Trends in the spatial distribution of hake long line fishing effort

by

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1 Summary

Set level information on hake longline sets were made available to OLSPS by DFFE on 4 July 2022. These data were analyzed to provide information about changes in the spatial distribution of hake longline effort over time. K-means clustering using longitude and latitude (of the average of the start and end of line setting) as input variables was used as a convenient means of splitting the data into spatially distinct groups. The number of sets per group per year was examined. Groups were assigned to either the West Coast or the South Coast. For these two groups plots of the number of sets per year show important trends over time that have a bearing on the scale of competition for space to fish within traditional Deep Sea Trawling fishing grounds, and changes in this scale over time. This study is an initial report dealing with the spatio-temporal dynamics of hake longline effort. This is in response to requests for such analyses, based on a view that they would reflect the primary concern about whether consideration of sectoral changes might not be adequately addressed in the hake OMP revision process (see Anon, 2022).

2 Background

HAKE/BG1 argues that a number of scientific issues need to be addressed in order to adequately evaluate the impact on the resource and on the deep sea trawl fishery of proposals (see Government Gazette (2021a,b), and HAKE/BG1) to reduce the % allocation of the hake TAC to the Deep Sea Trawl Sector, and increase the allocation to the Hake Long Line Sector (by ~ 50%). These issues include the following:

1. Consideration of the scale of longline effort and the likely scale of the induced wastage due to depredation and fish lost off hooks dead.
2. The present spatial overlap between longline and offshore trawl fishing activity and the consequential impact on the offshore trawl CPUE as a result of avoidance of longline gear

3. To quantify the level of utilization in the hake longline sector, and the extent to which poor utilization in that sector would exacerbate the losses of employment, revenue generation and investment that would follow the sectoral reallocation proposed in the draft policy of September 2021
4. The reliability of stock assessments and OMP trials given that crucial data on hake longline catch-at-lengths and CPUE levels have not been taken into consideration.

Discussions regarding this took place at the DSWG meeting of 6 April 2022 (Anon, 2022). It was suggested at that meeting that point (2) above is the most substantive potential issue, and that in order for this to be an issue that would need to be investigated as part of assessing the robustness of the hake OMP to the proposed sectoral allocation changes, it is necessary to demonstrate that the spatial distribution of longline effort has changed:

"*The possibility that a spatial shift in longline effort has resulted in an increase in operational interactions between the longline and deepsea trawl fisheries that may have introduced a bias in the deepsea trawl CPUE is a cause for some concern.*

It was agreed that efforts to properly test this hypothesis should be prioritised, but that the OMP review will be continued as planned.

In the event that compelling evidence in support of the hypothesis is presented to the DSGW, the Exceptional Circumstances provisions could be invoked, requiring that the OMP be reviewed again to take this source of uncertainty into account." (Anon, 2022)

This document reports results which give an indication of the changes in the spatial distribution of hake longlining effort over time. This should not be interpreted as agreement by the authors to the proposition that this is the only substantive issue that needs to be addressed w.r.t. the proposed sectoral allocation changes.

3 Methods

A PAIA request was submitted in March 2022 for the available logbook records for the hake long-line fishery, and DFFE made these data available on 4 July 2022. The hake deep sea data which were requested in the same PAIA request were made available on 11 August 2022. Only the hake longline data were analyzed for the purpose of this document. The hake longline data comprised set level information for the period 1994 to 2022. For obvious reasons the information for 2022 does not represent a full year of data. Although numerous fields are available per set, including catch records, the only four fields relevant to the analysis reported on here are the set longitude (start and end), the set latitude (start and end), the set calendar year, and the catch for the set.

Although a large number of data audits continue to be run on the dataset, for this document the main checks run were to verify (a) that the data supplied comprised the bulk of the commercial catch and data have not been 'lost' and (b) the plausibility if the GPS locations was evaluated qualitatively.

Thereafter, a K-means algorithm was run with the number of clusters fixed at 20 using the average end/start latitude and end/start longitude as cluster variables. This provided a useful mechanism to group sets in two dimensional latitude/longitude space. The time trends in the number of sets per cluster using calendar year as the time variable were analysed. Results by cluster and by logical groups of clusters are presented.

4 Results

Table 1 shows the annual catch in the dataset for the period 1994 to 2022, as well as the number of sets per year.

Table 2 shows the number of sets per year by year, for 11 clusters. This table indicates those clusters which are located on the South Coast and those which are located on the West Coast.

Table 3. A table of the mean longitude, latitude and depth of hake longline sets on the West Coast, as well as their standard deviation.

Table 4. A table of the mean longitude, latitude and depth of hake longline sets on the South Coast, as well as their standard deviation.

Figure 1 shows a scatter plot of all longline sets in the data set supplied to OLSPS, superimposed on a map.

Figure 2 shows a colour enhanced plot of longline sets in the dataset, where colours are keyed to K-means cluster.

Figure 3 is a plot of the total number of sets by year, for sets aggregated into two groups, one a West Coast groups and the other a South Coast group. In the aggregation, Cluster-11 was omitted because it is a mixed cluster being part West Coast and part South Coast. The actual values used in this plot are given in Table 2.

Figure 4 is a plot of the mean annual set length in the hake longline fishery based on the application of the Haversine formula to the start and end set latitude and longitude values.

Figure 5. CPUE trends in the hake longline fishery based on Somhlaba et al (2016). Units: kg / ‘000 Hooks ((source: Somhlaba et al, 2016)).

Figure 6. Scatter plot of hake longlining set locations 1994 to 2021. The colours indicate regions designated as either West Coast or South Coast for the purpose of other results shown in this document.

Figure 7 . Centroids by year of hake longline fishing activity, West and South Coasts.

Figure 8. Centroids by year of hake longline fishing activity, West and South Coasts, with points after and including 2014 shown in red.

Figure 9. Various statistics for the centroid of hake longline fishing activity on the West Coast.

Figure 10. Various statistics for the centroid of hake longline fishing activity on the South Coast.

Figure 11. Mean fishing depth over time in the hake longline fishery.

Figure 12. Number of hooks per year by coast, or in total in the South African hake longline fishery, based on data supplied to OLSPS Marine by DFFE.

5 Comments

Figure 3 demonstrates important changes in the distribution of hake longline effort between 1994 and 2021. From a peak in 2006 the number of sets on the South Coast (as defined here) declines to a very low level by about 2015 and remains very low. The number of sets on the West Coast increases from 2010 to reach a plateau by 2014 which persists until 2021. Figure 3 shows the point in time that a code of conduct between SADSTIA and SAHLLA was signed to regulate competition for space to fish at sea (see Appendix). The timing of this code of conduct appears to be a logical result of an increase in recent years (at that time) of a large

shift in longline effort from the South Coast to the West Coast. The shift itself appears to be congruent with CPUE trends shown in Figure 5. These illustrate declines in hake longline CPUE which may have driven relocation of longline fishing further west in search of improved catch rates. Figure 4 is relevant since it shows that were one to scale the results in Figure 3 by the mean set length per annum, the increase in hake longline fishing effort would be more marked.

Other Tables and Figures presented here provide additional outputs which we do not comment on in detail, except to draw the readers attention to the trends in the number of hooks (Figure 12) and fishing depth (Figure 11) in the hake longline fishery.

This document has considered the first out of a large number of possible questions: "Have there been important time trends in the spatial distribution of hake longline effort?" Additional research will be carried out using the hake longline data and including the logbook data for the Deep Sea Trawl sector. Examples of related relevant topics are:

1. The spatial and temporal scale of longline sets and deep sea trawls.
2. The distribution of the number of longline sets per day
3. The time of day that sets are made in comparison to when trawl are made
4. Whether the number of trawls in an area per day is inversely related to the number of sets.
5. Whether the number of trawls in an area per day is inversely related to the number of sets at times when an area is yielding high CPUEs.

6 Acknowledgements

To DFFE for the provision of the hake longline and hake deep-sea trawl data (the preparation of these datasets represents a very substantial amount of work).

7 References

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Table 1. The catch (kg green weight) and number of sets per calendar year in the dataset provided to OLSPS Marine by DFFE.

