Chapter 5.7 Biodiversity Baselines in the Global Ocean

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5.7 Biodiversity Baselines in the Global Ocean

5.7.1 Summary and Key Messages

Summary

This chapter provides baselines on what is currently known about the taxonomic, biogeographic, and conservation status of marine species using the world's largest marine biodiversity database, the Ocean Biogeographic Information System (OBIS; iobis.org).

The ocean may be home to one million or more species, with 230,000 so far described by science. The age of discovery continues, with the rate of description of new marine species higher than ever, suggesting that most will be discovered by the end of this century. The importance of species diversity for marine ecosystem functioning is well known. It is therefore important to know which species live where, why, in what abundance, and how these factors are changing through time.

Despite increased biodiversity monitoring since the 1950s globally, with daily averages of 120 sampling events and 1 800 observations in OBIS, 98.7 per cent of the ocean volume can still be regarded as severely under-sampled and all we know of 62 per cent of all marine species might be based on a single record. Assessments of completeness based on nonparametric richness estimators confirm that many species remain to be sampled in most parts of the world's ocean. For only 1.5 per cent of all marine regions, knowledge of species richness is >80 per cent complete. For >50 per cent of the ocean, however, no reliable estimate could be calculated and even in highly-sampled regions such as Europe, there are still many spots with over 30 per cent undiscovered or unreported species. When restricted to fish, completeness scores are higher globally, particularly in coastal areas, but not in open waters.

Understanding where species occur is a necessary first step towards identifying areas of *high* richness, endemicity, or threat, and is thus essential for effective conservation planning. For those areas with sufficient data, several biodiversity indices agree that Southeast Asia, the Southwest Pacific, the Gulf of Mexico and the Caribbean Sea are notably rich in biodiversity. This agreement is encouraging given the significant gaps and biases in OBIS data.

According to the Red List of the International Union for Conservation of Nature (IUCN), 17 per cent of marine species assessed are considered to be threatened with extinction and 20 are extinct. When plotted in OBIS, areas of greatest importance to species known to be threatened include the Caribbean and Atlantic Coast of the USA, waters between Eastern Africa and Madagascar, and the Indo-Pacific. However, considering that little is known of rare species, true rates of threat in marine species may be substantially higher, and spatially more distributed, than current estimates suggest. In addition, OBIS lists almost 500 species that have >10 observations but have not been recorded at all in the last 50 years.

Monitoring ocean biodiversity is expensive and can be risky, and requires highly skilled people. Very few marine regions or taxonomic groups have benefitted from long-term monitoring programs; hence stocktaking remains far from complete. Publishing existing biodiversity data into open data repositories such as OBIS provides the most cost-effective means to address this shortfall, and we hope that momentum in this direction can be maintained, alongside new efforts to discover and document the diversity and distribution of life in the ocean. In addition, we recommend focused efforts to monitor the abundance of key species at all trophic levels, potentially as part of a global initiative such as the Global Ocean Observing System (GOOS).

Key Messages

- Biodiversity is our natural capital, our life insurance. Understanding how much the ocean impacts us and how we impact the ocean is critical to managing our world;
- Knowledge of ocean biodiversity is highly variable: there is much more data from recent decades, and some areas of the world are far better studied than others; and

- Over 99 per cent of Earth's habitable space is marine, yet for 99 per cent of this vast realm we lack the basic biodiversity knowledge required for effective management.

5.7.2 Main Findings, Discussion and Conclusions

Taxonomic knowledge - how many species are there in the ocean?

The most basic metric of biodiversity is the number of species, and for decades scientists have been seeking to determine how many species there are on land and in the ocean. Recent estimates range from fewer than a million to 2.2 million marine species (Appeltans et al. 2012; Mora et al. 2011), much lower than past estimates of >10 million species (Grassle and Maciolek, 1992). Nonetheless, considerable uncertainty remains around the proportion of species still to be discovered (30-90 per cent; Appeltans et al. 2012; Mora et al. 2011). An authoritative listing of all currently known species on which to base such estimates is now available in the World Register of Marine Species (WoRMS; Boxshall et al., 2014), an international effort involving over 200 taxonomists. WoRMS currently lists >400,000 marine species names, of which 227,000 are accepted. The total number of described species is probably close to 230,000. WoRMS also makes it easier to track the rate of new species descriptions. Approximately 20,000 marine species new to science have been described in the past decade, and the rate of new species discoveries shows no sign of slowing down. This is due to increased taxonomic effort, new technologies, and access to previously unexplored and remote habitats.

An overview of species richness across all major eukaryotic groups, together with estimates of the number of unknown species, is given in Appeltans et al. (2012). Undiscovered species are unevenly distributed across taxa: several thousand, perhaps even >100,000 species remain to be discovered in macro-invertebrate groups such as Mollusca and Crustacea, but >50 per cent of species in most phyla are already known, and at current description rates most species will be discovered by the end of this century. For example, around 5,000 marine fish species remain to be discovered, which implies complete description of this group within three decades at the current rates of 150 new species described per year.

Despite the oceans constituting >99 per cent of Earth's available living space (Dawson, 2012), there are probably around six times fewer species in the ocean than on land. Much of this discrepancy is explained by the rapid diversification and co-evolution of terrestrial flowering plants and insects (Vermeij and Grosberg, 2010), which together comprise about 65 per cent of all species on Earth. In contrast, the ocean harbours greater evolutionary diversity and variety in life forms: life originated there, and over a third of all animal phyla remain uniquely marine, whereas only one is unique on land (May, 1994).

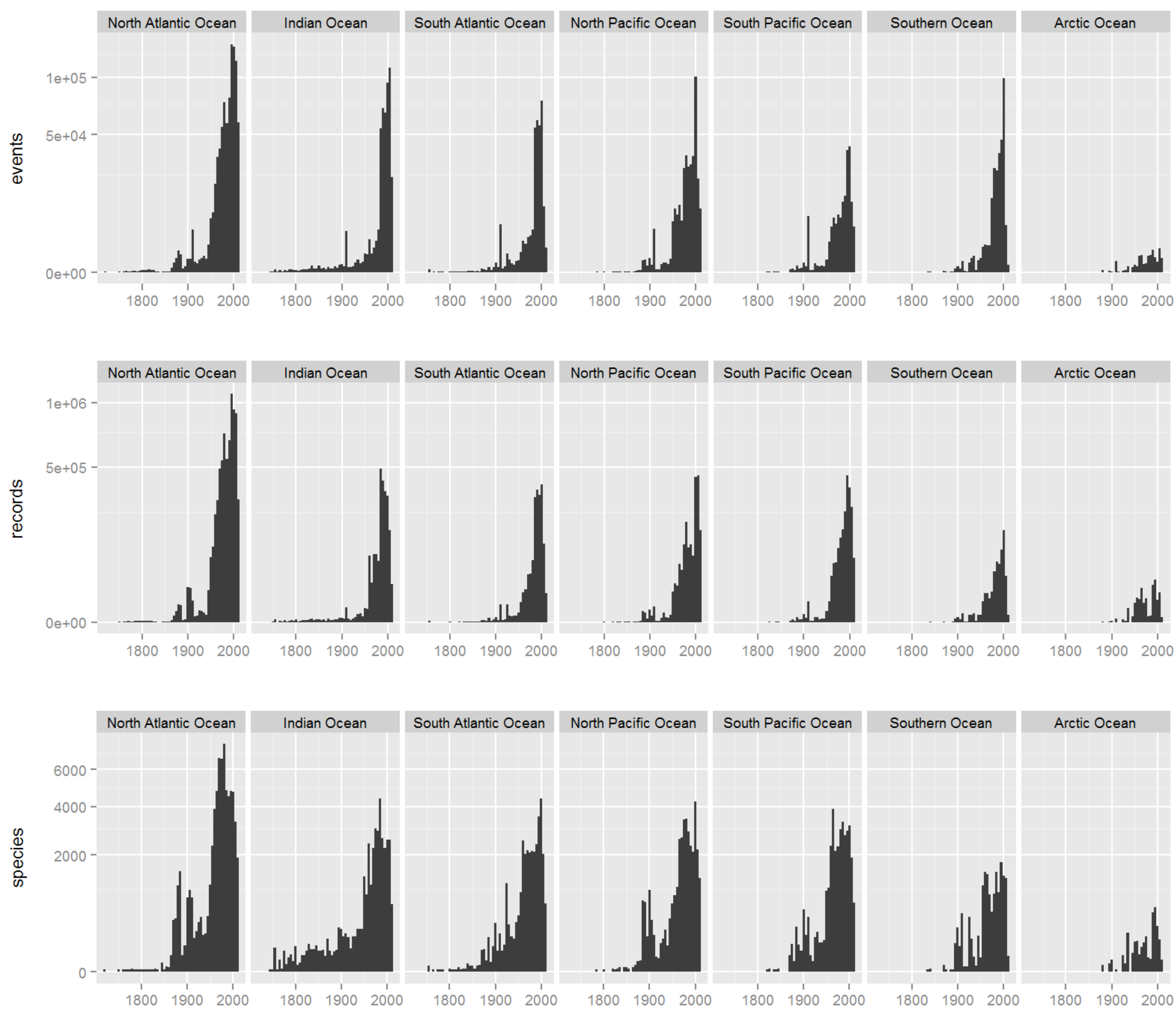
These figures do not consider the diversity of Bacteria and Archaea, which is *likely* to be at least an order of magnitude higher than eukaryotic diversity. However, due to the *high* uncertainty around prokaryotic diversity, as well as the difficulty of applying standard species concepts to these groups, they are not treated here.

