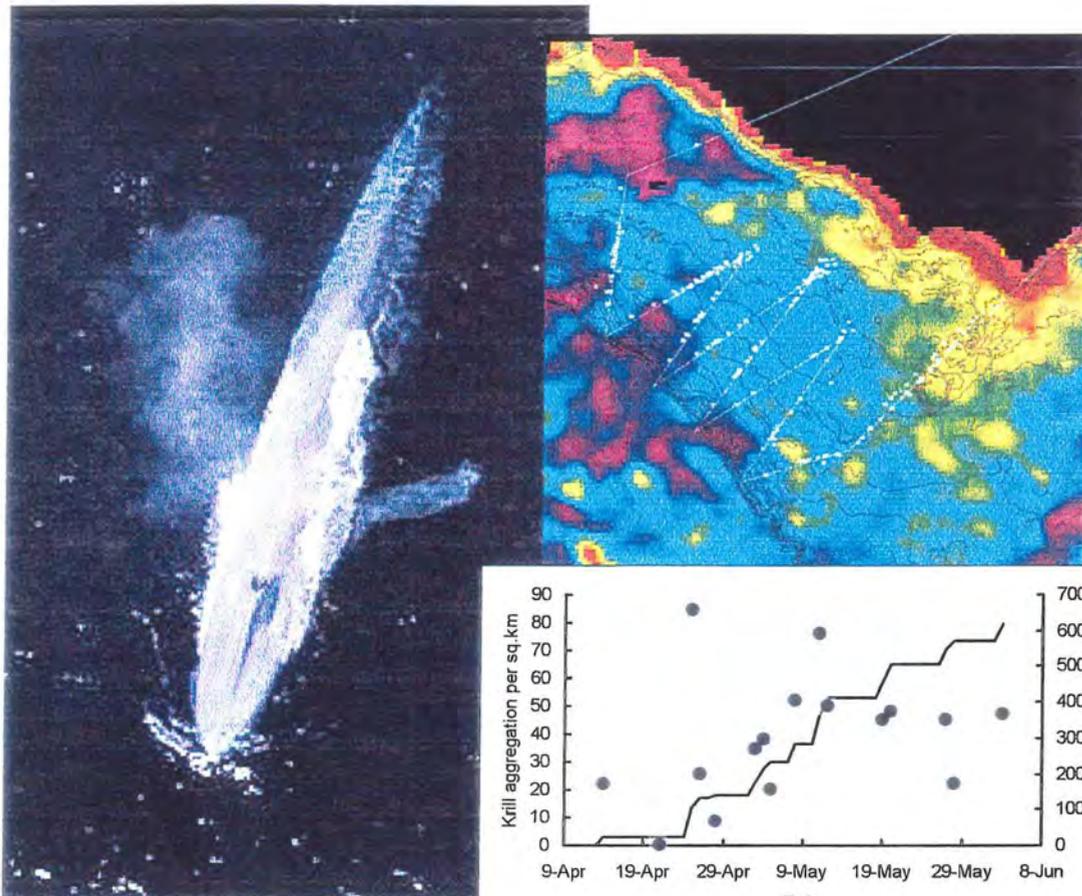


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# ASSESSING THE DISTRIBUTION OF KRILL AND BLUE WHALES IN THE OTWAY BASIN USING AERIAL SURVEY



Natural Resources  
and Environment

AGRICULTURE  
RESOURCES  
CONSERVATION  
LAND MANAGEMENT



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**EXECUTIVE SUMMARY**

- The potential effect that energy resource exploration and production has on the behaviour and ecology of large cetaceans has elevated concerns about the impact of these activities on the diversity and functionality of marine ecosystems.
- During May and June 2001, Woodside Energy Ltd. (Woodside) undertook exploratory gas drilling at two locations in the offshore Otway Basin, southwestern Victoria. Because this region is inhabited by blue whales during summer and autumn, Woodside commissioned research to (1) establish baseline information on the extent to which cold-water upwelling, krill aggregations and blue whales were spatially associated in the vicinity of drilling activities, and (2) meet compliance requirements determined by Environment Australia for commencement of drilling at the two locations. This report summarises the results of this research program.
- Seventeen standardised aerial surveys were undertaken in the area between 14 April and 3 June 2001. The incidence of blue whales and krill aggregations were noted during surveys, and the locations of sightings was logged. Remotely sensed satellite images were used to estimate spatial variation in sea surface temperature on each of these survey occasions.
- Double-count and line transect techniques were used to quantify the effect prevailing weather conditions and distance from the aircraft had on the sightability of blue whales and krill, and to estimate multiplicative correction factors to account for these sources of bias.
- The sighting rate for blue whales declined from the last week in April, suggesting whales began leaving the area at about this time. The last blue whale was sighted during surveys on 19 May. In contrast, while the abundance of krill aggregations varied considerably over the survey period, there was no apparent tendency for overall density to decline as the survey period progressed. This suggests that blue whales did not leave the area due to a decline in the availability of krill.
- The spatial association of sea surface temperature and the location of krill aggregations was assessed using a spatial cluster analysis technique, and by comparing the distribution of sea surface temperatures along the survey flight line, with that for point locations of krill observations. While both the spatial pattern of sea surface temperatures and the occurrence of krill aggregations varied considerably due to prevailing weather conditions, there was a clear tendency for krill aggregations to occur in areas with lower than average surface temperatures.
- The abundance of krill aggregations in the Otway Basin appears to be influenced by the persistence of discrete areas of colder surface water, presumably because these areas sustain higher levels of phytoplanktonic activity. Weather conditions that lead to a deterioration in sea state (i.e. those that shift sea state from calm to moderate seas, or from moderate to high seas), appear to reduce the persistence of these areas of colder surface water, reducing the density of krill aggregations. The implications of these transient declines in the density of krill aggregations for the foraging behaviour of blue whales remains unknown.
- We recommend that future research focuses on the development of quantitative models that directly link prevailing weather conditions to sea state, sea state to the probability that krill aggregations will occur in specific parts of the Otway Basin, and the occurrence of krill aggregations to blue whale activity. These models could provide benchmark predictions of blue whale activity, against which any apparent influence of energy exploration or exploitation could be compared.

## **INTRODUCTION AND BACKGROUND TO THE RESEARCH**

The potential effect that energy resource exploration and production has on the behaviour and ecology of marine life has elevated concerns about the impact of these activities on the diversity and functionality of marine ecosystems. Of particular concern is the effect that consistent acoustic pollution from anthropogenic sources (e.g. shipping, defence activities, petroleum exploration activities), may have on cetaceans (whales, dolphins and porpoises) given their role as top-order predators in marine ecosystems. Large baleen whales, such as humpback, southern right and blue whales, are at least partially reliant on sound to communicate their presence to conspecifics, and may also use sound to locate sources of food while foraging. As such, activities that elevate underwater background noise to levels that interfere with these functions may make parts of the ocean difficult or impossible for whales to utilise. Depending on the degree to which the effective foraging range of whales is compromised by elevated noise levels, sources of anthropogenic noise, including some petroleum exploration activities, may have consequences for (1) the capacity of whale populations to utilise available food resources, and (2) the role that foraging by whales plays in structuring marine ecosystems.

Gill (2001) described an aggregation of blue whales (*Balenoptera musculus*) off the coast of western Victoria in summer and early autumn, which appeared to be associated with the upwelling of cold water onto the continental shelf due to prevailing weather patterns. Gill (2001) suggested that this upwelling (the Bonney upwelling) produced areas of high phytoplankton productivity, and the consequent aggregation of krill (primarily coastal krill *Nyctiphanes australis*). In late 1998, Gill initiated a study which is assessing the linkages between cold water upwelling, phytoplankton productivity, krill aggregation and the distribution of blue whales in an area of offshore waters between Warnambool in western Victoria and Robe in South Australia. Gill's (2001) results indicate that blue whales are present in his survey area between December and late-April or early May, which is the period when the Bonney upwelling is most active.

During May and June 2001, Woodside Energy Ltd. (Woodside) undertook exploratory gas drilling at two locations (Geographe-1 and Thylacine-1) in the offshore Otway Basin, southwestern Victoria (Survey Route Map). This area is to the east of that in which Gill is undertaking his research on blue whales and krill. As part of the process of gaining environmental approvals to undertake this drilling (under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*), Woodside committed to commissioning and funding a dedicated research project to assess the distribution and abundance of blue whales, krill aggregations and cold-water upwelling in the vicinity of the two drilling locations, prior to and during drilling operations. This information is necessary to (1) establish baseline information on the extent to which cold-water upwelling, krill aggregations and blue whales were spatially associated in the vicinity of drilling activities, and (2) meet compliance requirements determined by Environment Australia for commencement of drilling at the two locations. This report summarises the results of this research program. The main body of the report details the data collected during aerial surveys to assess broadscale patterns of association between upwelling, krill and blue whales, with the surveys conducted to assess the specific compliance requirements set by Environment Australia summarised in Appendix A.

### ***Aims of the research program***

- Using aerial survey, assess changes in the location and abundance of krill and blue whales along a specified survey route;
- Using appropriate satellite imagery, assess changes in sea surface temperature over the duration of the survey program;
- Analyse patterns in the distribution and abundance of blue whale and krill sightings over the course of the survey program;
- Assess the influence environmental conditions and distance from the aircraft has on the detectability of blue whales and krill; and
- Assess the effect sea surface temperature has on the occurrence of krill aggregations in the survey area.

## **METHODS**

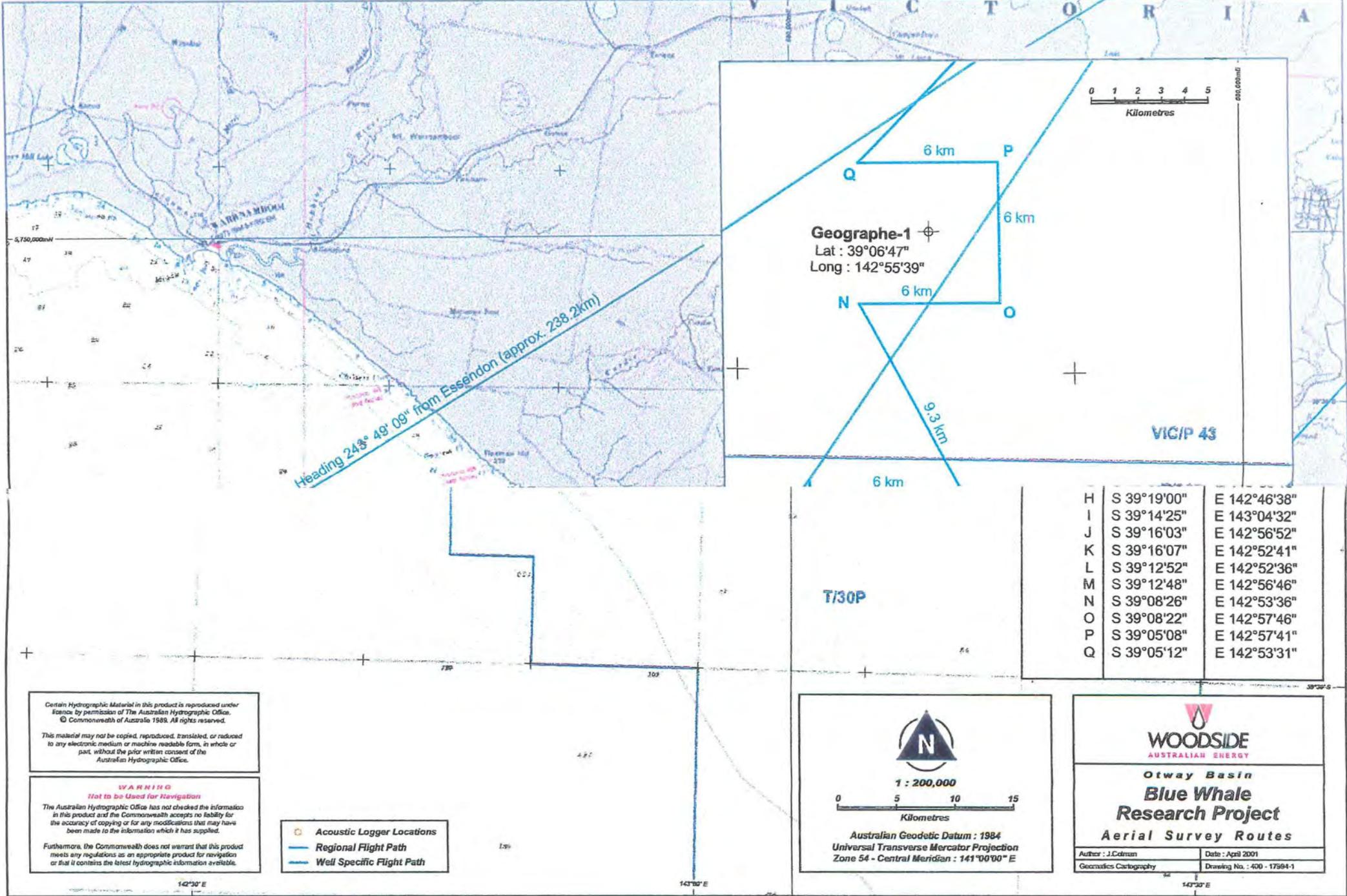
### ***Aerial surveys***

A sequence of 17 aerial surveys was undertaken between 14 April and 3 June 2001. Of these, 12 surveys flew a 408.9 km route made up of 10 linked transects that varied from 27 to 57 km in length (see Survey Route Map). These transects described a route running from the coast southeast of Warnambool (transect 1), out to a sequence of eight transects that zig-zagged over the continental shelf in a general southeastern direction (transects 2-9), then back to the coast to the west of Cape Otway (transect 10). A further four surveys flew the same route, but did not fly transect 10 in order to cover a sequence of shorter compliance transects in the immediate area of the drill sites. A single survey that took in the compliance transects only was also flown.

Aerial surveys were flown from a high-winged, twin-engined AeroCommander Shrike AC500 aircraft. Nominal survey altitude was 1,500 ft (460 m), which was reduced to 1,000 ft (308 m) to avoid low cloud during two surveys. Nominal ground speed was 130 knots. Cloud cover and sea state were recorded at the start of each of the 10 linked transects, and at the start and end of the compliance transects. Cloud cover was scored in octals, and sea state as calm, slight, moderate, or high. Aerial surveys were cancelled if cloud cover exceeded 4/8 when seas were high, or if the predicted cloud base was below 1,000 ft.

Surveys were flown with either one observer on either side of the aircraft (single-count surveys), or two observers on one side of the aircraft and a third on the other side (double-count surveys). For single-count surveys, observers noted occurrences of blue whales, aggregations of krill, and any incidental observations (i.e. other cetaceans, bird aggregations, wind surfers etc.). When blue whales were sighted, the current aircraft position was logged on a constantly running Global Positioning System receiver (GPS), before the aircraft left the transect line and flew to the position of the whale/s where another position was logged. When krill aggregations were sighted, the current aircraft position was logged, the relative size of the aggregation was classed as large, medium or small, and its position relative to the aircraft was judged as being within 250 m, or between 250 and 500 m. No krill aggregations were sighted at distances judged to be greater than 500 m from the aircraft. When incidental observations were judged to be within 250 m of the aircraft, the current position of the aircraft was logged. When incidental observations were judged to be greater than 250 m from the aircraft, the current position of the aircraft was logged, before the aircraft left the transect line and flew to the position of the observation where another position was logged. At the completion of each survey, positions of observations logged on the GPS receiver were downloaded onto a PC in decimal latitude/longitude format. Details of each of the aerial surveys flown during the project are summarised in Table 1.

Survey Route Map. The flight lines used during research and compliance components of the aerial survey program. The drilling locations are shown as Geographe-1 and Thylacine-1.



**Geographe-1**  
 Lat : 39°06'47"  
 Long : 142°55'39"

Heading 243° 49' 09" from Essendon (approx. 238.2km)

H	S 39°19'00"	E 142°46'38"
I	S 39°14'25"	E 143°04'32"
J	S 39°16'03"	E 142°56'52"
K	S 39°16'07"	E 142°52'41"
L	S 39°12'52"	E 142°52'36"
M	S 39°12'48"	E 142°56'46"
N	S 39°08'26"	E 142°53'36"
O	S 39°08'22"	E 142°57'46"
P	S 39°05'08"	E 142°57'41"
Q	S 39°05'12"	E 142°53'31"

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- Acoustic Logger Locations
- Regional Flight Path
- Well Specific Flight Path

  
**1 : 200,000**  
  
 Kilometres  
 Australian Geodetic Datum : 1984  
 Universal Transverse Mercator Projection  
 Zone 54 - Central Meridian : 141°00'00" E

  
**WOODSIDE**  
 AUSTRALIAN ENERGY  
 Otway Basin  
**Blue Whale**  
 Research Project  
 Aerial Survey Routes  
 Author : J.Calman      Date : April 2001  
 Geomatics Cartography      Drawing No. : 400 - 17594-1

Survey	Date	Type	Transects flown	Length of survey line <sup>1</sup>	Number of observers	Cloud cover	Sea state
1	14 April	R	1 – 10	408.9	2	3 / 8	Moderate
2	21 April	R & C	1 – 9	351.9	2	4 / 8	Moderate
3	24 April	C		0	2	8 / 8	Slight
4	25 April	R & C	1 – 9	351.9	2	7 / 8	Calm
5	26 April	R & C	1 – 9	351.9	2	2 / 8	High
6	28 April	R & C	1 – 9	351.9	2	5 / 8	Calm
7	3 May	R	1 – 10	408.9	3	7 / 8	Calm
8	4 May	R	1 – 10	408.9	3	4 / 8	Calm
9	5 May	R	1 – 10	408.9	2	2 / 8	Calm
10	8 May	R	1 – 10	408.9	3	1 / 8	Calm
11	11 May	R	1 – 10	408.9	3	5 / 8	Calm
12	12 May	R	1 – 10	408.9	3	7 / 8	Calm
13	19 May	R	1 – 10	408.9	2	4 / 8	Slight
14	20 May	R	1 – 10	408.9	3	5 / 8	Moderate
15	27 May	R	1 – 10	408.9	3	4 / 8	Slight
16	28 May	R	1 – 10	408.9	2	4 / 8	Slight
17	3 June	R	1 – 10	408.9	2	2 / 8	Calm

<sup>1</sup>The length of the survey line refers to the 10 linked transects flown for the research surveys only. All data relevant to the compliance surveys are described in Appendix A.

Table 1. Dates, survey type (Research, Compliance), transects flown, number of observers used and prevailing conditions for the 17 surveys undertaken over the course of the program. Note that where both research and compliance components of the program were flown in the same survey, the final research transect back to the coast (transect 10) was not flown. Cloud cover was scored in octals, and sea state as calm, slight moderate or high.

### **Remotely sensed data**

Spatial datasets used in this study were been categorised as primary and secondary datasets. Primary datasets were defined as datasets used as the key inputs to the spatial analysis phase of this project. Secondary datasets were datasets generated as a result of this spatial analysis. Primary datasets were further classified into source datasets, and derived datasets generated from source datasets for use in the spatial analysis phase (see below).

All spatial datasets were managed and analysed in a Geographic Information System (GIS) using ESRI produced ArcINFO computer software.

### **Primary Input Data**

Primary input datasets were stored in either vector or raster format depending on how the information was captured or acquired.

Key source datasets used in this study were:

- Sightings (aerial survey results);
- Flight paths;
- Bathymetry;
- Sea surface temperature; and
- Sea surface productivity.

Sighting, flight path and source bathymetry datasets were stored as ArcINFO vector coverages, and sea surface temperature and productivity information (which was obtained from satellite imagery) as ArcINFO GRID (raster) datasets. A summary of primary input source datasets and the relevant variables used in this study is provided in Table 2.

DATASET	FORMAT	SOURCE	VARIABLES	DESCRIPTION
<i>Source</i>				
SST (T)	Raster		Temperature	Sea surface temperature
SPI (P)	Raster		Chlorophyll A	Chlorophyll A index – sea surface productivity index
LAND	Vector – poly		Land	Coastline delimiter
BATH (D)	Vector – line		Depth	Bathymetry
FLIGHT	Vector – line			Survey flight path
SZONE3	Vector – poly	FLIGHT	Zone	Survey flight path 3 km zone
SZONE6	Vector – poly	FLIGHT	Zone	Survey flight path 6 km zone
SZONE12	Vector – poly	FLIGHT	Zone	Survey flight path 12 km zone
SIGHTINGS	Vector – point		Location WHALES KRILL OTHER	Locations of marine fauna sightings

Table 2. Primary Inputs – Source Datasets

*Sightings (Aerial Survey Results) – Point Feature Vector Dataset*

The aerial survey results for each survey day were represented as an individual ArcINFO points coverage. A total of 17 survey result datasets were created, although only 15 results were viewed as valid and subsequently used in further processing. The two data sets that were not used were the compliance only survey undertaken on 24 April, and the survey on 21 April when no observations of krill aggregations or whales were made. The sightings datasets were created from a MS Excel file prepared for each survey day by the aerial survey team. This file was created by downloading information from a hand held data logging device used in the survey aircraft. A latitude and longitude value assigned to each sighting by the (GPS) function of the data logging device was used to generate the spatial location of each sighting.

*Flight Paths – Line Feature Vector Dataset*

A survey flight path dataset was created using flight way points provided by Woodside. Two flight paths were identified, the survey flight path and compliance flight path. A further dataset identifying the compliance zone was created using a 3km buffer distance around drill locations.

*Bathymetry – Line Feature Vector Dataset*

Bathymetry at a map source scale of 1:250,000 for the study area was obtained from the Victorian Department of Natural Resources and Environment (DNRE). This dataset identified water depth contours at intervals of up to 10 metres. Additional bathymetry information was provided by Woodside.

A digital elevation model (DEM) of the ocean floor was created using the bathymetry information.

*Sea surface temperature – Grid dataset*

Sea Surface Temperature (SST) images for the survey area were obtained on a daily basis for the survey period (commencing 14 April 2001 to 8 June 2001) from the Marine Research Remote Sensing Project team, CSIRO, based in Hobart, Tasmania, which runs a ground station for the reception and processing of data from the NOAA AVHRR (Advanced Very High Resolution Radar) satellite. Images were downloaded from a web site managed by the CSIRO team on a subscription basis. The percentage of cloud coverage and time the image was taken were provided for each image provided. Between one and four images were provided for each day depending on cloud levels and other factors.

The SST images provided by CSIRO were derived from AVHRR data (NOAA satellite) and had a spatial resolution of 1 km by 1 km. Image cells were assigned a temperature rating of between 2 and 254, where a value of 2 corresponded to  $-4.84^{\circ}$  Celsius and 254 a value of  $35.00^{\circ}$  Celsius. A linear conversion was applied to these images to assign a real temperature value. Mr Kim Badcock, of the CSIRO team, advised that temperature values less than  $13^{\circ}$  C and greater than  $19^{\circ}$  C were likely to be erroneous, resulting from the effects of cloud and other mitigating factors.

The best SST image for each survey period (up to three days before and after each aerial survey day) was converted to an ArcINFO grid. Images were selected on the basis of cloud information and a visual check.

#### Sea Productivity – Grid Dataset

Four Sea Surface Productivity (SSP) or Chlorophyll-A (SPI) images for the survey area were obtained for the survey period. The dates of the four images obtained were 14 April 2001, 5 May 2001, 12 May 2001 and 3 June 2001. Image dates were chosen based on the cloud levels observed for SST imagery for each aerial survey date.

Chlorophyll-A images were obtained from Orbimage in the USA, who generated the images from data received from the SeaWiFS (Sea-viewing Wide Field-of-View Sensor) satellite.

#### Primary Input Data – Derived Datasets

Key primary input datasets derived from source datasets used in this study were:

- Survey flight path zones derived from the flight path dataset;
- Digital elevation model surfaces derived from bathymetry; and
- Survey day (smoothed) sea surface temperature surface derived from SST images for each survey period (up to three days before and after each aerial survey day).

All primary input dataset grids generated in this project had a cell resolution of 250 m. Satellite images with a cell resolution of 1,000m were resampled to 250 m for the purpose of further analysis.

A summary of primary input derived datasets and the relevant variables used in this study is provided in Table 3.

DATASET	FORMAT	SOURCE	VARIABLES	DESCRIPTION
<b>Derived</b>				
<b>Vector-based</b>				
SZONE3	Vector – poly	FLIGHT	Zone	Survey flight path 3 km zone
SZONE6	Vector – poly	FLIGHT	Zone	Survey flight path 6 km zone
SZONE12	Vector – poly	FLIGHT	Zone	Survey flight path 12 km zone
<b>Cell-based</b>				
SDIST	Raster	FLIGHT	Distance	Distance from transect line to all ocean cells
DDEM	Raster	BATH	Depth	Sea bottom depth surface
DSLTP	Raster	DDEM	Bottom slope	Sea bottom slope surface
D2SLTP	Raster	DSLTP	Log Bottom slope	Sea bottom slope surface log transform
DCUV	Raster	DDEM	Bottom curvature	Sea bottom curvature surface
D2CUV	Raster	DCUV	Log Bottom curvature	Sea bottom curvature surface log transform
SST (T)	Raster		Temperature	Sea surface temperature
TSLP	Raster	SST	Temperature slope	Sea temperature slope surface

Table 3. Primary Inputs – Derived Datasets

*Digital Elevation Model Surfaces – Grid Dataset*

Digital elevation model surface datasets were derived from a 250 m resolution digital elevation model, created using bathymetry data. Slope and slope curvature surface datasets were created as potential inputs to the spatial analysis phase of this study.

*Survey Day (Smoothed) Sea Surface Temperature – Grid Dataset*

For each valid survey day (15 days from a total of 17 aerial survey dates) the 12 datasets listed in Table 3 were created from the processed sea surface temperature images. Due to the continued presence of cloud it was decided that the best approach was to create a set of data derived from the five best images (the best image for the survey day and two images either side of the best) for each survey day. The method used to create this five image temperature average was:

1. For each surface remove the spurious data ranges (<14.5°C and >16.5°C) were assigned as NODATA (as for cloud).
2. Cell resolution was 1 x 1 kilometer.
3. For each cell calculate the sum of valid data values = sum.
4. For each cell calculate the number of valid data values = number.
5. For each cell calculate the average of valid data values as average = sum / number.
6. For each cell calculate the average temperature in a 5 x 5 cell rectangle = GSSTAV.

This process effectively smoothed the temperature for each day temporally and spatially, and was implemented in ArcInfo GRID as a DOCELL algorithm.

The GSSTAV grid was then considered the smoothed sea surface temperature. Using this surface as an input 11 other derived inputs were created for each of 15 valid survey days, as illustrated in Table 4.

DATASET	VARIABLE	DATASET	VARIABLE
Derived		Derived	
Absolute		Relative	
GSSTAV	Average value in focal distance (radius of 5 x 5 cells) of the accumulated 5 image average (Average of 2 best images either side and closest to survey plus survey day)	RTLAV	Standardised GSSTAV (0 – 1)
GSSTMX	Maximum value of GSSTAV in focal distance	RTLMX	Standardised GSSTMX (0 – 1)
GSSTMN	Minimum value of GSSTAV in focal distance	RTL MN	Standardised GSSTMN (0 – 1)
GSSTSD	Standard deviation of GSSTAV value in focal distance	RTLSD	Standardised GSSTSD (0 – 1)
GSSTMD	Median of GSSTAV in focal distance	RTLMD	Standardised GSSTMD (0 – 1)
GSSTRG	Value range of GSSTAV in focal distance	RTLRG	Standardised GSSTRG (0 – 1)

Table 4. Smoothed Sea Surface Temperature Datasets – Derived Inputs

*Aggregating SST Data Over the Survey Period*

Given the relatively low number of krill sightings on any given day it was then decided that further analysis would benefit from using all krill data from the survey period (see below). In order to examine the krill sightings as a single unit, the smoothed sea surface temperature surfaces (identified in Table 4) for each day, were aggregated to provide a further set of derived data – see Table 5 below. These datasets were created to assist in the analysis of trends and aid in subsequent spatial data analyses (maximum likelihood classification and regression analysis).

The method used to create the aggregate SST-derived datasets was:

1. Create a data 'stack' of the relevant surface from each survey day.
2. Use the GRID functions MEAN (average of the stack), MAX(maximum of the stack), MIN(minimum of the stack), MEDIAN(median of the stack), RANGE(range of the stack) to create aggregate surface for the absolute and relative SST inputs.

where:

- A. S0305 G & T = derived surfaces and DBF files of survey data surfaces at krill site locations and for the entire swath of the survey day flight line. These data tables were supplied to the Arthur Rylah Institute for further trend analysis.
- B. Absolute = actual sea surface temperature (SST) values as inputs.
- C. Relative = standardised SST.
- D. SURVEY = data derived for EACH survey day.
- E. PERIOD = aggregate of all survey day inputs.

