ECOMMAS Static acoustic monitoring of small cetaceans 2012 to 2023 by Marine Scotland

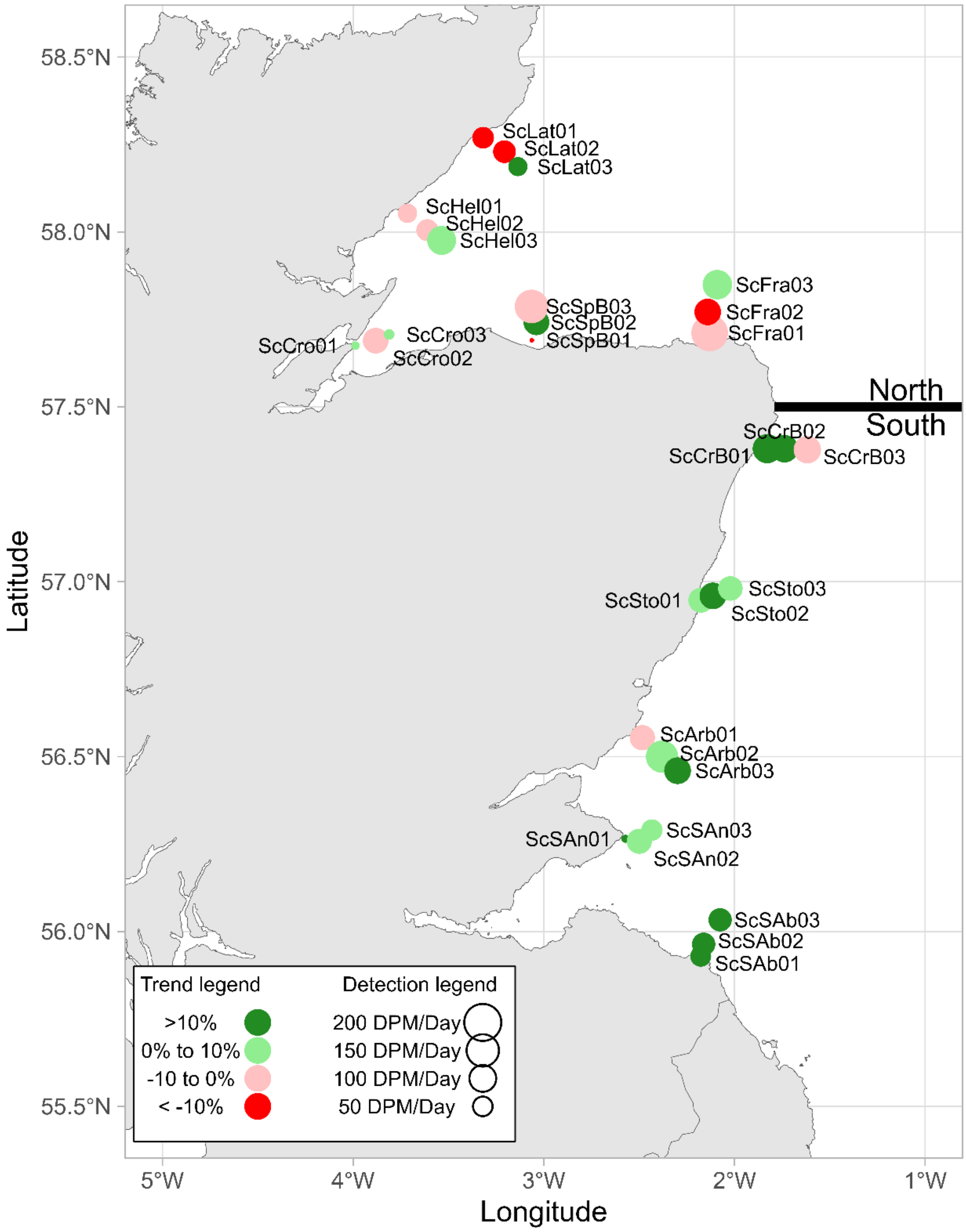
This is not an official report, but an analysis by Chelonia Ltd to illustrate the application of the PYRA trend analysis method and a comparison of C-PODs and F-PODs.

ECOMMAS included deployment of C-POD loggers at 30 sites on the east coast of Scotland from 2012. These instruments allow porpoises to be distinguished from dolphins, but do not distinguish between dolphin species. The maps below show the mean DPM = mean number of minutes with detections per day during the days of recording.

The sites have been arbitrarily divided into a northern and a southern half of sites for parts of this analysis.

Porpoise detections

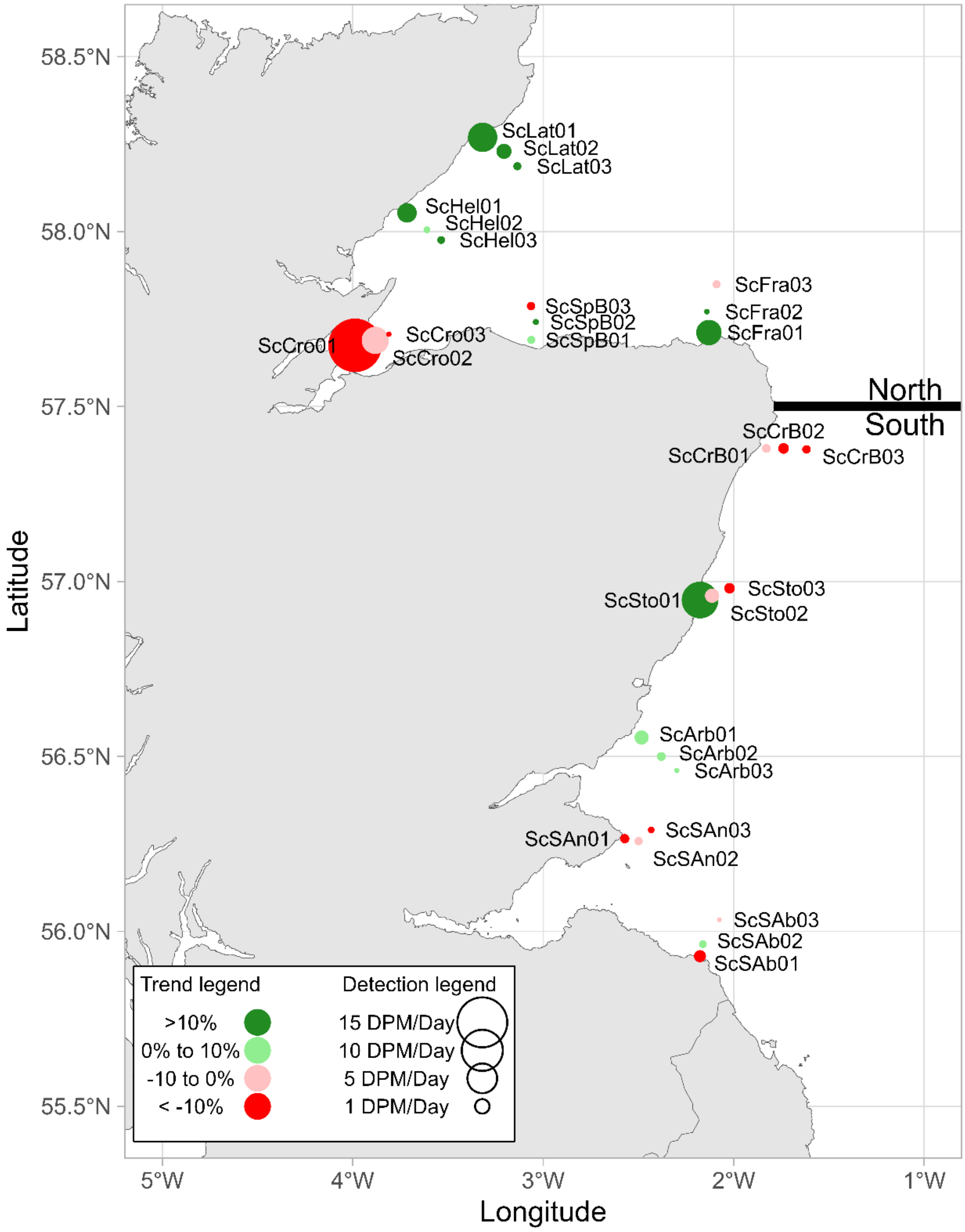
Figure 1. Porpoise detections, as mean DPM (Detection Positive Minutes) / day.
Red sites showed a decline, green an increase. Circle size is proportional to detection rate.



