

Final Report: The economic impact of penguin island closures on the pelagic fishing industry: Extract for the Panel

OLRAC

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1 Executive Summary amended for this excerpt

The original ToRs for this project envisaged analyzing the pelagic data to detect evidence that fishing outside or adjacent to penguin protection areas is more expensive (lower catch rate) than within penguin protection areas. However, the commercial perception is that the impact of excluding fishing from these areas is to reduce the volume of anchovy and related species that are caught in a given year. This perception is consistent with the reality that the anchovy TAC is typically undercaught, as distinct for example from the directed pilchard TAC, which is landed in its entirety. It is rooted in the concept of an opportunity based fishery where opportunities are limited in time and space, and where operational constraints are active. Analytical approaches to explore the original ToRs are GLMs where the target variable is the set level or day level catch. For the “opportunity concept”, a different analytical approach has to be employed, in the form of the opportunity based model presented here. This approach involves retrospectively re-assessing the history of the fishery in the light of the hypothetical exclusion of pelagic fishing from penguin protection areas, and in the process quantifying the additional portion of the TAC which would not have been landed.

The essential features of the OBM model are as follows:

Definition of alternative fishing opportunities, as illustrated in the maps Figure 5-3 and Figure 5-4, by means of the following categories:

- a) Grids adjacent to intersecting grids
- b) Grids adjacent to grids adjacent to island closure areas
- c) The other island (i.e. on the west coast Robben Island if Dassen Island is closed and vice versa)
- d) Gansbaai for sets made on the West Coast.
- e) The St Helena Bay fishing area.
- f) The area between the West Coast islands and Gansbaai.

These alternative opportunity grids are shown in Figure 5-3 and Figure 5-4. Note that adjacent and adjacent to adjacent grids are specific to particular intersecting grids so that grids may fall into more than one of the (a) - (f) categories. **Note:** An intersecting grid is a grid which is entirely within or straddles the boundary of a penguin protection area.

Fishing opportunities are specific to grid and day and are calculated as the average standardised catch per set for a given grid and day.

Following the definition of fishing opportunities, the historical data for the fishery is examined on a set by set basis and replaced where possible, if within a penguin protection area, according to the following steps:

1. For the i-th set a determination is made whether it occurs in an intersecting grid or not.
2. If the i-th set lies within an intersecting grid, then a random selection is made as to whether it lies inside the penguin closure area or outside the penguin closure area. This is based on the proportion of area for that grid which is inside / outside the penguin protection area.
3. A search is carried out to determine the existence of viable alternative opportunities, at a given point in the search hierarchy. The search hierarchy is Other Island, Adj, Adj2, Gansbaai, St Helena

Bay, Extra. These alternative opportunities are unique to each grid, and may therefore include intersecting grids themselves in the case of the Adj level of the hierarchy.

4. If a viable opportunity exists at a particular level of the hierarchy, further searches at later levels in the hierarchy are not carried out.
5. If an alternative opportunity exists which is itself within in an intersecting grid, a random selection process is carried out to determine if that opportunity is viable, i.e. lies outside the penguin protection area. This random selection process is based on the proportion of area for that grid which is inside / outside the penguin protection area.
6. Opportunities are average standardised catches at a day and grid level.
7. Finally (a) the replacement opportunity is randomly selected from the finalised set of viable opportunities, (b) the replacement catch is constrained to not exceed the catch that is being replaced, and (c) the replacement catch is corrected for (multiplied by) the boat factor for the vessel in question.

The results from the OBM are presented as plots of the unreplaceable catch within the penguin protection area, versus the historically recorded catch within the penguin area. Typical results are shown in Figure 5-5 to Figure 5-9

A previous version of this document was submitted to the Pelagic Working Group in mid-October 2015. Requests for further work were received from the PWG and from BirdLife South Africa. The authors also made two suggestions for further work. The summarised set of suggestions and requests for further work was as follows:

- **1a,b,c. Reduce vessels:** Running the OBM model with fewer vessels to check the OBM model logic.
- **2a,b,c,d. Increase survey days:** When including survey data, to deem a survey value as representing opportunities earlier and later in time by up to 3 days.
- **3a,b Increase Opportunities:** Including additional grids as opportunities, being the St Helena Bay fishing area and the area between the islands and Gansbaai.
- **4a. Editorial Minor:** Minor but necessary improvements to the document of an editorial nature.
- **4b. Editorial Moderate:** Moderate improvements to the document, more than just editorial.
- **5. GLM Analyses.** There were technical suggestions for improvements to the GLM analyses reported on in the October 2015 version of the document.
- **7. Revise Economics:** Revision of the basis for the Economic Calculations.
- **8. Resolve Grids / Duplicates:** Revision of Grid naming and south / west coast allocations.

A determination as to the relative importance of these possible further research topics was carried out. It was felt, for example, that (5) was unlikely to significantly alter the economic estimates obtained previously. In addition, it was felt that should 1a,b,c suggest that the alternative opportunities in the historical catch record were close to saturation, that it was not necessary to also complete 2a,b,c,d. As a result, the additional work carried out post-October 2015 was as follows:

1. To investigate further the assumption underlying the economic impact estimates in the October 2015 document, that the available fishing opportunities are fully represented by the fishing events in the historical record. This investigation involves reducing the set of opportunities via a reduction in the number of vessels contributing to that set. At the mid-October 2015 PWG meeting it was suggested that should such a reduction result in a relationship between the % of unreplaceable catch in the penguin protection area (A) and the % of vessels included in the historical set of opportunities (B) which shows that A is tending to a limiting value with increasing values of B, then the historical record could be considered to provide a complete set, or a high percentage of, the true opportunities available historically, to an extent dependent on the shape of the A to B relationship.

2. Including additional opportunities in the set of opportunities which could replace sets made historically within penguin closure areas. The October 2015 document considered grids that were adjacent, adjacent to adjacent, the other island and Gansbaai (for the West Coast). Additions included here are pelagic statistical grids in the St Helena Bay vicinity, and pelagic statistical grids between the West Coast islands and Gansbaai.
3. Editorial improvements to the October document of both a minor and a moderate nature.
4. Correcting the calculations in the October document for errors relating to duplicate pelagic statistical grid numbers between the South and West Coasts.
5. Minor revisions of the economic calculations and estimates presented in the October 2015 document.

The post October 2015 modifications and updates led to some important differences which form part of the economic estimates mentioned earlier but are mentioned briefly here:

- The additional historical fishing opportunities did not substantially change the % of unreplaceable catch in penguin protection areas. (See Figure 5-5 to Figure 5-9)
- Correcting the duplicate grid issue reduced the % of unreplaceable catch from about 50% to about 40%, but it also increased the absolute tonnage historically landed within the penguin protection area. On balance therefore the value of unreplaceable catch that is foregone is larger. (Also Figure 5-5 to Figure 5-9)
- Two different methods were used to produce the graphs related to the fleet reduction exercise. The reason for the application of two methods is as follows. The original method proposed by the PWG was to reduce the fleet size to test for “opportunity saturation”. However, this has the potential to create a false result because vessels contribute greatly differing number of sets to the total of alternative opportunities. Thus, for example, with this first approach, when the fleet is reduced by 50% for example, this may imply a very different % reduction in the number of sets comprising all surviving alternative opportunities. In addition, the data span 1987 to 2014, and so vessels may contribute sets early in the period and not later. Thus removing vessels may only impact on the opportunities early or later in the total period, potentially biasing the final result. A second method was therefore implemented. This involved first limiting the analysis to the 1997 to 2007 period. Then various random selections of vessels are made, incrementally, to achieve a particular % reduction in the total number of sets available as alternative opportunities. Both of these methods indicate a limiting tendency for the % of unreplaceable catch as the % of the fleet or the % of effort included in the historical opportunities is increased towards 100%. See Figure 5-10 and Figure 5-11.

Relating to the last point above, the question of the asymptotic level for Figure 5-11 was explored by means of a range of functions, being the standard Excel functions of power, logarithmic and linear, as well as a set of three and two parameter exponential functions and a four parameter logistic function. The figures at the back of this excerpt are self-explanatory as to the sensitivity of the limiting value in Figure 5-11 to different fitting functions - see Figure 5-14 and Figure 5-15.

2 Background and Introduction

... section omitted ...

A previous version of this document was submitted to the Pelagic Working Group in mid-October 2015. Comments and suggestions for further work and for clarifications were received from the PWG and from BirdLife South Africa and the authors made two suggestions for further work. An analysis of all of these taken together reduced to the following topics:

- **1a,b,c. Reduce vessels:** Running the OBM model with fewer vessels to check the OBM model logic.
- **2a,b,c,d. Increase survey days:** When including survey data, to deem a survey value as representing opportunities earlier and later in time by up to 3 days.
- **3a,b Increase Opportunities:** Including additional grids as opportunities, being the St Helena Bay fishing area and the area between the islands and Gansbaai.

- **4a. Editorial Minor:** Minor but necessary improvements to the document of an editorial nature.
- **4b. Editorial Moderate:** Moderate improvements to the document, more than just editorial.
- **5. GLM Analyses.** There were technical suggestions for improvements to the GLM analysis reported on in the October 2015 version of the document.
- **7. Revise Economics:** Revision of the basis for the Economic Calculations.
- **8. Resolve Grids / Duplicates:** Revision of Grid naming and south / west coast allocations.

The following further work is reported upon in this November version of the document: 1a,b,c, 3a,b, 4a, 4b, 7, and 8. Items 3a,b and 5 were not addressed as part of this study.

3 Methods in Overview

3.1 Methods modified

Discussions took place with both the PWG and the pelagic fishing industry about the proposed direction of the study. These discussions resulted in a significant expansion of the original scope of the study. The main input made by the industry was clarification of the unique characteristics of the fishery, and the suggestion that a different and/or additional approach was appropriate for this study. As a result of that discussion, it is understood that the fishery needs to be understood as an opportunity based fishery, where fishing opportunities are available at particular points in space and time. With anchovy, for example, pulses of recruits move south along the West Coast travelling at between 10 and 20 km per day. The pulsed nature of this movement of recruits means that there is variability as to when anchovy are found at particular points along the west coast. Superimposed on this population variability is weather induced variability. In order for anchovy to be commercially exploitable, they have to shoal at a particular density and extent, and be sufficiently close to the surface. Cold fronts and other adverse weather phenomena disrupts this shoaling pattern, which takes some days to be restored once there is a lull in the weather.