Biogeographic knowledge of marine biodiversity

The importance of species diversity for marine ecosystem functioning is well known (Solan et al. 2012). It is therefore important to know which species live where, why, in what abundance, and how these factors are changing through time.

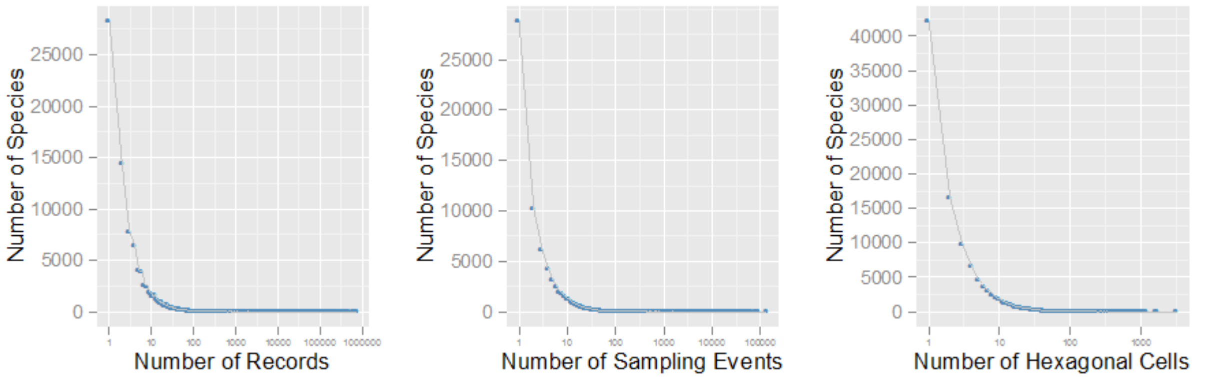
The 38 million distribution records in the Ocean Biogeographic Information System (See Methods) cover 114,000 marine species from bacteria to whales. Records are drawn from a total of 37,753 sampling days between 1562 and 2014. Figure 5.29 shows the number of sampling days, records, and species over time for each major ocean basin. Early peaks in species numbers are observed in the Indian Ocean, but species records in all regions begin to increase in the late 19th century, and especially as sampling effort intensified worldwide in the mid-20th century. Since the 1960s, sampling has been intensive, with daily averages of 120 sampling events and 1,800 observations. Over this period, the North Atlantic has been the most heavily sampled ocean basin. Globally, the number of species reported peaked with a decadal maximum of 40,000 species observed in the 1980s, earlier than the peak of 800,000 sampling events and 10 million records in 1990s. Again, the North Atlantic dominates this trend, where the relative number of observed species was twice as high as in other ocean basins during the 1970s-1980s, but drastically decreased afterwards.

Figure 5.29. Number of sampling events (top), records (middle) and species (bottom) in OBIS per major ocean basin through time.



Most species in OBIS are known from very few records (Figure 5.7.2). Only 1,133 (1 per cent) species have been observed >1,000 times. The ‘average’ species (median values) is known from 5 records, 2 grid cells (*c.*100,000 km^2), and 2 sampling events, and 25 per cent of species only have a single record. Previous analyses have also found that most species are known from few records; for instance, around 30 per cent of all species have only been collected once and are thus ‘uniques’ (Thessen et al. 2012; Lim et al. 2012); and more generally rarity is the norm in marine species (Connolly et al. 2014). If all marine species that are not recorded in OBIS are known only from their type locality, the prevalence of uniques could be as high as 62 per cent.

Figure 5.30. Number of species with different number of total OBIS records (left), distinct sampling events (centre), and number of occupied hexagonal grid cells (right). The x-axis is logarithmic in each case. Most species have very few records, from few sampling events, and occur in few hexagonal cells - very often just a single record is available.



Sampling effort on a geographical scale is provided by mapping the global distribution of the number of sampling days, records, species and phyla. Each variable is shown on an equal area icosahedron grid (Carr et al. 1997) containing 2,562 cells each of *c*. 200,000 km^2. The highest number of sampling events (Figure 5.31) occurred in Northwest Europe, Northeast US and South Africa, with high levels of sampling in the oceanic North Atlantic and Northwest Pacific due to the Continuous Plankton Recorder Survey. Generally there have been fewer sampling events in the Southern Hemisphere, especially in the open ocean and in Southeast Asia, although areas of more intensive sampling exist on the Patagonian Shelf, Southern Africa, Eastern Australia and around New Zealand. The highest number of records (Figure 5.32) is clearly concentrated around coastal areas but with gaps off Chile, Ecuador, Mexico, north-eastern South America, Angola, North-Africa, Tanzania, Somalia, the Red Sea, Southeast Asia and the Northwest Pacific. The number of observed species (Figure 5.33) is often correlated with sampling effort with high numbers of species reported around the UK and Ireland, Northeast US, Gulf of Mexico, South Africa, the Mozambique Channel, Northeast Australia (Great Barrier Reef), New Caledonia and the Antarctic Peninsula. However, parts of Southeast Asia and the Southwest Pacific Islands also have high species numbers, despite little sampling effort. High species richness does not necessarily mean all taxonomic groups are equally well represented or sampled everywhere. In addition, the number of species per phylum varies from one to many thousands. Nonetheless, the number of phyla sampled per grid cell provides an indicator of gaps in sampling coverage (Figure 5.34). Interestingly, compared to other regions with comparably low sampling intensity, the Indian Ocean is rich in phyla.

Figure 5.35 shows the number of species recorded in each major taxonomic group for the continental shelf (<200m depth) and open ocean (>200m depth) regions of each ocean basin. The Arctic Ocean, the Southern Ocean and the North Pacific have fewer species in OBIS compared to other regions. The three largest taxonomic groups (Pisces, Crustacea and Mollusca) have the greatest representation in all regions except for the Polar seas. In the Arctic Ocean the three largest groups are Crustacea (25.0 per cent), Annelida (11.6 per cent), and Foraminifera (10.5 per cent), whereas Crustacea (19.0 per cent), Mollusca (11.5 per cent), and Bryozoa (11.3 per cent) dominate in the Southern Ocean. Crustacea constitute between 18.5 per cent (Indian Ocean) and 25.0 per cent (Arctic Ocean) of all species in a region, Pisces vary between 2.9 per cent (Southern Ocean) and 23.7 per cent (North Pacific), and Mollusca between 10.4 per cent (Arctic Ocean) and 19.9 per cent (Indian Ocean).

Figure 5.31. Global map showing the number of sampling days in OBIS per hexagonal grid cell of c. 200,000 km².

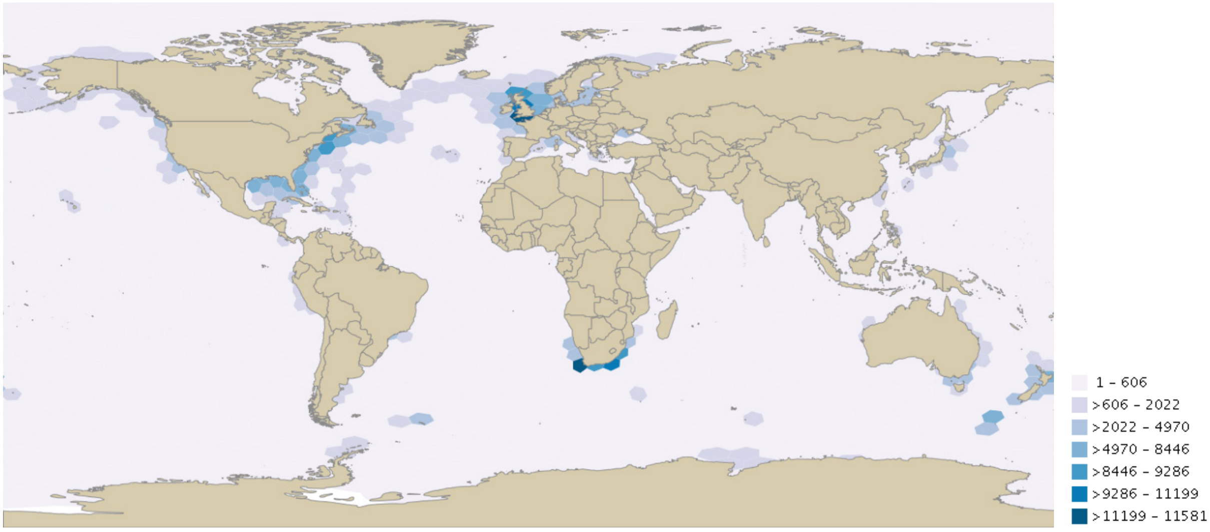


Figure 5.32. Global map showing the number of records in OBIS per hexagonal grid cell of c. 200,000 km².