North = +2.2%, South = +12.2% average annual change.

Dolphin detections

Figure 2. Dolphin detections, as mean DPM (Detection Positive Minutes) / day.
Red sites showed a decline, green an increase. Circle size is proportional to detection rate.



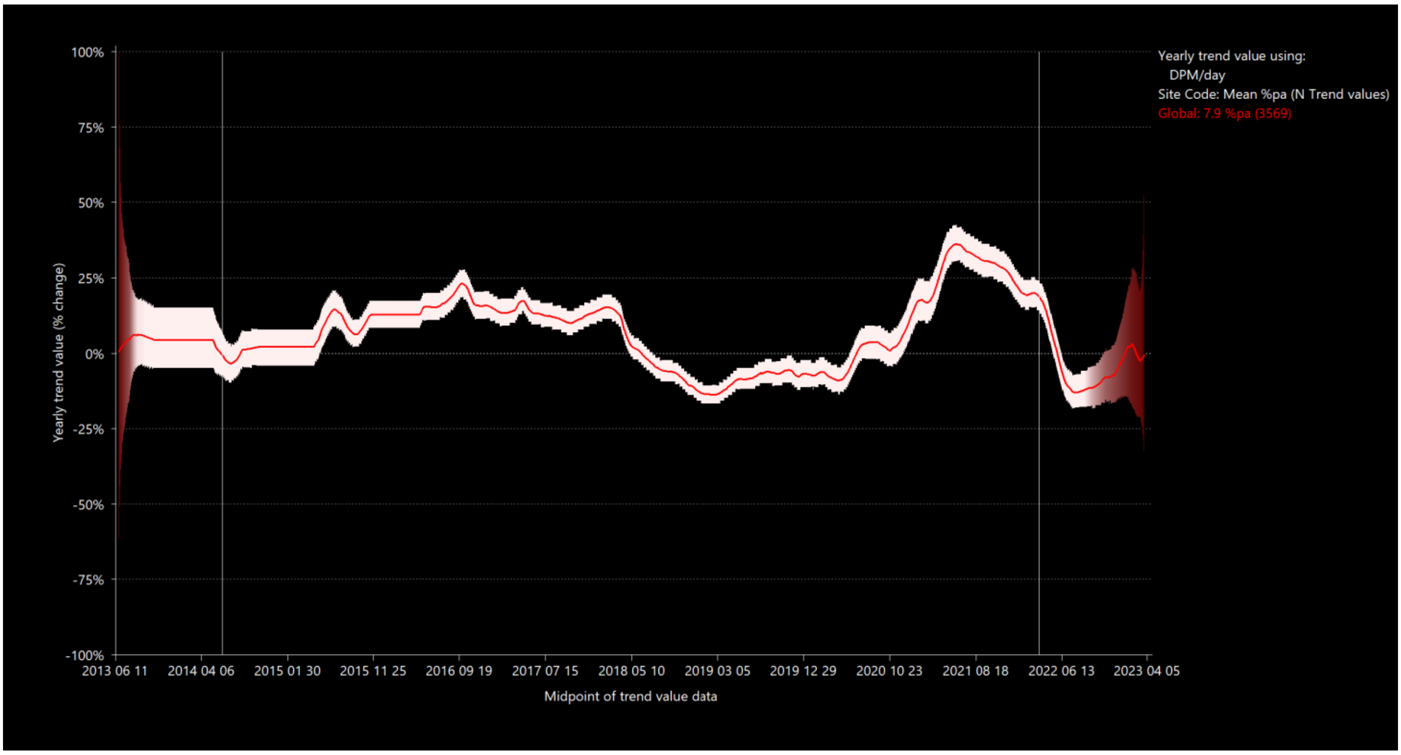
The Cromarty sites, which are highest for dolphins were among the lowest for porpoises. Similar findings were reported by Thompson *et al.* 2013 (https://assets.publishing.service.gov.uk/media/5df1160be5274a71dc6b45df/Moray_Firth_Final_Report_-_November_2013.pdf).

Trends in detections

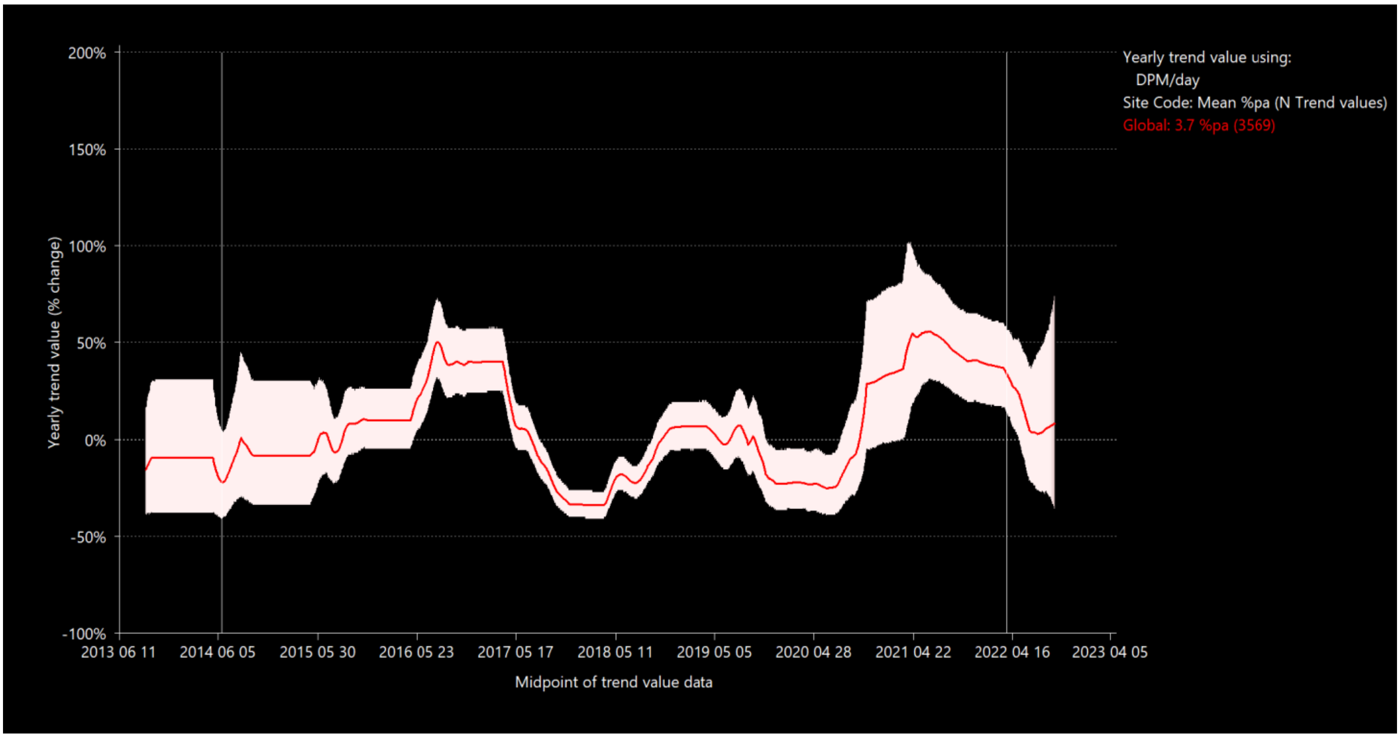
Trends have been estimated using paired year ratio estimation (more below).