Furthermore, there are operational and logistic constraints at work which impose constraints on the flexibility of the industry. For example, many vessels fishing for industrial fish must discharge fish at a factory within 30 hours of capture in order to maintain the quality of the final meal product. Another important constraint is the limitation on factory processing capacity for fish meal. For example, an analysis by Badenhorst shows that beyond an anchovy TAC of about 300 000 metric tonnes the industry is subject to factory processing capacity constraints and is therefore unable to take advantage of the full TAC.

The result is that anchovy are only available on certain days of the year, and then only in certain areas. A matrix of statistical grid by day of the year will show that only a small proportion of the grid is populated by fishing set information. The pelagic fishing industry contends that the grids where there is fishing activity for a particular species for a given day reflects virtually all the available fishing opportunities on that day. This position gains some credence when one considers that the industry's search capacity is enhanced by communications from different sectors of the fishing industry (e.g. trawlers and rock lobster catching vessels), and that predator activity (seabirds, seals, dolphins, piscivorous fish) is indicative of pelagic fish schools close to the surface, and these are highly visible, often from the shore. A further factor is that historically fishing takes place relatively close inshore.

Given the above input, a decision was made to include in this study an opportunity based simulation modeling approach, the "Opportunity Model". This component of the study focusses on estimating whether and to what extent catches that were made in island closure areas can be replaced by hypothetical catches taken elsewhere on the same day.

The "Opportunity Model" quantifies the percentage of the catch within the closure area of a particular island which can be replaced by fishing outside the closure area. This is of particular relevance to anchovy for which the full TAC is typically not caught (the directed pilchard TAC is routinely caught in its entirety). Thus in the case of anchovy loss of potential catch is possible and likely and this is what is being quantified

by the opportunity model, i.e. potential but foregone catch. The GLM analyses reported upon here quantifies the increase in catching costs due to island closures. Both aspects need to be considered, the first related to foregone catch, and the other to possible increases in catching costs.

The “Opportunity Model”, and some preliminary results from it were presented to the PWG, as well as to a small technical task group of the PWG. At both of these meetings the assumption the model made about the source of the universe of opportunities, as the record of historic catches, was queried. At the root of this query is the sense that there have to be additional fishing opportunities other than those evident in the historic record of actual fishing (by species, grid, year, month and day). In order to explore this,

1. Additional fishing opportunities were considered in the OBM model. The first implementation only considered alternative opportunities adjacent to the island penguin area in question. However, following the meetings referred to above, opportunities were considered in grids adjacent to adjacent grids (as defined here), at the other island, and for islands on the west coast, at Gansbaai. Following the submission of the October version of this document, additional opportunities were also considered at St Helena Bay, and the area between the west coast islands and Gansbaai.
2. The scope of this study was expanded yet further to include consideration of the fishing opportunities suggested by the pelagic survey data. As a result analysis are included in this document which are an assessment of whether the survey results show the existence of fishing opportunities over and above those that were actually utilized by the fishery, and quantifies the impact that this is likely to make on the OBM model.

The following analytical and simulation approaches and results are therefore reported on in this document:

- a) ... omitted ...
1. Various runs of the “Opportunity Model”, where alternative fishing opportunities are sourced from:
 - g) Grids adjacent to island closure areas (strictly adjacent to grids which intersect with island closure areas),
 - h) Grids adjacent to those adjacent to island closure areas (strictly as immediately above)
 - i) The other island (i.e. on the west coast Robben Island if Dassen Island is closed and vice versa, the same for St Croix and Bird Island Algoa Bay)
 - j) Gansbaai for sets made on the West Coast.
 - k) The St Helena Bay fishing area.
 - l) The area between the West Coast islands and Gansbaai.
2. Analysis of survey data, cross checked against the historic catch data to assess the number and quality of additional fishing opportunities which are not reflected in actual historical fishing records - a fishing opportunity exists on a day if there is any opportunity in a grid on a given day, i.e. opportunity resolution is grid x day. This information was used in additional runs of the OBM to assess to what extent the existence of such additional fishing opportunities as are revealed by the surveys makes it possible to substitute catches in the penguin closure area with catches linked to other fishing opportunities.

4 Opportunity Based Model (OBM)

4.1.1 Description of Methodology

The rationale for this section is that fishing opportunities are limited in time and space due to a number of factors:

- Particularly on the west coast anchovy recruits move down the coast in pulses

- Periodic weather events disrupt the pattern of aggregation of anchovy. This frequently renders the fish unavailable to the fishery and it takes a number of days following a weather event, typically a cold front, for the fish to be catchable again. In particular, when there is strong upwelling it takes time for phytoplankton growth and secondary zooplankton growth to reach a point where anchovy are able to feed near the surface where they are available to the fishery.

Additional factors are constraints on processing capacity and the need to get product to the factory timeously to avoid product degradation.

As a result fishing is based on opportunities which become available in time and space, and alternative opportunities may not be accessible on the same day, or within reach. Two important questions are (i) whether fishing makes use of all available opportunities or whether substantial other opportunities exist, and (ii) whether the loss of fishing opportunities from the closure of areas around breeding islands can be substituted without appreciable economic loss using other fishing opportunities demonstrated by the history of fishing, or possibly yet other additional opportunities manifest in the survey data.

In order to explore this issue an opportunity based model was developed. This model views the fishery in a four dimensional historic catch array, where the dimensions are as follows:

1. Grid
2. Unique calendar day
3. Pelagic fishing vessel
4. Set

Associated with each element of this array are the species specific catches recorded since 1987.

The OBM is a model which develops an alternative to the historic catch array by imposing penguin island closures since 1987. The basic approach involves replacing sets in island closure areas by a set outside of the closure area, drawing the replacement set from a permissible set of proximal locations outside the closure area, using a fishing opportunity array. In the initial implementation of the OBM the opportunity array is the same as the historic catch array, suitably standardized, which involves dividing the catch per set by a boat efficiency factor derived from a separate GLM analysis. In later developments of this model we also examined whether the survey data provides insights into additional fishing opportunities which should be considered when running the OBM.

Further detail about the steps involved in the OBM model are given below.

4.1.2 Data pre-processing for opportunity based model

4.1.2.1 Primary Data Used:

1. Detailed “grid set data” dataset from 1987 to 2014
2. Penguin closure data – defining intersecting grids and the proportion of their surface area which lies inside penguin closure areas
3. Estimates of the total catch within penguin closure areas
4. Survey data from 1987 to 2014 - just position, date and overall density (for the analyses carried out here we did not have access to depth information)

4.1.2.2 Strategy Definition:

- A set is categorised as “other” if it constitutes less than 40% of ‘Direct Pilchard’.
- A set is categorised as anchovy for sets containing at least some anchovy catch.

4.1.2.3 Opportunity Grids:

A list of possible ‘alternate opportunity’ grids is assigned to each set. These opportunity grids are categorised into the following:

1. Adjacent (Adj) – grids immediately adjacent to the set grid (including diagonally adjacent grids)
2. Adjacent² (Adj²) – grids immediately adjacent to the ‘Adjacent’ grids

3. Other Island (Other) – grids incorporating the neighbouring island closure area (on the premise that only one neighbouring island will be closed at a time)
4. Gansbaai (GB or Gansbaai) – grids in and around Gansbaai (valid for West Coast)
5. St. Helena – grids in and around St. Helena (valid for West Coast)
6. Extra – grids along the coast, between Gansbaai and Robben Island, that contain significant opportunities (valid for West Coast)

The grids which are used within the categories defined above, for each of Dassen Island and Robben Island, are presented in Table 5-1. These are also represented in the maps in Figure 5-3 and Figure 5-4.

4.1.2.4 Boat Factor:

For each of the two “strategies” defined, a ‘boat factor’ is derived using a GLM model. The result is a factor for each boat and strategy by which the opportunity set catches are divided. The purpose of these boat factors is to effectively standardize the opportunity sets, as the boats have differing capacities.

4.1.2.5 Grid Ratio:

For grid containing a portion of a penguin closure area, the grid ratio is calculated as one minus the area of the closure in that grid divided by the total grid area. Grids not containing a portion of a penguin closure area have a grid ratio of 1.

4.1.2.6 Overall Data:

The “grid set data” is aggregated to a mean set catch by date and grid level. These are the data considered as alternative opportunities for application to sets which lie inside a penguin protection area.

4.1.2.7 Metier:

The vessel type or metier limits how viable any given alternate opportunity grid is. Bigger vessels may travel further, for example. The probability of a grid being selected from the resulting set of opportunities is modified by the following ‘metier factors’ (Table 4-1)

Table 4-1. Probability of different types of grid being selected, by vessel type.

Metier	Adj	Adj2	Other	Gansbaai	St. Helena	Extra
type 1	1	1	1	1	1	1
type 2	1	1	1	1	1	1
type 3	1	1	1	1	1	1
type 4	1	1	1	1	1	1

4.1.2.8 Subset:

Only the “grid set data” that is in a grid containing a portion of a penguin protection area is selected to be run through the OBM model, although of course all catches relevant to opportunity sets are part of the selection process for alternative opportunities. This is the only data which may be affected by closure from the point of view of the catching process and the determination of unreplaceable catch.

4.1.2.9 Survey Data:

The analyses involving the survey data reduce the scope of the OBM analysis to the portion of the survey data for which there are matching dates in the “grid set data”. Two analyses are carried out, for comparison. The first excludes the survey based opportunities while the second includes them. The set catches associated with a particular survey reading is calculated from a linear regression equation obtained by regressing mean catches per date per grid versus the mean survey readings per date per grid, for matching grids and dates between the survey and the “grid set data”.

4.1.3 OBM Logic and Operation

The OBM model loops through the grid set data. Sets which lie inside intersecting grids are assigned to inside or outside the penguin protection area on a probabilistic basis. This involves the calculation of a proportion which is the proportion of the grid area which lies outside the closure area. A uniform random number is generated to decide whether the set lies inside the closure area.

