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The Use of Density Analyses to Delineate Significant Concentrations of Pennatulaceans from Trawl Survey Data

by

F.J. Murillo[1], E. Kenchington[2], C. Gonzalez[1], and M.Sacau[1]

[1] Instituto Español de Oceanografía, Vigo, Spain
[2]Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada

Introduction

Previously, the Working Group on Ecosystem Approach to Fisheries Management (WGEAFM) was asked to delineate significant concentrations of corals and sponge in the NAFO Regulatory Area (NAFO 2008a, b, 2009a). This was a two step process whereby corals were considered first (NAFO 2008a, b) and sponges second (NAFO 2009a). Previously NAFO and ICES had defined the conservation units as sea pen fields, large gorgonians and small gorgonians for the coral, and sponge grounds - which in the NAFO Regulatory Area (NRA) are dominated by *Geodia* sp. (Fuller *et al*. 2008, ICES 2009). These taxa were reviewed against the FAO (2009) criteria for vulnerable marine ecosystems (VME). Initially in the analyses of the coral, plots of the cumulative catch weight distribution from the groundfish trawl surveys were used (NAFO 2008a, b). It was noted that the distribution of cumulative catch weights was highly skewed, with most tows catching small quantities, and only small numbers of tows with larger catches. The WGEAFM was unable to link any specific catch weight from these distributions to a threshold that would say whether the location was a VME or just a catch of the widespread but isolated occurrence of some of these species. The WGEAFM did feel that the very largest of the catches did constitute a VME based solely on their relative size, and therefore opted to use the upper 97.5 quantile as a standard (2.5% of the catches were above this value) based on standard statistical conventions (NAFO 2008a, b). These were applied to the sea pen and small gorgonian bycatch, while a more precautionary 90% quantile was used for the large gorgonians where it was felt that retention efficiency was lower and the taxa are prone to breakage. Other RFMOs also used properties of the bycatch distribution for decision making, but were equally unable to link any particular value with a biological or ecological property. Through the consideration of this issue, NAFO developed a spatial approach to identify significant concentrations of sponge, that is, sponge grounds (Kenchington *et al.* 2009, NAFO 2009a). Essentially, the research vessel data on sponge bycatch were used to create a biomass map (kg/km^2). A kernel density function was used to interpolate the data as this method is superior for identifying concentrations (over other smoothing methods such as Kriging or IDW). The biomass raster is then contoured by areas of equal or greater bycatch, creating polygons for each bycatch “threshold”. This method worked well because the sponges not only had a catch distribution as described above, with few medium-sized catches, many small ones and few large ones, but the location of these larger catches were highly aggregated. These two properties allowed for the identification of sponge grounds by comparing the relative increase in area with increasing bycatch weight threshold. The area occupied by the largest catches did not increase very much as smaller catches were included - up to a point. Once the catches were outside of the sponge ground the area expanded rapidly. Through evaluation of the performance of this technique, confidence was gained in selecting the threshold that best defined the sponge grounds for these *Geodia* sponges and their associated sponge fauna (NAFO 2009a). The area of the polygon encompassing the sponge grounds is an estimate of sponge habitat, which gives this approach a more direct biological basis for selection of thresholds. In principle, this approach could also be applied to the coral conservation units described above (NAFO 2008a, b). Sea pens or pennatulaceans are known to form dense aggregations known as sea pen fields but are otherwise broadly distributed at low density (Fuller *et al*. 2008), and so should be good candidates for spatial analysis. When a trawl encounters a dense aggregation the catch is consequently very much higher than when fishing on low density areas. Further, it was noted that when the positions of the significant concentrations of coral were plotted by the WGEAFM (NAFO 2008a, b) they were grouped into 'key locations', that is, the high catches were spatially aggregated. This was not surprising as it supports the notion that these catches are in fact 'evidence of a VME'. Here we apply the spatial analytical approach used on sponges by NAFO (2009a) to the pennatulacean data used previously when applying the cumulative catch weight distribution methodology (NAFO 2008a, b). This information can be used when NAFO reconsiders the spatial closures to protect coral and sponge in 2011. The dominant sea pen taxa observed in the surveys are *Anthoptilum grandiflorum*, *Halipteris finmarchica* and *Pennatula aculeata*. Full details of the method for extracting the area of pennatulacean grounds occupied at different threshold values can be found in Kenchington *et al.* (2009).

