4. Potential for offshore mariculture development

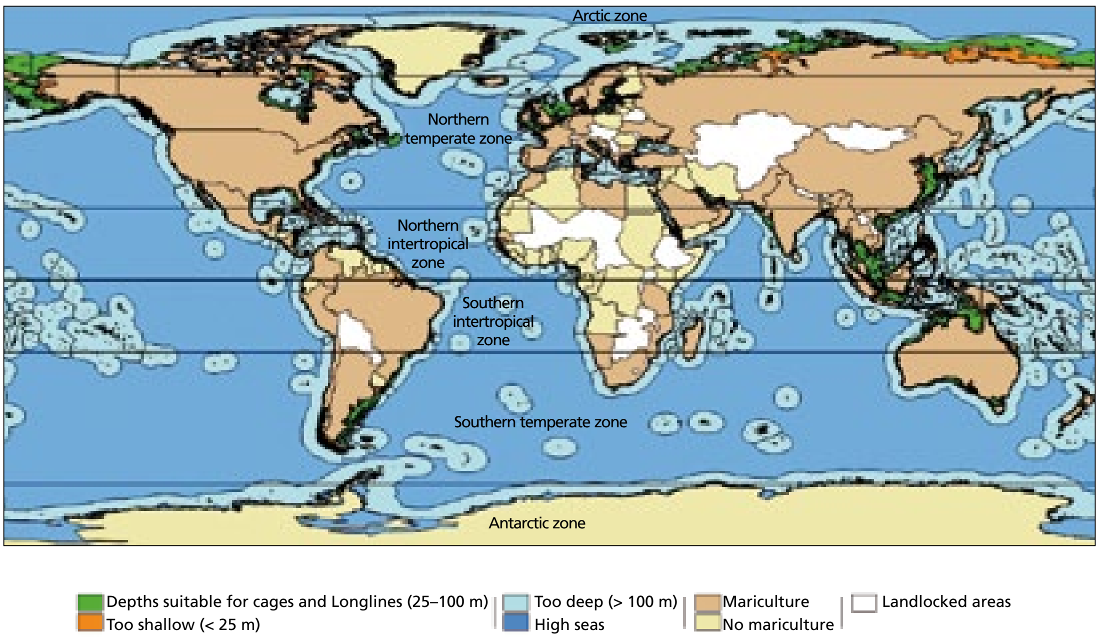
4.1 Overview

This chapter sets out offshore mariculture potential in a stepwise fashion. First, environments where it is technically feasible to place offshore cages for fish and longlines for mussels are established on the basis of water depth and current speed. The cost-effective area for development, one of many measures of economic feasibility of offshore mariculture within EEZs, is established in terms of access to a port and as the area that lies within 25 nm (46.3 km) of a port. Second, environments for favourable grow-out of cultured organisms are identified based on temperature for all three species and on chlorophyll-*a* concentration for the mussel. Then, environments for favourable grow-out are spatially integrated with the locations suitable for cage and longline systems as well as with cost-effective areas for offshore development. Finally, MPAs, as examples of locations that can compete or conflict with offshore mariculture for ocean space, are identified with respect to potential for offshore cobia culture.

4.2 Areas where it is technically feasible to place culture installations

The first technical measure of potential was depths suitable for submerged cages for fish and submerged longlines for shellfish (25–100 m) (Figure 9). Total global potential in this regard amounts to 12.4 million km^2 among the 82 mariculture nations, but only 1.0 million km^2 among the 71 non-mariculture nations (Table 3). Among the mariculture nations with the largest areas suitable for cages and longlines in this depth range are the Russian Federation, Australia and the Republic of Indonesia (Figure 10). For the Russian Federation, much of the area meeting the depth criterion is at high latitudes and

FIGURE 9
Areas with depths suitable for sea cages and longlines within economic zones



may not be available because of ice cover. Among the non-mariculture nations with the largest areas suitable for cages and longlines in this depth range are the Islamic Republic of Iran, the Bolivarian Republic of Venezuela and the Republic of Finland (Figure 11).

TABLE 3
Number of nations and corresponding areas meeting depth, current speed and cost-effective area criteria for offshore mariculture development

Technical and economic feasibility	Mariculture nations		Non-mariculture nations		Total	
	Nations	Area (km²)	Nations	Area (km²)	Nations	Area (km²)
Depths suitable for cages and longlines (25–100 m)	82	12 405 003	71	1 000 446	153	13 405 449
Current speed suitable for cages (10–100 cm/s)	77	84 244 659	69	16 790 002	146	101 034 662
Depths (25–100 m) and current speeds (10–100 cm/s) suitable for cages and longlines	73	1 234 771	65	190 383	138	1 425 154
Cost-effective area (25 nm, or 46.3 km, from a port)	79	5 119 018	74	1 015 430	153	6 134 448
Cost-effective area (25 nm, or 46.3 km, from a port) and depths and current speeds suitable for cages	69	146 820	52	42 648	121	189 468

FIGURE 10
Ranking by area of main mariculture nations in depths suitable for sea cages and longlines

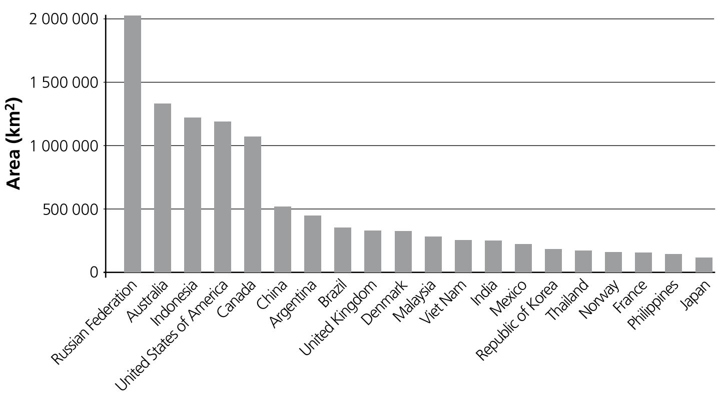
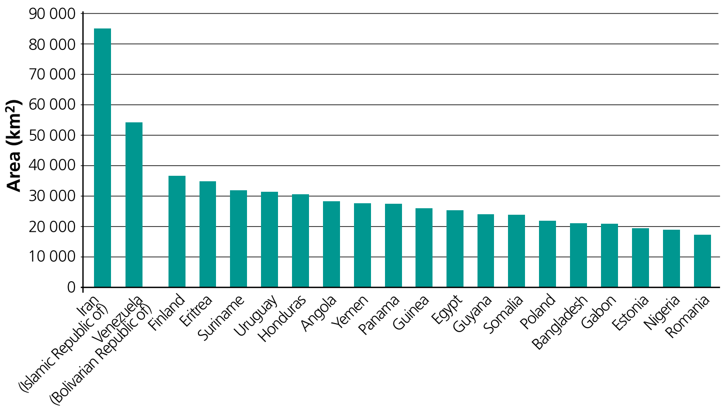
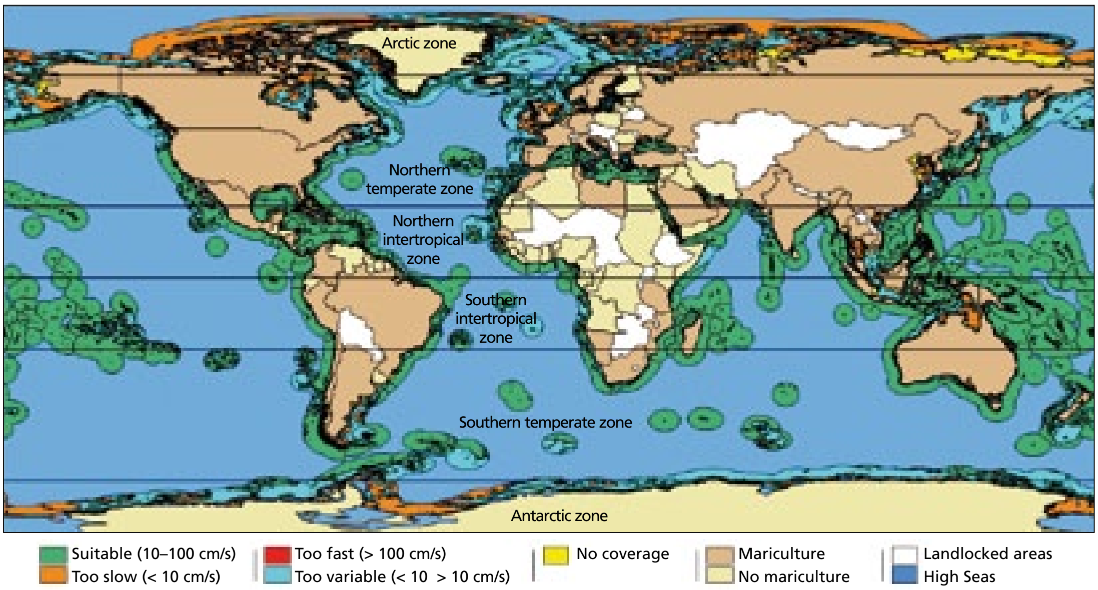


FIGURE 11
Ranking by area of main non-mariculture nations in depths suitable for sea cages and longlines



The second measure of technical potential was current speeds suitable for sea cages and longlines. The importance of current speeds as a fundamental criterion for assessing potential cannot be overemphasized for its effects on the endurance of culture structures and on the well-being of cultured organisms (Figure 2). Globally, there are large areas totalling 84.2 million km² within EEZs that have current speeds within the 10–100 cm/s threshold range. There are 77 mariculture nations, and 16.8 million km² among the 69 non-mariculture nations meeting this criterion (Table 3; Figure 12). Leading nations among those already practising mariculture are the French Republic, the United States of America and Australia (Figure 13). Leading non-mariculture nations with current speeds suitable for cages and longlines are the Federated States of Micronesia, the Republic of the Marshall Islands and the Republic of Ecuador (Figure 14).

FIGURE 12
Areas within EEZs with current speeds suitable for sea cages and longlines



Note: Areas that were identified as too fast (> 100 cm/s) are not visible at a global scale.

As would be expected with the integration of the thresholds of two technical criteria (water depths suitable for cages and longlines and current speeds), the area fulfilling both criteria is much reduced. Among the 73 mariculture nations, it is 1.2 million km^2 and among the 65 non-mariculture nations, it is only 190 000 km^2 (Table 3). The Federative Republic of Brazil, (Figure 15)[5], the Republic of Indonesia and the United States of America possess the largest area that is suitable depth-wise and in current speed for cages and longlines (Figure 16). Among the non-mariculture nations, the Bolivarian Republic of Venezuela, the Somali Republic and the Republic of Uruguay are the most important in this regard (Figure 17).

