15,000 BP [Before Present] and today.

Source: © Christian Depraetere.

Table 2.1 Size ranking of continents and islands of the 'world archipelago'.

Continents and islands	*Size* S_{km^2}	*% Earth* %	*Rank* R_i	*Rank proportion* $100*S(R_i)/S(R_{i-1})$	*Comments or context*
Ocean	454,204,533	76.1			*excluding Caspian and Aral seas*
Old World	77,355,469	13.0			
Eurasia	*48,032,081*	*8.0*	1		
Africa	*29,323,387*	*4.9*	2	61.0	
New World	37,255,401	6.2			
North America	*19,574,227*	*3.3*	3	66.8	
South America	*17,681,174*	*3.0*	4	90.3	
Antarctica	10,540,223	1.77			*mostly ice caps*
Australia	7,605,661	1.27	5	43.0	*the 'island continent'*
Greenland	2,104,005	0.35			*mostly ice caps*
Islands>=0.1km²	7,733,461	1.30			*computed from GSHHS*
New Guinea	*783,408*		6	10.3	*part of the Sahul plate*
Borneo	*735,853*		7	93.9	*part of the Sunda Shelf*
Madagascar	*592,495*		8	80.5	*micro-plate*
Baffin	*477,549*		9	80.6	*northern Canadian Shield*
Sumatra	*430,802*		10	90.2	*part of the Sunda Shelf*
Honshu	*227,899*		11	52.9	*part of the Pacific rim of fire*
Victoria	*219,135*		12	96.2	*northern Canadian Shield*
Great Britain	*218,571*		13	99.7	*part of Western European shelf*
Ellesmere	*199,289*		14	91.2	*northern Canadian Shield*
Sulawesi	*170,493*		15	85.6	*part of Wallacea*
South Island (NZ)	*149,955*		16	88.0	*micro-plate*
Java	*127,207*		17	84.8	*part of the Sunda Shelf*
North Island (NZ)	*113,886*		18	89.5	*cut off from mainland by glacier*
Newfoundland	*109,315*		19	96.0	*cut off from mainland by glacier*
Cuba	*105,797*		20	96.8	*Micro-plate*
Luzon	*105,548*		21	99.8	*part of Wallacea*
Iceland	*101,794*		22	96.4	*volcanic mid-Atlantic ridge*
Mindanao	*94,550*		23	92.9	*part of Wallacea*
Ireland	*83,577*		24	88.4	*part of Western European shelf*
Hokkaïdo	*77,661*		25	92.9	*part of the Pacific rim of fire*
etc.	...	...	...		
Islands<0.1km²	28,570	0.005			*estimated from power law of fractal surface*

at the end of the last ice age have not yet been impacted significantly by a reduction in their number via erosion.

Order does not come without underlying patterning: a theoretical approach can help to describe the complex origin of the world archipelago. Several authors, including Mandelbrot (1982), suggest that the world looks like a fractal surface with inherently similar properties that are shared at various scales. Thus, changing magnification will still result in typically large but few chunks of mainland plus smaller but more numerous islands, both set in a largely aquatic frame (see Map 2.2). This can help answer a key question: *how many islands are there?*

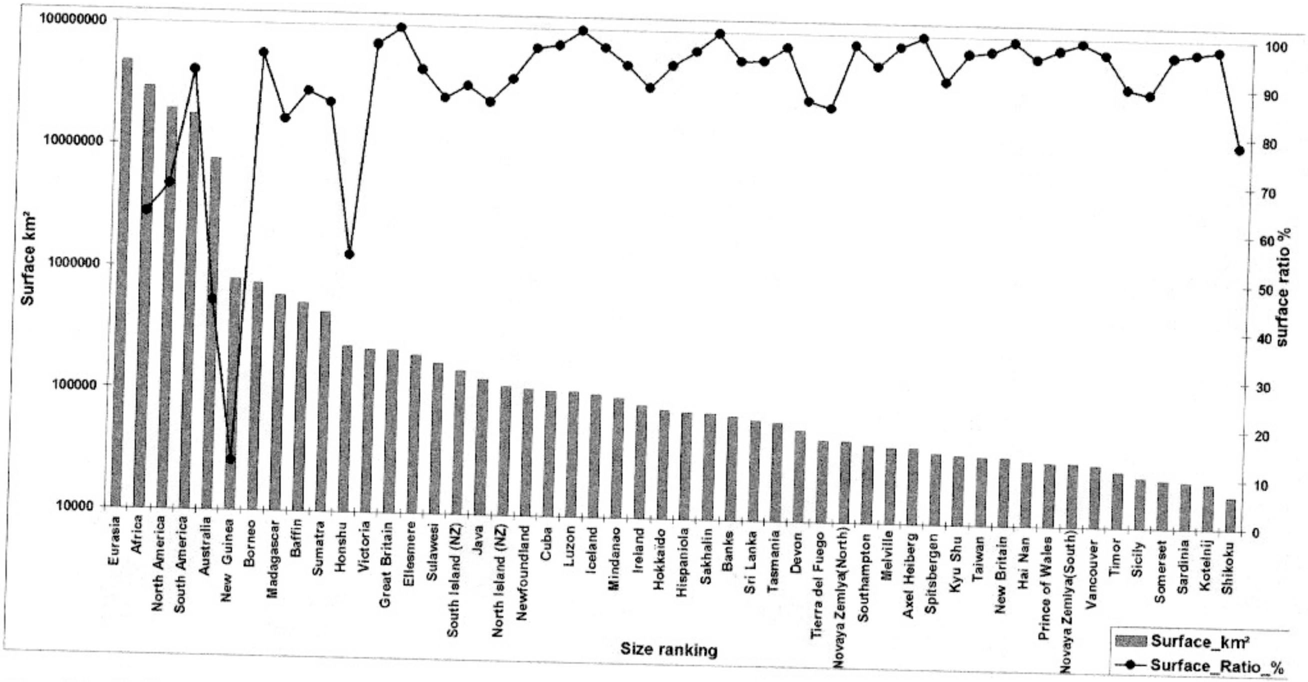
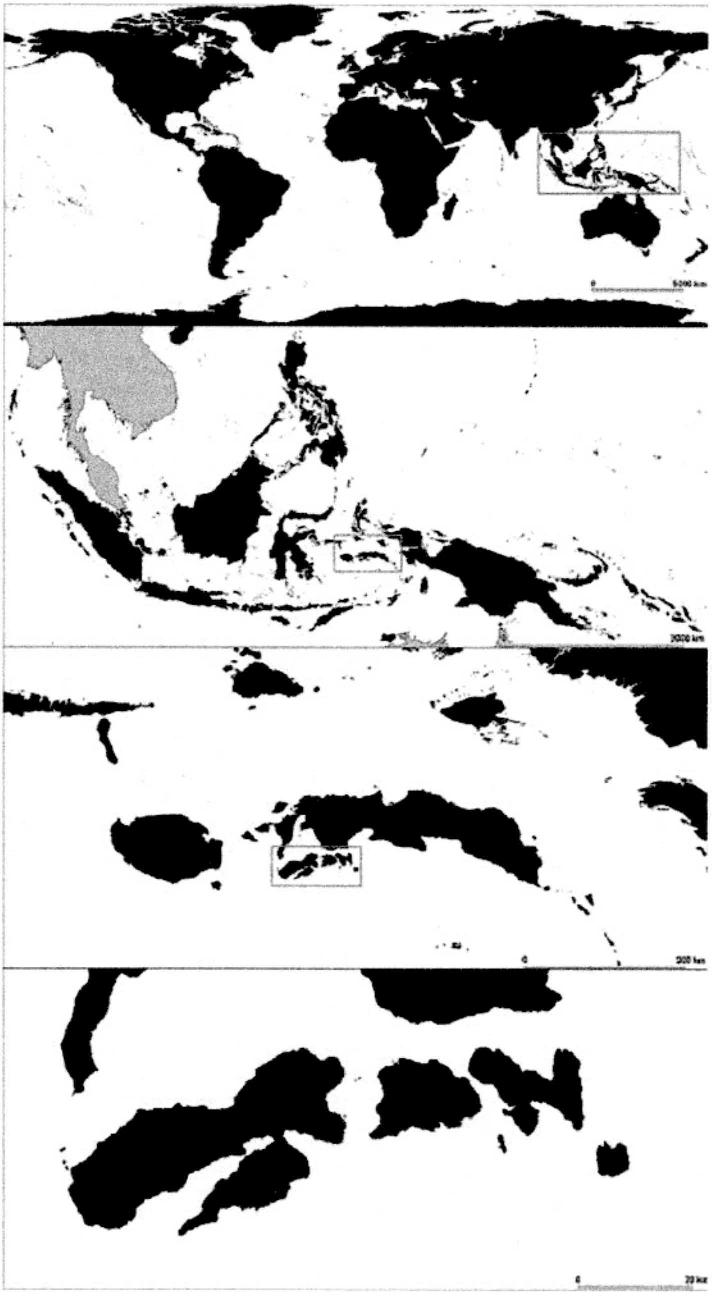


Figure 2.1 Surface proportion of lands over 100.000 km² according to their size ranking.

Source: © Christian Depraetere.



Map 2.2 Islands as a fractal property of the land surface of the Earth.

Source: © Christian Depraetere.

How many islands?

Looking at maps from global to local scales suggests some sort of constancy in the structure of emerged lands. The search for islands is an endless quest, down to very small patches of land only visible at a large scale (see Map 2.2). This observation fits with the underlying concept of self-similarity implied by fractal theory.

The fractal dimension D of the world archipelago can be estimated from the relationship between island size and frequency, given a cumulative size-frequency distribution (Burrough 1986). This has been calibrated on the Global, self-consistent, hierarchical, high-resolution shoreline database (GSHHS) (Wessel and Smith 1996) which is homogenous and includes all pieces of land greater than 0.1 km², as shown on a Log(Frequency)/Log(Area) graph (see Figure 2.2). Thus, we can expect only one island with a land area of around 10,000,000km², but close to 100 islands with a land area of 9,000 km². The frequency of lands with area **a** above the value **A** can be estimated from equation (1):

$$(1)\ F(a > A) = \alpha . A^{-\beta}$$

Where: $\alpha = 26702$; $\beta = 0.6295$

(Calibration on land between 0.1km² and 100,000km² from GSHHS data)

From equation (1), the fractal dimension D is 1.26 ($D=2\beta$) and is consistent with the previous estimation of 1.3 (Mandelbrot 1975). The extrapolation of this relationship to islands smaller than 0.1 km² is questionable, since some authors suggest that "the land surface is not unifractal" (Evans 1995). Assuming that it is unifractal, the number of islands according to their size can be estimated (see Table 2.2).