If the set is assigned as inside the closure area, alternate opportunities are sought. The magnitude of an alternate opportunity is based on the corresponding "Overall Data" (which is initially standardized as described elsewhere) multiplied by the relevant boat factor for that set and fishing strategy (two possible strategies are considered in the OBM model: i) Industrial Fish, ii) Anchovy only). The viability of any given opportunity is constrained as follows:

- a) Gansbaai, St. Helena and Extra grids are only considered to be alternative opportunities for the West Coast runs of the OBM.
- b) Opportunities are prioritised by the following hierarchy: Other Island > Adjacent > Adjacent² > Gansbaai>St Helena Bay>Extra. This means that if a set lies within the penguin closure area, then opportunities are first sought at the adjacent island, if none are available there, then they are sought from Adjacent grids, then from grids adjacent to those, and so forth. Opportunities in this sense are grid level averages of catches on the day across all fishing vessels.
- c) The probability of any given opportunity being chosen is modified by the relevant metier factor.
- d) Past closures are accounted for in the sense that set replacement does not happen if a set lies inside a closure area and that area in question was actually closed.
- e) The use of boat factors ensures that the size of any given opportunity is proportional to the capacity of the boat in question.
- f) Only non-zero opportunities are considered.

Note that model runs are carried out separately for the West Coast and the South Coast. The runs can be disaggregated by island, Dassen Island and Robben Island on the West Coast, and St Croix and Bird Island on the South Coast, however this disaggregation of results is not reported here.

The calculation sequence involved in running the OBM is as follows:

8. For the i-th set a determination is made whether it occurs in an intersecting grid or not.
9. If the i-th set lies within an intersecting grid, then a random selection is made as to whether it lies inside the penguin closure area or outside the penguin closure area. This is based on the proportion of area for that grid which is inside / outside the penguin protection area.
10. A search is carried out to determine the existence of viable alternative opportunities, at a given point in the search hierarchy. The search hierarchy is Other Island, Adj, Adj2, Gansbaai, St Helena Bay, Extra. These alternative opportunities are unique to each grid, and may therefore include intersecting grids themselves in the case of the Adj level of the hierarchy.
11. If a viable opportunity exists at a particular level of the hierarchy, further searches at later levels in the hierarchy are not carried out.
12. If an alternative opportunity exists which is in an intersecting grid, a random selection process is carried out to determine if that opportunity is viable. This is based on the proportion of area for that grid which is inside / outside the penguin protection area.
13. Opportunities are average standardised catches at a day and grid level.
14. Finally (a) the replacement opportunity is randomly selected from the finalised set of viable opportunities, (b) the replacement catch is constrained to not exceed the catch that is being replaced.

The results from the OBM analyses are as follows:

- West Coast (other industrial fish, Anchovy only), excluding survey opportunities, for years 1987 to 2014: Figure 5-5:
- South Coast (other industrial fish), excluding survey opportunities, for years 1987 to 2014: Figure 5-6
- West Coast (other industrial fish, Anchovy only), excluding survey opportunities, for years 1987 to 2008: Figure 5-8.

4.2 Survey Data Analyses with OBM

The survey data supplied for this study comprised 8279 records, covering years 1985 to 2015 (PelagicSurveyData.xlsx). There were 19 variables in the data, i.e.

1. OBJECTID	2. NDX	3. Year
4. Interval	5. Date	6. Time
7. DateTime	8. Latitude	9. Longitude
10. Anchovy	11. Sardine	12. Redeye
13. HMackerel	14. DEPTH	15. Closures
16. Grid	17. Area_km2	18. Grid Centroid Latitude
19. Grid Centroid Longitude		

In the 8279 records there are 604 unique days, 468 unique grids, and 5852 unique day grid combinations, indicating a sample rate of about 1.3 per grid. The data are understood to comprise density estimates by species.

When compared with the 1987 - 2014 “grid set data”, there are 490 days which are common between the survey data and the grid set dataset, spread over the period 1987 to 2014. These common days can be used to extract the portions of the survey dataset and the “grid set data” dataset which are associated with these common days. On the survey dataset side this, “Survey_Common” corresponds to 6831 records and for the “grid set data” dataset, “Grid_Set_Common”, the relevant subset which has days in common with the survey days comprises 25452 records.

The 6831 survey records “Survey_Common” and the 25452 grid set records “Grid_Set_Common” can be aggregated down to day and grid level, averaging the hydroacoustic based density reading and the set catches respectively. An inner join can then be carried out between these aggregated datasets, at the level of day and grid. The resultant dataset represents day grid combinations which are unique and common to the survey data and the grid set data. Figure 5-12 shows a scatterplot of the mean value for anchovy plotted from this last dataset.

This graph (forced through the intercept) serves as a basis for calibrating the survey density values with commercial set level catches. In the case of anchovy the set level catch is 0.1566 times the survey density reading. This formula can then be applied to the “Survey_Common” dataset to convert the Anchovy density reading to a “potential” commercial catch which was not realized but could potentially be realized.

Figure 5-13 is a combined histogram of the actual and potential anchovy set level catches so derived from the derivation described for “Survey_Common”, including the actual set level catches in “Grid_Set_Common”. The smaller values are those associated with the survey data.

These results appear to suggest that the additional fishing opportunities that are indicated by the survey results are of an inferior quality to those that were actually utilized by the fishery. A more detailed appraisal of this is however necessary, since this analysis does not match grids in island closure areas with neighbouring fishing opportunities from the survey day. This issue was investigated by carrying out a restricted OBM analysis in which only matching dates between the survey and fishing activity was investigated. The OBM results obtained from this analysis is as follows:

- Figure 5-7: This figure shows two panels, one where the survey opportunities are not considered, and another where the survey opportunities are included in the historic set of opportunities. The commercial logbook data, the “grid set data” for this example, is limited to the period 1987 - 2014. The analysis was carried out for anchovy. Note this is a very restricted OBM analysis since it is limited to days in the historical record where both survey data and commercial fishing took place.
- Figure 5-9: This figure presents results for analyses which are the same as are presented in Figure 5-7, except that the commercial logbook data for this example are limited to the period 1987 – 2008.

These results contrast a situation in which the survey opportunities are not included in the analysis with one in which they are. The difference between the LHS and RHS panel in each case are the key results and it is clear that this difference is small.

4.3 Fleet Reduction Analyses with OBM

A previous version of this document was submitted to the Pelagic Working Group in mid-October 2015. An important suggestion that was received post the submission of the October 2015 report was to investigate further the assumption underlying the economic impact estimates in the October 2015 document, that the available fishing opportunities are fully represented by the fishing events in the historical record. This investigation involves reducing the set of opportunities via a reduction in the number of vessels contributing to that set. At the mid-October 2015 PWG meeting it was suggested that should such a reduction result in a relationship between the % of unreplaceable catch in the penguin protection area (A) and the % of vessels included in the historical set of opportunities (B) which shows that A is tending to a limiting value with increasing values of B, then the historical record could be considered to provide a complete set or a high percentage of the true opportunities available historically, to an extent dependent on the shape of the A to B relationship.

Initial analyses in response to this request were carried out for anchovy only on the West Coast. Figure 5-10 presents the result for anchovy only on the West Coast which corresponds to the panel in Figure 5-5, Adj, Adj2, Other, Gansbaai, St Helena. Each point in Figure 5-10 is the average of 10 random iterations. In each iteration whether each set lies inside or outside the penguin protection area as well as the selection of boats is randomized (although for sets, as described earlier, this random selection is weighted according to inside / outside grid area). E.g., for point '50 boats', a random subset of 50 boats was selected for each of the 10 iterations and the mean and standard deviation found. The error bars are the mean standard deviation expressed as a percentage of overall catch in the respective closure grid. Only the set of available opportunities are affected by the fleet reduction process, the actual catches and sets considered for replacement when within a penguin protection area remain as given in the historical record. Although Figure 5-10 conforms to an asymptotic behaviour, it is problematic, because the vessels that are admitted to the analysis contribute to a greatly varying extent over the years, and so this feature alone could give rise to the asymptotic behaviour.

An alternative approach was therefore pursued, again for anchovy only on the West Coast, but for years 1997 to 2007 only. The results are shown in Figure 5-11. As for Figure 5-10, each point is the mean result for 10 iterations. In each iteration the choice of whether a set in an intersecting grid is inside or outside the closure area is chosen pro rata to surface area (as described in text). In addition, vessels are selected at random and incrementally until the total effort (measured as number of sets) reaches the selection %, where the %'s are those depicted on the x-axis of Figure 5-11. For example, for 80 “Percentage of Overall Sets”, there are 10 different random vessel selections each of which comprises 80% of the total number of sets. The error bars are the standard deviation of the unreplaceable tonnage expressed as a % of the original catch in the penguin closure area, averaged over all years and island. So this is a measure of the variability of the results across the 10 iterations referred to, but at a year and island level.

5 Tables

Table 5-1. List of grid numbers that fall within the categories of Adj, Adj2, Other, Gansbaai, St Helena or Extra for Dassen Island and Robben Island, as used in the Opportunity Based Model. Note however that all alternative opportunity sets are specific to a particular grid and so, for example, grids defined as Adj will include some intersecting grids. This is obviously less common in the case of Adj2 and other levels of the search hierarchy involving alternative fishing opportunities in the OBM. See also the graphical depiction of these grids in Figure 5-3 and Figure 5-4.

