5. Comparisons and verifications for offshore mariculture potential

Estimates of offshore mariculture potential require verification to improve the design of future investigations and to be credible for development planning. The main issue with the verification of the results of this study is that potential for the development of offshore mariculture is being estimated where it largely does not yet exist. Thus, there were few opportunities to directly verify the results that would be used to compare areas found suitable for offshore mariculture with actual offshore mariculture locations. As a consequence, predictions of potential were examined through three kinds of comparisons based on the offshore potential found for each of the three species-culture system combinations and IMTA. The comparisons were:

(i) **National-level potential and production comparison:** Offshore mariculture potential in square kilometres compared with the mariculture production of nations already practising mariculture of the species-culture system combination at the national level.

(ii) **National to local level offshore mariculture potential compared with inshore mariculture locations:** These were comparisons on maps at the national level to the local level of areas found to have offshore potential compared with either the actual locations of inshore mariculture installations of the species (e.g., Figures 47a and b) or with inshore farming areas in which mariculture of the species was being practised.

(iii) **Offshore mariculture potential compared with actual offshore mariculture locations:** These were comparisons on maps of areas with offshore mariculture potential with the actual locations of offshore installations. These comparisons are the actual verification of the results.

For these comparisons, emphasis was placed on meeting temperature thresholds for all three species, as well as the chlorophyll-*a* threshold for the blue mussel, as these were the environmental variables used to assess grow-out performance. However, depth and current speed criteria were also taken into account and reported.

5.1 COBIA

5.1.1 National-level potential and production comparison

Potential was found in all five of the nations reporting cobia culture to FAO (2010) (Table 9).

TABLE 9
National-level potential and production comparison for cobia: mean annual production (2004–2008) of cobia-producing nations with areas meeting temperature, depth and current speed criteria and areas meeting the first two criteria

Nation	Mean annual production 2004–2008 (tonnes)	Area with potential (km²)	
		Temperature, depth and current speed	Temperature and depth
China	19 982	13 208	53 137
Taiwan Province of China	3 140	3 472	4 573
Belize	384	99	1 702
Mayotte (France)	5	430	593
Singapore	4	32	176

5.1.2 National to local level offshore mariculture potential compared with inshore mariculture locations

At local levels comparison data were available from eight nations, with cobia locations that spanned the latitudes from 8° to 24°N and one at 8°S. Among the eight nations, locations were obtained for 22 cage sites and nine cobia-farming areas, of which 27 are listed in Tables 10 and the remaining 4 in Table 11.

Two cage sites in the People's Republic of China, both in the south of Hainan Island, met the 22–32 °C favourable grow-out threshold, but 5 farming areas in the Socialist Republic of Viet Nam and 1 farming area in the Taiwan Province of China had temperatures seasonally too cool that did not meet the threshold.

The cage sites in the People's Republic of China that did not meet the temperature threshold (Table 10) suffered from unseasonably low (13 °C) temperatures that killed cobia in the early spring of 2008 (C. Zhou, personal communication, 2011).

The areas offshore from these inshore farm locations had temperatures below the 22 °C threshold from December through March over the long term of the 17-year data set. Unfortunately, the actual temperature data that were available at only one inshore cage site did not cover the coolest months of the year, January to March. The two cobia culture areas that were within the favourable grow-out temperature threshold were on the south side of Hainan Island, the southernmost part of the country (Tables 10 and 11, Figure 47f).

Cobia are raised in four main regions in the Socialist Republic of Viet Nam. Beginning in the north, cobia are raised in Hai Phong and Quang Ninh provinces, then further south in Nghe An and Khanh Hoa provinces, and finally in the southernmost location in Vung Tau province (Svennevig and Huy, 2005). Seasonally low temperatures that put cobia at risk during the winter season were indicated for the Hai Phong, Quang Ninh and Nghe An province farming areas in the north of the Socialist Republic of Viet Nam. The temperature range in the northern portion of the country is given as 14–31 °C.

In presenting the grow-out pattern of cobia in sea cages in the Socialist Republic of Viet Nam, Nhu *et al.* (2009) indicate that growth does not occur when the temperature is less than 22 °C. The locations in Hai Phong and Quang Ninh provinces are below the 22 °C threshold from December to March, while the next farming area south in Nghe An province is borderline in January and below the threshold in February. For the purposes of this technical paper, these northern culture areas are deemed unsuitable because of the temperatures that are below the lower threshold limit of cobia grow-out potential of 22 °C.

There are two main cobia-farming areas in the Taiwan Province of China; one area is in the Penghu Islands (west central, offshore) and the other is in Pingtung County (southwest) (Hsu, Chen and Liao, 2005). Although the Penghu Island area falls outside of the temperature threshold range for the months of December through March, it lies just outside of and to the north of the area within the range. According to Liao *et al.* (2004), in central Taiwan Province of China overwintering is a problem for grow-out cages, especially in the Penghu Islands.