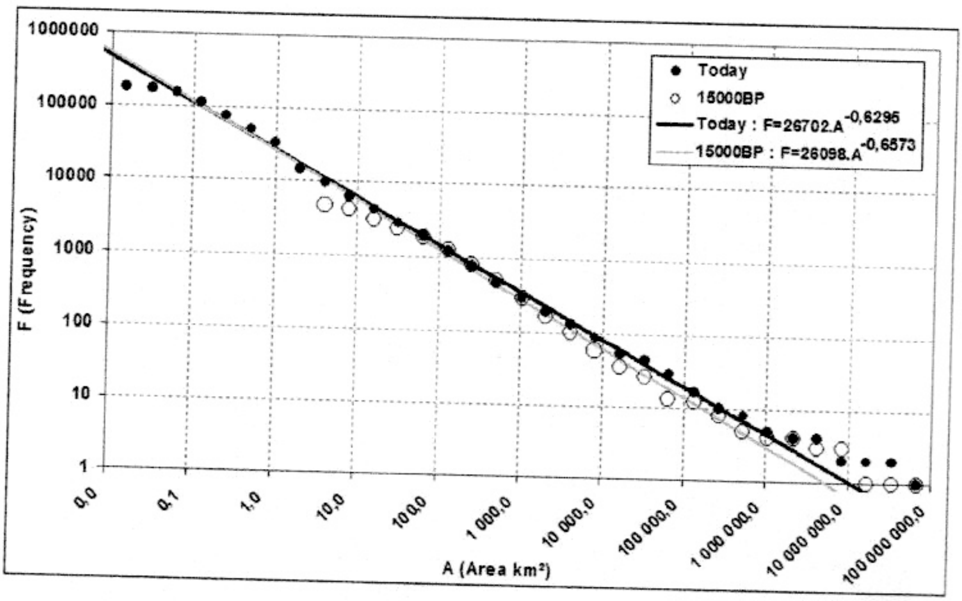


Figure 2.2 The distribution of land areas today and 15000 BP follows a power law as one might expect of the contours of a fractal surface (Departures from regression lines for small areas are due to under-sampling.)

Source: © Christian Depraetere.

Table 2.2 Classification of lands according to size magnitude.

Magnitude 10^m	*Class*	*of*	*Area*	*Number (from GSHHS)*	*Fractal (from* $F=\alpha.A^{-\beta}$*)*	*Surface* km^2	*Example*	*Prefix*	+	*Term*
7		A>=	10^7 km²	3	1	125,151,092	America	*standard*		continent
6	10^6 km²	< A <	10^7 km²	2	3	9,709,666	Australia	micro	-	continent
5	10^5 km²	< A <	10^6 km²	17	15	4,868,996	Madagascar	giga	-	island
4	10^4 km²	< A <	10^5 km²	53	62	1,653,299	Iceland	mega	-	island
3	10^3 km²	< A <	10^4 km²	219	264	674,559	Mauritius	*standard*		island
2	10^2 km²	< A <	10^3 km²	1,135	1,126	337,947	Barbados	micro	-	island
1	10 km²	< A <	10^2 km²	4,251	4,796	129,128	Nauru	nano	-	island
0	1 km²	< A <	10 km²	16,359	2,435	49,959	Pitcairn	giga	-	islet
−1	0.1 km²	< A <	1 km²	63,324	8,072	19,573	Heligoland	mega	-	islet
−2	1 hectare	< A <	0.1 km²	90,446	371,005	16,060	Sala-y-Gómez	*standard*		islet
−3	1,000 m²	< A <	1 hectare		1,580,809	7,100		micro	-	islet
−4	100 m²	< A <	1,000 m²		6,735,650	3,139	Rockall	nano	-	islet
−5	10 m²	< A <	100 m²		28,699,843	1,388		mega	-	rock
−6	1 m²	< A <	10 m²		122,286,783	613		*standard*		rock
−7	0.1 m²	< A <	1 m²		521,050,143	271		micro	-	rock

We may thus expect about 370,000 'islets' ranging in size from 1 to 10 hectares (that is, from 10,000m² to 100,000m²). Some of these are well known, despite their small size: take Liberty Island (4.9 hectares) at the entrance to New York Harbour, or the two islets of Sala-y-Gómez (4 and 11 hectares respectively, see Figure 2.3), the only land between the remote Chilean territory of Rapa Nui (Easter Island) and the islands closer to continental Chile of San Ambrosio, Robinson Crusoe and Alejandro Selkirk. A few of the nearly 7 billion 'nano-islets' are even sources of international disputes: Ireland, Iceland and Denmark contest the sovereignty of the UK over the bare, windy and misty bird-nesting refuge of Rockall (0.08 hectare) in the northeast Atlantic.

Answering the question 'how many islands?' requires setting a minimum size. Common sense suggests that there is a physical limit: a half-submerged grain of sand cannot be an island. In our counting, we stop arbitrarily at 0.1 m² (1 square foot): just enough for a bird or a child to have a rest on one of the expected hundreds of billions of 'micro-rocks'. We can safely assume that there are some 680 billion such 'islands'. This number originates either from observations for lands greater than 0.1 km², or from extrapolation from the smaller ones (see Table 2.2). This allows us to compute some statistics across a variety of sizes:

- three continents (land area greater than 1,000,000 km²): Old World, New World and Australia. (Greenland and Antarctica are considered as ice caps and so not counted as continents)
- 5,675 islands (with an area from 10 km² to 1,000,000 km²): for a total land area of 7,700,000 km²
- 8,800,000 islets (with an area from 10^{-4} km² to 10km²): for a total land area of 95,000 km²
- 672,000,000 rocks (with an area from 10^{-7} km² [one square foot] to 10^{-4} km²): for a total land area of 2,300 km².

Figure 2.3 The double islet of Sala-y-Gómez, Chile.

Source: Photo by Enrdes. Wikipedia Commons, https://en.wikipedia.org/wiki/File:Salaygomez.jpg.

This formal statistical exercise of island counting and defining shows that it is scale dependant and presupposes empirically defined limits. For instance, the official number of islands in Indonesia is sharply defined as 18,108, but without any reference to a minimum size (DK Atlas 2004). This limit is about 2.5 hectares computed from a size-frequency distribution of Indonesian islands.

This pattern of land and sea has changed over time, since it is known that, during the last glacial maximum of 15,000 BP, the sea level was 110 metres lower than today and ice shelves covered large parts of Europe and Northern America (see Map 2.1). The NOAA/NGDC ETOPO2 bathymetry data set used for that purpose (NOAA 2017) – with digital databases of seafloor and land elevations on a two-minute latitude/longitude grid – is not as accurate as the GSHHS used to define the seashore as it is today. Therefore, it is only relevant for paleo-emerged lands with an area greater than 50 km². This lowering of sea level has had dramatic consequences on the mainlands of the world archipelago (see Map 2.1):

- Connection of Eurasia and America via the Bering Strait ('Beringia').
- Emergence of the Sunda Shelf including Borneo, Sumatra, Java and Bali.
- Merging of New Guinea, Australia and Tasmania ('Sahul' paleo-continent).
- Disappearance of the English Channel and North Sea, linking the British Isles to Eurasia.

One major change in the oceanic domain was the emergence of large land areas where today only tiny sparse islands can be found. This phenomenon is exemplified in the Indian Ocean by the Seychelles, Maldives and Chagos archipelagos where several islands of more than 10,000 km² existed at that time. Another stunning case is the Grand Banks southeast of Newfoundland, now part of Canada, which formed a large island of 150,000 km² now completely submerged.

At that time, there was a less overwhelming predominance of the largest islands. This is due to the merging of many of them (Borneo, Sumatra, Great Britain, North Canada, North Siberia) into the main continent formed by Eurasia, Africa and America; new mainlands such as Sahul (New Guinea, Australia and Tasmania); and the merging of archipelagos into unique land masses and clusters (Indonesia, Japan, New Zealand, Philippines).

Islands in space and time

The statistical distribution of land *masses* within the world archipelago is consistent with the fractal hypothesis. This not true for island *locations* however, which are not evenly distributed around the Earth and do not follow a simple spatial distribution law. Islands tend to be aggregated in specific regions or to form large archipelagos where most of them are concentrated.

The distribution of islands according to latitude shows that most of them are located in the northern hemisphere, despite the fact that this has a lower proportion of ocean (Figure 2.4). The most striking result is the high occurrence of islands between latitude 50°N and 80°N with a sharp peak between 58°N and 66°N, latitudes also with the lowest ratio of ocean to land. This suggests that *pericontinental* islands (which tend to hug coastlines) are much more numerous than *oceanic* islands (that lie in mid-ocean).

The density of islands of about 90 per 10,000 km² between 58°N and 66°N is much higher than anywhere else. Most of these islands are coastal, creating a patchy landscape made of tiny islands separated by narrow channels. They are typical of the fjordlands of Norway, Greenland, Baffin, Labrador and western Canada where they have been carved from the continent during the last glaciation on the rims of the ice cap (see Nunn and Kumar, this volume). The same type of island structure occurs in the southern hemisphere in Chile, the Kerguelen and Falkland

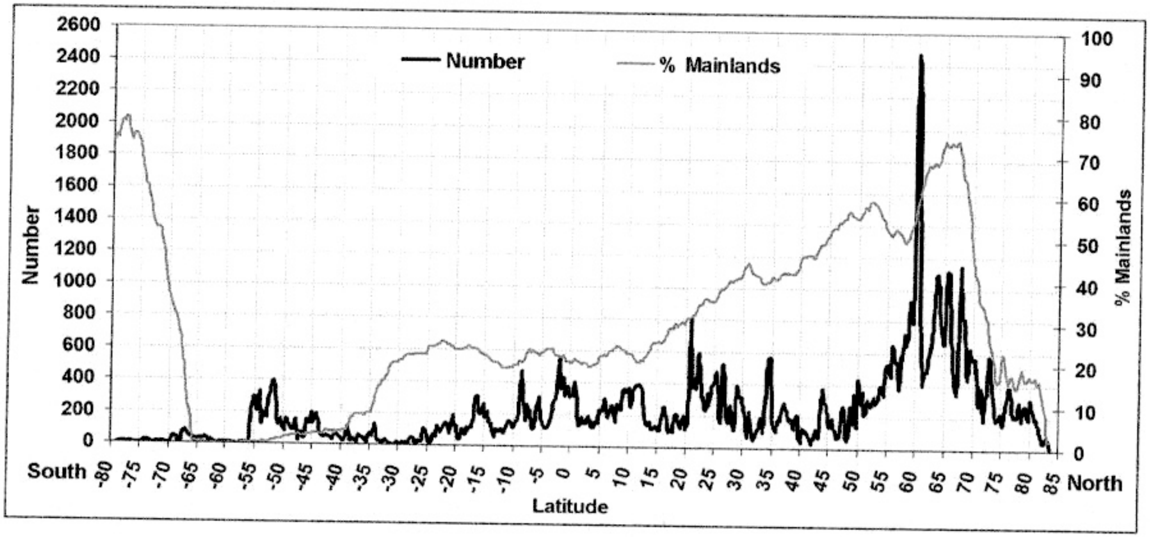


Figure 2.4 Location of islands according to latitude.

Source: © Christian Depraetere.

Islands, and on the west coast of the Antarctic Peninsula. Another consequence of reduced glaciation is the steady uplift of the Scandinavian shield at 1 cm/year in the northern part of the Baltic Sea. One result is the progressive rise of numerous low-lying islands along the coast, as beautifully exemplified by the Åland Archipelago: 3,000 patches of land over a surface of 15,000 km² create the world's highest density of islands (see Map 2.5).

