Ministry for Primary Industries
Manatū Ahu Matua

Generating random transects in PAU 5D using the NIWA survey design tool

New Zealand Fisheries Assessment Report 2016/16

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New Zealand Government

Growing and Protecting New Zealand

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EXECUTIVE SUMMARY

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Objective 2 of the Ministry for Primary Industries' project PAU 2008-02 involved timed-swim surveys of PAU 5D to estimate the abundance of paua in the commercial fishery. After two reviews of the timed-swim methodology it was concluded that the relationship between abundance and the survey indices was unlikely to be linear. The Shellfish Working Group decided to discontinue these surveys and to trial lead-line transect survey methods within part of PAU 5D to assess whether the variance associated with density estimates was low enough for the estimates to usefully inform the stock assessment model. The Shellfish Working Group discussed and agreed upon a survey methodology, which included the random selection of sites and a means of ensuring that transects were traversed perpendicular to the shore. To facilitate the design of surveys NIWA developed a survey design tool available to use in the open source GIS application QGIS.

This document describes the survey design, the survey tool, and provides instructions of the use of the survey tool which is available from the standard QGIS plugin repository as "Survey design plugin".

1. INTRODUCTION

In the past, timed swim surveys have been used to estimate the relative abundance of paua in PAU 5D (Andrew et al. 2000, 2002, McShane et al. 1996, Naylor & Kim 2004). Following two independent reviews of the method (Cordue 2009, Haist 2010) the Shellfish Working Group concluded that it may not provide a reliable index of paua abundance. A Technical Working Group convened by the Ministry of Fisheries in September 2011 determined that lead line transect methods would be more likely to provide reliable estimates of paua abundance.

In early 2013, in discussion with the Shellfish Working Group, a transect methodology was developed using an area in PAU 5D (between the eastern boundary of Statistical Area 12 and the northern boundary of Statistical Area 32, Figure 1) as a test case for how the methodology would work in the field. Recommendations from the Working Group were that transects should be chosen randomly with a minimum distance between sites to prevent clumping, transects should run from the level of mean spring low tide on the shore and out to sea in a line perpendicular to the shore and the determination of perpendicular should be prescribed rather than be done by eye. To minimise the variance associated with transects, it was also recommended to stratify the coast into areas of perceived high, medium, and low abundance. The random allocation of samples within these non-contiguous areas and the determination of the bearings resulting in transects being perpendicular to the shore required NIWA's development of a NIWA survey plugin for QGIS. The QGIS survey tool and the recommended methods for conducting lead line transect surveys in the PAU 5D fishery are described below.

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2. METHODS

2.1 Transect methods

The proposed method would be to use lead line transect methods within a stratified random sampling framework to estimate paua density within an area of PAU 5D (Figure 1).

The QMA should be stratified into areas expected to have similar levels of density. These areas should be chosen in consultation with commercial paua divers. All sites containing paua habitat should be available for selection. The location of transects within strata should be chosen randomly.

The Shellfish Working Group agreed that a total of 68 transects should be sufficient to assess the variance associated with estimates so a total of 68 transects were chosen using the survey plugin. In the field this would require about 12 days of diving under near perfect conditions.

It is recommended for PAU 5D that five categories of strata should be used. These are:

1. Areas of high catch.
2. Areas of moderate catch.
3. Areas of low catch.
4. Areas closed to commercial fishing.
5. Areas of sand (i.e. of no paua habitat)

Because of the very large coastline within the QMA, the level of sampling should be varied between strata, i.e. more transects should be allocated to the strata which provide most of the catch, and fewer should be allocated in strata which provide little or none of the catch. The number of transects that would be selected for each category is shown in Table 1. The number of transects in each category was

arbitrarily based on perceived importance to the fishery, i.e. more survey effort was allocated to areas of high catch. No transects were selected in closed areas or in areas of sand.

Table 1: Number of transects selected for categories of strata.