Year	Catch (kg green wt)	#Sets	Year	Catch (kg green wt)	#Sets
$null$	3044	1310	**2008**	8174254	3516
1994	1080672	756	**2009**	8285037	2583
1995	565681	452	**2010**	8156404	2393
1996	3998609	1644	**2011**	8498183	2274
1997	3938143	2111	**2012**	9665031	2653
1998	2009376	705	**2013**	9317527	2778
1999	6249111	2133	**2014**	9213094	3060
2000	6258842	1935	**2015**	8019230	3187
2001	5129049	1692	**2016**	8476743	3117
2002	9730455	3233	**2017**	7612064	2887
2003	9262602	3580	**2018**	7851697	2778
2004	8397024	3483	**2019**	8588092	2876
2005	9358052	4171	**2020**	7726867	2549
2006	8745935	4152	**2021**	8694375	2478
2007	7291620	3860	**2022**	809178	223

Table 2. Number of sets by year and cluster, for 11 out of 20 clusters produced by a K-means algorithm with a predetermined 20 clusters. 9 clusters represent points outside the area of interest and/or which have far too few records. Cluster 11 is a mixed cluster which lies in-between the South and West Coasts. The West Coast clusters are ordered from left to right such that they are going north to south along the west coast on the map Figure 2. The South Coast clusters ar e rom left to right such that they are going west to east on the map of Figure 2. West and South Coast totals exclude Cluster 11 counts, while Total includes Cluster 11 counts.

	West Coast North to South						Mixed	South Coast Left to Right							
Year	cluster-5	cluster-17	cluster-13	cluster-14	cluster-9	cluster-15	cluster-11	cluster-20	cluster-12	cluster-18	cluster-10	Year	West Coast	South Coast	Total
1994	14	14	268	1	144	49	2	30	193	25	3	**1994**	490	251	743
1995	0	1	91	2	92	28	6	15	176	5	14	**1995**	214	210	430
1996	103	23	434	4	427	25	2	60	393	146	27	**1996**	1016	626	1644
1997	35	8	601	7	762	24	1	61	405	166	40	**1997**	1437	672	2110
1998	43	7	136	3	70	29	7	36	150	176	47	**1998**	288	409	704
1999	51	30	233	18	385	211	4	404	422	262	104	**1999**	928	1192	2124
2000	24	135	408	11	393	327	8	164	195	157	107	**2000**	1298	623	1929
2001	94	97	209	51	329	360	3	29	177	235	108	**2001**	1140	549	1692
2002	156	37	382	96	962	256	9	95	474	365	398	**2002**	1889	1332	3230
2003	190	115	443	67	953	395	68	169	523	357	295	**2003**	2163	1344	3575
2004	189	115	253	87	933	430	221	235	469	306	244	**2004**	2007	1254	3482
2005	168	182	605	28	895	398	383	286	534	381	306	**2005**	2276	1507	4166
2006	64	115	291	26	913	534	356	400	761	472	216	**2006**	1943	1849	4148
2007	52	300	251	40	771	459	502	347	774	190	170	**2007**	1873	1481	3856
2008	96	44	317	8	584	422	451	458	645	226	263	**2008**	1471	1592	3514
2009	136	35	187	17	548	220	223	293	284	228	408	**2009**	1143	1213	2579
2010	47	35	112	47	424	246	265	360	166	228	460	**2010**	911	1214	2390
2011	3	5	34	417	472	108	272	289	130	224	318	**2011**	1039	961	2272
2012	8	31	480	230	647	163	192	232	114	228	324	**2012**	1559	898	2649
2013	42	58	508	352	620	429	144	90	167	185	181	**2013**	2009	623	2776
2014	51	114	689	470	910	524	107	20	83	49	39	**2014**	2758	191	3056
2015	75	193	479	569	861	593	366	9	24	3	4	**2015**	2770	40	3176
2016	401	339	735	403	638	399	198	2	0	0	0	**2016**	2915	2	3115
2017	651	494	523	341	457	327	92	0	0	0	0	**2017**	2793	0	2885
2018	415	344	471	306	566	264	395	2	3	7	4	**2018**	2366	16	2777
2019	386	339	748	319	368	389	153	70	25	32	46	**2019**	2549	173	2875
2020	340	181	682	268	320	338	233	7	64	52	58	**2020**	2129	181	2543
2021	478	312	372	158	507	450	112	2	41	33	12	**2021**	2277	88	2477

Table 3. A table of the mean longitude, latitude and depth of hake longline sets on the West Coast, as well as their standard deviation.

	West Coast						
Year	Longitude Mean	Longitude SD	Latitude Mean	Latitude SD	Depth Mean	Depth SD	N Sets
1994	17.74	0.64	-33.73	0.95	227.0	0.0	492
1995	17.99	0.66	-34.14	0.89			219
1996	17.67	0.73	-33.62	1.15	251.0	0.0	1018
1997	17.81	0.52	-33.94	0.88			1438
1998	17.48	1.18	-33.35	1.67			295
1999	17.97	0.84	-34.11	1.25	341.5	71.3	931
2000	17.93	0.83	-34.02	1.28	309.5	101.0	1305
2001	17.92	1.02	-34.06	1.49	306.3	94.7	1143
2002	17.89	0.83	-34.07	1.25	336.7	87.8	1898
2003	17.91	0.98	-34.06	1.40	316.5	90.6	2230
2004	18.11	1.09	-34.31	1.48	325.2	107.5	2228
2005	18.09	1.14	-34.22	1.50	324.8	126.1	2659
2006	18.45	1.07	-34.71	1.27	383.1	298.8	2298
2007	18.41	1.32	-34.60	1.46	340.7	221.1	2330
2008	18.56	1.30	-34.76	1.45	360.5	219.4	1903
2009	18.34	1.29	-34.46	1.58	309.9	114.4	1364
2010	18.62	1.15	-34.87	1.32	307.7	102.7	1176
2011	18.49	1.00	-34.88	0.89	332.7	127.8	1311
2012	18.17	1.00	-34.45	1.04	3189.2	116971.3	1751
2013	18.10	0.91	-34.44	1.07	438.7	135.7	2153
2014	18.01	0.86	-34.36	1.06	464.0	170.1	2860
2015	18.17	1.05	-34.50	1.23	428.6	182.9	3136
2016	17.62	1.15	-33.67	1.63	401.0	135.4	3113
2017	17.26	1.21	-33.11	1.83	386.7	127.2	2885
2018	17.79	1.41	-33.81	1.88	385.0	138.6	2761
2019	17.51	1.19	-33.52	1.67	443.4	976.5	2700
2020	17.72	1.28	-33.74	1.74	413.2	146.9	2362
2021	17.56	1.33	-33.51	1.91	403.5	190.4	2389

Table 4. A table of the mean longitude, latitude and depth of hake longline sets on the South Coast, as well as their standard deviation.

	South Coast						
Year	Longitude Mean	Longitude SD	Latitude Mean	Latitude SD	Depth Mean	Depth SD	N Sets
1994	23.64	0.43	-34.60	0.32	116.0	2.8	251
1995	23.70	0.51	-34.48	0.33			211
1996	23.84	0.52	-34.62	0.29			626
1997	23.80	0.55	-34.49	0.31			672
1998	24.07	0.57	-34.75	0.13			409
1999	23.65	0.75	-34.75	0.25	161.3	29.5	1193
2000	23.89	0.83	-34.66	0.29	158.5	54.6	624
2001	24.29	0.65	-34.58	0.22	175.6	53.7	549
2002	24.29	0.74	-34.56	0.22	191.8	64.1	1332
2003	24.10	0.75	-34.59	0.24	177.1	62.9	1345
2004	23.96	0.82	-34.63	0.23	177.4	51.1	1254
2005	24.06	0.83	-34.62	0.22	152.0	37.4	1507
2006	23.86	0.76	-34.64	0.23	157.0	106.2	1850
2007	23.66	0.82	-34.64	0.29	152.3	101.9	1526
2008	23.79	0.88	-34.70	0.23	158.2	43.7	1611
2009	24.18	1.05	-34.62	0.20	165.4	46.0	1215
2010	24.17	1.11	-34.57	0.17	159.1	46.2	1214
2011	24.10	1.04	-34.63	0.17	161.5	44.6	961
2012	24.22	0.98	-34.65	0.17	172.1	73.3	898
2013	24.23	0.88	-34.69	0.16	165.1	43.0	623
2014	23.96	0.95	-34.73	0.23	163.1	36.0	196
2015	23.68	0.67	-34.75	0.15	160.3	41.8	40
2016	22.34	0.11	-34.00	1.09	498.5	71.4	2
2018	24.23	0.70	-34.71	0.13	167.5	6.8	16
2019	23.93	0.99	-34.79	0.25	204.3	57.0	175
2020	24.41	0.66	-34.59	0.18	174.3	63.3	181
2021	24.16	0.54	-34.59	0.22	157.5	51.9	88