The frequency of islands by latitude in the tropical zone is quite erratic, depending mostly on the location of the main clusters of islands, such as the Caribbean (10°N to 25°N), Insulindia, from Indonesia to the Solomon Islands (15°N to 10°S) and the numerous archipelagos of the South Pacific (5°S to 25°S). The reef-building activity of living coral from northernmost Bermuda (32°N) to southernmost Lord Howe (32°S) also has a noticeable effect by constructing or preserving many islands with a volcanic basement. The absence of coral reefs may partly explain the minimum frequencies of islands observed at subtropical latitudes in both hemispheres.

The proximity of islands to continental landmasses is another significant geographic detail. For that purpose, a useful criterion is the coastal maritime zone, legally defined as the territorial sea (12 nautical miles, or 22.2 km), which also corresponds to the distance from which the coast is visible at sea level. Since an island within this zone also has a territorial sea, such islands may extend this continental coastal zone beyond 12 miles, and so on until there are no more islands within the zone. This criterion defines two classes: the 'pericontinental' islands located within this continental coastal zone and subject to strong continental influences, and 'open ocean' islands distant from immediate continental areas.

Most islands are located near continents, while 'open ocean' islands are less numerous but include a much larger total island area (see Table 2.3). This contrast between the two main island classes can be summarised by calculating a coastal/archipelagic island density (ID) using equation (2):

$$(2)\ \mathbf{ID} = \mathbf{10{,}000} \times \mathbf{NI} / (\mathbf{CZ} - \mathbf{IA})$$

Where:

NI: number of islands in a given area
CZ: area in km² of the 12 nautical mile coastal zone including the area of the islands themselves
IA: area in km² of the islands

The reference surface is 10,000 km², which approximates a square degree at the equator.

The density along continental coasts (ID=85 islands/10,000km²) is more than twice that of archipelagos (ID=36).

These island-forming processes lead to sharp contrasts in the distribution and density of islands. For example, the US west coast from San Francisco, California, along Oregon and up to Anchorage, Alaska, has hardly any islets before Cape Flattery (at the northwest tip of the State of Washington, USA); while, to the north, and already within the Juan de Fuca Strait, there is a labyrinth of innumerable islands, islets and rocks. The same is true along most of the world's coasts, except for Africa which has fewer than 2,000 pericontinental islands with a total land area of less than 10,000 km² (see Map 2.3). (Antarctica may be affected by under-sampling. Moreover, 30 per cent of its coast lies under ice caps or ice shelves, as is the case for Ross Island.) African coastlines with significant islands are limited to the Red Sea, the Mediterranean coast near Suez, and portions of East Africa. The small continent of Australia has more coastal islands than Africa in both numbers and area.

Much of the open sea is empty of land above water. Some parts of the southern Pacific are 3,000 km from the closest land. There are isolated islands such as uninhabited Bouvet, a Norwegian

Table 2.3 Islands according to their distance to/from the nearest mainland.

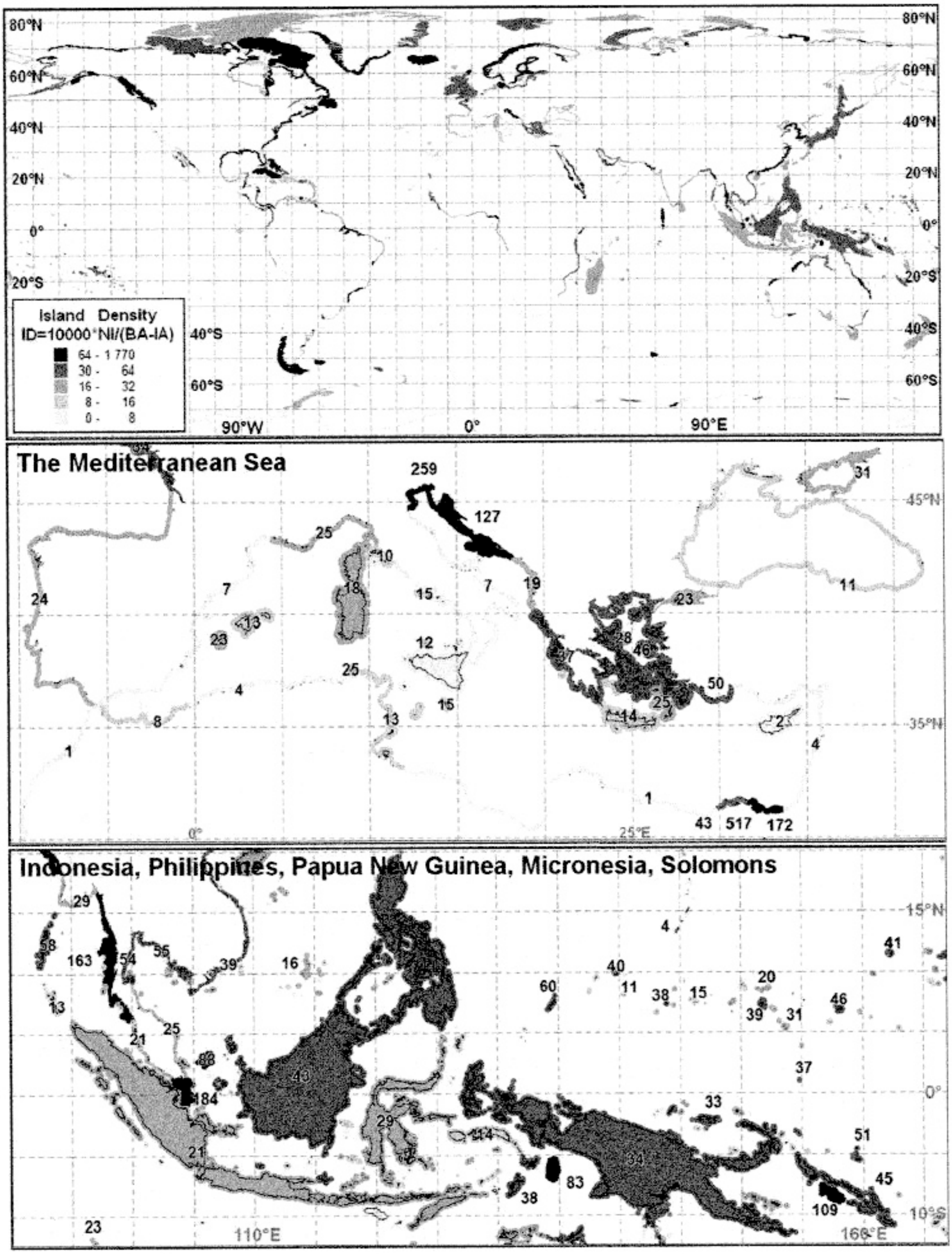
Type of islands according to distance to mainland	*Number of islands (NI)*	*12 nautical mile Coastal Zone (CZ km²)*	*Island Area (IA km²)*	*(NI %)*	*(CZ %)*	*(IA %)*	*Island Density ID=10000 × NI/ (CZ-IA)*
World archipelago	86,732	22,415,363	7,738,683	100.0	100.0	100.0	59
'Pericontinental' islands	58,913	7,580,845	647,009	67.9	33.8	8.4	85
Europe	*15,422*	*1,000,058*	*102,633*	*17.8*	*4.5*	*1.3*	*172*
Greenland	*4,392*	*383,602*	*51,061*	*5.1*	*1.7*	*0.7*	*132*
North America	*16,872*	*1,612,737*	*204,968*	*19.5*	*7.2*	*2.6*	*120*
South America	*6,902*	*898,321*	*155,525*	*8.0*	*4.0*	*2.0*	*93*
Asia	*10,247*	*1,661,328*	*72,179*	*11.8*	*7.4*	*0.9*	*64*
Australia	*2,556*	*603,872*	*28,187*	*2.9*	*2.7*	*0.4*	*44*
Africa	*1,940*	*747,398*	*9,488*	*2.2*	*3.3*	*0.1*	*26*
Antarctica	*544*	*631,733*	*22,518*	*0.6*	*2.8*	*0.3*	*9*
'Open ocean' islands	27,819	14,834,518	7,091,675	32.1	66.2	91.6	36
North Canada	*4,942*	*2,069,373*	*1,346,028*	*5.7*	*9.2*	*17.4*	*68*
Caribbean	*1,877*	*516,595*	*213,763*	*2.2*	*2.3*	*2.8*	*62*
Indonesia, Philippines, PNG, Solomons	*7,387*	*5,134,339*	*2,908,367*	*8.5*	*22.9*	*37.6*	*33*

possession, 1,600 km from Antarctica and 2,500 km from southern Africa; or Tristan da Cunha, the world's most remote inhabited archipelago, 2,000 km from the nearest inhabited land, Saint Helena, and 2,400 km from the nearest continental land, South Africa. Open ocean islands only occupy a small proportion of the oceanic expanse: even with their 15 billion km² of coastal zones, they barely represent 3.3 per cent of the ocean surface (1.7 per cent for pericontinental zones).

Islands tend to amass in clusters or lines, giving birth to the fuzzy term 'archipelago'. On occasion, it reflects the tangible reality of a group of islands isolated from others, as in the case of Cape Verde or Hawai'i. There are other examples where this term is used more loosely, such as the Dodecanese archipelago in Greece.

There are three main 'mega-archipelagos' in the world: the group bounded by Sumatra, Timor, the Solomons and Philippines; the archipelagos of northern Canada; and the Caribbean. Together, they contain more islands, and cover a larger area, than all other open ocean archipelagos put together, and include most of the world's largest islands. Their island densities range from 33 to 68 islands/10,000km², but with major differences among the component archipelagos. In the Caribbean (see Map 2.4), Cuba and part of the patchy coral keys of the Bahamas reach a density of 100 islands/10,000km² compared to 15 for the massive Hispaniola and Jamaica groups, while the spotty line of mostly volcanic islands in the Lesser Antilles has a density of 28/10,000km². Puerto Rico and its tiny eastern neighbours in the Virgin Islands lie in between these, at 56 islands/10,000km².