FIGURE 13
Ranking by area of main mariculture nations with current speeds suitable for sea cages and longlines

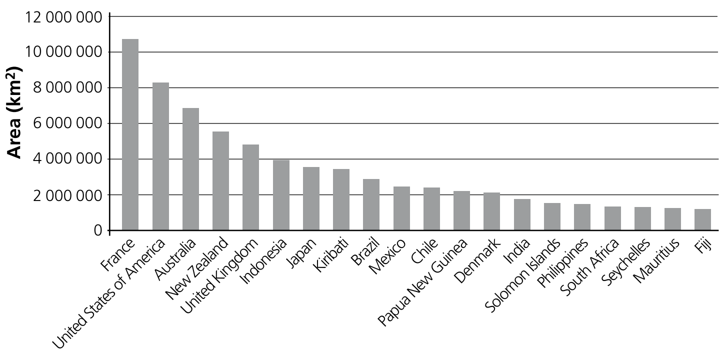
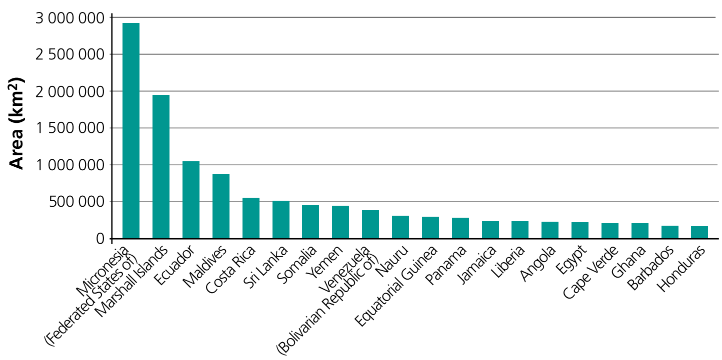


FIGURE 14
Ranking by area of main non-mariculture nations with current speeds suitable for sea cages and longlines



[5] Not all measures of offshore mariculture potential can be discerned on a map with a global view. Thus, regional views are used to call attention to countries with high potential.

FIGURE 15
Areas in northern Latin America with current speeds and depths suitable for sea cages and longlines

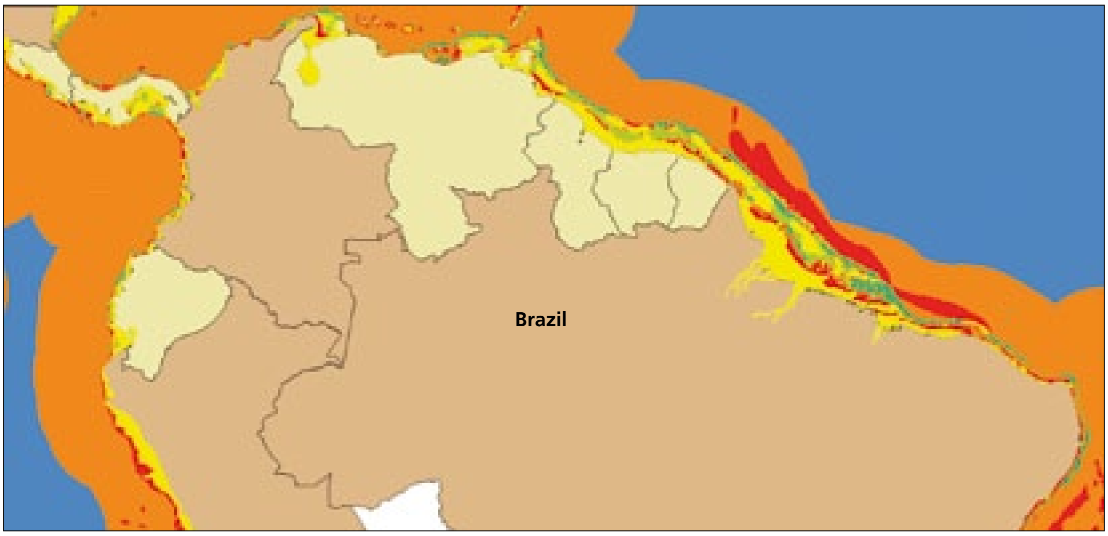


FIGURE 16
Ranking by area of main mariculture nations with current speeds and depths suitable for sea cages and longlines

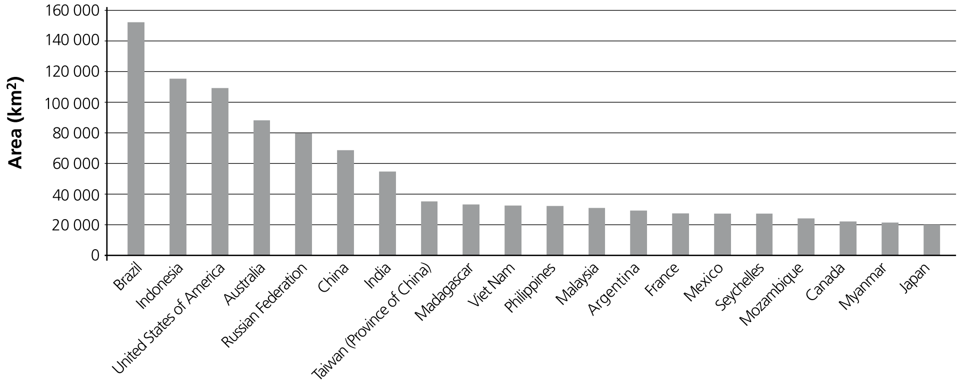
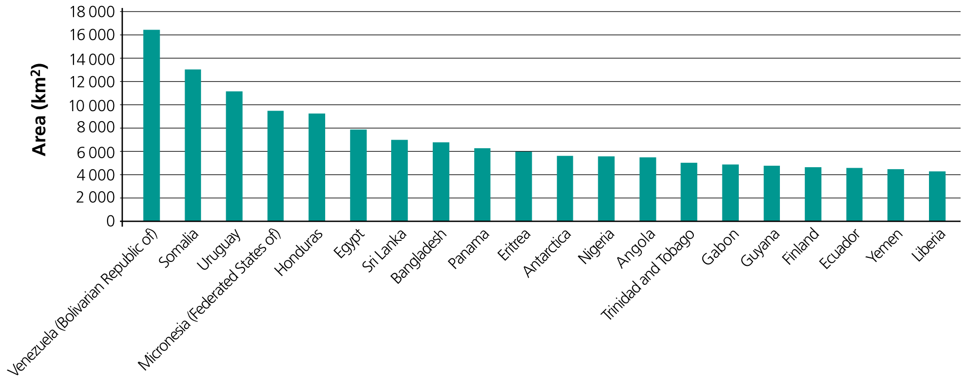


FIGURE 17
Ranking by area of main non-mariculture nations with current speeds and depths suitable for sea cages and longlines



4.2.1 Areas within a cost-effective distance for offshore mariculture development and with access to ports

The economic feasibility of offshore mariculture is a broad topic that involves the analysis of many variables. As with offshore mariculture itself, the economics of offshore mariculture is in its infancy and there are only a handful of studies cited by Knapp (forthcoming) that relate this topic. Nevertheless, one important spatial aspect of economic feasibility was analysed in this study: the cost-effective area for development. It consists of two components. The first is the cost-effective distance from the coastline to an offshore installation - 25 nm (46.3) - adopted from Jin (2008). The second component refers to the locations suitable for onshore support facilities with all-weather access to the sea. This component was spatially represented by the locations of world ports (World Port Index, 2009). Integration of the two components defines the cost-effective area for development that is the sea area that is within a 25 nm radius from a port. The total cost-effective area for development is 5.1 million km^2 among 79 mariculture nations and 1.0 million km^2 among 74 non-mariculture nations (Table 3; Figure 18). Among the mariculture nations, the United States of America, the Republic of Indonesia and Canada are the most prominent (Figure 19). The non-mariculture nations with the greatest cost-effective area for development are the Republic of Angola, the Republic of Finland and the Islamic Republic of Iran (Figure 20).

FIGURE 18
Cost-effective area for offshore mariculture development that is within 25 nm of a port

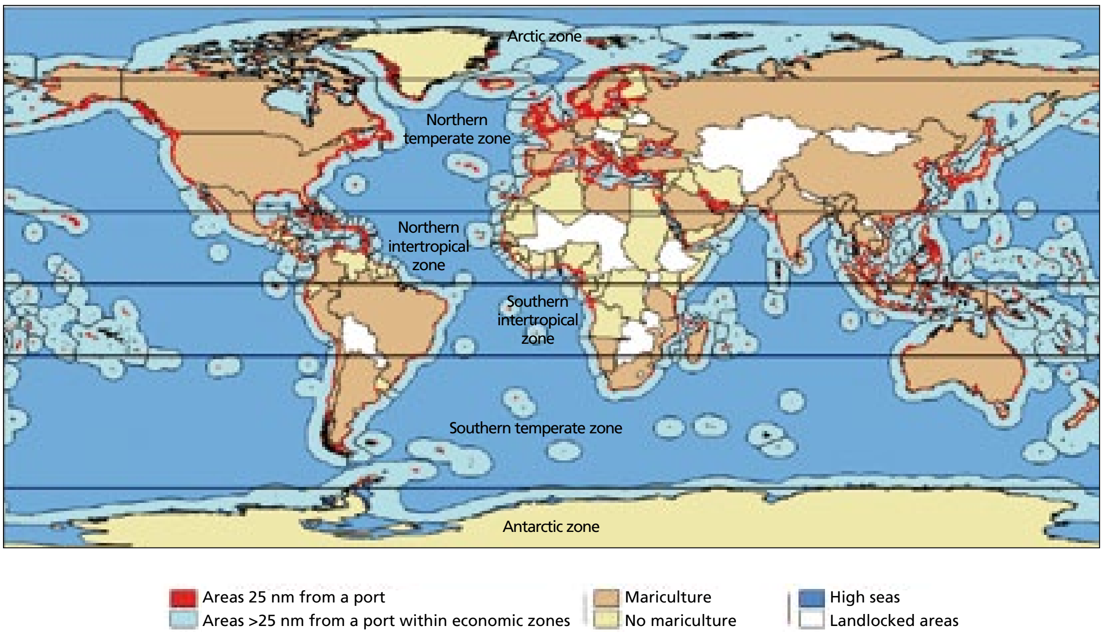


FIGURE 19
Ranking by area of main mariculture nations in cost-effective area for development

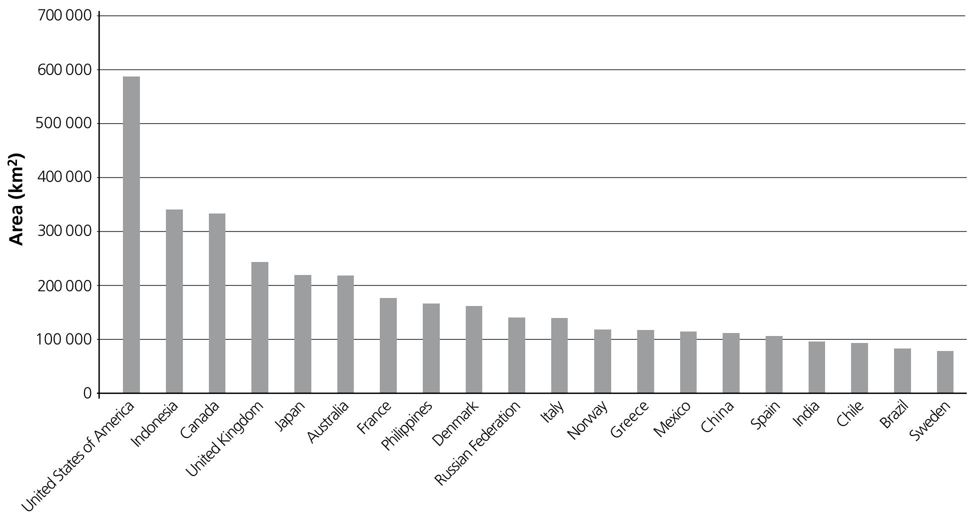
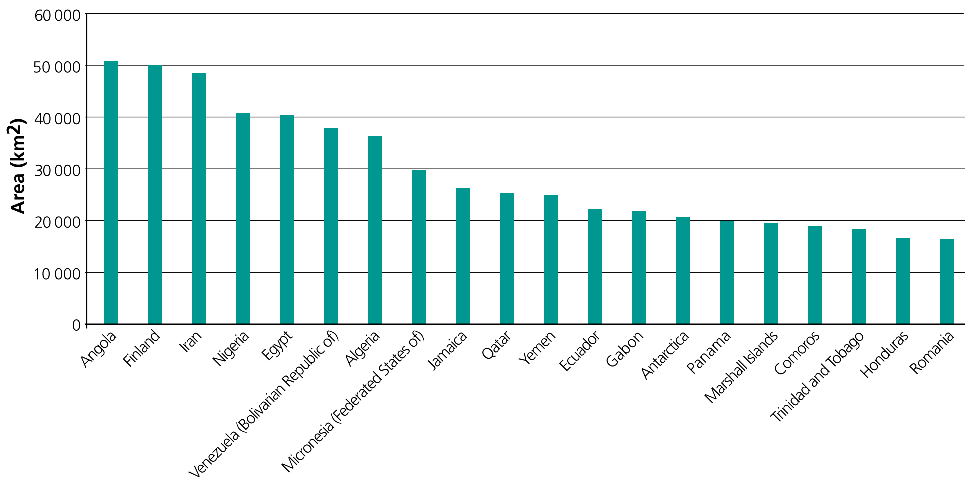