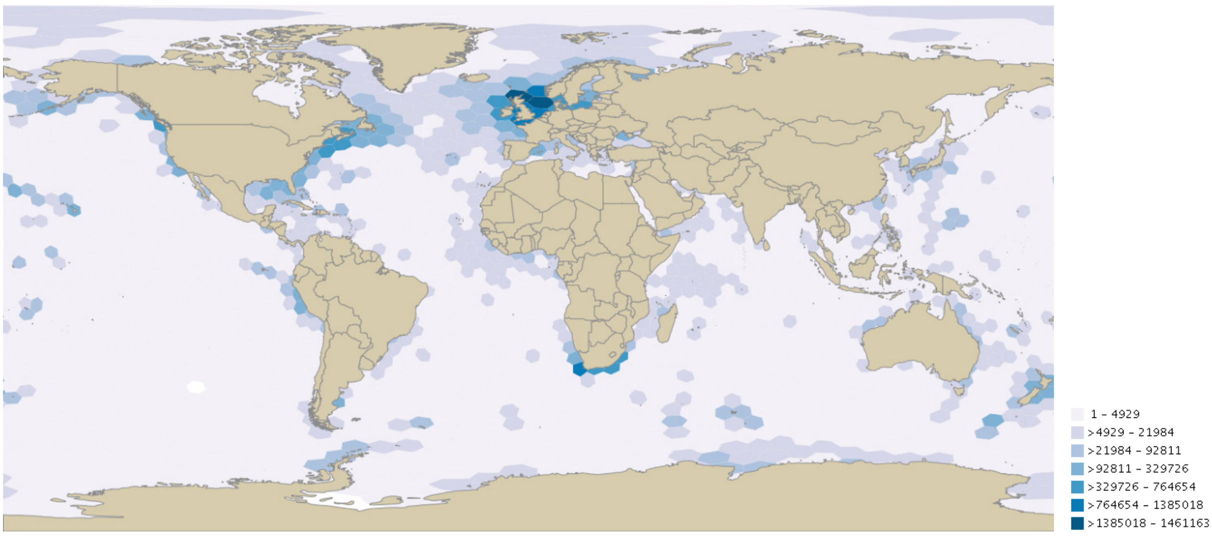


Figure 5.33. Global map showing the number of species in OBIS per hexagonal grid cell of c. 200,000 km².

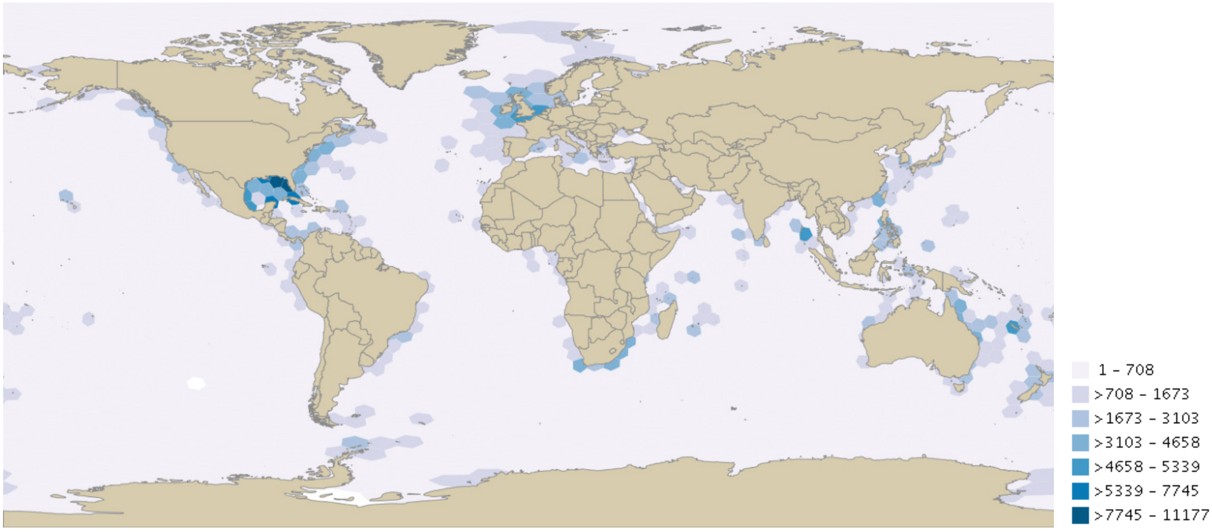


Figure 5.34. Global map showing the number of phyla in OBIS per hexagonal grid cell of c. 200,000 km².

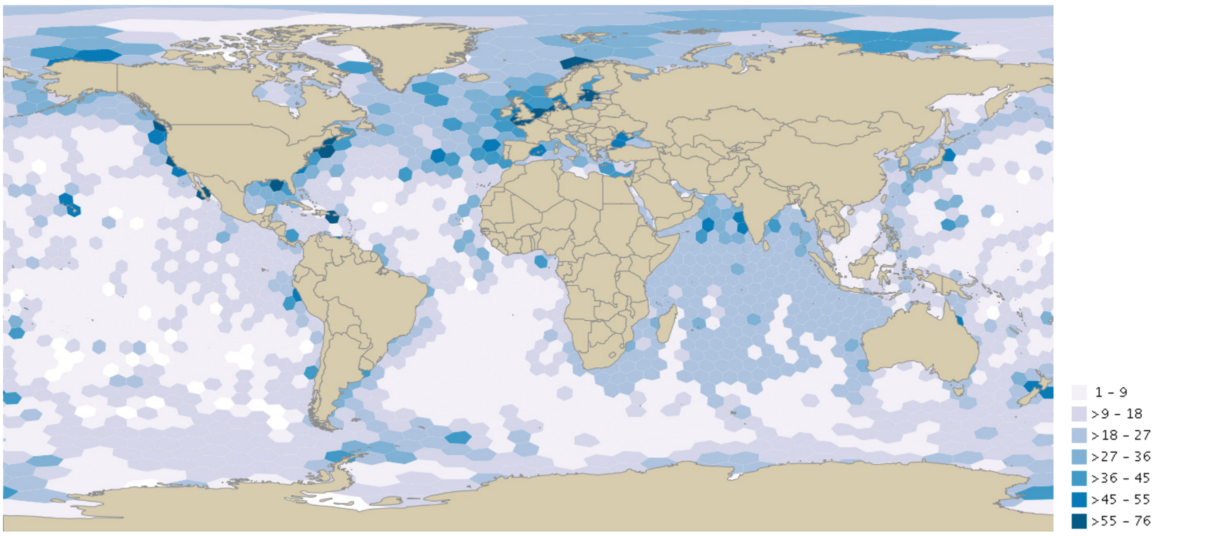
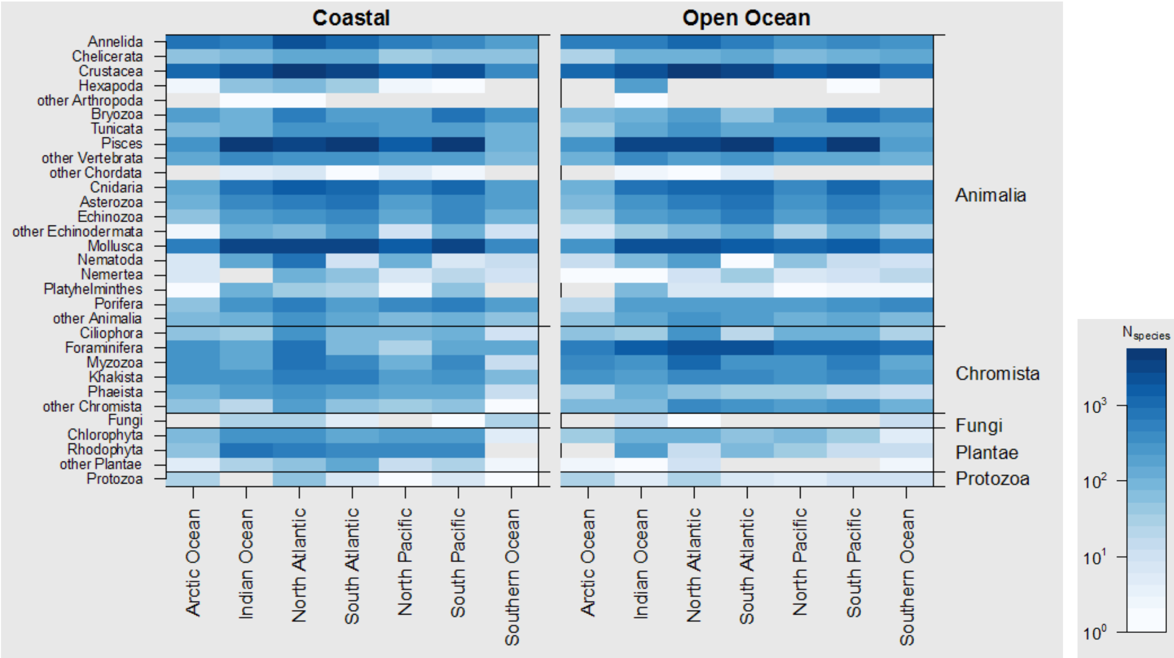


Figure 5.35. Number of species in OBIS per major taxonomic group, per ocean basin (divided in coastal/continental shelf and open ocean/deep sea).