Detection rates have increased over the ten years for both porpoises and dolphins with a Pearson's correlation between the two trends over time of r = 0.62:

PORPOISE TREND – overall trend = +7.9% per annum



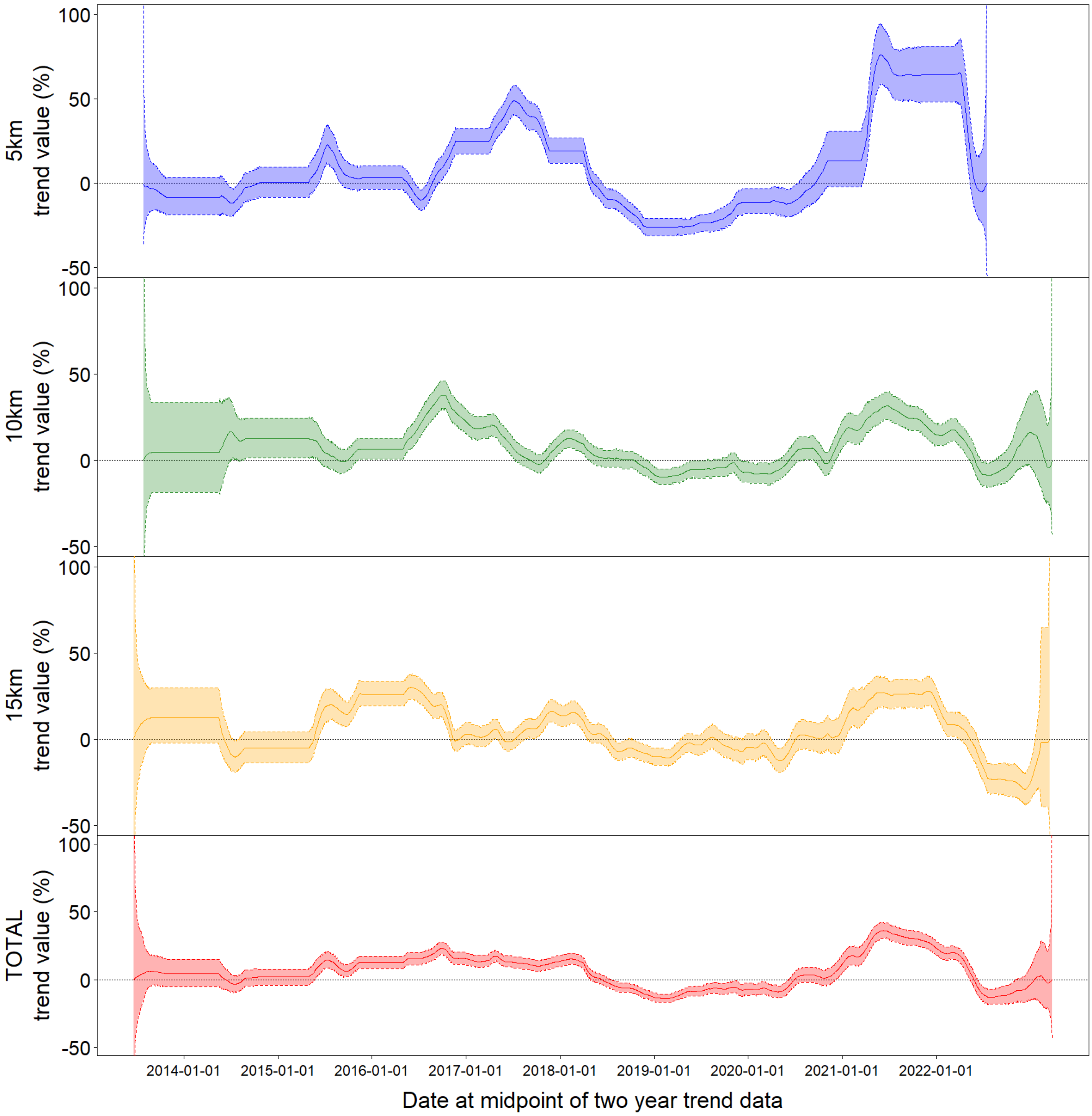
DOLPHIN TREND – overall trend = +3.7% per annum



Distance from shore

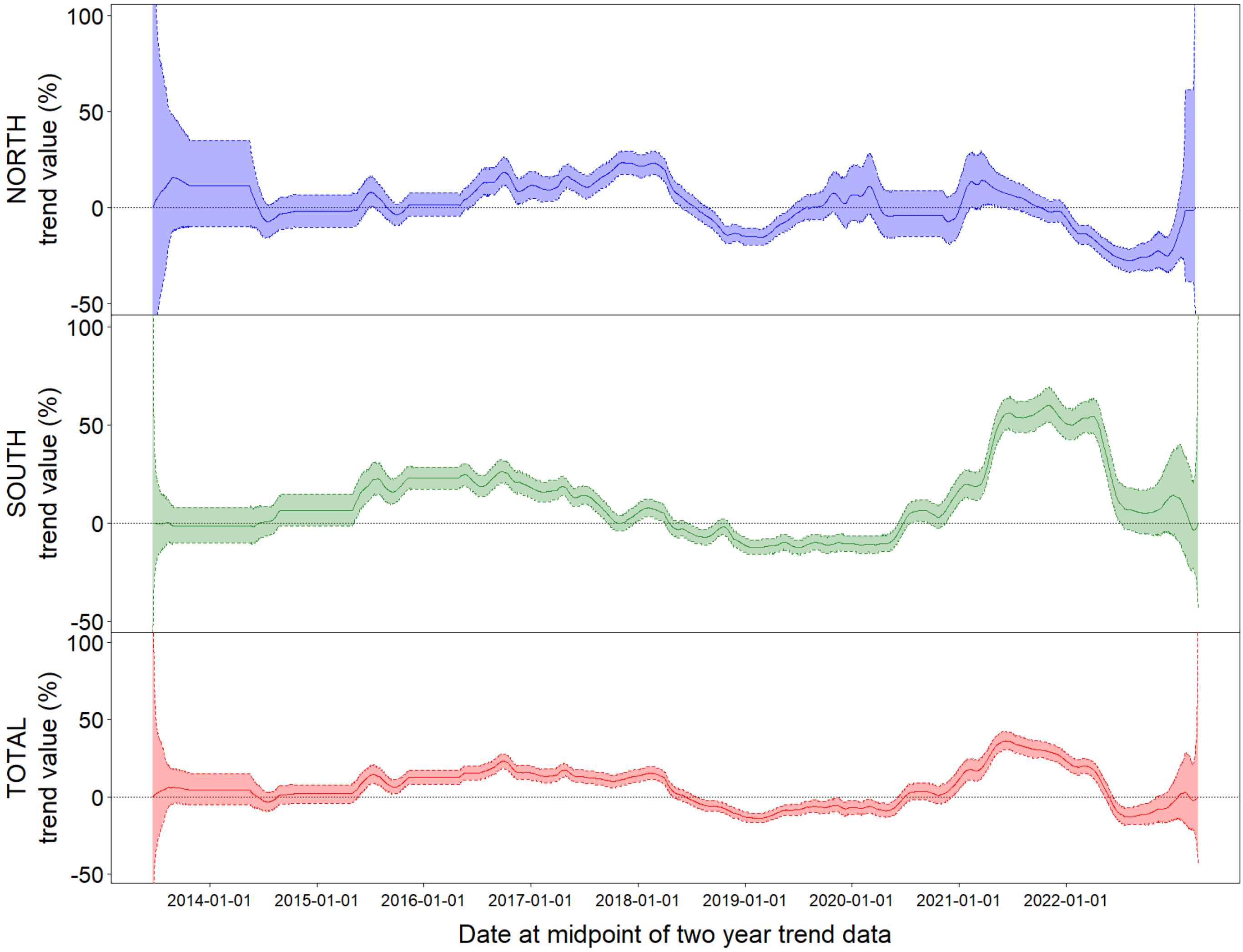
The ECOMMAS sites are in groups of three with offshore distances of around 5,10 and 15km.