FIGURE 20
Ranking by area of main non-mariculture nations in cost-effective area for development



4.2.2 Spatial integration of technical feasibility for cages and longlines with cost-effective area for development

Spatial integration of water depth and current speed suitable for cages and longlines and cost-effective area for development resulted in relatively modest areas: 147 000 km^2 for mariculture nations and 43 000 km^2 for non-mariculture nations. However, the number of nations included is relatively high, 69 and 52 for mariculture and non-mariculture nations, respectively (Table 3). The mariculture nations with the largest areas meeting all three criteria are the Federative Republic of Brazil, the Republic of India and the Taiwan Province of China (Figure 21). The non-mariculture nations that lead in suitable area are the Federal Republic of Nigeria, the Bolivarian Republic of Venezuela and the Republic of Liberia (Figure 22).

FIGURE 21
Ranking by area of main mariculture nations with current speeds and depths suitable for sea cages and longlines and within the cost-effective area for development

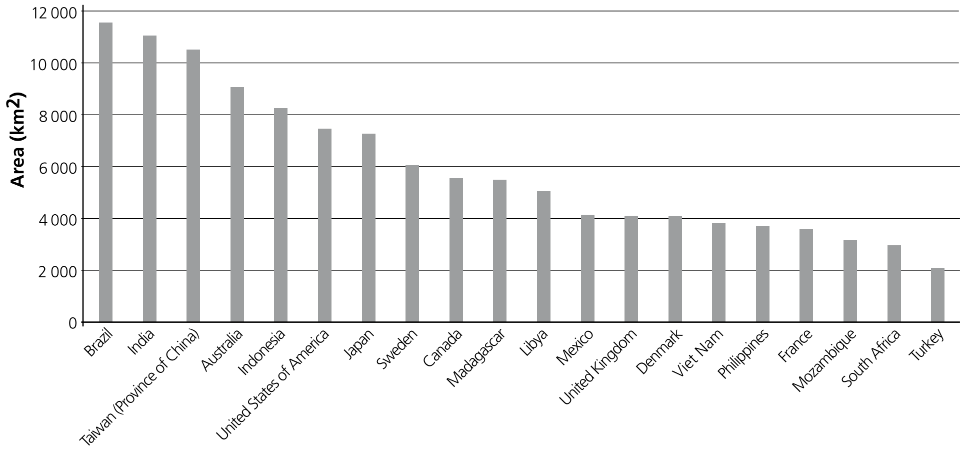
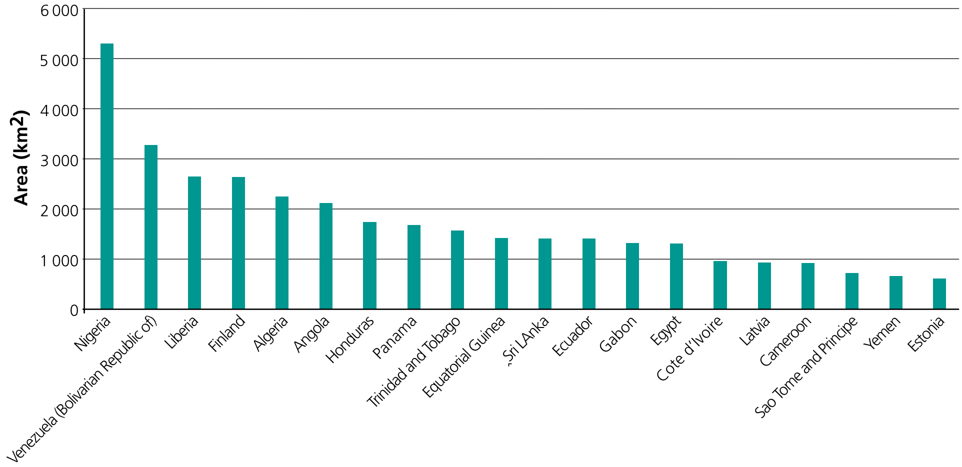


FIGURE 22
Ranking by area of main non-mariculture nations with current speeds and depths suitable for sea cages and longlines and within the cost-effective area for development



The results above (Figures 21 and 22) call attention to the nations that have the largest areas with potential when all three criteria are spatially integrated. Likewise, the results from Sections 4.2 and 4.3 show the results when the criteria are treated individually. However, it is of interest to identify the nations that have all-around potential. Those are the nations that have both high area-wise potential and that also consistently rank highly across all three of the criteria for offshore mariculture development potential. Those nations were identified by selecting those that ranked among the first 20 across all three criteria: depth for cages and longlines, current speeds for cages and longlines, and cost-effective area for economic development. Then the ranks achieved in each criterion were summed to make an overall score. The possible range of scores is from 3 (most potential) to 60 (least potential). Among the mariculture nations, there were 10 that appeared among the ranking top 20 with regard to all three criteria. Among those nations, the United States of America, the Republic of Indonesia and Australia scored highest. Similarly, for the non-mariculture nations five appeared among all of the criteria. Among those, the Bolivarian Republic of Venezuela, the Republic of Angola and the Republic of Yemen scored best (Table 4).

TABLE 4
Nations consistently scoring high in potential for offshore mariculture development in technical and cost-effective area for development as measured by ranks and overall scores

Nation	Cages and longlines				Cost-effective area		Overall score
	Depth suitable		Current speed suitable				
	Rank	Area (km²)	Rank	Area (km²)	Rank	Area (km²)	
Mariculture nations							
United States of America	4	1 190 441	2	8 277 236	1	587 387	7
Indonesia	3	1 220 487	6	3 949 545	2	340 352	11
Australia	2	1 333 993	3	6 869 770	6	218 361	11
United Kingdom	9	330 699	5	4 821 415	4	242 888	18
France	18	155 302	1	10 720 729	7	177 013	26
Japan	20	118 197	7	3 553 548	5	218 753	32
Denmark	10	324 421	13	2 107 512	9	161 082	32
Brazil	8	353 479	9	2 865 618	19	83 096	36
Philippines	19	142 131	16	1 458 577	8	166 666	43
India	13	248 777	14	1 750 865	17	95 634	44
Non-mariculture nations							
Bolivarian Republic of Venezuela	2	54 355	9	383 994	6	37 859	17
Angola	8	28 289	15	231 565	1	50 916	24
Yemen	9	27 605	8	447 196	11	25 055	28
Egypt	12	25 373	16	219 927	5	40 473	33
Honduras	7	30 626	20	170 655	19	16 578	46

4.2.3 Summary of technical feasibility for cages and longlines and the cost-effective area for development

The following are the salient results from this section on the technical feasibility for cages and longlines and on the cost-effective area for the development of offshore mariculture.

(i) As a group, nations already practising mariculture possess much more area than nations yet to develop mariculture with regard to offshore area suitable for cages and longlines in terms of depth, current speed, integrated depth and current speed, cost-effective area for development, and with all of these criteria spatially integrated and when successively integrated (Figure 23). Nevertheless, the absolute areas with offshore potential are large collectively both for mariculture and non-mariculture nations alike, and the number of nations with offshore potential is large even where the area is relatively small (Figure 24).

(ii) Nations that are the current leaders in inshore mariculture production (e.g. the top three in the period 2004–2008 – the People's Republic of China, the Republic of the Philippines, Japan) – are not necessarily those with the greatest offshore areas suitable for cages and longlines and within the cost-effective area for development (e.g. Figure 21).

(iii) Ten mariculture nations and five non-mariculture nations with consistent relatively large potential for offshore mariculture development across all technical and economic criteria have been identified (Table 4).

(iv) These results, in addition to those set out in Chapter 2, point to much unrealized offshore mariculture potential from global and from national viewpoints alike.

FIGURE 23
Offshore mariculture potential for sea cages and longlines by areas meeting depth, current speed and cost-effective area for development criteria

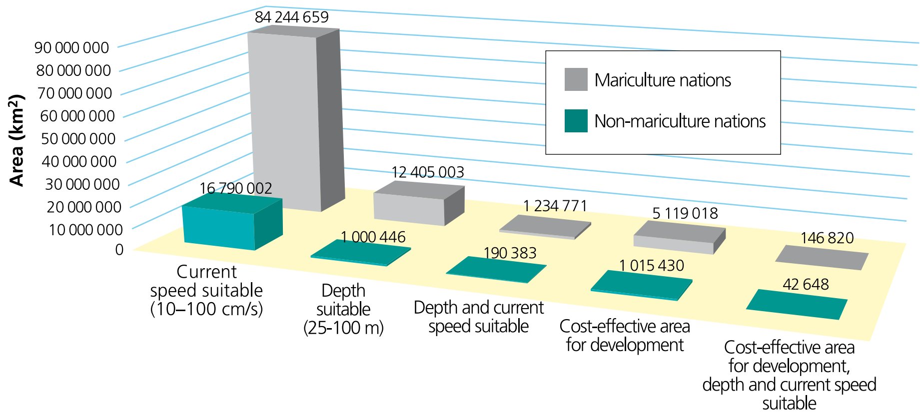
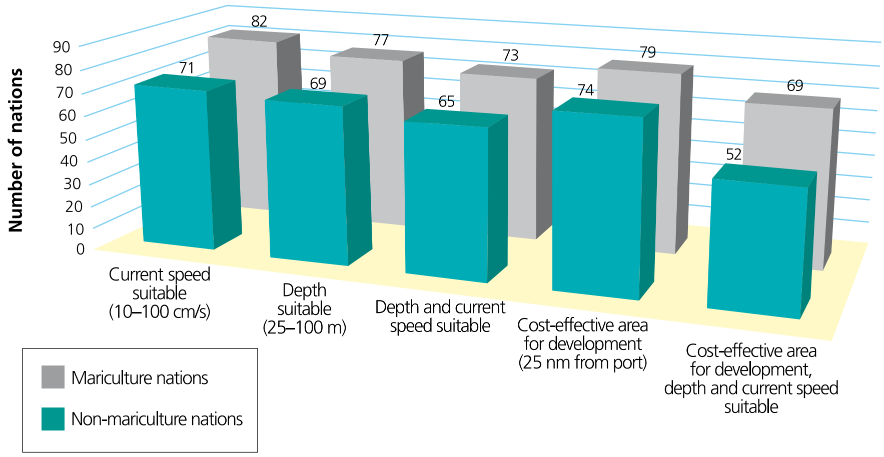


FIGURE 24
Offshore mariculture potential for sea cages and longlines by numbers of nations meeting depth, current speed and cost-effective area for development criteria



4.3 Areas favouring grow-out of fish and mussels spatially integrated with areas technically feasible for cages and longlines

In this section, temperature is introduced as an environmental variable defining the space suitable for the favourable grow-out of three species: cobia, Atlantic salmon and blue mussel. For the last species, a filter feeder, the concentration of chlorophyll-*a* also is used to identify areas with favourable grow-out potential. Additionally, areas for IMTA (Soto, 2009) of the Atlantic salmon and blue mussel are located based on the integration of the temperature thresholds favouring their grow-out and in meeting the chlorophyll-*a* concentration threshold for the blue mussel. Finally, the technical limits from the previous section, depths and current speeds suitable for culture installations, are integrated with the temperature and chlorophyll-*a* thresholds for these selected species in order to provide a broad picture of mariculture potential in species-culture system combinations as summarized in Table 5.