	Dassen Island	Robben Island
Adj	4810W, 4815W, 4825W, 4835W, 4845W, 4855W, 4850W, 4921W, 4931W, 4932W, 4941W, 4942W, 4820W, 4830W, 4840W, 4951W, 4952W, 4953W, 4943W	4901W, 4951W, 4943W, 4953W, 4942W, 4952W, 4902W, 4903W, 4931W, 4932W, 4941W, 4840W, 4850W, 4800W, 5810W, 5911W, 5912W, 5913W
Adj2	4810W, 4815W, 4825W, 4835W, 4845W, 4855W, 4850W, 4921W, 4931W, 4932W, 4941W, 4942W, 4820W, 4830W, 4840W, 4951W, 4952W, 4953W, 4943W, 3800W, 3805W, 3804W, 4814W, 4824W, 4834W, 4844W, 4854W, 4804W, 4805W, 4800W, 4901W, 4902W, 4903W	4901W, 4951W, 4943W, 4953W, 4942W, 4952W, 4902W, 4903W, 4931W, 4932W, 4941W, 4840W, 4850W, 4800W, 5810W, 5911W, 5912W, 5913W, 4820W, 4921W, 4835W, 4830W, 4845W, 4855W, 4805W, 5815W, 5820W, 5921W, 5922W, 5923W
Other	4901W, 4951W, 4943W, 4953W, 4942W, 4952W, 4902W, 4903W	4921W, 4931W, 4932W, 4941W, 4942W, 4820W, 4830W, 4840W
Gansbaai	5031W, 5032W, 5041W, 5042W, 5043W, 5051W, 5052W, 5053W	5031W, 5032W, 5041W, 5042W, 5043W, 5051W, 5052W, 5053W
St Helena	3942W, 3932W, 3931W, 3941W, 3951W	3942W, 3932W, 3931W, 3941W, 3951W
Extra	5930W, 5940W, 5935W, 5945W, 5934W, 5944W, 5932W, 5933W, 5922W, 5911W, 5912W	5930W, 5940W, 5935W, 5945W, 5934W, 5944W, 5932W, 5933W, 5922W, 5911W, 5912W

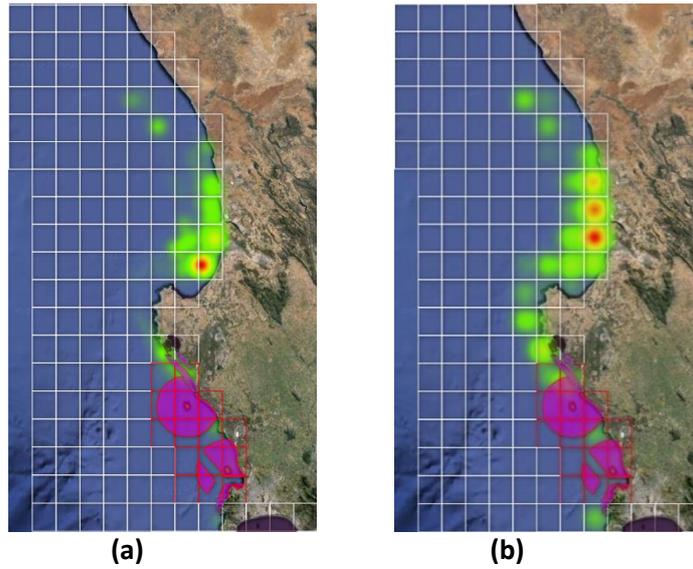


Figure 5-1: Comparison of survey data (a) and set data (b) catching anchovies for matching trip dates between 1987 and 2014

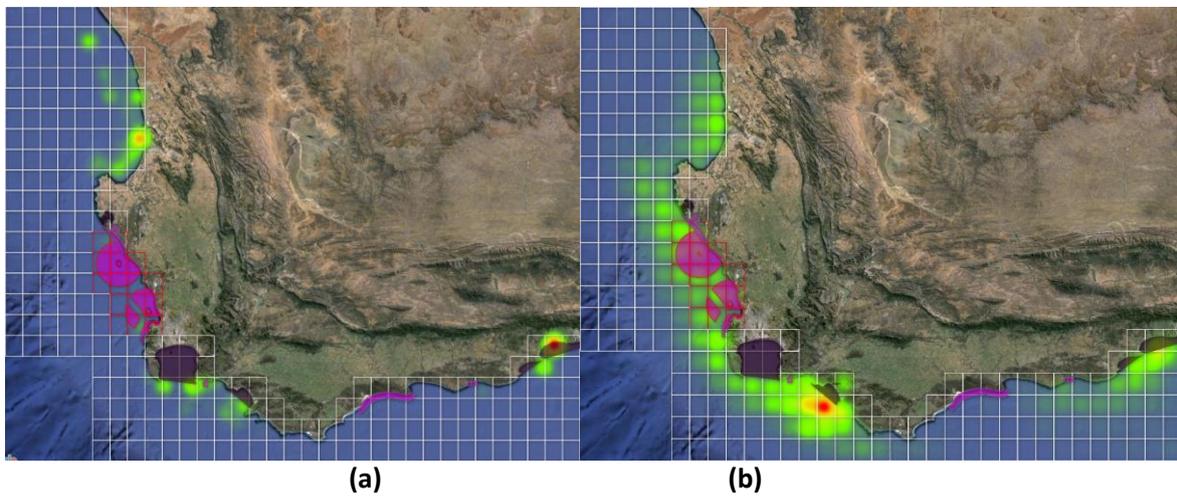


Figure 5-2: Comparison of survey data (a) and set data (b) catching sardines for matching trip dates between 1987 and 2014.

F

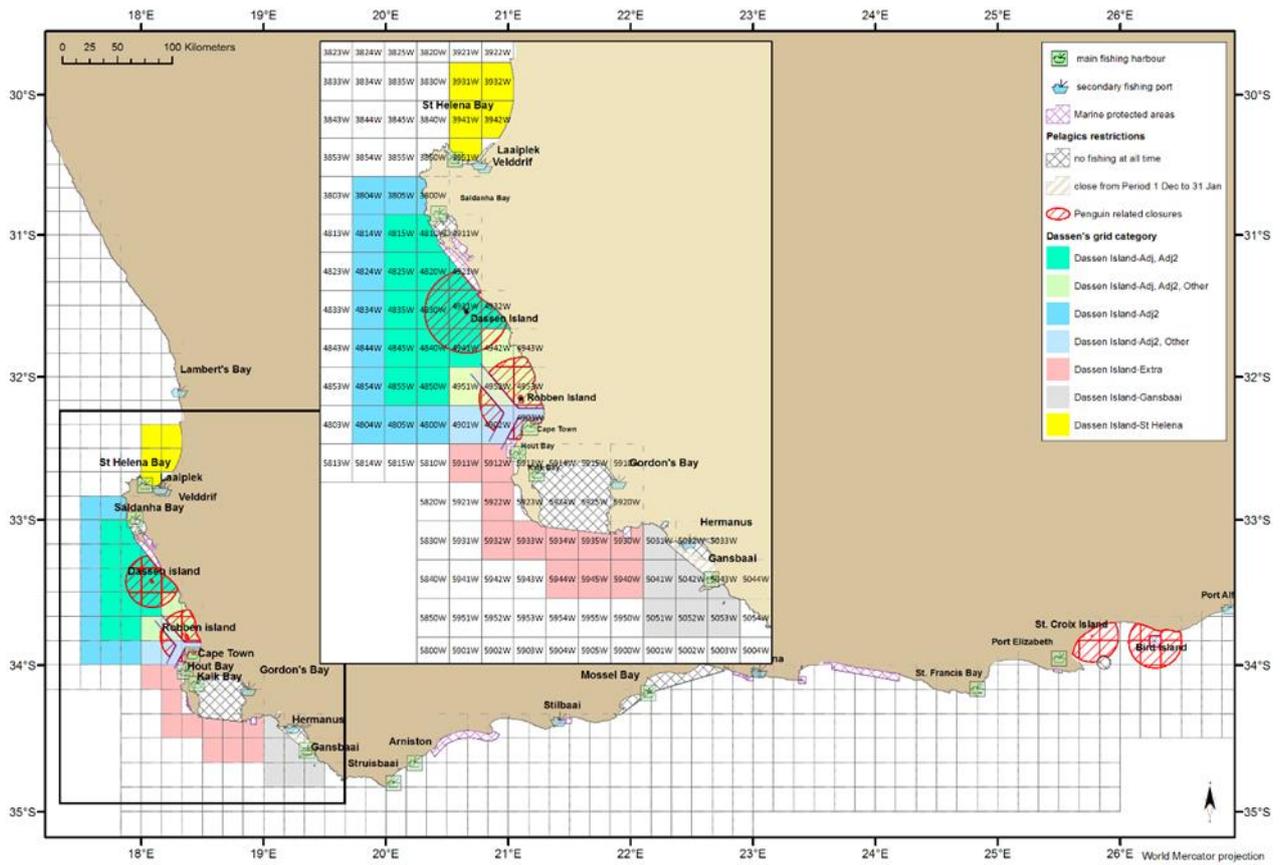


Figure 5-3. Map showing the different grid categories for the penguin's protection area around Dassen Island. The position of a grid w.r.t. any other grid can be either adjacent (Adj), or adjacent once removed (Adj2). The same grid can also at the same time be in the "other" set of grids". Two particular sets of grids to the north and south of the protection area are respectively the grids in the St Helena (in yellow) and in the Gansbaai (in grey) area.