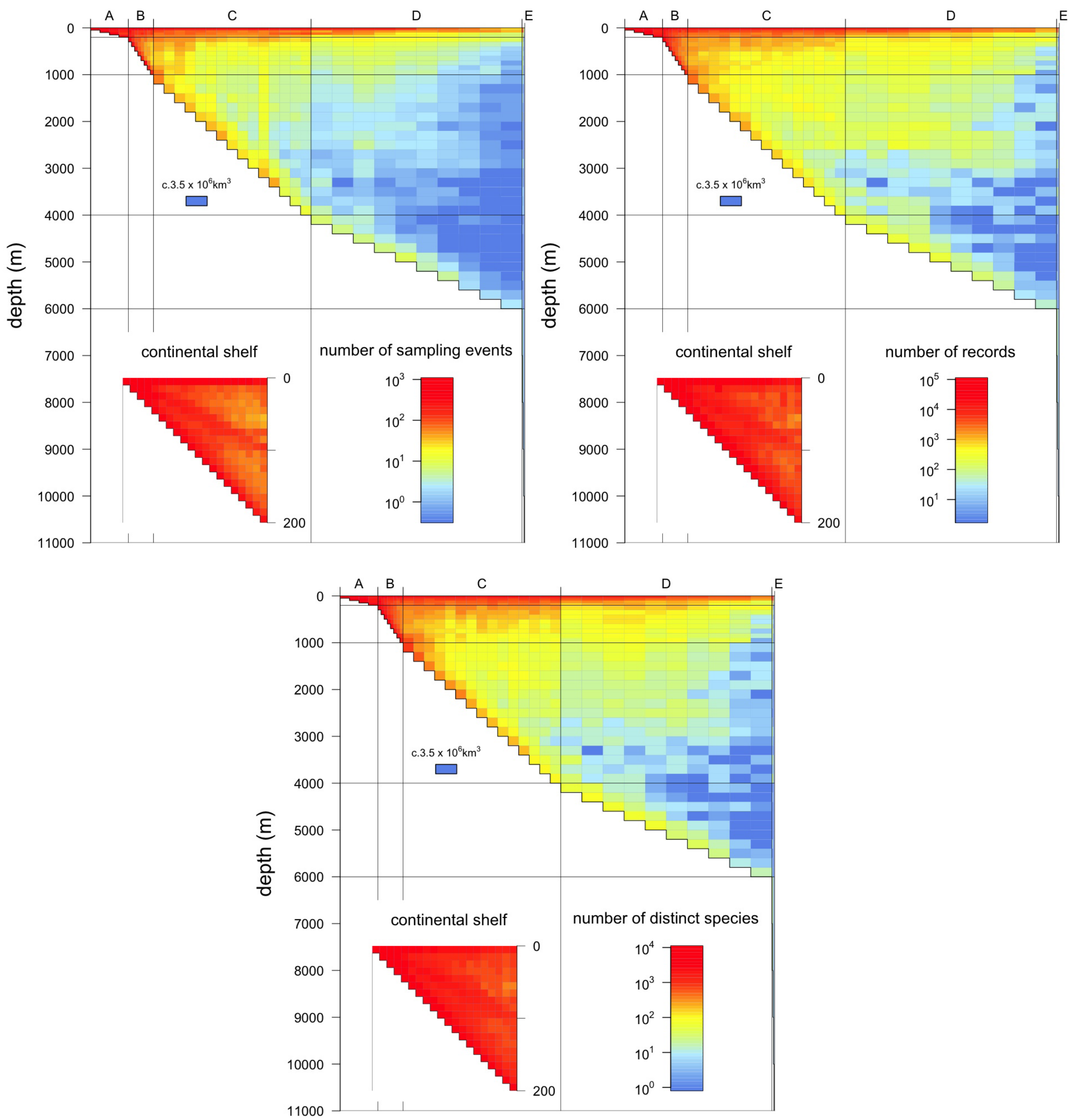


Figures 5.36 shows the distribution of sampling events, records and species in the water column using the c. 19 million OBIS records with sampling depth information (see also Table 5.7.1). This figure updates Webb *et al.* (2010), which used c. 7 million records. Values in each cell are standardized to the cell's volume. Sample depth varies from the sea surface to 10,900 m. The seas above the continental shelf (0-200m) are clearly the most heavily sampled, followed by the mesopelagic continental slope (200-1,000m deep). In contrast, there are only two species records for every 100,000km^3 above the abyssal plain (4,000-6,000 m), a zone that represents 70 per cent of the ocean volume. In fact, all zones with bottom depth deeper than 1,000 m (zones C, D, E in Figure V and Table 5.7.1) are severely under sampled. Together these zones make up 98.7 per cent of the total ocean volume, or c. 98.5 per cent of the entire planet's habitable volume.

Table 5.7 Number of sampling days, species distribution records and species within each depth zone of the global ocean (see also Figure 5.36). Actual counts are followed in parentheses by numbers normalized per 105 km^3. The contribution of each zone to the volume of the global ocean is also shown.

Zone	Sampling days	Records	Species	% Ocean Volume
A: Continental shelf (0-200m)	529,248 (13,471)	10,154,841 (258,467)	89,418 (2,276)	0.31
B: Mesopelagic continental slope (200-1,000m)	266,846 (1,961)	2,086,305 (15,330)	42,200 (310)	1.07
C: Bathypelagic continental slope (1,000-4,000m)	339,696 (100)	2,428,958 (713)	43,743 (13)	26.77
D: Abyssal plain (4,000-6,000m)	103,038 (12)	778,213 (87)	17,650 (2)	70.32
E: Hadal zone (>6,000m)	1,790 (10)	21,039 (106)	1,749 (9)	1.56

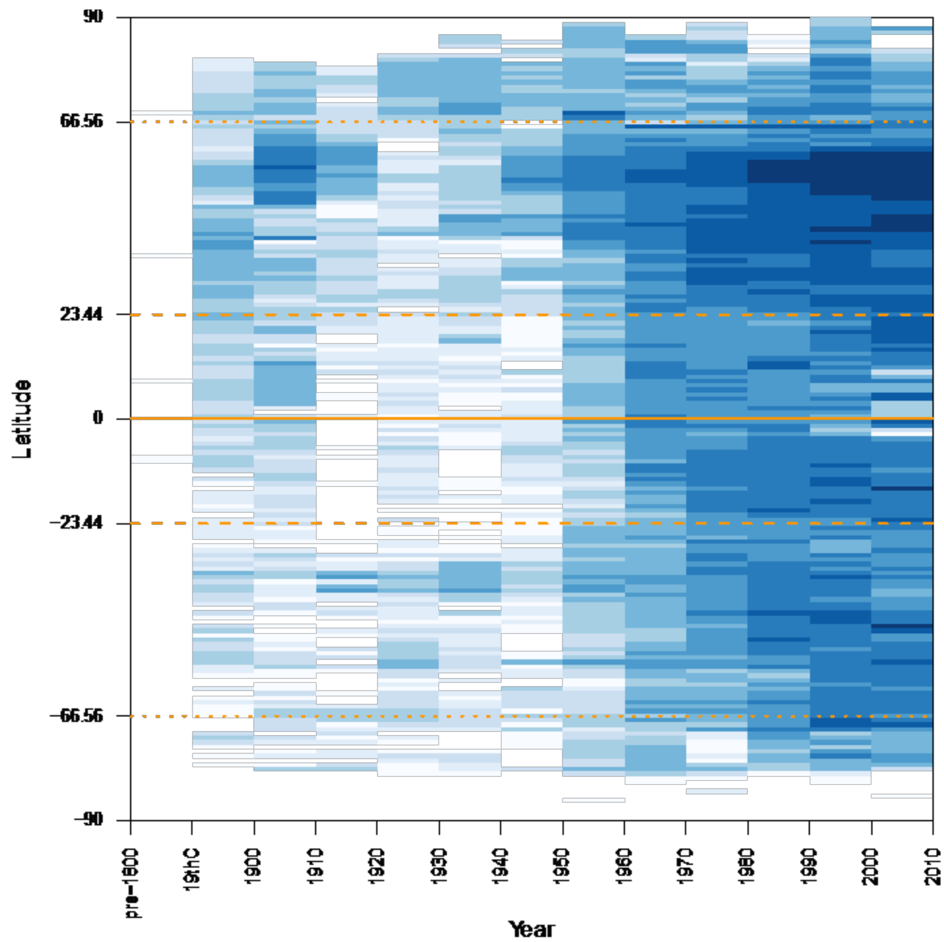
Figure 5.36. Standardised depth figures with the global distribution of sampling days (a), records (b) and species (c) in OBIS. The inset shows the continental shelf (zone A) in greater detail, where the highest values are recorded.