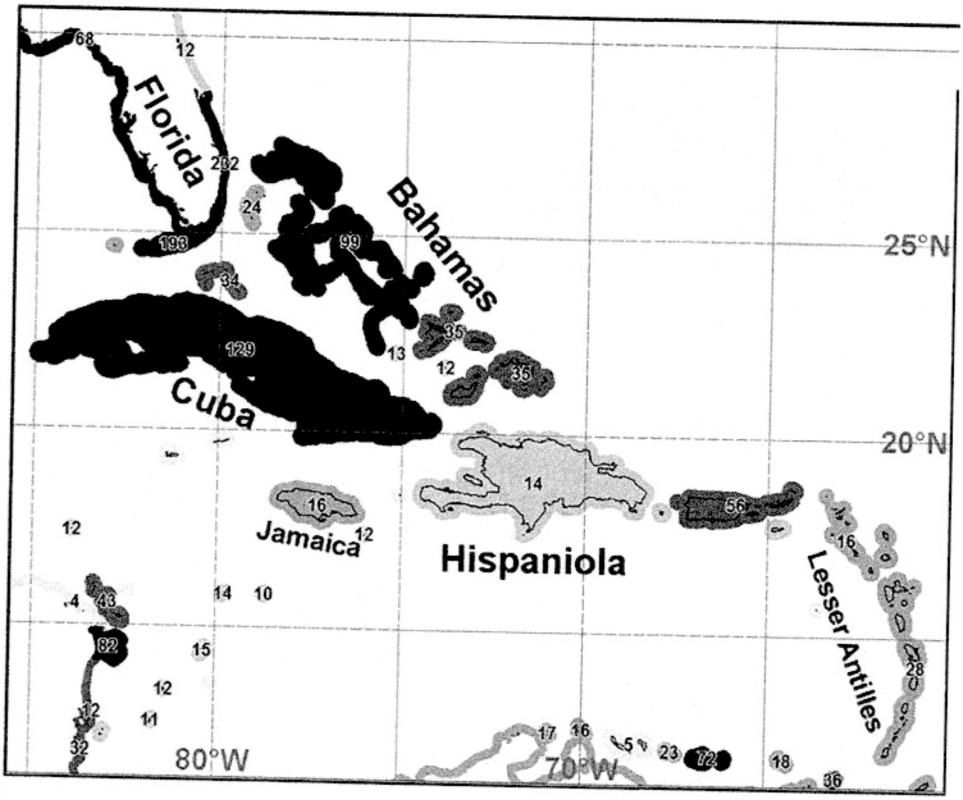
What has caused such contrasts in island locations and density? While plate tectonics provides a global explanation, the location, density and spatial structure of islands depend on climatic, geological, oceanic, hydrological and biological processes.



Map 2.3 Island density along the continental coast and within archipelagos.

Source: © Christian Depraetere.

Consider the case of archipelagos or sets of islands well defined by origin (see Table 2.4). The bulky ice caps and the post glacial uplift resulting from their melting created most of the numerous pericontinental islands at high latitudes, with densities of 300 islands/10,000km² or even more (case of Åland, see Map 2.5). Coral reef formation only in tropical waters of over 20°C

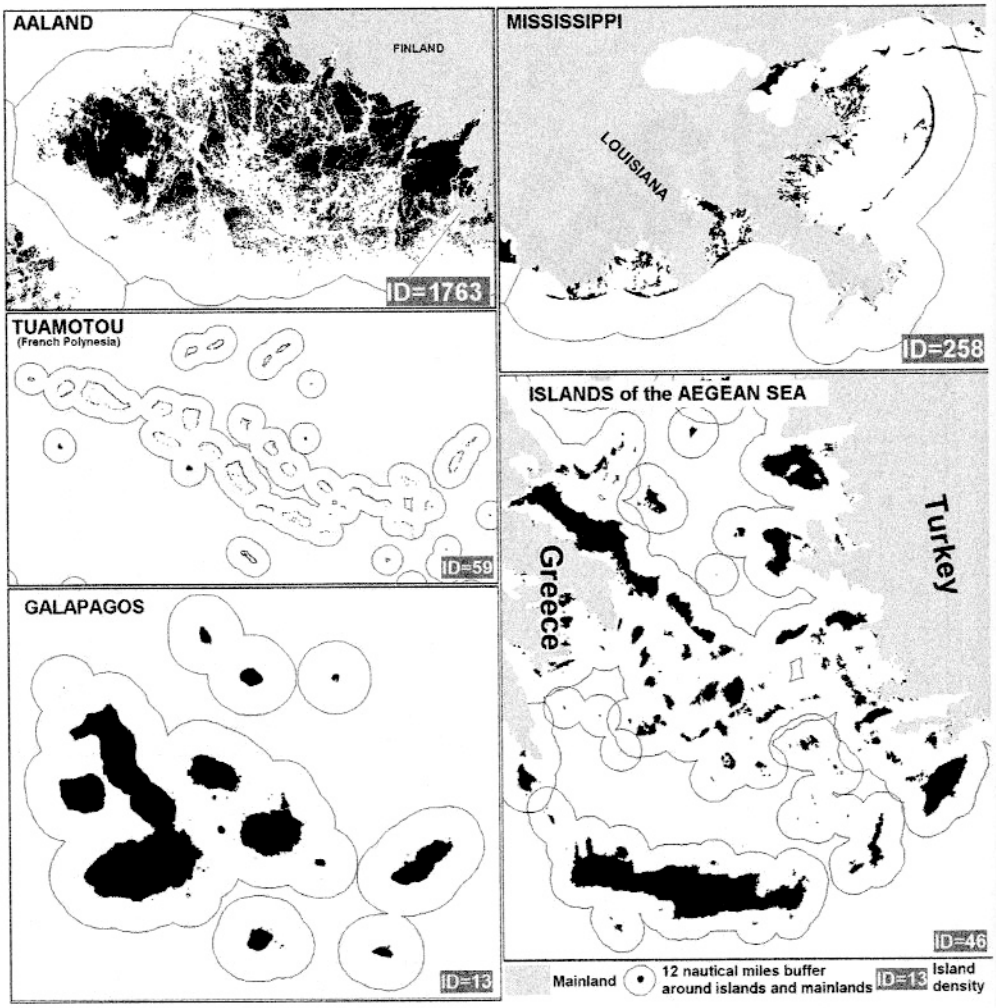


Map 2.4 Island density in the Caribbean.

Source: © Christian Depraetere.

Table 2.4 Examples of islands according to their dominant geological origin.

Type of islands according to processes	*Example*	*NI*	*CZ km²*	*IA km²*	*Largest km²*	*Island density*	*Mean ID*
Glacial processes including post glacial isostatic uplift	Åland (Finland)	2,874	20,412	4,112	879	1,763	
	Norway	4,236	124,400	22,229	2,239	415	300
	Chile	4,511	289,916	127,630	47,107	278	
	West Canada	3,107	222,158	97,943	31,947	250	
Coral processes including uplifted coral	Bahamas	1,099	157,711	14,390	3,618	77	
	Maldives	489	66,045	215	6	74	70
	Tuamotou (French Polynesia)	566	99,008	562	56	57	
Volcanic processes	Lesser Antilles	129	61,597	6,049	1,469	23	
	Galápagos (Ecuador)	41	44,295	8,087	4,739	11	15
	Cape Verde	17	33,872	4,139	1,006	6	
Alluvial processes at the mouth of main rivers	Mississippi (USA)	505	20,382	796	41	258	
	Lena (Russia)	476	21,377	1,394	71	238	250
	Orinoco (Venezuela)	65	3,034	542	81	261	



Map 2.5 Island density (ID) in coastal zones and archipelagos according to dominant processes.
Source: © Christian Depraetere.

generates archipelagos with an average density of 70 islands/10,000km² in at least three cases: generally small atolls as in the Maldives; uplifted coral islands reaching up to 50 km² as in the Tuamotous; or even islands of more than 1,000 km² in the Bahamas. Compared to these two types, volcanic islands can be found at any latitude. They are mostly located far from the mainland in isolated archipelagos or islands in areas of subduction at the borders of continental plates ('the rim of fire', in the Pacific), along oceanic ridges, or at hot spots within oceanic plates. They give birth to islands of a few thousand square kilometres, like Big Island in Hawai'i, or more if they merge as Isabella, the largest of the Galápagos. For that reason, the density of their archipelagos is only 15 islands/10,000 km². The alluvial islands formed at the front shore of main continental river deltas, while they may result from a terrestrial hydrological system, are a major local element of the pericontinental seascape, with a high density of 250 islands/10,000 km² in the case of the Mississippi River on the Gulf of Mexico, the Orinoco in Venezuela and the Lena in Northern Siberia.

Another useful measure is the coastal index (Ic) proposed by Doumenge (1984, 1989), based on the relationship between the perimeter (length of coastline) (P) and the surface area of an island (S) (equation 3):

$$(3)\,\mathbf{Ic} = \mathbf{S} / \mathbf{P}$$

This coastal index has the advantage of being simple in formulation, while also easily interpreted in geographical terms. "The importance of the line of coastal contact in relation to the surface area of an island is an expression of the degree of direct influence that maritime affairs exercise on the island" (Doumenge 1989, p. 41). The coastal index gives the length of the coast for 1 km^2 of land. As a consequence, the smaller the island, the larger is its coastal index. However, this index cannot be used unless the coast has been measured at the same scale of maps or resolution of images (Depraetere 1991a), because the length (P) of the coastline, as a fractal object, depends on the scale (Mandelbrot 1967). Fortunately, uniform global data sets derived from satellite imagery offer a solution to this problem.

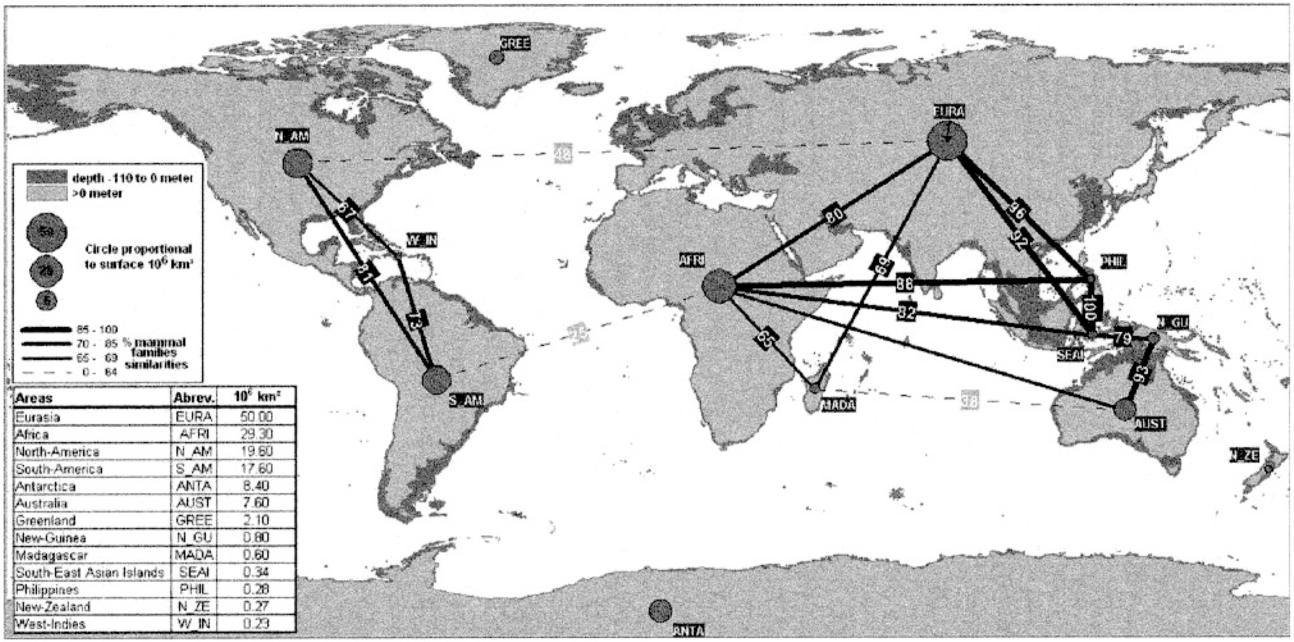
Island life

The analysis of the geographic features of islands, their size, form and composition, their proximity to or isolation from other islands or continents, and their situation in terms of winds, currents, climate and migratory pathways, all help to explain their biological populations. Again, the dynamic processes involved have to be understood in the context not only of islands as they are at present, but also as they have changed over time. Islands that were once part of a continent until they were cut off by rising sea levels will be much richer biologically for having started with a continental fauna and flora. Those that are actually ancient continental fragments that have drifted away from adjacent land masses may even preserve primitive life forms that became extinct or were replaced as evolution proceeded elsewhere. Volcanic islands and atolls, in contrast, start with nothing and accumulate biota with the passage of time. Moreover, some islands may be repeatedly submerged and exposed as sea levels have risen and fallen during the ice ages, and with each exposure the process of terrestrial colonisation must start over again. With all these processes operating, it is difficult to find any two islands that are completely identical. Each one represents variations on a theme or a series of themes, and the result is an endless diversity of island life forms and ecosystems with many surprises.