Material and methods

Data Source

1. DFO NL Groundfish Surveys (Research Vessel Engel 145 Otter Trawl): 2004-2007 (Divs 3LMNO): 145 records of pennatulaceans from 2472 tows between 40 and 1494 m (provided by DFO NWAFC);

2. IEO Platuxa Survey (Research Vessel Campelen 1800 Bottom Trawl): 2005-2007 (Divs 3NO): 52 records of pennatulaceans from 349 tows covering the 'Tail' of the Grand Banks (NRA) between 40 and 1500 m depth, (provided by IEO);

3. EU Flemish Cap Survey (Research Vessel Lofoten Bottom Trawl): 2006-2007 (Div 3M): 195 records of pennatulaceans from 355 tows covering all the trawlable Flemish Cap (NRA) between 130 and 1450 m (provided by IEO);

4. IEO Fletán negro Survey (Research Vessel Campelen 1800 Bottom Trawl): 2006-2007 (Div 3L): 67 records of pennatulaceans from 180 tows covering the 'Nose' of the Grand Banks and Flemish pass (NRA) between 110 and 1450 m (provided by IEO).

5. Canada EEZ Survey (Research Vessel Campelen 1800 Bottom Trawl): 2007 (Div 3L): 14 records of pennatulaceans from 26 tows carried out by IEO within the Canadian EEZ (provided by IEO);

The location of these tows is illustrated in Figure 1 and shows good spatial coverage of the NAFO Area (Divs. 3LMNO). Start position of the survey fishing tows were used to represent these locations. In the NRA sea pens occur broadly over the slopes of Flemish Cap, with the exception of the steep slopes on the southern flank.

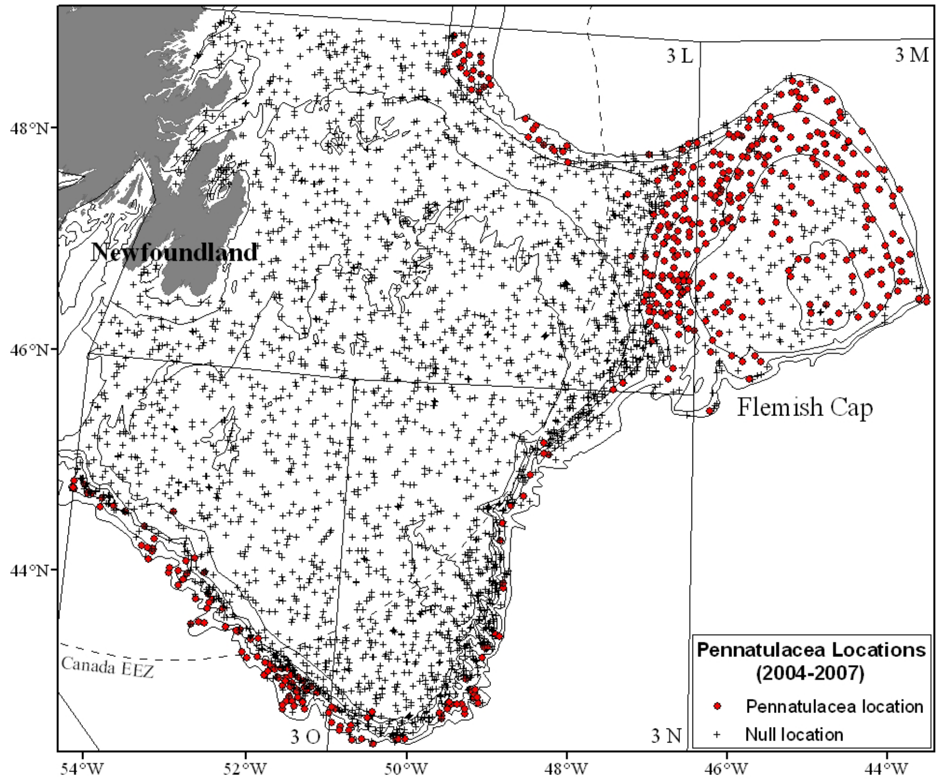


Figure 1. Location of sampling points in the NAFO Area (Divs. 3LMNO) used for the analysis. Red dots represent locations with pennatulacean presence and black crosses represent pennatulacean absence.