Figures 5.37, 5.38 and 5.39 show how species distribution records have accumulated through time by latitude, longitude, distance from the nearest land, and depth. Figure 5.37 shows the clear trend towards more sampling starting from the 1950s-1960s, initially in northern temperate regions but with progressively more sampling in the Southern Hemisphere, the Tropics, and Polar regions. In all decades since, most sampling has been within 250 km of the coast, although since 1950 sampling has increased up to 1750km out to sea (Figure 5.38). Almost no sampling has occurred in the remotest parts of the ocean > 2000 km from land, except for a few records from the 1960s. Although the deep sea remains poorly sampled, sampling the shelf (for example: 500-1,500m) has increased through time, with 70x more records in the 1990s (*c.*170,000) than in the 1950s (*c.* 2,500, Figure 5.39). Sampling between 3,000-5,000m peaked in the 1970s (*c.* 7,500 records), dropping to *c.* 1,600 records in the 2000s, and sampling between

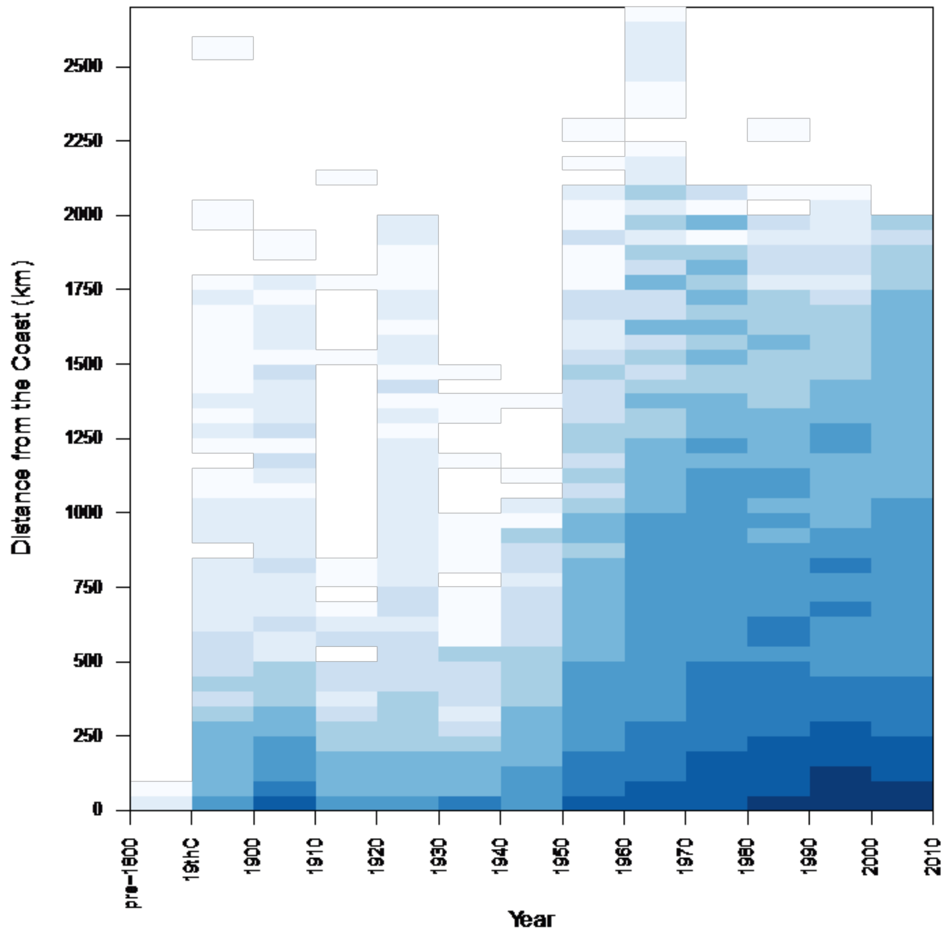
1,000-3,000m peaked in the 1990s (*c.* 78,000 records), down to *c.* 37,000 records in 2000s. The peaks in the 1970s correspond with the origins of quantitative deep-sea ecology (Sanders and Hessler 1969) and the discovery of hydrothermal vent communities (Spiess et al. 1980). Recent drop-offs may be due to the time lag between sampling events and transfer of data to OBIS.

Figure 5.37. The number of species distribution records per decade in OBIS per latitude and longitude.



Understanding where species occur is a necessary first step towards identifying areas of *high* richness, endemicity, or threat, and is thus essential for effective conservation planning. A complete map of species richness could be achieved in theory by globally comprehensive sampling until no new species are found in any region. Given the large shortfall in both taxonomic descriptions and spatial sampling outlined above, this is not practical for all groups in the ocean, although existing data have allowed global analyses of certain taxonomic or functional groups (for example: Roberts et al. 2002, Tittensor et al. 2010). For larger sets of species, species richness estimators can be used to estimate the total number of species across a spatial grid. For instance, the Chao2 index uses the frequency of rarely observed species (those occurring either once or twice in a sampling unit such as a spatial grid cell) to estimate the *likely* number of undetected species, and thus to extrapolate from samples to estimates of total species richness (Gotelli and Colwell, 2011; Chao et al. 2009). Figure 5.40 maps the Chao2 estimate of species richness globally, together with estimates of the completeness of OBIS coverage (number of species observed in OBIS divided by Chao2 estimated species richness). Some areas in Southeast Asia have *very high* estimates of species richness. However, overall estimates still appear to be strongly influenced by sampling intensity (compare Figure 5.40 with Figure 5.32), with higher estimated richness in the (well sampled) North Sea than in many parts of the (poorly sampled) tropics.

Figure 5.38. The number of species distribution records per decade in OBIS as a factor of distance away from the nearest land.



To address to some extent the different levels of taxonomic completeness of surveys in different parts of the world, Figure 5.40 also provides maps for fish only. Surveys aiming to sample the entire fish community are not uncommon, and together fish represent 50 per cent of all records in OBIS.

The completeness maps provide an overview of the current status of knowledge. For 56 per cent of the grid cells no reliable Chao2 estimate (nor completeness score) could be calculated because (i) the number of unique species in that area was higher than 50 per cent or (ii) the confidence intervals were so high that the estimate would be unreliable. Only 3 per cent of those areas for which Chao2 could be calculated (for example: 1.5 per cent of all marine regions) have a completeness score >80 per cent, suggesting that many species remain to be sampled in most parts of the world's ocean. Completeness scores were somewhat higher for fish, but estimates of total richness were largely restricted to coastal areas in this case. Even regions like Europe with high sampling intensity still have many areas with over 30 per cent undiscovered or unreported species. Clearly the higher sampling effort in those areas in the Southern Hemisphere noted in 2.1, such as the Patagonian Shelf and the part of the Southern Ocean south of Australia, has resulted in relatively high completeness scores.

Other biodiversity indices attempt to correct for sampling bias in other ways. Figure 5.41 maps global diversity patterns from OBIS data based on three alternatives. The Hulbert index (or ES50) calculates the expected number of species in a random selection of 50 records (Figure 5.41a). Hill numbers (Hill 1973) account for species' relative abundance (here, number of records in OBIS). Hill1 can be roughly interpreted as the number of species with 'typical' abundances (Figure 5.7.8b); Hill2 (Figure 5.7.8c), which discounts rare species, can be interpreted as the equivalent

Figure 5.39. Three plots showing the number of species distribution records for depths of ‹200m, 200-1000m, and ›1000m in OBIS. The colour scale is re-set for each plot, so that dark blue means many more records in the ‹200m plot than in the ›1000m plot. The depth resolution changes too (10m -› 50m -› 500m).