Table 5 summarises the 36 datasets created using this method.

	Average	Maximum	Minimum	Standard Deviation	Median	Range	
<b>SURVEY</b>							
							<b>DATE</b>
DAY 1	S0305 G&T						S1404
DAY 2						S2504	
DAY 3						S2604	
DAY 4						S2804	
DAY 5						S0305	
DAY 6						S0405	
DAY 7						S0505	
DAY 8						S0805	
DAY 9						S1105	
DAY 10						S1205	
DAY 11						S1905	
DAY 12						S2005	
DAY 13						S2705	
DAY 14						S2805	
DAY 15						S0306	
<b>PERIOD</b>							
<b>Absolute</b>							
<b>Relative</b>							

Table 5. Datasets – Data & Survey Day Summary

The derived SST information for the entire survey period was combined with both a krill sightings grid, created from individual aerial survey day observations, and a grid for the entire swath of the survey day flight line, to create two dBase IV (DBF) files. These two files identified the suite of absolute and relative SST variables assigned to krill sightings and to the entire survey swath area, respectively. These files were used as inputs into a statistical modelling process that investigated the correlation between krill sightings and SST variables (see below).

#### *Blue Whale Sightings*

The distance from the transect line surface was combined with the blue whale sightings grid, created from individual aerial survey day observations, to create a DBF file. This file identified the distance from the transect line assigned to all blue whale sightings. The data contained in this file was used to assess the effect distance between observers and whales had on whale detectability (see below).

#### *Spatial Analysis*

The sea surface temperature data collated for this project represents slices of space in time. The general thrust of the investigation into the collated data was to determine if there were any significant temporal and/or spatial relationships between individual variables developed in the analysis. To accomplish this, two methods were selected that suited the general line of enquiry and the data available from the survey and other sources. The first of these was an unsupervised classification using combination of a cluster analysis technique and a maximum likelihood classification. The second was a logistic regression to produce a preliminary set of predictive surfaces for further investigation.

The cluster analysis was run across both individual survey day variables and combinations of survey period variables. The logistic regression runs were applied data aggregated over the entire survey period data due to the relatively low number of krill sightings during any single survey.

Two types of data were identified for the purposes of spatial analysis:

- Temporal data (that related to the one survey day); and
- Survey period data (that identified values for the entire survey period and hence provided the one view of data)

#### *Cluster Analysis and Maximum Likelihood Classification*

The cluster analysis implemented in this project used an isodata clustering algorithm to determine the characteristics of the natural groupings of cells in multidimensional-attribute space and stored the results in an output ASCII signature file. This process clusters the multivariate data combined in a stack (set of grids). The resulting signature file is used as the input for a classification that produces an unsupervised classification grid. The ArcInfo GRID implementation of the clustering algorithm (ISOCLUSTER) uses a modified iterative optimisation clustering procedure, also known as the migrating means technique. The algorithm separates all cells into a user-specified number of distinct unimodal groups in the multidimensional space of a stack. The function is most often used as a preparation for unsupervised classification.

The ISO prefix of the isodata clustering algorithm is an abbreviation for the Iterative Self Organizing way of performing clustering. This type of clustering uses a process in which all samples are assigned to existing cluster centres and new means are recalculated for every class during each iteration. The optimal number of classes in these analyses are usually unknown.

The ISOCLUSTER algorithm is an iterative process for computing the minimum Euclidean distance when assigning each candidate cell to a cluster. The process starts with arbitrary means being assigned by the software, one for each cluster (the number of clusters is

dictated by the user input). Every cell is then assigned to the closest of these means (all in the multidimensional-attribute space). New means are then recalculated for each cluster based on the attribute distances of the cells that belong to the cluster after the first iteration. The process is repeated, each cell being assigned to the closest mean in multidimensional-attribute space and new means calculated for each cluster based on the membership of cells from the current iteration.

In the context of this project, cluster analysis involves analysing a variable over time with the aim of creating a classification surface that may reflect temporal trends in the data. This analysis is undertaken using a cluster analysis algorithm available in the ArcINFO GRID module (*isocluster*), and a signature file generated from the temporal stack of the smoothed SST images variables for each survey day. The results of the clustering analysis process were fed into a maximum likelihood classification algorithm (available in ArcINFO GRID called *mlclassify*). The algorithm used by the MLCLASSIFY function is based on two principles:

- The cells in each class sample in the multidimensional space are normally distributed.
- Bayes's theorem of decision making.

The maximum-likelihood classifier considers both the variances and covariances of the class signatures when assigning each cell to one of the classes represented in the signature file. With the assumption that the distribution of a class sample is normal, a class can be characterized by the mean vector and the covariance matrix. Given these two characteristics for each cell value, the statistical probability is computed for each class to determine the membership of the cells to the class. When the default EQUAL option is specified, each cell is assigned to the class to which it has the highest probability of being a member.

When a maximum-likelihood classification is performed, an optional {o\_reject\_grid} can also be produced. This grid shows the levels of classification confidence. The number of levels of confidence is 14, which is directly related to the number of valid Reject Fractions values. The first level of confidence, coded in the {o\_reject\_grid} as 1, consists of cells with the shortest distance to any mean vector stored in the <signature>. Therefore, the classification of these cells has highest certainty. The cells comprising the second level of confidence (cell value 2 on the {o\_reject\_grid}) would be classified only if the {reject\_fraction} is .99 or smaller. The lowest level of confidence has value of 14 on the {o\_reject\_grid} showing the cells which would most likely be misclassified. Cells of this level will not be classified when the {reject\_fraction} is 0.005 or greater. This procedure is analogous to an unsupervised classification undertaken in remote sensing.

The process developed as part of this study produces three key outputs:

- A classified surface (where the number of classes created can be set by the operator);
- A confidence surface that is a representation of the confidence or reliability of the classification for each cell in the classification surface; and
- A summary textfile with a covariance matrix for the stack of processed images, the correlation matrix for the stack, a dendrogram of the classification, a summary of the signature file used in the classification, and finally a frequency of the classification and confidence grids.

As part of this study, the process was developed for:

- A single variable through time (which draws on the individual survey day information); and
- Two or three survey period variables

Table 6 identifies the types of combinations that were possible using the analysis framework developed for the project, where:

1. Signature file is created from a sampling interval defined (20 cells), and a target classification interval (10). This file contains the covariance values for the stack of grids being analysed.

2. A dendrogram is provided in the summary information to assist in interpreting the relationships between the auto-defined classes.
3. Surface = surface a unsupervised isocluster classification of the stack of grids being analysed.
4. Confidence = a confidence surface illustrating the relative confidence in the classification for each cell location.
5. TTT = three SST inputs (temptemp) used to derived the classification surface.
6. TTD = two SST and one DEM inputs (temptempdem) used to derived the classification surface.
7. TDD = one SST and two DEM inputs (tempdemdem) used to derived the classification surface.
8. TT = two SST (temptemp) used to derived the classification surface.
9. TD = one SST and one DEM inputs (tempdem) used to derived the classification surface.
10. DD = two DEM inputs (demdem) used to derived the classification surface.

ID	OUTPUT	TECHNIQUE	VARIABLES	DESCRIPTION
<b>Survey</b>				
<b>T</b> Absolute Relative	Surface Signature File Dendrogram Confidence	Sample signature Isocluster Max likelihood	Absolute and relative temperature	A classified surface – temporal/spatial classification of one temperature surface for each survey day using an isoclustering technique.
<b>Period</b>				
<b>TT</b>	Surface Signature File Dendrogram Confidence	Sample signature Isocluster Max likelihood	Temperature	A classified surface – temporal/spatial classification of two temperature surfaces using an isoclustering technique.
<b>TTT</b>	Surface Signature File Dendrogram Confidence	Sample signature Isocluster Max likelihood	Temperature	A classified surface – temporal/spatial classification of three temperature surfaces using an isoclustering technique.
<b>TTD</b>	Surface Signature File Dendrogram Confidence	Sample signature Isocluster Max likelihood	Temperature Terrain	A classified surface – temporal/spatial classification of two temperature and one terrain surface using an isoclustering technique.
<b>TDD</b>	Surface Signature File Dendrogram Confidence	Sample signature Isocluster Max likelihood	Temperature Terrain	A classified surface – temporal/spatial classification of one temperature and two terrain surfaces using an isoclustering technique.
<b>TD</b>	Surface Signature File Dendrogram Confidence	Sample signature Isocluster Max likelihood	Temperature Terrain	A classified surface – temporal/spatial classification of one temperature and one terrain surface using an isoclustering technique.
<b>DD</b>	Surface Signature File Dendrogram Confidence	Sample signature Isocluster Max likelihood	Terrain	A classified surface – temporal/spatial classification of two terrain surfaces using an isoclustering technique.

Table 6. Spatial Analysis of Data: Maximum Likelihood Classification – Cluster Analysis

*Logistic Regression Analysis*

The second method of spatial analysis used to investigate data trends involved implementation of a logistic regression to create a predictive surface for krill based on SST variables aggregated over the course of the survey program. Due to the small number of

sightings on any one day there was insufficient data to use the results for any one day. A process was established to undertake a regression based on one, two or three survey variables, where the inputs used were any of the aggregated variables identified in Table 5, in addition to terrain variables.

The logistic regression involved the following steps:

1. Creation of a sample using the flight line and krill data to produce a presence and absence signature file. An assumption was made that locations along the flight line where no krill sightings were recorded were no sighting points. While this is not an optimal approach (ie. it would have been better to have observations that identified no sighting), this process was necessary to obtain a null case for the purposes of the regression analysis.
2. Implementation of the regression analysis. Once the signature file was created it was passed into the regression function available in ArcINFO GRID (using the *logistic* option). This produced three outputs:
  - The RMS value for the regression;
  - The chi-squared value for the regression (goodness of fit measure); and
  - The coefficients for the regression function.
3. Creating a predictive surface. The coefficients were then utilised with the input surfaces to produce a prediction surface with values ranging from 0 to 1 where 1 represented 100% likelihood of finding in this case, Krill using the prediction formula:

$$Z = 1 / ( 1 + \text{EXP} ( - \sum a_i x_i ) )$$

where:

- Z = krill prediction at each cell.
  - A = regression coefficient for input variable I
  - X = value of input variable I at each cell.
4. Creating a reclassified surface. As another analytical tool this predictive surface was reclassified into 10 equal interval classes and summary statistics for the se classes produced.

The regression cell size and sampling signature cell size used in the logistic regression approach analysis was 1,000m.

Table 7 identifies the types of combinations that are possible using the analysis framework that has been developed for the project, where:

1. RMS = root mean square error value.
2. Chi-square = goodness of fit statistic.
3. Signature file = using krill sampling points (all) (= presence) and locations along the flight line where no krill were sites (= absence) to create a signature file for analysis.
4. Surface = surface extrapolated from the signature file that defines (0 – 1) of the probability of the presence of krill.
5. TTT = three SST inputs (tempttemp) used to derived the probability surface.
6. TTD = two SST and one DEM inputs (temptempdem) used to derived the probability surface.
7. TDD = one SST and two DEM inputs (tempdemdem) used to derived the probability surface.
8. TT = two SST (temptemp) used to derived the probability surface.
9. TD = one SST and one DEM inputs (tempdem) used to derived the probability surface.
10. DD = two DEM inputs (demdem) used to derived the probability surface.

ID	OUTPUT	TECHNIQUE	VARIABLES	DESCRIPTION
<b>T</b>	Rms/chi-square Surface Signature File	Sample signature Regression	Temperature	Logistic regression – temporal/spatial classification of one accumulative SST surface
<b>TT</b>	Rms/chi-square Surface Signature File	Sample signature Regression	Temperature	Logistic regression – temporal/spatial classification of two accumulative SST surfaces
<b>TTT</b>	Rms/chi-square Surface Signature File	Sample signature Regression	Temperature	Logistic regression – temporal/spatial classification of three accumulative SST surfaces
<b>TTD</b>	Rms/chi-square Surface Signature File	Sample signature Regression	Temperature Terrain	Logistic regression – temporal/spatial classification of two accumulative SST surfaces and one DEM surface
<b>TDD</b>	Rms/chi-square Surface Signature File	Sample signature Regression	Temperature Terrain	Logistic regression – temporal/spatial classification of one accumulative SST surface and two DEM surface
<b>DDD</b>	Rms/chi-square Surface Signature File	Sample signature Regression	Terrain	Logistic regression – temporal/spatial classification of three DEM surfaces
<b>TD</b>	Rms/chi-square Surface Signature File	Sample signature Regression	Temperature Terrain	Logistic regression – temporal/spatial classification of one accumulative SST surface and one DEM surface
<b>DD</b>	Rms/chi-square Surface Signature File	Sample signature Regression	Terrain	Logistic regression – temporal/spatial classification of two DEM surfaces

Table 7. Spatial Analysis of Data: Logistic Regression Analysis

### Analysis

#### *Sightability of blue whales and krill*

The sightability of blue whales and krill aggregations was estimated from data collected during double-count surveys, in which the same two observers seated on one side of the aircraft simultaneously scanned the survey area. The two observers that participated in double-count surveys alternated their positions between the front and rear seats. Sightability, estimated as the average proportion of entities present in the surveyed area that were seen by each observer, was calculated from the proportion of blue whales and krill aggregations that fell into each of three categories:

- $S_1$  Entities seen by observer 1, but missed by observer 2
- $S_2$  Entities missed by observer 1, but seen by observer 2
- $B$  Entities seen by both observers

When either observer sighted blue whales or krill aggregations, they would wait until the other observer had sufficient opportunity to make the sighting (typically four or five seconds), then confirm whether or not the entity had been sighted. The Petersen Estimate (Seber 1973), described in detail with respect to aerial survey by Caughley and Grice (1982) was used to estimate the abundance of blue whale and krill sightings ( $N_w$  and  $N_k$  respectively), and the probability that the two observers will see a blue whale or krill aggregation ( $P_{x1}$  and  $P_{x2}$  respectively where  $x$  corresponds to either blue whales ( $w$ ) or krill ( $k$ )):

$$N_x = (B_x + S_{x1})(B_x + S_{x2}) / B_x$$

$$P_{x1} = B_x / (B_x + S_{x2})$$

$$P_{x2} = B_x / (B_x + S_{x1})$$

$P_{x1}$  and  $P_{x2}$  for each double-count survey were used to test for between-observer differences in the probability of sighting blue whales and krill. Visibility bias associated with sightings of blue whales and krill ( $V_x$ ), was considered the inverse of sighting fractions averaged across the front and rear observers:

$$1 - [(P_{x1} + P_{x2}) / 2]$$

Within the constraints of conditions encountered during double-count surveys, between-survey variation in  $V_x$  was used to investigate the effect cloud cover and sea state on the sightability of blue whales and krill.

#### *The effect of distance on the blue whale detectability*

The detectability of animals during surveys such as those undertaken in this study generally declines as their distance from observers increases. This decline means that a decreasing proportion of animals that are available to be sighted by observers are actually seen as their distance from those observers increases. Unless the effect that distance has on detectability is accounted for, estimates of density that are based on the number of animals sighted will represent underestimates of the actual number of animals present. In the current survey, blue whales at or near the surface probably became more difficult to see as their distance from survey transects increased. This means that the number of whales sighted may have been a substantial underestimate of the number of whales available to be seen. To investigate the effect that distance from survey transects had on the detectability of blue whales, the perpendicular distance of each blue whale sighting from the survey transect was estimated from the logged sighting location and the projected flight line of the aircraft. A distance-based detection model (the hazard function) was then fitted to these data using the program DISTANCE (v 3.5) (Research Unit for Wildlife Population Assessment, University of St. Andrews, Scotland 1998-99). DISTANCE normally fits a number of models to the frequency distribution of perpendicular distances between the location of sighting entities and the line of travel during a survey, in order to identify the model that best predicts the effects of distance on detectability. However, because the limited amount of data available in this study would render statistical comparison between detection models largely meaningless, only the hazard rate function was fitted.

Because krill aggregations were not generally seen at distances greater than 500 m from survey transects, perpendicular distance from the survey line was not estimated. Krill density was estimated within a fixed width transect truncated at a distance of 500 m either side of the aircraft. Krill sightings were corrected for the effect of cloud cover on sightability (see below) and a density estimated for each survey from the combined length of the linked transects (10 transects for research surveys, nine transects for combined research and compliance surveys) using the ratio method (Caughley and Grigg 1981). The ratio method is simply the corrected number of krill aggregations, divided by the total area sampled (transect length x 1 km).

#### *The relationship between sea surface temperature and the incidence of krill*

The relationship between sea surface temperatures and the incidence of krill was assessed by statistically comparing the temperature characteristics of a 500 m-wide swathe either side of the survey flight line (351.9 or 408.9 km), with equivalent characteristics for point locations of krill. The actual data used to derive temperature characteristics for the flight line and point locations of krill were aggregated within time and space (see Table 5). Summaries of these analyses for each survey day are included in Appendix B. In this report, we provide an example of a specific survey analysis (survey 11 on the 11 May), and an analysis of data aggregated over the entire survey period. To ensure that any seasonal changes in sea surface temperature do not introduce bias into the analysis of aggregated data, we contrasted the relative rather than absolute temperatures for both the flight line, and for the aggregated point locations of krill. Distributions of average relative temperatures for the survey flight line and for point locations of krill aggregations were compared using the Wald-Wolfowitz runs

test. This test contrasts the length of adjacent runs in the sorted temperature data in order to identify whether the two data sets are drawn from two populations that differ in some respect. In addition to contrasting the mean values for the two data sets, this test evaluates differences in the general shape of the distributions being compared (Siegel 1956). The two data sets were also contrasted using two more conventional non-parametric tests, the Mann-Whitney U-test and the Kolmogorov-Smirnov test.

## RESULTS

### *Sightability of whales and krill*

A total of seven double-count surveys were undertaken over the course of the research program. Table 8 summarises the data from these surveys for the sightability of blue whales and krill aggregations. Unfortunately, only two blue whales were sighted during the double-count surveys, and both were sighted by both observers. While this suggests that there is no visibility bias associated with sightings of blue whales, both whales sighted during the double-count surveys were within 500 m of the survey transect. The analysis of distance-based sightings of blue whales (see below) strongly suggests that sightability decreases at greater distances from the aircraft. As such, the lack of apparent visibility bias indicated by double-count surveys should be treated with caution.

Survey	Blue whales					
	$S_1$	$S_2$	$B$	$P_1$	$P_2$	$V$
7	0	0	0	-	-	-
8	0	0	0	-	-	-
10	0	0	1	1	1	0
11	0	0	1	1	1	0
12	0	0	0	-	-	-
14	0	0	0	-	-	-
15	0	0	0	-	-	-
	Krill aggregations					
	$S_1$	$S_2$	$B$	$P_1$	$P_2$	$V$
7	2	4	10	0.71	0.83	0.23
8	4	4	24	0.86	0.86	0.14
10	0	2	32	0.94	1.00	0.03
11	4	7	32	0.82	0.89	0.15
12	1	3	5	0.63	0.83	0.27
14	1	3	9	0.75	0.90	0.18
15	2	3	18	0.86	0.90	0.12

Table 8. Number of blue whales and krill aggregations sighted by two observers ( $S$ ), associated probabilities of each observer sighting whales or krill ( $P$ ), and average visibility bias ( $V$ ) estimated for seven double-count surveys.

In contrast to observations of blue whales, sightings of krill aggregations during double-count surveys were numerous, with between 9 and 43 aggregations sighted in each survey. The apparent tendency for observer 2 to see a higher proportion of krill aggregations ( $P_2 = 0.89$ ) than observer 1 ( $P_1 = 0.80$ ) was statistically significant ( $t$ -value = 3.45,  $df = 6$ ,  $P$ -value = 0.014). Regression of average visibility bias on the octals of cloud prevailing at the time of each double-count survey (Fig. 2) indicates that the sightability of krill aggregations declined with cloud cover ( $F$ -value = 87.14,  $df = 1, 5$ ,  $P$ -value < 0.001). The intercept of the fitted line of best fit was not statistically significant (intercept = -0.014,  $t$ -value = 0.684,  $P$ -value = 0.525), suggesting that visibility bias associated with counts of krill aggregations may be negligible under the survey conditions of little or no cloud. Only a limited range of sea state conditions were encountered during double-count surveys (5 surveys undertaken when sea state was calm, two surveys undertaken when sea state was moderate), limiting our capacity to evaluate the effect sea state had on the sightability of krill aggregations. Nevertheless, there

was no apparent difference in average visibility bias estimated for surveys undertaken when sea state was calm (average  $V = 0.163$ ) and moderate (average  $V = 0.148$ ,  $t$ -value = 0.298,  $df = 5$ ,  $P$ -value = 0.777).

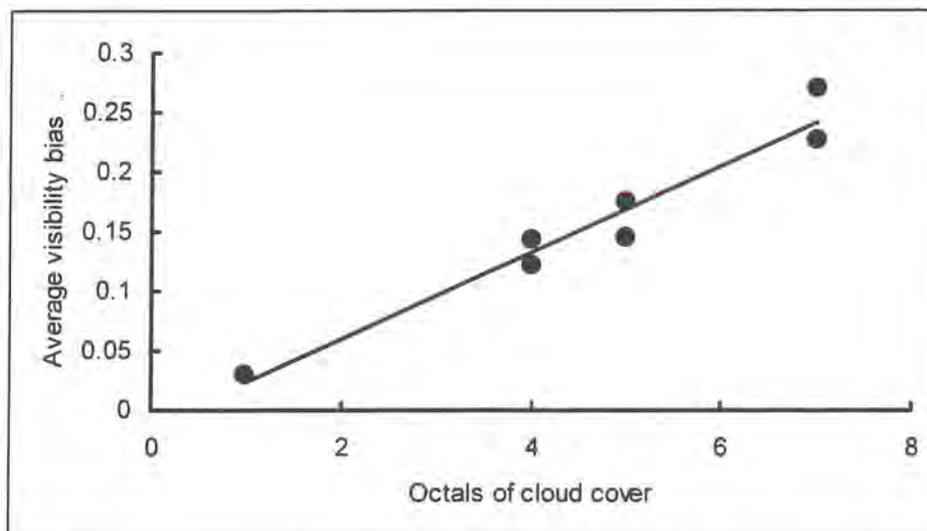


Fig. 2 The relationship between octals of cloud cover prevailing during seven aerial surveys and the level of visibility bias associated krill aggregations sighted during the surveys. Visibility bias was estimated from independent counts made by two observers. The fitted line is the least squares line of best fit described by  $Y = -0.014 + (X 0.037)$ .

### **Variation in blue whale and krill sightings**

#### *Blue whales*

In all, 12 blue whales were sighted over the course of the survey program (Map 1). Six of the whales were sighted as individuals, and six were sighted as three groups of two. The rate at which blue whales were sighted declined over the course of the survey program (Fig. 3), with eight sightings over the first third of the program (17 days), an additional four sightings during the middle third of the program, and just one additional sighting over the final third of the program. The decline in blue whale sightings as the survey program progressed coincides with the movement of blue whales out of coastal waters to west of the study area late in autumn, as described by Gill (2001).

Map 1. Distribution of blue whales sighted over the course of the survey program, relative to the survey flight line.



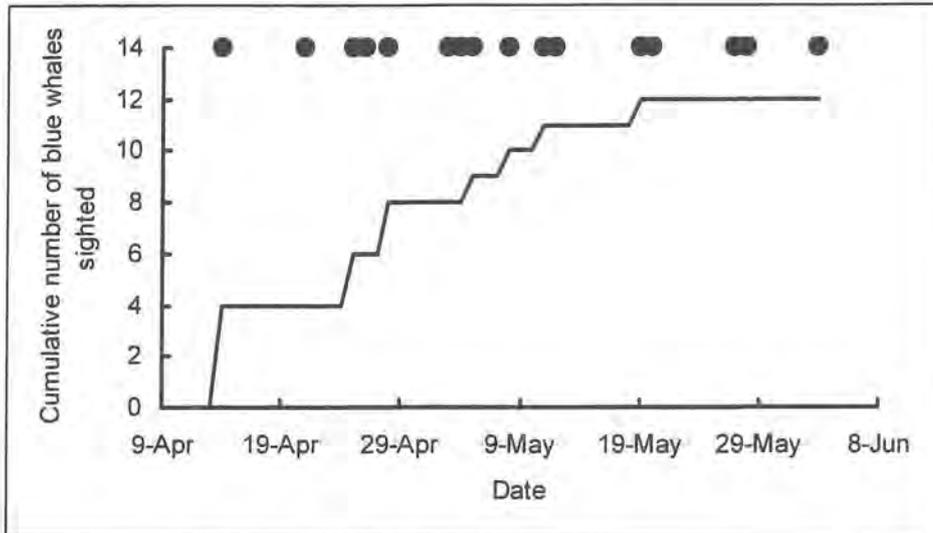


Fig. 3. Cumulative increase in blue whale sightings over the course of the survey program. The dots at the top of the figure indicate where surveys took place.

In order to fit the hazard rate function to the frequency distribution of distances for aggregated blue whale observations, distances were combined into four classes (0 to 500 m, 500 to 1,000 m, 1,000 to 1,500 m, and > 1,500 m). The hazard rate function provided a reasonable fit to the aggregated distance data given the low sample size involved (Chi-square  $P$ -value = 0.231, Akaike Information Criteria = 25.52). The resultant detection probability function (Fig. 4) indicates that the detectability of blue whales at or near the surface approached 1 (all whales sighted) within 250 m of the aircraft, and declined steadily beyond this point. The fitted function suggests that fewer than 10% of whales available for sighting at distances beyond about 2,000 m will be seen by observers. The fact that all or most whales at or near the surface within 250 m of the aircraft were theoretically visible to observers accords with the fact that both sightings during double-count surveys were within 500 m of the aircraft distance, and were seen by both observers.

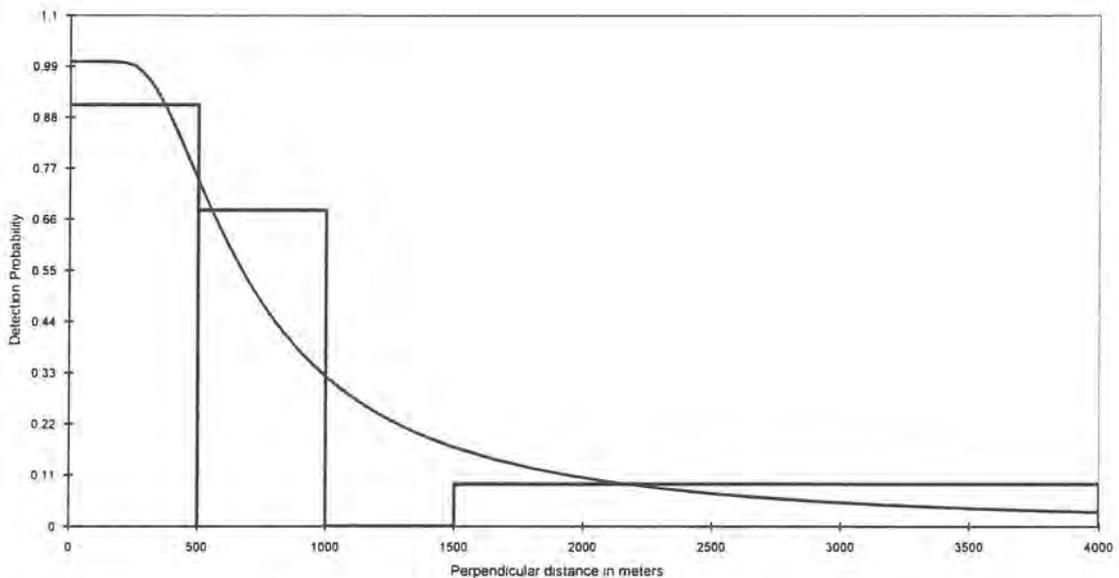


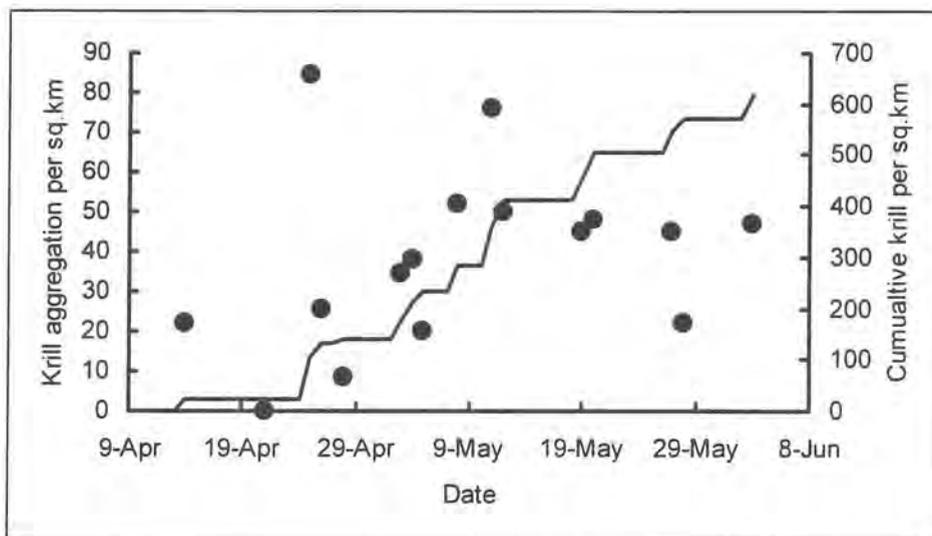
Fig. 4 Detection probability function for blue whales sighted during aerial surveys. The fitted function is a hazard rate estimator with the form  $y = 1 - \exp [ - (x / 595.6)^{-1.817} ]$ . The function was fitted using the program DISTANCE (Research Unit for Wildlife Population Assessment, University of St. Andrews, Scotland 1998-99).