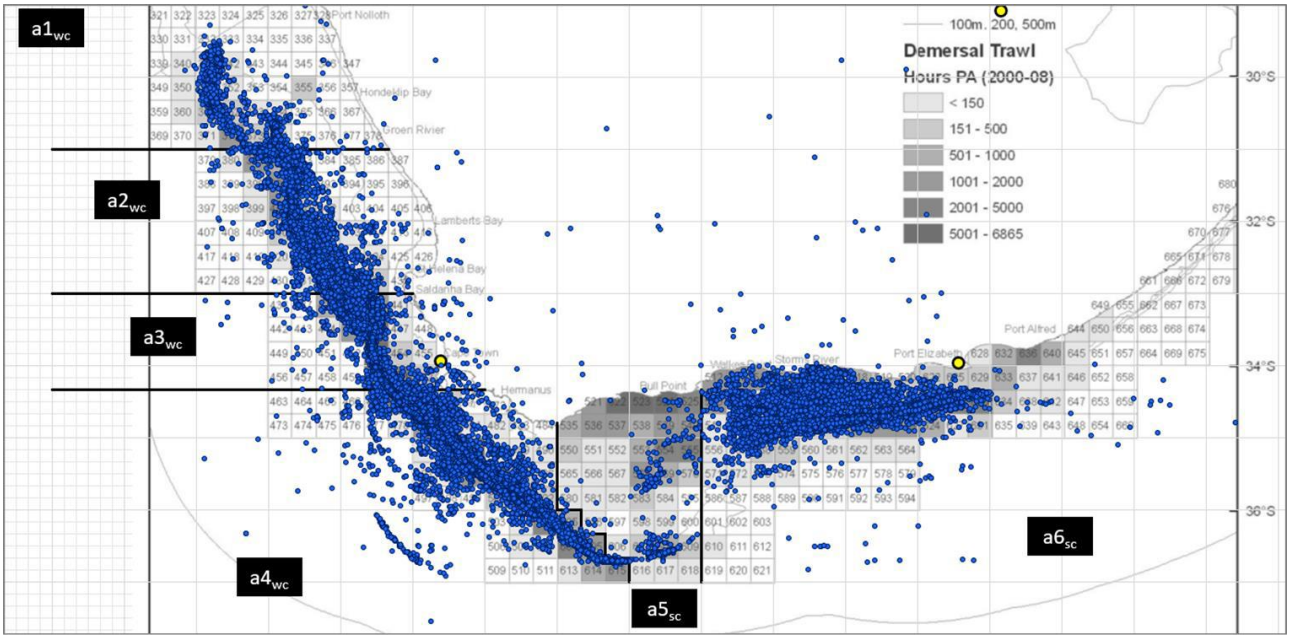


Figure 1. Scatter plot of all hake longline sets in the dataset supplied to OLSPS Marine by DFFE, 1994 to 2022.

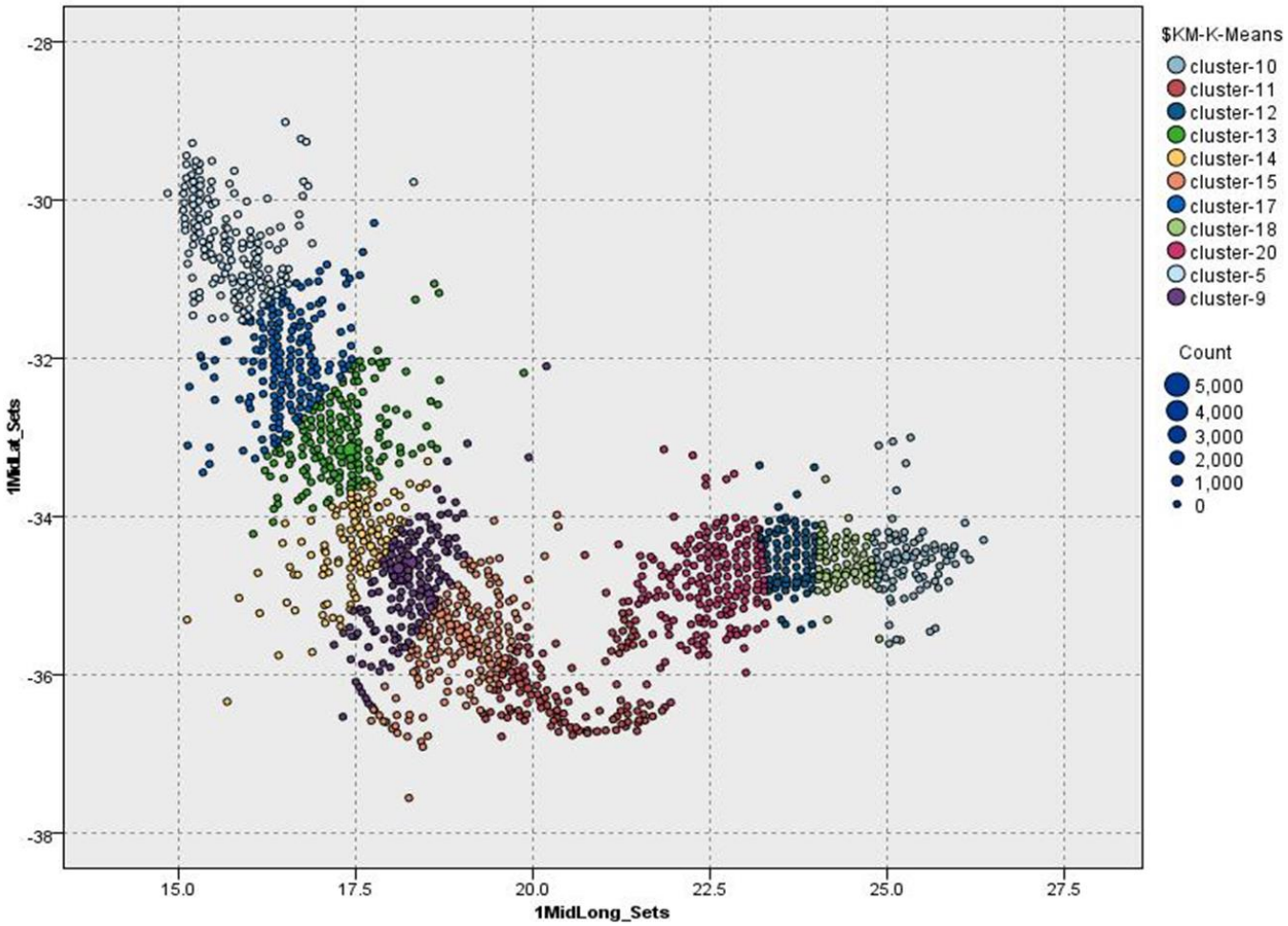


Figure 2. Scatter plot of hake longline sets in the dataset supplied to OLSPS Marine by DFFE, 1994 to 2021 (i.e. 2022 excluded). Clusters containing very few sets have been excluded. 11/20 cluster survive this exclusion rule.

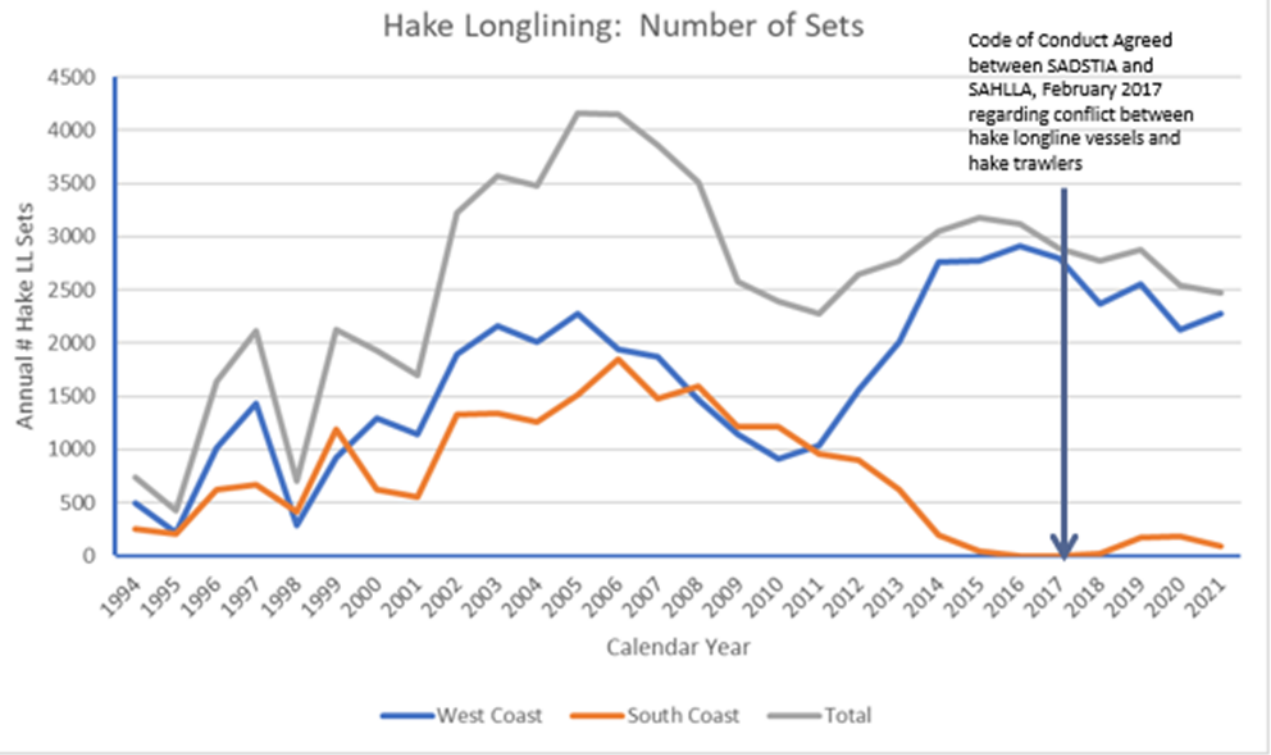


Figure 3. Plot of the number of hake longlining sets per year on the West and South Coasts,as well as the Total, as defined in Table 2.