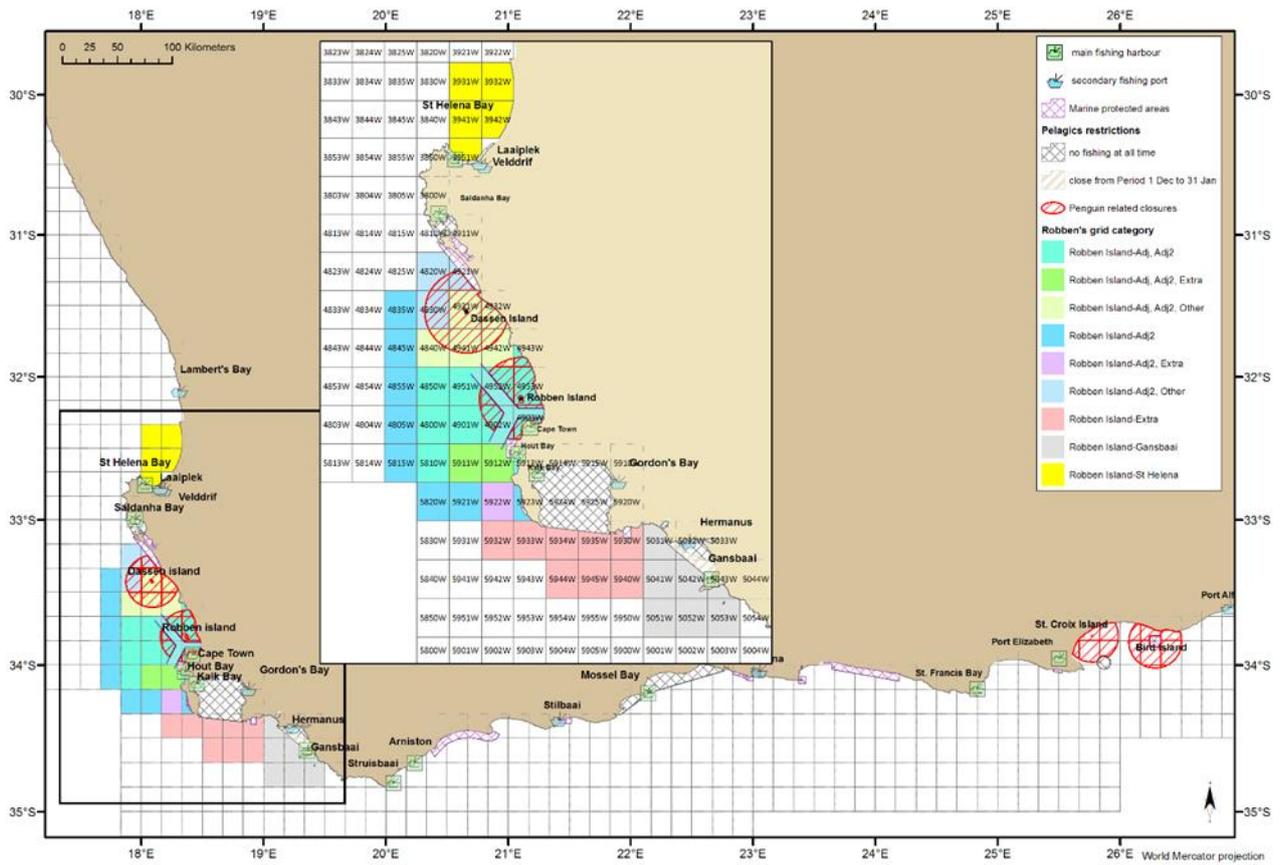


Figure 5-4. Map showing the different grid categories for the penguin's protection area around Robben Island. The position of a grid w.r.t. any other grid can be either adjacent (Adj), or adjacent once removed (Adj2). The same grid can also at the same time be in the "other" set of grids". Two particular sets of grids to the north and south of the protection area are respectively the grids in the St Helena (in yellow) and in the Gansbaai (in grey) area.

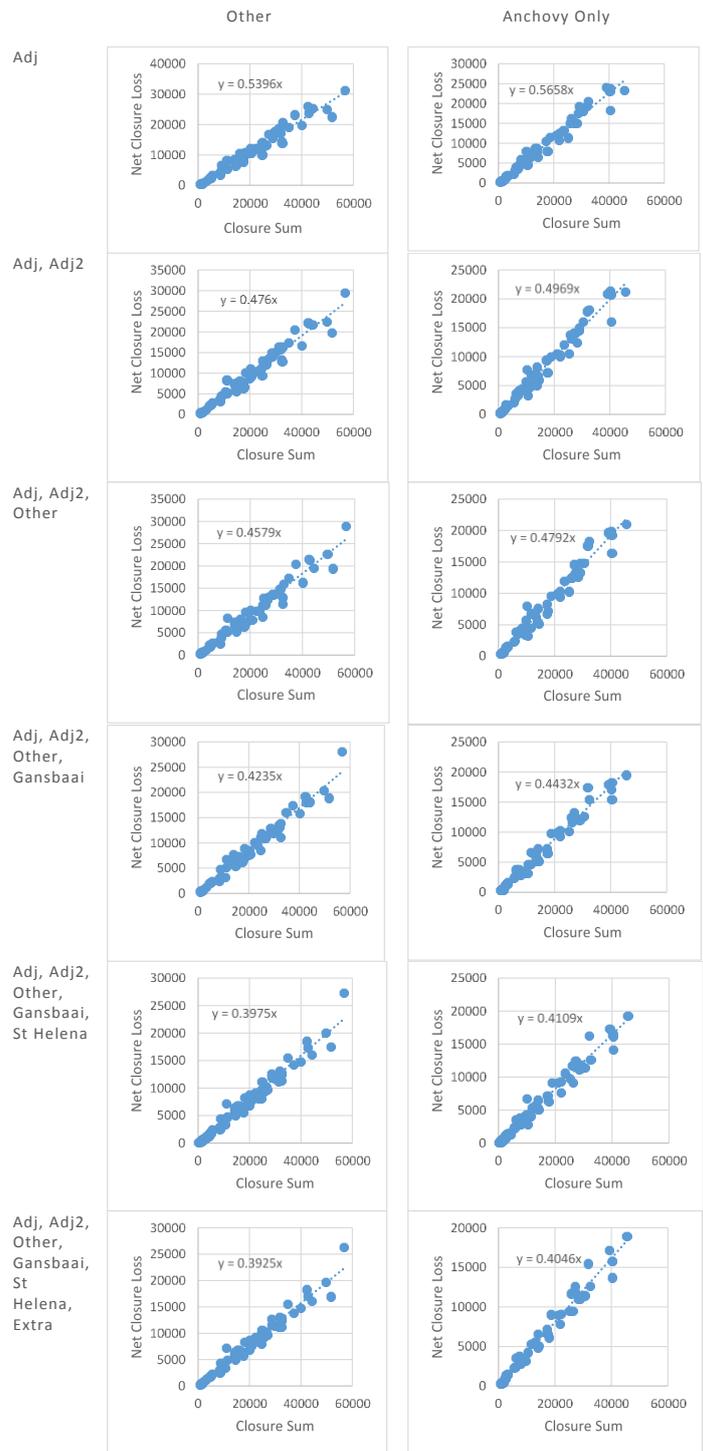
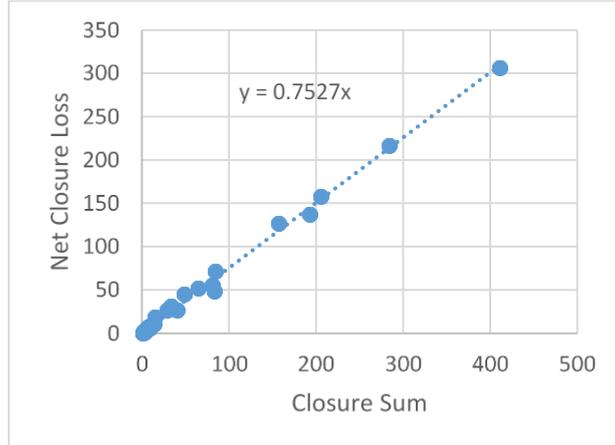


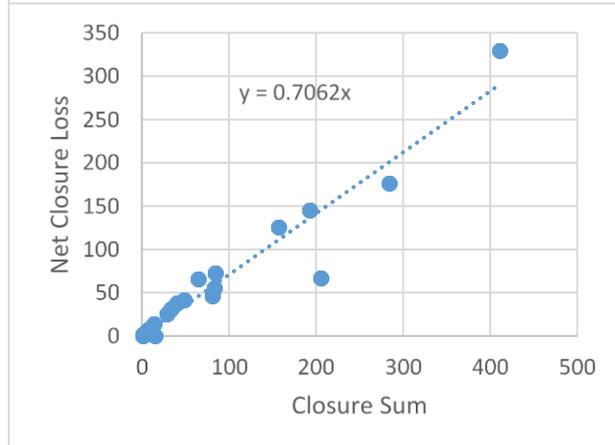
Figure 5-5. Results of the OBM model **for the West Coast only, for other (industrial fish. Column 1 panels), and for anchovy (column 2 panels).** The y-axis (Net Closure Loss) is the “unreplaceable” tonnage within the penguin protection area, while the x-axis (Closure Sum) gives the original calculated tonnage caught within the penguin protection area. Dots represent results by year and island **for the period 1987 - 2014.** The rows represent an expanding set of alternative opportunities as described in the text, but excluding those indicated by the survey data.

Other

Adj



Adj,
Adj2



Adj,
Adj2,
Other

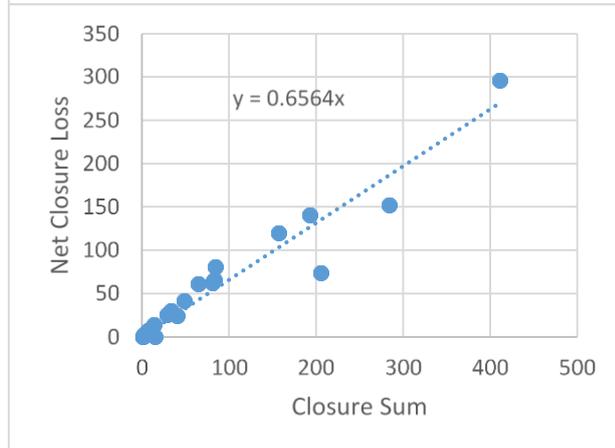


Figure 5-6. Results of the OBM model **for the South Coast only, for other (industrial fish)**. The y-axis (Net Closure Loss) is the “unreplaceable” tonnage within the penguin protection area, while the x-axis (Closure Sum) gives the original calculated tonnage caught within the penguin protection area. Dots represent results by year and island **for the period 1987 - 2014**. The rows represent two different sets of additional fishing opportunities as described in the text, but excluding those indicated by the survey data.