The average **porpoise detection rates by offshore stratum** are show below:



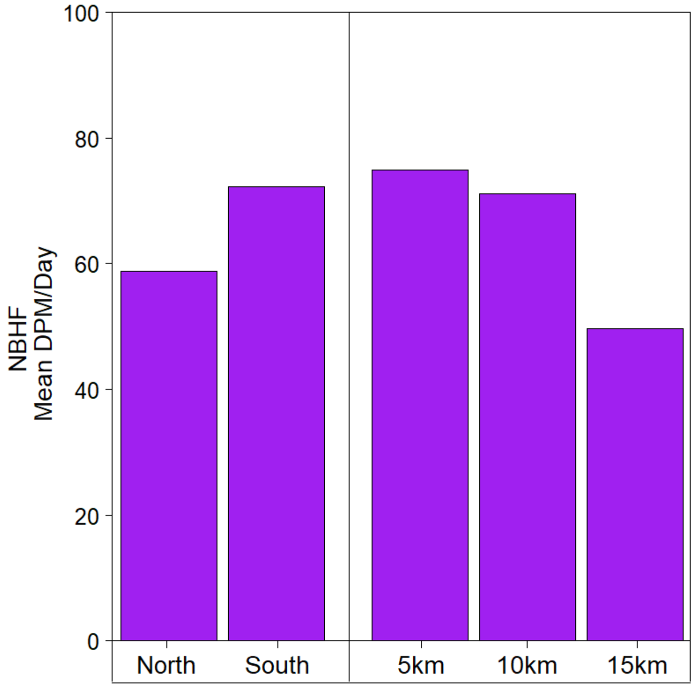
North – South

The trend in **porpoises in the northern and southern strata** are shown below followed by the overall trend:



Detection Rates

Mean porpoise detection rates



The Pearson's correlations between offshore stratum trend profiles were:

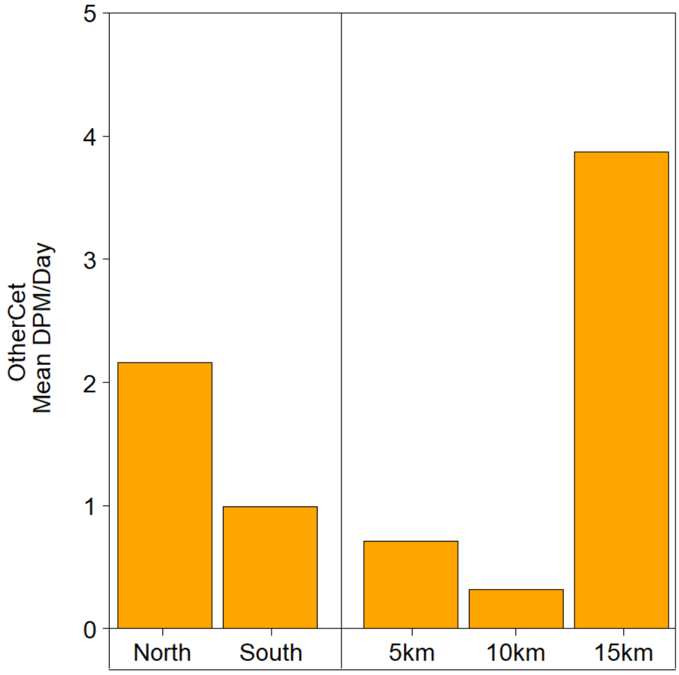
5km-10km: r = 0.64,

5km-15km: r = 0.52

10km-15km: r = 0.50.

The Pearson's correlation between the North and South strata was r = 0.00.

Mean dolphin detection rates

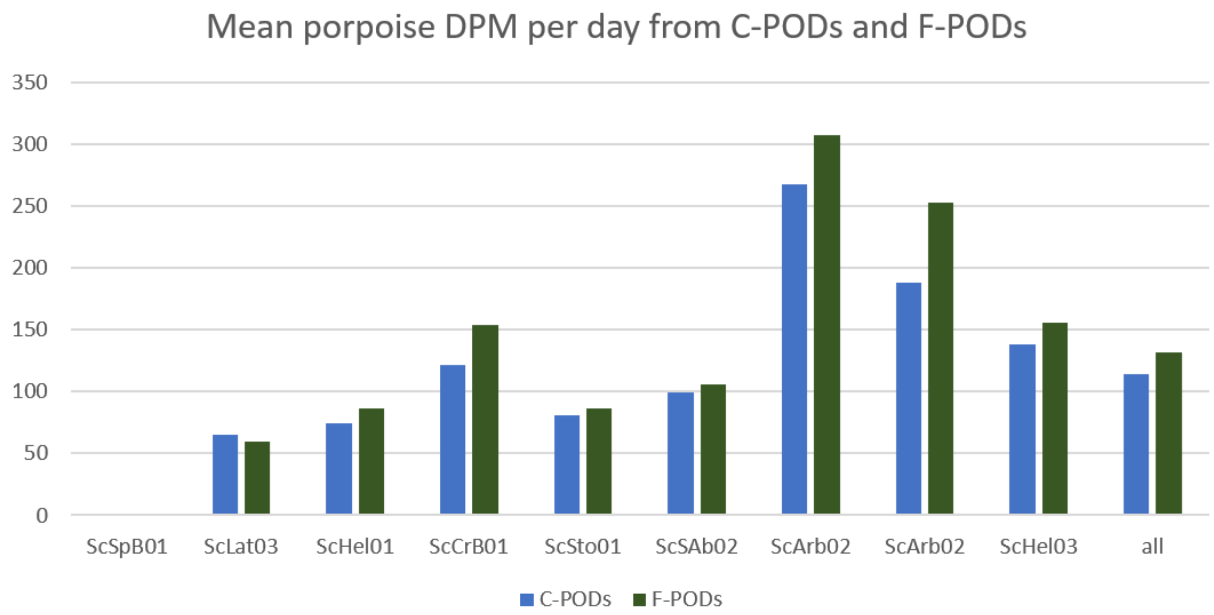


The distribution of dolphin detection rates is far less even than the porpoise distribution.

There is a downward trend in detections in the inner Moray Firth and increases at inshore monitoring stations further away from the Inner Firth. Those inshore increases extend into the northern part of the southern sector.

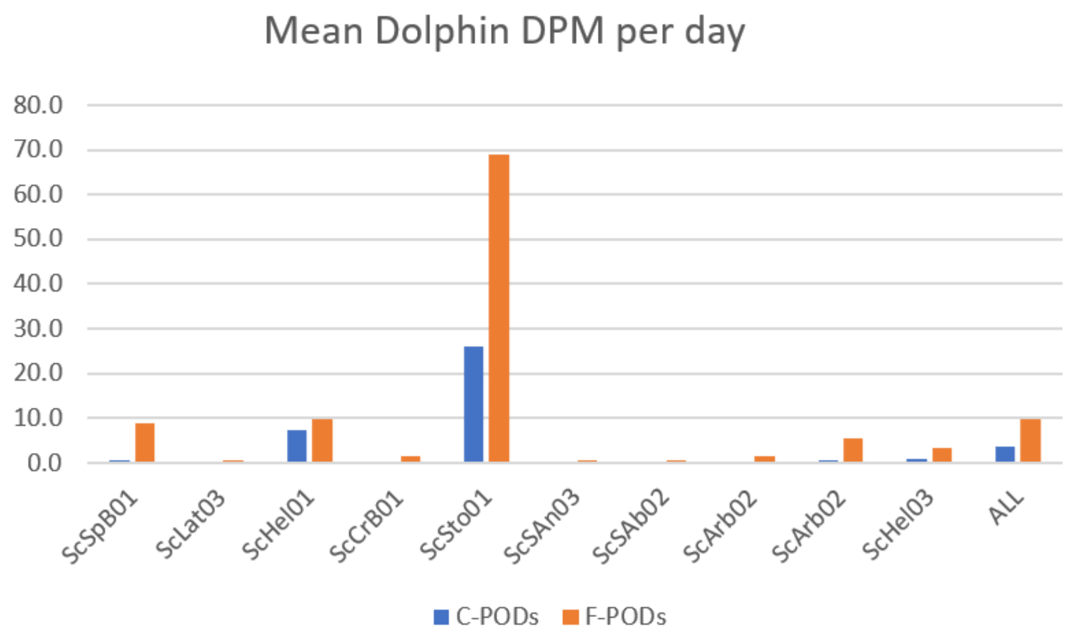
The inshore offshore distribution is lowest at the 10km station, which may might different species e.g. bottlenose dolphins inshore and common dolphins offshore.