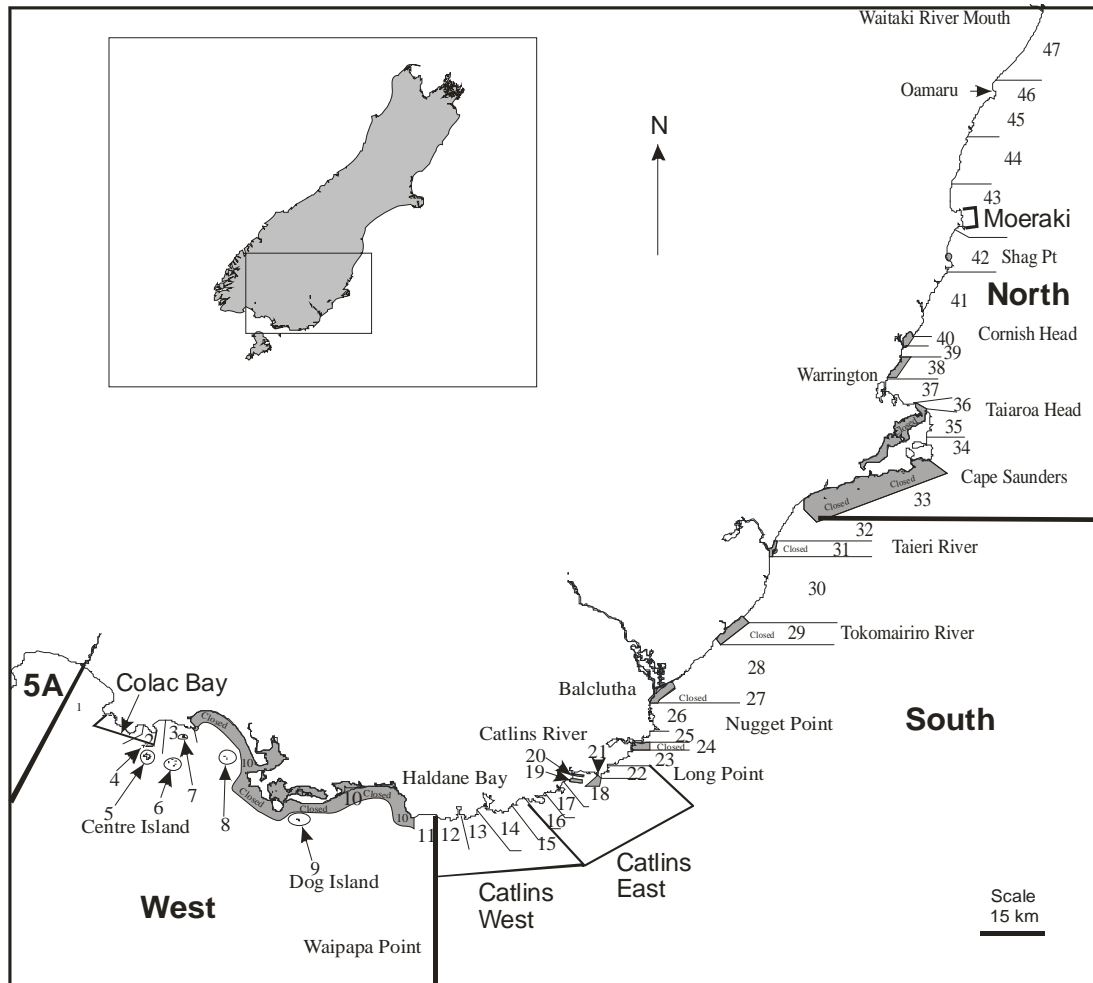| Category	Number of transects
High catch	32
Moderate catch	20
Low catch (one stratum)	16

Figure 1: Map showing the boundaries of the four high catch strata in PAU 5D, labelled, from east to west, as Colac Bay, Catlins West, Catlins East, and Moeraki. Shaded areas represent areas closed to commercial fishing. The boundaries of the western, southern, and northern parts of the QMA are also shown.

Transects would run perpendicular to the trend of the coast beginning at mean low-water spring (MLWS) to a depth of 10 m or until the reef habitat runs out. Each randomly selected point within the GIS framework should be associated with an automatically calculated heading from which an orthogonal heading can be calculated. If the pre-determined heading is clearly not perpendicular to the shore because of the scale of digitisation, the divers should take bearings on points equidistant from the site, and calculate a bearing that bisects those bearings. If, because of the configuration of the coastline this method does not produce a transect direction which appears to be close to perpendicular to the trend of the coast, divers should use their discretion in choosing a bearing. Transect bearings used at all sites should be recorded on the data sheets, along with the method used to choose the heading.