GIS Analyses

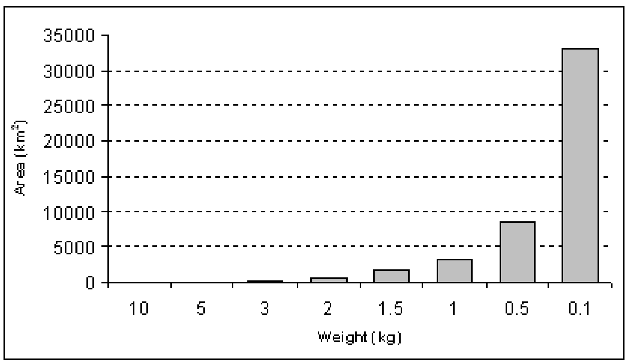
ArcGIS 9.2 (ESRI Canada Limited) was used to create a kernel density map of pennatulacean distribution along the Grand Banks and Flemish Pass/Cap area. The kernel density function is ideal for locating high concentrations of data. The pennatulacean data were plotted in using the UTM projected coordinate system (Zone 23N) to avoid distorting the data surfaces. Moreover, bathymetric curves were exported as shapefiles (ArcMap format) from the General Bathymetric Chart of the Oceans (GEBCO 2003). The ultimate goal of the following model was to map pennatulacean density and subsequently determine the area of polygons that follow density contours that fully encompass points representative of decreasing weight thresholds. The bycatch categories used to examine polygon areas were: ≥ 10 kg, ≥ 5, ≥ 3, ≥ 2, ≥ 1, ≥ 0.5, ≥ 0.1kg. The area for each of these thresholds was then extracted following the model outlined in Kenchington *et al.* (2009).

Results

Pennatulacean Area-Catch Threshold Relationships

Figure 2 shows the area occupied by each of the pennatulacean weight thresholds from the combined Canadian and Spanish/EU data sets. Other than the initial increase in area as the largest catches are mapped, the largest important increase in area occurs between catches of 0.5 and 0.1 kg. This coincides with an area of 8484 km^2 for the 0.5 kg catch threshold and a 3.7 times increase to 33,053 km^2 for the 0.1 kg catch. This change is considered to be robust as it is created by the addition of 125 data points. The only other large increase in area is seen in going from 3 kg to 2 kg (3.5 times) but this is due to the addition of a single data point and is not considered to be robust.

Figure 3 shows the increase in polygon area when decreasing the pennatulacean weight catch from 1 to 0.5 kg and from 0.5 kg to 0.1 kg. From this figure we can see that in going from 1 to 0.5 kg, there is not a large increase in the area for the areas in Flemish Pass and the new points added are located near the 1 kg and greater weight catches, that is, they were a clearly part of the same sea pens grounds. On the eastern Flemish Cap, a new area is resolved which may be explained by a different species composition. Meanwhile, in going from 0.5 to 0.1 kg the area increases considerably at all of the locations which is explained by the widespread occurrence of isolated individuals. Consequently the 0.5 kg weight threshold could be considered as a good indicator of the higher pennatulaceans concentrations in the study area. Their present day habitat is approximately 8484 km^2. The location of the catches from the NRA (excluding the catches within Canada's EEZ) and their associated weight is provided in Table 1 and illustrated in Figure 4. Compared with the 1.6 kg threshold obtained from the cumulative curve distribution (NAFO 2008a, b), 29 new points have been added (Figure 4) with this methodology in the NRA (Divs. 3LMNO). These tend to occur within the same geographic area (Figure 4), confirming the robustness of this approach in identifying pennatulaceans concentrations. These locations are shown in relation to the fishing footprint in Figure 5. The fishing footprint was taken from the composite plot of coordinates of bottom fishing activity data submitted by all flag States for 2003-2007 (NAFO 2009b). The portion of the VMS dataset containing speed data (Japan, Portugal and Norway) was filtered to include data only when the vessel was traveling between 1.0-4.0 knots. The point dataset used was derived from an interpolated (Krig) GIS raster which calculates the number of times vessels would frequent a single 2.5 km box in at least two separate years at the speeds identified. It can be seen that the higher pennatulaceans concentrations are located in areas where there has been no or light fishing activity.



Weight (kg)	Area (km^2)	N tows
10	11	1
5	90	3
3	180	4
2	638	5
1.5	1682	14
1	3172	22
0.5	8484	46
0.1	33053	171

Figure 2. Polygon area (km^2) occupied by tows with decreasing catch weight from ≥ 10 kg to ≥ 0.1 kg.