*Krill aggregations*

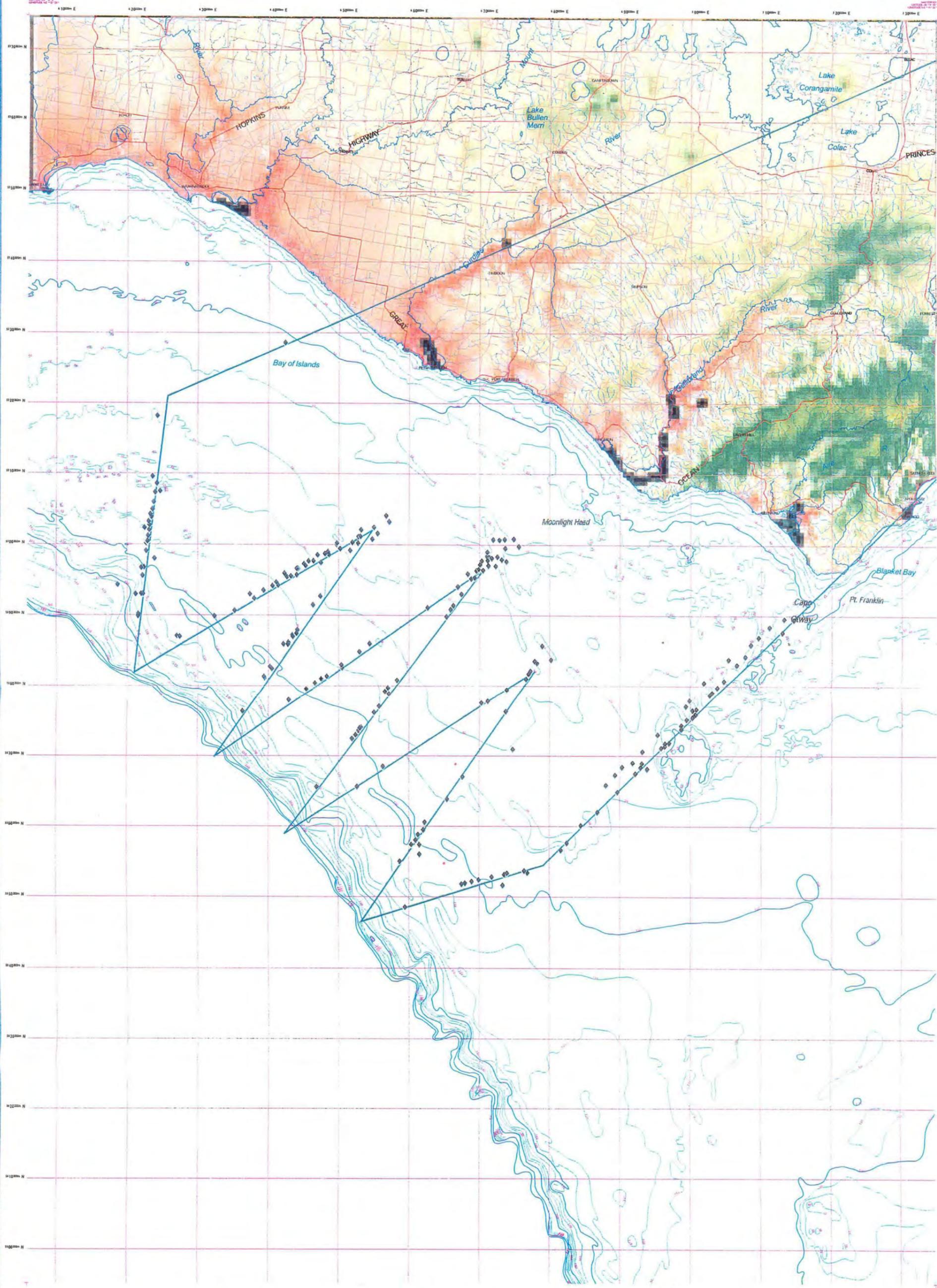
In all, 526 krill aggregations were sighted over the course of the survey program (Map. 2). Table 9 gives the density of krill aggregations estimated from each aerial survey. There was no clear trend in the apparent abundance of krill over time, and, unlike blue whales, no indication that the abundance of krill declined over the duration of the survey program (Fig. 5). However, there was a tendency for krill densities to be reduce as seas state conditions deteriorated (Fig. 6). Unfortunately, because most aerial surveys were conducted when seas were calm (see Table 1), there was insufficient data to formally evaluate the influence sea state had on the density of krill aggregations in the survey area. The apparent affect that sea state conditions had on the density of krill aggregations may reflect the influence that high winds have on the persistence of areas of consistently cold water at or near the ocean surface (see below).

Survey	Date	Transect length (km)	Corrected number of krill aggregations	Density of krill (aggregations/sq.km)
1	14 April	408.9	22.13	0.05
2	21 April	351.9	0	0
4	25 April	351.9	84.50	0.24
5	26 April	351.9	25.52	0.07
6	28 April	351.9	8.42	0.02
7	3 May	408.9	34.33	0.08
8	4 May	408.9	38.05	0.09
9	5 May	408.9	20.20	0.05
10	8 May	408.9	52.20	0.13
11	11 May	408.9	75.84	0.19
12	12 May	408.9	50.17	0.12
13	19 May	408.9	44.97	0.11
14	20 May	408.9	48.16	0.12
15	27 May	408.9	44.97	0.11
16	28 May	408.9	21.91	0.05
17	3 June	408.9	46.79	0.11

Table 9. Estimated density of krill aggregations along the survey flight line for each aerial survey undertaken along the 10 linked transects.



Map 2. Distribution of krill aggregations sighted over the course of the survey program, relative to the survey flight line.



SURVEY RESULTS - KRILL SIGHTINGS



This map illustrates the information collected as part of the Victorian Energy Ltd Blue Whale Research Project - Otway Basin, being undertaken by the Victorian Department of Natural Resources, Environment and Conservation (DNREC) in partnership with Spatial Vision, Melbourne, Victoria, 3000. The project commenced in early April 2001 and will continue until June 2002. The map is for informational purposes only and should not be used for navigation. The map is based on the Victorian Government's Geographical Data Library.

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- Otway Flyer Path
- Contour Line
- Survey
- ▲ Blue Whale
- ◆ Blue Whale
- Blue Whale



MAP ANGLE: GRID NORTH  
 HORIZONTAL DATUM: GDA94 AUSTRALIAN SPHERICAL DATUM  
 VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM  
 PROJECTION: UTM  
 GRID UNIT: METRE

Fig. 5. The density of krill aggregations, corrected for the effects of cloud cover on krill sightability (dots), and the cumulative abundance of krill (line) over the course of the survey program.

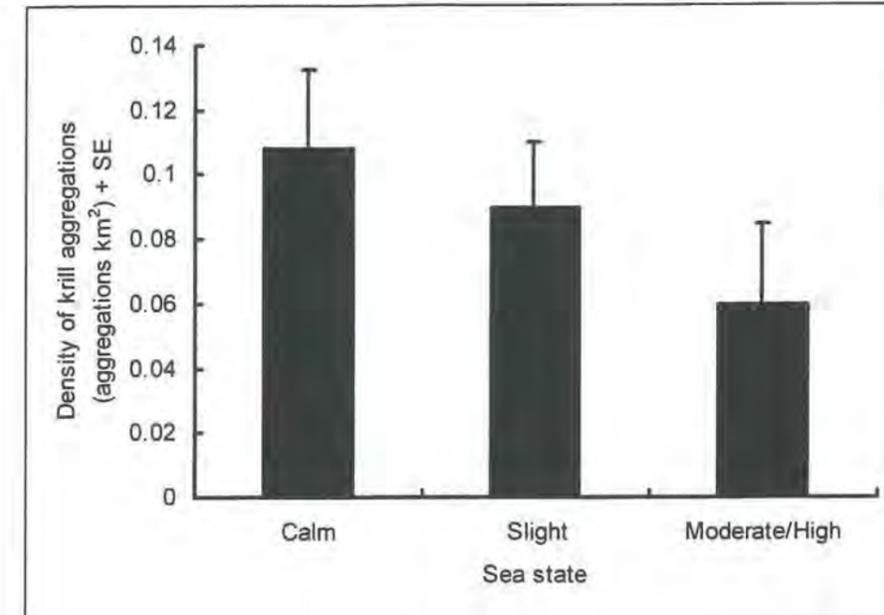


Fig. 6 Average density of krill aggregations (+ SE) in the survey area, under the range of sea state conditions encountered.

### **Spatial analyses**

#### *Cluster Analysis*

Figure 7 shows the results of a cluster analysis classification based on the Absolute Average Temperature SST variable (GSSTAV) for each survey day over the entire survey period. In this example the GSSTAV grids for each day were classified into 10 equal interval classes. The 15 classified grids were then used as inputs in an unsupervised classification based on a clustering algorithm implemented in ArcInfo GRID (ISOCLUSTER) that creates a sample signature file. The unsupervised classification was directed to create 10 classes based on information in the signature file. Ten classes were chosen in this classification because of the very narrow range of raw temperature values in the data. This process uses a maximum likelihood algorithm implemented in ArcInfo GRID that produces two output surfaces. The first of these surfaces is the 10 class classification that represents cells that are displaying a similar profile in that variable (ie. GSSTAV) as indicated in the signature file. The second output from the classification process is a confidence surface that indicates the degree of confidence in the classification at each cell location. The summary text file created with this analysis containing relevant statistical information is provided in Appendix C.

The cluster analysis results identify a slight correlation between the location of Krill and sea surface temperature. However, SST values and particularly their spatial distribution for the survey period, varied significantly. It is possible that an increase in the sampling period, or sampling over several seasons, may reduce the impact of spatial variability in the SST data.

Given the relatively small absolute temperature range (2-3 degrees) and the raw image cell resolution (1 kilometre) it is probable that the cell temperature values have an exaggerated degree of precision. The use of weighted filters (particularly laplacian filters) on the derived survey day sea surface temperature parameters may also assist by improving the identification of areas of significant change in the SST values. A further area of investigation

Fig. 7. Results of a cluster analysis classification based on the Absolute Average Temperature SST variable (GSSTAV) for each survey day over the entire survey period

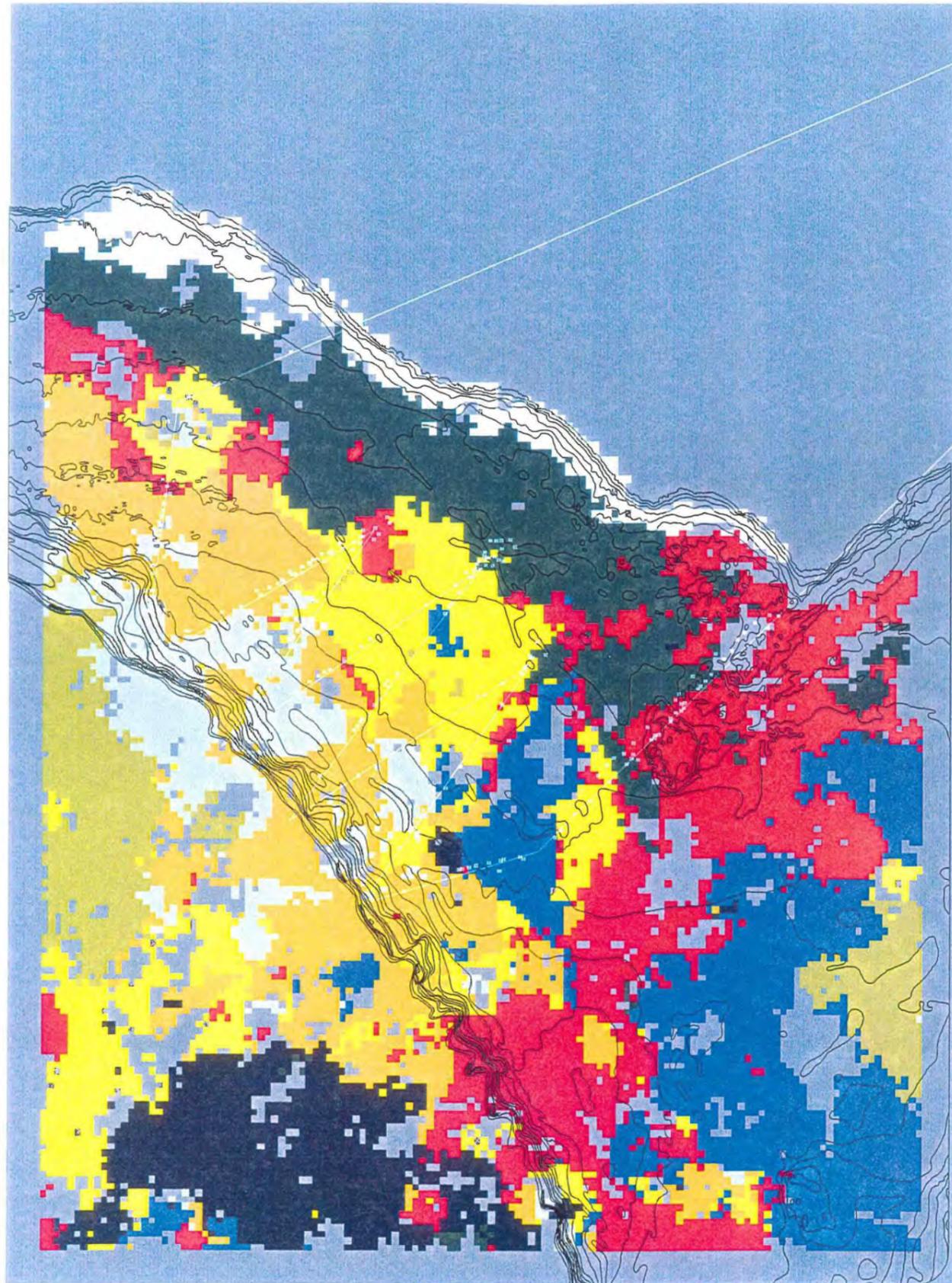


Fig. 7. Results of a cluster analysis classification based on the Absolute Average Temperature SST variable (GSSTAV) for each survey day over the entire survey period

would be to consider increasing the neighborhood size in determining the spatial averages of the derived SST parameters.

#### *Logistic Regression Analysis*

Fig. 8 shows the results of a regression analysis using the Relative Mean Average Temperature SST variable (RATMEAN) for the entire survey period. The results are displayed as the predictive surface created, and the results from classifying this predictive surface into 10 classes. The input variable grid used (RELMEAN) is also shown. This regression has a RMS of 1.531 and a Chi-square value of 120.997.

Figure 9 shows the results of a regression analysis using the Relative Mean Temperature (RLTMEAN) and Relative Minimum Temperature (RLTMIN) for the entire survey period. The results show the predictive surface created, and the results from classifying this predictive surface into 10 classes, and the input variables used (RLTMEAN) and (RLTMIN). This regression has a RMS of 0.451 and a Chi-square value of 120.783.

#### *Stability of Sea Surface Temperatures*

The spatial distribution of sea surface temperatures varies significantly over time. Over the survey period there appears to be times of greater and lesser relative spatial stability in the distribution of SST. The time interval between aerial surveys varied, however there are six periods where the interval between acquired SST data was only one day. The variability in the SST for each pair of days is presented in Figs 10 - 15. Table 10 below summarizes the day pair assessment. The assessment in this table represents a comparison of the accumulated average temperature (GSSTAV) parameter for each day.

DAY PAIR	CORRELATION COEFFICIENT
2504 – 2506	0.689
0305 – 0405	0.829
0405 – 0505	0.957
1105 – 1205	0.723
1905 – 2005	0.919
2705 – 2805	0.639

Table 10: Comparison of the accumulated average temperature (GSSTAV) parameter for each pair of SST images

A brief summary of the methodology used to create the correlation coefficient follows.

The correlation coefficient calculates the cross correlation between two input grids. Spatial autocorrelation is a measure of the similarity of objects within an area. An object can have at least two types of descriptive elements; 1) aspatial attributes (i.e., soil parameters, elevation, slope), and 2) spatial attributes (i.e., the x, y location in a specified coordinate system). From an object-based view of spatial data, spatial autocorrelation measures the relationship between the difference of the aspatial attributes of objects with the distance between the objects.

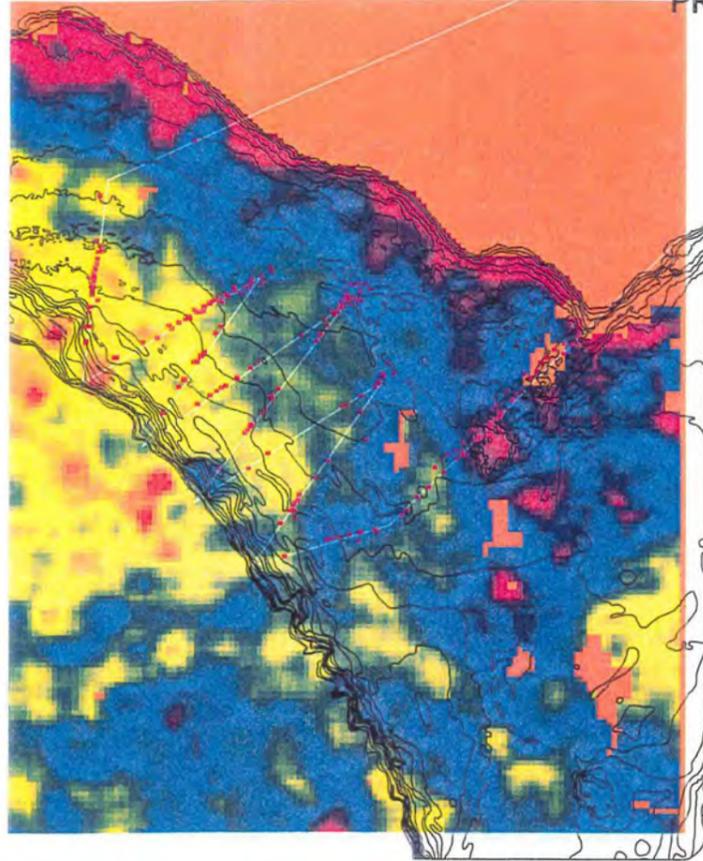
For example, two objects which are close together and that have very similar aspatial descriptors are highly spatially correlated. Two objects close together that have very different aspatial descriptors are not very spatially autocorrelated (the objects are considered spatially independent). However, a negative spatial autocorrelation exists when objects that are close together have very different aspatial attributes than objects that are farther apart (Goodchild, 1986).

The general notation used in correlation formulas and their GRID interpretations are the following:

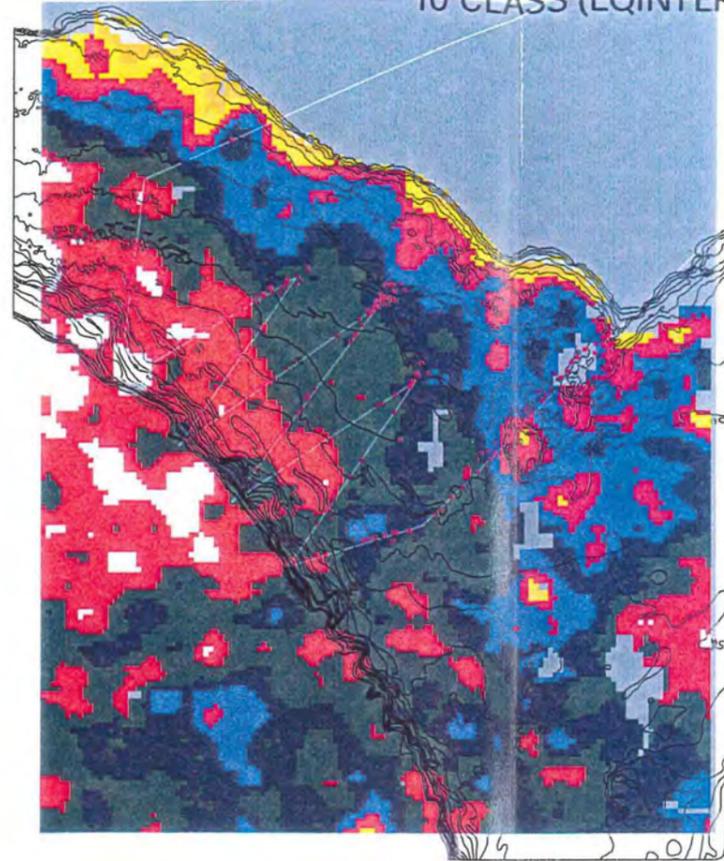
Fig. 8 Results of a regression analysis using the Relative Mean Average Temperature SST variable (RLTMEAN) for the entire survey period, showing the predictive surface created, the results from classifying this predictive surface into 10 classes, and the input variable used (RLTMEAN). The predictive surface has been colored using a rainbow spectrum of 255 colors, where red indicates a low probability and purple a high probability. A linear stretch has been applied to the color ramp. An alternative representation of the prediction surface is also shown. This represents a 10 class equal interval slice of the predictive surface, where white indicates a low probability and gold a high probability.

Regression temperature : RLTMEAN - 01-07-11.13:26:01,Wed

PREDICTION



10 CLASS (EQINTERVAL) PRED



```

PREDICTION GRID: PREDI  N      MAX      MEAN      STD
Record 1          0.175      0.629      0.318      0.06

ZONE GRID: PREDI (10 EQUAL INTERVAL SLICE)
Record  VALUE      COUNT
1         1         560
2         2        3240
3         3        4682
4         4        3546
5         5        2417
6         6        1100
7         7        360
8         8        195
9         9         84
10        10         23

ZONE STATS PREDI  N      MIN      MAX      MEAN      STD
Record  VALUE      VALUE      VALUE      VALUE      VALUE
1         1         0.1754     0.2208     0.2092     0.0097
2         2         0.2208     0.2662     0.2454     0.0125
3         3         0.2662     0.3116     0.2897     0.0128
4         4         0.3116     0.3569     0.3387     0.0130
5         5         0.3569     0.4024     0.3787     0.0128
6         6         0.4024     0.4477     0.4204     0.0127
7         7         0.4477     0.4933     0.4674     0.0132
8         8         0.4933     0.5390     0.5117     0.0125
9         9         0.5390     0.5841     0.5595     0.0124
10        10         0.5841     0.6294     0.5997     0.0114

Regression Information:
### RMS: 1.531 - Chi-Square 120.997

Coefficients:
#### A0: 1.531
#### A1: (rltmean) -3.905

Analysis Information:
#### CELLSIZE LR: 1000 -- CELLSIZE SAMPLE 1000
    
```

GRD: RLTMEAN

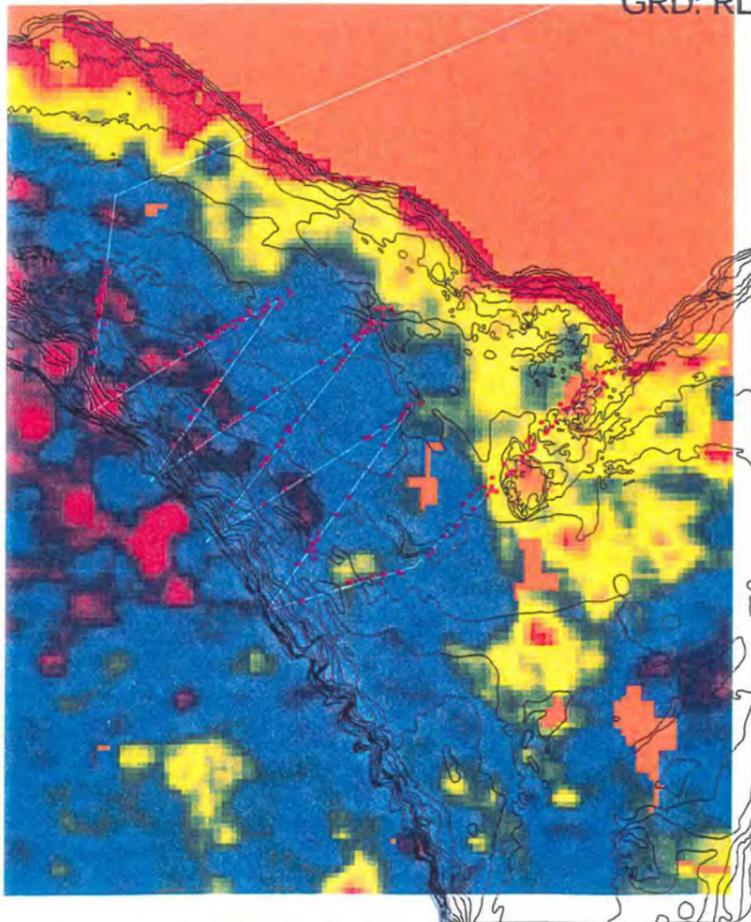
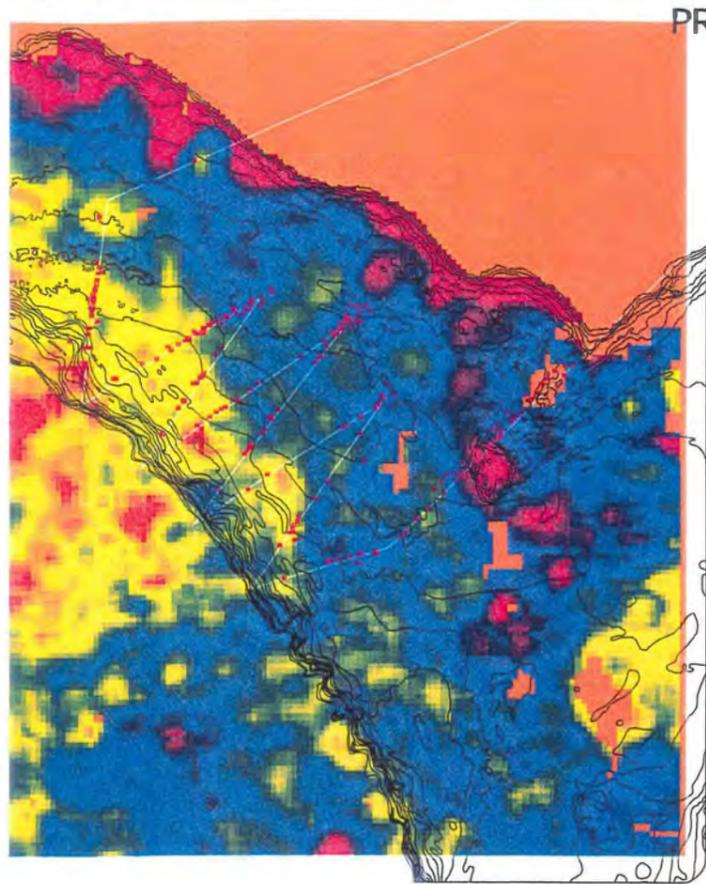


Fig. 8 Results of a regression analysis using the Relative Mean Average Temperature SST variable (RLTMEAN) for the entire survey period, showing the predictive surface created, the results from classifying this predictive surface into 10 classes, and the input variable used (RLTMEAN).