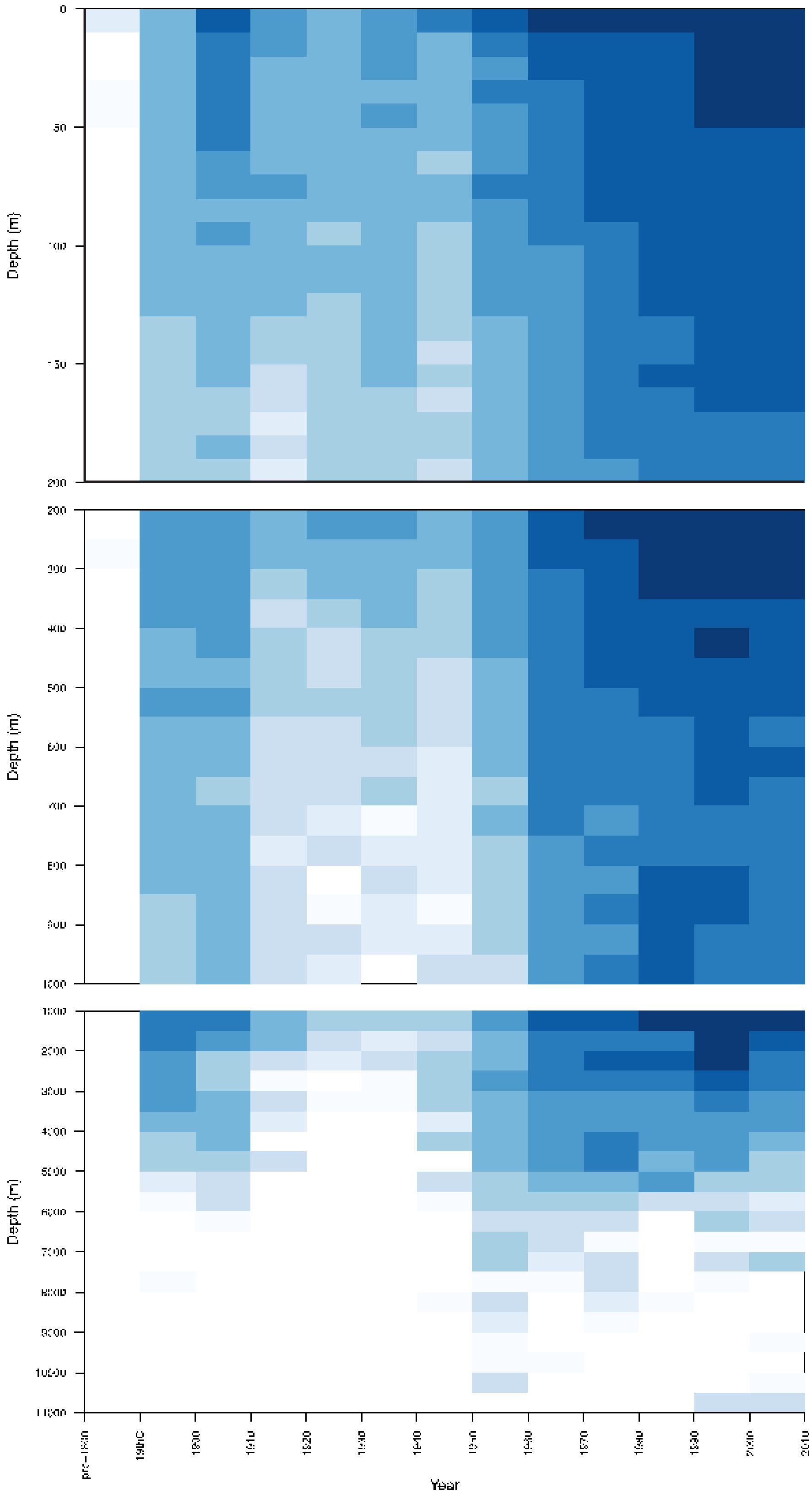


Figure 5.40. Global map showing the total species richness estimates and completeness scores per hexagonal grid cell of c. 200,000 km² based on the unbiased non-parametric Chao2 index using data from OBIS. (a-b) includes all biota, (c-d) is restricted to fish data from OBIS.

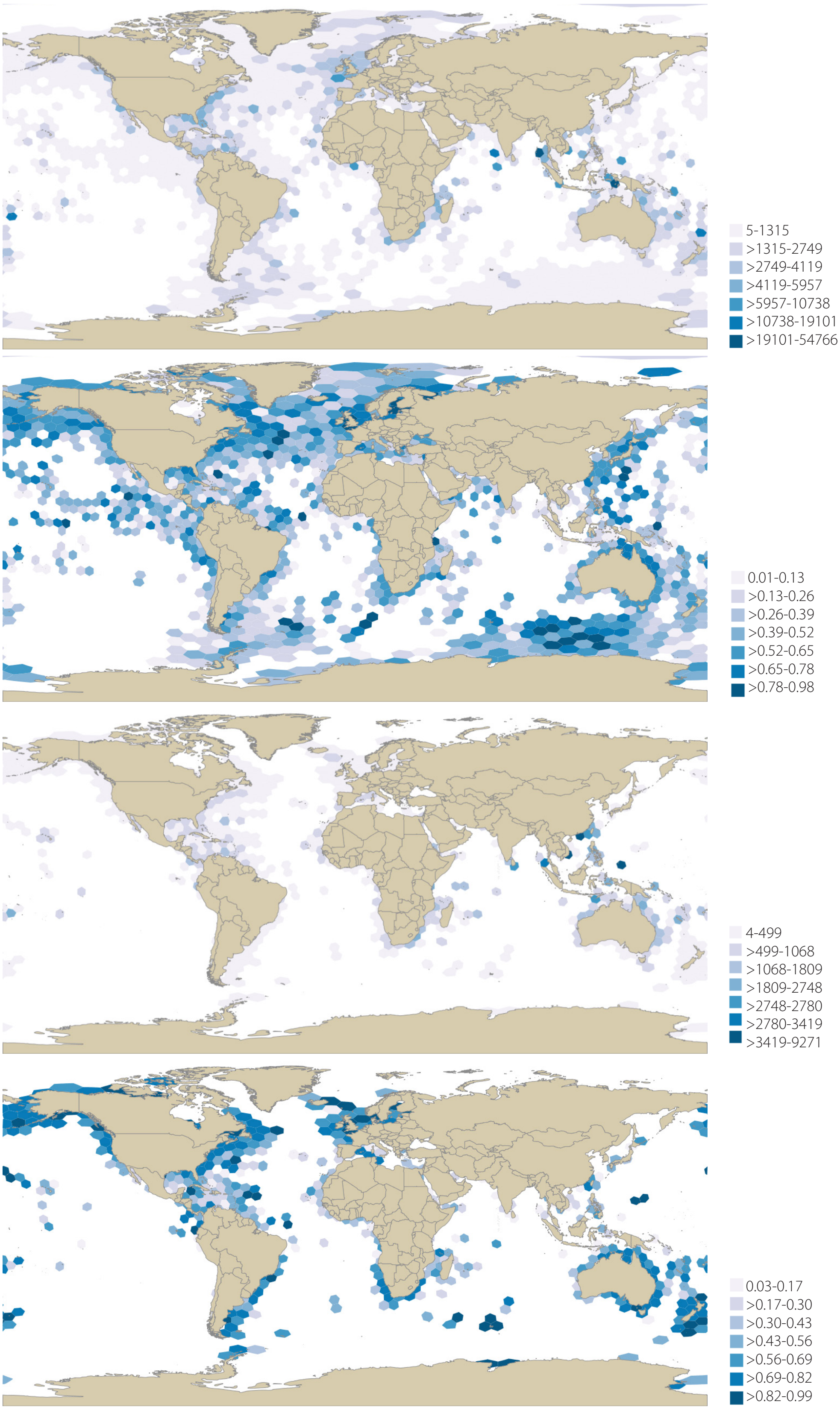
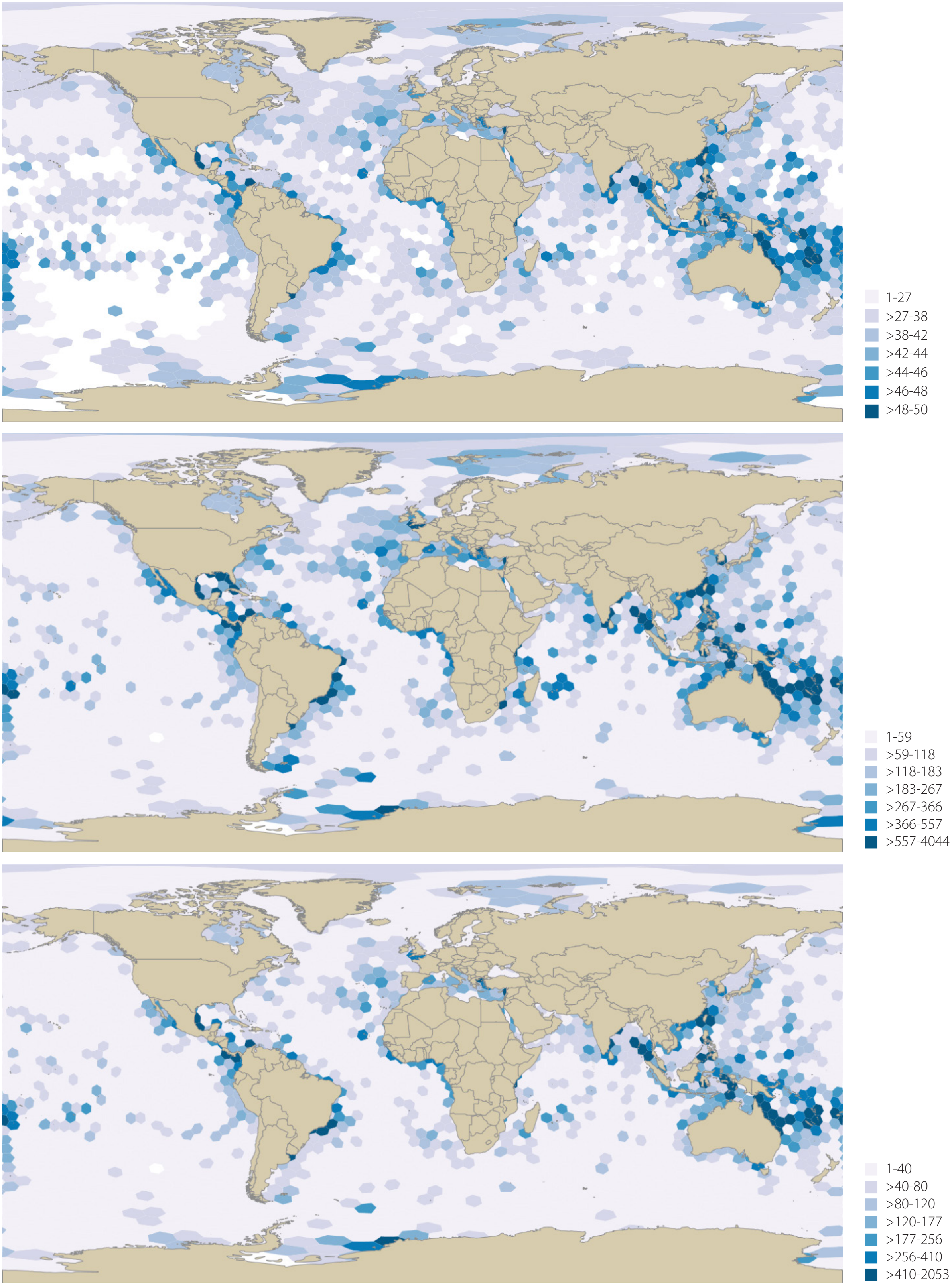