TABLE 5
Number of nations and corresponding areas with potential for favourable growth for cobia, Atlantic salmon and blue mussel integrated with suitable depth and current speed for cages and longlines

Growth and technical criteria	Mariculture nations		Non-mariculture nations		Total	
	Nations	Area (km²)	Nations	Area (km²)	Nations	Area (km²)
Cobia temperature range 22–32 °C; depths and current speeds suitable for cages	44	658 031	40	135 907	84	793 938
Atlantic salmon temperature range 1.5–16 °C; depths and current speeds suitable for cages	14	30 566	0	0	14	30 566
Blue mussel temperature range 2.5–19 °C and chlorophyll-*a* > 0.5 mg/m³; depths and current speeds suitable for longlines	15	29 960	0	0	15	29 960
IMTA temperature range 2.5 to 16 °C and chlorophyll-*a* > 0.5 mg/m³; depths and current speeds suitable for cages and longlines	9	14 590	0	0	9	14 590

4.3.1 Areas favouring grow-out of fish and mussels

Areas with temperatures favouring grow-out of cobia (22–32 °C) within EEZs were identified (Figure 25). The areas with temperatures favouring cobia grow-out are vast and span the globe in much of the Intertropical Convergence Zone and in the small portions of the Northern and Southern Temperate Zones. The potential of cobia for offshore mariculture development was assessed by integrating the areas with favourable grow-out temperatures with depths and current speeds suitable for submerged cages.

FIGURE 25
Areas within EEZs with temperatures favourable for offshore grow-out of cobia

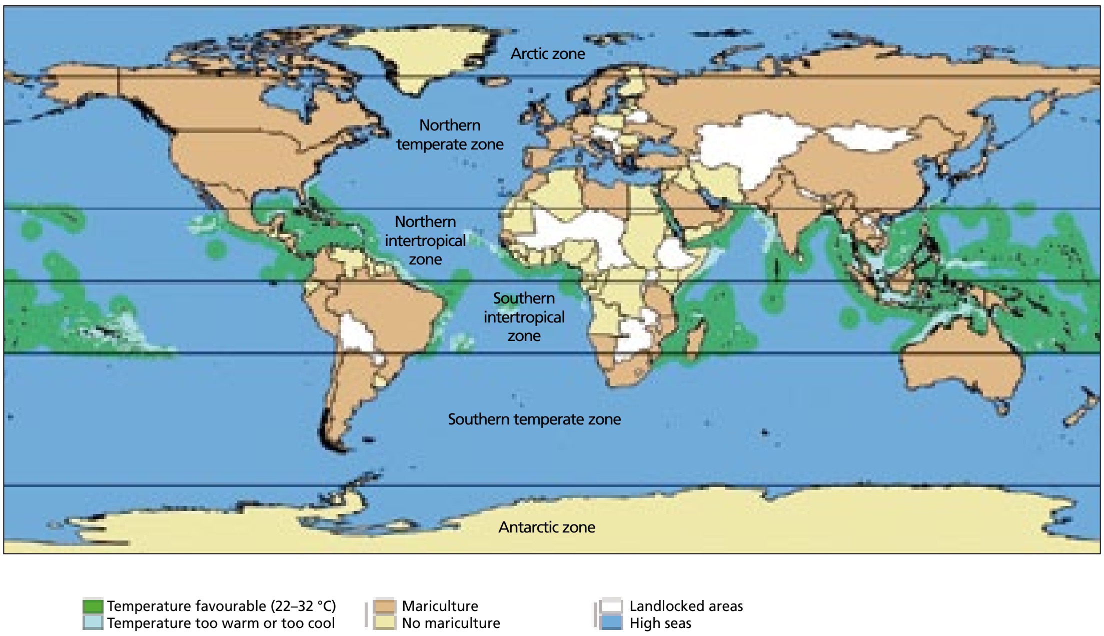
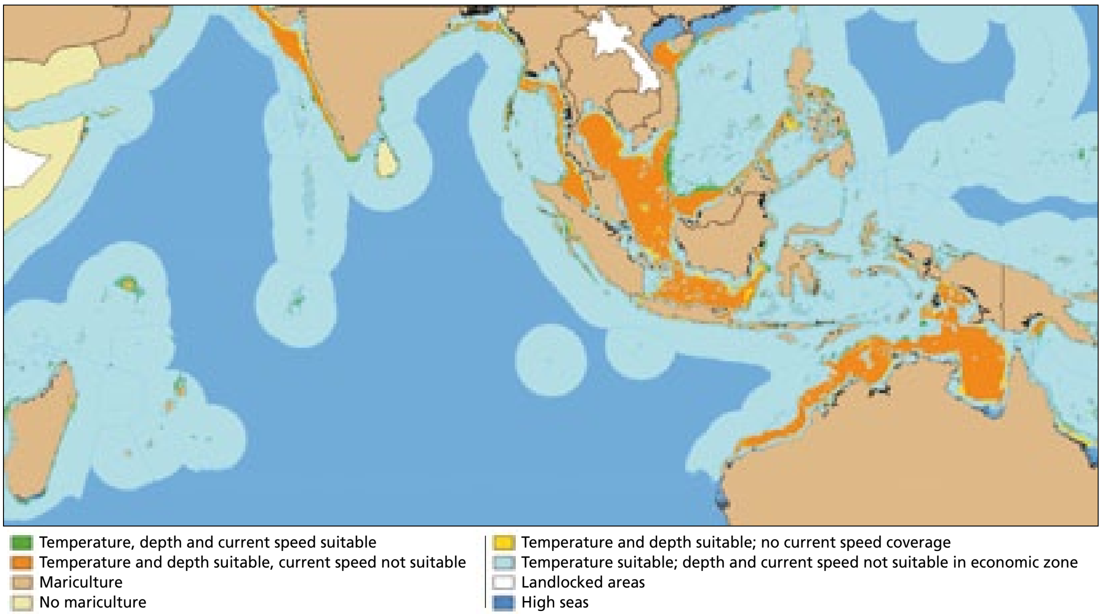


FIGURE 26
Regional view of areas in South Asia-Oceania with temperatures favourable for offshore grow-out of cobia and depths and current speeds suitable for sea cages



Overall, potential for cobia amounts to 658 031 km^2 among 44 mariculture nations and 135 907 km^2 among 40 non-mariculture nations (Table 5). The mariculture nations with the largest potential are the Republic of Indonesia (Figure 26), the Federative Republic of Brazil and the Republic of India (Figure 27), and the leading non-mariculture nations are the Bolivarian Republic of Venezuela, the Somali Republic and the Federated States of Micronesia (Figure 28).

FIGURE 27
Ranking by area of main mariculture nations with temperatures favourable for cobia grow-out and current speeds and depths suitable for sea cages

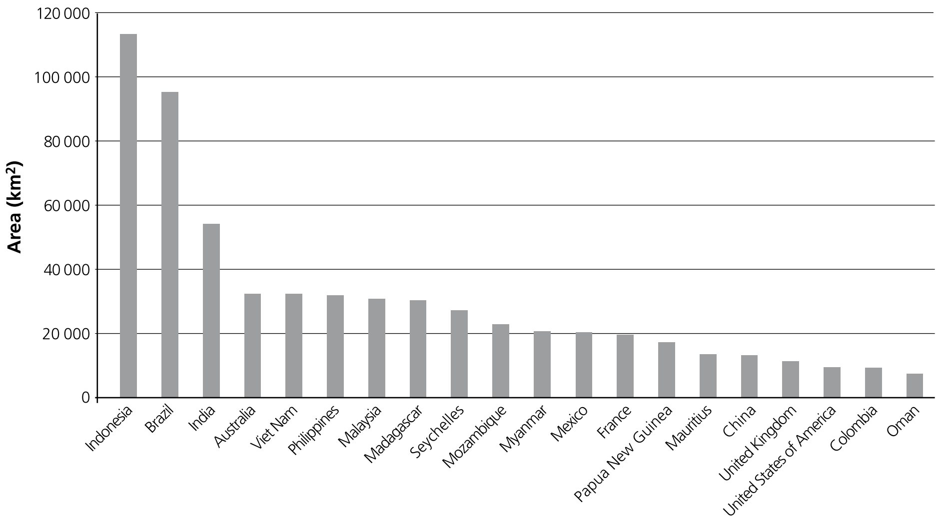
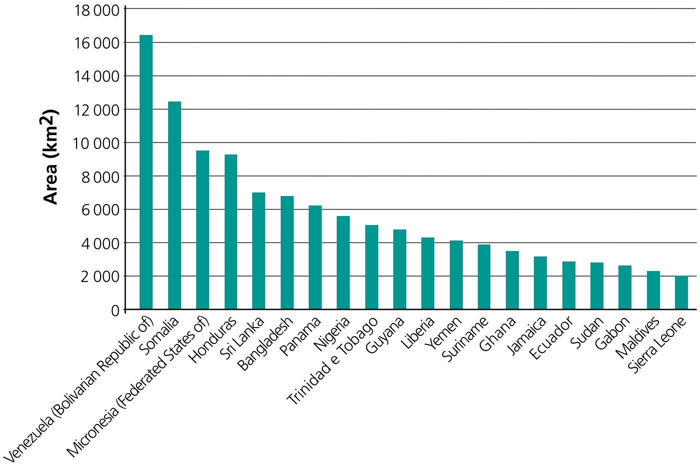


FIGURE 28

Ranking by area of main non-mariculture nations with temperatures favourable for cobia grow-out and current speeds and depths suitable for sea cages