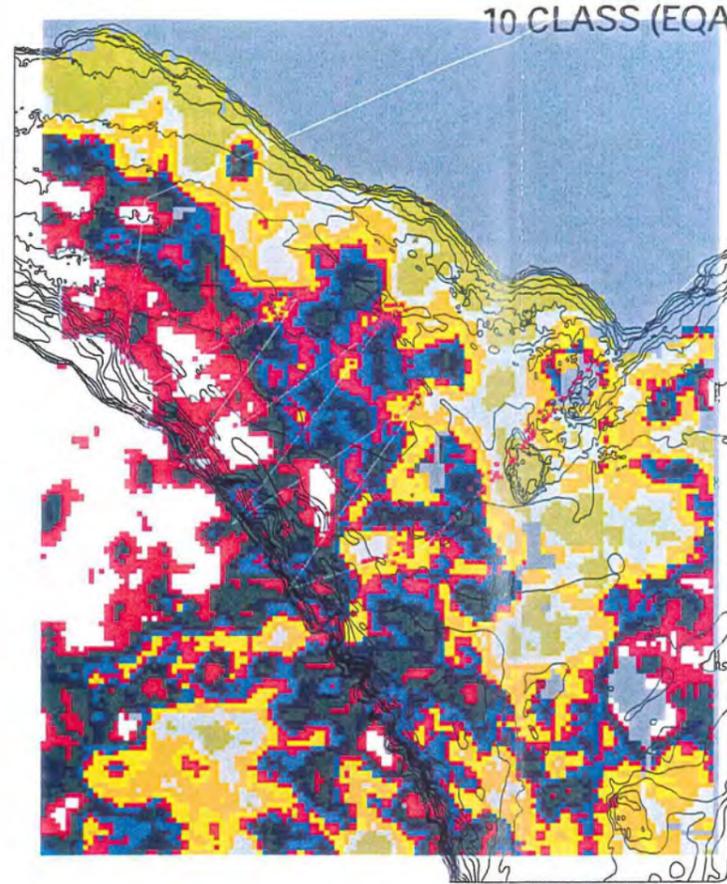
The predictive surface has been colored using a rainbow spectrum of 255 colors, where red indicates a low probability and purple a high probability. A linear stretch has been applied to the color ramp.

An alternative representation of the prediction surface is also shown. This represents a 10 class equal interval slice of the predictive surface, where white indicates a low probability and gold a high probability.

Fig. 9 Results of a regression analysis using the Relative Mean Temperature (RLTMEAN) and Relative Minimum Temperature (RLTMIN) for the entire survey period: showing the predictive surface created, and the results from classifying this predictive surface into 10 classes, and the input variables used (RLTMEAN) and (RLTMIN). The predictive surface has been colored using a rainbow spectrum of 255 colors, where red indicates a low probability and purple a high probability. A linear stretch has been applied to the color ramp. An alternative representation of the prediction surface is also shown. This represents a 10 class equal interval slice of the predictive surface, where white indicates a low probability and gold a high probability.



PREDICTION



10 CLASS (EQAREA) PRED

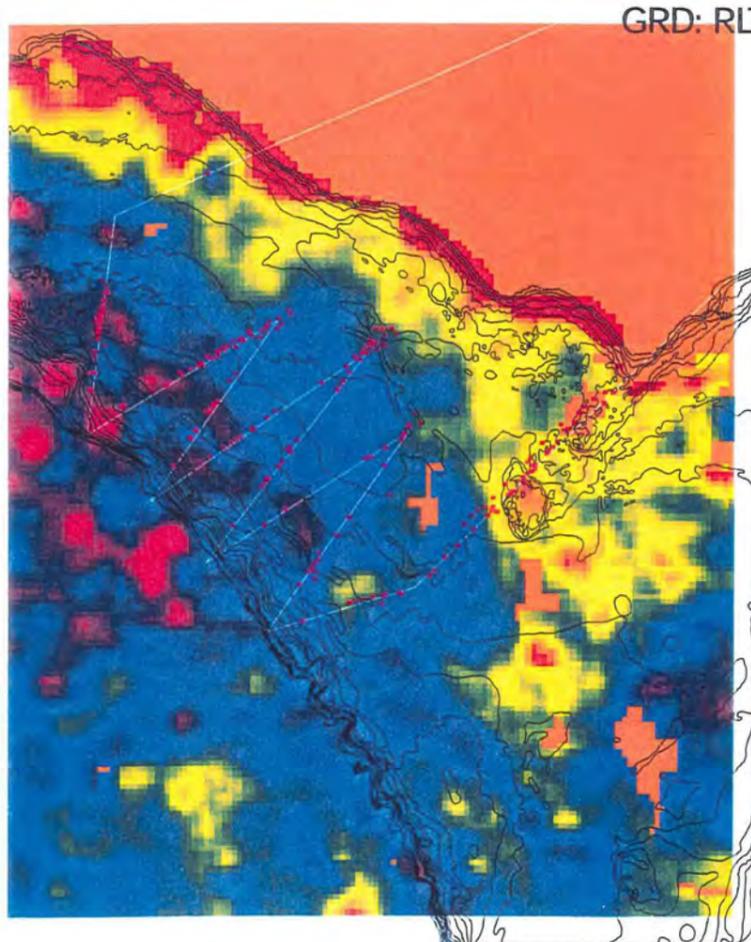
PREDICTION GRID: PRED2		MIN	MAX	MEAN	STD
Record	1	0.131	0.704	0.314	0.07
ZONE GRID: PRED2S		MIN	MAX	MEAN	STD
Record	1	0.131	0.704	0.314	0.07
ZONE STATS PRED2S		MIN	MAX	MEAN	STD
Record	1	0.1314	0.2230	0.1993	0.0178
	2	0.2231	0.2521	0.2379	0.0086
	3	0.2521	0.2745	0.2638	0.0065
	4	0.2745	0.2946	0.2850	0.0057
	5	0.2946	0.3102	0.3026	0.0045
	6	0.3103	0.3259	0.3177	0.0045
	7	0.3259	0.3460	0.3354	0.0058
	8	0.3460	0.3728	0.3596	0.0076
	9	0.3729	0.4107	0.3897	0.0109
	10	0.4109	0.7038	0.4669	0.0530

Regression Information:  
 RMS: 0.451 - Chi-Square 120.783  
 Coefficients:  
 A0: 2.196 -- A1: (rltmean) - 5.931 -- A2: (rltmin) 1.504  
 Analysis Information:  
 CELLSIZE LR: 1000 -- CELLSIZE SAMPLE 1000

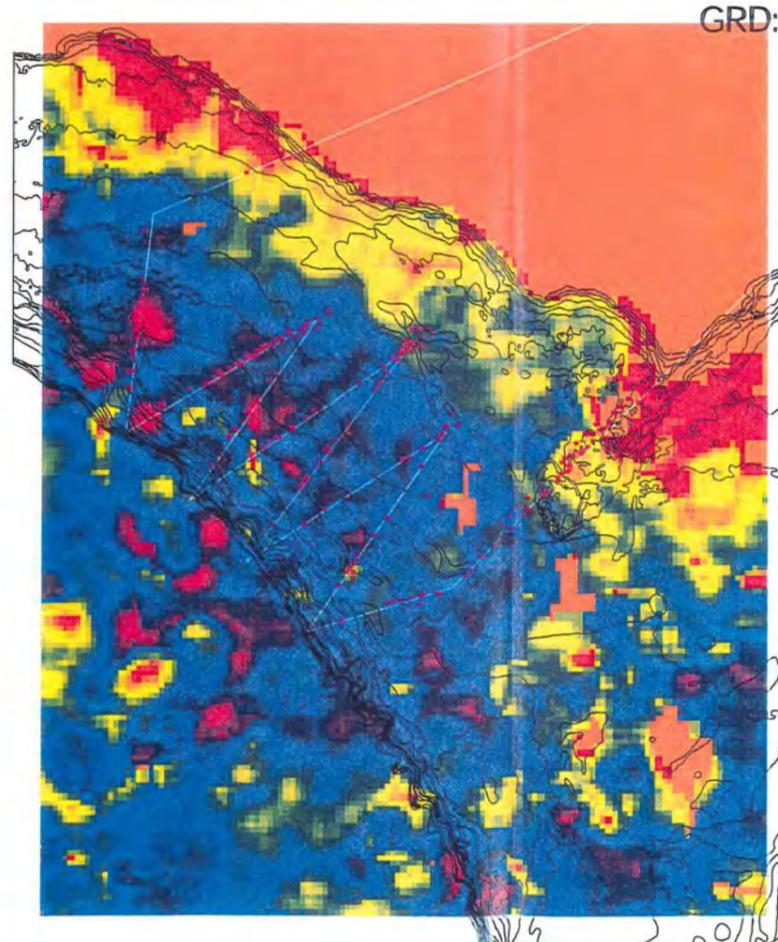
Fig. 9 Results of a regression analysis using the Relative Mean Temperature (RLTMEAN) and Relative Minimum Temperature (RLTMIN) for the entire survey period: showing the predictive surface created, and the results from classifying this predictive surface into 10 classes, and the input variables used (RLTMEAN) and (RLTMIN).

The predictive surface has been colored using a rainbow spectrum of 255 colors, where red indicates a low probability and purple a high probability. A linear stretch has been applied to the color ramp.

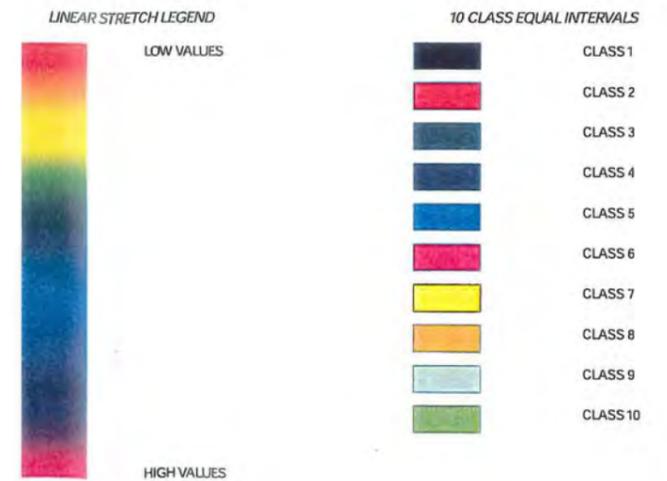
An alternative representation of the prediction surface is also shown. This represents a 10 class equal interval slice of the predictive surface, where white indicates a low probability and gold a high probability.



GRD: RLTMEAN



GRD: RLTMIN



n - the total number of cells in a grid: NROWS \* NCOLS  
 i - any cell on the first input grid  
 j - any cell on the second input grid that is offset from i's location by the specified x-, y-offset

zi – the value of the attribute of cell i  
 zj – the value of the attribute of cell j  
 $Z_i$  – the mean value of the attribute of the first grid  
 $Z_j$  – the mean value of the attribute of the second grid  
 $C_{ij}$  – the similarity of i's and j's attributes:  $(z_i - Z_i) * (z_j - Z_j)$

In terms of the above, spatial autocorrelation is simply a measure of the attributes similarities in the set  $c_{ij}$  with the locational similarities, and then summing the result into a single coefficient (Goodchild, 1986)

The correlation index formula is

$$C = \sum ( c_{ij} / ( \text{sqrt}( \sum (z_i - Z_i)^2 ) * \text{sqrt}( \sum (z_j - Z_j)^2 ) )$$

In the context of the ArcInfo GRID analysis undertaken in this project, the objects correspond to cells and the aspatial descriptors or attributes correspond to cell values.

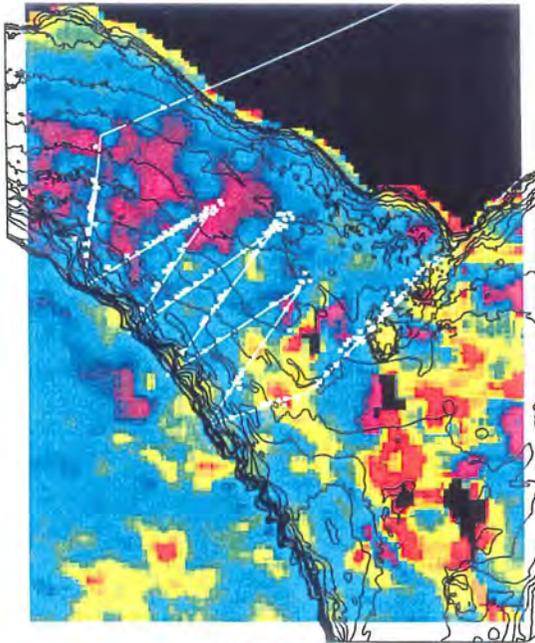
While the number of occasions on which surveys were flown on consecutive days limits our capacity to relate overall stability in sea surface temperatures to prevailing conditions, there was a tendency for the degree of correlation in the spatial distribution of sea surface temperature to decline as sea state conditions deteriorated (Fig. 16). This pattern coincides with the apparent decline in the density of krill aggregations with deteriorating sea surface conditions suggested in Fig. 6, suggesting that loss of stability in sea surface temperature may reduce the tendency of krill to form aggregations.

Since five SST images were used to provide the SST values for any given survey date, a fair degree of smoothing has occurred with the data used in the analysis of SST variation between paired dates.

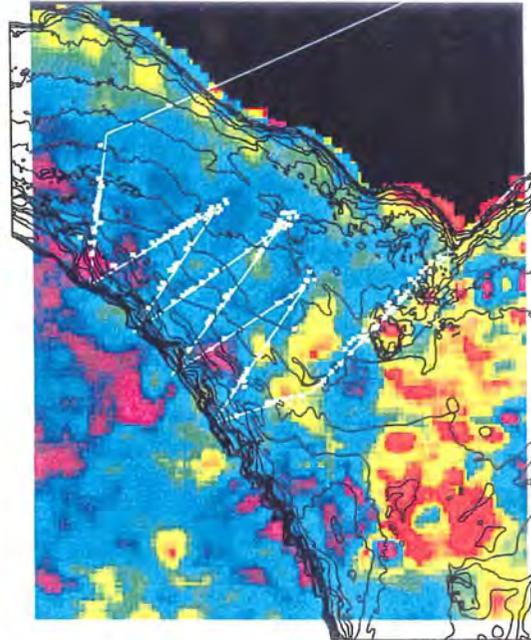
Figs 10-15 summarise the degree of correlation in sea surface temperature for six occasions over the survey period, where aerial surveys were conducted on consecutive days. Each Figure corresponds to a given pair of consecutive days, and provides surface temperature distributions for each day, along with scatterplots of cell temperatures on consecutive days for a swathe 500 m either side of the survey line. Correlation coefficients for surface temperatures along the survey line on consecutive days varied from 0.64 to 0.96, suggesting that the stability of sea surface temperatures within the survey area was higher at some times over the survey program than it was at other times

Figs 10-15 Summaries of the degree of correlation in sea surface temperature for six occasions over the survey period, where aerial surveys were conducted on consecutive days.

Day Pairs: 2504 - 2604



S2504 - gsstav



S2604 - gsstav

Figure 10

Average Sea Surface Temperature Day Pair 5

*A spatial autocorrelation analysis*

This plot is a DAY PAIR comparison of a Sea Surface Temperature parameter derived from the raw remotely sensed data.

The two map graphics represent the particular day pair variable being compared. A linear stretch has been applied in order to shade the dataset.

The scatter plot represents a cell by cell comparison of the two days (10 cell sample interval).

The histograms show the distribution of the sea surface temperature parameter.

The correlation coefficient is an estimate of the cross correlation of the sea surface parameter between the two days. This spatial autocorrelation index is a measure of the similarity of objects within an area. In this context the objects correspond to cells and the cell values are the spatial attributes being assessed for similarity.

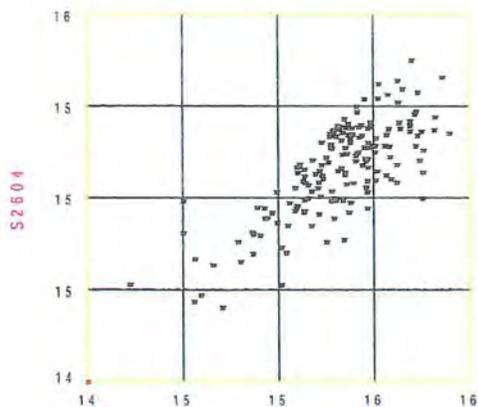
The correlation coefficient value has values ranging from -1 to 1:

- > -1 ===== Strong negative correlation
- > 0 ===== Independent
- > 1 ===== Highly cross correlated

Correlation Coefficient (r): CORRELATION 0.6894295379075

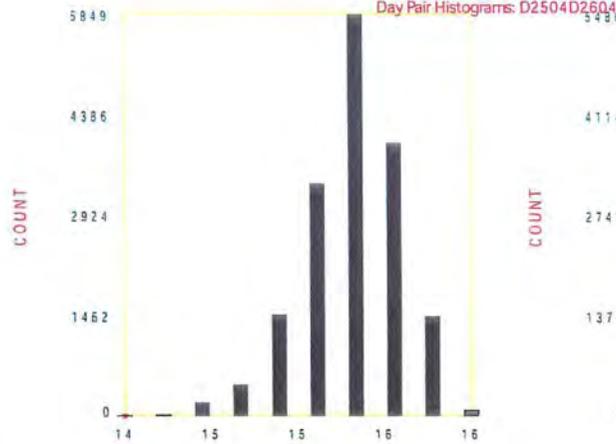
Created: 01-08-29.11:38:16.Wed

Day Pair Scatterplot: D2504D2604



S2504

Day Pair Histograms: D2504D2604



S2504

S2604

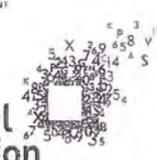
LINEAR STRETCH LEGEND



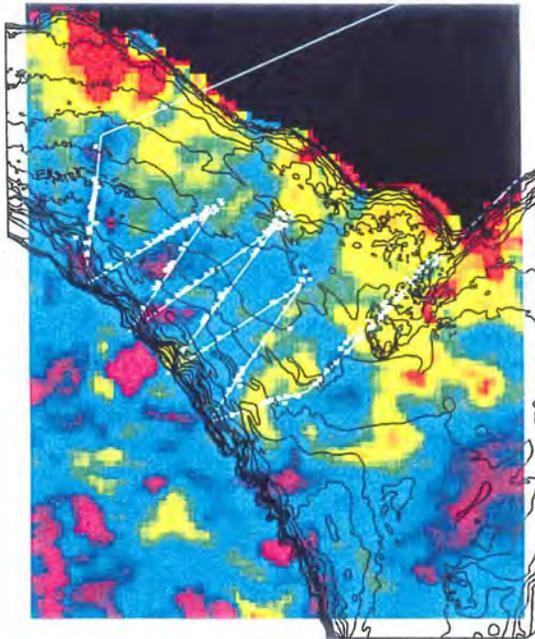
Natural Resources and Environment

AGRICULTURE  
RESOURCES  
CONSERVATION  
LAND MANAGEMENT

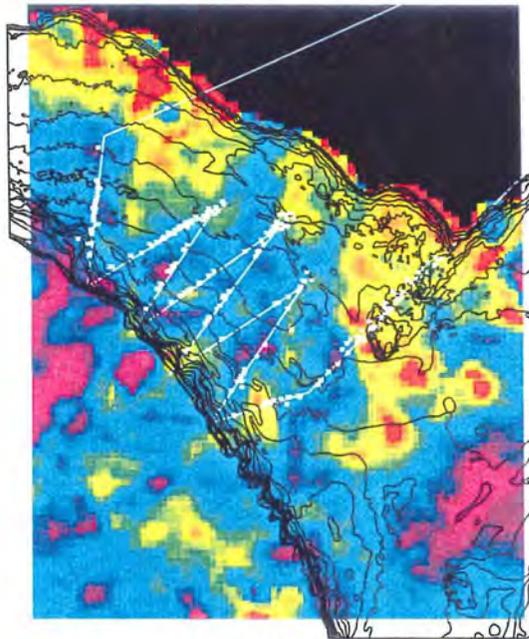
Spatial  
Vision



Day Pairs: 0305 - 0405



S0305 - gsstav



S0405 - gsstav

Figure 11

Average Sea Surface Temperature Day Pair 5

A spatial autocorrelation analysis

This plot is a DAY PAIR comparison of a Sea Surface Temperature parameter derived from the raw remotely sensed data.

The two map graphics represent the particular day pair variable being compared. A linear stretch has been applied in order to shade the dataset.

The scatter plot represents a cell by cell comparison of the two days (10 cell sample interval).

The histograms show the distribution of the sea surface temperature parameter.

The correlation coefficient is an estimate of the cross correlation of the sea surface parameter between the two days. This spatial autocorrelation index is a measure of the similarity of objects within an area. In this context the objects correspond to cells and the cell values are the aspatial attributes being assessed for similarity.

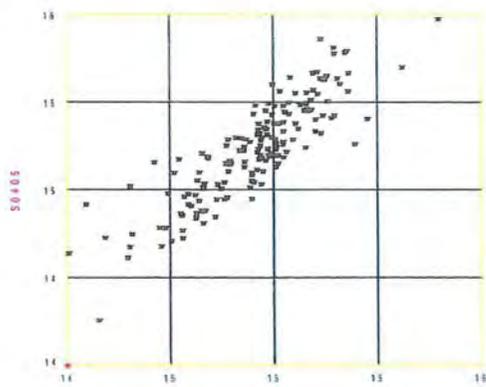
The correlation coefficient value has values ranging from -1 to 1:

- > -1 ===== Strong negative correlation
- > 0 ===== Independent
- > 1 ===== Highly cross correlated

Correlation Coefficient (r): CORRELATION 0.8291784710853

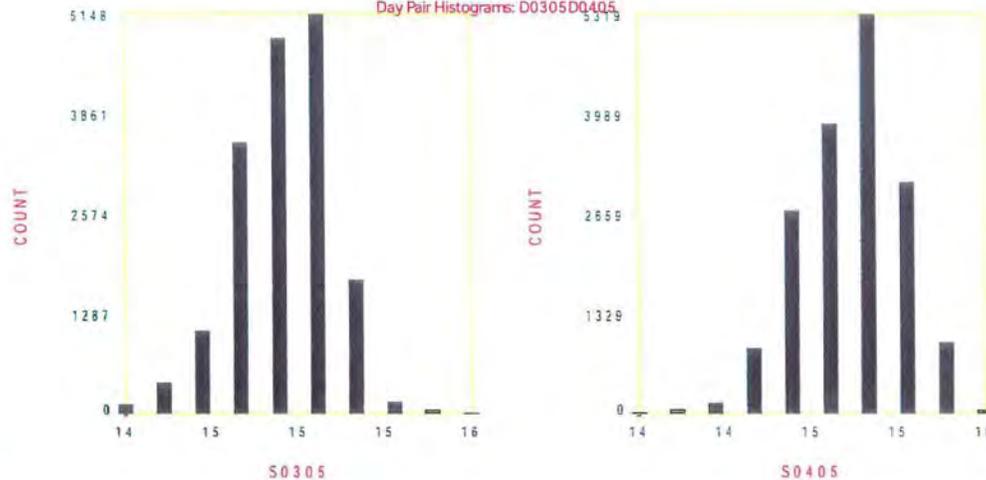
Created: 01-08-29.11:38:42.Wed

Day Pair Scatterplot: D0305D0405



S0305

Day Pair Histograms: D0305D0405



S0305

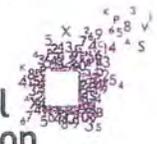
S0405



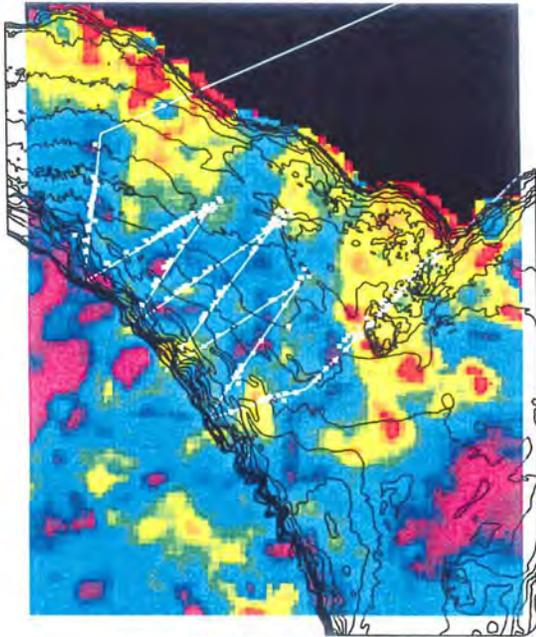
Natural Resources and Environment

AGRICULTURE  
RESOURCES  
CONSERVATION  
LAND MANAGEMENT

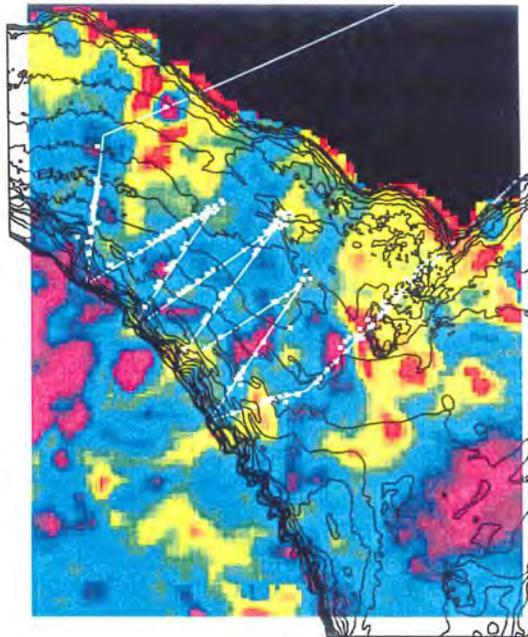
Spatial Vision



Day Pairs: 0405 - 0505



S0405 - gsstav



S0505 - gsstav

**Figure 12**  
Average Sea Surface Temperature Day Pair 5  
*A spatial autocorrelation analysis*

This plot is a DAY PAIR comparison of a Sea Surface Temperature parameter derived from the raw remotely sensed data.

The two map graphics represent the particular day pair variable being compared. A linear stretch has been applied in order to shade the dataset.

The scatter plot represents a cell by cell comparison of the two days (10 cell sample interval).

The histograms show the distribution of the sea surface temperature parameter.

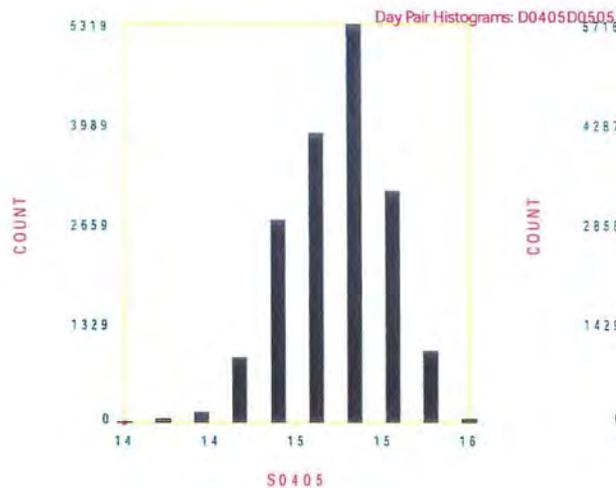
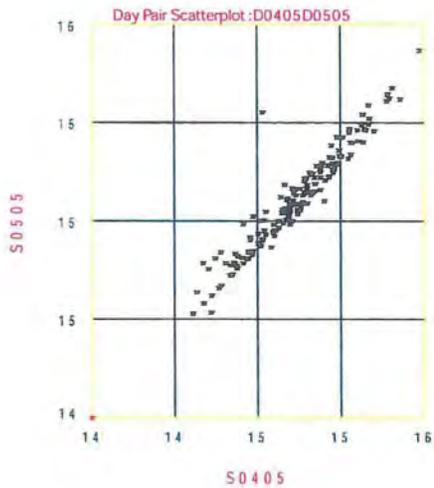
The correlation coefficient is an estimate of the cross correlation of the sea surface parameter between the two days. This spatial autocorrelation index is a measure of the similarity of objects within an area. In this context the objects correspond to cells and the cell values are the aspatial attributes being assessed for similarity.