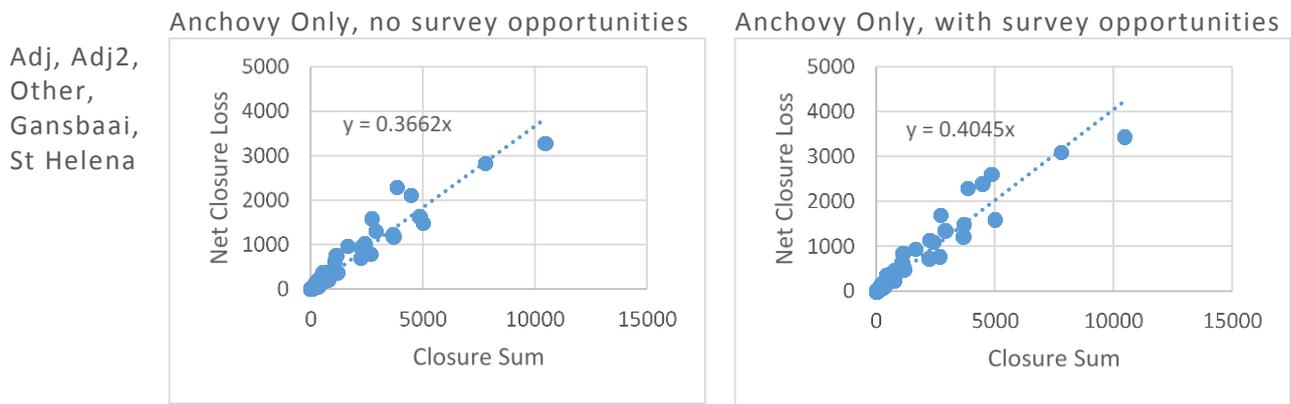


Figure 5-7. Results of the OBM model for the West Coast only, and for Anchovy only. This is a restricted analysis for the matching dates (day level) between the grid set data and the survey data. Only one set of non-survey based alternative opportunities is considered, i.e. Adj, Adj2, Other, Gansbaai and St Helena Bay. The y-axis (Net Closure Loss) is the “unreplaceable” tonnage within the penguin protection area, while the x-axis gives the original calculated tonnage caught within the penguin protection area. Dots represent results by year and island **for the period 1987 - 2014**. The figure on the LHS does not allow for the additional survey indicated opportunities to be considered, while that on the RHS **does**.

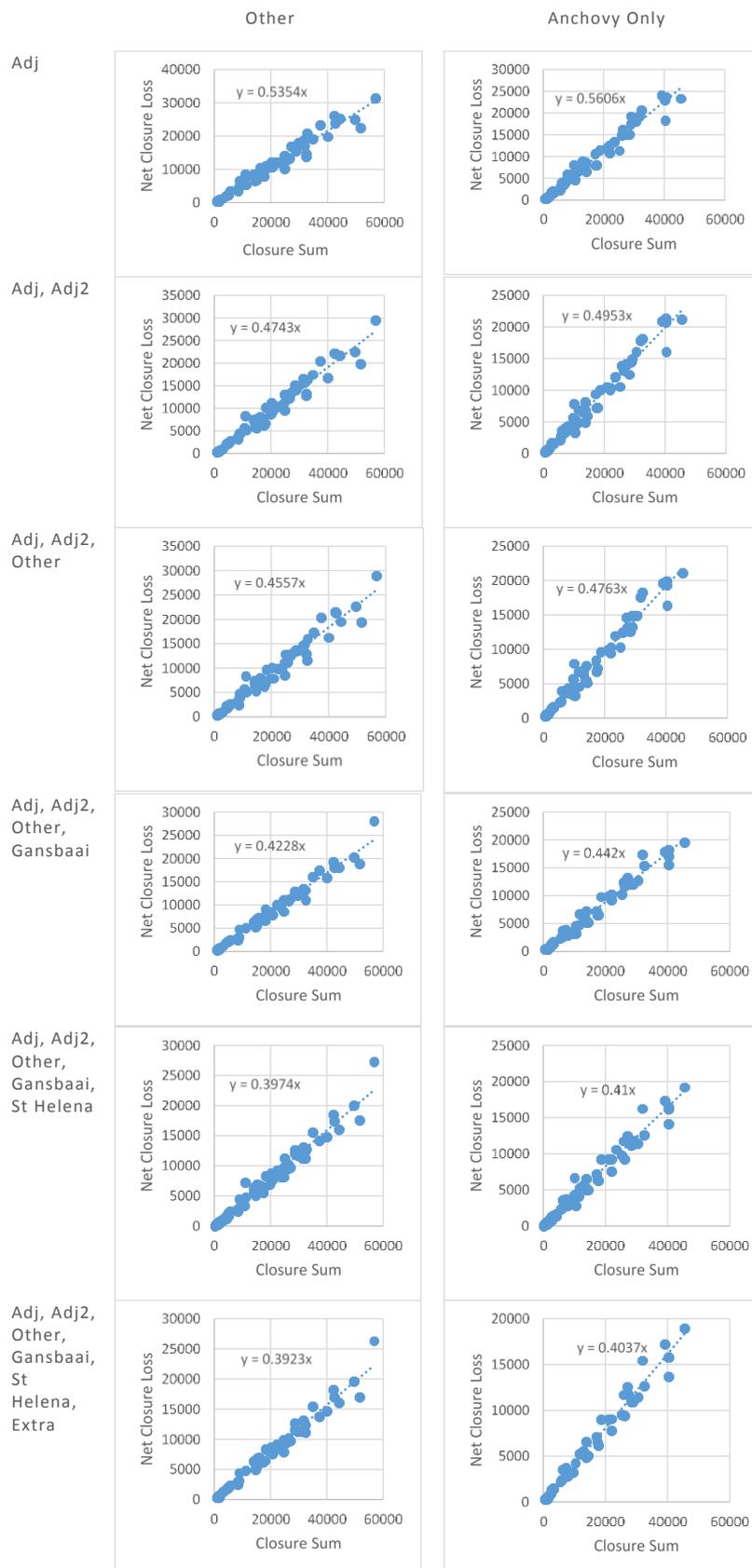


Figure 5-8 Results of the OBM model for the West Coast only, for industrial fish (Other), and for anchovy. The y-axis (Net Closure Loss) is the “unreplaceable” tonnage within the penguin protection area, while the x-axis gives the original calculated tonnage caught within the penguin protection area. Dots represent results by year and island **for the period 1987 - 2008**. The rows represent an expanding set of alternative opportunities as described in the text, but excluding those indicated by the survey data. These graphs exclude the years 2008 onwards during a period when closures were applied.

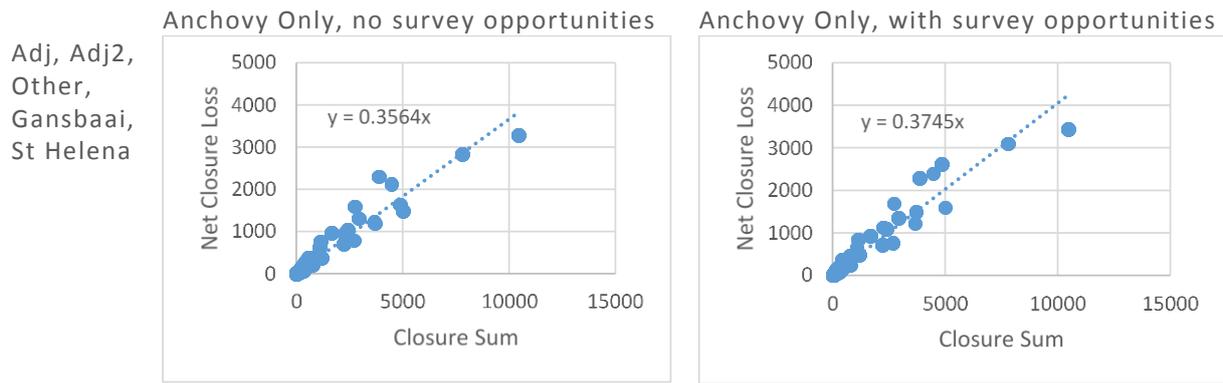


Figure 5-9. Results of the OBM model for the West Coast only, and for Anchovy only. This is a restricted analysis for the matching dates (day level) between the grid set data and the survey data. Only one set of non-survey based alternative opportunities is considered, i.e. Adj, Adj2, Other, Gansbaai and St Helena. The y-axis (Net Closure Loss) is the “unreplaceable” tonnage within the penguin protection area, while the x-axis gives the original calculated tonnage caught within the penguin protection area. Dots represent results by year **for the period 1987 - 2008**. The figure on the LHS does not allow for the additional survey indicated opportunities to be considered, while that on the RHS does.

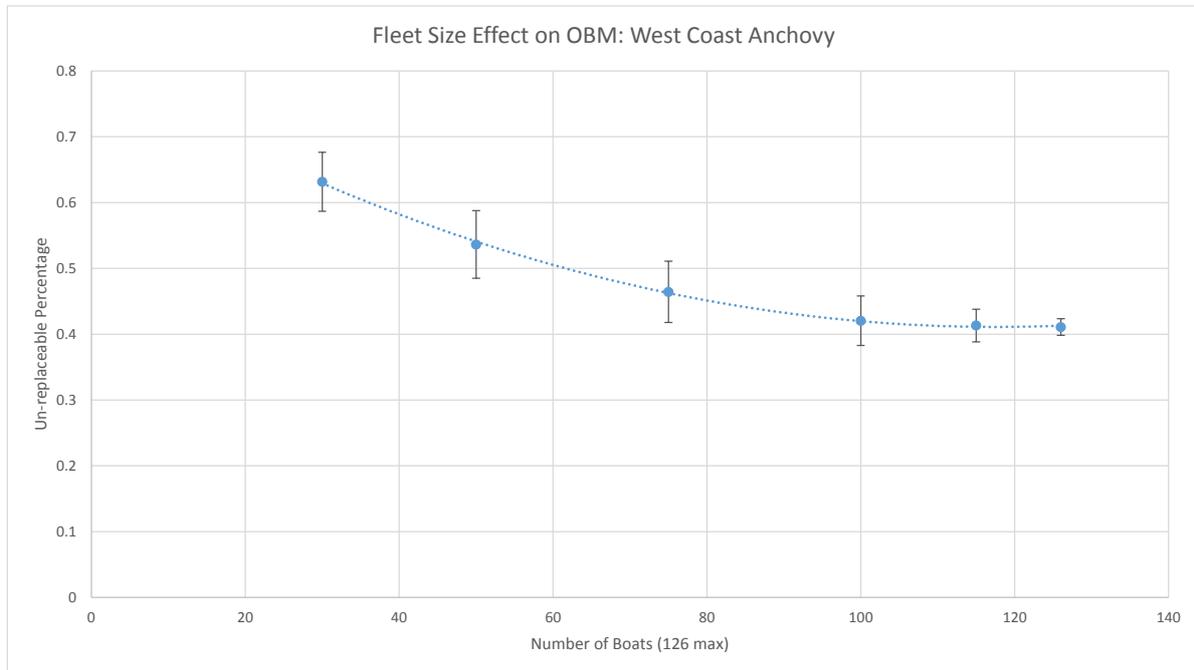


Figure 5-10. Fleet size effect analysis on OBM model. This is done for anchovy only on the West Coast which corresponds to the panel in Figure 5-5, Adj, Adj2, Other, Gansbaai, St Helena. Each point consists of 10 random iterations. In each iteration the random logistic flags are randomized as well as the selection of boats. E.g.. for point '50 boats', a random subset of 50 boats was selected for each of the 10 iterations and the mean and standard deviation found. The error bars are the mean standard deviation expressed as a percentage of overall catch in the respective closure grid. The same scale as the un-replaceable percentage on the Y-axis. Only the set of available opportunities are affected by the fleet reduction process, the actual catches and sets considered for replacement when within a penguin protection area remain.