C-POD versus F-POD



On average F-POD registered 16% more detection positive minutes than C-PODs.

> Using the principles set out in Ivanchikova et al (https://doi.org/10.1371/journal.pone.0293402) we determined the error rates which were <<1% for porpoises and <2% for dolphins for both instruments.



On average F-POD registered 169% more Dolphin detection positive minutes than C-POD.

This value is high and varies substantially between data files.

It would be difficult to obtain a reliable scaling factor for dolphins to related C-POD data to F-POD data.

(The C-POD does log the 'missing' dolphin clicks but the KERNO classifier could not reliably classify them. The KERNO-F classifier is able to classify them as dolphin clicks because it has more detailed and more precise click descriptions)

Discussion

This is a highly innovative project by Marine Scotland that has the capacity to evaluate static acoustic monitoring of small cetacean echo-location on this scale, and answer other significant questions.

Distributions

The overall evenness of porpoise density is interesting, as is the evidence that hotspots for dolphins are predominantly inshore features.

Trends

For porpoises the overall growth rate averaged +7.9% per annum. There was 2.2% average annual increase in the northern part while in the southern section the growth rate averaged 12.2% per annum.

There is clear coherence in the data with year-on-year trends profiles matching to some degree across both the north south and inshore-offshore stratifications. There is also a weak correlation between the pattern of trends in porpoises and dolphins.

The trend patterns indicate that redistribution is a substantial factor and that over the 10-year duration of the project an average trend is beginning to emerge. The patterns also show that large changes in population, such as those that occurred after the emergence of persistent organo-chlorine pesticide pollution, would be detected both much earlier, and more clearly, than by any other monitoring method.

Data uses

The patterns of natural variation over time of detection rates provides a much stronger basis for assessing the impact of developments, such as offshore wind, than has been previously available. Method: A distribution of change values over time following many 'nothing happened' time points can readily be derived from the data and provide a baseline for evaluation of real impacts.

Spatial Monitoring strategy & instruments

The inshore position may be too far offshore to capture detections of the local inshore bottlenose dolphins except at one site. Depth selections are clearly very significant choices in monitoring coastal waters.

A switch to F-PODs is unavoidable if long term monitoring continues as the C-PODs can no longer be replaced. The F-POD showed superior performance in this study with a greatly increased detection rate for dolphins and would greatly increase the quality of dolphin monitoring. This is not because the C-POD did not log them, but because they could not be reliably identified as dolphins by the KERNO classifier.

Species discrimination among dolphins would add value to this work and is an area that Chelonia plan to address in the context of F-Pod data only, but it is well known to be a difficult problem!

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20th November 2023

Data report

Trend analysis using PYRA

The FPOD app determines trends in the detection rates from PODs at one or more fixed sites using the 'Paired Year Ratio Assessment' (PYRA) method. This method and limitation of PYRA are described and discussed in 'Estimating cetacean population trends from static acoustic monitoring data using Paired Year Ratio Assessment (PYRA)' (Grist *et al.* 2022; https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0264289)

The distinctive advantage of PYRA is that it avoids the need for estimation of both seasonal and diel patterns. Cetaceans often show big seasonal and diel patterns of activity and their estimation from gappy data is a major source of error in some other methods.

How it works:

PYRA requires 2 or more years of data and handles gaps in the data by using only data from days that can be 'paired' or 'matched' with data from the same day in the following year. So, the sum total of the detection metric in the second year is divided by the matching total in the first year to give a ratio that represents the growth or shrinkage of the activity logged.

This two-year data window is moved forward one day at a time to produce a growth ratio for each date i.e., 1 day at a time. The date for this growth ratio is the date between the two years i.e., the end of the first year. If the data window is moved further the number of matched days falls and when the volume of detections becomes low the ratio becomes more and more wild! That's also true at any time when there are few detections and to avoid wild results a small 'ballast' is added to both years. This has the effect of pushing the ratio towards 1.0 = no growth.

The process ends when there is no longer any paired data in the Y2 period and can also start when there is only 1 paired day, but these 'thin ends' are of little value and the process is limited in here, so that ratios based on less than a mean of 1 DPM (detection positive minute) are not graphed.

A measure of uncertainty is obtained by random resampling of whole days, with replacement, within a 21-day window centred on the paired day.

What does it tell us?

Measuring the trend in cetacean activity at a sample of sites is often a much cheaper way of getting a handle on what is happening to a cetacean population than doing line transect surveys of its entire distribution from boats, planes, or drones. Much larger numbers of detections can be made within the lower cost and give much greater precision. So, what's not to like?

The sites chosen will usually cover a small part of the distribution of the species (but the monitoring of the Vaquita is a notable exception) so, redistribution is potentially a major issue. Has the species declined, or has it moved away? Has it increased or become more concentrated in the area logged? Habitat type will often be a factor in redistribution, and analysis of trends at logging sites with differing characteristics may be relevant (the app allows you to select and view subsets of the sites and to export data from all sites individually). These questions need to be considered and related to other biological or physical data, so these trend results form a part of that larger picture.

The bottom line is the trend values are the trend seen in the set of sites, and their predictive value for the 'local population' and the whole population needs to be determined using other data which might include prior data from such trend monitoring elsewhere, data on fish stock changes, physical oceanographic data, etc.

Limitations

Gappy data: when logged periods don't align across years the un-paired days are not used, so it's good to log the same parts of successive years if the whole year cannot be logged.

Site stability: sites should be fixed, and any change in position of more than 200m should be treated as a new site. This is because detection rates of porpoises vary significantly at this scale. (A fully randomised spatial design is theoretically possible and would use only the overall statistics for each year but would require many more sites).

If a site changes – perhaps construction works starts nearby, or it is a maturing aquaculture site – then the local trend may be due to those changes, so it should be excluded from the overall trend analysis, but its own trend may still be of real interest.

Data Validation

All C-POD files were cropped to remove time periods at each end when the POD was not in the sea or affected by the deployment vessel and its sonar.

A sample of files were visually validated to identify false positive rates. These were very low and insufficient to significantly affect any of the results given here. For more information on POD validation see Ivanchikova & Tregenza 2023 (https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0293402).

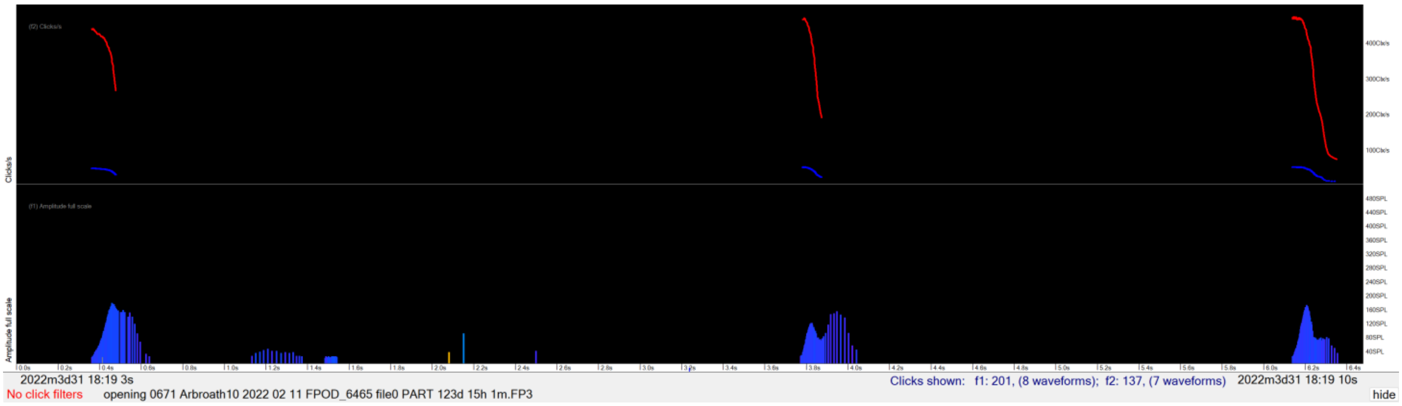

Figure 1: A screenshot taken from FPOD.exe of cetacean clicks over a 6.4 second time frame showing the click rate (clicks per second) and the amplitude (SPL) or three distinct click bursts.