The correlation coefficient value has values ranging from -1 to 1:

- > -1 ===== Strong negative correlation
- > 0 ===== Independent
- > 1 ===== Highly cross correlated

Correlation Coefficient (r): CORRELATION 0.9567456836597

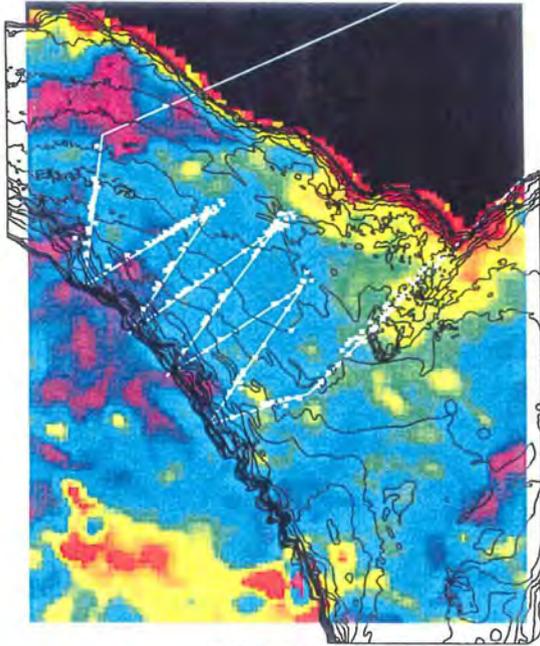
Created: 01-08-29.11:39:07.Wed



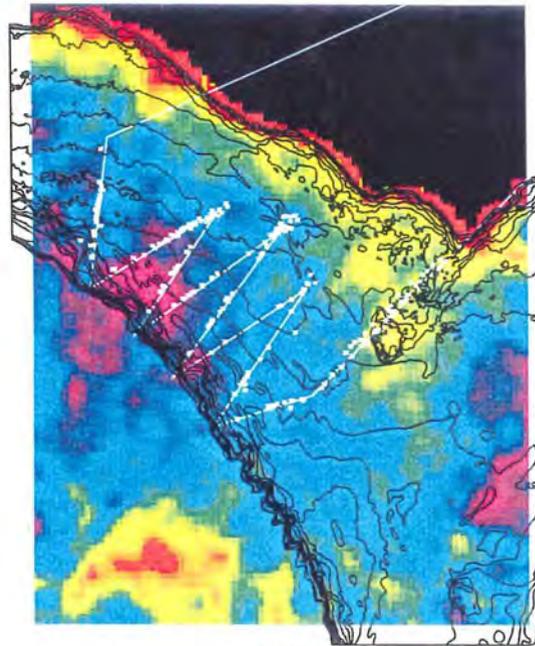
Natural Resources  
and Environment  
AGRICULTURE  
RESOURCES  
CONSERVATION  
LAND MANAGEMENT



Day Pairs: 1105 - 1205



S1105 - gsstav



S1205 - gsstav

Figure 13

Average Sea Surface Temperature Day Pair 5

A spatial autocorrelation analysis

This plot is a DAY PAIR comparison of a Sea Surface Temperature parameter derived from the raw remotely sensed data.

The two map graphics represent the particular day pair variable being compared. A linear stretch has been applied in order to shade the dataset.

The scatter plot represents a cell by cell comparison of the two days (10 cell sample interval).

The histograms show the distribution of the sea surface temperature parameter.

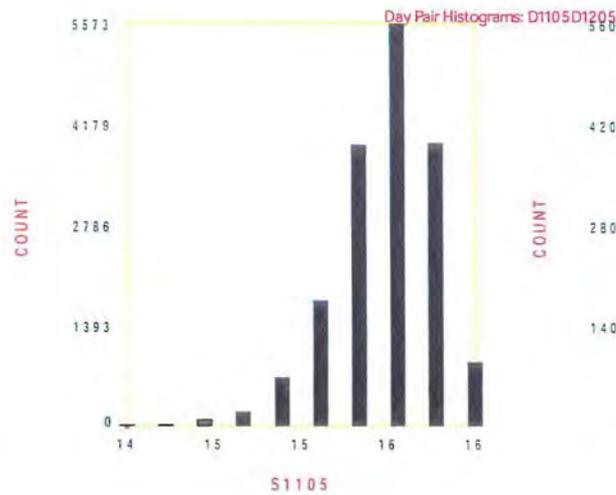
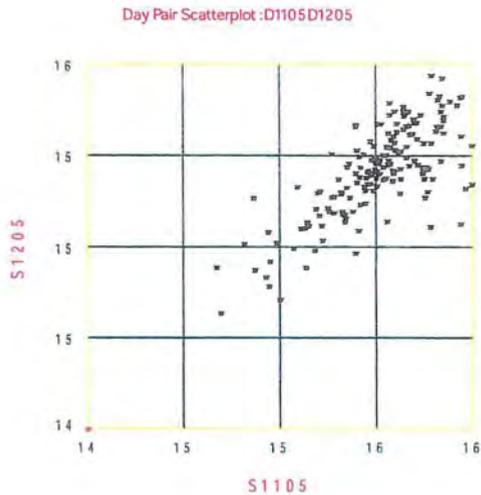
The correlation coefficient is an estimate of the cross correlation of the sea surface parameter between the two days. This spatial autocorrelation index is a measure of the similarity of objects within an area. In this context the objects correspond to cells and the cell values are the spatial attributes being assessed for similarity.

The correlation coefficient value has values ranging from -1 to 1:

- > -1 ===== Strong negative correlation
- > 0 ===== Independent
- > 1 ===== Highly cross correlated

Correlation Coefficient (r): CORRELATION 0.7233659834456

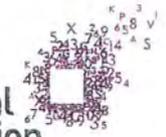
Created: 01-08-29.11:39:33.Wed



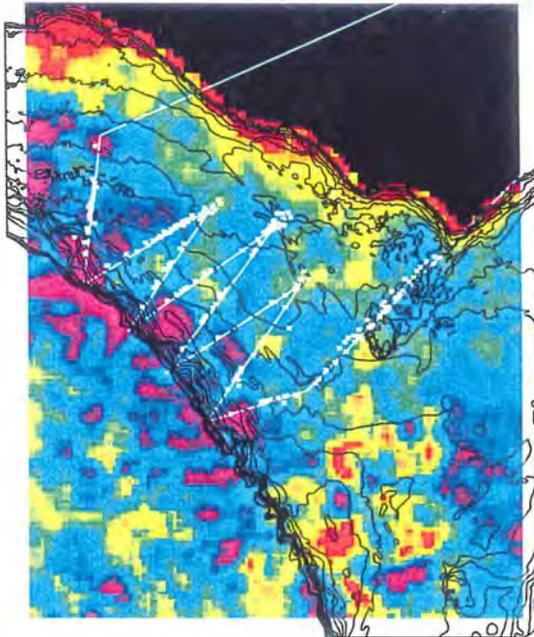
LINEAR STRETCH LEGEND



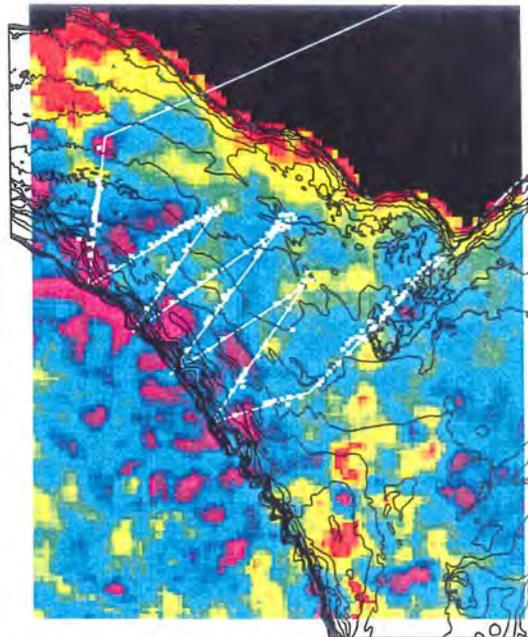
Spatial Vision



Day Pairs: 1905 - 2005



S1905 - gsstav



S2005 - gsstav

Figure 14

Average Sea Surface Temperature Day Pair 5  
A spatial autocorrelation analysis

This plot is a DAY PAIR comparison of a Sea Surface Temperature parameter derived from the raw remotely sensed data.

The two map graphics represent the particular day pair variable being compared. A linear stretch has been applied in order to shade the dataset.

The scatter plot represents a cell by cell comparison of the two days (10 cell sample interval).

The histograms show the distribution of the sea surface temperature parameter.

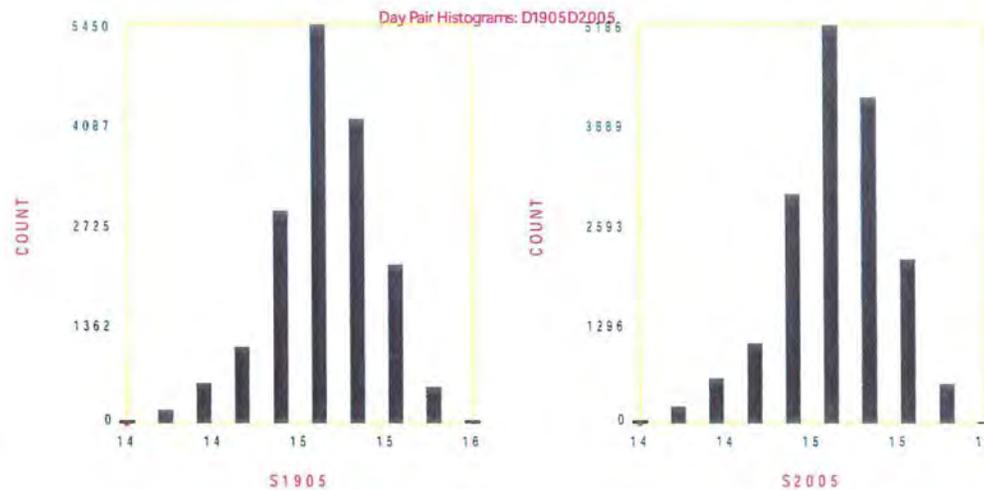
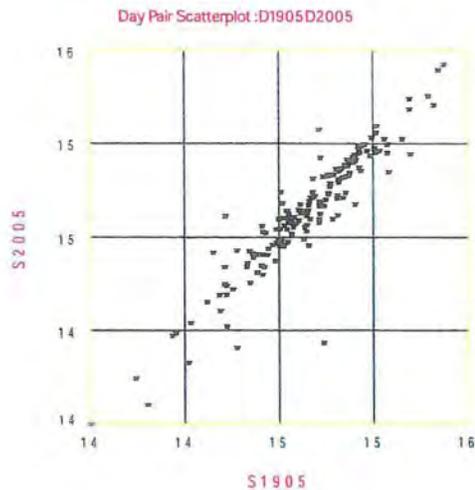
The correlation coefficient is an estimate of the cross correlation of the sea surface parameter between the two days. This spatial autocorrelation index is a measure of the similarity of objects within an area. In this context the objects correspond to cells and the cell values are the spatial attributes being assessed for similarity.

The correlation coefficient value has values ranging from -1 to 1:

- > -1 ===== Strong negative correlation
- > 0 ===== Independent
- > 1 ===== Highly cross correlated

Correlation Coefficient (r): CORRELATION 0.9099518256721

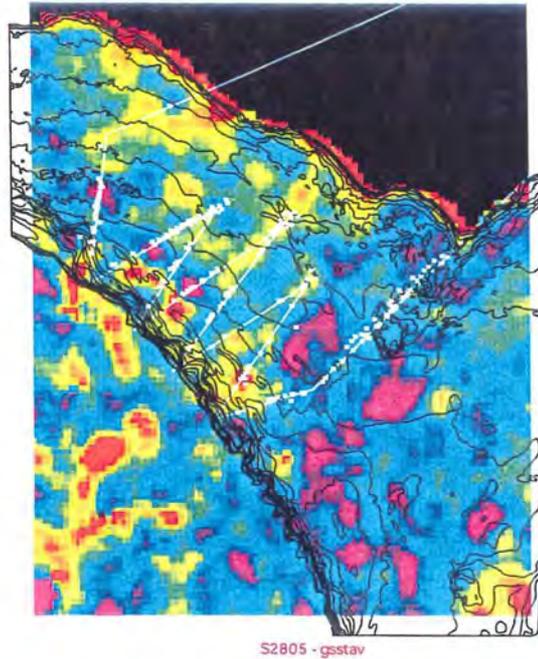
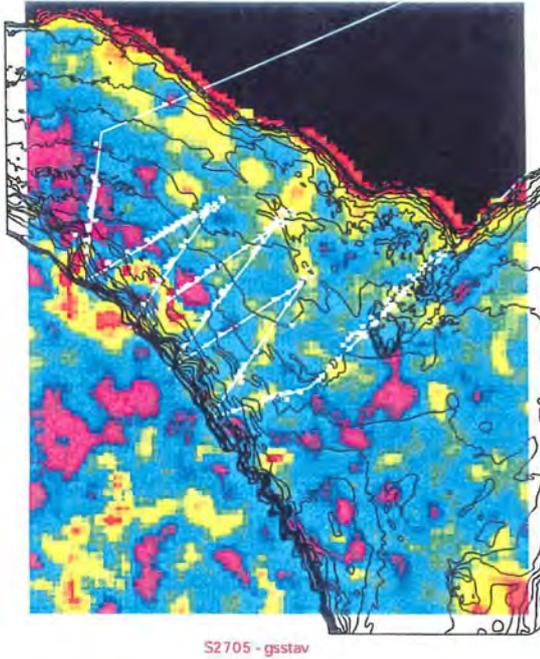
Created: 01-08-29.11:39:58.Wed



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LAND MANAGEMENT



Day Pairs: 2705 - 2805



**Figure 15**  
Average Sea Surface Temperature Day Pair 5  
*A spatial autocorrelation analysis*

This plot is a DAY PAIR comparison of a Sea Surface Temperature parameter derived from the raw remotely sensed data.

The two map graphics represent the particular day pair variable being compared. A linear stretch has been applied in order to shade the dataset.

The scatter plot represents a cell by cell comparison of the two days (10 cell sample interval).

The histograms show the distribution of the sea surface temperature parameter.

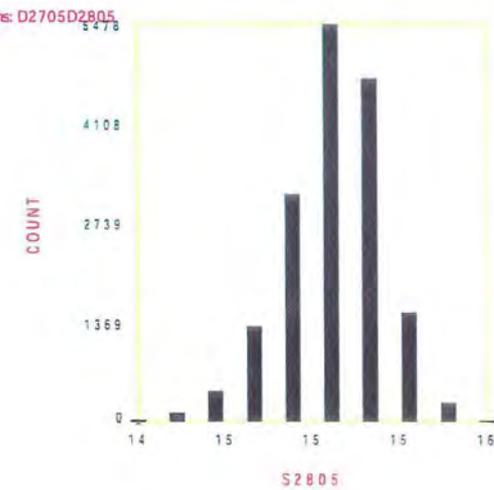
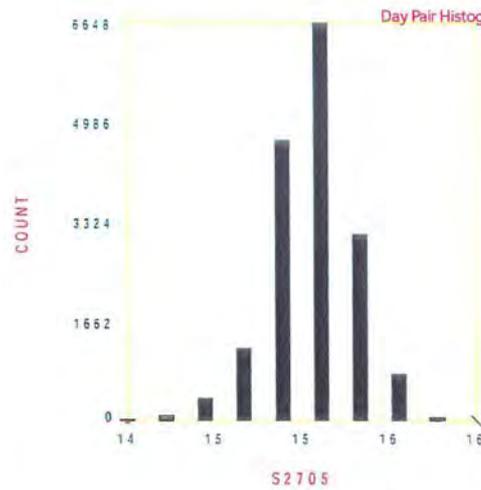
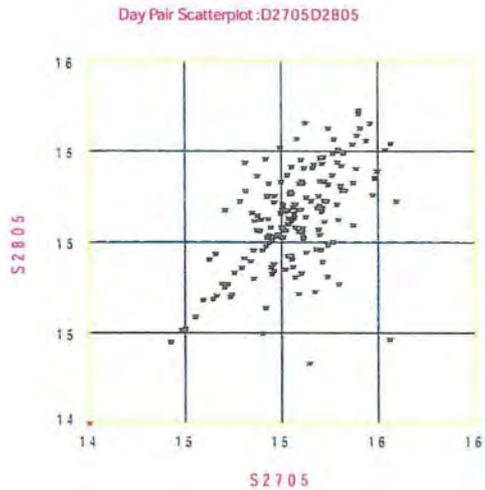
The correlation coefficient is a estimate of the cross correlation of the sea surface parameter between the two days. This spatial autocorrelation index is a measure of the similarity of objects within an area. In this context the objects correspond to cells and the cell values are the aspatial attributes being assessed for similarity.

The correlation coefficient value has values ranging from -1 to 1:

- > -1 ===== Strong negative correlation
- > 0 ===== Independent
- > 1 ===== Highly cross correlated

Correlation Coefficient (r): CORRELATION 0.6389703393051

Created: 01-08-29.11:40:25.Wed



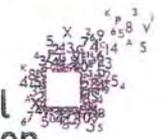
LINEAR STRETCH LEGEND



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EDUCATION  
LAND MANAGEMENT

Spatial  
Vision



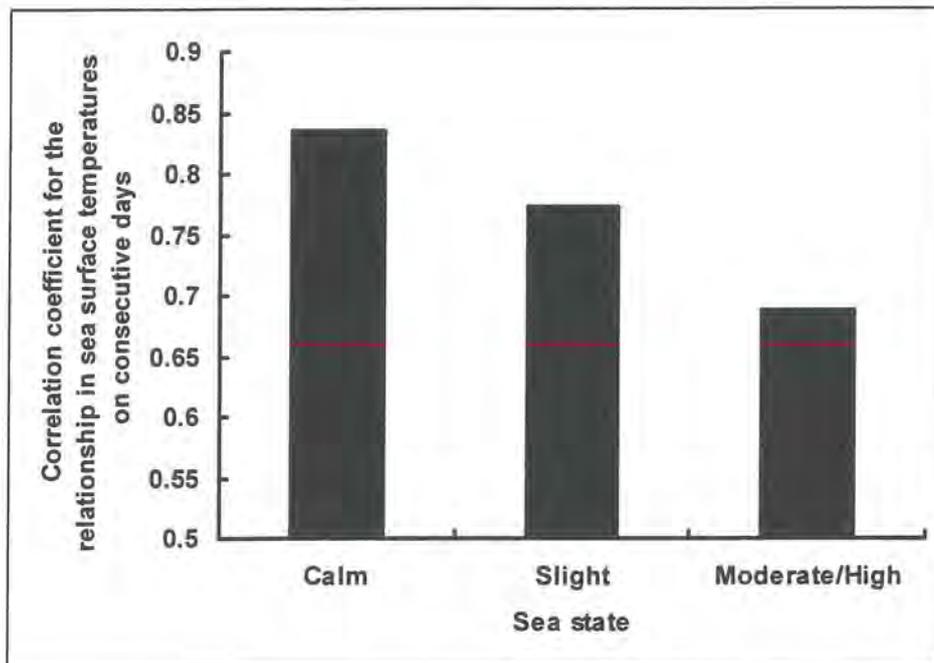


Fig. 16 Average correlation coefficients in the spatial distribution of sea surface temperatures on consecutive days, for different categories of sea state. Sea state was taken as that prevailing on the second day of each pair of surveys.

*Sea surface temperature and the incidence of krill*

Fig. 17 shows medians, quartiles and ranges for the relative average sea surface temperature projected for the survey transect on 11 May, and for the point locations of krill aggregations observed on that day. Median and mean relative average temperature for the survey flight line (0.794 and 0.782 respectively) were higher than those for the point locations of krill aggregations (0.748 and 0.756 respectively). The Wald-Wolfowitz runs test indicated that the two data sets were drawn from distinct populations (Runs = 47, Ties = 8, adjusted Z-value = -9.24, P-value < 0.001), indicating that on average krill were located in areas with lower sea surface temperatures than the range encountered over the course of the aerial survey. This pattern was supported by the more general statistical comparisons between the two data sets, although the inference was not as strong (i.e. Mann-Whitney U-test: U-value = 67186, Z-value = 1.952, P-value = 0.051; Kolmogorov-Smirnov two-sample test: Maximum negative difference = -0.073, Maximum positive difference = 0.264, P-value < 0.10).

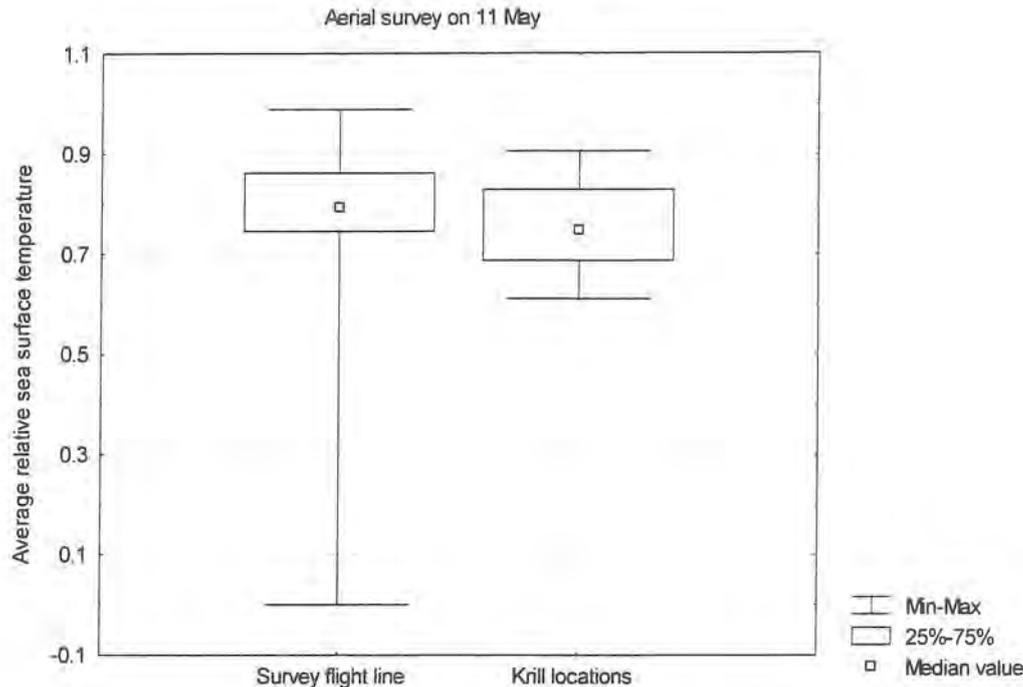
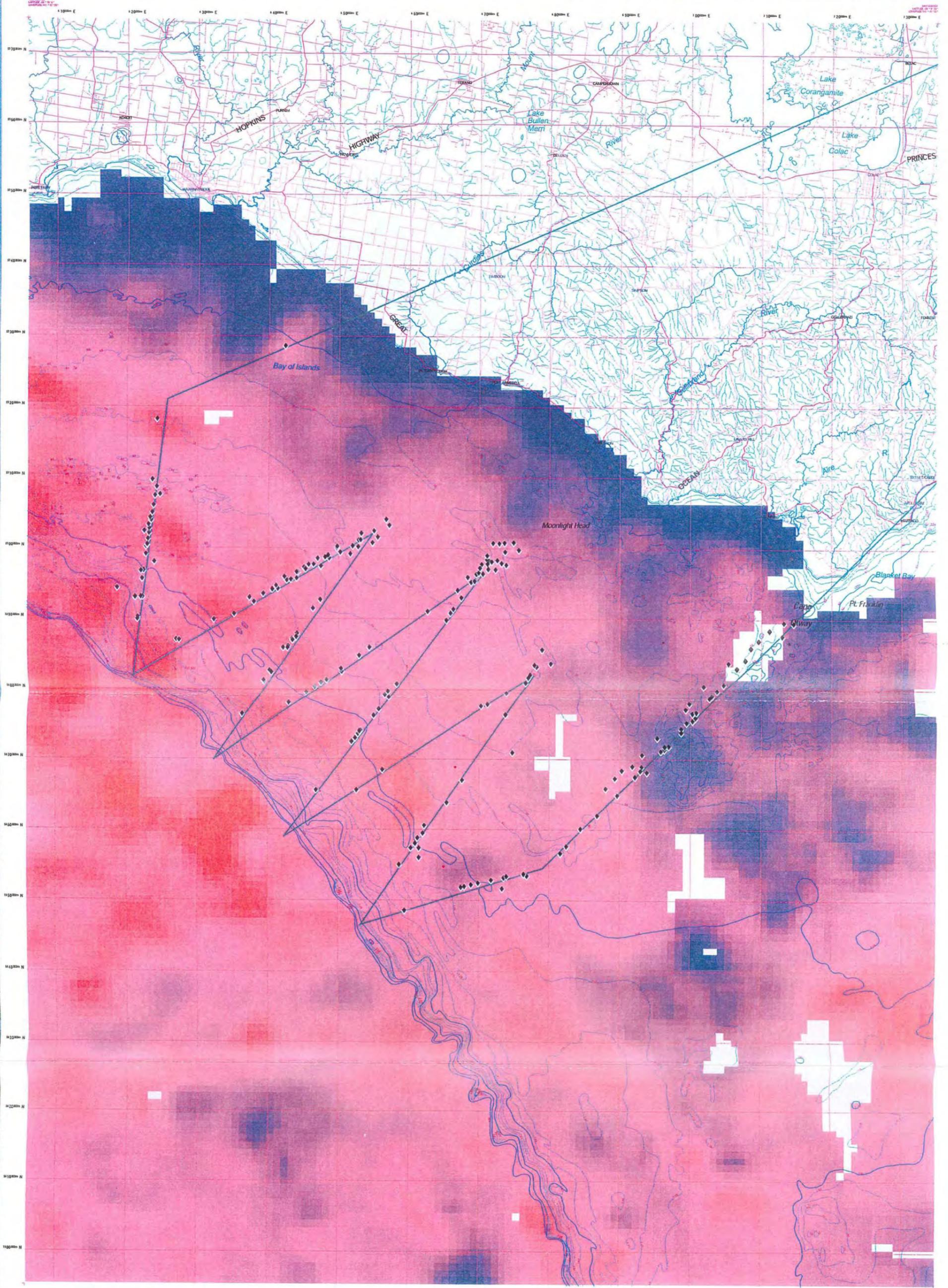


Fig. 17. Distributions of relative average sea surface temperatures along the survey flight line and at the point locations of krill aggregations for the survey conducted on 11 May.

Map 3 shows all krill sightings over the course of the survey program, plotted over relative average sea surface temperature. Fig 18 shows medians, quartiles and ranges for the relative average sea surface temperature averaged across all survey flights, and for all point locations of krill aggregations combined. Median and mean relative average temperature for the combined survey data (0.631 and 0.626 respectively) were higher than those for the point locations of krill aggregations (0.616 and 0.615 respectively). The Wald-Wolfowitz runs test indicated that the two data sets were drawn from distinct populations (Runs = 333, Ties = 125, adjusted Z-value = -19.673,  $P$ -value < 0.001), indicating that on average krill were located in areas with lower sea surface temperatures than the range encountered over the course of the aerial surveys. This pattern was supported by the more general statistical comparisons between the two data sets (i.e. Mann-Whitney U-test:  $U$ -value = 636878, Z-value = 2.715,  $P$ -value = 0.0066; Kolmogorov-Smirnov two-sample test: Maximum negative difference = -0.044, Maximum positive difference = 0.160,  $P$ -value < 0.001).

Map 3. Map of all Krill sightings over the survey program, plotted over average relative sea surface temperature for the period 14 April to 3 June, 2001. This map identifies areas with a minimum SST of 14.5°C as blue and maximum SST of 16.5°C as red, with coloring stretched between these two colors based of SST values.

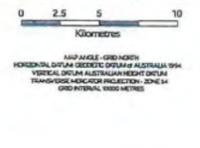
SURVEY RESULTS - KRILL SIGHTINGS AND AVERAGE SEA SURFACE TEMPERATURE (14.5C Blue -16.5C Red)



This map is a derivative of information collected as part of the Otway Basin Blue Whale Survey. It is a product of the Victorian Department of Natural Resources and Environment and Spatial Vision. The data was collected during the survey period from 14 April to 3 June 2001. The map is for information purposes only and does not constitute a guarantee of accuracy. It is not to be used for navigation or other purposes. For more information, contact the Victorian Department of Natural Resources and Environment, PO Box 221, Heidelberg, Victoria, 3086. Copyright © 2001, Department of Natural Resources and Environment, Victoria. All rights reserved.