The principles of island biogeography also apply somewhat to the marine biology of islands. Many coastal species stick to shallow water or require a hard substrate to attach themselves; others depend on coastal habitats for food or shelter. For such species, islands may be just as isolated as for terrestrial species, with immigration perhaps dependent on how long their larvae can drift in ocean currents before they either settle or die. One variance is that there may be seamounts or reefs that do not qualify as islands because they fail to emerge above the ocean surface – examples of these lie in the northwest Pacific – but which can still serve as stepping stones for marine migrants. So the geographical relationships at a regional scale may be distinct from those of terrestrial forms.

The same principles operate at all the geographic scales of the world archipelago, whether for the flora of islets and rocks or the distribution of mammalian species among the continents and largest islands. The map of mammalian similarities across the world archipelago includes five groups of islands that illustrate their relationships with neighbouring continents (see Map 2.6).

For a start, the Philippines and southeast Asian islands are similar in mammalian fauna with a score of 100 per cent. This is consistent in that they were all part of the former Wallacea



Map 2.6 Mammalian similarities across the 'world archipelago'.

Source: © Christian Depraetere.

archipelago bounded by two major biogeographic lines: the Wallace line to the west and the Weber line to the south and east. They also show strong similarities with Eurasia and the islands of Sunda Shelf to the west (92 per cent or more) and weaker relationships of 50 per cent to 79 per cent with their southeastern neighbours of New Guinea and Australia, both split apart from Sahul. This suggests that the Weber line was more of an obstacle to mammalian dispersal than its western counterpart, and is coherent with the average width of straits up to 15,000BP, which were significantly narrower between Wallacea and the Sunda Shelf (approx. 20km) than between Wallacea and Sahul (approx. 100km). The two parts of Sahul, New Guinea and Australia, have similar mammalian faunas with a score of 93 per cent, despite different climates. This reflects their recent separation only 8,000 years ago. The two other insular biogeographic units were more isolated from their nearest continents both today and during the last ice age: the West Indies are 70km from South America and 120km from North America; Madagascar is 350km from Africa. The mammalian similarities between those insular units and their continents are respectively 73 per cent, 67 per cent and 65 per cent. These figures demonstrate the relationship between species similarities and such simple geographical features as the width of straits during the late Quaternary era. Other factors should also be taken into account, in particular the paleogeography of plate tectonic movements during the Tertiary era when mammals were evolving. If geographical constraints are obvious for a class of animals at the global scale, they are even more significant at other scales for genera, species or varieties. The specificity of islands compared to the vast terrestrial continuum of continents is largely the outcome of their relative isolation by water gaps that constitute drastic dispersal barriers for most species.

A geographic analysis of the different facets of 'islandness' can have considerable predictive and explanatory value in understanding island biogeography. Islands in turn have been important laboratories of evolution whose study has done much to advance the biological sciences (see Berry and Gillespie; Percy, Cronk and Blackmore; and Berry and Lister; this volume).

Stages of human discovery and settlement

The same tools of geographic analysis that shed light on island biogeography can also help to explain the interaction of geographic, technological and cultural factors behind the migrations of people into island regions, migrations that have been the subject of many analyses not only by historians but by anthropologists, archaeologists, linguists and geneticists, especially in the Pacific (Gibbons 1994, Connell, this volume). For people to settle on an island, they have to get there. Beyond the distance that people can swim, this requires some technology in raft, canoe or boat-building, propulsion by paddle or sail, and skills in navigation or orientation. Even with the technology, there is the psychological and cultural capacity to overcome the fear of the unknown and to want to explore new opportunities, and particularly to venture out of sight of land. There are enormous gaps in time between the migrations that were possible overland, those that could take place by navigating within sight of land, and those courageous adventurers who were ready to set out over the horizon in the hope of finding a new home.

With three-dimensional, geographic data sets of islands – such as the Enhanced Land Elevation Data from the Space Shuttle Radar Topography Mission, available for latitudes 61°N to 60°S (NASA 2017b) – and information on the sea level at the time of human migrations that has been documented with archaeological evidence, it is possible to calculate where there were land bridges between areas that today are islands, and where someone on the highest point of an island or coast could see the next piece of land across the water, and thus know that, in setting out from the shore in a particular direction, a landfall was certain, a process that we can call *island hopping*.

According to paleo-anthropology, it seems that the pre-*homo sapiens* was trapped on the mainland of the world archipelago, and it took quite some time before mastering the ability to get out of the African peninsula cradle via the isthmus of Sinaï or the Bab el Mandeb narrow strait.

Before considering the stages of human saga over the marginal isolated lands, as we may called islands, one needs to know the equation (4) which gives the 'visibility range' (Lewis 1994) on our spherical planet:

$$(4)\ \mathbf{V_{km} = 3.57 \times Z_m^{0.5}}$$

Where:

V_{km}: distance of visibility in km

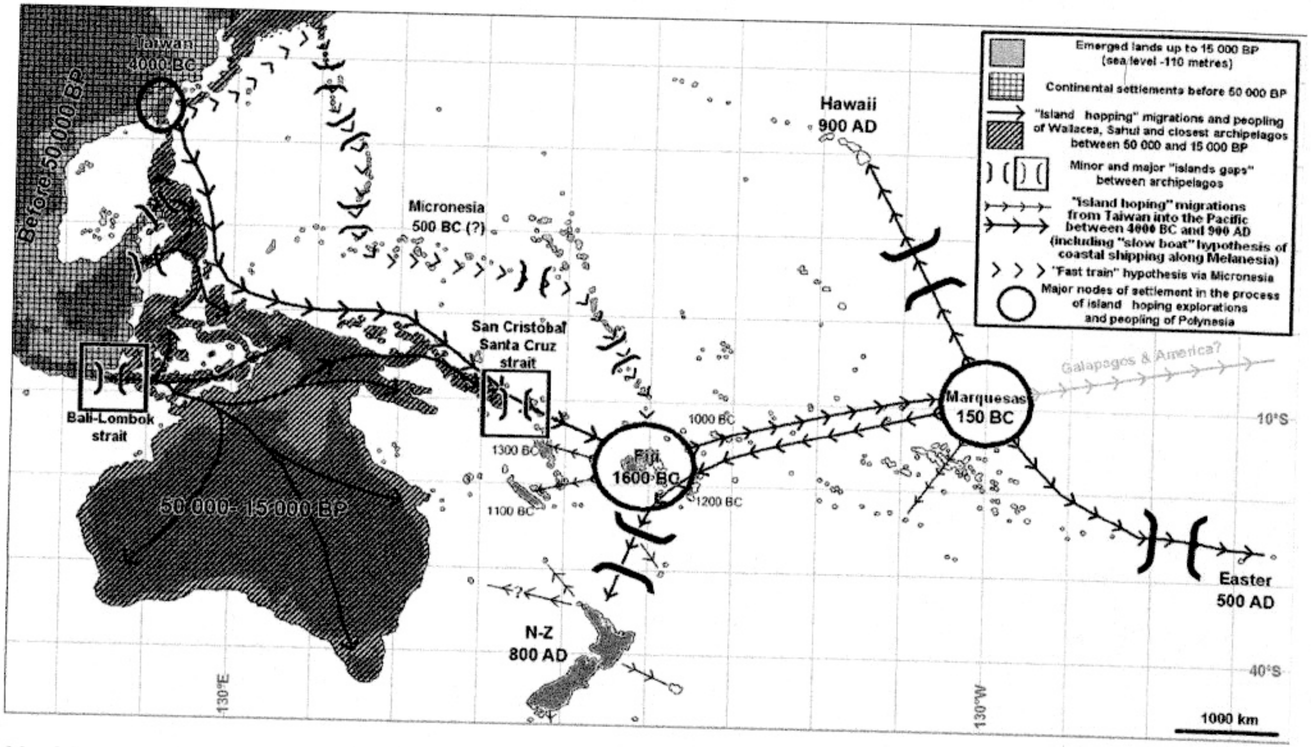
$Z_m^{0.5}$: elevation in metres.

We are thus able to roughly determine theoretically which islands are visible from the highest or closest point on an adjacent island or continental coast. Two other factors need to be added to the calculation. The first is the notion of intervisibility: a point where two other specific points are within sight. It is relevant to the island hopping process since two islands may only be within eyesight simultaneously when a navigator is half-way in between. The second factor relates to the timing of the observation by island hoppers, with reference to the elevation to be considered when sea level has changed. In that case, the elevation as given today must take into account the relative variation of sea level in the past. To estimate the actual elevation during the last glacial maximum at 15,000 BP, the difference of elevation due to see level change (SLC) must be subtracted from the elevation as calculated today:

$$Z\ (15{,}000\text{BP}) = Z(\text{Present}) - \text{SLC}\ (15{,}000\text{BP})\ \text{with SLC}\ (15{,}000\text{BP}) = -110\ \text{metres.}$$

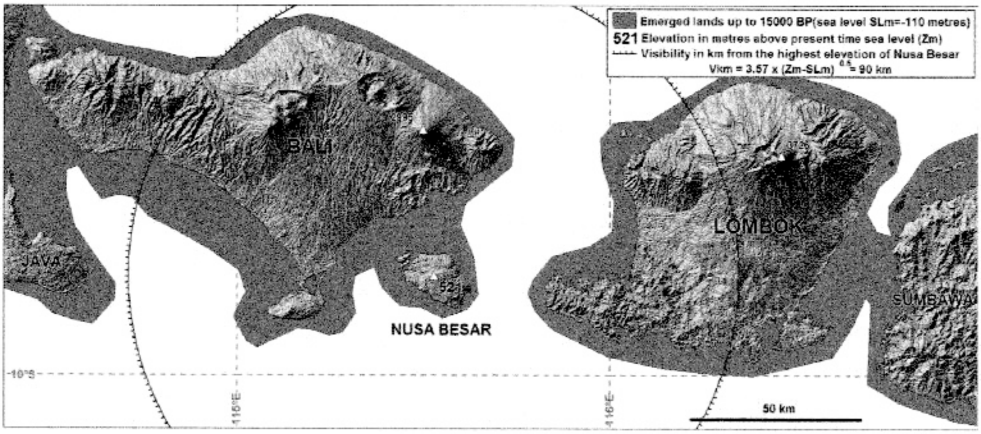
These notions can be applied to specific regions such as southeast Asia and Sunda Shelf, including the southern line of islands constituted by Sumatra, Java, Bali and Borneo (see Map 2.7). The migration of pre-*homo sapiens* was blocked there by critical water gaps along what is called now the Wallace line: the straits between Bali and Lombok (see Map 2.8) and between Borneo and the Philippines. Once the *homo sapiens* Asian peoples had developed the technology to cross the water, island hopping began about 50,000 BP and continued through 15,000 BP, covering all of the south and east lands of Wallacea, Sahul and as far as the Solomon Islands, involving the ancestors of the dark-skinned Aborigines, Papuans and Melanesians. This migration reached its limit beyond the Solomon Islands where there was a major 'island gap' before the Santa Cruz Archipelago. Island hopping stopped there because there was no more land visible on the horizon to encourage another step. The statement that only *homo sapiens* was able to 'island hop' has however been recently shaken. *Homo floresiensis*, a dwarf form of *homo erectus* dated from 12,000 BP, was discovered on the island of Flores (Brown et al. 2004) beyond the Bali-Lombok water gap. Scientists are thus considering various hypotheses that would explain how the Flores exemplar was possibly a side effect of *homo sapiens* migrations.