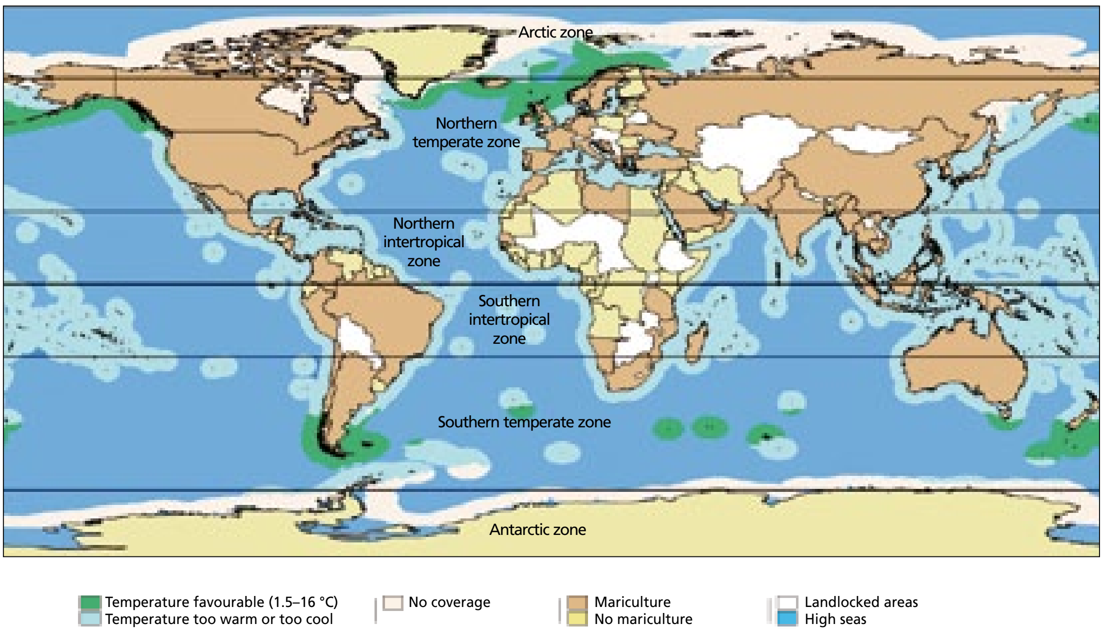


Potential for Atlantic salmon was identified by integrating its initial growth-temperature threshold (4–16 °C) with depths and current speeds suitable for cages. However, in the initial results, areas with existing inshore Atlantic salmon culture in the northeastern United States of America and southeastern Canada were not identified as having potential. Actual grow-out temperature data from the inshore culture sites of a major producer in this region were evaluated. The results indicated that salmon farming was successful at temperatures seasonally ranging as low as 1.5 °C. Accordingly, the lower threshold was extended to make a final threshold range of 1.5–16 °C. The global distribution of the temperatures favouring offshore Atlantic salmon grow-out within EEZs is shown in Figure 29. Areas where Atlantic salmon are already grown out in inshore waters are included, but there are other large areas with temperatures favouring offshore grow-out in the Northern and Southern Temperate Zones.

Global offshore potential for Atlantic salmon was found in a relatively modest area (31 000 km^2) among 11 mariculture nations, which includes three national territories as well (Table 5). The leading nations in Atlantic salmon potential are the Republic of Chile, the Argentine Republic and the French Republic, the last one by virtue of Southern Hemisphere territories. The United Kingdom of Great Britain and Northern Ireland also

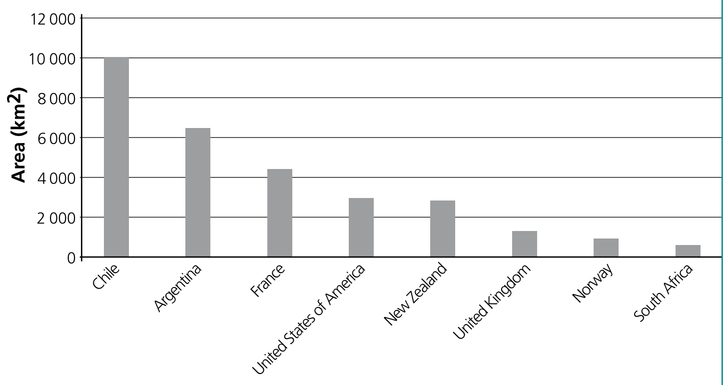
FIGURE 29

Areas within EEZs with temperatures favourable for offshore grow-out of Atlantic salmon



has territories in the Southern Hemisphere that contribute to the overall area (Figure 30). There was no potential for Atlantic salmon among non-mariculture nations.

FIGURE 30
Ranking by area of main mariculture nations with temperatures favourable for Atlantic salmon grow-out and current speeds and depths suitable for sea cages



Potential for blue mussel mariculture in offshore waters was initially based on the integration of temperatures from 4 to 18 °C, a coastal chlorophyll-*a* concentration greater than 1 mg/m^3, and current speeds and depths suitable for submerged longlines (Section 4.2). These temperature and chlorophyll-*a* thresholds did not include the locations of some existing blue mussel culture areas in some countries in Europe and several offshore installations in the United States of America. Temperature and chlorophyll-*a* estimates from the spatial data archive along with actual in-water measurements from selected culture sites as well as temperature and chlorophyll-*a* concentrations obtained by parameter retrieval were examined and new thresholds were established at 2.5–19 °C and chlorophyll-*a* concentrations at > 0.5 mg/m^3. The global distribution of the areas meeting the temperature and chlorophyll-*a* thresholds within EEZs is shown in Figure 31. Large areas in the Northern and Southern Temperate Zones meet these thresholds. With the modified thresholds established and integrated with depths and current speeds for longlines, potential for offshore mariculture of blue mussel was found among 15 mariculture nations and territories in a total of 29 960 km^2. Among the mariculture nations, the Argentine Republic dominated followed by the Republic of Chile and Australia (Figure 32). No potential for offshore mariculture of the blue mussel was found among non-mariculture nations.

FIGURE 31
Areas within EEZs with temperatures and chlorophyll-*a* concentrations favourable for offshore grow-out of the blue mussel

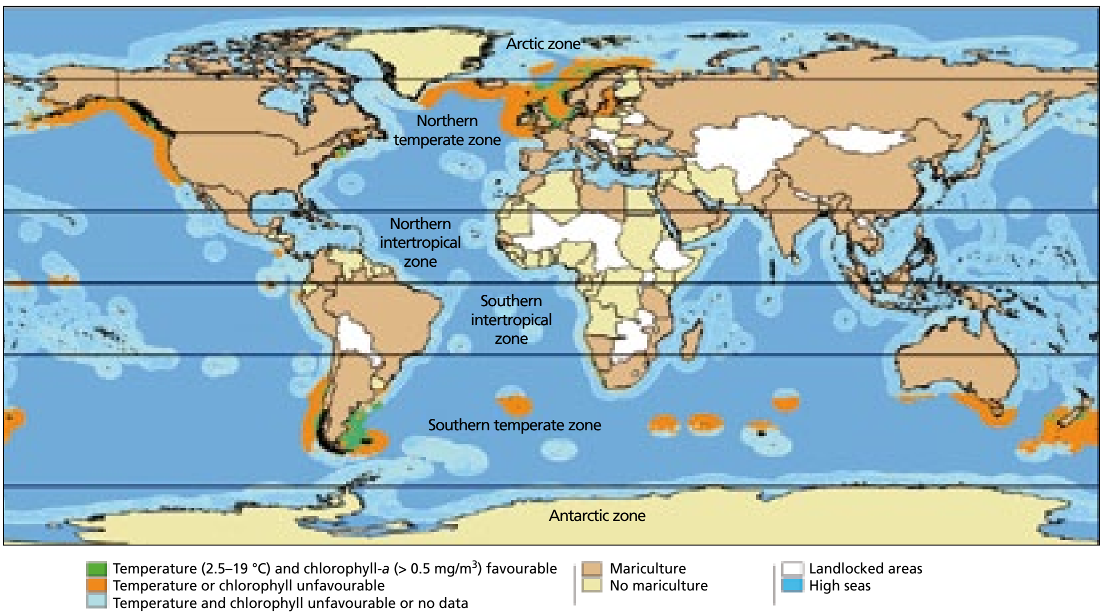
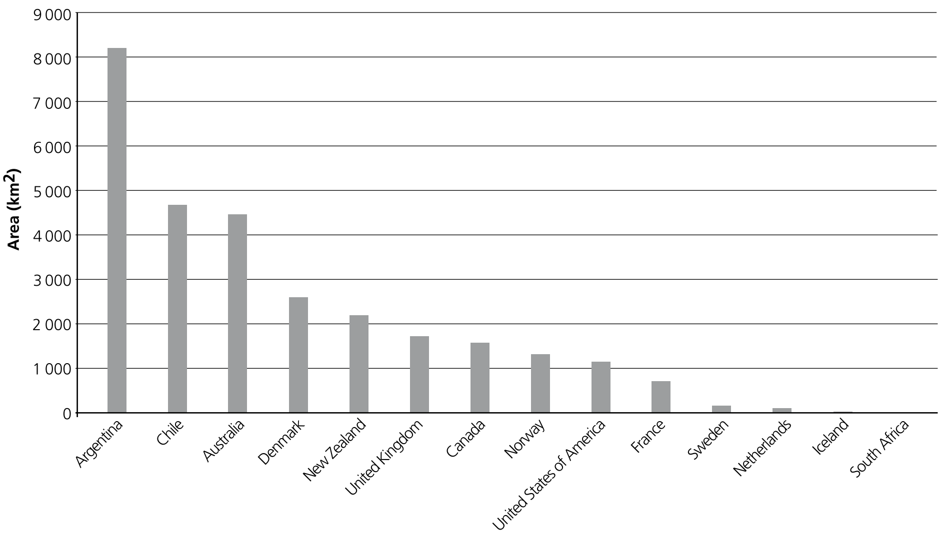


FIGURE 32
Ranking by area of main mariculture nations with temperatures and chlorophyll-*a* concentrations favourable for blue mussel grow-out and depths and current speeds suitable for longlines



Potential for IMTA of Atlantic salmon and blue mussel was found among nine nations in a total of 14 590 km^2 (Table 5). The area with potential for IMTA is less than the area for either species because it is defined by the portions of the temperature ranges that overlap one another (2.5–16 °C), as well as including the chlorophyll-*a* threshold for the blue mussel. The Argentine Republic and the Republic of Chile stand out area-wise (Figure 33), while New Zealand and the other nations possess much less suitable area (Figure 34).