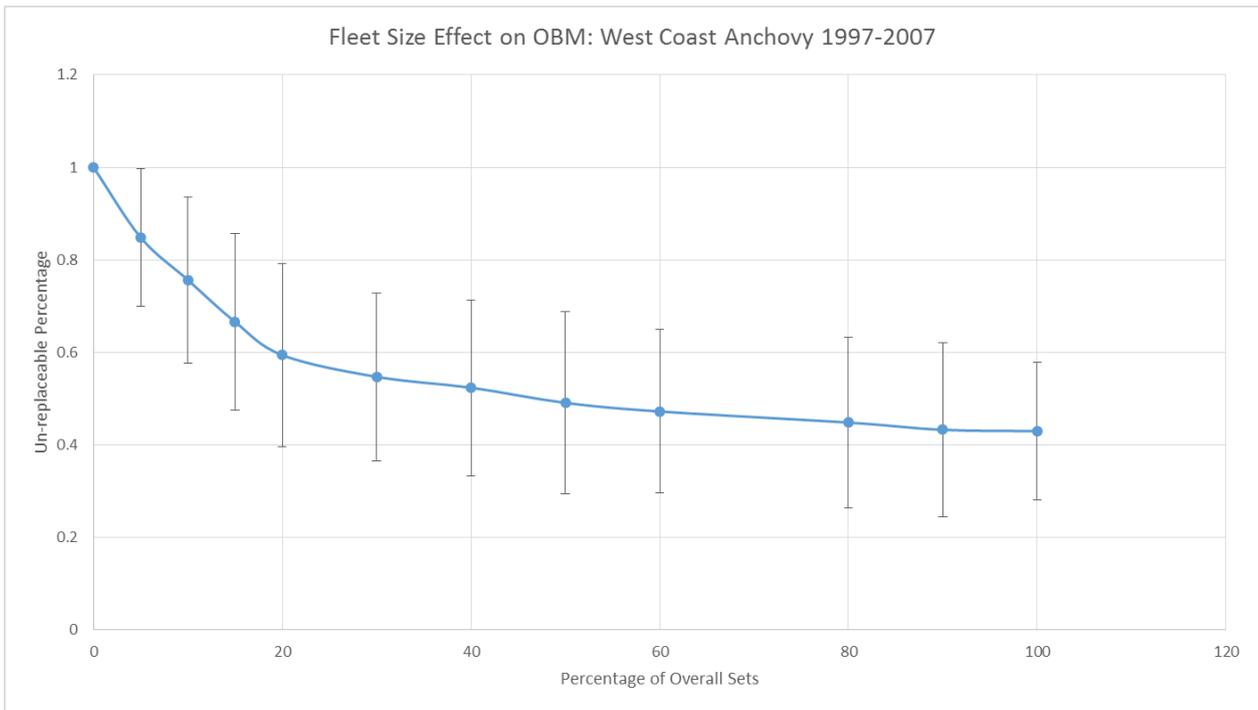


Figure 5-11. Fleet size effect analysis on OBM model. This is done for anchovy only on the West Coast for years 1997 to 2007 only, for reasons described in the text, and the 100% point on the x-axis corresponds to the panel in Figure 5-5 for , Adj, Adj2, Other, Gansbaai. Each point consists of 10 random iterations. In each iteration the choice of whether a set in an intersecting grid is inside or outside the closure area is chosen pro rate to surface area (described in text) and a random selection of x%. In addition, vessels are selected at random and incrementally until the total effort (measured as number of sets) reaches the selection %, where the %'s are those depicted on the x-axis of the figure. For example, for 80 "Percentage of Overall Sets", there are 10 different random vessel selections each of which comprises 80% of the total number of sets. The error bars are the standard deviation of the unreplaceable tonnage expressed as a % of the original catch in the penguin closure area, averaged over all years and island. So this is a measure of the variability of the results across the 10 iterations referred to, but at a year and island level.

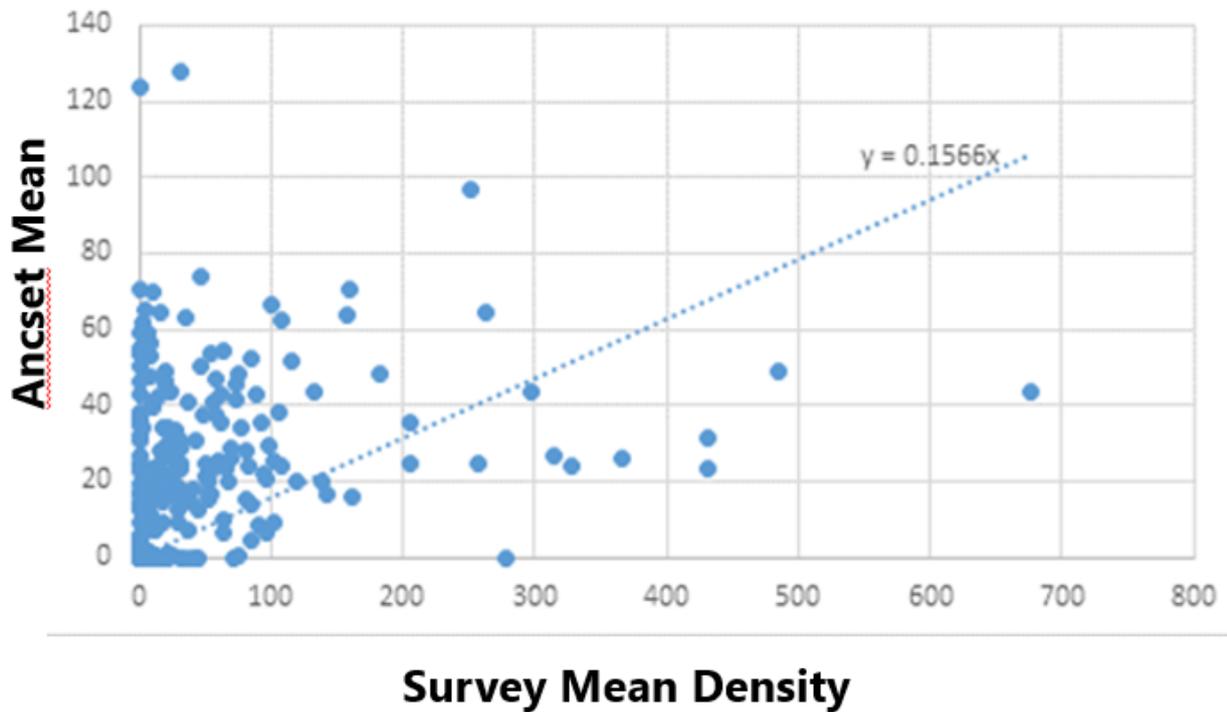


Figure 5-12. A scatterplot of the mean catch of anchovy against the mean survey value, for data where there is a common date and grid between the commercial fishing logbook data and the survey data. In this figure the y-axis is the mean catch per set for a day and grid from the commercial logbook data (Ancset Mean) and the x-axis shows the mean density reading from the survey data (Survey Mean Density).

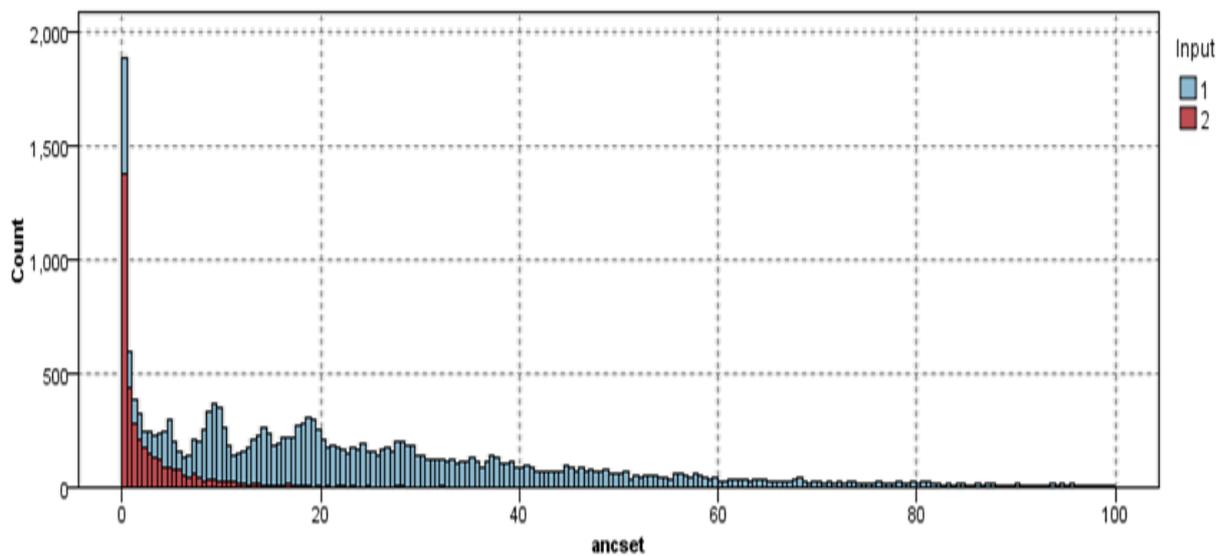


Figure 5-13. Combined histogram of the actual historically recorded anchovy set level catches (blue), and the survey based additional potential anchovy set level catches. These data are based on matching grid and days between the catch logs from the commercial fishery and the dates and positions of the survey data. The commercial data (in blue) which have been used are the “grid set data” for the 1987 - 2014 period. The survey data (in maroon) are those supplied to OLRAC SPS by DAFF. The survey density readings have been calibrated by the calculations described in the text and illustrated in Figure 5-12.