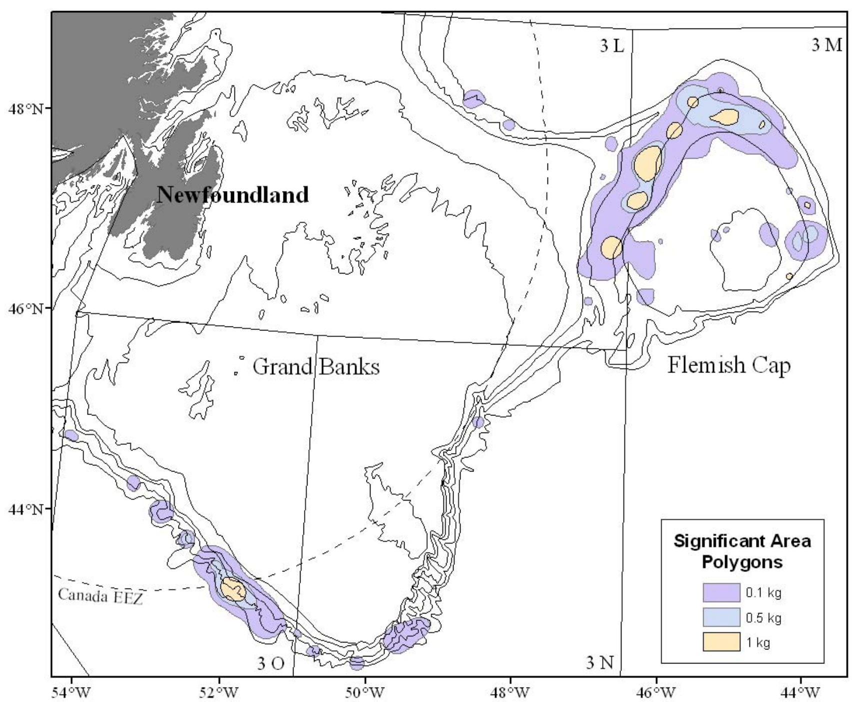


Figure 3. Area polygons for ≥ 1, ≥ 0.5, and ≥ 0.1 kg pennatulacean catch weight showing the increasing area occupied by successive threshold values. The area occupied by ≥ 0.5 kg is considered to represent the significant concentrations of sea pens.

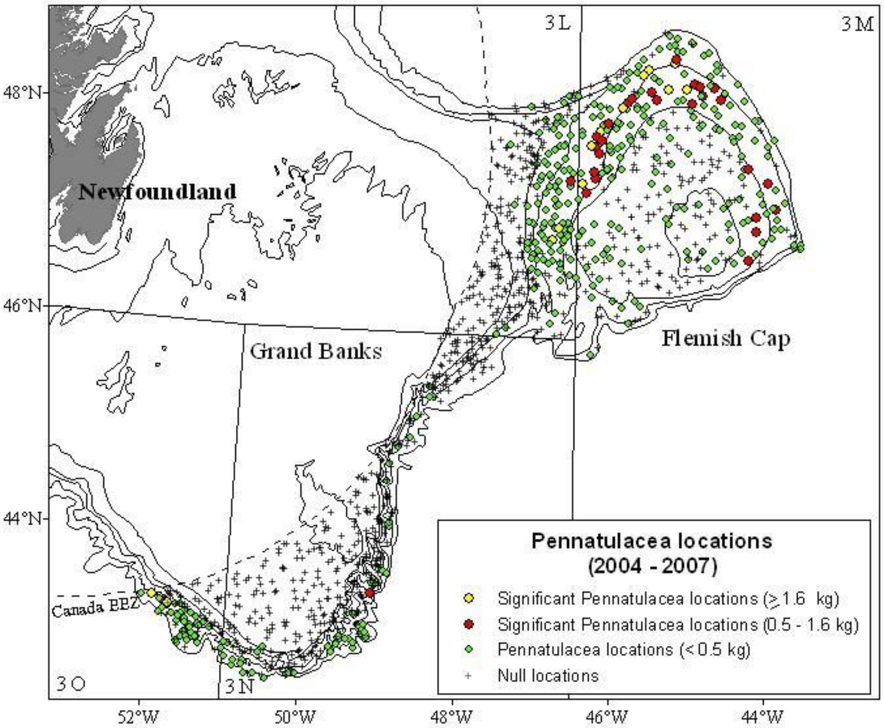


Figure 4. Significant pennatulacean locations (≥ 0.5 kg/trawl) in the NRA (Divs 3LMNO) derived from the spatial density analysis are indicated in red and yellow. Yellow dots represent catches higher than 1.6 kg (threshold obtained from the cumulative curve distribution, NAFO 2008a, b). Green dots represent catches below 0.5 kg. Black crosses represent catches without pennatulacean records.