Water temperatures during the winter season can drop down to 16 °C. Growth of cobia is usually retarded at low temperatures, and sometimes high mortality also occurs when the temperature decreases to below 16 °C. As a result, the culture period in these sea-cage areas is longer (up to 17 months) compared with the sea-cage areas in southern Taiwan Province of China (11–14 months), where the water temperature range is between 23.5 and 28 °C all year around. According to Shih, Chou and Chiau (2009), the average temperature in the Penghu Islands is 25–27 °C in spring to autumn, declining to 21–22 °C in the winter, with a low temperature of 16 °C during the winter season. However, according to Miao *et al.* (2009), mid-winter temperatures in the Penghu Islands area can dip below 15 °C, resulting in heavy mortality while prevailing winter temperatures are around 18 °C.

At the two inshore farm locations in Belize (Figure 47c), at one offshore farm in the Republic of Panama (Figure 47d), and at one of two inshore farming areas in the Socialist Republic of Viet Nam, all three thresholds were met close offshore. At a cobia site in

Muttom, Tamil Nadu, the Republic of India, cobia cages have been established at a distance of about 0.6 km m from shore at 20 m depth (P. Anilkumar, personal communication, 2012; Anilkumar, 2012) in an area meeting the temperature threshold, but too shallow to meet the depth threshold of 25 m and with current speeds lower or higher than 10–100 cm threshold.

In the vicinity of Muttom, areas meeting all three thresholds are at least 13 km offshore. At the second farming area in the Socialist Republic of Viet Nam, all thresholds were met, but very distant from the inshore farming area (Table 10). Although the temperature and depth thresholds were met at one farming area in the southwest of the Taiwan Province of China and at one farm location near the Commonwealth of Puerto Rico, current speed coverage was lacking.

TABLE 10
Comparison of offshore potential of cobia with inshore cage sites and farming areas based on meeting the 22–32 °C temperature threshold

No.	Country or territory	Administrative unit	Location	Temperature threshold (22–32 °C) met (Y=Yes; N=No)	Cage site (CS) or farming area (FA)
1	Belize (Figure 47c)	Unknown	Marine Farms Belize, Site 1	Y	CS
2	Belize (Figure 47c)	Unknown	Marine Farms Belize, Site 2	Y	CS
3	China	Guangdong	Dapeng Bay, Huizhou	N	CS
4	China	Guangdong	Zhapo, Gang, Yangjiang	N	CS
5	China	Guangdong	Techeng Dao 1, Zhanjiang	N	CS
6	China	Guangdong	Wushi, Zhanjiang	N	CS
7	China	Guangdong	Dongli, Zhanjiang	N	CS
8	China	Guangdong	Liusha Gang, Zhanjiang	N	CS
9	China	Guangdong	Techeng Dao 2, Zhanjiang	N	CS
10	China	Guangxi	Bailong, Fangchenggang	N	CS
11	China	Guangxi	Tieshan Gang, Beihai	N	CS
12	China	Hainan	Xinying Gang, Lingao	N	CS
13	China	Hainan	Jinpai Gang, Lingao	N	CS
14	China	Hainan	Xinyingzhen	N	CS
15	China	Hainan	Lingshui, Sanya	Y	CS
16	India	Tamil Nadu	Muttom	Y	CS
17	Panama	Unknown	Panama Mariculture Company	Y	CS
18	Taiwan Province of China	Penghu County	Penghu Islands	N	FA
19	Taiwan Province of China	Pingtung County	Shiao-Liu-Chio	Y	FA
20	United States of America	Puerto Rico	Snapperfarm, Inc.	Y	CS
21	Viet Nam	Hai Phong	Hai Phong	N	FA
22	Viet Nam	Khanh Hoa	Van Phong Bay	Y	FA
23	Viet Nam	Nghe An	Cua Lo District	N	FA
24	Viet Nam	Nghe An	Quynh lap District	N	FA
25	Viet Nam	Quang Ninh	Ha Long Bay	N	FA
26	Viet Nam	Quang Ninh	Bai Tu Long Bay	N	FA
27	Viet Nam	Vung Tau	Vung Tau	Y	FA

Notes: Grey color indicates cage sites or farming areas that met the temperature threshold.

5.1.3 Offshore mariculture potential compared with actual offshore mariculture locations

Three of the four locations shown in Table 11 are well offshore (the Federative Republic of Brazil and the Republic of Panama), and the last one is offshore of Hainan Island, the People's Republic of China. These locations offer the opportunity for verification of predicted potential with actual offshore locations. Of the four, the location in the Republic of Panama met all criteria (Figure 47d). The Aqualider cage site in the Federative Republic of Brazil was well offshore and met two of the three criteria. It was just to the east of an area meeting all three criteria (Figure 47e). The MPA site is in the same vicinity as the Aqualider site and 6 km offshore (Figure 47 e). It is in an area meeting the grow-out temperature criterion, but is sited at 23m depth (R.Cavallii, personal communication, 2012) so would not meet the depth threshold and in an area where current speeds are too variable to meet the current speed threshold. The site in the People's Republic of China on the south side of Hainan Island was closely adjacent to an area meeting temperature and depth criteria, but lacked current speed coverage. There is an area meeting all criteria lying further east (Figure 47f).

TABLE 11
Cobia mariculture locations that are offshore

No.	Country or territory	Administrative unit	Location	Temperature threshold (22–32 °C) met (Y=Yes; N=No)	Cage site (CS) or farming area (FA)
1	Brazil (Figure 47e)	Recife	Aqualider	Y	CS
2	Brazil (Figure 47e)	Recife	MPA	Y	CS
3	Panama (Figure 47d)	Unknown	Open Blue Sea Farm	Y	CS
4	China (Figure 47f)	Hainan	Jiu Suocun	Y	CS

Note: Grey color indicates cage sites or farming areas that met the temperature threshold.