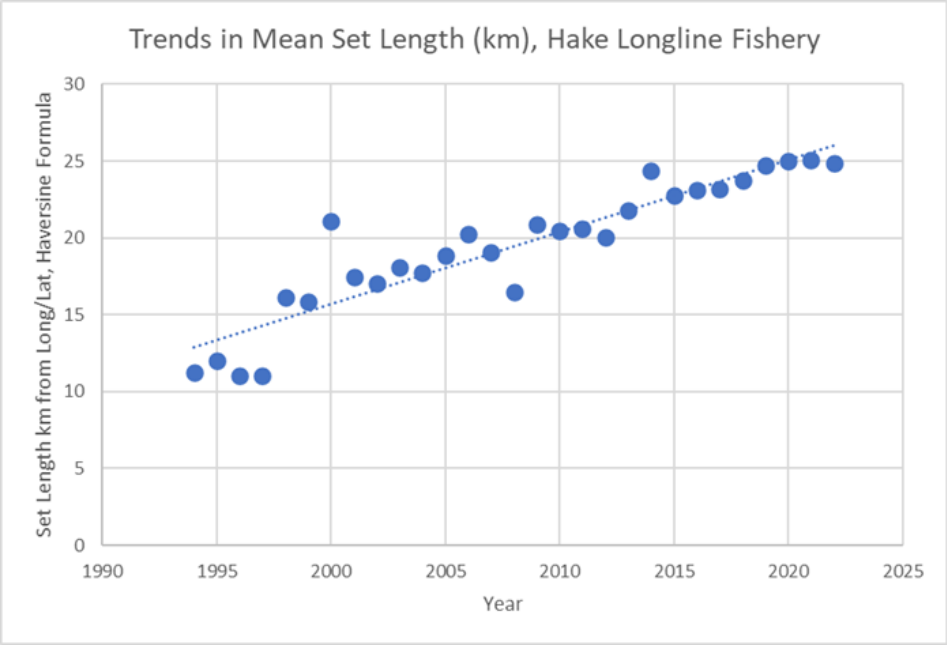
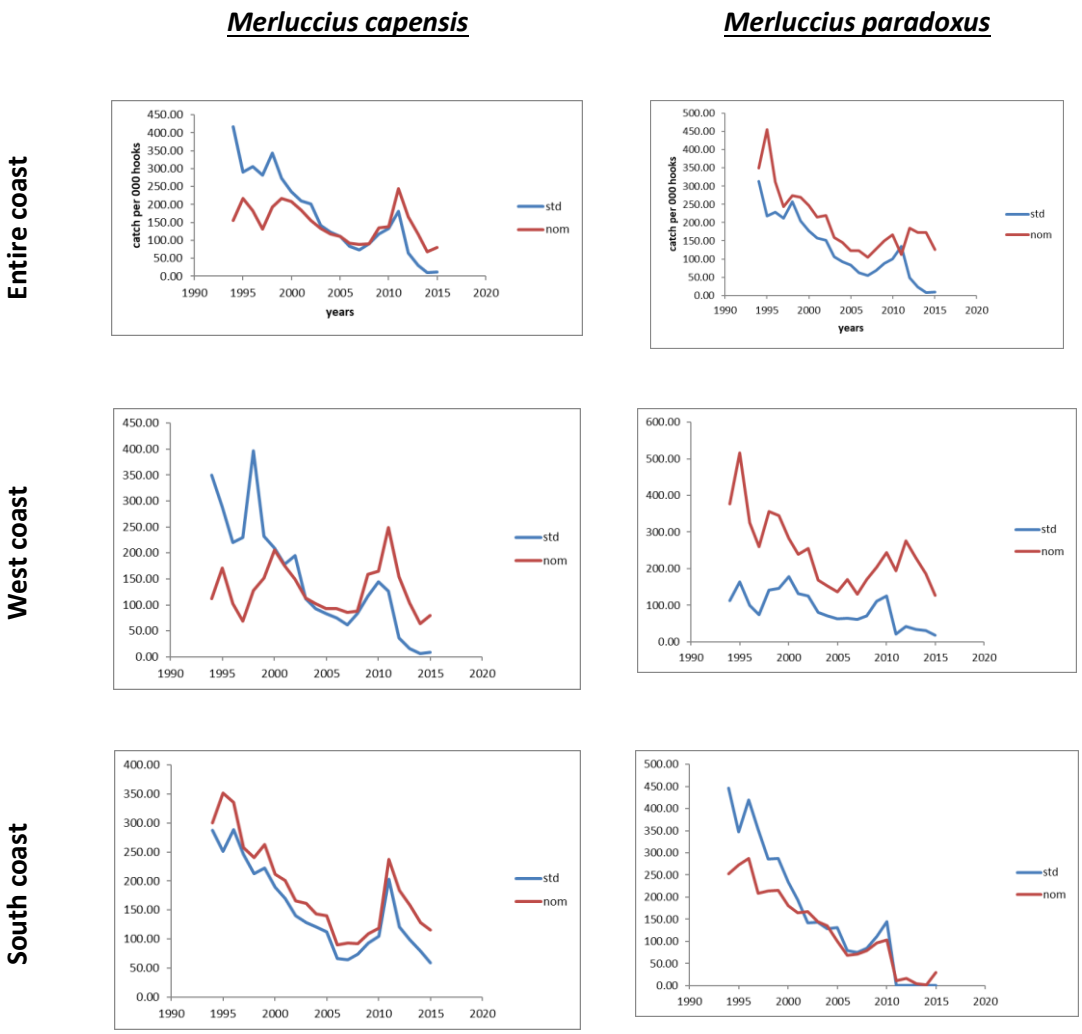


Figure 4. Trend in the mean set length in km calculated (via the Haversine formula) using the longitude and latitude of the start and end of the setting process; for the hake longlining fishery.