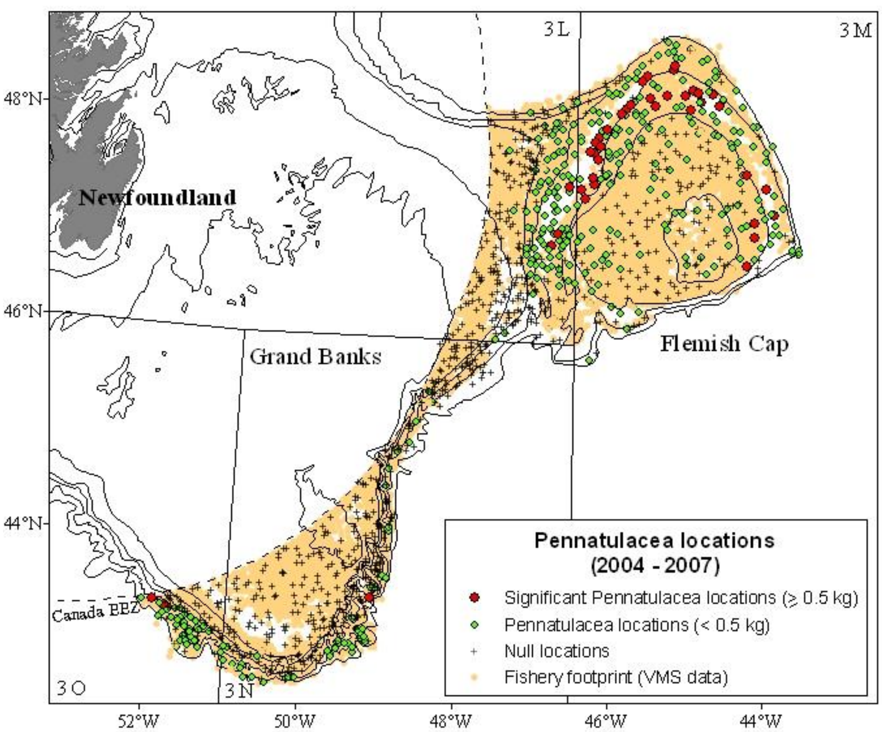


Figure 5. Significant pennatulacean locations derived from the density analysis in the NRA (Divs 3LMNO) overlapping with the fishery footprint (VMS data; NAFO 2009b). Red dots represent catches ≥ 0.5 kg. Green dots represent catches ≤ 0.5 kg. Black crosses represent catches without pennatulacean records.

Table 1. Start and end positions of tows with ≥ 0.5 kg of pennatulaceans derived from the density analysis in the NRA (Divs. 3LMNO) with their corresponding catch weight.