Most paua are found at depths shallower than 10 m relative to MLWS, however, this limit also allows divers to do many more dives during a day than deeper diving would allow. Tide levels above MLWS should be calculated for each randomly selected site at 15 minute intervals over the period of the field trip using NIWA's tide forecasting model. To standardise depth between sites at different phases of the tide, the difference between MLWS and the tidal height, at the time the transect is started, should be recorded on each diver's slate and subtracted from the depth showing on the diver's computer. A marked lead line should be laid out by two divers and each should count the number of paua within one metre of one side of the line. If paua are judged to be more than 50% within the 1 m band they should be counted as inside the transect band. If they are more than 50% outside of the band they should not be counted. If paua are judged to be half in and half out, on one (randomly chosen) side of the transect, the first should be counted as in, the second should be counted as out, and thereafter alternating. On the other side of the transect, the first paua in this category should be counted as out, the second as in, and so on.

Information on sea state should be recorded at each site on a five point scale corresponding to the following categories:

    1   = calm
    2   = wind chop
    3   = swell < 1 m
    4   = swell 1 – 2 m
    5   = swell > 2 m

Information on topography should be recorded at each site based on the following categories of bottom type:

    1   = solid reef
    2   = huge boulders
    3   = rocks (0.25 m^2)
    4   = cobbles
    5   = pebbles/gravel
    6   = conglomerate
    7   = sand

The dominant macro algae at each site should also be recorded as should the relative numbers of kina and rock lobsters (on a four point abundance scale between absent, low, medium, or high).

Three divers should be deployed to the field. Only two divers should do transects on any one day. Divers should rotate in a systematic fashion so that all combinations of divers do transects. The side of the transect that each diver surveys should be chosen randomly at all sites and counts between divers on each side of the transect line should be analysed for systematic bias, which should be removed from the survey estimates by standardisation.

If weather conditions precluded the transect beginning at MLWS, the transect should not be done at that time, and divers should proceed to the next randomly selected site.

The number of paua present should be recorded in three depth categories, 0 to 2 m, 2 to 5 m, and 5 to 10 m below MLWS. Depth should be measured using wrist-mounted Suunto dive computers which should be calibrated at three monthly intervals. The distance from shore at which these depths occur should also be noted. Divers should carry a 1 m plastic pole perpendicular to the transect to define their search area. The length of each transect should also be recorded. Within each of the three depth categories, if paua density was relatively low, divers should collect all paua encountered. If the density of paua was moderate or high, divers should collect every second, third, fourth or more paua in a systematic fashion such that the paua are collected as evenly as possible over the length of reef within each depth category, and such that the number of paua collected from each depth category does not occupy more than an

estimated one third of the catch bag (in the order of 100 paua, depending on size, i.e. paua from deeper depth categories should not be excluded from collection because too many paua from shallower depth categories have been collected).

Paua should be measured to the nearest millimetre on board the vessel using vernier calipers and then replaced back on the reef by the divers. The maximum length of any transect should be 150 m, however, in reality, the depth limit of 10 m will usually be reached well before this.

The variance associated with density estimates for each stratum should be examined once transects in all strata have been completed. This should allow an assessment of whether a time series of indices derived using this methodology can be usefully incorporated into the stock assessment for this QMA.

2.2   NIWA survey design tool

A random stratified survey tool was developed using the open source GIS application QGIS. The software was developed by Brent Wood (NIWA) and Dr. Marco Hugentobler (Sourcepole, Zürich, Switzerland). Appendix 1 provides a guide to the use of the software and Appendix 2 describes the algorithms used to generate the random starting points for transects and the bearing of transects.

The initial data set used was a national coastline (land) polygon shapefile (available from http://data.linz.govt.nz with a user account). The polygon shapefile was then converted into a line representing the coastline rather than a polygon. A buffer polygon 300 m wide was then generated and clipped to the coastline to retain the offshore component. This polygon was divided into individual regions according to the categories of abundance or habitat ascribed by three commercial paua divers familiar with this section of coast (Ross Newton, Steven Newton, and Craig Leith, Table 2). The separate regions were then accumulated into multipolygon strata as follows:

Table 2: Strata key.