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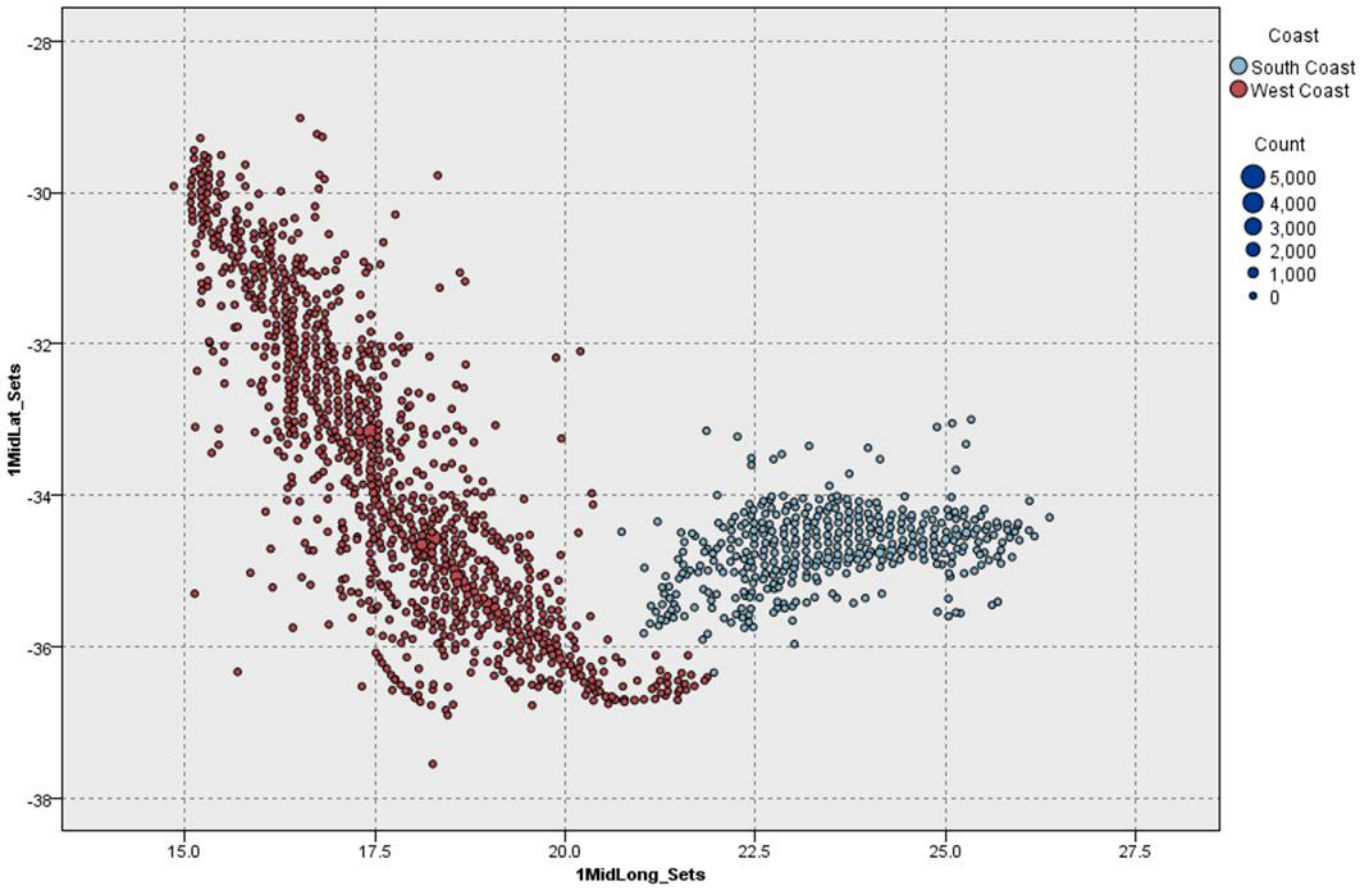
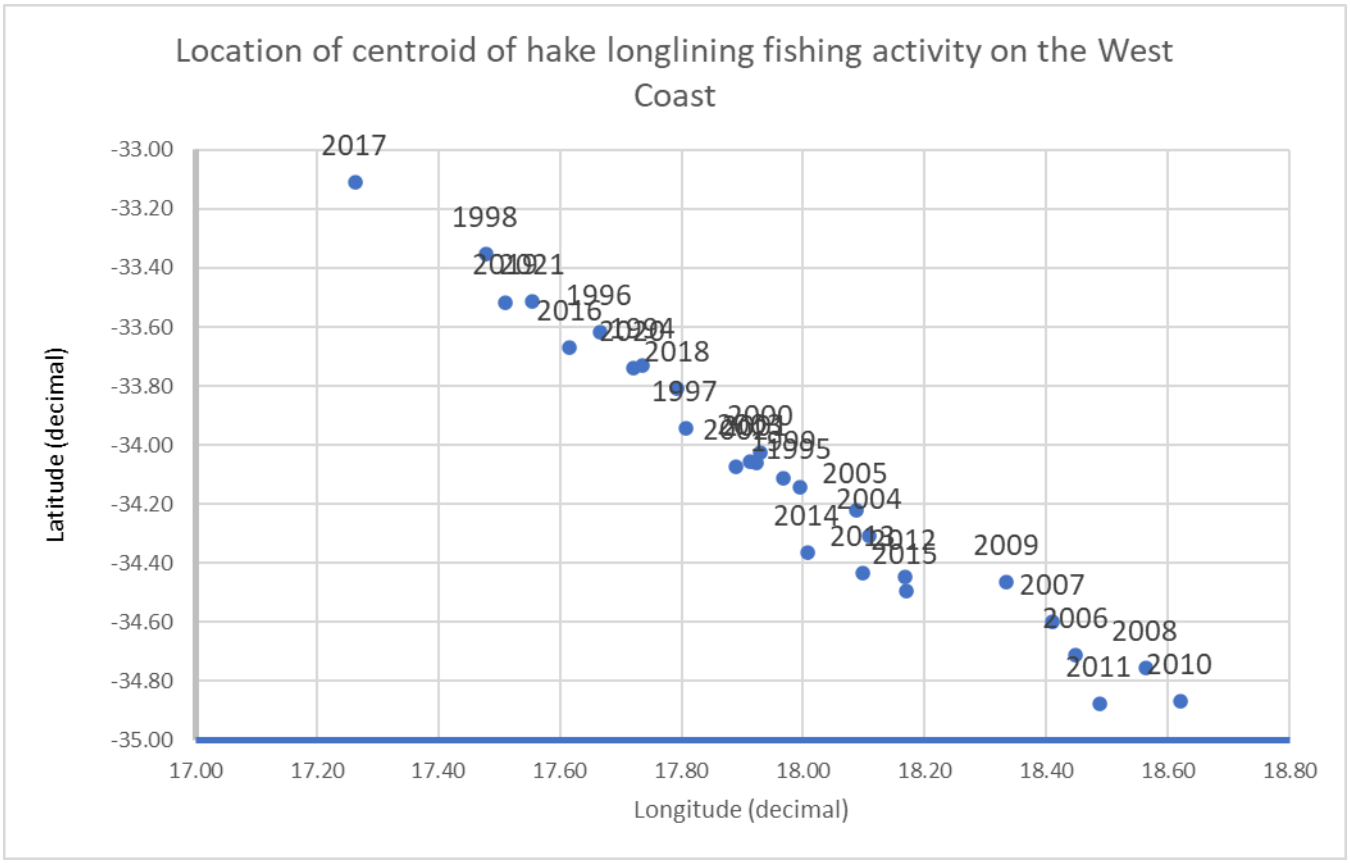


Figure 6. Scatter plot of hake longlining set locations 1994 to 2021. The colours indicate regions designated as either West Coast or South Coast for the purpose of other results shown in this document.