Porpoise data

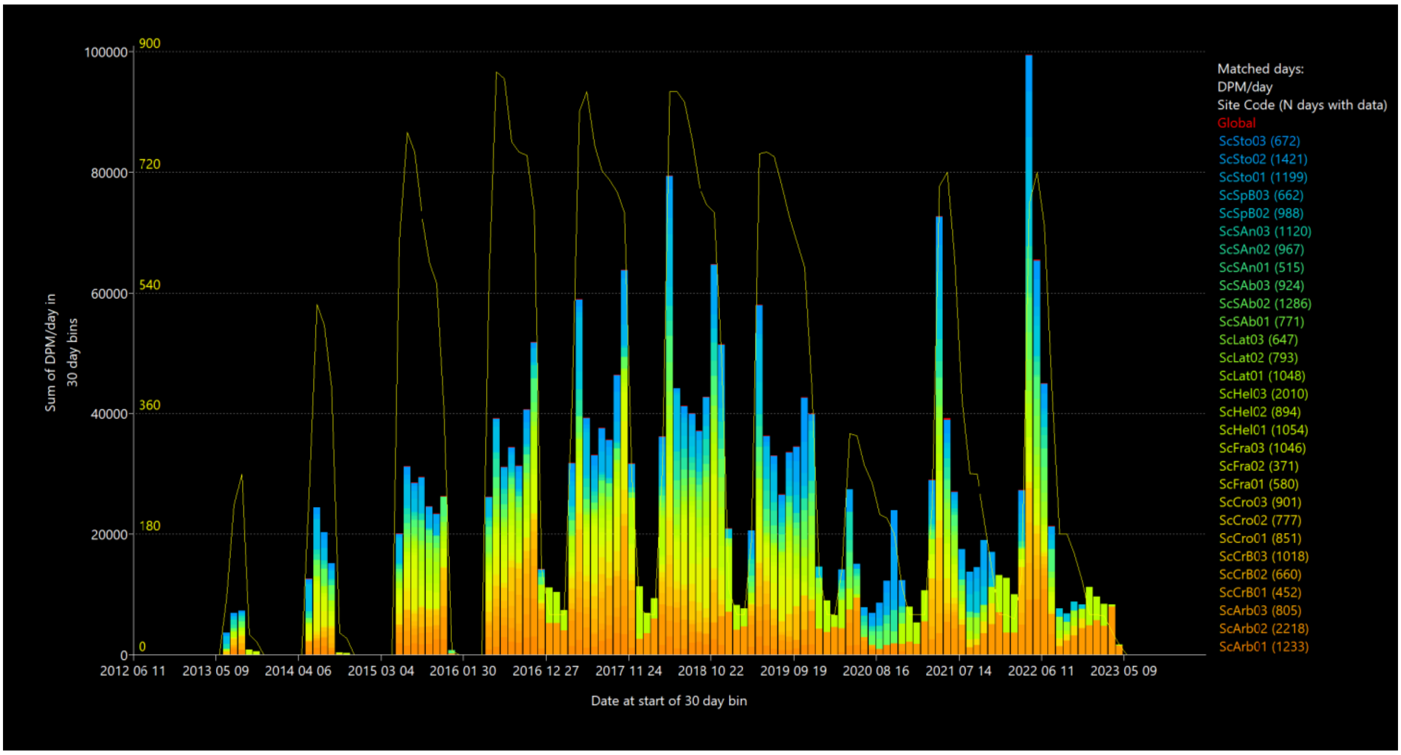

Figure 2: The number of porpoise DPM (Detection positive minutes) in 30-day bins (stacked bars) for each site with trend values in the ECOMMAS study. The yellow line and yellow numbers on the y-axis indicate the number of full days recorded within a 30-day bin across all sites (900 days being the maximum: 30 days x 30 sites).

The graph below shows the porpoise trend values for each site. The trend ratio is ballasted which has the effect of pushing it toward no change when detection rates are low.

Figure 3: Porpoise trend lines for all sites in the ECOMMAS study area with the thick red line showing the overall trend for all sites. If a trend value was calculated from a DPM < 365 in year 1 or in year 2, it is not plotted here. All values are ballasted by 5% of the overall 95th centile DPM value.

The graph below shows the distribution of porpoise trend values obtained by resampling the data

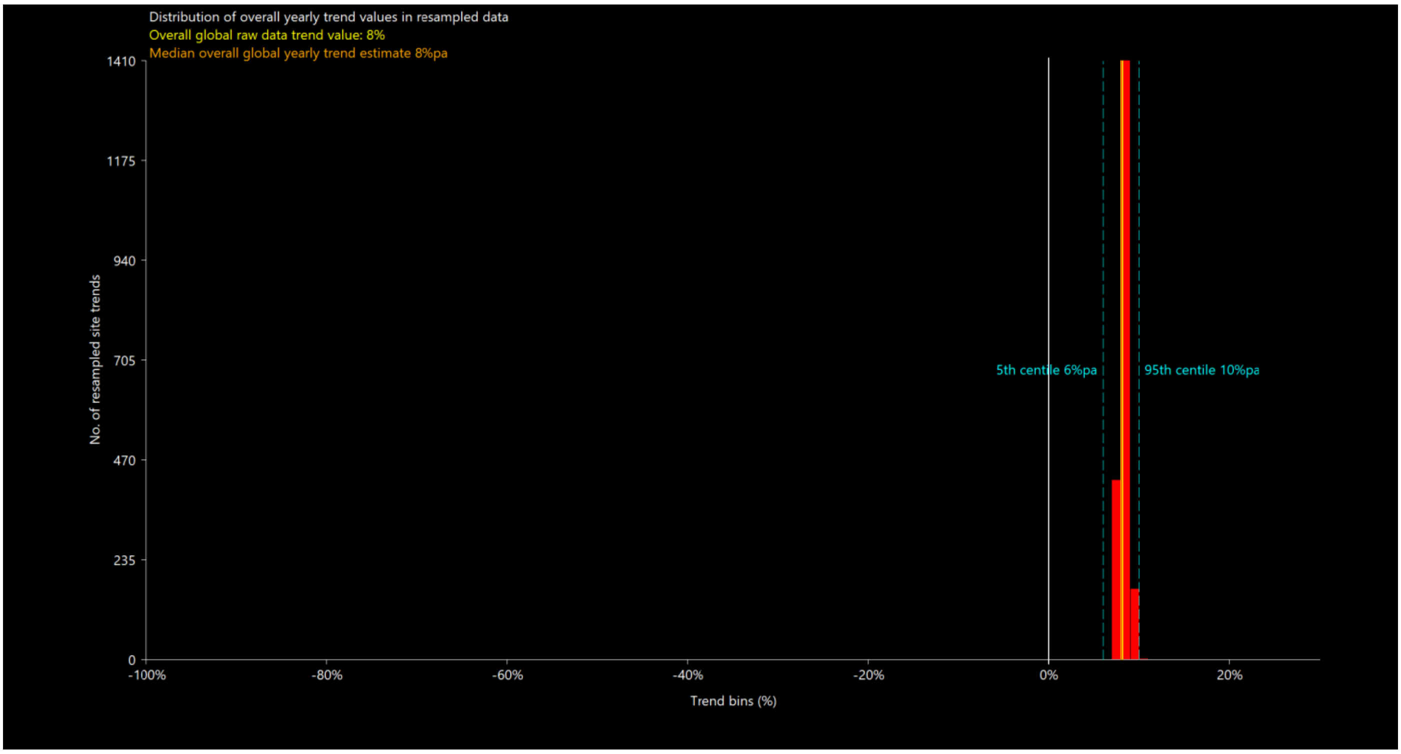

Figure 4: The overall distribution of resampled trend values of porpoise DPM (red bars, 2000 resamples). The yellow line shows the overall raw (not resampled) trend value, the orange line shows the median resampled trend value and the blue dashed lines show the 5th and 95th centiles.