FIGURE 47a
Cobia cages in site 1 near Belize City, Belize

Location: 17°21’11.00”N, 88°10’22.42”W

FIGURE 47b
Cobia cages in site 2 near Belize City, Belize

Location: 17°18’28.05”N, 88° 9’57.91”W

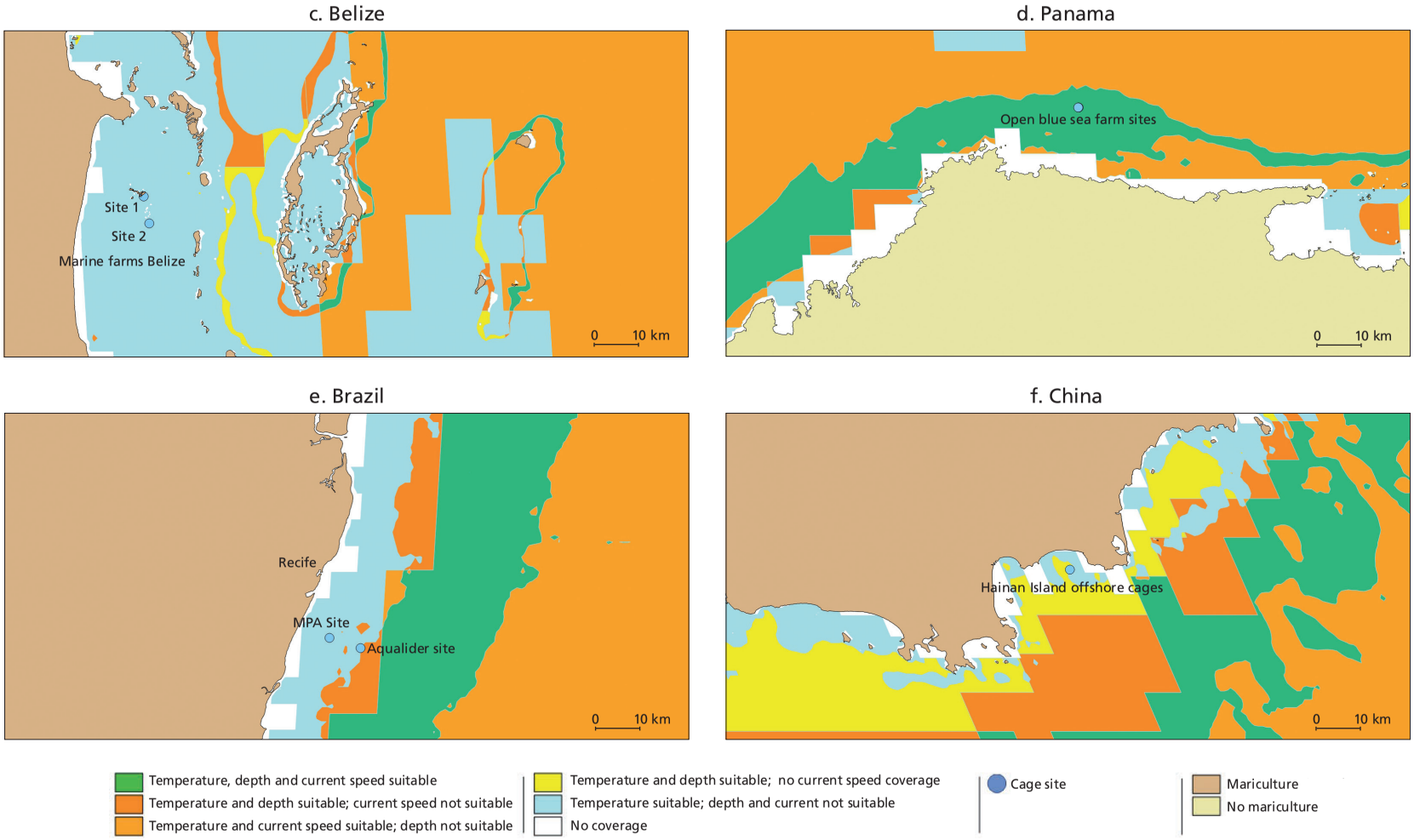
Notes:
Marine Farms Belize has two concessions; in the lagoon and mangrove areas, and in an exposed area. Although the two sites appear similar in Figure 47c, Site 1 in Figure 47a is somewhat sheltered while Site 2 in Figure 47b is in open waters and has more consistent water quality to Site 1.

Cage site water temperatures vary between average 26°C in the winter months (December–March), to 30–31°C in the peak of the summer (June–September). Depth in the cages sites reach 20 metres, and current is variable but mainly north to south with peaks of 0.5 knots and days of slack current. The feed barge in Site 2 can hold 100 tonnes of pellets, and is equipped with generators and blowers for automatic feeding, as well as a house for the guard and workers.

Source notes: J. Alarcon (personal communication, 2012).
Source images: © 2012 Google, Image © 2012 Digital Globe.