The next stage in the island quest of humankind remains undoubtedly the giant advance that led to the Polynesian migration across the Pacific. This came about because these people had the technology to master long sea voyages with everything necessary to colonise a new island (Dening 2004). What remains outstanding is their courage and cultural framework that enabled these peoples to hope that there would be another island beyond the one they were



Map 2.7 From 'island hopping' to 'island hoping' in the Pacific.

Source: © Christian Depraetere.



Map 2.8 The strait between Bali and Lombok islands, up to 15,000 BP.

Source: © Christian Depraetere.

leaving behind, and possibly also the confidence that they could sail back if they did not find land in time. This great migration from 4000 BC to AD 1200, can be understood as being fuelled by the hope of finding an island, or *island hoping*. These Polynesians reached all over, except the easternmost Pacific islands close to South and Central America. Two migration routes have been proposed for these people who probably originated in Taiwan: an 'express' route down through Micronesia to Polynesia from near Japan, thus bypassing Melanesia; and a 'slow' route along the fringes of Melanesia, with some interchange along the way with Melanesian peoples (see Map 2.7) (Gibbons 1994).

One geographic factor that may have encouraged this island hoping is the linear alignment of most island groups, such that the probability of finding another island was considerably greater along the axis of known islands. This of course requires a strong cultural sense of geography as well as orientation and navigation, which the Polynesian and Micronesian people acquired and maintained (Lewis 1994). The stick-charts of Micronesia illustrate the ability of their navigators to synthesise their knowledge into a reticular structure made of points and lines (see Figure 2.5).

The knowledge of seas and their currents, winds, stars and other signs acquired during their oceanic migrations, whether voluntary or not, gave them an empirical knowledge as useful as that of modern island cartography (see Map 2.9).

In general, Melanesian peoples were culturally more land based, developing many different local cultural and linguistic forms corresponding to the fragmented terrain of their high islands. Their island hoping, when they finally reached Fiji, Vanuatu and New Caledonia (1600 BC–1100 BC), was contemporaneous with the eastward Polynesian migrations and may well have been inspired and enabled by transfers of Polynesian technologies and cultural elements. Significantly, the Melanesian legends and myths of those archipelagos retain no trace of their island migrations (Bonnemaison 1986, Nunn 2003). The Melanesians became totally rooted in their new lands without looking back and with no expectation of discovering new lands beyond the horizon. New Zealand was only about 1,400 km from New Caledonia with Norfolk Island half way in between; but it was only discovered by the Maori around AD 800.

Beyond the Pacific, lie other examples of both island hopping and island hoping. One of the most dramatic examples is the settlement of Madagascar by people coming from Borneo after a

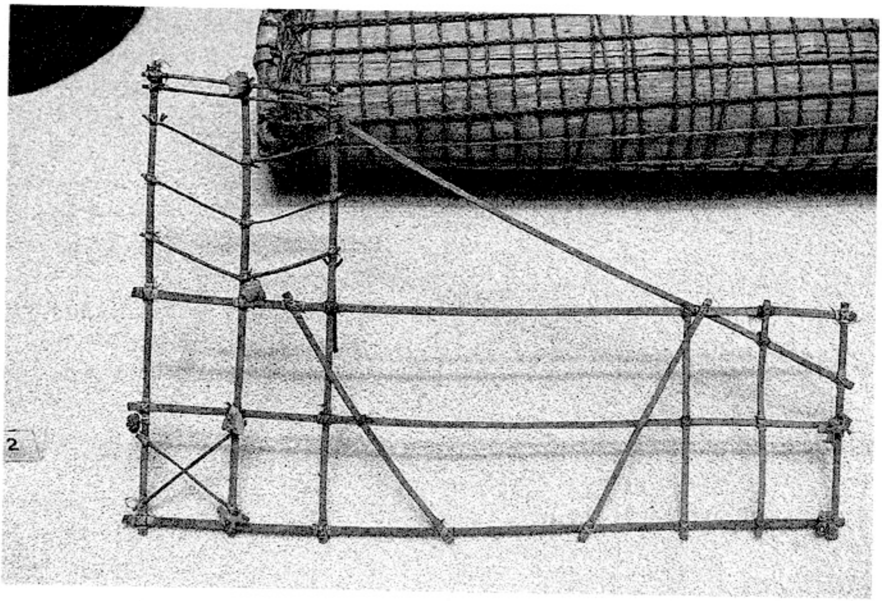
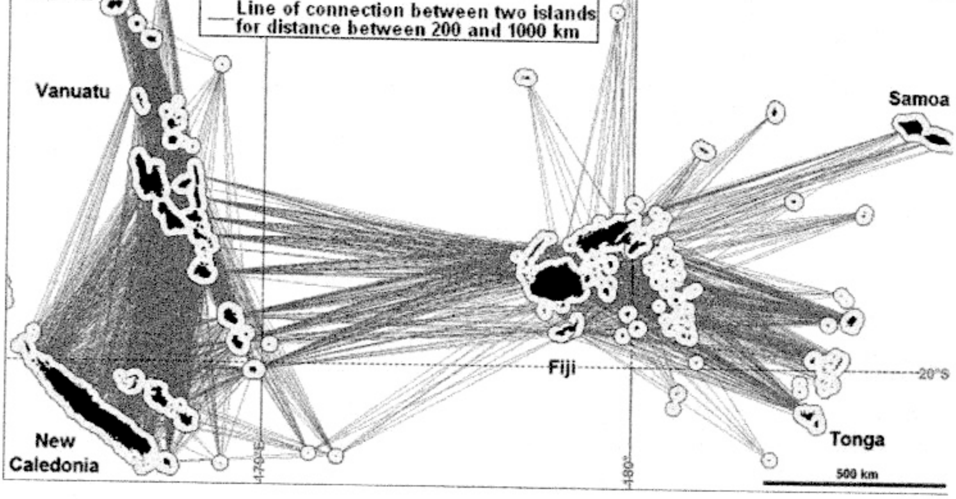


Figure 2.5 Stick-chart from the Marshall Islands made of shells representing islands and sticks indicating currents and lines of swell.

Source: Photo by Daderot, Wikimedia Commons. Exhibit in the Ethnological Museum, Berlin, Germany. Photo taken in the museum without restriction. https://commons.wikimedia.org/wiki/File:Stick_chart_used_for_navigation,_Marshall_Islands,_undated_-_Ethnological_Museum,_Berlin_-_DSC01161.JPG.



Map 2.9 The reticular structure of connections between islands.

Source: © Christian Depraetere.

long sea migration along the southern coast of Asia and the east coast of Africa. They probably crossed the Mozambique Strait via the Comoros Archipelago by island hoping before landing on Madagascar some 1,800 BP. Today, the Malagasy language is part of the Nusantarian (or Austronesian) family that includes Malay and Polynesian, but with significant lexical influences from African and even Indian origins.

The Mediterranean islands were only settled rather recently, despite most of them being visible from adjacent mainlands. Cyprus was colonised early: about 6000 BC, probably by Neolithic groups coming from Anatolia. Since it cannot be seen by coastal shipping from the continent, the Balearic archipelago was the last to be inhabited, around 3000 BC.

By heading westward from their native peninsula of Scandinavia, the Vikings initiated island hoping in the North Atlantic; their descendants are proud to recall these voyages in their famous sagas: Faroes in AD 800, Iceland in AD 860 and Greenland in AD 982. Their ultimate landing at the L'Anse aux Meadows site in Newfoundland around AD 1000 after sailing along the wooded coast of Labrador proved that they were able to reach the New World, without realising that it was much more than a large island.

With the Europeans, the process of exploring and peopling the uninhabited island margins of the known world changes in nature, with more mercantile, exploitative and political objectives rather than (or apart from) settlement (see Warrington and Milne, this volume). As an example, and with such protagonists as Henry the Navigator (AD 1394–1460), Portugal had a deliberate policy priority to explore both the African coast and the country's oceanic neighbourhood. While the discovery of Madeira and the Azores during the 14th century could be classified as an island-hoping process, the pace and nature of exploration start to change during the 15th century with an engagement with the Cape Verde Archipelago and the line of volcanic islands including Fernando Poo, Príncipe, São Tomé and Annobon in the Gulf of Guinea. It was no longer island hoping *per se*, but a systematic exploration for strategic and logistic reasons: an '*island claiming and naming*' exercise that lasted until the 19th century (see Map 2.10).