Object identifier	Stratum	Key
1	high	
2	medium	
3	low	
4	sand	
5	closed	

After specifying the transect parameters (number of transects and the minimum distance between sites, Table 3) the survey tool was used to randomly generate transects. The minimum distance between sites was estimated as the length of coastline (metres) divided by the number of transects and multiplied by 0.2 (the software calculates the shoreline length of each stratum). The basis of minimum distance calculation is that it appears sensible.

Table 3: Survey parameters.

Object identifier	Stratum	Number of transects	Minimum distance
1	high	32	200
2	medium	20	345
3	low	16	800
4	sand	0	0
5	closed	0	0

The random numbers for transect starting points are generated in C++ using an implementation of the fast pseudo-random number generator (Matsumoto &Nishimura 1998), (Table 4).

For each stratum, the program creates a buffer linestring, approximately 200 m offshore from the baseline, which is clipped to the stratum. At each randomly chosen starting point, the bearing to the closest point on this buffer line is calculated, and the transect is generated along this bearing and clipped to the stratum.

3.   RESULTS

A total of 68 transects were chosen in the southern area, 32 in the areas of high abundance, 20 in the areas of medium abundance, and 16 in the areas of low abundance. No sites were selected from areas designated as either 'closed' or 'sand'. Transect start positions and transect bearings which ensure that transects are close to perpendicular to the shore are shown in Table 4 and an example of the output from the survey tool is shown in Figure 2.
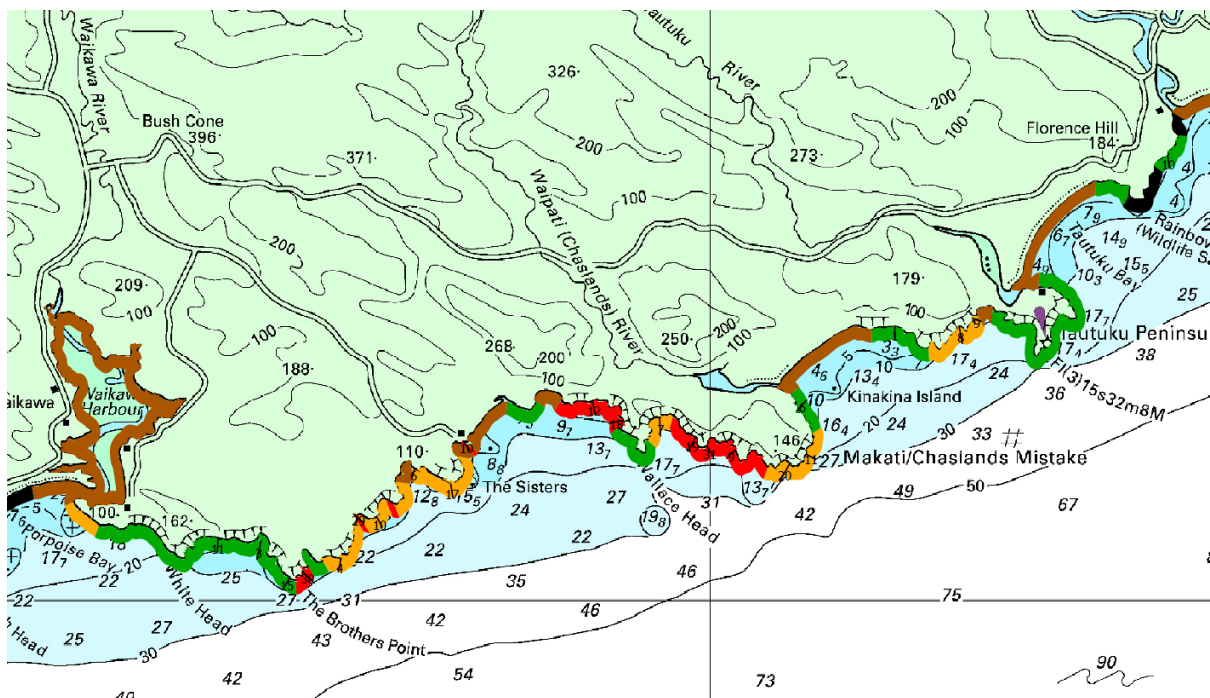

Figure 2: An example of output from the survey tool showing numbered transects within strata. Colours reflect the strata shown in Table 1.