Figure 5.41. Global map showing biodiversity richness indices based on Hulbert index (a), Hill1 (b) and Hill2 (c) per hexagonal grid cell of c. 200,000 km².



to the number of more dominant species and so is less sensitive to sample size than Hill1. Each of these indices has its own issues (Gotelli and Colwell, 2001), especially when applied to such a large and heterogeneous dataset as OBIS; yet there is general agreement that Southeast Asia, the Southwest Pacific, the Gulf of Mexico and the Caribbean Sea are rich in biodiversity. Together, indices like Chao2, ES50, and Hill numbers can help to identify regions that are especially rich or especially poorly sampled, helping to set priorities for future exploration of the ocean.

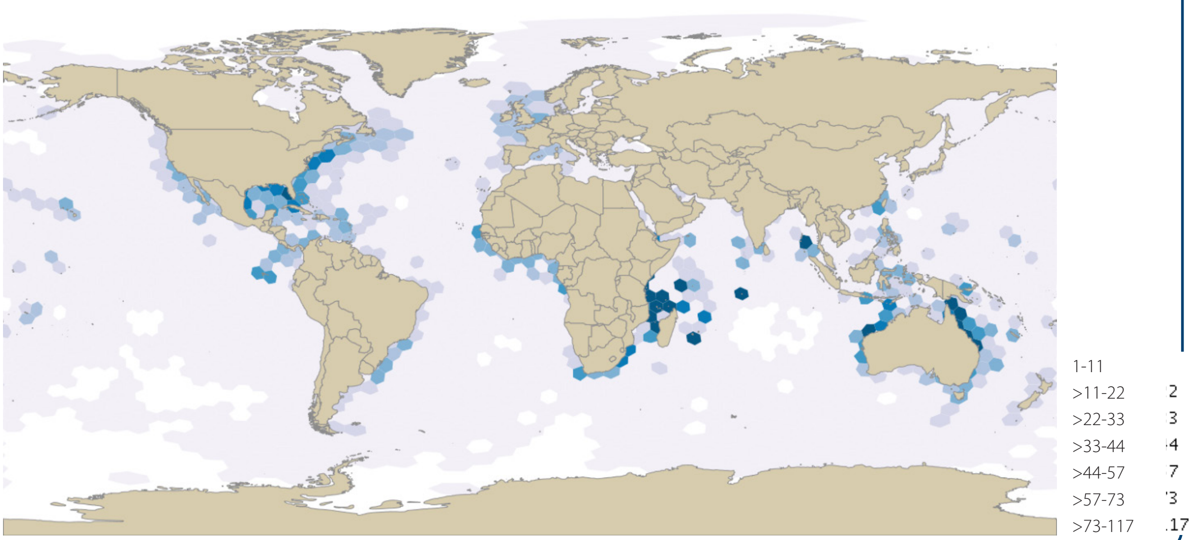
Threats to biodiversity

A recent comprehensive inventory of threats across 24 key global ocean areas was provided by the Census of Marine Life (PLoS One, 2010). Briefly, overfishing, habitat loss, and pollution are the greatest threats to biodiversity in all regions, followed by invasive species and impacts of climate change. Establishing biodiversity baselines requires that recent declines and extinctions of marine species due to these pressures are quantified.

Only 4 per cent of described marine species (9,554 out of 230,000) have been assessed by the IUCN, of which 2,730 (29 per cent) are rated as Data Deficient (DD), too poorly known to assign to an IUCN category. Of the remaining 6,824 species, 1,194 (17 per cent) are considered to be threatened with extinction (IUCN categories Vulnerable VU, Endangered EN or Critically Endangered CR) and 20 are extinct. For the best-known taxonomic groups, rates of extinction risk across assessed species average 20-25 per cent (Webb and Mindel, 2015).

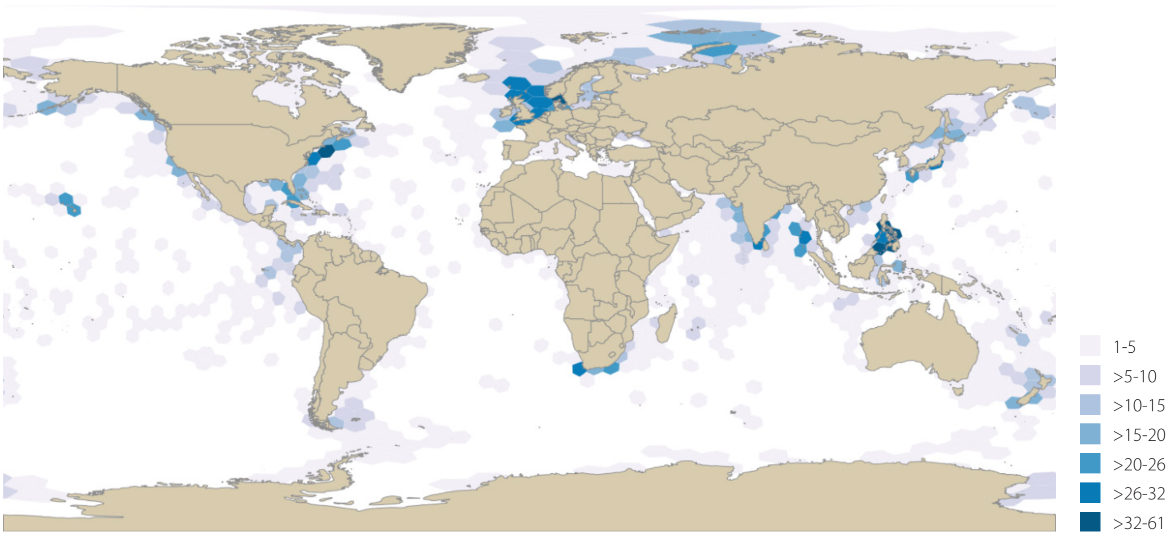
Areas of greatest importance to species known to be threatened (IUCN categories VU, EN, and CR) include the Caribbean and Atlantic Coast of the USA, waters between Eastern Africa and Madagascar, and the Indo-Pacific (Figure 5.42). However, given that DD species often have characteristics typical of threatened species (Pimm et al. 2014, Dulvy et al. 2014) and may occur in different regions from species known to be threatened (Pimm et al. 2014), true rates of threat in marine species may be substantially higher, and spatially more distributed, than current estimates suggest.

Figure 5.42. Global map showing the number of threatened species per hexagonal grid cell of c. 200,000 km² following the IUCN Red List Species categories EN, CR and VU based on species distribution records from OBIS.