FIGURE 33
Regional view of areas in southern Latin America with temperatures and chlorophyll-*a* concentrations favourable for Atlantic salmon-blue mussel IMTA and depths and current speeds suitable for sea cages and longlines

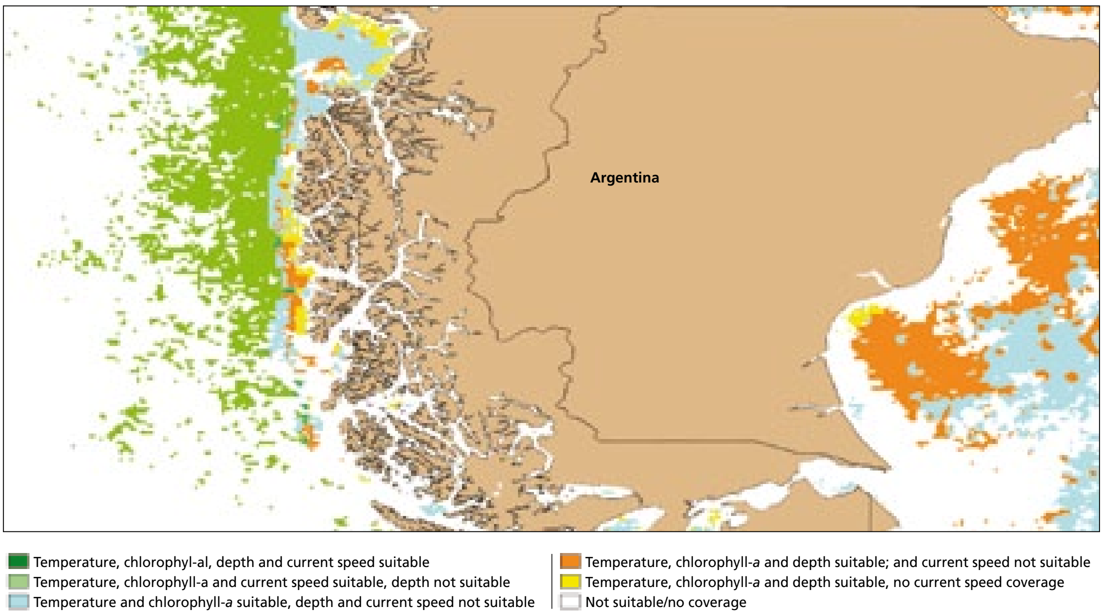
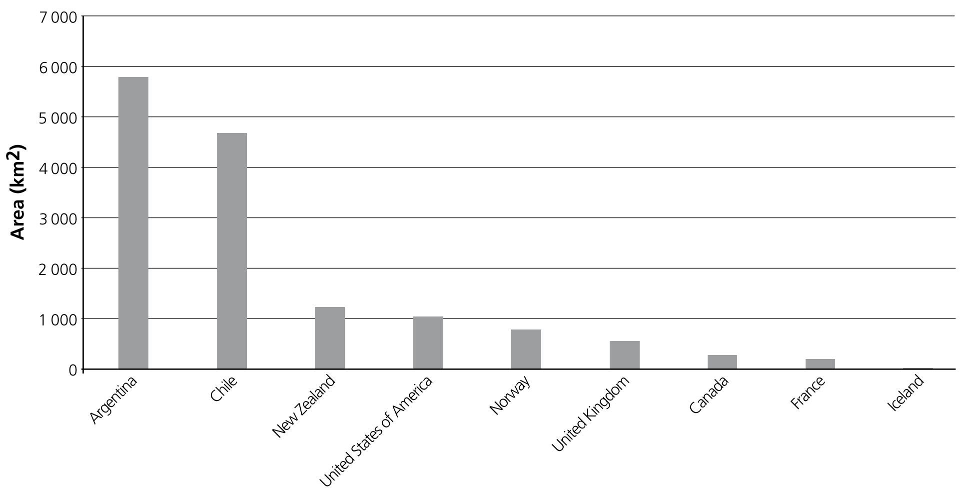


FIGURE 34
Ranking by area of main mariculture nations with temperatures and chlorophyll-*a* concentrations favourable for Atlantic salmon-blue mussel IMTA and current speeds and depths suitable for sea cages and longlines



4.3.2 Spatial integration of areas with favourable grow-out for fish and mussels with areas technically feasible for cages and longlines and within the cost-effective area for development

Integrating the cost-effective area for development – the area within 25 nm (46.3 km) of a port that is within an EEZ - with potential for cobia in terms of temperature, depths and current speeds for cages provides an estimate of potential that emphasizes the operational dependence of offshore culture installations on the proximity to essential onshore facilities, as well as the distance limit to maintain economic viability of the operation. The introduction of this new, but nevertheless important criterion, changes the results for cobia, Atlantic salmon, blue mussel and IMTA already reported above in Table 5 in that the areas that satisfy all of the criteria are much reduced, especially for countries that have relatively few ports listed in the World Port Index (2009) (Table 6).

TABLE 6
Number of nations and corresponding areas within the cost-effective area for development integrated with favourable grow-out for cobia, Atlantic salmon, blue mussel and IMTA and depths and current speeds suitable for sea cages and longlines

Grow-out, technical, and cost-effective area criteria	Mariculture nations		Non-mariculture nations		Total	
	Nations	Area (km^2)	Nations	Area (km^2)	Nations	Area (km^2)
Cobia	42	66 188	34	31 004	76	97 192
Atlantic salmon	6	2 447	0	0	6	2 447
Blue mussel	11	5 848	0	0	11	5 848
IMTA	6	1 202	0	0	6	1 202

In the case of cobia, taking into account the cost-effective area for development reduces cobia potential among mariculture countries to 66 188 km^2, about 10 percent of that when cost-effective area is not considered, but the number of countries with potential is reduced by only two to 42 (Table 6). Among the mariculture countries, the Republic of India, the Federative Republic of Brazil and the Republic of Indonesia stand out (Figures 35a and 35b). Among the non-mariculture nations, the total area is 31 004 km^2 with 34 nations possessing potential for cobia. The Federal Republic of Nigeria stands out, and the Bolivarian Republic of Venezuela and the Republic of Liberia possess the next most abundant area in this category (Figures 36a and 36b). Viewed from a regional and subregional perspective, potential for cobia is widely distributed with the largest potential in Southeastern Asia, South America and Eastern Africa (Table 7).

FIGURE 35a

Ranking by area of main mariculture nations in cost-effective area for development, temperatures favourable for offshore grow-out of cobia and current speeds and depths suitable for sea cages

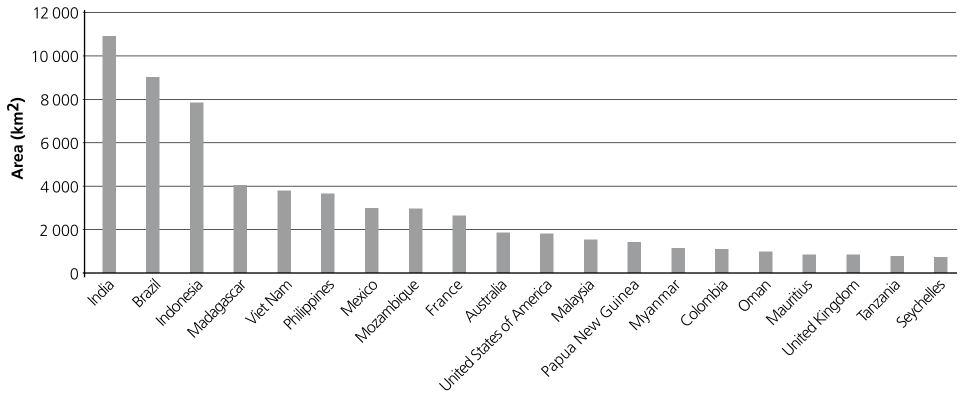


FIGURE 35b

Ranking by area of main mariculture nations in cost-effective area for development, temperatures favourable for offshore grow-out of cobia and current speeds and depths suitable for sea cages

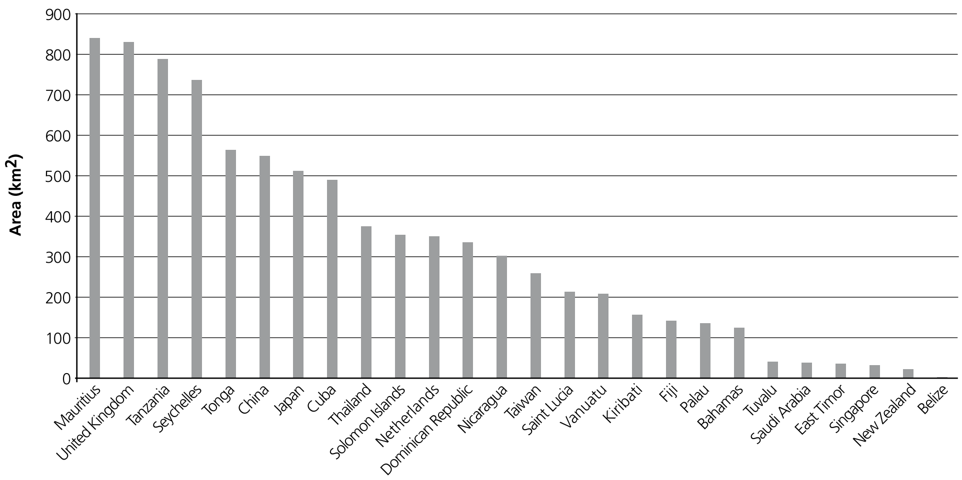


FIGURE 36a
Ranking by area of main non-mariculture nations in cost-effective area for development, temperatures favourable for offshore grow-out of cobia and current speeds and depths suitable for sea cages

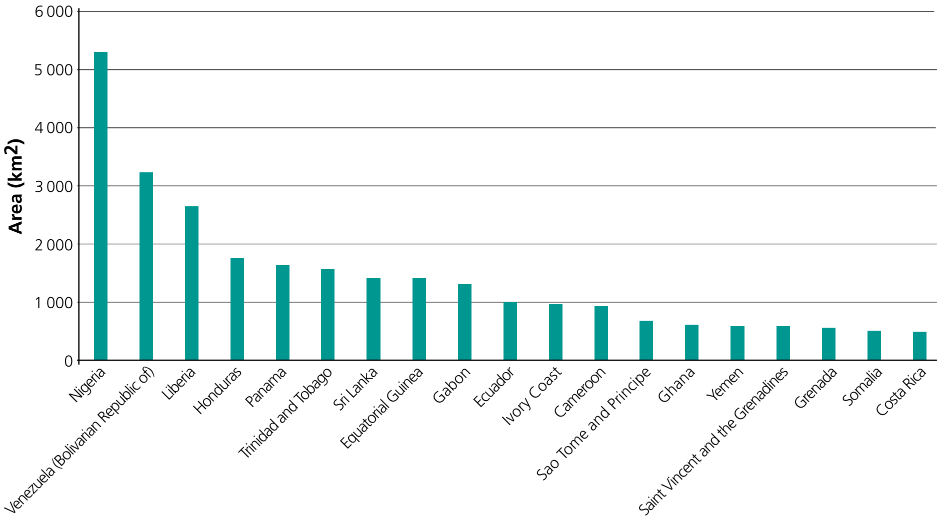


FIGURE 36b
Ranking by area of main non-mariculture nations in cost-effective area for development, temperatures favourable for offshore grow-out of cobia and current speeds and depths suitable for sea cages

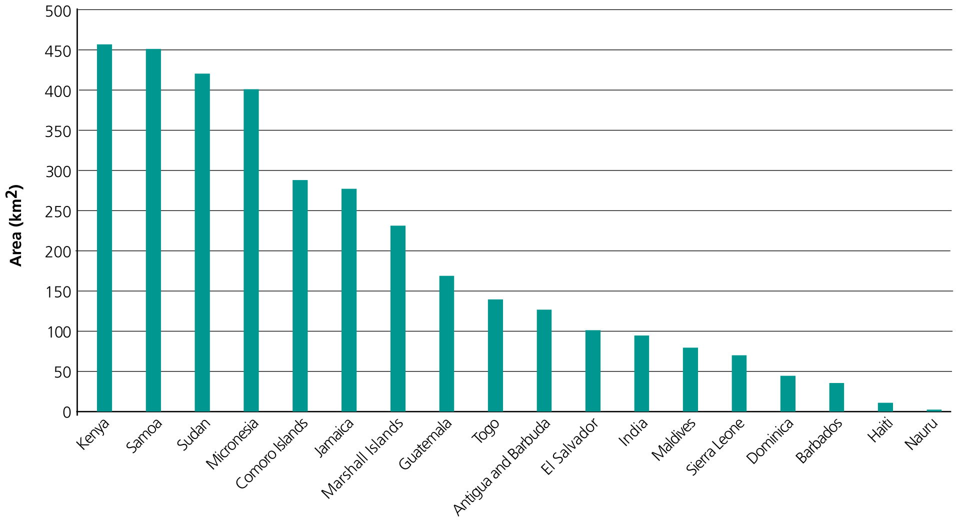


TABLE 7

Estimates of mariculture potential for cobia by regions and subregions

Regions/ subregions	Sum of area (km^2)
Asia	33 955
Southeastern Asia	18 489
Southern Asia	12 542
Western Asia	1 605
Eastern Asia	1 319
Americas	29 614
South America	14 838
Central America	7 451
Caribbean	6 663
Northern America	662
Africa	26 021
Eastern Africa	11 030
Western Africa	10 241
Middle Africa	4 329
Northern Africa	421
Oceania	7 601
Melanesia	2 636
Polynesia	2 254
Australia and New Zealand	1 785
Micronesia	927
Total	**97 192**

Taking into account the cost-effective area for development for Atlantic salmon among mariculture nations results in a total area of 2 447 km^2 among six nations, with the United States of America and the Kingdom of Norway dominant (Figure 37).