FIGURE 47c, d, e, f

Areas with temperatures favourable for grow-out of cobia and depths and current speeds suitable for sea cages compared with locations of cobia sea cage sites



5.2 ATLANTIC SALMON

5.2.1 National-level potential and production comparison

The comparison of national-level offshore potential for Atlantic salmon with production showed that among the 14 nations and territories already producing Atlantic salmon, offshore potential with all three criteria met was found among seven (Table 12). Three of the nations for which potential meeting all three criteria was not found are small producers (1 to 158 tonnes), but a fourth, Australia, is becoming important. Additionally, offshore potential was identified for seven nations or territories not yet producing Atlantic salmon. It is interesting to note that in the Kerguelen Islands territory (Table 12), Atlantic salmon were introduced more than 25 years ago and the population still persists (Ayllon *et al.*, 2004).

A comparison among nations and territories meeting all three criteria and those meeting two criteria indicates that current speed is the criterion limiting potential. This result is affirmed in that, when only temperature and depth are considered, offshore potential is lacking in only two nations (the Kingdom of Spain and the Kingdom of Denmark) of the fourteen nations and territories (Table 12). These are nations with the least quantities of production, suggesting that conditions for inshore Atlantic salmon production may not be favourable there or that space with potential is limited.

TABLE 12
National-level comparison of Atlantic salmon annual production with potential by nation tabulated as areas meeting two temperature threshold ranges as well as depth and current speed criteria, and areas meeting the first two criteria

No.	Nation or national territory	Mean annual production 2004–2008 (tonnes)	Potential (km^2) by temperature threshold			
			Depth and current speed are suitable		Depth is suitable	
			4–16 °C	1.5–16 °C	4–16 °C	1.5–16 °C
1	Norway (Figure 48a)	653 483	594	912	33 083	41 856
2	Chile (Figure 48d)	365 636	10 011	10 022	53 249	54 184
3	United Kingdom	135 749	606	606	150 568	150 568
4	Canada (Figure 48c)	103 957	284	284	25 397	32 253
5	Denmark (Faroe Islands)	26 762	0	0	6 274	6 274
6	Australia	21 008	0	0	1 335	1 335
7	United States of America	12 546	1 120	2 945	44 595	161 715
8	Ireland (Figure 48b)	11 786	0	0	27 393	27 393
9	Iceland	3 412	427	600	8 702	21 729
10	France	1 103	0	0	1 373	1 373
11	Russian Federation	158	0	0	0	720
12	Spain	12	0	0	0	0
13	Denmark	1	0	0	0	0
14	New Zealand	Unknown quantity**	2 826	2 826	25 412	25 412

No.	Nation or national territory	Mean annual production 2004–2008 (tonnes)	Potential (km²) by temperature threshold			
			Depth and current speed are suitable		Depth is suitable	
			4–16 °C	1.5–16 °C	4–16 °C	1.5–16 °C
Potential of nations or territories not producing Atlantic salmon						
1	Argentina	0	6 454	6 454	145 503	150 851
2	South Africa (Prince Edward Island)	0	610	610	618	620
3	Australia (Macquarie Island)	0	51	190	64	258
4	France (Crozet Island)	0	1 163	1 814	1 751	2 682
5	France (Kerguelen Islands)	0	0	2 601	0	12 605
6	United Kingdom (the Falkland Islands [Malvinas]	0	421	424	23 796	23 976
7	United Kingdom (Tristan Da Cunha)	0	279	279	405	405

**Atlantic salmon have been introduced to New Zealand, but only Chinook salmon (*Oncorhynchus tshawytscha*) is successfully farmed on a significant scale there (New Zealand salmon farmers association; www.salmon.org.nz).

Note: Grey colour is used to indicate the seven countries that met the depth and current speed criteria.

5.2.2 National to local level offshore mariculture potential compared with inshore mariculture locations

The comparison of offshore mariculture potential of Atlantic salmon with inshore farm locations was accomplished by visually comparing individual cage sites for the Kingdom of Norway, western Ireland, British Columbia in Canada, and for a part of the Republic of Chile with offshore areas meeting various combinations of thresholds (Figures 48a–d). Atlantic salmon farms are distributed all along the coast of the Kingdom of Norway, well into the Arctic Climate Zone, and the growth-temperature criterion is met in those nearshore areas where there is data coverage. In the areas with off-lying islands in the Kingdom of Norway, there are farms in areas meeting offshore temperature and depth criteria and there are areas nearby meeting all criteria (Figure 48a). In western Ireland, as in the Kingdom of Norway, nearly all of the Atlantic salmon farms are in sheltered waters (Figure 48b). There are many areas just offshore of the inshore salmon farming areas that meet both temperature and depth criteria, and otherwise much of the offshore area possesses temperatures suitable for Atlantic salmon. However, no areas in western Ireland meet all three criteria. In British Columbia, Canada, temperature and depth criteria were met along the west coast of Vancouver Island just offshore of the salmon farms that are located in sheltered waters (Figure 48c). Temperatures are suitable in an area in the northeast portion of Vancouver Island close to the mainland. The areas meeting all criteria are just south of the border with the United States of America as well as northwest of the area in which Atlantic salmon are currently farmed in western Canada.