OBIS allows us to identify some priority species by tracking occurrences through time. For instance, 472 species have >10 records in OBIS but have not been recorded at all in the last 50 years. These pseudo-extinctions have occurred notably in the Baltic and the equatorial coast of Western Africa (Figure 5.43), and are worthy of further investigation.

Figure 5.43. Global map showing the number of "pseudo-extinct" species per hexagonal grid cell of c. 200,000 km^2, i.e. those with <10 records in OBIS but not observed anymore in the past 50 years.



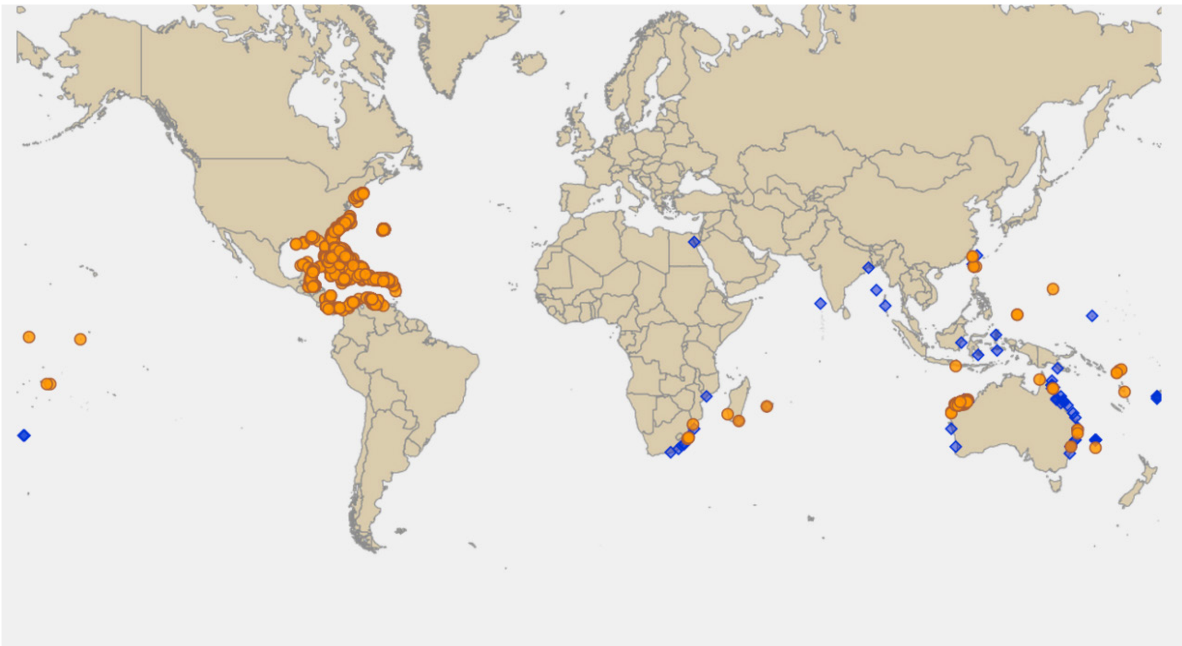
Non-native species are an increasing threat to marine environments and their biodiversity (Carlton, 2000; Rilov and Crooks, 2009). Invasions encompass both natural expansion of a species' geographic range, and direct introduction by humans. Regions have on average of 122 aliens, although some regions have many more: >600 (c. 4 per cent) of all Mediterranean species originated in another ocean area, and high numbers of aliens are also reported for Atlantic Europe and the Baltic Sea, New Zealand and Australia. Molluscs, crustaceans, and fish are the most common alien species (Costello et al. 2010). The Invasive Species Compendium (http://www.cabi.org/isc) lists the alga *Caulerpa taxifolia* and several invertebrates (for example: green crab *Carcinus maenas*, sea walnut *Mnemiopsis leidyi*, veined Rapa whelk *Rapana venosa*) as particularly significant invasive species with impacts including decreased local biodiversity and collapsed fisheries.

Differentiating native and introduced species requires baseline taxonomic and biogeographic knowledge. OBIS data provides time series of observation records of species in different geographical regions. A good example application traces the spread of the lionfish (*Pterois volitans*) in the Caribbean since its first report in 1985 (Figure 5.44) (Schofield, 2009). This species may eventually cause significant reduction in local biodiversity and abundance due to the fact that it is a voracious top predator from an early stage, has a *very high* fecundity, and resists environmental changes (Albins and Hixon, 2008; Betancur-R et al. 2011).

5.7.3 Conclusions and Recommendations

The ocean may be home to one million or more species, of which 230,000 have been described by science. The age of discovery continues, with the rate of description of new marine species higher than ever, suggesting that most will be discovered by the end of this century. It is timely then, to summarize what is currently known about the taxonomic, biogeographic, and conservation status of marine species. This study aimed to provide such a baseline, using the 38 million observations of 114,000 marine species contained in the world's largest marine biodiversity database, the OBIS. Knowledge of which species live where is highly variable: some regions are now well known, but there are also vast volumes of the oceans for which we have little or no knowledge. We know most about large, charismatic, and

Figure 5.44. Global map showing the lion fish invasion in the Caribbean Sea since 1985, based on distribution records in OBIS (orange are all species distribution records after 1985).



commercially important taxonomic groups, but most species are small and rare (scarce) or endemic (confined to small geographical areas), making them hard to identify and difficult to observe. This is reflected by the fact that the average species has just five observations in OBIS, with at least 25 per cent of species represented in the database by only a single record. On the conservative assumption that half of the remaining described marine species, not currently recorded in OBIS, are also only known from their type locality, the global prevalence of 'uniques' (species only ever observed once) could be as high as 62 per cent.

Marine biodiversity monitoring intensified worldwide in the mid-20th century, starting in the Northern Hemisphere, and progressively increasing in the Southern Hemisphere, the Tropics and Polar Regions. Most biodiversity records come from the continental shelf, but through time, sampling has intensified further away from the coast and deeper into the ocean. However, sampling remains low in very remote places (>2,000 km from land) and at >5,000m depth, and 98.7 per cent of the ocean volume (all zones with bottom depth deeper than 1,000m) can be regarded as severely under-sampled. As a consequence, there is not enough data to make a reliable estimate of species richness for more than half the ocean. For those areas with sufficient data, multiple biodiversity indices all show that South-East Asia, the South-West Pacific, the Gulf of Mexico and the Caribbean Sea are notably rich in biodiversity. This agreement is encouraging given the significant gaps and biases in OBIS data.

Increasing threats to biodiversity are causing many local population extirpations, but so far the IUCN has only documented 20 global marine species extinctions. However, around 20 per cent of marine species that have been formally assessed by the IUCN are considered to be currently threatened with extinction. Many of these threatened species occur in the most biodiversity rich and poorly monitored regions. In addition, 28 per cent of assessed species have been classified as Data Deficient (of which many may be at risk), and 96 per cent of marine species have not been assessed at all. Taking this into account, rates of extinction risk in the sea appear comparable with those on land. This is supported by the large number of species (472), which have been observed at least 10 times, but never in the last 50 years. Whether any of these are extinct remains to be established, but the picture of scarcity, decline, and risk is clear.

Changes in community composition have also been driven by increased rates of species invasions, a trend *likely* to be exacerbated as species shift their distributions in response to the changing climate. Such disruptions can have severe impacts and may alter the carrying capacity of the local ecosystem, sometimes resulting in irreversible change. Using global-scale databases to understand biodiversity baselines can help in efforts to rapidly detect change and to distinguish invasions from natural variations.

Monitoring ocean biodiversity can be expensive and risky, and requires highly skilled people. Very few marine regions or taxonomic groups have benefitted from long-term monitoring programs, hence stocktaking remains far from complete. Publishing existing biodiversity data into open data repositories, such as OBIS, provides the most cost-effective means to address this shortfall. It is hoped that momentum in this direction can be maintained, alongside new efforts to discover and document the diversity and distribution of life in the ocean. In addition, it is recommended that focused efforts are used to monitor the abundance of key species at all trophic levels, potentially as part of a global initiative such as the GOOS.

5.7.4 Notes on Methods

The biggest international initiative ever to document what lived, lives and will live in the ocean was the decade-long Census of Marine Life (2000-2010), which united 2,700 scientists from 80 nations. The Census developed a central data platform, the Ocean Biogeographic Information System (OBIS), providing an integrated map of life. This now operates and continues to grow under the auspices of UNESCO's Intergovernmental Oceanographic Commission, as a project of the International Oceanographic Data and Information Exchange (IODE) program. As of December 2014 OBIS holds 38 million observations from 1,550 datasets provided by 500 institutions in 56 countries, with new records being added all the time. The data is freely accessible online (www.iobis.org) and is used around the world for research, global and regional assessments, marine spatial planning and conservation policies. Google Scholar returns >1,000 publications that have cited OBIS (October 2014), and still grows at a rate of 7 papers per month. As the world's largest database on marine biodiversity, OBIS provides the best available source of information for this baseline chapter.

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