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- Overview Flight Path
- Coast Line
- ▲ Blue Whale
- ◆ Krill
- OBS Site



MAP ANGLE: GRID NORTH  
HORIZONTAL DATUM: GEODETIC DATUM OF AUSTRALIA 1984  
VERTICAL DATUM: AUSTRALIAN MEAN SEA LEVEL  
TRANSVERSE MERCATOR PROJECTION - ZONE 54  
GRID INTERVAL: 5000 METRES

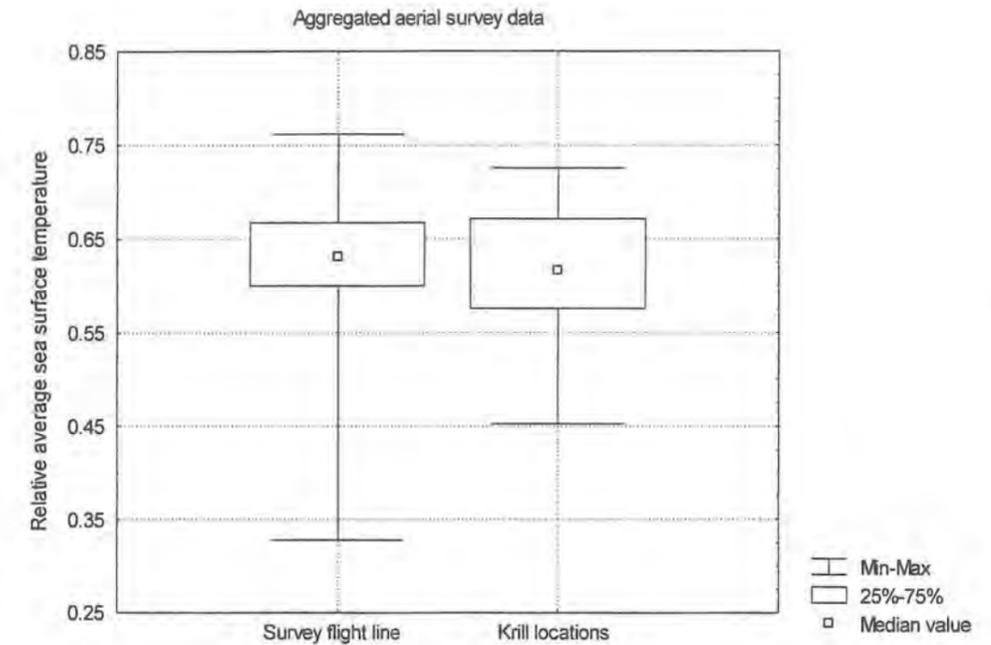


Fig. 18. Distributions of relative average sea surface temperatures along the survey flight line and at the point locations of krill aggregations combined for all aerial surveys.

Map 4 provides an example of daily survey results – the data contained in the table is from the GPS survey log and has been georeferenced to the study area.

#### Sea Surface Productivity - SeaWiFS

The spatial distribution of Chlorophyll A (obtained from SeaWiFS imagery) was presented in combination with the corresponding aerial survey results for four dates. The aerial survey dates for which corresponding Chlorophyll A information was presented with survey results were: 14 April 2001, 08 May 2001, 21 May 2001, and 03 June 2001.

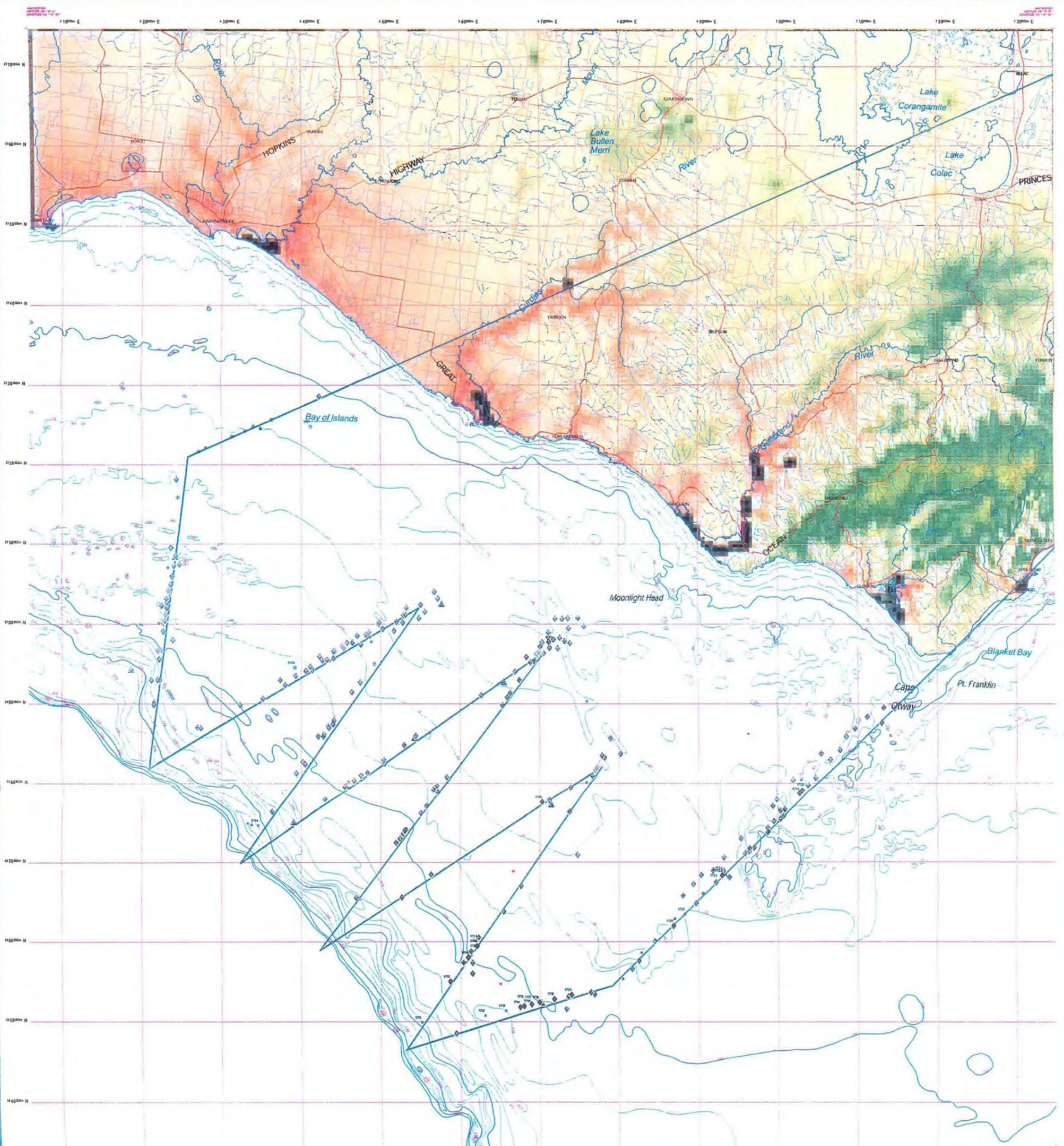
Appendix D contains a map for each date for which SeaWiFS imagery was obtained. The maps show sea surface productivity (Chlorophyll A) values together with aerial survey results. The results indicate a degree of spatial variation in the distribution of Chlorophyll A over the four dates. Since SeaWiFS data was obtained late in the project period there was no statistical analysis undertaken on the correlation between Chlorophyll A values and the Krill observations.

#### Discussion

*How are sea surface temperature, productivity and krill related to the occurrence of blue whales in the Otway Basin?*

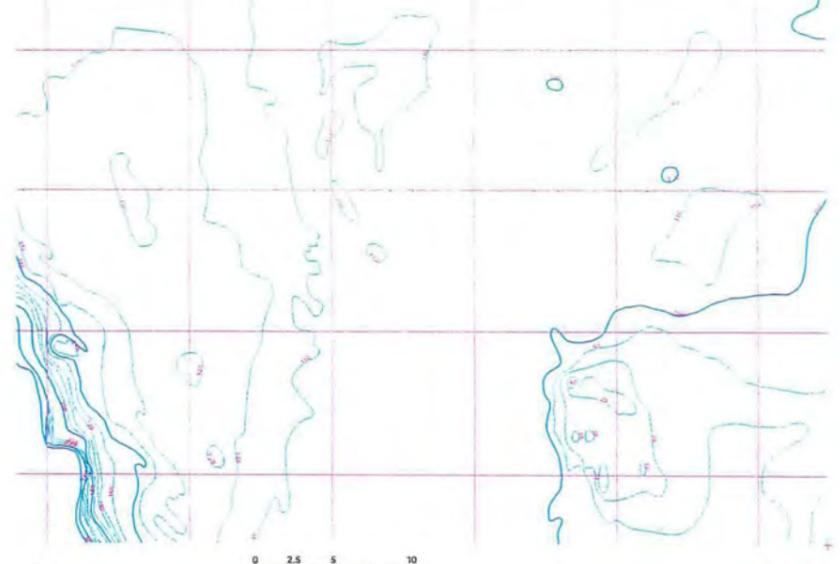
The abundance of blue whales in the study area declined over the course of the aerial survey program, with the last sighting made on 19 May. This decline mirrors that reported for blue whales in waters further west along the Victorian coast and off eastern South Australia, where abundance declines as autumn progresses (Gill 2001). In contrast, while the density of coastal krill aggregations varied considerably from survey-to-survey, overall abundance showed no systematic decline over the course of the survey program. This suggests that blue whales do not leave the study area in response to a decline in the overall availability of coastal krill.

Map4: An example of daily survey.



Survey Summary 03 June 2001

SITE ID	WAYPOINT	OBSERVER	LONGITUDE	LATITUDE	TIME	TYPE	KRILL DENSITY	NUMBER	DESCRIPTION
1701	236	LG	142.82174	-38.81353	0:00	3	0	3	Birds - ruff
1702	237	LG	142.80461	-38.88647	0:00	3	0	1	Birds - ruff
1703	238	LG	142.71466	-38.85571	0:00	3	0	4	Dolphins
1704	239	DC	142.55566	-38.68898	0:00	3	0	10	Dolphins
1705	240	LG	142.98740	-38.03453	0:00	2	1	1	Krill - small
1706	241	LG	142.87674	-38.19870	0:00	2	3	4	Krill - large
1707	241	LG	142.87674	-38.19870	0:00	2	2	2	Krill - medium
1708	241	LG	142.87674	-38.19870	0:00	2	1	3	Krill - small
1709	242	LG	142.84452	-38.21197	0:00	2	1	1	Krill - medium
1710	243	DC	142.83910	-38.22943	0:00	2	2	3	Krill - medium
1711	244	LG	142.79872	-38.28822	0:00	6	0	2	Southern right whales at surface
1712	246	LG	142.89062	-38.27692	0:00	5	0	8	Dolphins
1713	247	LG	142.92057	-38.27116	0:00	5	0	10	Dolphins
1714	248	LG	142.84172	-38.28860	0:00	2	3	1	Krill - large
1715	249	LG	142.94737	-38.26538	0:00	2	2	2	Krill - medium
1716	249	LG	142.94737	-38.26538	0:00	2	1	3	Krill - small
1717	250	LG	142.95825	-38.26217	0:00	2	1	3	Krill - small
1718	251	DC	142.98979	-38.26077	0:00	2	2	2	Krill - medium
1719	252	LG	142.99125	-38.25653	0:00	2	1	2	Krill - small
1720	253	LG	143.01624	-38.25139	0:00	2	2	1	Krill - medium
1721	254	LG	143.16282	-38.17101	0:00	2	1	1	Krill - small
1722	255	LG	143.17887	-38.15741	0:00	5	0	15	Dolphins
1723	256	LG	143.23156	-38.11257	0:00	5	0	10	Dolphins
1724	256	LG	143.23156	-38.11257	0:00	2	1	1	Krill - small
1725	256	LG	143.23156	-38.11257	0:00	2	3	3	Krill - large
1726	256	LG	143.23156	-38.11257	0:00	2	1	8	Dolphins
1727	257	DC	143.34195	-38.07753	0:00	2	2	2	Krill - medium
1728	258	LG	143.34594	-38.01404	0:00	2	1	1	Krill - small



SURVEY SUMMARY REPORT - 03 June 2001



This map is a derivative of the information contained in the Victorian Blue Whale Research Project - Otway Basin Survey conducted by the Victorian Department of Natural Resources and Environment and Spatial Vision. The project was funded by the Victorian Government and the Otway Basin Shire Council. The project was conducted from 14 April to 3 June 2001. The project was a joint venture between the Victorian Department of Natural Resources and Environment and Spatial Vision. The project was a joint venture between the Victorian Department of Natural Resources and Environment and Spatial Vision. The project was a joint venture between the Victorian Department of Natural Resources and Environment and Spatial Vision.

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- Otway Basin



MAP SCALE: 0:2.5:5:10 KILOMETRES  
 HORIZONTAL CONTROL: GEODETIC DATUM AUSTRALIA 1984  
 VERTICAL CONTROL: AUSTRALIAN HEIGHT DATUM  
 TRANSFORMED TO AUSTRALIAN DATUM  
 GEOGRAPHIC COORDINATES: GDA 94  
 GDA 94 DATUM: 1994

While there was a clear tendency for krill aggregations to be more common in areas characterised by lower surface temperatures, this association was not particularly strong or consistent (see Appendix C), and was obscured by the high survey-to-survey variability in the density of krill aggregations. The high variability in the density of krill aggregations appeared to be at least partially due to the influence of prevailing sea state conditions. Moderate to high seas tended to obscure any consistent spatial pattern in surface temperatures across the survey area, presumably because associated higher winds increased the degree to which surface water was mixed. Under these conditions, any tendency for cold water upwelling to create defined areas where surface waters were markedly colder than that in the surrounding ocean, would be reduced. As areas of colder water at or near the surface became more transient, the capacity of these areas to sustain consistently high phytoplanktonic productivity would also have declined. Any decline in the density or extent of areas sustaining consistently higher phytoplanktonic productivity as sea state conditions deteriorated, would lead to a reduction in the tendency for krill to form associated feeding aggregations. In this study, this effect manifested itself as reduced persistence in the spatial pattern of sea surface temperature, and a decrease in the average density of krill aggregations as sea state went from calm to slight, and from slight to moderate or high. However, aerial surveys were not conducted with sufficient frequency to determine how the influence that poorer sea state conditions had on the tendency for krill to aggregate persisted, once seas reverted to calm conditions.

The low frequency of blue whale sightings and the nature of the aerial survey design limited the extent to which the association of blue whales with krill aggregations could be formally evaluated in this study. In order to evaluate whether blue whales in the survey area were specifically associating with krill aggregations, their location would have to be demonstrated to be non-random with respect to these aggregations. While the survey design used in this study allowed the distribution of blue whales and krill aggregations to be mapped along the survey line, it did not allow their distribution to be mapped with respect to each other. The assessment of sightability demonstrated that under conditions of little or no cloud, krill aggregations had a high probability of being sighted if they were within 500 m of the flight line, and blue whales if they were within 250 m of the flight line. As such, when krill aggregations were located along the flight line, we had no way of knowing whether or not blue whales were associating with these aggregations, unless the whales were within 250 m of the flight line. Similarly, if blue whales were sighted along the flight line, we had no way of knowing whether they were associating with krill aggregations, unless the aggregations were within 500 m of the flight line. The basic limitation of the approach used in this study is that an essentially linear sampling protocol cannot be used to assess what is a two-dimensional<sup>1</sup> spatial association.

A more robust approach to assessing the spatial distribution of blue whales relative to that of krill would be to formally compare the occurrence of whales in areas that do and do not contain krill aggregations. This would require some area around a series of point locations at which krill aggregations do or do not occur to be systematically searched for blue whales in order to estimate relative detection (sighting) rates. The null hypothesis of no association would be:

$$(D_w / A)_k = (D_w / A)_{nk}$$

where  $D_w$  is the mean detection rate of whales (whales sighted  $t^{-1}$ , corrected for the effects of distance on sightability), in a sample of areas of given size ( $A$ ) that do ( $k$ ) and do not ( $nk$ ) contain krill aggregations. A survey design that could be used to evaluate this hypothesis is described below.

#### *Implications for further research*

To determine whether additional sources of anthropogenic noise, such as those produced through energy exploration or exploitation, are influencing the forging behaviour of blue

<sup>1</sup> In reality, the association of blue whales and krill is three-dimensional, although currently available technology limits us to assessing it in two-dimensions.

whales in the Otway Basin, baseline information on whale activity will be required. To provide a quantitative framework for interpreting observed changes in whale activity, this baseline information should account for natural variation in the location and timing of blue whale activity within the basin. Two important sources of this variation appear to be (1) the seasonal movement of blue whales into and out of the basin, and (2) the putative association of blue whales with the krill aggregations that occur in areas where cold water upwelling leads to high phytoplanktonic activity. This study has confirmed Gill's (2001) observation that blue whales which arrive in the area over summer, depart over the latter half of autumn. However, the data collected on the association of sea surface temperature, the density of krill aggregations and the distribution of blue whales, highlights three areas where additional research will be necessary before models that can predict where and why blue whales ought to be active in the Basin can be developed:

1. *The effect that prevailing weather conditions has on the stability of spatial patterns in sea surface temperature and direct measures of sea surface productivity needs to be evaluated more systematically.* The results obtained during this study suggest that as sea state conditions deteriorated, the persistence of defined areas of cold surface water declined. If this influence manifests itself as a reduction in the persistence of areas of high phytoplanktonic productivity, it may well influence the distribution and density of krill aggregations across the Basin, and the consequent distribution of blue whales. A more detailed assessment of the influence prevailing weather and sea state has on the stability of spatial patterns in sea surface temperature would undertake a formal analysis of the systematic influence that wind speed, wind direction, and a range of measures related to sea state had on the consistency of sea surface temperatures across the Otway Basin, obtained from corrected satellite imagery. Such an analysis could be based on spatial general linear modelling techniques, and relevant geospatial multivariate approaches. The emphasis of such an analysis would be on developing the best unbiased, predictive model that allows spatial and temporal variation in sea surface temperatures to be predicted across the basin, with a known degree of certainty. A similar analysis could be conducted for spatial variation in sea surface productivity.
2. *The association of krill aggregations with sea surface temperature and/or productivity needs to be validated using independent data.* While this study demonstrated a clear tendency for krill aggregations to be more frequent in areas of colder surface water, this association was relatively weak and inconsistent from survey-to-survey. In order to improve our capacity to predict where and when krill aggregations will occur, we suggest a more systematic evaluation of (1) the degree to which krill aggregations are associated with direct measures of sea surface productivity, and (2) the effect of prevailing weather conditions on sea surface temperature and direct measures of sea surface productivity.
3. *The direct association of the presence of krill aggregations on blue whale activity needs to be quantified.* As described above, the capacity of the survey approach adopted in this study to evaluate the degree to which blue whales are spatially associated with the occurrence of krill aggregations is severely limited. There are two alternative survey approaches that could be adopted to directly evaluate this association:
  - Simultaneous mapping of krill and whale abundance by flying systematic survey lines over (1) the entire survey area, or (2) randomly selected blocks of the survey area. This would allow the proximity of whales to nearest krill aggregations to be estimated and compared to locations selected at random. This approach has the advantage that it does not require an area around krill locations where whales would be expected to occur given an association to be assumed. However, it has the disadvantage of requiring very extensive survey programs to furnish useful maps. For example, flight lines would need to be spaced so that there was a high probability of sighting whales and krill aggregations if they were available to be seen. While krill aggregations would require 500 m spacings, blue whales really require 250 m spacings. This not only leads to very long surveys, but creates problems with contagion between flight lines, particularly for whales which are highly mobile.
  - Establishing point locations where krill aggregations do and do not occur, then systematically surveying a specified area around these locations. This would allow the whale activity (measured as detection or sighting rate) to be compared in areas that demonstrably do and do not contain krill aggregations. This approach has the advantage of requiring much less intensive surveys than that required for the

mapping approach. However, it has the disadvantage of requiring the maximum area around a point location at which blue whales would be expected to occur if they were associating with that location, to be specified (i.e. the area around the point location that would be systematically surveyed).

A random spatial sampling approach could be used to simultaneously develop predictive models of the spatial occurrence of krill aggregations across the Otway Basin, and test the association of blue whales with these aggregations. This approach would use models based on sea surface temperature, sea surface productivity, and additive and multiplicative derivations of these factors, to map predicted probabilities of krill occurrence across the Otway Basin from current satellite imagery. The spatial scale for these probability maps would be specified according to the spatial resolution of the satellite data obtained, but would probably be in the order of  $1 \text{ km}^2$ . A number of randomly selected locations (1 km grid squares) across the Basin, covering the range of these predicted probabilities (i.e. krill occurrence 0-20% certain, 20-40% certain, etc.) would be sampled within a day or two of the probability map being derived. The rate at which krill aggregations were located within grid squares would provide a direct test of the predictive power of the models.

For an equal number of grid squares that did and did not contain krill aggregations, a constrained radial adaptive sampling transect could be flown in an attempt to locate whales. The total area covered by the sampling transect should be set to ensure that any whales associated with the sampled grid square will be seen if they are at the surface. We suggest that an area of  $5 \times 5 \text{ km}$  ( $25 \text{ km}^2$ ) be surveyed, with the flight line placed so it passes within 500 m of this entire area (Fig. 19). By combining the evaluation of influence sea surface temperature and/or productivity has on the occurrence of krill aggregations, and that of the influence that the presence of krill has on blue whale activity, a single survey program can be used to validate the important functional associations that determine spatial patterns of blue whale activity within the basin. If these associations were mathematically linked to the models that predict variation in sea surface temperature and/or productivity from weather and sea state, the probability of blue whale activity across the Otway Basin could be predicted from satellite data in virtual "real" time. These predictions could be used to benchmark blue whale activity, in order to evaluate the influence that any new source of anthropogenic noise has on blue whale activity within the Basin.

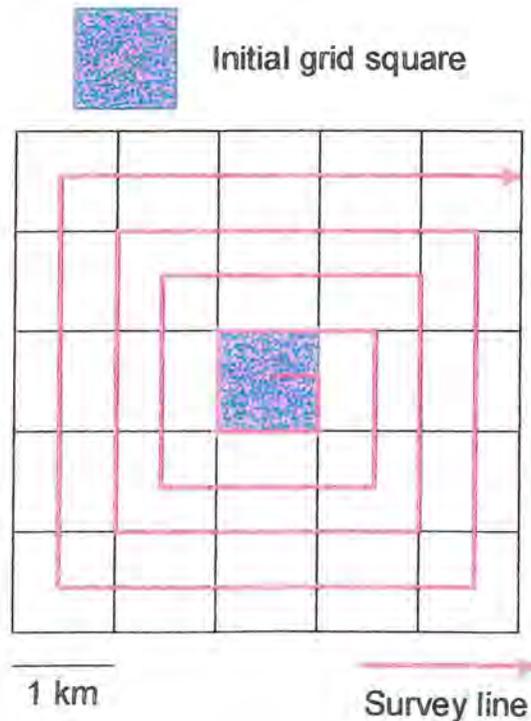


Fig. 19. A diagrammatic representation of a spiral adaptive sampling line to assess the presence of whales in a 25 km<sup>2</sup> area immediately around a 1 km<sup>2</sup> grid square, in which the presence of krill has ascertained. The flight line originates in the grid square sampled for krill, then moves out progressively from this square, taking a path in which every part of the sampling frame is viewed from a maximum distance of 500 m. If blue whales are seen, the flight line terminates.

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## ACKNOWLEDGEMENTS

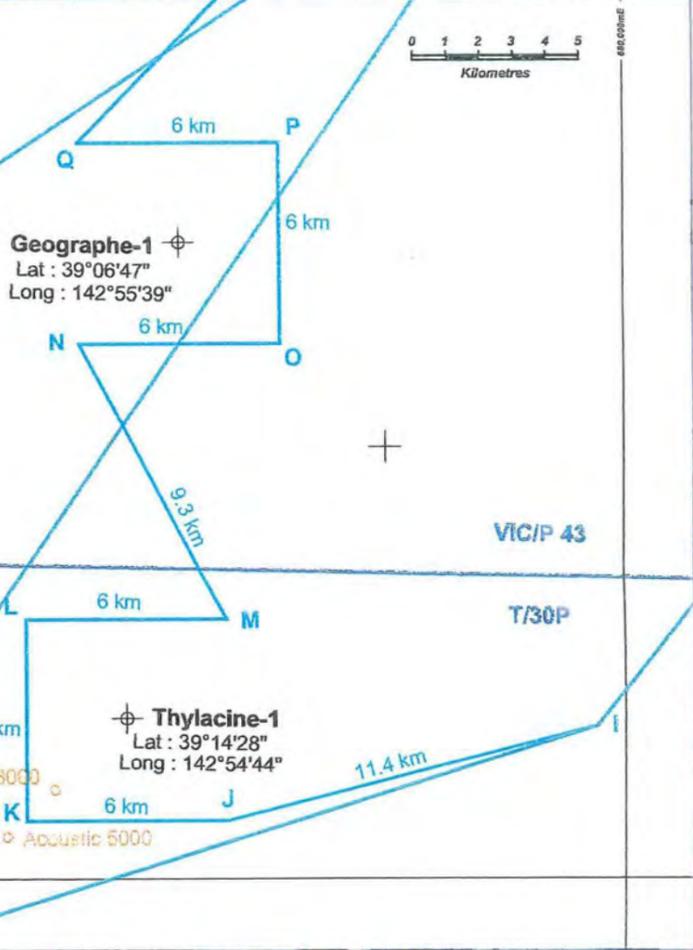
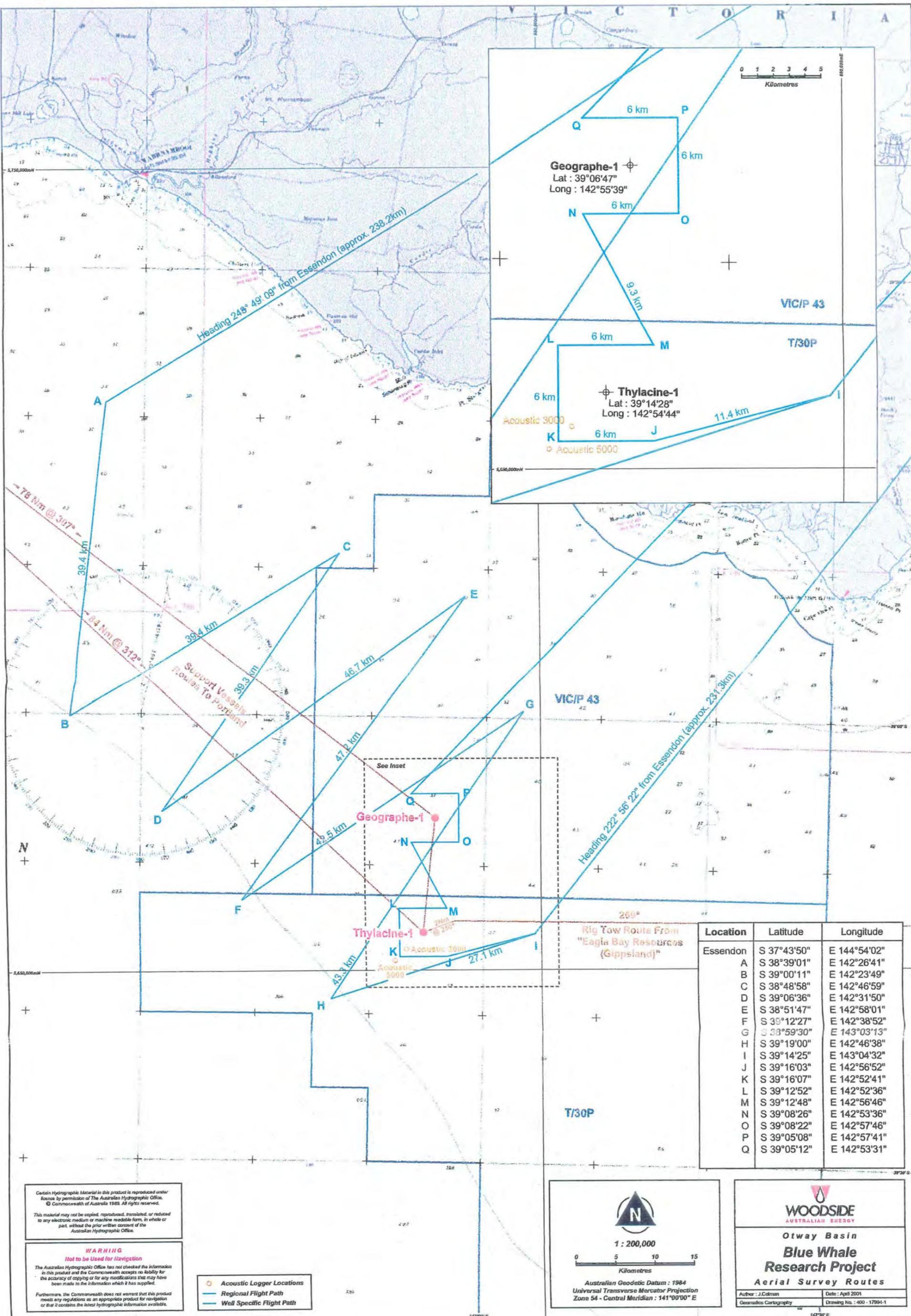
Funding for this research was made available by Woodside Energy Ltd., Origin Energy Resources Ltd., CalEnergy Gas (UK) Ltd., and Benaris International N.V. We would like to thank Jeremy Colman, Peter Hillier and Birgit Cropp for coordinating survey logistics, Jeremy Colman for assisting with compliance surveys, and Louise Grgat for acting as the third observer on all double-count surveys.

Appendix A: Compliance surveys

Five compliance surveys were flown on a route in the immediate area of the two drilling points (see inset on Map 5). No blue whales were observed during any of the surveys. Conditions prevailing during each of the compliance surveys are summarised below.