Atlantic salmon are also farmed in eastern Canadian provinces, as far south as New Brunswick and nearby in northeast Maine (United States of America), and as far north as Newfoundland; however, no potential was found in those areas because of temperatures not meeting the threshold. As explained in Chapter 4, mean monthly temperatures in the Maine to Newfoundland areas from February through April were

below the initial threshold of 4 °C. This prompted a re-evaluation of the temperature threshold. Actual temperatures at Atlantic salmon farms in this region were acquired. Also, mean monthly temperatures obtained from the spatial data archive at locations offshore of the most exposed culture sites were sampled. Accordingly, the lower threshold was decreased to 1.5 °C (Table 12) to better reflect the lower temperature limit of culture practice in this region. As a consequence, the Maine, Nova Scotia and New Brunswick areas were identified as having offshore potential consistent with inshore mariculture practice there, but not in Newfoundland. With the lower threshold extended to 1.5 °C, the area with potential is increased for most countries and territories (Table 12).

Potential for Atlantic salmon offshore farming occurs along most of the coast of the Republic of Chile, with the largest areas that meet all criteria being in the south. However, the area for which farm locations are available is relatively small and the farms are in inshore sheltered locations (Figure 48d). There, temperature and depth criteria are met in much of the area proximate to the farms as well as along the coast open to the ocean, and there are also small areas meeting all three criteria offshore. Additionally, temperatures are suitable for Atlantic salmon in the remaining areas.

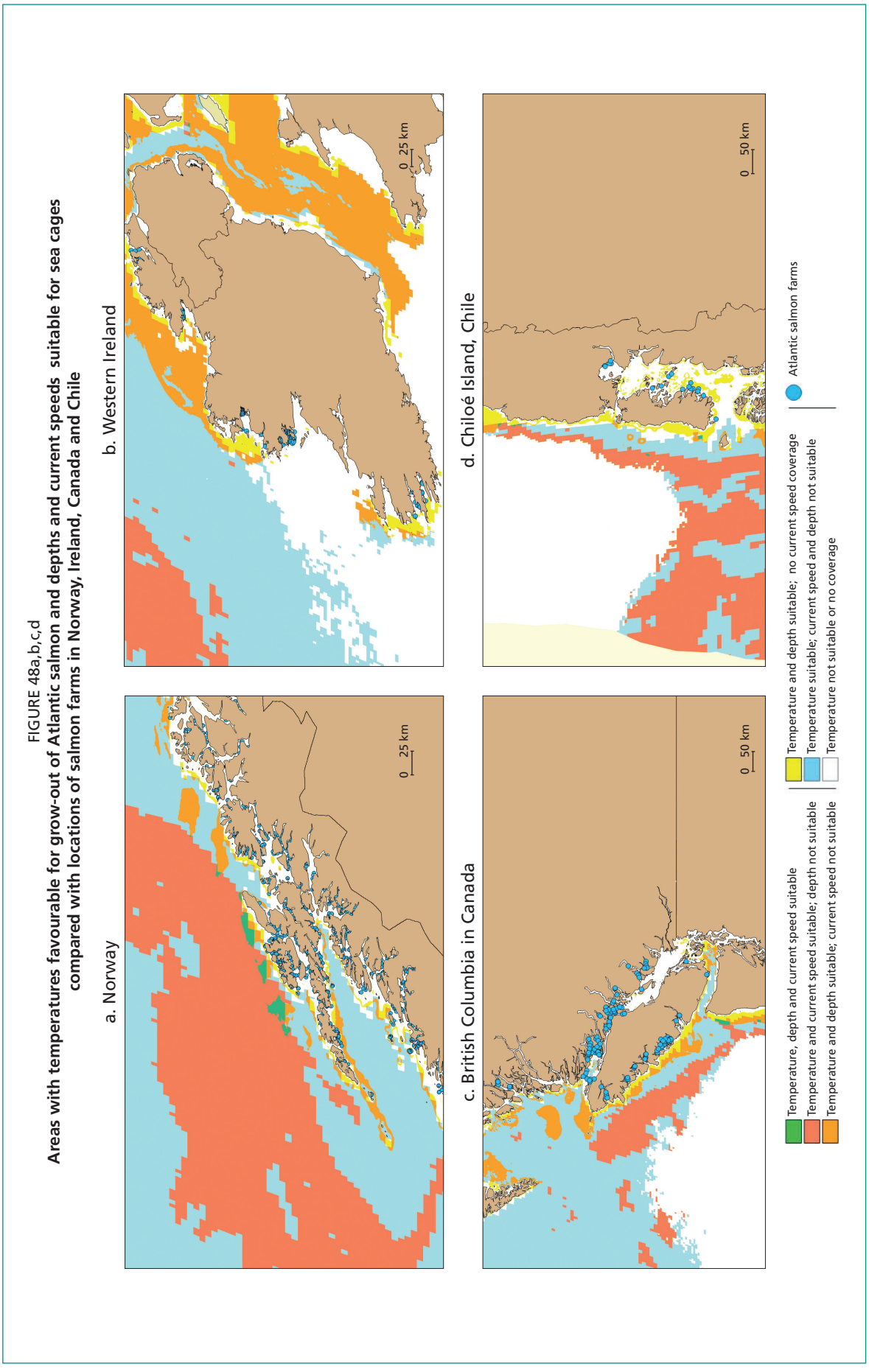


FIGURE 48a,b,c,d
Areas with temperatures favourable for grow-out of Atlantic salmon and depths and current speeds suitable for sea cages compared with locations of salmon farms in Norway, Ireland, Canada and Chile