Potential for the blue mussel within the cost-effective area for development is 5 848 km^2 among 11 mariculture nations. The Kingdom of Denmark and the United Kingdom of Great Britain and Northern Ireland stand out (Figure 38).

Potential for IMTA within the cost-effective area for development amounts to only 1 202 km^2 among six nations, dominated by the United States of America and the Kingdom of Norway (Figure 39). A Southern Hemisphere territory accounts for a part of the potential of the United Kingdom of Great Britain and Northern Ireland.

FIGURE 37
Ranking by area of main mariculture nations within the cost-effective area for development, with temperatures favourable for Atlantic salmon grow-out and current speeds and depths suitable for sea cages

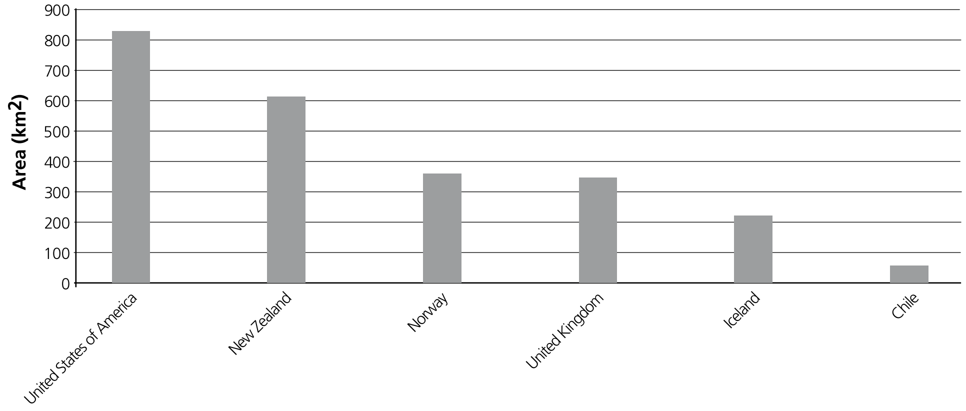


FIGURE 38
Ranking by area of main mariculture nations within the cost-effective area for development, with temperature and chlorophyll-a concentration favourable for blue mussel grow-out and current speeds and depths suitable for longlines

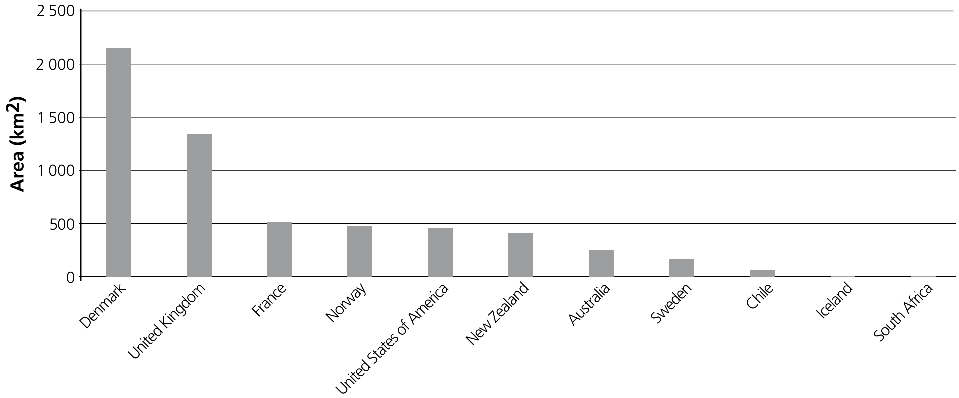
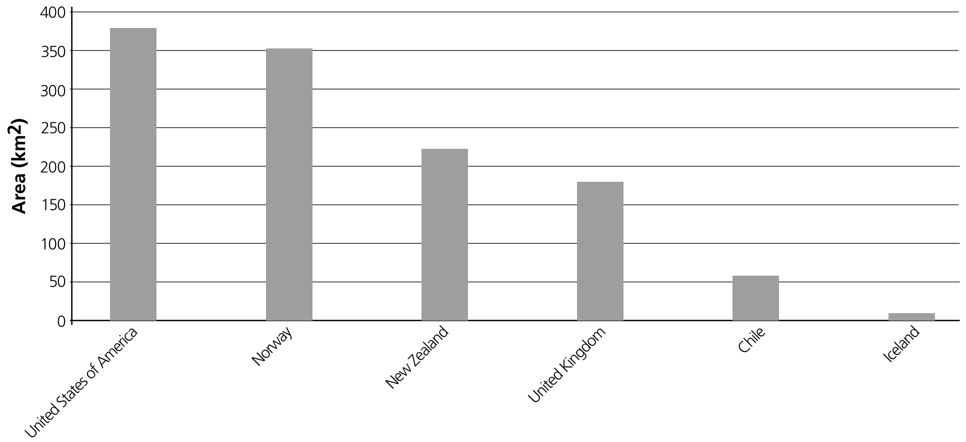


FIGURE 39
Ranking by area of main mariculture nations within the cost-effective area for development, with temperatures and chlorophyll-*a* concentration favourable for Atlantic salmon-blue mussel IMTA and current speeds and depths suitable for sea cages and longlines



4.4 Hypothetical loss of offshore mariculture potential due to competing and conflicting uses

In addition to offshore mariculture, there is a host of potentially competing and conflicting uses for the water surface, water column, bottom and sub-bottom. Most of these alternative uses fall within central or local government administration and regulation, but some may be international in scope. The objective for mariculture development is to avoid or minimize the competing and conflicting uses while identifying adjacent uses that would be complementary. Complementary uses currently under discussion include wind-farm supporting structures, wave energy, and unused oil or gas platforms, but areas closed to fishing need not be off-limits to mariculture. Similarly, there are possible competing and conflicting uses of the space needed for onshore mariculture support facilities, with many alternative uses for the space required. In contrast to the offshore situation, sites for onshore facilities are likely to be under the jurisdictions of local authorities.

Marine protected areas (MPAs) (IUCN and UNEP-WCMC, 2010) provide an example of alternative uses of space possibly conflicting, or alternatively, possibly offering complementary opportunities for mariculture. MPAs were selected because the database is global and because MPAs can be both national and international in scope.

Based on an analysis of the 2010 MPA data (IUCN and UNEP-WCMC, op. cit.), there are about 3.8 million km^2 devoted to MPAs worldwide. Nearly all of the MPA area of 3.5 million km^2 is among 71 mariculture nations, while the remainder is among 49 non-mariculture nations (Table 8). The mariculture nations with the greatest MPA expanses are the United States of America and Australia (Figure 40), with the Republic of Ecuador possessing by far the largest area among non-mariculture nations (Figure 41).

TABLE 8
Number of nations and corresponding MPA area, and nations and corresponding areas within MPAs with potential for cobia offshore mariculture

Criteria	Mariculture nations		Non-mariculture nations		Total	
	Nations	Area (km^2)	Nations	Area (km^2)	Nations	Area (km^2)
MPAs	71	3 533 612	49	296 957	120	3 830 569
Temperatures suitable for cobia and depths and current speeds suitable for cages inside MPAs	31	44 863	12	2 092	43	46 955

In order to illustrate the effect of other uses on mariculture potential, it is assumed here that all of the area that is suitable for cobia culture in terms of temperature favourable for growth, depths and current speeds for cages, and that is also within national MPAs that are themselves within economic zones, is excluded from the development of offshore mariculture.

The outcome is that, altogether, cobia potential would be reduced by nearly 47 000 km^2, amounting to about 6 percent of the total potential that was identified without regard to conflicting, competing or complimentary uses (Section 4.3).

However, cobia potential among mariculture nations would be reduced by 7 percent, while that of non-mariculture nations would be reduced by only 2 percent. Thirty-one mariculture practising nations would stand to lose some potential (Table 8).

FIGURE 40
Ranking by area of main mariculture nations in marine protected areas

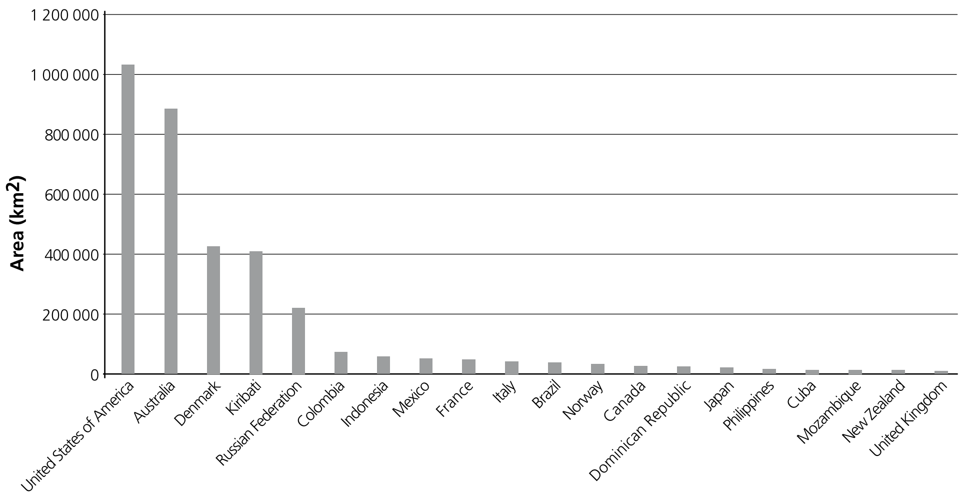
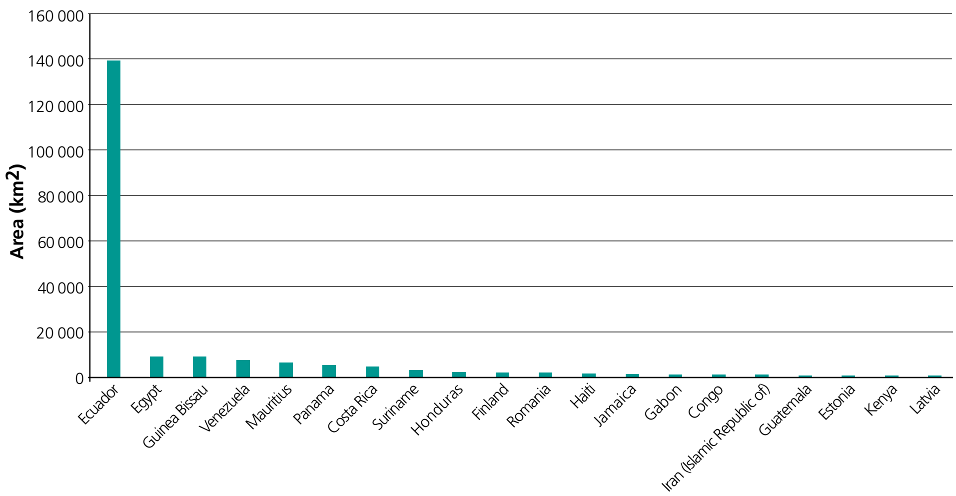


FIGURE 41
Ranking by area of main non-mariculture nations in marine protected areas



Australia, the United States of America and the Republic of Indonesia would lose the greatest amounts of area with potential for the mariculture of cobia (Figure 42; Figure 43). Twelve non-mariculture nations also would lose some cobia mariculture potential (Table 8), and those most affected would be the Arab Republic of Egypt, the Republic of Costa Rica and the Republic of Honduras (Figure 44).