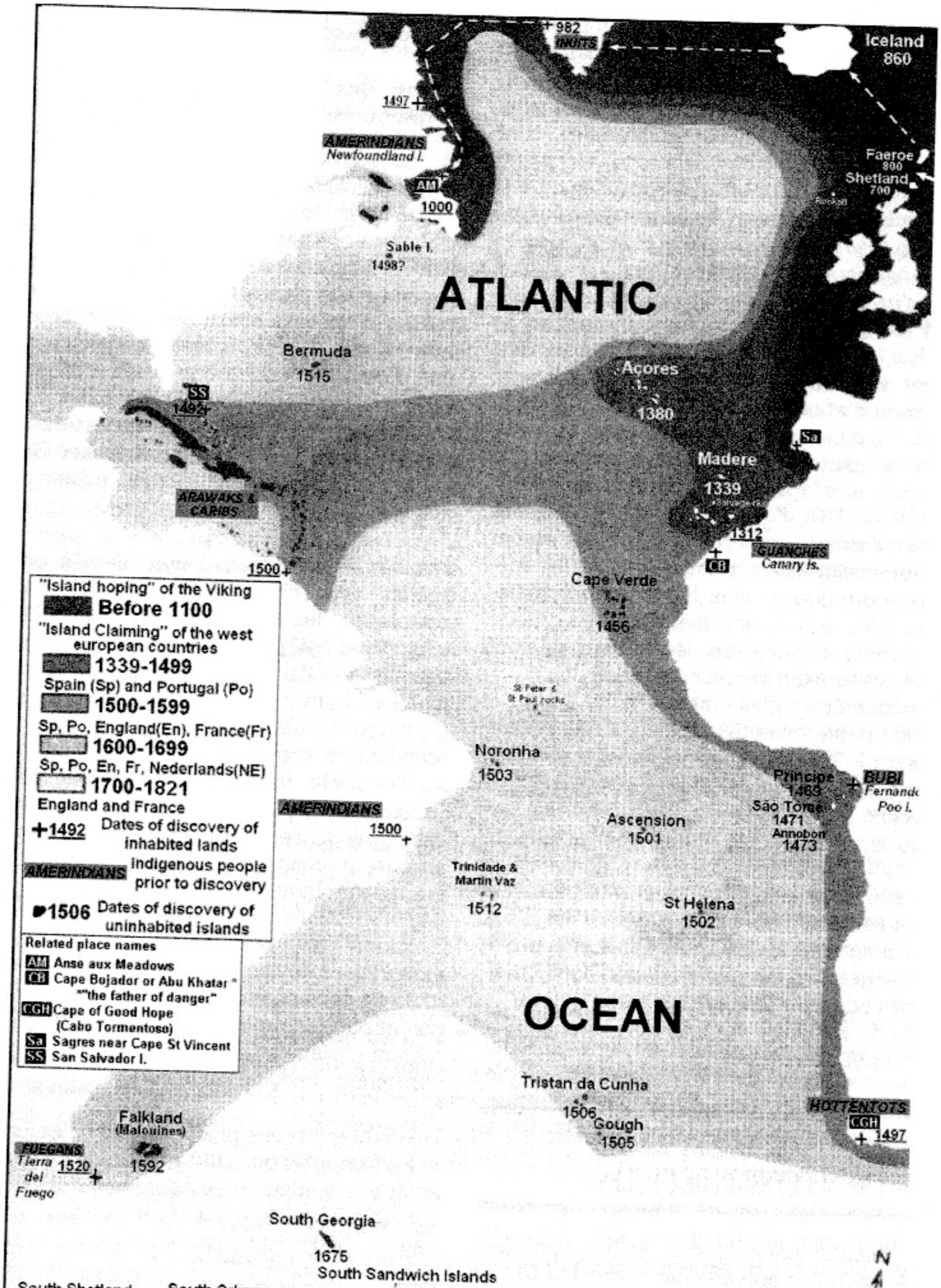
The apex of this new process between AD 1488 and 1522 saw outstanding navigators like Bartolomeu Dias, Christoforo Colombo (Columbus), Vasco de Gama and Fernão de Magalhães (Magellan) who pioneered the exploration of oceanic space on behalf of the Iberian powers. This led steadily to the discovery and exploitation of the last islands that remained out of human reach.

The combination in the long term of all these processes of island hopping, hoping, claiming and naming is responsible for the present intricate geopolitical situation that many islands find themselves in today.

The current island situation

The same geographic processes that have operated in the past on the evolution of island biodiversity and the mosaic of island cultures are now influencing island societies in new ways as they integrate into a globalising world. Air travel, radio, telephone, satellite connections, the internet and other new technologies of transportation and communications have reduced island isolation in some cases and increased it in others.

For example, considerable work has been done on island economies which, because of their small size, openness, limited diversity and lack of economies of scale, have been considered to be vulnerable to outside perturbations, and arguably cannot be competitive in world markets, except in specialised niches like and within tourism (Briguglio 1995). Others have considered



Map 2.10 European explorations and discoveries in the Atlantic Ocean.

Source: Based on Marrou (1998).

the inevitable openness of small island societies to external trade as a spur for strategic flexibility, economies of scope and the venturing into novel forms of entrepreneurship: financial services; citizenship by investment schemes; sale of country level internet domain names (Baldacchino 2015).

Culturally, the picture is more mixed. On the one hand, the wave of global culture in popular music, dress, films and television, and now the internet has swept over islands as it has the rest of the inhabited world. Yet, islands are as subject to the digital gap as other remote areas, and the cost of these services where there are no economies of scale is very high. Emigration to find work or wider opportunities has led to many island countries having larger populations overseas than at home (see Connell, this volume). Nevertheless, the special conditions that spawned distinct island cultures remain, and many island cultural traits have demonstrated surprising resilience, and even a renaissance. Island peoples continue to make a significant contribution towards global cultural diversity.

Politically, how do you weigh the influence of a nation of ten thousand or a hundred thousand people against one of a hundred million or a billion? Yet, population is not everything, as will be evident in the analysis below. Even politically, small island developing states (SIDS) have learned that there is power in numbers, and in fora where each nation has one vote, SIDS can represent a significant voting block of some 40 sovereign states. Starting from regional groupings of island states and territories in the Pacific and Caribbean, SIDS have built a range of global political processes to define their particular situation and identify policy responses. Islands were included as a program area in Agenda 21, the action plan for environment and development adopted at the Rio Earth Summit in 1992 (UN 1992). This led to the Conference on Sustainable Development of Small Island Developing States in Barbados in 1994, which adopted the Barbados Programme of Action (UN 1994), assured the regular inclusion of SIDS issues in subsequent international negotiations, and ushered a follow-up international meeting in Mauritius ten years later, in January 2005 (UN 2005), and a third in Samoa in 2014 (UN 2014).

Moreover, clearly aware of their limitations on the world stage, small island states joined forces in 1991 to set up the Alliance of Small Island States (AOSIS), now with 39 member countries (see Table 2.5) and five subnational island jurisdictions (SNIJs) as observers, giving them a stronger and unified international voice. The Alliance includes four low-lying coastal states which are mostly continental (Belize, Guinea Bissau, Guyana and Surinam). AOSIS adopts common positions on key international issues such as climate change and is able to defend them with its votes at the United Nations and the meetings of the Conferences of the Parties (COP) as part of the United Nations Framework Convention on Climate Change (UNFCCC). In these and similar ways, AOSIS demonstrates strength in numbers that can help to counterbalance the power of major countries at both global and regional scales.

While independent island states have found a political voice at an international level, others have persevered as SNIJs, remaining part of larger states or distant fragments of former empires (Baldacchino and Milne 2009). Thus, while transportation and communications links have reduced the isolation of many island communities, their marginality is expressed today in more economic and political terms.

The present geopolitical situation of islands can be mapped (for SNIJs globally in Map 2.11; and, for the Caribbean only, in Map 2.12). A distinction should be made between island states and continental states, as they do not have the same views on oceanic issues, both in terms of scale and necessity. The UK is an exception, because it is an island state yet often acts like a continental power. The fact that many islands are the dependent possessions in one way or another of continental countries is a major reality of ocean geopolitics. In some cases, this is a simple extension

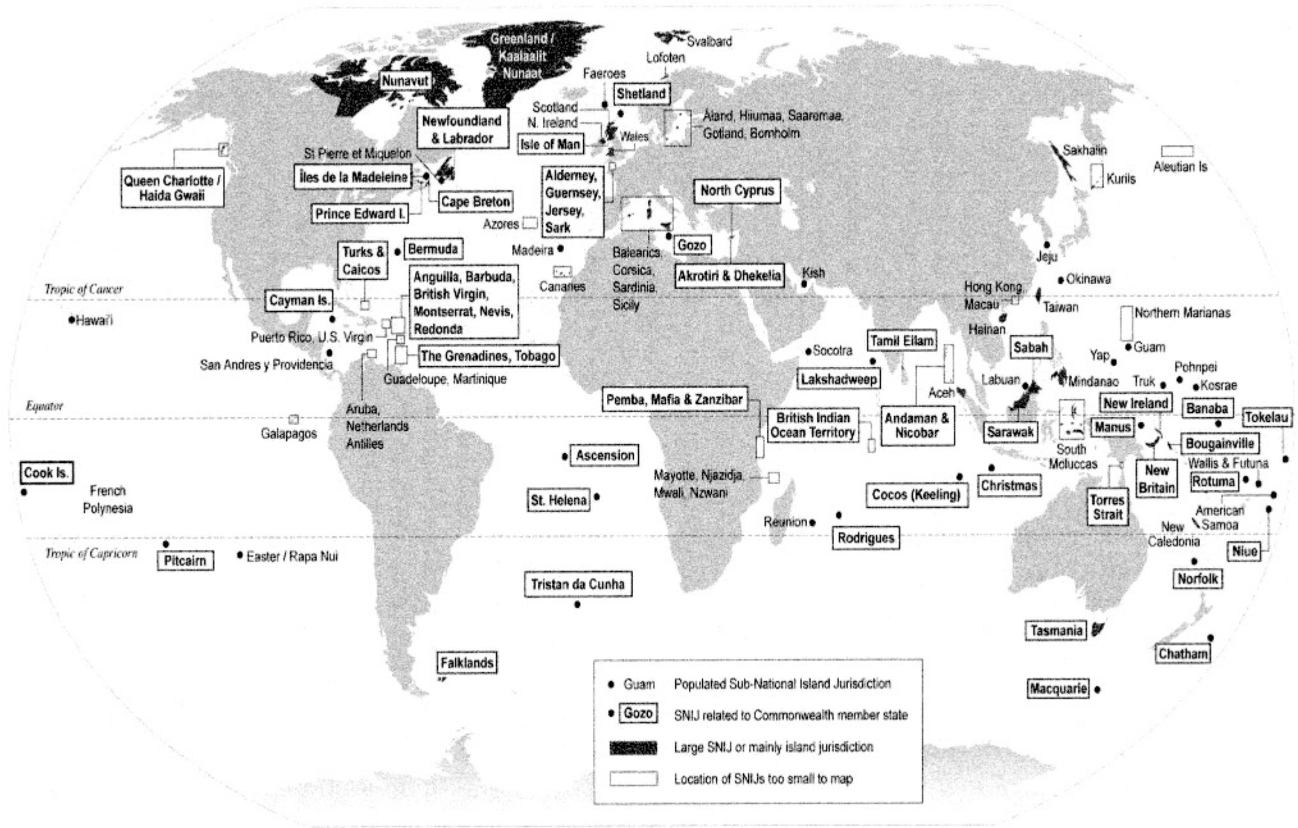
Table 2.5 The UN's Small Island Developing States (SIDS).

AIMS (Atlantic, Indian Ocean and South China Sea)	*Pacific region*	*Caribbean region*
1. Cape Verde	9. Cook Islands	24. Antigua and Barbuda
2. Comoros	10. Fiji	25. Bahamas
3. Guinea-Bissau	11. Kiribati	26. Barbados
4. Maldives	12. Marshall Islands	27. Belize
5. Mauritius	13. Micronesia, Federated States of	28. Cuba
6. São Tomé and Principe	14. Nauru	29. Dominica
7. Seychelles	15. Niue	30. Dominican Republic
8. Singapore	16. Palau	31. Grenada
	17. Papua New Guinea	32. Guyana
	18. Samoa	33. Haiti
	19. Solomon Islands	34. Jamaica
	20. Timor-Leste	35. Saint Kitts and Nevis
	21. Tonga	36. Saint Lucia
	22. Tuvalu	37. Saint Vincent and the Grenadines
	23. Vanuatu	38. Suriname
		39. Trinidad and Tobago

of their coastal waters to nearby islands, as in Australia, India, Chile and Portugal. In other cases, these are remote island territories far away and without geographic continuity, often the heritage of the colonial past of island claiming. Three countries control overseas island territories in many oceans: France, the UK and USA. Some islands in the Caribbean are still attached to the Netherlands, the Faroes and Greenland are still linked to Denmark while Norway has Bouvet and Peter Islands near Antarctica. One consequence of this is that the truly island states have neighbouring SNIJs that are, to some degree, controlled by global or local continental countries. This mix of small island developing states and world powers (via SNIJs) makes regional policy-making difficult, as exemplified in the Caribbean, Pacific and Indian Oceans. All the near-Antarctic islands below 35°S are under the control of European countries or former dominions of the UK (Australia, New Zealand and South Africa). This overwhelming extension of continental national sovereignty over islands at the world scale has direct consequences for access to oceanic economic resources as they are defined by the 200 nautical mile (370 km) exclusive economic zone.