Survey	Date	Cloud cover	Sea state
2	21 April	4 / 8	Moderate
3	24 April	8 / 8	Slight
4	25 April	7 / 8	Calm
5	26 April	2 / 8	High
6	28 April	5 / 8	Calm

Map 5. Overall aerial survey route with the additional compliance transects detailed in the inset.



Location	Latitude	Longitude
Essendon	S 37°43'50"	E 144°54'02"
A	S 38°39'01"	E 142°26'41"
B	S 39°00'11"	E 142°23'49"
C	S 38°48'58"	E 142°46'59"
D	S 39°06'36"	E 142°31'50"
E	S 38°51'47"	E 142°58'01"
F	S 35°12'27"	E 142°38'52"
G	S 38°59'30"	E 143°03'13"
H	S 39°19'00"	E 142°46'38"
I	S 39°14'25"	E 143°04'32"
J	S 39°16'03"	E 142°56'52"
K	S 39°16'07"	E 142°52'41"
L	S 39°12'52"	E 142°52'36"
M	S 39°12'48"	E 142°56'46"
N	S 39°08'26"	E 142°53'36"
O	S 39°08'22"	E 142°57'46"
P	S 39°05'08"	E 142°57'41"
Q	S 39°05'12"	E 142°53'31"

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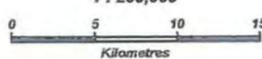
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- Acoustic Logger Locations
- Regional Flight Path
- Well Specific Flight Path

  
 1 : 200,000  
  
 Australian Geodetic Datum : 1984  
 Universal Transverse Mercator Projection  
 Zone 54 - Central Meridian : 141°00'00" E

  
**WOODSIDE**  
 AUSTRALIAN ENERGY  
 Otway Basin  
**Blue Whale**  
 Research Project  
 Aerial Survey Routes  
 Author : J. Colman      Date : April 2001  
 Geomatics Cartography      Drawing No. : 400-17994-1

Appendix B: Statistical comparisons of sea surface temperature along the aerial survey route and at point locations of krill for each aerial survey.

Date	Average relative temperature		Statistical Test									
	Overall	Krill locations	Wolda-Wolfowitz Runs Test				Mann-Whitney <i>U</i> -test			Kolmogrov-Smirnov Two-sample Test		
			Runs	Ties	Adjusted Z-value	<i>P</i> -value	<i>U</i> -value	Adjusted Z-value	<i>P</i> -value	Maximum negative difference	Maximum positive difference	<i>P</i> -value
14 April	0.757	0.773	21	9	-1.976	0.048	32089	-2.155	0.829	-0.156	0.107	>0.10
25 April	0.717	0.789	39	11	-3.5206	<0.001	81209	-3.519	<0.001	-0.428	0.015	<0.005
26 April	0.631	0.655	23	8	-1.589	0.112	25830	-0.896	0.370	-0.229	0.085	>0.10
28 April	0.651	0.700	11	0	-3.866	<0.001	9004	-1.366	0.172	-0.371	0.055	>0.10
3 May	0.469	0.566	9	3	57.464	<0.001	19383	-3.742	<0.001	-0.732	0.133	<0.001
4 May	0.627	0.583	29	9	-1.308	0.191	34514	1.663	0.096	-0.377	0.319	>0.10
5 May	0.569	0.574	19	8	-2.216	0.027	28799	0.169	0.865	-0.203	0.268	>0.10
8 May	0.478	0.454	41	4	2.692	0.007	58393	1.264	0.206	-0.132	0.342	<0.025
11 May	0.794	0.748	47	8	-9.241	<0.001	67186	1.952	0.051	-0.073	0.264	<0.10
12 May	0.759	0.815	29	7	3.984	<0.001	35259	-1.985	0.047	-0.357	0.029	<0.05
19 May	0.624	0.601	31	11	12.471	<0.001	51002	1.087	0.277	-0.185	0.369	<0.025
20 May	0.629	0.579	39	12	-0.815	0.393	47398	1.868	0.062	-0.039	0.258	>0.10
27 May	0.521	0.504	37	12	10.606	<0.001	63716	0.707	0.479	-0.031	0.133	>0.10
28 May	0.517	0.604	23	5	5.074	<0.001	20047	-2.987	0.003	-0.451	0.082	<0.025
3 June	0.565	0.533	29	9	19.871	<0.001	53811	0.709	0.477	-0.102	0.207	>0.10

Appendix C: Cluster analysis summary textfile

Cluster analysis summary textfile showing the results for a classification based on the Absolute Average Temperature SST variable (GSSTAV) for each survey day over the entire survey period. This analysis contains relevant statistical information including: a covariance matrix for the stack of processed images, the correlation matrix for the stack, a dendrogram of the classification, a summary of the signature file used in the classification, and finally a frequency of the classification and confidence grids

```

# STATISTICS of INDIVIDUAL LAYERS
#
# Layer      MIN      MAX      MEAN     STD
#-----
# 1          1.0000   10.0000   5.0600   1.4090
# 2          1.0000   10.0000   6.6636   1.4818
# 3          1.0000   10.0000   5.1271   1.3188
# 4          1.0000   10.0000   7.4870   1.3646
# 5          1.0000   10.0000   6.2359   1.5450
# 6          1.0000   10.0000   7.0588   1.4249
# 7          1.0000   10.0000   5.7986   1.2391
# 8          1.0000   10.0000   6.1208   1.4295
# 9          1.0000   10.0000   5.2679   1.8879
# 10         1.0000   10.0000   6.0786   1.3713
# 11         1.0000   10.0000   7.9261   1.4735
# 12         1.0000   10.0000   7.7559   1.2393
# 13         1.0000   10.0000   6.2118   1.5750
# 14         1.0000   10.0000   6.1687   1.3898
# 15         1.0000   10.0000   6.3806   1.3685
#-----
# COVARIANCE MATRIX
#
# Layer      1          2          3          4          5          6          7          8          9          10         11         12         13         14         15
#-----
# 1          1.26978  1.06707  0.60525  0.54461  0.54655  0.10713  0.25110  0.15138  0.81575  0.88570  0.39941  0.34563  0.57598  0.33485  0.52589
# 2          1.06707  1.40992  0.98067  0.64814  0.56626  0.09713  0.23088  0.15516  0.61638  1.19379  0.49336  0.31333  0.57774  0.25072  0.41269
# 3          0.60525  0.98067  1.11399  0.62446  0.49687  0.14837  0.16664  0.05711  0.42361  0.90428  0.46614  0.24740  0.49736  0.23842  0.33715
# 4          0.54461  0.64814  0.62446  1.20019  0.75018  0.30052  0.36884  0.14654  0.66705  0.55642  0.90547  0.42382  0.70073  0.36401  0.40026
# 5          0.54655  0.56626  0.49687  0.75018  1.52900  0.22640  0.33128  0.18724  0.73985  0.42841  0.61283  0.46115  1.37650  0.30875  0.41821
# 6          0.10713  0.09713  0.14837  0.30052  0.22640  1.29063  0.16126  -0.08351  0.02543  0.11287  0.38980  0.18139  0.12333  0.83779  0.68946
# 7          0.25110  0.23088  0.16664  0.36884  0.33128  0.16126  0.98340  0.68603  0.35264  0.17774  0.34582  0.31302  0.27028  0.24232  0.23734
# 8          0.15138  0.15516  0.05711  0.14654  0.18724  -0.08351  0.68603  1.30871  0.24810  0.10921  0.10093  0.18772  0.11906  -0.08693  -0.08894
# 9          0.81575  0.61638  0.42361  0.66705  0.73985  0.02543  0.35264  0.24810  2.23415  0.45337  0.47816  0.51088  0.78173  0.34851  0.52945
# 10         0.88570  1.19379  0.90428  0.55642  0.42841  0.11287  0.17774  0.10921  0.47816  1.20665  0.48168  0.22757  0.42967  0.20677  0.29875
# 11         0.39941  0.49336  0.46614  0.90547  0.61283  0.38980  0.34582  0.47816  0.48168  1.39249  0.23863  0.52477  0.36390  0.35808  0.40290
# 12         0.34563  0.31333  0.24740  0.42382  0.46115  0.18139  0.31302  0.18772  0.51088  0.22757  0.23863  0.98797  0.50613  0.36701  0.40290
# 13         0.57598  0.57774  0.49736  0.70073  1.37650  0.83779  0.24232  0.11906  0.78173  0.42967  0.52477  0.50613  1.58399  0.26633  0.39552
# 14         0.33485  0.25072  0.23842  0.36401  0.30875  0.83779  0.24232  0.34851  0.20677  0.36390  0.36701  0.26633  1.24491  1.06161  1.06161
# 15         0.52589  0.41269  0.33715  0.40026  0.41821  0.68946  0.23734  0.52945  0.29875  0.35808  0.40290  0.39952  1.06161  1.06161  1.20733
#-----
# CORRELATION MATRIX
#
# Layer      1          2          3          4          5          6          7          8          9          10         11         12         13         14         15
#-----
# 1          1.00000  0.79753  0.50889  0.44116  0.39225  0.08368  0.22471  0.11743  0.48433  0.71554  0.30037  0.30859  0.40613  0.26633  0.42473
# 2          0.79753  1.00000  0.78253  0.49826  0.38568  0.07201  0.19608  0.11423  0.34730  0.91528  0.35212  0.26549  0.38661  0.18925  0.31632
# 3          0.50889  0.78253  1.00000  0.54006  0.38071  0.12374  0.15921  0.04730  0.26852  0.77996  0.37427  0.23582  0.37441  0.20245  0.29072
# 4          0.44116  0.49826  0.54006  1.00000  0.55378  0.24146  0.33951  0.11692  0.40736  0.46237  0.70041  0.38921  0.51402  0.29780  0.33251
# 5          0.39225  0.38568  0.38071  0.55378  1.00000  0.16117  0.27016  0.12237  0.40030  0.31540  0.41999  0.37520  0.88450  0.22379  0.30780
#-----

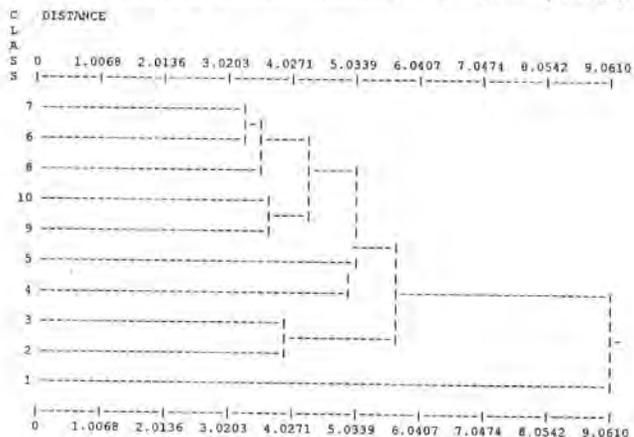
```

6	0.08368	0.07201	0.12374	0.24146	0.16117	1.00000	0.14314	-0.06425	0.01498	0.09045	0.28629	0.16063	0.08625	0.66095	0.55232
7	0.22471	0.19608	0.15921	0.33951	0.27016	0.14314	1.00000	0.60473	0.23791	0.16317	0.29552	0.31757	0.21656	0.21901	0.21782
8	0.11743	0.11423	0.04730	0.11692	0.13237	-0.06425	0.60473	1.00000	0.14510	0.08691	0.07477	0.16509	0.08270	-0.06810	-0.07871
9	0.46433	0.34730	0.26852	0.40736	0.40030	0.01498	0.23791	0.14510	1.00000	0.27612	0.27109	0.34387	0.41555	0.20897	0.32237
10	0.71554	0.91529	0.77996	0.46237	0.31540	0.09045	0.16317	0.08691	0.27612	1.00000	0.27109	0.34387	0.41555	0.20897	0.32237
11	0.30037	0.35212	0.37427	0.70041	0.41999	0.28629	0.29552	0.07477	0.27109	0.37160	1.00000	0.20843	0.31079	0.16871	0.24752
12	0.30859	0.26549	0.23582	0.38921	0.37520	0.16063	0.31757	0.16509	0.34387	0.20843	0.20345	1.00000	0.20345	0.35334	0.27617
13	0.40613	0.38661	0.37441	0.51402	0.88450	0.08625	0.21656	0.08270	0.41555	0.31079	0.35334	0.40459	1.00000	0.18966	0.28890
14	0.26633	0.18925	0.20245	0.29780	0.22379	0.66095	0.21901	-0.06810	0.20897	0.16871	0.27639	0.33093	0.18966	1.00000	0.86593
15	0.42473	0.31632	0.29072	0.33251	0.30780	0.55232	0.21782	-0.07871	0.32237	0.24752	0.27617	0.36890	0.28890	0.86593	1.00000

Distances between Pairs of Combined Classes  
(in the sequence of merging)

Remaining Class	Merged Class	Between-Class Distance
6	7	3.352417
6	8	3.629410
9	10	3.720469
2	3	3.988423
6	9	4.291977
5	6	5.091434
4	5	5.011376
2	4	5.748373
1	2	9.060984

Dendrogram of /project/sv000322/data/grids/analysis/mlc/gststov/gsgfiles/gststov.gsg



```

# Signatures Produced by Clustering of
# Stack /project/sv000322/data/grids/analysis/mic/gsatov/qgsstov
# number of classes=10 max_iterations=100 min_class_size=20
# sampling interval=5
# Number of selected grids
/*
15
# Layer-Number Grid-name
/* 1 s0305
/* 2 s0405
/* 3 s0805
/* 4 s1205
/* 5 s1905
/* 6 s2504
/* 7 s2705
/* 8 s2805
/* 9 s0306
/* 10 s0505
/* 11 s1105
/* 12 s1404
/* 13 s2005
/* 14 s2604
/* 15 s2804
    
```

```

# Type Number of Classes Number of Layers Number of Parametric Layers
1 10 15 15
#
    
```

Class ID	Number of Cells	Class Name														
1	109															
Layers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Means	2.79817	4.65138	3.61468	4.93578	3.05505	6.51376	3.79817	4.16514	2.39450	4.50459	5.93486	5.21101	2.88073	5.48541	5.63303	
Covariance	1	2.12555	1.05861	0.14373	-0.13345	-0.00731	0.35466	-0.18000	-0.12377	0.16369	0.76019	-0.11697	-0.40146	0.11459	0.62870	0.81114
	2	1.05861	1.54400	1.03109	0.07000	0.34743	0.01232	0.06736	0.12954	-0.22477	-0.21279	-0.19011	0.58172	0.72273		
	3	0.14373	1.03109	1.83163	0.19725	-0.36748	0.05165	0.25484	0.09786	0.98327	-0.31422	0.30428	-0.39823	0.13710	0.10729	
	4	-0.13345	0.07000	0.19725	0.76436	0.29060	0.18145	0.63507	0.70515	-0.14382	0.69300	0.64331	0.22375	-0.25493	-0.48675	
	5	-0.00731	-0.22137	-0.36748	0.29060	0.95990	0.11961	0.03899	0.17601	0.09845	0.48140	0.20124	0.77514	-0.29604	-0.46109	
	6	0.35466	0.34743	0.05165	0.29060	0.95990	0.11961	0.03899	0.17601	0.09845	0.48140	0.20124	0.77514	-0.29604	-0.46109	
	7	-0.18000	0.01232	0.06736	0.29060	0.95990	0.11961	0.03899	0.17601	0.09845	0.48140	0.20124	0.77514	-0.29604	-0.46109	
	8	-0.12377	0.06736	0.25484	0.63507	0.03899	0.16947	1.53296	1.54290	0.30258	0.23242	1.01266	0.68187	-0.05207	-0.29723	-0.57475
	9	0.16369	0.12954	0.09786	0.07000	0.17601	0.01622	1.54290	1.91692	0.45277	0.34183	0.90715	0.86298	0.13099	-0.55479	-0.92958
	10	0.76019	1.22384	0.98327	0.19725	0.03899	0.03619	0.30258	0.45277	0.51886	0.16021	0.01945	0.28636	0.09378	-0.03984	-0.10389
	11	-0.11697	-0.22477	-0.31422	0.29060	0.30095	0.23242	0.34183	0.16021	1.28923	0.00076	-0.00561	-0.19852	0.46067	0.48318	
	12	-0.40146	-0.21279	0.30428	0.64331	0.61340	1.01266	0.90715	0.01945	0.00076	2.26877	0.48887	0.31346	0.11035	-0.11672	
	13	0.11459	-0.19011	-0.39823	0.22375	0.77514	0.05725	0.68187	0.86298	-0.00561	0.48887	1.16803	0.17355	-0.47587	-0.74592	
	14	0.62870	0.58172	0.13710	-0.25493	-0.29604	0.75238	0.13099	0.09378	-0.19852	0.31346	0.17355	0.92083	-0.30148	-0.47010	
	15	0.81114	0.72273	0.10729	-0.48675	-0.46109	0.81065	-0.57475	-0.92958	-0.10389	0.48318	-0.11672	-0.74592	-0.47010	1.57238	2.06779

Class ID	Number of Cells	Class Name														
2	210															
Layers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Means	3.38095	4.84762	3.89048	6.85238	5.96667	5.99524	6.06190	6.94286	3.46190	4.32857	7.00952	7.36667	6.05714	4.72857	4.71429	
Covariance	1	0.54318	0.36455	0.21896	0.13306	0.07974	-0.05559	0.03851	-0.00684	0.22032	0.28093	0.04899	0.07496	0.15516	-0.04443	0.03281
	2	0.36455	1.04844	0.61959	0.21185	0.33939	-0.17296	-0.03827	-0.03746	-0.35033	0.71538	-0.12294	0.02265	0.38195	-0.12290	-0.03418
	3	0.21896	0.61959	0.61474	-0.02103	0.24514	0.00905	0.02595	0.07027	-0.26017	0.49549	-0.19512	0.01164	0.25509	0.02755	0.07382
	4	0.13306	0.21185	-0.02103	0.11467	0.11467	-0.48396	0.06181	-0.13298	0.55177	-0.14443	0.35548	0.09266	0.22379	-0.28906	-0.26726
	5	0.07974	0.33939	0.24514	0.11467	0.60654	-0.04801	-0.02185	-0.04498	-0.35295	0.22632	-0.08102	-0.07384	0.51866	0.40473	0.00478
	6	-0.05559	-0.17296	0.00905	-0.48396	0.60654	-0.04801	-0.02185	-0.04498	-0.35295	0.22632	-0.08102	-0.07384	0.51866	0.40473	0.00478
	7	0.03851	0.03837	0.02595	0.06181	-0.04801	1.98562	0.09121	0.24375	-0.54324	-0.11934	-0.07480	-0.11934	0.63028	0.48667	
	8	-0.00684	-0.03746	0.07027	-0.13298	-0.04498	0.09121	0.66122	0.42939	0.31577	0.06828	0.05375	-0.05619	0.05995	0.04170	
	9	0.22032	-0.35033	-0.26017	0.55177	-0.35295	0.24375	0.42939	0.77184	0.23705	-0.01941	-0.20519	0.09282	0.17102	0.11757	
	10	0.28093	0.71538	0.49549	0.14443	0.22632	-0.15154	0.30827	3.08227	0.08227	-0.12379	0.70371	0.03557	-0.20355	-0.31900	-0.50376
	11	0.04899	-0.12294	-0.19512	0.35548	-0.08102	-0.03488	-0.01376	-0.01376	-0.01941	-0.07491	0.00335	-0.07300	-0.09699	-0.06357	
	12	0.07496	0.02265	0.01164	0.09266	-0.07384	0.51866	0.40473	0.03557	0.06828	-0.07491	0.03557	-0.04361	-0.22707	-0.19344	
	13	0.15516	0.38195	0.25509	0.22379	0.51866	-0.11934	-0.07480	-0.05619	-0.20519	-0.04361	-0.09761	0.75270	-0.12392	0.14354	
	14	-0.04443	-0.12290	0.02755	-0.28906	-0.04737	0.63028	0.05995	0.17102	-0.31900	-0.09699	-0.09761	0.75270	-0.12392	-0.03623	0.59672
	15	0.03281	-0.03418	0.07382	-0.26726	0.00478	0.48667	0.04170	0.11757	-0.50376	-0.06357	-0.19344	0.14354	-0.03623	0.59672	0.78879



# Covariance	5.40794	6.02310	4.88448	7.68953	5.31047	7.60650	6.67870	7.42238	5.83394	6.22383	8.15407	7.63538	4.98917	6.92419	6.87365
1	0.82211	0.53257	0.10165	-0.07941	-0.16697	-0.25918	-0.06773	0.20750	0.06437	0.43372	-0.04131	-0.19130	0.12038	0.13249	0.19304
2	0.53257	0.77657	0.38166	-0.08773	-0.02821	-0.15319	-0.01719	0.10035	-0.08383	0.63032	-0.09678	-0.22415	0.09953	0.01915	0.03916
3	0.10165	0.38166	0.79095	0.08719	0.10121	0.01959	0.06624	-0.00900	0.14017	-0.08857	-0.11112	-0.00488	-0.04140	0.02883	0.02883
4	-0.07941	-0.08773	0.08719	0.41051	0.19094	0.06942	0.09554	-0.08451	-0.05695	-0.02263	-0.07827	-0.01964	0.08532	-0.01498	-0.01498
5	-0.16697	-0.02821	0.10121	0.19094	1.38152	0.29653	0.11461	-0.02544	-0.25710	0.02978	0.01058	-0.00776	0.04441	0.09355	0.20557
6	-0.25918	-0.15319	0.01959	0.06942	0.29653	1.01489	-0.02544	0.63915	0.15794	0.83182	0.24793	0.07178	-0.19645	0.08532	-0.05343
7	-0.06773	-0.01719	-0.06624	0.09554	0.11461	-0.02544	0.63915	0.15794	0.83182	0.24793	0.07178	-0.19645	0.08532	0.06535	0.03706
8	0.20750	0.10035	-0.00900	-0.15824	-0.08451	-0.25710	0.63915	0.15794	0.83182	0.24793	0.07178	-0.19645	0.08532	0.06535	0.03706
9	0.06437	-0.00383	0.14017	0.03159	-0.05695	-0.22863	0.02978	0.24793	1.98682	-0.00980	0.06857	0.18923	0.13140	-0.15264	-0.08774
10	0.43372	0.63032	0.31581	-0.08243	-0.02989	-0.07827	0.01058	0.07178	-0.00980	0.83378	-0.01160	0.05610	0.08532	-0.12858	-0.06220
11	-0.04131	-0.09678	-0.08857	0.18159	0.28580	-0.00876	0.05610	-0.19645	0.06857	-0.01160	0.82133	-0.02557	0.01944	0.00925	0.06493
12	-0.19130	-0.22415	-0.11112	0.04943	0.06651	0.04441	0.08935	0.08532	0.08935	-0.20795	-0.02557	0.93541	0.11923	-0.16542	-0.16943
13	0.12038	0.09953	-0.00488	0.07634	0.77511	0.09355	0.06535	0.13140	-0.11776	0.11113	0.01944	0.11923	1.14643	-0.12764	-0.05572
14	0.13249	0.01915	-0.04140	0.05971	-0.07058	0.02557	-0.05343	-0.15264	-0.12858	-0.01196	0.00925	-0.16542	-0.12764	0.74423	0.45053
15	0.19304	0.03916	0.02883	0.07295	-0.01498	0.03706	0.00273	-0.08774	-0.10802	-0.06220	0.06493	-0.16943	-0.05572	0.45053	0.70499

# Class ID	Number of Cells	Class Name														
7	331															
# Layers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
# Means	5.80363	7.49849	5.72205	7.83082	6.22961	7.59819	5.74924	5.37180	5.55589	6.81873	8.07251	8.32628	6.22054	6.93656	7.15408	
# Covariance																
1	1.01284	0.42546	-0.18505	-0.13635	-0.07296	-0.21248	0.00212	0.08835	0.16404	0.29157	-0.27057	0.10669	-0.14141	0.10265	0.32429	
2	0.42546	0.56591	0.15412	-0.02996	-0.05177	-0.15970	0.03144	-0.25056	0.10590	0.43912	-0.18171	0.00655	-0.09209	-0.01676	0.05326	
3	-0.18505	0.15412	0.58312	0.13768	-0.12307	-0.08778	0.00888	0.10057	-0.22467	0.23431	-0.04039	-0.01521	-0.03548	-0.12375	-0.16917	
4	-0.13635	-0.05177	0.13768	0.55311	-0.08831	0.05000	0.02108	-0.11270	0.04585	-0.02470	0.26978	-0.04160	-0.08379	-0.02592	-0.03749	
5	-0.07296	-0.02996	-0.12307	-0.08831	0.68651	0.06527	-0.09680	0.12351	-0.10984	-0.03704	-0.05609	-0.22666	0.47942	-0.05509	-0.16276	
6	-0.21248	-0.15970	-0.08778	0.05000	0.06527	0.81078	0.03227	-0.10128	-0.14275	-0.00680	-0.15032	-0.10808	-0.15032	-0.05509	-0.16276	
7	0.00212	0.03144	0.00888	0.02108	-0.09680	0.03227	0.80057	0.05407	-0.08746	0.03320	0.10612	0.07904	-0.11726	0.22898	0.04695	
8	0.08835	0.25056	0.10057	-0.11270	0.12351	0.10128	0.05407	1.27059	0.09886	0.27059	-0.07248	-0.30646	-0.00038	-0.14605	0.12966	
9	0.16404	0.10590	0.22467	0.04585	-0.10984	-0.03704	-0.08746	0.09886	1.67793	0.11622	0.04139	0.01504	0.04067	-0.13735	-0.02227	
10	0.29157	0.43912	0.23431	-0.02470	-0.03704	-0.14275	0.03320	0.27059	0.11622	1.56704	-0.18985	0.56704	-0.09626	-0.04487	-0.07774	
11	-0.27057	-0.18171	-0.04039	0.26978	-0.05609	0.08680	0.10612	-0.07248	0.04139	-0.18985	0.99473	-0.04191	-0.05846	-0.02872	-0.00515	
12	0.10669	0.00655	-0.01521	-0.04160	-0.22666	-0.15032	0.07904	-0.30646	0.01504	0.03508	-0.04191	0.77200	-0.14491	0.07531	0.22836	
13	-0.14141	-0.09209	-0.03548	-0.08379	0.47942	-0.10980	-0.11726	-0.00038	0.04067	-0.09626	-0.05846	-0.14491	0.66333	-0.10718	-0.18560	
14	0.10265	-0.01676	-0.12375	-0.02592	-0.05509	0.22898	0.11435	-0.14605	-0.13735	-0.04467	-0.02872	0.07531	-0.10718	0.45966	0.33708	
15	0.32429	0.05326	-0.16917	-0.03749	-0.16276	0.04695	0.12966	-0.28470	-0.02227	-0.04774	-0.00515	0.22836	-0.18560	0.33708	0.60952	

# Class ID	Number of Cells	Class Name														
6	413															
# Layers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
# Means	5.27361	6.60048	5.15012	8.38015	7.68039	7.62228	6.61743	6.51090	6.90315	5.80872	8.74576	8.14286	7.64091	6.99758	7.34867	
# Covariance																
1	0.60700	0.38385	0.08261	-0.02417	0.05611	-0.10271	0.05396	0.23123	0.10666	0.31460	0.04546	-0.10229	0.01862	0.00795	0.08884	
2	0.38385	0.65311	0.25866	-0.00795	0.01520	0.23514	0.28228	0.05102	0.54718	0.08993	-0.12483	-0.10177	0.05486	0.06682	0.06682	
3	0.08261	0.25866	0.64731	0.12241	-0.09753	0.13451	0.27359	0.06147	0.17477	0.40257	0.08923	0.01491	-0.13649	0.11201	0.15141	
4	-0.02417	-0.00795	0.12241	0.60028	-0.09908	0.24831	0.13850	-0.20197	0.32817	0.01949	0.30077	0.21255	-0.13077	0.20723	0.22636	
5	0.05611	0.01520	-0.09753	-0.09908	0.67915	-0.00694	0.04491	0.06174	-0.05045	-0.00789	-0.00864	-0.15569	0.43849	-0.00078	0.01705	
6	-0.10271	0.23514	0.13451	0.24831	1.18222	0.02591	0.24831	0.39398	-0.04442	0.10476	-0.00676	0.14147	-0.21061	0.57190	0.44513	
7	0.05396	0.23514	0.27359	0.13850	0.04491	0.39398	1.12999	0.43379	-0.08326	0.28587	0.11367	-0.03502	-0.14678	0.24664	0.22595	
8	0.23123	0.28228	0.06147	-0.20197	0.06174	0.39398	0.43379	1.28447	-0.06690	0.30185	-0.11494	-0.14112	-0.06291	-0.05944	-0.10818	
9	0.10666	0.05102	0.17477	0.30077	-0.05045	-0.00789	-0.00864	0.10476	1.23817	0.03240	0.09668	0.19834	-0.00011	-0.02451	0.14550	
10	0.31460	0.54718	0.40257	0.01949	-0.00789	0.10476	-0.00864	0.30185	0.03240	1.23817	0.09668	0.19834	-0.00011	-0.02451	0.14550	
11	0.04546	0.08993	0.08923	0.01491	-0.13649	0.11201	-0.13649	0.11201	0.09668	0.08717	0.63666	0.07524	-0.06278	0.15472	0.14954	
12	-0.10229	-0.10177	-0.12483	-0.13077	-0.15569	0.43849	-0.00078	-0.00078	0.19834	-0.06727	0.07524	0.65187	-0.02982	0.10957	0.11026	
13	0.01862	-0.10177	-0.13649	-0.13077	-0.15569	0.43849	-0.00078	-0.00078	0.19834	-0.06727	0.07524	0.65187	-0.02982	0.10957	0.11026	
14	0.00795	0.05486	0.11201	0.20723	-0.00078	0.01705	0.20723	0.24664	-0.05944	-0.00011	-0.02451	-0.10616	-0.06278	0.68954	-0.08823	
15	0.08884	0.06682	0.15141	0.22636	0.01705	0.44513	0.22595	-0.10818	0.14550	0.07171	0.14954	0.11026	-0.03506	0.49114	0.62085	