Looking more broadly at the loss of areas with potential for mariculture development that is due to competing and conflicting uses, the countries that would most likely be affected would be those nations not only with the largest expanses of MPAs, but also those with already developed multiple uses of maritime areas, such as for mineral resources extraction (oil, metals), well-developed commercial, artisanal and recreational fisheries, and large, busy ports.

FIGURE 42
Regional view of area within MPAs with temperatures favourable for cobia grow-out and depths and current speeds suitable for sea cages

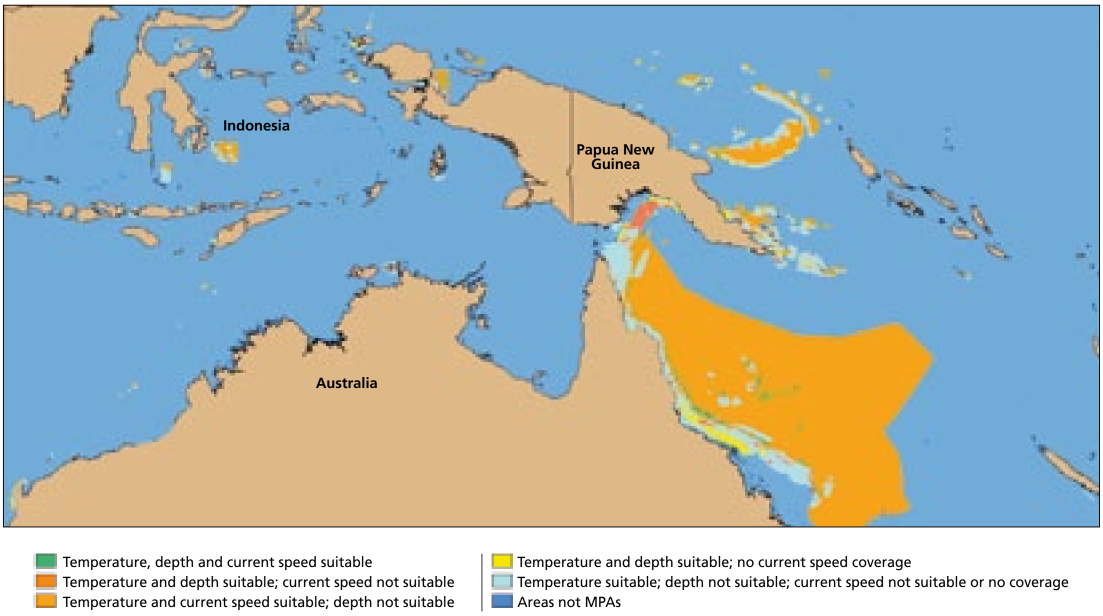


FIGURE 43
Ranking by area of main mariculture nations in hypothetical loss of area with potential for offshore mariculture of cobia due to exclusion from MPAs

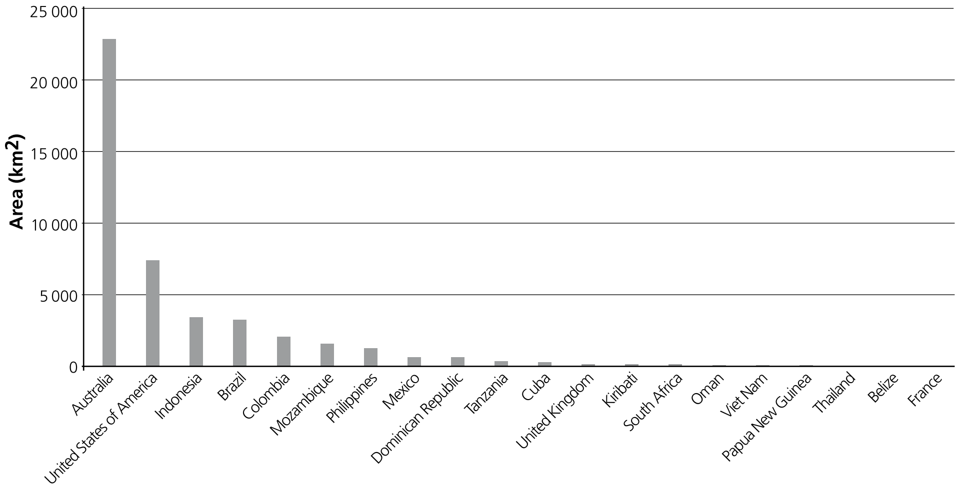
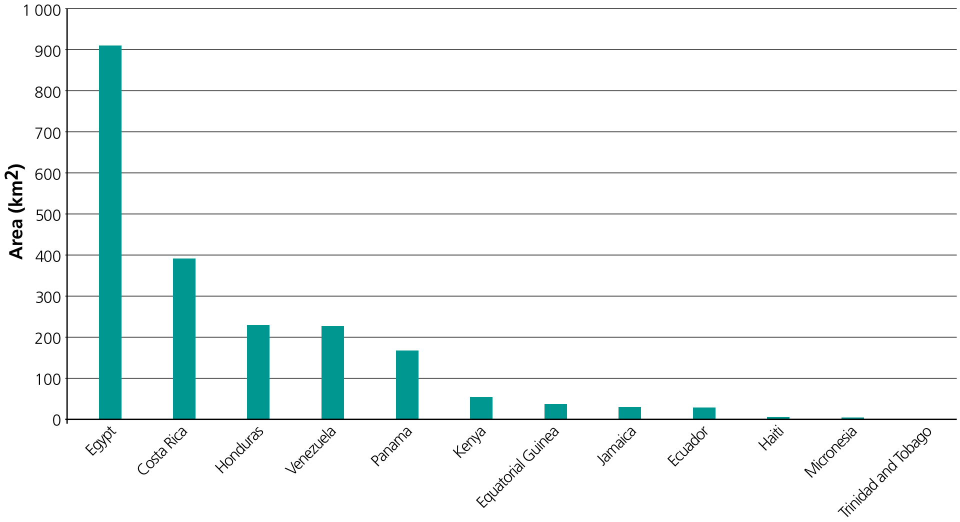


FIGURE 44
Ranking by area of main non-mariculture nations with a hypothetical loss of area with potential for offshore mariculture of cobia due to exclusion from MPAs



4.5 Summary of the results on offshore mariculture potential with species, culture systems and cost-effective area for development integrated

The salient results on offshore mariculture potential from this section are summarized in the following paragraph and supported by results shown in Figures 45 and 46.

(i) Integration of basic criteria for cage and longline culture systems (depth, current speed) with criteria for favourable grow-out of cultured animals (temperature, food availability as chlorophyll-*a* for the mussel) indicates large areas globally, among many nations, with potential for development of offshore mariculture.

(ii) Apart from the species used here to represent potential, the results are also indicative of offshore mariculture potential for other species with similar temperature and chlorophyll-*a* requirements for grow-out and with cage and longline culture system requirements similar to those as specified in this document.

FIGURE 45
Area suitable for offshore mariculture of cobia, Atlantic salmon, blue mussel and IMTA among mariculture nations overall and within the cost-effective area for development

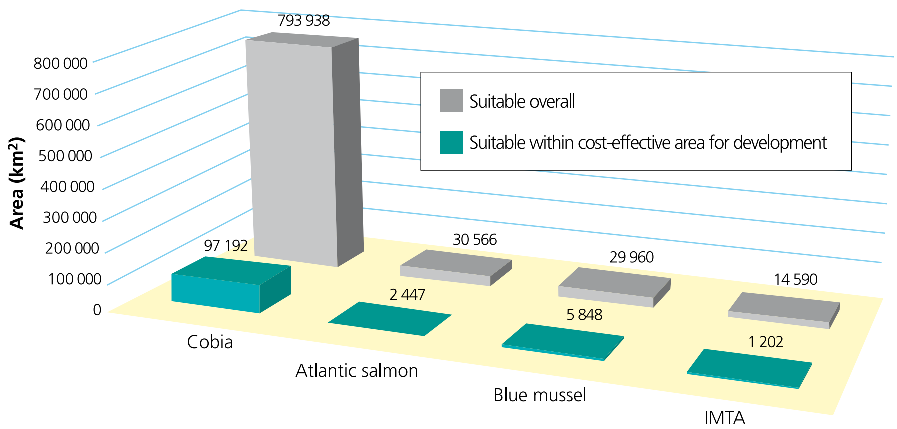
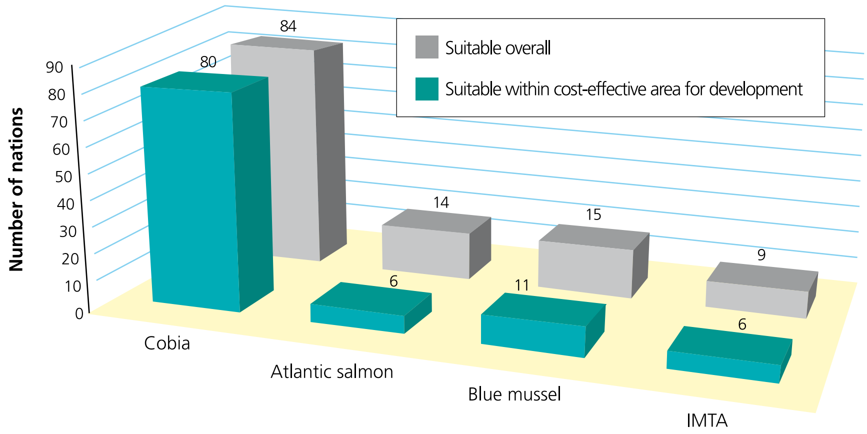


FIGURE 46

Numbers of nations with areas suitable for offshore mariculture of cobia, Atlantic salmon, blue mussel and IMTA among mariculture nations overall and within the cost-effective area for development



(iii) Even when further constrained by including the cost-effective for area for development as an additional criterion, large areas with potential for offshore mariculture development remain and the potential is found among many nations.

(iv) Among the species, potential for cobia is much greater than that for the Atlantic salmon, blue mussel and IMTA, both in terms of the number of nations with potential and in terms of sea-surface area. This result suggests that there is greater offshore mariculture potential for species that can be grown out in warm temperate and tropical waters (e.g. Figure 25) than for those species with cool and cold temperate grow-out regimes (e.g. Figures 29 and 31). However, actual future offshore production may differ from the estimates of potential herein owing to the influence of the many factors not included in this study.

(v) Hypothetically, setting aside MPAs as zones excluding offshore cobia mariculture resulted in a minimal loss of potential in area and in terms of number of nations; however, this is only one among many possible competing or conflicting uses for marine space. Thus, it can be expected that many additional offshore waters with potential for offshore mariculture will be out of reach or in contention.