5.3 BLUE MUSSEL

5.3.1 National-level potential and production comparison

Fifteen nations and territories produced blue mussel in the 2004–2008 period, but potential, as estimated through meeting temperature, chlorophyll-*a*, depth and current speed thresholds, was found in only seven of them in relatively small areas except for the Argentine Republic (Table 13). Temperatures (4–18 °C) and depths for longlines (25–100 m) among the most important producer countries, all European nations, were suitable. Eastern Canada, including Prince Edward Island, Nova Scotia, New Brunswick, Newfoundland and Quebec provinces, is Canada's major mussel farming region (Canadian Aquaculture Industry Alliance, 2010). Blue mussels are also cultured in that region in Maine, the state adjacent to Canada, in the United States of America (New England Aquarium, 2010). However, as with Atlantic salmon, no blue mussel potential was found in that region, and for the same reason: winter temperatures that are below the 4 °C threshold range. In a similar fashion to Atlantic salmon, actual temperatures at an experimental offshore blue mussel farm in this region were acquired, and mean monthly temperatures in the spatial data archive at locations of several offshore culture sites were sampled in order to determine the long-term offshore monthly means. Accordingly, the lower threshold was decreased to 2.5 °C, while the upper threshold was extended to 19 °C to better reflect the temperatures experienced in culture practice in this region. As a consequence, the Maine, Nova Scotia and New Brunswick areas were identified as having potential consistent with mariculture practice there, but not in the more northern mussel-growing provinces.

The coastal chlorophyll-*a* criterion of concentrations greater than 1 mg/m^3 limited estimates of potential in the European region among the blue-mussel-producing nations, particularly in Ireland and the Kingdom of Norway (Table 13). According to R. Langan (personal communication, 2009), excellent growth and good condition are obtained in the open ocean at chlorophyll-*a* concentrations of 0.5 to 2 mg/m^3 at an experimental site 10 km offshore in the Gulf of Maine. At that site seven cohorts of blue mussels had been grown to a marketable size with an average production cycle of 13 months, which corresponded to good growth (Langan and Horton, 2005). No online actual chlorophyll-*a* measurement data were available for that site, but the spatial database for coastal chlorophyll was queried at the location of the experimental farm and the result was that the lowest mean monthly chlorophyll-*a* concentration was 0.5 mg/m^3 over seven years. Additionally, other offshore experimental farms are being established in the area, and a newly established commercial offshore mussel farm nearby the experimental site is proving to be successful. With these indications, the coastal chlorophyll-*a* threshold was decreased to concentrations greater than 0.5 mg/m^3.

In summary, for the comparison of offshore potential with production at the national level, whereas there were only 7 out of 15 mussel-producing nations and territories with offshore mussel potential based on all of the original criteria, by eliminating current speed as a criterion the number of nations and territories with offshore mussel potential increased to 13 (Table 13). In contrast, the effect of broadening the temperature and chlorophyll-*a* thresholds while retaining the current speed and depth criteria showed that ten nations had offshore potential (Table 13). With the broadened temperature and chlorophyll-*a* thresholds, but eliminating current speed as a criterion, all of the nations and territories currently producing the blue mussel were found to have offshore potential (Table 13).

TABLE 13
Blue mussel annual production by nation compared with offshore potential with areas meeting two temperature and two chlorophyll-*a* threshold ranges, as well as depth and current speed criteria, and areas meeting the first two criteria

No.	Nation or national territory	Mean annual production 2004–2008 (tonnes)	Potential (km^2) by temperature and chlorophyll-*a* threshold			
			Depth (25–100m) and current speed (10–100 cm/s)		Depth (25–100 m)	
			4 to 18 °C CHL >1 mg/m^3	2.5 to 19 °C CHL > 0.5 mg/m^3	4 to 18 °C CHL >1 mg/m^3	2.5 to 19 °C CHL > 0.5 mg/m^3
1	France	56 708	67	716	558	11 482
2	Netherlands	47 562	6	108	2 234	14 443
3	Ireland (Figure 49b)	36 751	0	0	1 454	30 405
4	United Kingdom	27 354	15	1 723	21 936	133 469
5	Canada	22 670	268	1 586	13 747	27 322
6	Germany	8 610	0	0	81	14 513
7	Norway (Figure 49a)	3 384	0	1 321	810	16 113
8	United States of America	2 017	379	1 158	15 846	60 570
9	Sweden	1 475	0	164	0	356
10	Denmark	686	0	2 596	2	14 781
11	Channel Islands	60	0	0	0	3 677
12	Argentina	30	5 247	8 208	20 215	177 072
13	Namibia	10	0	0	2 183	5 772
14	Iceland	6	0	24	133	4 049
15	United Kingdom (Falkland Islands [Malvinas])	6	77	0	206	7 646
Potential of nations or territories not yet producing blue mussel						
1	Chile	0	2 881	4 684	22 084	36 929
2	Australia	0	0	4 472	0	16 295
3	New Zealand	0	12	2 199	217	31 150
4	Belgium	0	0	0	249	1 217
5	South Africa	0	0	0	248	5 225
6	Spain	0	0	0	141	1 454
7	Denmark (Faroe Islands)	0	0	0	0	206
8	Denmark (Bornholm)	0	0	0	0	5
9	France (Crozet Islands)	0	0	0	0	418
10	France (Kerguelen Islands)	0	0	0	0	18
11	Portugal	0	0	0	0	2 130
12	United Kingdom (Tristan De Cunha)	0	0	0	0	10