# Class ID	Number of Cells	Class Name														
9	180															
# Layers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
# Means	6.28889	7.93889	6.30000	8.93889	8.25556	7.55000	5.34444	4.90556	7.19444	7.22222	9.09444	8.55000	8.32222	7.17778	7.60000	
# Covariance																
1	0.77641	0.30267	-0.15978	-0.09957	-0.14128	0.11955	0.28541	0.27883	0.11111	0.22036	-0.16710	0.00223	-0.14388	0.09361	0.16648	
2	0.30267	0.81636	0.24804	0.01300	-0.04922	0.11760	0.12731	0.20643	-0.21710	0.45500	-0.03889	0.06173	0.02539	0.03327	0.01453	

3	-0.15978	0.34804	0.89274	0.00726	0.26369	-0.00950	-0.08156	0.03966	-0.43296	0.43017	0.01061	0.16927	0.25475	0.04693	-0.04693
4	-0.09957	0.01300	0.00726	0.67222	-0.08485	0.09525	-0.34196	-0.23485	0.03988	-0.03104	0.45832	0.17346	-0.09193	0.08914	0.06480
5	-0.14128	0.04922	0.26369	-0.08485	0.91757	-0.14134	-0.04382	0.11924	-0.19522	0.16636	-0.06896	0.00950	0.82781	-0.12390	-0.14302
6	0.11955	0.11760	-0.00950	0.09525	-0.14134	0.96397	0.21732	0.01313	-0.16341	0.07821	0.09302	0.00866	-0.18939	0.60000	0.52849
7	0.28541	0.12731	-0.09156	-0.34196	-0.04382	0.21732	1.70192	0.91539	0.13377	0.11352	-0.21707	-0.08994	-0.06691	0.06691	0.12179
8	0.27883	0.20649	0.03966	-0.23485	0.11924	0.01313	0.91539	1.62790	0.25869	1.01785	-0.23340	0.53135	-0.15813	-0.11999	-0.16747
9	0.11111	-0.21710	-0.43296	0.03988	-0.19522	-0.16341	0.13377	0.25869	1.01785	-0.23340	0.53135	-0.15813	-0.11999	-0.16747	-0.08268
10	0.22036	0.45500	0.43017	-0.03104	0.16636	0.07821	0.13532	0.17753	-0.23340	0.53135	-0.10490	0.05587	0.12911	-0.18560	-0.00559
11	-0.16710	-0.03689	0.01061	0.45832	-0.06896	0.09302	-0.21707	-0.33740	-0.15813	-0.10490	0.94634	0.08184	0.04966	0.06034	-0.01676
12	0.00223	0.06173	0.16927	0.17346	0.00950	0.00866	-0.08994	0.09693	-0.00140	0.05587	0.08184	0.45000	0.03408	0.07250	0.06480
13	-0.14389	0.02539	0.25475	-0.09193	0.82781	-0.18939	-0.06691	0.11999	-0.25295	0.12911	-0.11999	0.03408	0.99056	-0.11906	-0.15531
14	0.09361	0.03327	0.04693	0.08914	-0.12390	0.60000	0.06691	-0.16747	-0.18560	0.04966	0.07250	0.07486	-0.11906	0.60782	0.07822
15	0.16648	0.01453	-0.04693	0.06480	-0.14302	0.52849	0.12179	-0.08268	-0.00559	-0.01676	0.06034	0.06480	-0.15531	0.60782	0.75531

# Class ID	Number of Cells	Class Name													
10	181														
# Layers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
# Means															
# Covariance	6.48066	8.74566	7.42541	8.93923	7.21547	7.93923	6.24309	6.26729	4.74033	8.17127	9.33149	0.15470	7.30939	7.32597	7.54696
1	0.72879	0.35617	-0.13339	0.04604	-0.08192	0.02382	-0.14527	-0.31108	0.47551	0.37277	0.10089	-0.19699	-0.06065	-0.24088	-0.15325
2	0.35617	0.57950	0.24205	-0.05442	-0.03382	-0.05442	-0.29343	-0.19325	-0.11142	0.44932	0.09583	-0.09380	-0.09760	-0.17225	-0.04355
3	-0.13339	0.24205	0.71246	-0.00734	-0.06440	-0.20178	-0.05955	-0.01179	-0.26670	0.31007	0.10264	0.26160	-0.04346	0.19389	0.22713
4	0.04604	-0.05442	-0.00734	0.45740	-0.14650	-0.08705	-0.15737	-0.11578	0.31191	-0.00064	0.18692	-0.05721	0.13002	-0.07452	-0.09435
5	-0.08192	-0.03382	-0.06440	0.14650	1.11443	0.21317	-0.36934	0.07664	0.25071	-0.15933	0.07818	-0.17241	0.79408	-0.12618	-0.16851
6	0.02382	-0.05442	-0.20178	-0.08705	0.21317	0.70184	-0.07959	-0.06578	0.18969	-0.11731	-0.01863	-0.04610	0.11335	0.11992	0.09454
7	-0.14527	-0.29343	-0.05955	-0.15737	-0.36934	-0.07959	1.10724	0.32422	-0.28653	-0.19742	-0.19770	0.33441	-0.23118	-0.26476	-0.26074
8	-0.31108	-0.19325	-0.01179	-0.11578	0.07664	-0.06578	0.32422	1.08367	-0.25276	-0.17170	-0.25132	0.08309	0.07729	0.26476	0.26074
9	0.47551	0.11142	-0.26670	0.31191	0.25071	0.18969	-0.28653	-0.25276	1.60442	0.07805	0.32545	-0.12627	0.16412	-0.08023	-0.08023
10	0.37277	0.44932	0.31007	-0.00064	-0.15933	-0.11731	-0.19742	-0.17170	0.60205	0.07805	0.62050	0.10402	-0.00442	-0.13106	-0.13106
11	0.10089	0.09583	0.10264	0.18692	0.07818	-0.01863	-0.19770	-0.25132	0.32545	0.10402	0.69550	0.05399	0.04687	0.11912	0.13425
12	-0.19699	-0.09380	0.26160	-0.05721	-0.17241	-0.04610	0.33441	0.08309	-0.12627	-0.00442	0.05399	0.73149	-0.07591	0.51041	-0.53714
13	-0.06065	-0.09760	-0.04346	0.19389	0.13002	0.79408	0.11335	-0.23118	0.07729	0.16412	-0.13106	0.04687	-0.07591	0.75320	-0.10350
14	-0.24088	-0.17225	0.19389	-0.07452	-0.12618	0.11992	0.26476	-0.01639	-0.24266	-0.10058	0.11912	0.51041	-0.06252	0.99871	0.77072
15	-0.15325	-0.04355	0.22713	-0.09435	-0.16851	0.09454	0.26074	-0.08023	-0.15163	-0.00531	0.13435	0.53714	-0.10350	0.77072	0.91584

SUMMARY

GRID INPUT :s0305 s0405 s0805 s1205 s1905 s2504 s2705 s2805 s0306 s0505 s1105 s1404 s2095 s2604 s2804

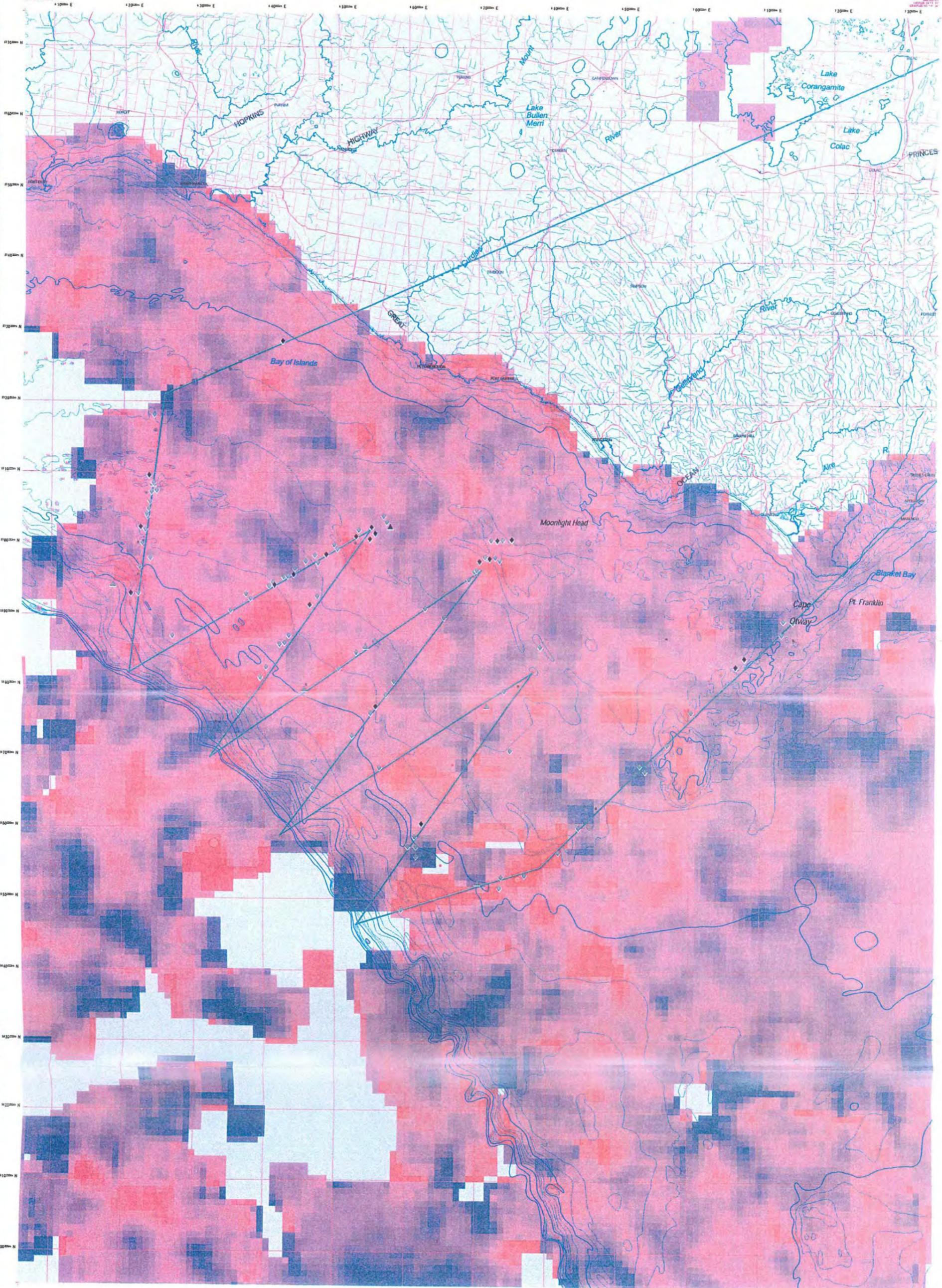
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2		2	2	5076
3		3	3	7704
4		4	4	4704
5		5	5	8200
6		6	6	6124
7		7	7	7272
8		8	8	9200
9		9	9	4236
10		10	10	3956

Record	CONFIDENCE	GRID	qsstav	- all classes	VALUE	COUNT
1			1		8	8
2			2		4	4
3			3		28	28
4			4		76	76
5			5		376	376
6			6		2140	2140
7			7		7736	7736
8			8		14772	14772
9			9		16660	16660
10			10		7868	7868
11			11		5244	5244
12			12		4168	4168
13			13		2180	2180
14			14		4248	4248

APPENDIX D: Sea surface productivity – SeaWIFS raster data

The following are representation of the SeaWIFs processed data for the four days.

SURVEY SUMMARY REPORT -08 May 2001 AND CHLOROPHYLL A LEVEL (0.01 mg/m Blue -64 mg/m Red)



This map was prepared for the Otway Basin Blue Whale Survey as part of the Victorian Energy and Environment Program. It was prepared by the Victorian Department of Natural Resources and Environment and the Victorian Department of Fisheries and Aquaculture. The map was prepared for the period 14 April to 3 June 2001. The map is a summary of the data collected during the survey. It is not intended to be used for navigation purposes.

**Overview**  
This map was prepared for the Otway Basin Blue Whale Survey as part of the Victorian Energy and Environment Program. It was prepared by the Victorian Department of Natural Resources and Environment and the Victorian Department of Fisheries and Aquaculture. The map was prepared for the period 14 April to 3 June 2001. The map is a summary of the data collected during the survey. It is not intended to be used for navigation purposes.

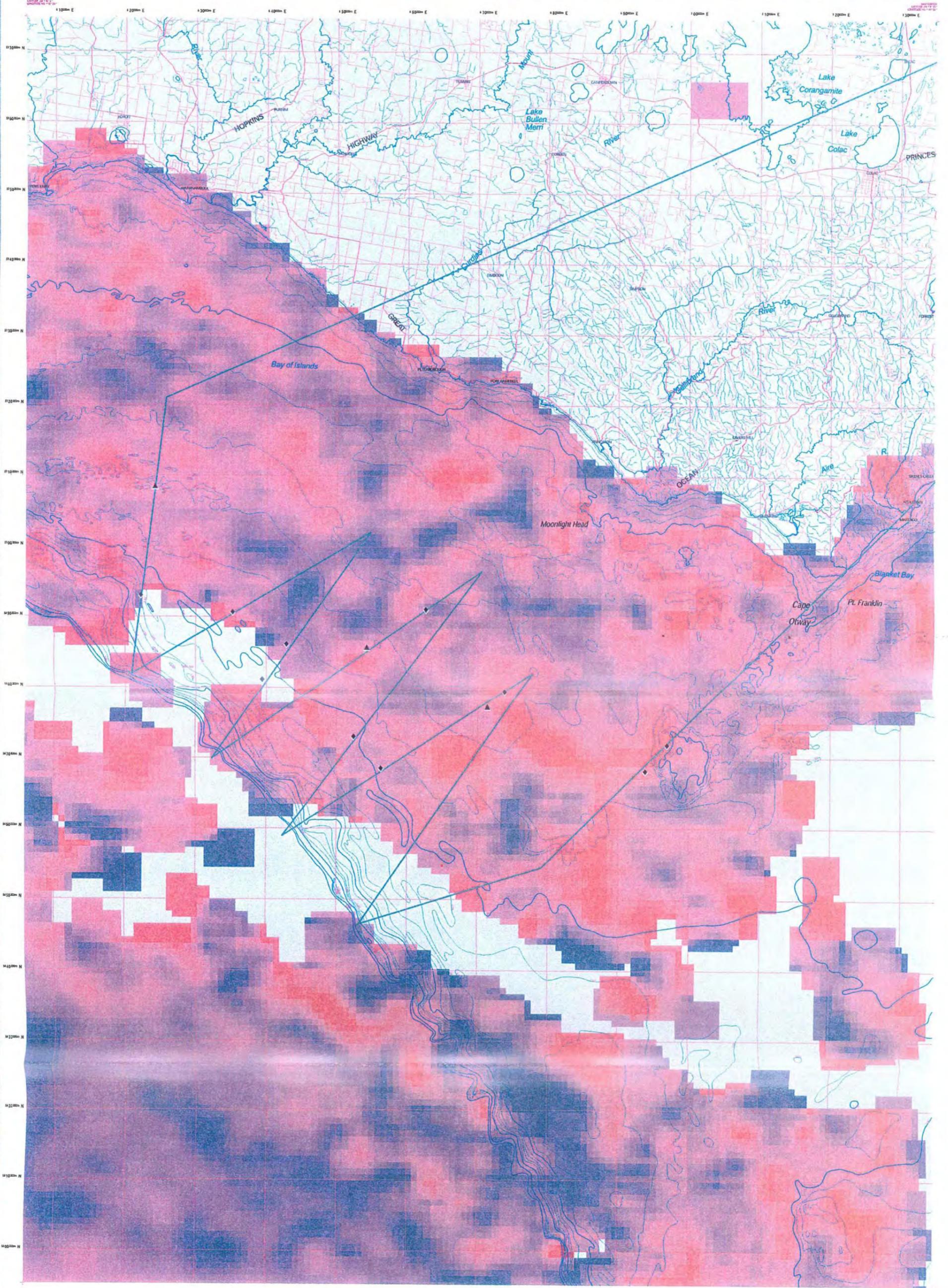
- Otway Basin
- Survey Line
- ▲ Blue Whale
- Blue Whale
- Blue Whale



0 2.5 5 10  
Kilometers

VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM  
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM  
PROJECTION: UTM  
SCALE: 1:50,000

SURVEY SUMMARY REPORT - 14 April 2001 AND CHLOROPHYLL A LEVEL (0.01 mg/m Blue - 64 mg/m Red)



This map was prepared as part of the Otway Basin Blue Whale Survey. It is a product of the Department of Natural Resources and Environment, Victoria. The data was collected during the survey period from 14 April to 3 June 2001. The map is for information only and is not to be used for navigation purposes.

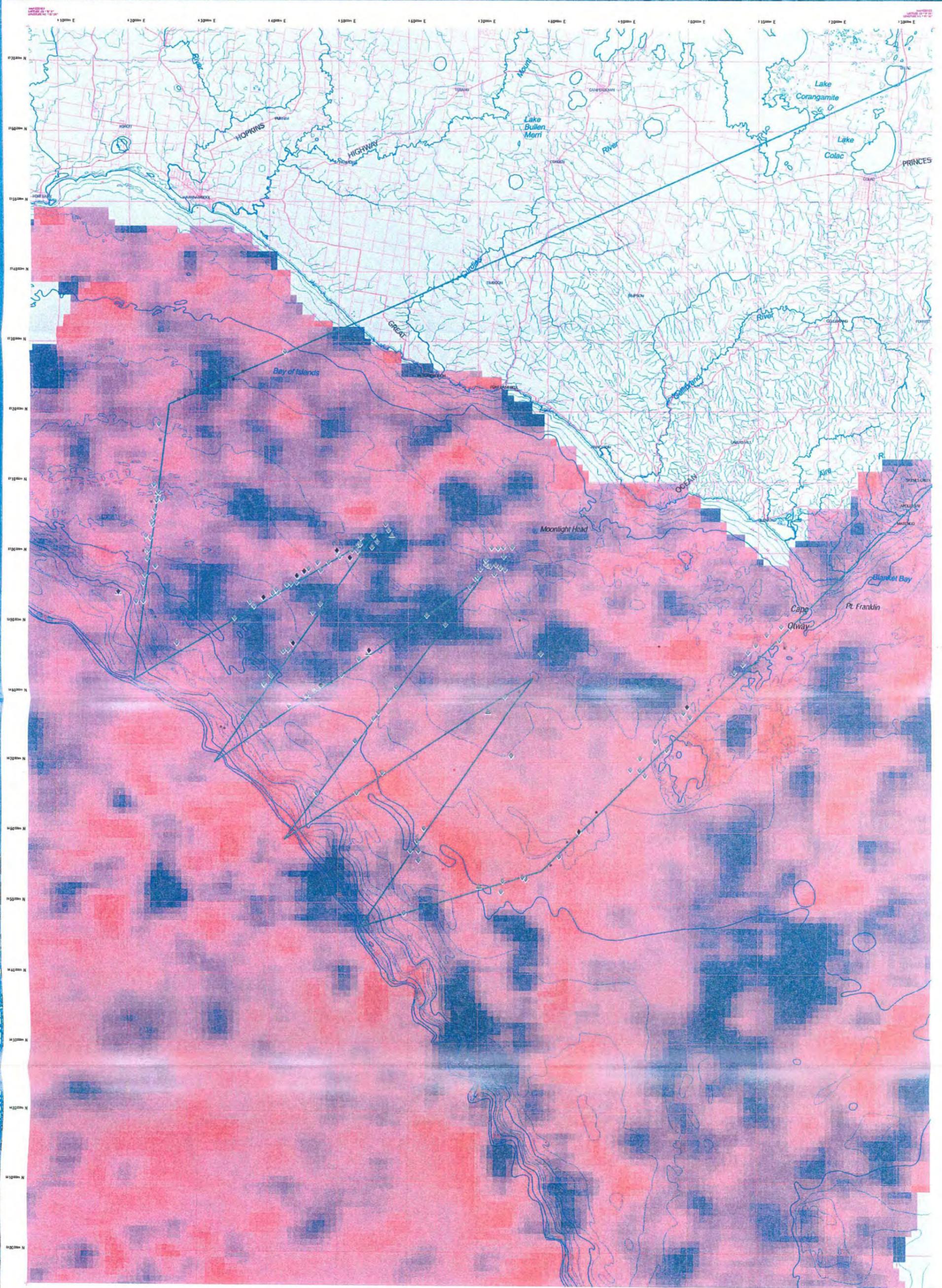
**Disclaimer**  
This map has been prepared for information purposes only and is not to be used for navigation purposes. While every effort has been made to ensure the accuracy of the information, the Department of Natural Resources and Environment does not accept any liability for any loss or damage resulting from the use of this map.

- Contour (10m, 20m, 30m)
- Contour Line
- ▲ Survey Track
- ◆ Survey Track
- OBS Site



MAP SCALE: GRID NORTH  
HORIZONTAL DATUM: GEODETIC DATUM OF AUSTRALIA 1984  
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM  
TRANSFORMED DATUM: AUSTRALIAN DATUM 1984  
GRID INTERVAL: 1000 METRES

SURVEY SUMMARY REPORT - 12 May 2001 AND CHLOROPHYLL A LEVEL (0.01 mg/m Blue - 64 mg/m Red)

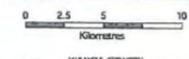


**Spatial Vision**

This map is the result of a collaboration as part of the Otway Basin Blue Whale Research Project - Otway Basin, using information from the Victorian Department of Natural Resources and Environment and Spatial Vision. The map was prepared for the purpose of displaying the survey tracks and chlorophyll a levels. It is not intended for navigation purposes. The map is the property of the Victorian Department of Natural Resources and Environment and Spatial Vision. It is not to be used for navigation purposes.

**Disclaimer**  
This map has been distributed for internal purposes only and is not to be used for navigation purposes. It is not intended for navigation purposes. The map is the property of the Victorian Department of Natural Resources and Environment and Spatial Vision. It is not to be used for navigation purposes.

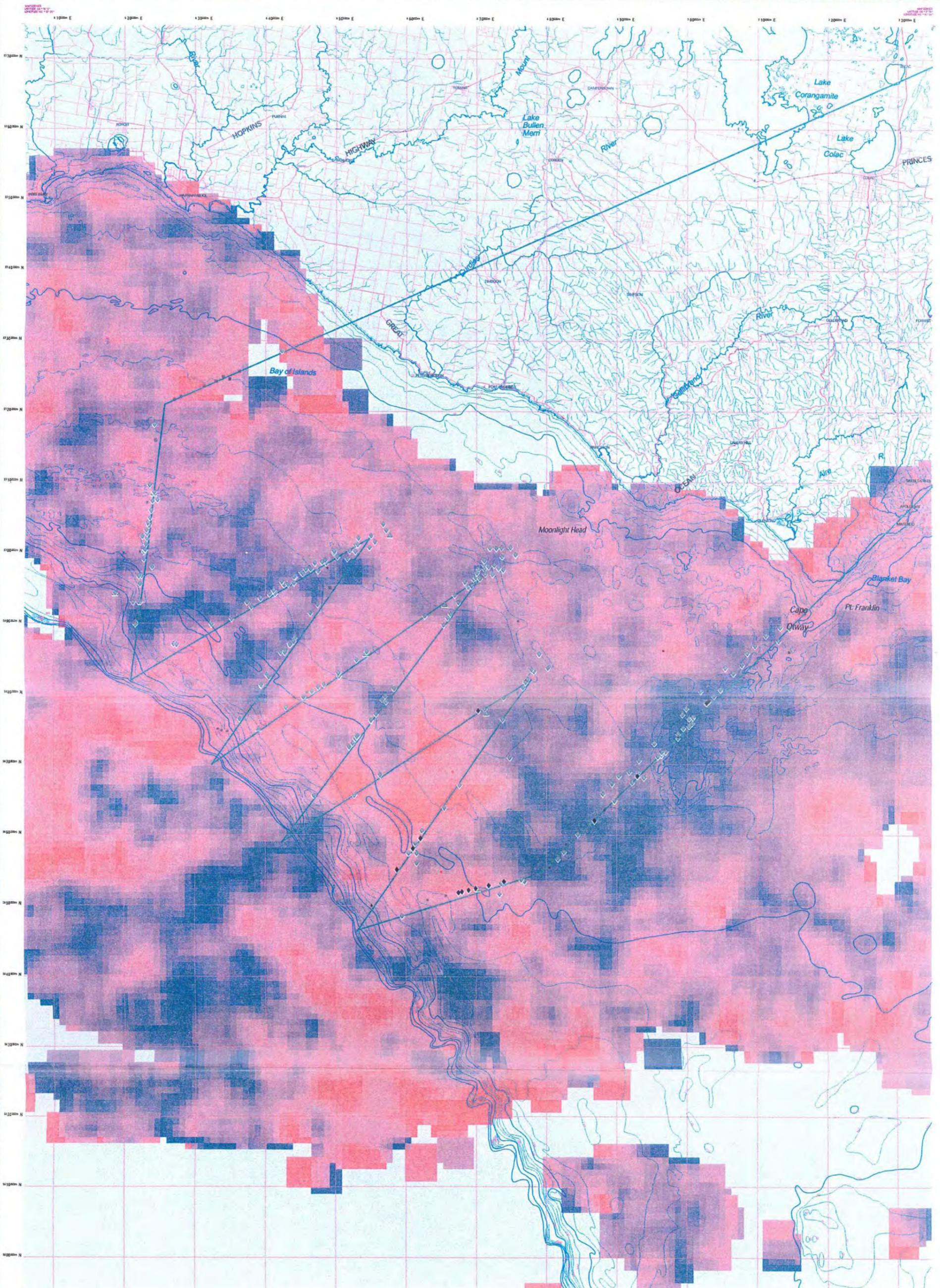
- Survey Flight Path
- Survey Line
- Group
- Blue Whale
- Site
- Depth



0 2.5 5 10  
KILOMETRES

MAP ANGLE: 60.00 NORTH  
HORIZONTAL DATUM: GEODETIC DATUM OF AUSTRALIA 1984  
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM  
TRANSVERSE MERCATOR PROJECTION: UTM  
GRID INTERVAL: 500 METRES

SURVEY SUMMARY REPORT -03 June 2001 AND CHLOROPHYLL A LEVEL (0.01 mg/m Blue -64 mg/m Red)

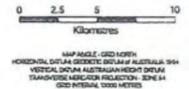


This map is the information product of the Otway Basin Blue Whale Survey - Otway Basin, undertaken by the Victorian Department of Natural Resources and Environment and Spatial Vision. It is a product of the Otway Basin Blue Whale Survey. The map is a product of the Otway Basin Blue Whale Survey. The map is a product of the Otway Basin Blue Whale Survey.

**Source:**  
 Department of Natural Resources and Environment (DNRE)  
 Victorian Department of Planning and Environment (VDE)  
 Spatial Vision  
 Level 1, 175 Queen Street, Melbourne, Victoria 3000  
 Email: info@spatialvision.com.au

**Legend:**

- Green line: Ocean Floor
- Blue line: Coast Line
- Star: Survey
- Triangle: Blue Whales
- Diamond: WOs
- Square: DRSs



MAP SCALE: GRID NORTH  
 HORIZONTAL DATUM: GEODESIC DATUM OF AUSTRALIA 1984  
 VERTICAL DATUM: AUSTRALIAN MEAN SEA LEVEL  
 TRANSFORMED MERCATOR PROJECTION: EPSG:314  
 GRID INTERVAL: 1000 METRES