N	Survey	Start position		End position		Weight (kg)
		Latitude	Longitude	Latitude	Longitude	
1	DFO-CAN	47° 58' 12" N	46° 11' 24" W	47° 58' 55" N	46° 10' 55" W	1.615
2	DFO-CAN	43° 19' 55" N	51° 47' 06" W	43° 19' 23" N	51° 46' 23" W	1.578
3	DFO-CAN	48° 15' 18" N	45° 48' 00" W	48° 15' 47" N	45° 47' 24" W	1.2
4	DFO-CAN	43° 18' 36" N	51° 44' 06" W	43° 18' 00" N	51° 43' 19" W	1.024
5	DFO-CAN	47° 23' 42" N	46° 22' 30" W	47° 23' 24" N	46° 23' 24" W	0.501
6	SPAIN-EU	47° 02' 52" N	46° 44' 11" W	47° 01' 28" N	46° 44' 58" W	10.116
7	SPAIN-EU	48° 30' 29" N	45° 34' 46" W	48° 29' 17" N	45° 35' 53" W	5.717
8	SPAIN-EU	43° 23' 15" N	51° 57' 14" W	43° 23' 34" N	51° 59' 12" W	5.517
9	SPAIN-EU	48° 33' 45" N	45° 30' 39" W	48° 34' 59" N	45° 29' 22" W	3.3
10	SPAIN-EU	46° 56' 02" N	46° 50' 04" W	46° 54' 32" N	46° 50' 08" W	2.3
11	SPAIN-EU	47° 50' 37" N	46° 18' 42" W	47° 52' 01" N	46° 17' 47" W	1.994
12	SPAIN-EU	48° 11' 59" N	45° 52' 58" W	48° 13' 10" N	45° 51' 25" W	1.988
13	SPAIN-EU	48° 22' 58" N	44° 57' 49" W	48° 21' 53" N	44° 59' 18" W	1.953
14	SPAIN-EU	47° 28' 39" N	46° 25' 17" W	47° 29' 52" N	46° 23' 55" W	1.941
15	SPAIN-EU	48° 22' 49" N	45° 13' 38" W	48° 22' 01" N	45° 15' 50" W	1.898
16	SPAIN-EU	48° 37' 51" N	45° 08' 32" W	48° 38' 00" N	45° 10' 47" W	1.7
17	SPAIN-EU	47° 28' 50" N	43° 50' 09" W	47° 30' 31" N	43° 50' 28" W	1.599
18	SPAIN-EU	47° 35' 35" N	46° 16' 00" W	47° 36' 55" N	46° 14' 52" W	1.498
19	SPAIN-EU	48° 16' 46" N	44° 28' 37" W	48° 17' 51" N	44° 30' 28" W	1.428
20	SPAIN-EU	47° 55' 23" N	46° 13' 54" W	47° 54' 42" N	46° 11' 52" W	1.3
21	SPAIN-EU	46° 44' 49" N	44° 07' 02" W	46° 46' 14" N	44° 05' 31" W	1.246
22	SPAIN-EU	48° 03' 28" N	46° 04' 17" W	48° 04' 43" N	46° 06' 19" W	1.2
23	SPAIN-EU	48° 17' 31" N	45° 45' 03" W	48° 16' 02" N	45° 46' 08" W	1.051
24	SPAIN-EU	48° 19' 04" N	44° 44' 24" W	48° 20' 01" N	44° 46' 17" W	0.9
25	SPAIN-EU	48° 14' 53" N	44° 52' 55" W	48° 15' 40" N	44° 55' 13" W	0.863
26	SPAIN-EU	47° 49' 38" N	46° 15' 22" W	47° 48' 08" N	46° 15' 23" W	0.85
27	SPAIN-EU	47° 45' 57" N	46° 11' 40" W	47° 44' 34" N	46° 12' 23" W	0.85
28	SPAIN-EU	48° 23' 46" N	44° 34' 49" W	48° 22' 55" N	44° 32' 56" W	0.8
29	SPAIN-EU	47° 37' 13" N	44° 06' 03" W	47° 38' 42" N	44° 07' 23" W	0.8
30	SPAIN-EU	47° 14' 00" N	43° 43' 52" W	47° 12' 22" N	43° 43' 13" W	0.8
31	SPAIN-EU	47° 29' 48" N	46° 35' 49" W	47° 31' 11" N	46° 34' 11" W	0.755
32	SPAIN-EU	48° 21' 20" N	45° 27' 35" W	48° 20' 11" N	45° 29' 29" W	0.712
33	SPAIN-EU	48° 25' 34" N	44° 50' 40" W	48° 26' 14" N	44° 52' 49" W	0.67
34	SPAIN-EU	48° 39' 37" N	45° 06' 55" W	48° 39' 54" N	45° 09' 13" W	0.654
35	SPAIN-EU	48° 16' 28" N	45° 23' 43" W	48° 17' 10" N	45° 21' 40" W	0.65
36	SPAIN-EU	47° 31' 25" N	46° 15' 20" W	47° 32' 34" N	46° 13' 59" W	0.65
37	SPAIN-EU	47° 09' 16" N	43° 59' 38" W	47° 07' 34" N	43° 59' 33" W	0.62
38	SPAIN-EU	48° 24' 20" N	44° 47' 07" W	48° 25' 13" N	44° 49' 10" W	0.56
39	SPAIN-EU	43° 31' 13" N	49° 07' 16" W	43° 32' 25" N	49° 06' 37" W	0.557
40	SPAIN-EU	47° 01' 29" N	43° 59' 52" W	47° 03' 05" N	44° 00' 16" W	0.544
41	SPAIN-EU	47° 53' 36" N	46° 10' 09" W	47° 52' 00" N	46° 10' 05" W	0.502

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