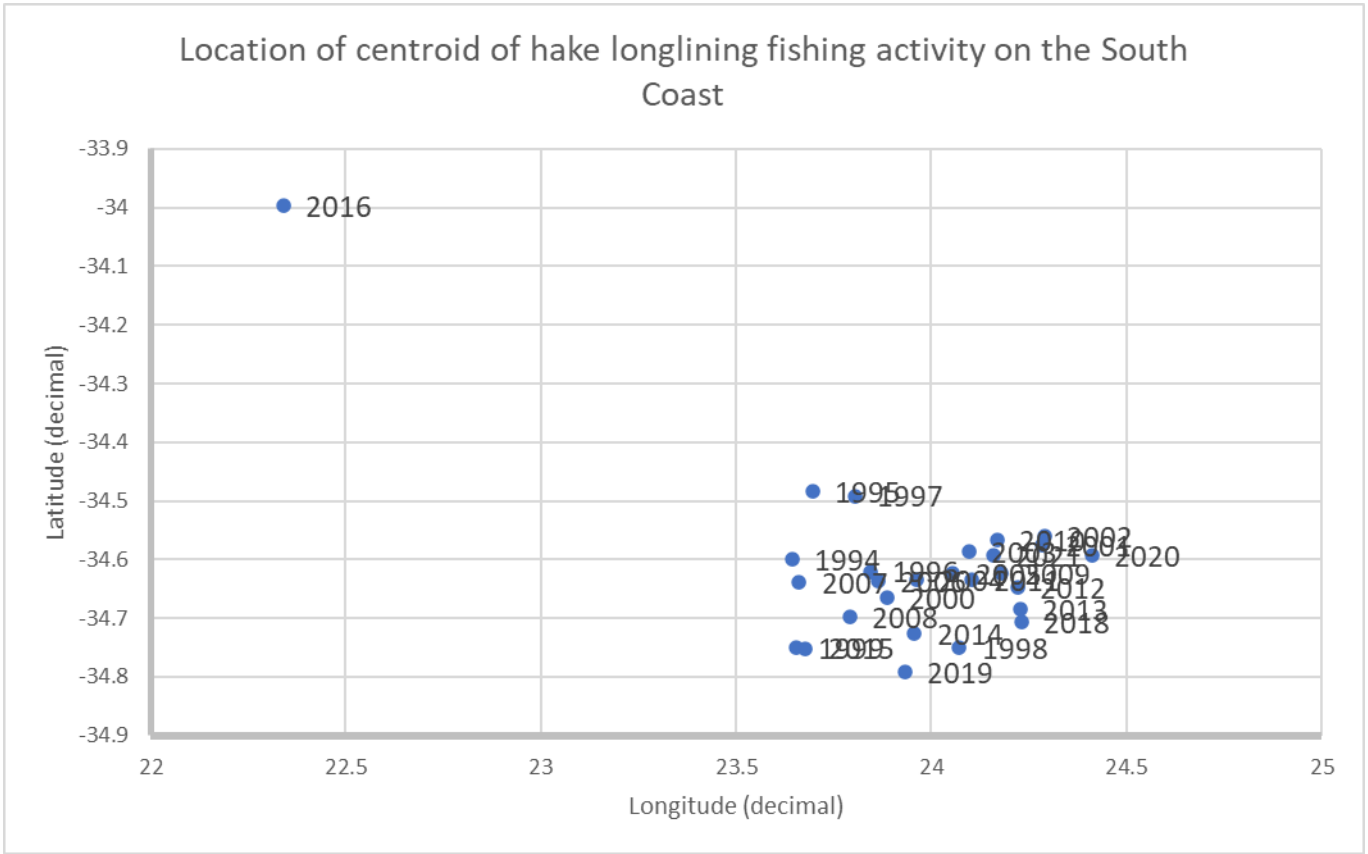
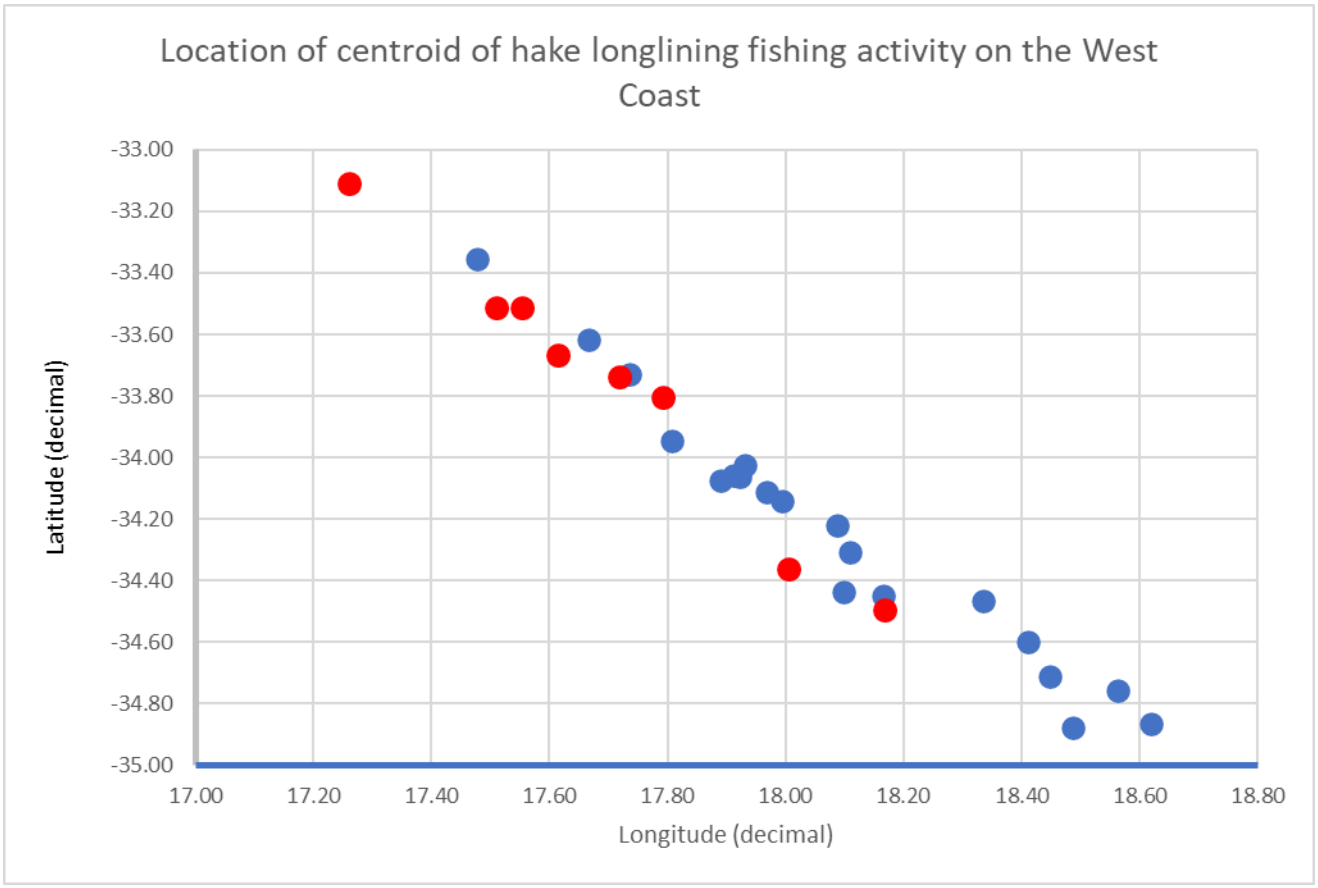
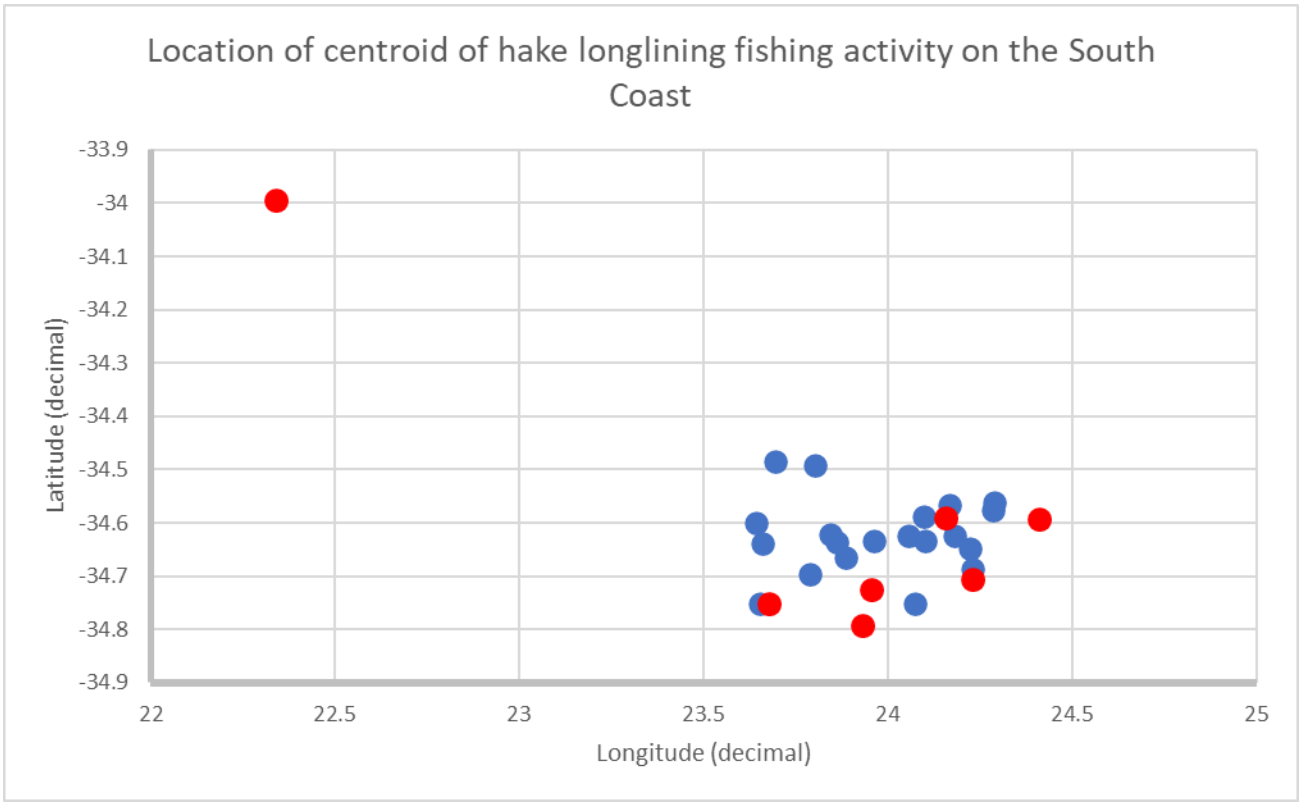


Figure 7 . Centroids by year of hake longline fishing activity, West and South Coasts.