Table 4: Transect start positions and bearings for high, medium, and low abundance strata.

Station ID	Stratum ID	Station	Start latitude	Start longitude	Bearing
1	high	high_1	-46.6740	169.0005	204.1
2	high	high_2	-46.6726	169.0149	160.4
3	high	high_3	-46.5356	169.6574	143.0
4	high	high_4	-46.4683	169.7740	192.1
5	high	high_5	-46.6664	169.0774	166.3
6	high	high_6	-46.4677	169.7762	90.4
7	high	high_7	-46.6723	169.0588	180.1
8	high	high_8	-46.4685	169.7626	193.5
9	high	high_9	-46.6345	169.3411	224.7
10	high	high_10	-46.6326	169.2566	146.1
11	high	high_11	-46.4462	169.8033	198.2
12	high	high_12	-46.6242	169.2968	168.3
13	high	high_13	-46.4483	169.8140	161.0
14	high	high_14	-46.6726	169.0190	175.3
15	high	high_15	-46.6722	169.0081	175.5
16	high	high_16	-46.4492	169.8107	199.5
17	high	high_17	-46.5402	169.6168	182.8
18	high	high_18	-46.6282	169.3063	260.1
19	high	high_19	-46.6319	169.3288	207.5
20	high	high_20	-46.5565	169.6120	17.6
21	high	high_21	-46.5400	169.6213	174.4
22	high	high_22	-46.4479	169.8067	179.8
23	high	high_23	-46.5342	169.6599	148.8
24	high	high_24	-46.6719	169.0627	158.0
25	high	high_25	-46.4598	169.7817	74.0
26	high	high_26	-46.5388	169.6531	171.6
27	high	high_27	-46.5387	169.6397	140.9
28	high	high_28	-46.6704	169.0553	304.6
29	high	high_29	-46.6481	169.2226	130.6
30	high	high_30	-46.6604	169.2067	133.8
31	high	high_31	-46.6337	169.3325	150.0
32	high	high_32	-46.5389	169.6496	171.7
1	medium	medium_1	-46.5272	169.6724	172.3
2	medium	medium_2	-46.6697	168.9728	186.0
3	medium	medium_3	-46.6680	168.9600	207.3
4	medium	medium_4	-46.6577	169.2186	190.7
5	medium	medium_5	-46.4791	169.7549	159.7
6	medium	medium_6	-46.6386	169.2414	194.2
7	medium	medium_7	-46.6278	169.3177	177.1
8	medium	medium_8	-46.6080	169.4108	169.6
9	medium	medium_9	-46.6065	169.4149	107.7
10	medium	medium_10	-46.6488	169.2298	151.6
11	medium	medium_11	-46.6354	169.3635	120.0
12	medium	medium_12	-46.5207	169.6945	182.7
13	medium	medium_13	-46.4815	169.7524	195.5
14	medium	medium_14	-46.5331	169.6611	128.8
15	medium	medium_15	-46.6686	168.9956	255.6
16	medium	medium_16	-46.6618	168.9489	213.3
17	medium	medium_17	-46.6419	169.2528	171.4
18	medium	medium_18	-46.6678	168.9783	133.3
19	medium	medium_19	-46.5218	169.6904	177.4
20	medium	medium_20	-46.6375	169.3580	209.5
1	low	low_1	-46.6081	169.3908	181.6
2	low	low_2	-46.0995	170.1978	134.0
3	low	low_3	-46.6539	169.1938	192.7
4	low	low_4	-46.1625	170.1524	121.8

Station ID	Stratum ID	Station	Start latitude	Start longitude	Bearing
5	low	low_5	-46.5149	169.6936	62.3
6	low	low_6	-46.6257	169.3609	42.7
7	low	low_7	-46.3078	169.9052	176.2
8	low	low_8	-46.5655	169.5897	180.5
9	low	low_9	-46.1839	170.1261	160.7
10	low	low_10	-46.5717	169.4756	170.8
11	low	low_11	-46.6535	169.1804	182.9
12	low	low_12	-46.5582	169.6115	168.6
13	low	low_13	-46.4793	169.7496	264.6
14	low	low_14	-46.1890	170.1163	173.9
15	low	low_15	-46.6616	169.2028	209.3
16	low	low_16	-46.1275	170.1842	24.1