5.3.2 National to local level offshore mariculture potential compared with inshore mariculture locations

This comparison was accomplished by mapping the locations of inshore mussel farms in western Ireland and the Kingdom of Norway together with the offshore areas meeting various combinations of thresholds (Figures 49a and 49b). In the Kingdom of Norway, mussel farms are found all along the coast, but are less abundant in the far north. Generally, the near offshore areas of the Kingdom of Norway in the vicinity of mussel farms meet up to three thresholds, while a small area in a segment of the coast (Figure 49a) meets all four thresholds. In this segment, much of the off-lying area meets temperature, chlorophyll-*a* and current speed thresholds, but the depth is not suitable for longlines. Closer to the off-lying islands in this segment, the temperature and chlorophyll-*a* thresholds are suitable, but one or the other, or both the depth and current speed thresholds, are not met. In Ireland, mussel farms are clustered in the south, central and northwest in much the same three areas where salmon farms are shown in Figure 48b. The Ireland comparison is hampered by the lack of current speed coverage close along much of the coast where mussel farms are located (Figure 49b). In the northwest further offshore, the depths are not suitable, but the other three thresholds are met. In contrast, in the west central area, three thresholds are met, but there the current speed is not suitable. This is also the case for offshore potential in the southernmost area of mussel farms.

5.4 IMTA offshore mariculture potential compared with inshore Atlantic salmon and mussel farm locations

No data on IMTA collectively for a country or at individual offshore locations were available for comparison or verification; however, Atlantic salmon and blue mussel are cultured at a number of experimental IMTA inshore sites in New Brunswick in eastern Canada, and both species are farmed in the same general inshore areas in the Kingdom of Norway (Figures 48a and 49a) and in western Ireland (Figures 48b and 49b) where offshore IMTA potential was found.

There is no potential for blue mussel-Atlantic salmon IMTA in non-mariculture countries because there is no potential for salmon there.

5.5 Summary of comparisons of offshore mariculture potential of cobia, Atlantic salmon, blue mussel and IMTA with inshore mariculture of these species

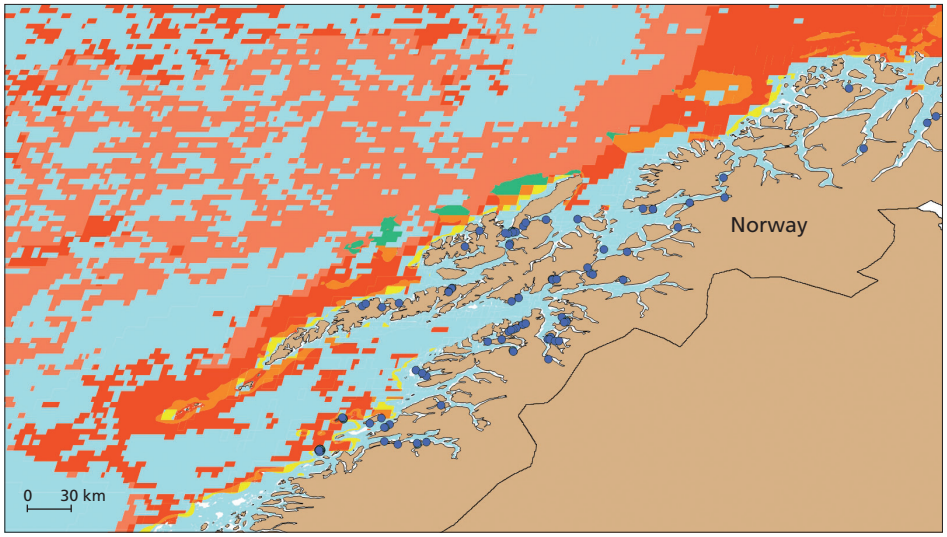
National-level offshore potential and national production comparisons

The rationale for a positive result from this comparison is simply that, where mariculture already exists in a country there is an advantage to its further development. Mariculture already in practice in a nation with the species used in this study is indicative of nationally established infrastructure, goods, services, juvenile production and other technologies as well as access to markets, which could be organized to support offshore development of these species.