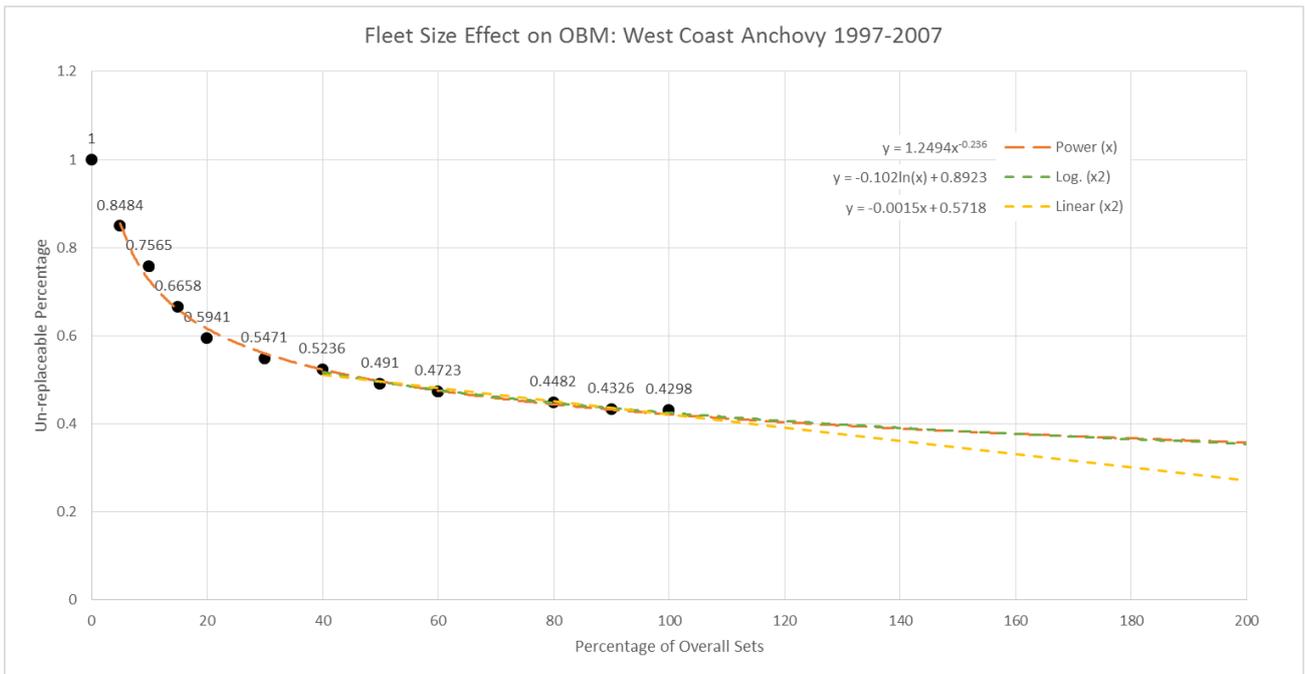
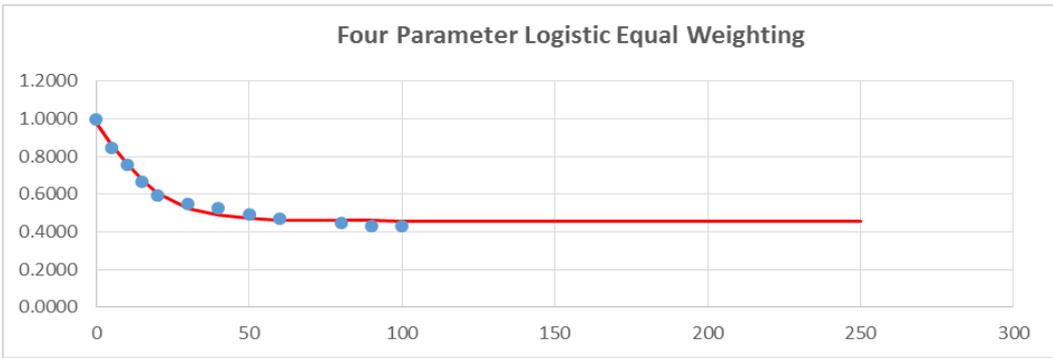
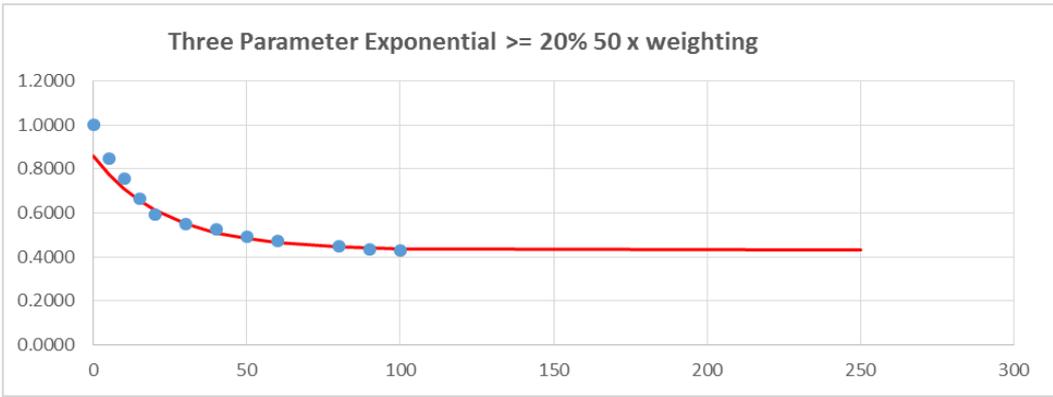
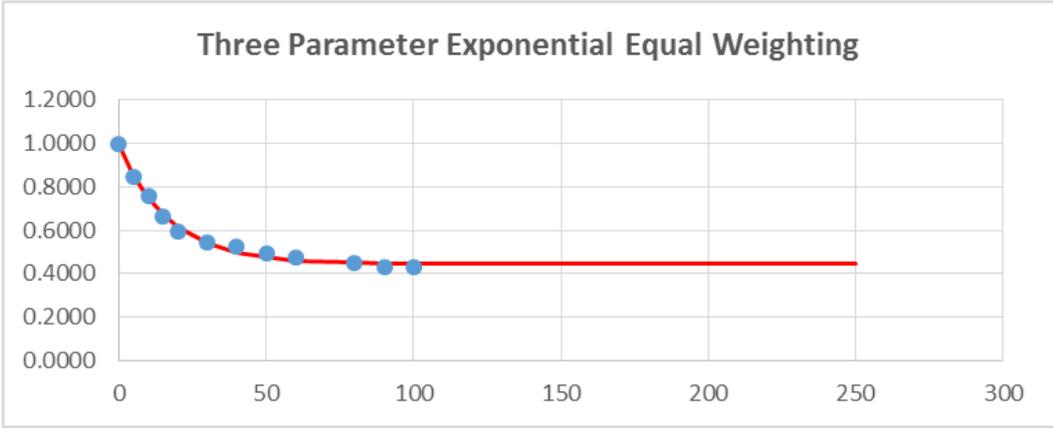


Figure 5-14. Standard Excel functions applied to the fleet reduction results to extrapolate to larger fleet sizes. x means all data points were used, x2 means only data points for x-axis values of 40% and above were used in the fit.



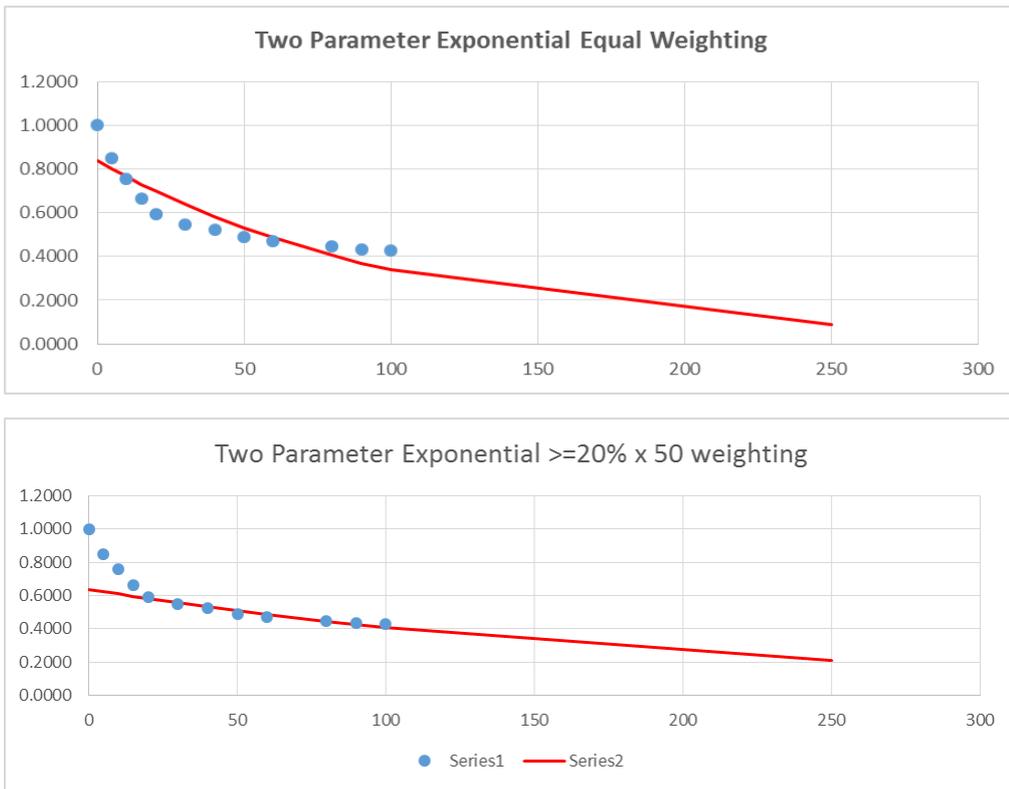


Figure 5-15. Various fits to the results of the fleet reduction exercise to provide an objective approach to the determination of the limiting factor of interest.