Dolphin Data

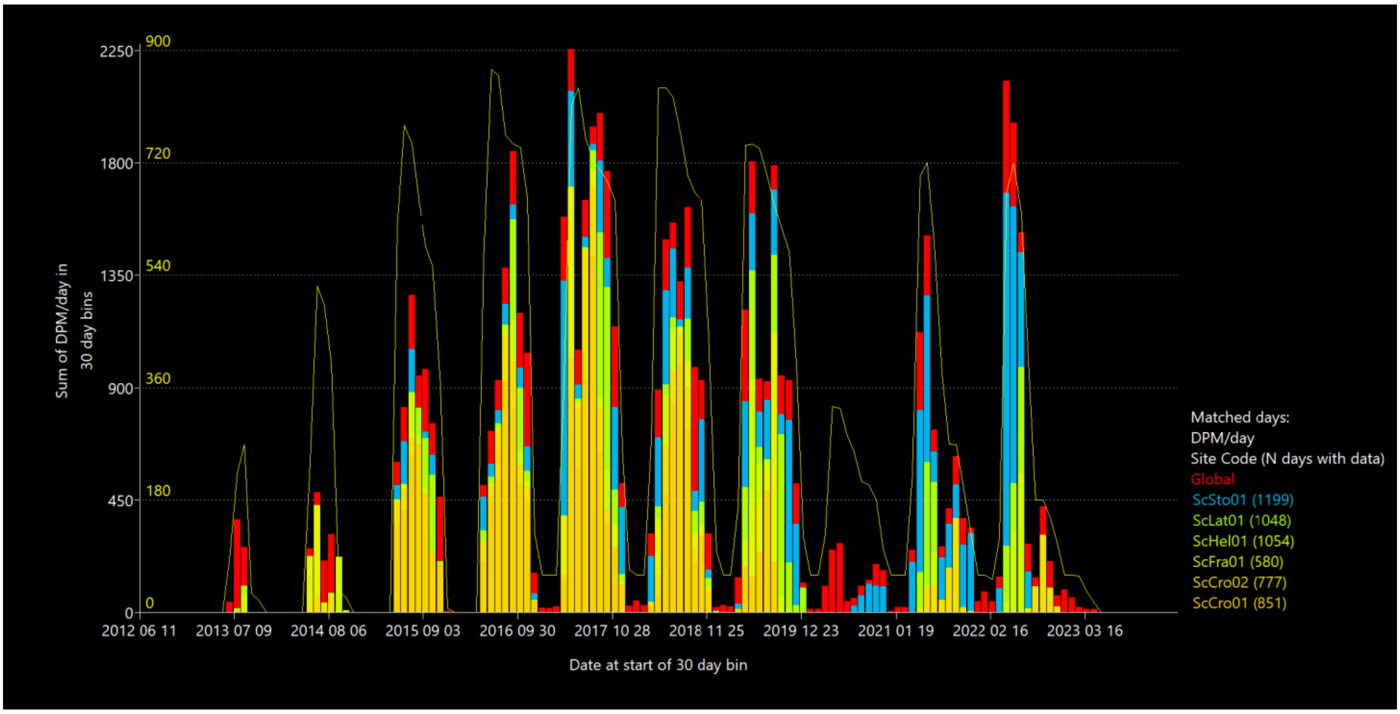

Figure 5: The number of dolphin DPM (Detection positive minutes) in 30-day bins (stacked bars) for each site with trend values in the ECOMMAS study. The yellow line and yellow numbers on the y-axis indicate the number of full days recorded within a 30-day bin across all sites (900 days being the maximum: 30 days x 30 sites).

The graph below shows the dolphin trend values for each site for dates at which the paired data from the year before and the year after had at least 365 DPM per year. Only 6 sites met this criterion at any point in the 10 year data set.

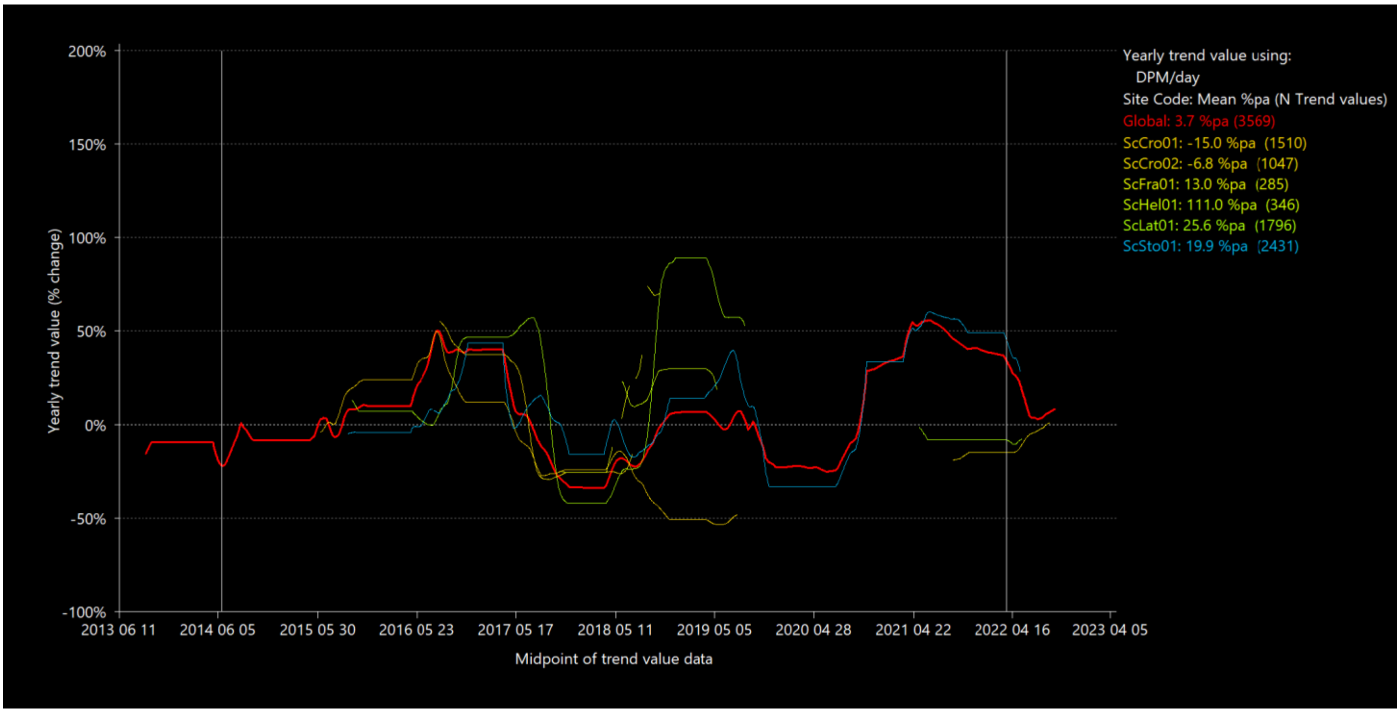

Figure 6 Dolphin trend lines for all sites in the ECOMMAS study area with the thick red line showing the overall trend for all sites. If a trend value was calculated from a DPM < 365 in year 1 or in year 2, it is not plotted here. All values are ballasted by 5% of the overall 95th centile DPM value.