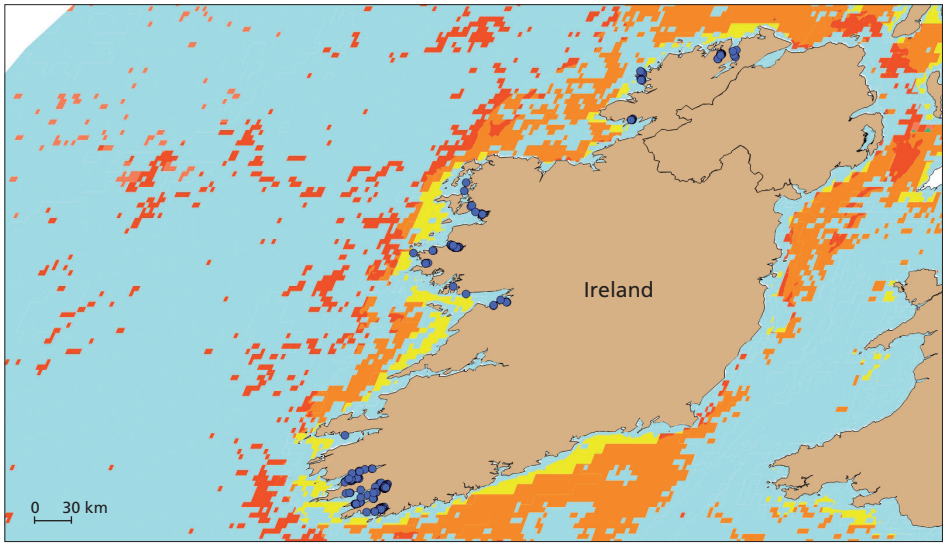
Potential was found in all five of the nations reporting cobia culture. For the Atlantic salmon, there were 14 producer nations or territories, though production in three of them was very modest, ranging from 1 to 158 tonnes. With current speed removed as a criterion, potential was found in 12 of the 14 currently producing nations. Additionally, potential was found among six nations and territories not yet producing Atlantic salmon. For the blue mussel, there were 15 producer nations and territories, and potential was found among 10 of them. In similar fashion to Atlantic salmon, with current speed removed as a criterion, potential was found in the entire 15 nations and territories currently producing blue mussel. Additionally, potential was found among 12 nations and/or territories not yet producing blue mussel.

FIGURE 49a,b
Areas with temperatures and chlorophyll-a favourable for blue mussel grow-out and depths and current speeds suitable for longlines compared with locations of mussel farms in Norway and Ireland

a. Norway



b. Ireland



Temperature, chlorophyll-*a*, depth and current speed suitable
Temperature, chlorophyll-*a* and current speed suitable; depth not suitable
Temperature, chlorophyll-*a* and depth suitable; current speed not suitable
Temperature, chlorophyll-*a* and depth suitable; current speed no coverage
Temperature and chlorophyll-*a* suitable; depth and current speed not suitable
Temperature and/or chlorophyll-*a* not suitable; or no coverage
Mussel farms

Offshore mariculture potential compared with inshore farm and farming area locations

The rationale for an advantage in the development of offshore mariculture in the areas where there is a correspondence between offshore potential and inshore practice is the same as for the national-level comparison above, but with all of the advantages of inshore practice being proximate to offshore areas with potential for development.

Cobia. For cobia, the locations of 22 cage sites and nine cobia farming areas among eight nations were examined for offshore potential. In all but 13 of the locations the

temperatures were seasonally too cool to meet the 22 °C lower threshold limit, and evidence from literature reviews showed that these were farming areas with risk of relatively long grow-out durations or of mortalities caused by low temperatures. The cobia temperature threshold range was established to provide temperatures favourable for grow-out and thereby to be risk averse. Thus, the lower limit of the threshold (22°C) is justified.

Among seven farm locations or farming areas in six countries, all three thresholds were met relatively close offshore of five locations. Temperature and depth thresholds were met offshore of two other locations indicating good correspondence between inshore cobia farming and offshore potential where temperatures remain suitable year round.

Atlantic salmon. The comparison of offshore potential with locations of inshore farms included the Kingdom of Norway and the Republic of Chile, the two leading nations in Atlantic salmon production worldwide, as well as Canada and Ireland. Among these four nations, all three, or two, of the criteria were met offshore of the inshore farming areas. The comparisons for Atlantic salmon substantiate the estimates of offshore potential in that offshore potential has been identified in areas where inshore culture of this species is already practised.

Blue mussel. At the national level, offshore potential has been identified in areas in western Ireland, one of the most important blue-mussel-producing countries (Table 12). Offshore potential has been identified where inshore culture of this species is already practised. However, at best, three of four thresholds were met in western Ireland. In the Kingdom of Norway, all four thresholds were met along a small segment of the coast, and elsewhere up to three thresholds were met.

IMTA. No data on IMTA collectively for a country or at individual offshore locations were available for comparison or verification, but inshore blue mussel and Atlantic salmon farming does occur in close proximity in western Ireland and the Kingdom of Norway where there is offshore potential for IMTA, suggesting that offshore IMTA of blue mussel with Atlantic salmon could be considered.

Cobia offshore potential verification

Only four offshore farm locations were available for comparison with offshore potential. At one of these locations, all three thresholds were met; at another location, one farm site was adjacent to an area that met all three thresholds but the other met only one threshold, and at the last, temperature and depth thresholds were met, but there was no current speed coverage.

To summarize, these comparisons, despite being hampered in some instances by a lack of spatial data coverage in inshore areas, or of no current speed coverage, lend substantial credibility to the conclusion that, by the criteria of this study, there is much unrealized offshore potential for the three species and IMTA offshore of farming areas in nations where the culture of these species is already established.