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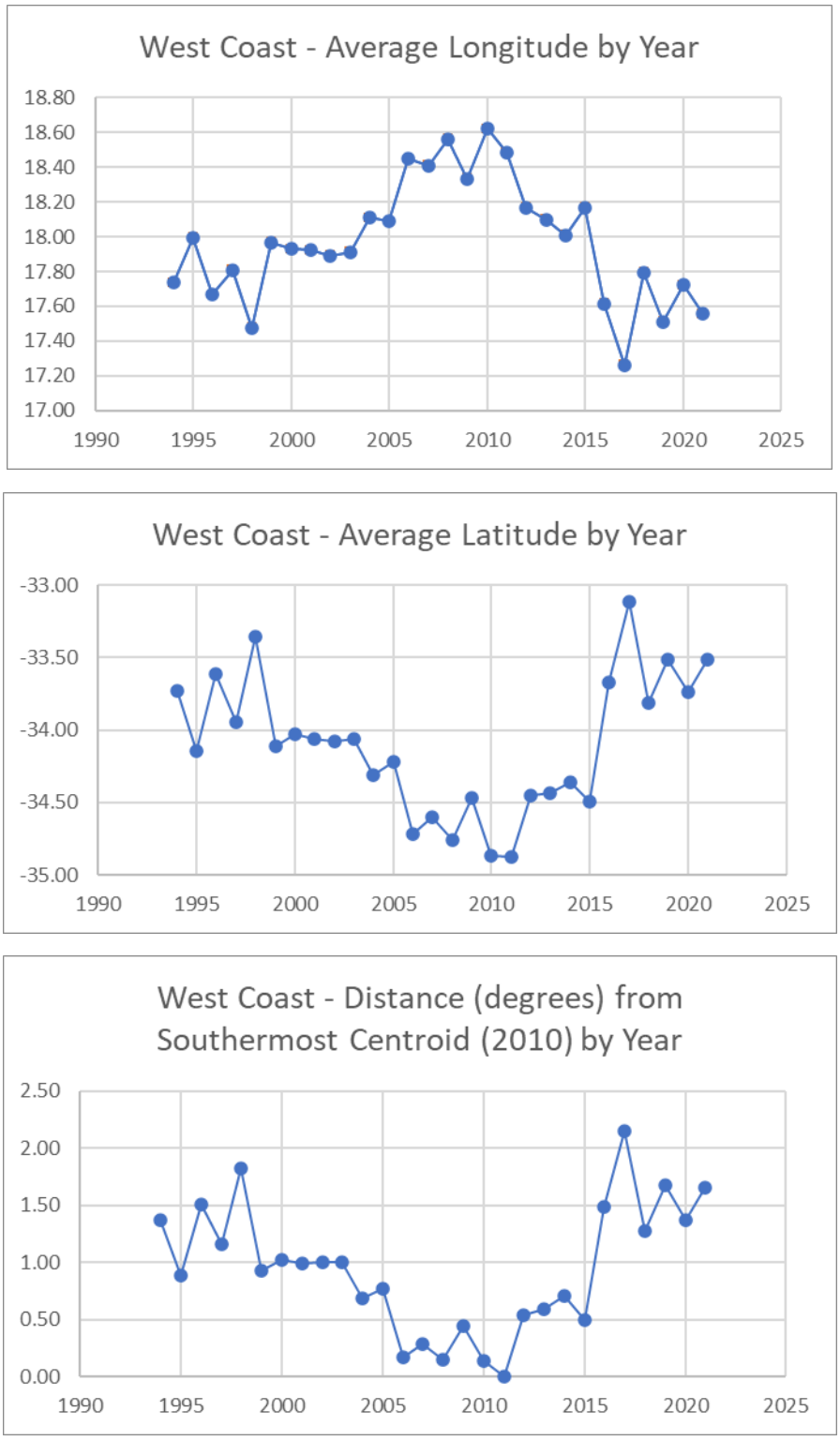


Figure 9. Various statistics for the centroid of hake longline fishing activity on the West Coast.

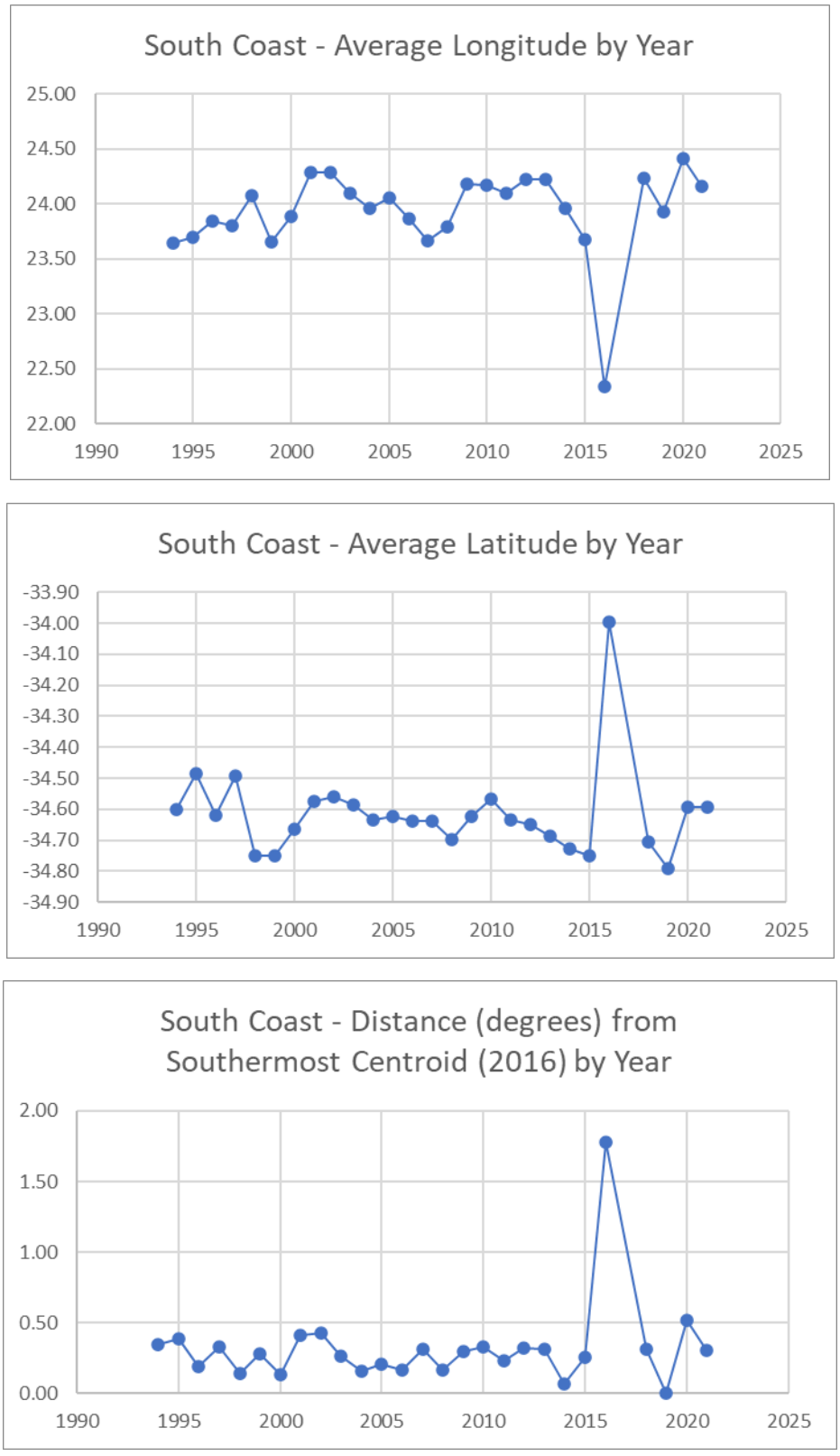


Figure 10. Various statistics for the centroid of hake longline fishing activity on the South Coast.