The political interest of states in island issues is related to the importance of islands in their national territory. For most countries, their islands are relatively insignificant in terms of area, population or economic activities, and are usually marginalised in political processes. However they take on added significance when they extend national sovereignty over coastal resources or undersea oil and gas reserves, or serve as strategic outposts. Consider the tension over a bunch of rocks in the East China Sea claimed by both China (and Taiwan) and Japan (Baldacchino 2017); and the even more complex dispute over the South China Sea and its various shoals, islands and reefs between all the regional players (Rolf and Agnew 2016).

While islands may be at the small end of those geographic entities on our planet of human significance, they do help us to understand our problems and challenges at many other scales. Islands do symbolise that balance of isolated independence and integration into larger systems that are essential characteristics of all physical existence, whether geographically or metaphorically. Our planet too is an island in space, and we may have yet to learn to live within its limits.



Map 2.11 Subnational island jurisdictions.

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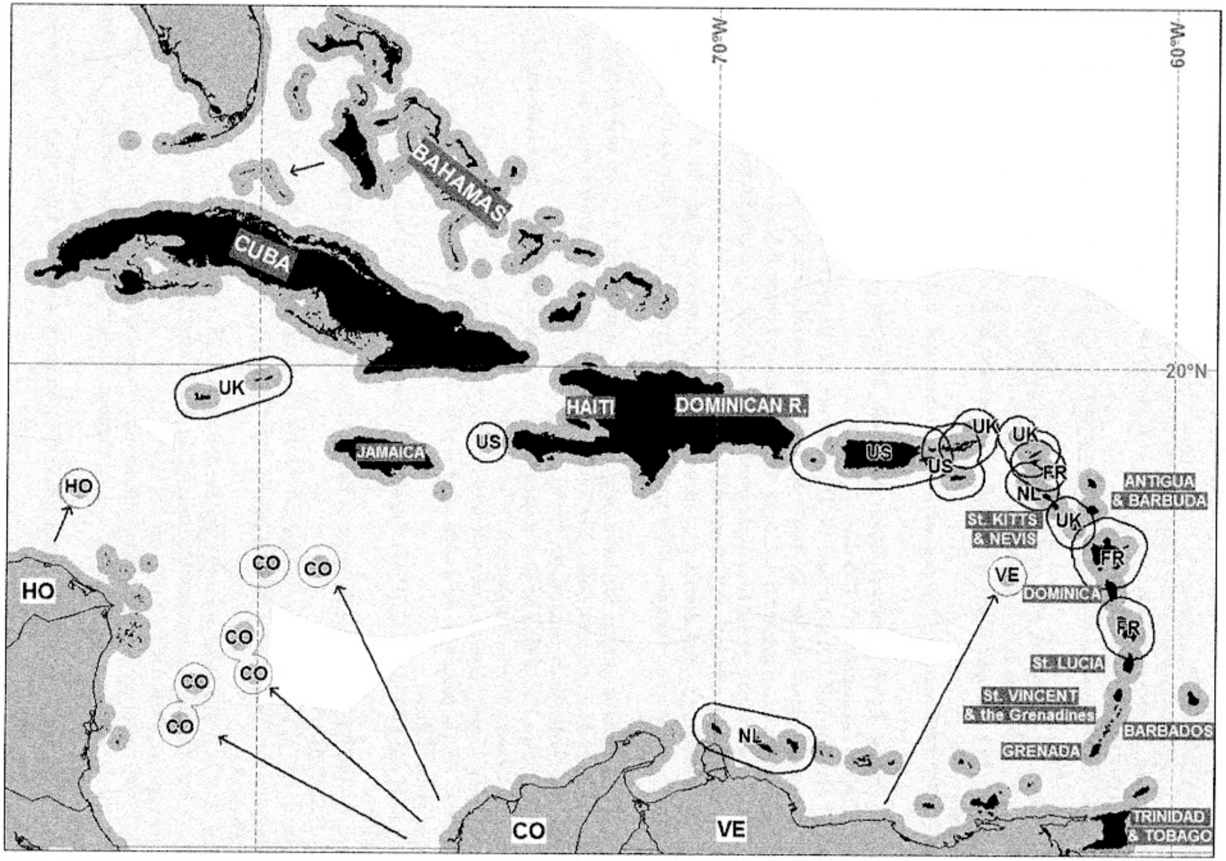

Map 2.12 Geopolitics of the Caribbean.

Source: © Christian Depraetere.

References

Baldacchino, G. (2015) *Entrepreneurship in small island states and territories*. London, Routledge.

Baldacchino, G. (2017) *Solution protocols to festering island disputes: 'win-win' solutions for the Diaoyu/Senkaku islands*. London, Routledge.

Baldacchino, G., and Milne, D. (eds.) (2009) *The case for non-sovereignty: lessons from sub-national island jurisdictions*. London, Routledge.

Bonnemaison, J. (1986) *Les fondements d'une identité, territoire, histoire et société dans l'archipel de Vanuatu (Mélanésie)*, Essai de géographie culturelle, Livre 1: *L'arbre et la Pirogue*, Paris, Editions de l'ORSTOM, Collection Travaux et Documents, No. 201.

Briguglio, L. (1995) Small island developing states and their economic vulnerabilities. *World Development*, 23(9), 1615–1632.

Brown, P., Sutikna, T., Morwood, M.J., and Soejono, R.P. (2004) A new small-bodied hominid from the Late Pleistocene of Flores, Indonesia. *Nature*, 431, 1055–1061.

Burrough, P.A. (1986) *Principles of geographical information systems for land resources assessment*. Oxford, Clarendon Press.

Dening, G. (2004) *Beach crossings: voyaging across times, cultures and self*. Melbourne, Australia, Miegunyah Press.

Depraetere, C. (1991a) Le phénomène insulaire à l'échelle du globe: tailles, hiérarchies et formes des îles océanes. *L'Espace Géographique*, 2, 126–134.

Depraetere, C. (1991b) NISSOLOG: Base de Données des Îles de plus de 100 km². Presented at XVII Pacific Science Congress (Pacific Science Association). Honolulu, Hawai'i. MSDOS Computer programme and unpublished manuscript, Centre de Montpellier, France, Editions de l'ORSTOM.

DK Atlas (2004) *The ultimate pocket book of the world atlas and fact-file*. London, Dorling Kindersley, Cambridge International Reference on Current Affairs (CIRCA).

Doumenge, F. (1984) Unity and diversity of natural features of tropical islands. In *Nature and people in tropical islands: reflections and examples*. [In French]. Bordeaux, France, CRET Bordeaux III and CEGIT, pp. 9–24.

Doumenge, F. (1989) Basic criteria for estimating the viability of small island states. In J. Kaminarides, L. Briguglio and J.N. Hoogendonk (eds.), *The economic development of small countries: problems, strategies, policies*, Delft, The Netherlands, Eburon, pp. 39–56.

Evans, I., and McClean, C. (1995) The land surface is not unifractal: variograms, cirque scale and allometry. *Zeitschrift fur Geomorphologie*, Supplement, 101, 127–147.

Gibbons, A. (1994) Genes point to a new identity for Pacific pioneers. *Science*, 263(5143), 32–33.

Lewis, D. (1994) *We, the navigators: the ancient art of land finding in the Pacific*, 2nd edn. Honolulu, HI, University of Hawai'i Press.

MacArthur, R.H., and Wilson, E.O. (1967) *The theory of island biogeography*. Princeton, NJ, Princeton University Press.

Mandelbrot, B. (1967) How long is the coast of Britain? Statistical self-similarity and fractional dimension. *Science*, 155(3775), 636–638.

Mandelbrot, B. (1975) Stochastic models for the Earth's relief, the shape and the fractal dimension of the coastlines, and the 'number-area' rule for islands. *Proceedings of the National Academy of Sciences of the USA*, 72, 3825–3828.

Mandelbrot, B. (1982) *The fractal geometry of nature*. New York, W.H. Freeman & Co.

Marrou, L. (1998) Les Îles Atlantiques Océaniques. In A. Miossec and L. Marrou (eds.), *L'Atlantique: un regard géographique*, Paris, UGI-CNFG, pp. 281–294.

McCall, G. (1994) Nissology: a proposal for consideration. *Journal of the Pacific Society*, 17(1), 1–14.

McCall, G. (1996) Clearing confusion in a disembedded world: the case for nissology. *Geographische Zeitschrift*, 84(2), 74–85.

NASA (2017a) WORLD WIND for global LANDSAT imagery. Available from: http://worldwind.arc.nasa.gov/.

NASA (2017b) Enhanced Shuttle Land Elevation Data available from 61°N to 60°S. Available from: www2.jpl.nasa.gov/srtm/.

NOAA (2017) NOAA/NGDC ETOPO2 bathymetry data. National Centers for Environmental Information. Available from: www.ngdc.noaa.gov/mgg/image/2minrelief.html.

Nunn, P.D. (2003) Fished up or thrown down: the geography of Pacific Island origin myths. *Annals of the Association of American Geographers*, 93(2), 350–364.

Rolf, S., and Agnew, J. (2016) Sovereignty regimes in the South China Sea: assessing contemporary Sino-US relations. *Eurasian Geography and Economics*, 57(2), 249–273.

UN (1992) *Agenda 21*. New York, United Nations. Available from: www.un.org/esa/sustdev/documents/agenda21/.

UN (1994) *Programme of action for sustainable development of small island developing states*. New York, United Nations. Available from: www.un.org/documents/ga/conf167/aconf167-9.htm.

UN (2005) *Report of International meeting to review implementation of programme of action for sustainable development of small island developing states*. Port Louis, Mauritius, January. New York, United Nations. Available from: http://daccessdds.un.org/doc/UNDOC/GEN/N05/237/16/PDF/N0523716.pdf?OpenElement.

UN (2014) *SIDS Accelerated Modalities of Action (SAMOA) Pathway A/RES/69/15*. New York, United Nations. Available from: www.un.org/ga/search/view_doc.asp?symbol=A/RES/69/15&Lang=E.

Wessel, P., and Smith, W.H.F. (1996) A global self-consistent, hierarchical, high-resolution shoreline database. *Journal of Geophysical Research*, 101(B4), 8741–8743. Available from: www.soest.hawaii.edu/wessel/gshhg/Wessel+Smith_1996_JGR.pdf.