The graph below shows the distribution of dolphin trend values obtained by resampling the data

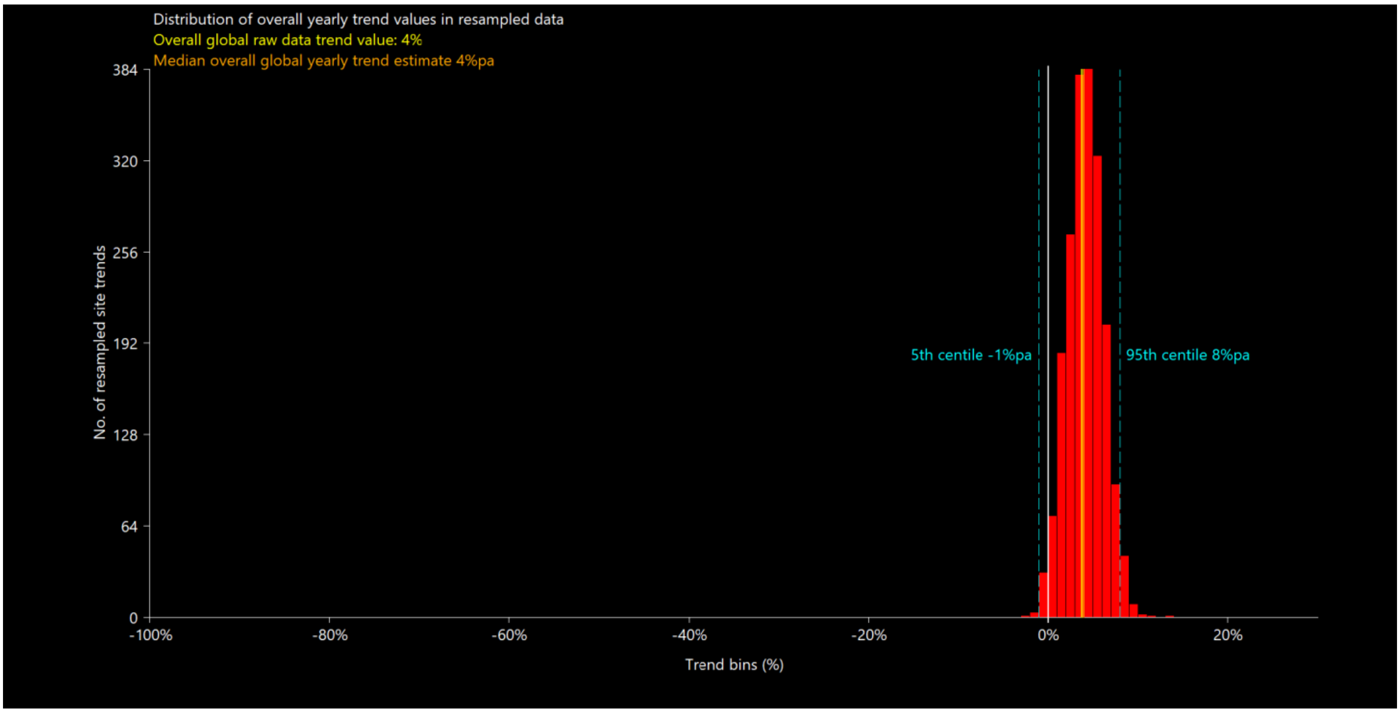

Figure 7: The overall distribution of resampled trend values of dolphin DPM (red bars, 2000 resamples). The yellow line shows the overall raw (not resampled) trend value, the orange line shows the median resampled trend value and the blue dashed lines show the 5th and 95th centiles.

Table 1: Data on individual sites within the ECOMMAS project with NBHF (Narrow band high frequency) species in purple and OtherCet (Other cetations) in orange. All trends were calcualted using DPM (detection positive minutes) and where a min DPM is stated, a minimum DPM of 365 in year 1 and year 2 had to be met.

Site	Start Date	End Date	No. Trend Values	No. Days with data	No. days with matched data	No. Trend values with min DPM NBHF	Mean % change pa NBHF	Site % of overall matched DPM/ day NBHF	No. Trend values with min DPM NBHF OtherCet	Mean % change pa OtherCet	Site % of overall matched DPM/ day OtherCet
Overalll	18/06/2013	27/03/2023	3569	#N\A	#N\A	3561	7.89	100	2639	3.67	100
ScArb01	26/07/2013	05/11/2020	2659	1656	1233	2642	-5.73	3.62	0	1.92	2.42
ScArb02	26/07/2013	27/03/2023	3531	2787	2218	3232	10.5	12.8	0	1.96	1.37
ScArb03	20/06/2013	17/07/2022	2633	1632	805	2615	15.9	3.15	0	1.65	0.11
ScCrB01	26/07/2013	15/07/2022	2035	1200	452	1995	78.3	3.01	0	-5.92	0.43
ScCrB02	24/05/2014	15/07/2022	2403	1190	660	2351	16.5	3.6	0	-13.9	0.78
ScCrB03	18/06/2013	21/11/2022	2799	1674	1018	2776	2.81	4.39	0	-21.6	0.57
ScCro01	31/07/2013	11/06/2021	1659	1294	851	745	9.5	0.19	1510	-15	27.9
ScCro02	01/08/2013	20/11/2022	2526	1362	777	2207	-4.09	2.96	1047	-6.78	7.69
ScCro03	31/07/2013	23/09/2022	2682	1564	901	1472	13.1	0.33	0	-35.3	0.18
ScFra01	24/07/2013	12/02/2022	1935	1306	580	1928	11.6	5.03	285	13	5.94
ScFra02	18/04/2015	15/07/2022	1999	792	371	1249	-26.8	1.6	0	10.4	0.06
ScFra03	16/05/2014	15/07/2022	2468	1561	1046	2434	1.72	5.12	0	-1.12	0.53
ScHel01	01/08/2013	13/07/2022	2787	1686	1054	2731	-3.37	1.9	346	111	5.37
ScHel02	19/06/2013	19/11/2022	1676	1558	894	1646	-4.84	2	0	5.38	0.25
ScHel03	19/06/2013	18/03/2023	3559	2662	2010	3538	4.07	8.76	0	31.6	0.97
ScLat01	31/07/2013	20/11/2022	2767	1719	1048	2415	-14.6	2.04	1796	25.6	11.9
ScLat02	19/06/2013	10/10/2022	2244	1575	793	2203	-16.2	2.72	0	60.3	2.18
ScLat03	19/06/2013	20/11/2022	2121	1470	647	2081	32.6	1.66	0	133	0.52
ScSAb01	27/07/2013	17/07/2022	3277	1236	771	3250	29.2	1.68	0	-63	1.42
ScSAb02	27/07/2013	17/07/2022	3236	1704	1286	3218	13.7	3.54	0	8.25	0.5
ScSAb03	19/06/2013	18/07/2022	2142	1632	924	2098	14.3	3.21	0	-8.96	0.11
ScSAn01	26/07/2013	26/11/2022	2040	1311	515	367	24	0.13	0	-18.8	0.44
ScSAn02	27/07/2013	17/07/2022	3235	1488	967	3211	6.97	3.18	0	-3.12	0.49
ScSAn03	20/06/2013	26/11/2022	3272	1715	1120	3246	8.55	2.52	0	-59.7	0.4
ScSpB01	23/07/2013	14/07/2022	2522	1655	1025	0	-36.2	0.04	0	2.56	0.55
ScSpB02	19/06/2013	19/11/2022	2289	1638	988	2228	37.3	3.97	0	18.1	0.29
ScSpB03	19/06/2013	31/07/2022	2701	1133	662	2677	-0.758	4.48	0	-51.3	0.49
ScSto01	25/07/2013	16/07/2022	2633	1713	1199	2596	9.14	3.67	2431	19.9	22.3
ScSto02	19/05/2014	16/07/2022	2980	1777	1421	2956	16.1	5.53	0	-2.88	2.74
ScSto03	18/06/2013	08/01/2023	2760	1531	672	2699	11	3.2	0	-42.8	1.01