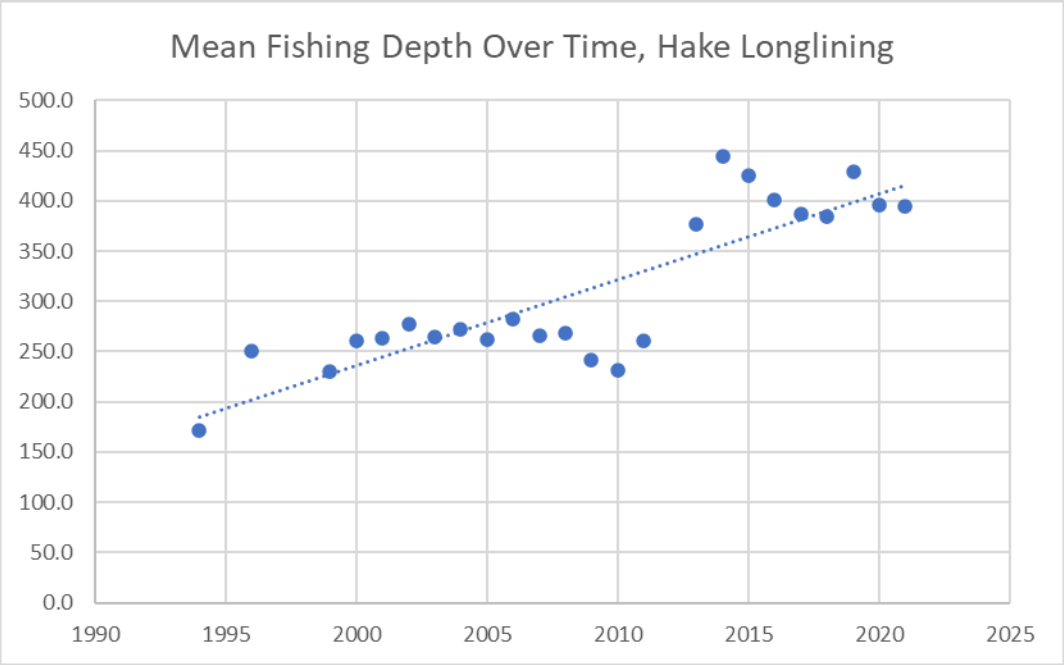
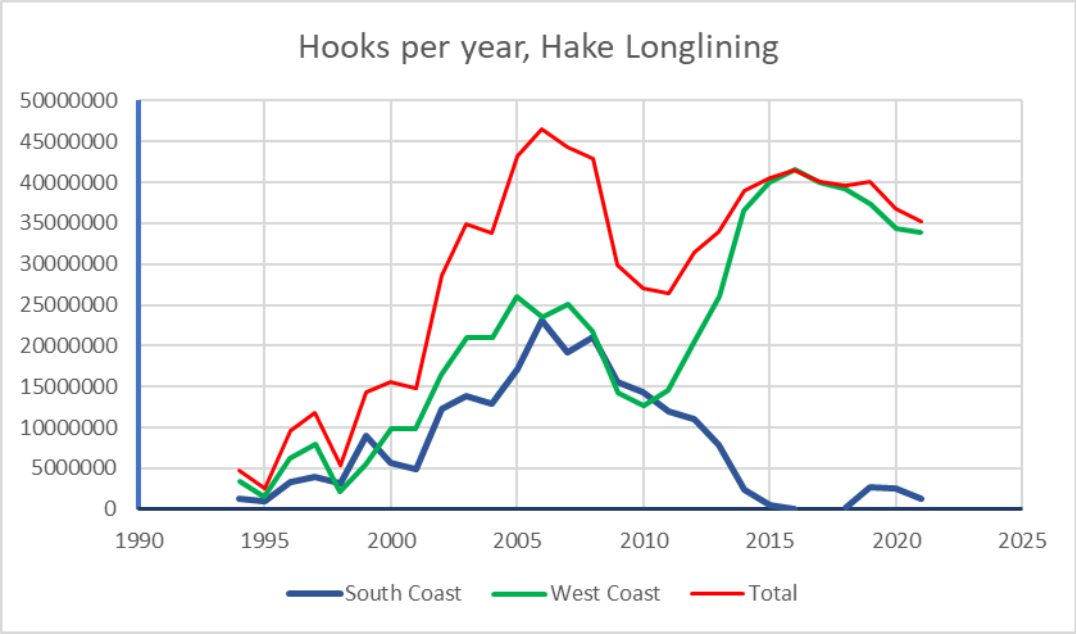


Figure 11. Mean fishing depth over time in the hake longline fishery.

Figure 12. Number of hooks per year by coast, or in total in the South African hake longline fishery, based on data supplied to OLSPS Marine by DFFE.



8 Appendix. Code of Conduct Agreed between SADSTIA and SAHLLA, February 2017 regarding conflict between hake longline vessels and hake trawlers

Resolving conflict between hake longline vessels and hake trawlers

Code of Conduct

The current scenario and problem

The basic problem arises from time to time when both trawlers and longliners wish to fish the same grounds. This has resulted in longline gear losses when trawlers have trawled over longlines that have been set where they intend to trawl and to claims against trawling companies. It should be emphasised that such conflict is not a common occurrence, and usually only a small number of trawlers, longliners and vessel masters are involved. The problem usually arises from a lack of effective communications between the vessels.

Background and history

The hake trawl fishery has a 120 year history – vessels began to fish in the 1890s. Initially, vessels were able to trawl close inshore and satisfy local demand for fish. However after World War II and the rise of export markets, the grounds expanded rapidly until most trawlable grounds were covered, up to a depth of approximately 700 m. These grounds are characterised by sandy, gravel or mud substrates. More recently, hard (rocky) bottoms have also been fished as bobbins, rollers and "rockhopper" gear have been developed.

The hake longline fishery developed out of the discontinued kingklip fishery in the 1990s. Initially, mostly hard grounds, less favoured for trawling, was used, and large fish were targeted. This changed over time as large fish became scarcer, and grounds used by trawlers also began to be used. At the same time, trawlers also began to move away from small fish and target larger fish demanded by the market. In general, both fleets now fish where hake abundance of the targeted sizes occurs.

Current accepted protocol

When intending to fish in an area, trawlers and longliners determine whether there are any other vessels in the area, using visual contact, radar or AIS identification. They then send out a VHF Channel 16 announcement to all vessels in the vicinity that they intend to conduct fishing operations, switch to Channel 8 and give further information, usually including their approximate starting position and heading. If there are no responses, they proceed with their gear deployment. If other vessels are in the way, they respond and, either give way, or respond that they have already deployed their gear or intend to deploy their gear and give their starting position and heading. If another vessel is already fishing or is about to fish the later vessel must select another area and repeat the process.

CODE OF CONDUCT

On behalf of their members, the South African Deep-Sea Trawling Industry Association (SADSTIA) and the South African Hake Longline Industry Association (SAHLLIA) therefore agree to follow the protocol as set out below:

- When intending to fish in an area, trawlers and longliners shall determine whether there are any other vessels in the area, using all means of recognition, including visual, radar, or AIS identification, bearing in mind that most longliners are smaller and have a lower profile superstructure than trawlers and do not usually carry radar reflectors. In most cases, however, vessels within 30 n.m. can be detected.

- Vessels intending to fish, shall contact all vessels in the vicinity on VHF Channel 16. They shall then immediately switch to VHF Channel 8 and indicate their intention to conduct fishing operations, giving starting point, heading and any other relevant information which could prevent interference between vessel activities.
- All communications shall be responded to immediately by affected vessels and will be conducted with due courtesy and consideration by both parties.
- If there are no responses from other vessels within 15 minutes, the vessel intending to fish may proceed with gear deployment.
- If other vessels are in the way, they shall immediately respond and, either give way within 30 minutes, or respond that they have already, or are about to deploy their gear and give their starting position and heading, or describe their approximate fishing track if it is not linear. If feasible it should also give the approximate end position.
- If another vessel is already about to deploy its gear or already fishing the later vessel must immediately select another area and repeat the process.
- If any vessel is observed to be transgressing the above Code of Conduct, SADSTIA and SAHLLA (the Associations) must be informed via a formal report in the prescribed template (attached) sent by the Captain via his company to the respective Secretaries of the Associations within 5 working days of the incident occurring. This can be submitted by any vessel affected by the activity or by another vessel in a position to observe or by other means witness the activity.
- SADSTIA or SAHLLA shall then request that the reported vessel give a written response within 5 working days, via its counterpart Association.
- The parties shall attempt to resolve the matter and agree on responsibility for the incident within 15 working days.
- If the parties cannot resolve the matter, SADSTIA and/or SAHLLA shall within 7 working days submit the complaint and response to an arbitration lawyer, agreed on and jointly appointed by both Associations, who will assess the case, determine who is the transgressing party, report to the Associations and issue an arbitration cost apportionment. This must be done within a calendar month of the case being assessed.
- There shall be no appeal.
- The arbitration report shall be published on the SADSTIA and SAHLLA websites within 5 working days after arbitration.
- The Secretaries of the Associations shall maintain a log of all reported incidents, noting the outcomes.

Note that the most important factor that determines whether or not an incident occurs is almost always the level of communication conducted between vessels. If adequate notifications are given and adequate responses received, incidents will seldom take place.

Signed on this day, 21 February 2017, at Harbour Place, Foreshore, Cape Town.