4. DISCUSSION

The document outlines a transect survey which appears to be robust and has been discussed and agreed to by the Shellfish Working Group. While not implemented in the field, the survey tool is likely to have wide application in future surveys in the selection and direction of transects. The issue of 'perpendicular to the shore' is made complex by the scale over which perpendicular is estimated. Assessing this at too fine or too coarse a scale is likely to result in transects that are either impractical or do not adequately represent the entire depth range of available paua habitat. In practice, the direction that is perpendicular to the shore is usually subjectively estimated by eye before the transect is laid out. The Shellfish Working Group; however, thought that the transect bearing should be more prescribed than this. We believe that the approach adopted within the survey design tool adequately addresses this issue and deals relatively well with convoluted coast because the transect bearings selected are close to perpendicular to the trend of the coast. The method eliminates transects being chosen which are parallel to the coast which in turn allows the entire coastline to be available for random selection. Transects parallel to the coast may not cover the entire depth range of paua habitat, and because transects cannot overlap, the coastline landward of a parallel transect would be excluded from random selection.

The ability of the survey tool to select random starting points within non-contiguous categories of coast is also advantageous because stratification based upon known or perceived density may reduce the variance associated with density estimates.

Over time, transect surveys may usefully indicate trends in density, which like other indices, may be incorporated into stock assessment models. The estimation of absolute biomass; however, is much more difficult and is not addressed here. This requires an estimate of reef area, which is confounded to some extent by temporal changes in reef area caused by the movement of sand. On a straight coastline, the calculation of reef area is relatively simple, requiring only an estimate of the reef's extension offshore. Transect density can then be multiplied by the area of reef running out from the beginning of the transect at the low water mark. Each sampling point along the coast therefore has a reef area associated with it to which an estimated density can be extrapolated. In the more usual case, where the coast is either a headland or a bay, the calculation of the reef area is more complicated, because on a headland the metre transect starting point on the shore will be associated with a greater reef area offshore (adjacent perpendicular transects are divergent) and in a bay it will be associated with a lesser reef area offshore (adjacent perpendicular transects are convergent). While the software could be developed to estimate areal parameters along a convoluted coast, there appears to be no compelling reason to do so.

QGIS is a free, open source, desktop mapping tool which is available at: http://www.qgis.org.
The plugin is available from the standard QGIS plugin repository as "Survey design plugin".

5.   ACKNOWLEDGMENTS

6.   REFERENCES

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7. APPENDIX 1

Random stratified survey tool with QGIS and the NIWA survey tool.

Introduction.

This document describes a survey design tool available within QGIS for designing random stratified surveys. This approach to designing a survey allows the user to divide the survey area into arbitrary sub-areas (strata) which are sampled randomly and largely independently. This allows sampling effort to be allocated as appropriate throughout the survey area, perhaps prioritising higher value or more important areas.

Typically, tools to design such surveys generate random points (stations or sample sites) throughout each stratum, with the user specifying how many to generate and the minimum distance between stations for each stratum. This tool can do this. Where it differs from most other such tools is that it can also be used to generate random transects, rather than points. This is designed to support coastal surveys, where random transects running out from the coast are required, rather than scattered points.

This example will generate strata representing Paua Statistical Areas, along the south east of the South Island, clipping the transects to no more than 300 m from the coast. It assumes you are already familiar with the basic use of QGIS, for zooming in and out, selecting features, etc.

Transect survey design.

The survey tool requires as minimum input, a dataset of strata to generate sample points within. If you want to create transect lines, you also need to provide a baseline from which to propagate the transects. This document describes how to generate transects for a dive survey for paua (abalone) along a section of New Zealand coast. The initial datasets used are a national coastline (land) polygon shapefile (available from http://data.linz.govt.nz – a user account is required), and a Paua Statistical Area dataset which can be requested from the NABIS team at nabis@mpi.govt.nz.

From these two datasets, you can use QGIS to derive all the input datasets required to create random transects for a diver survey.

The steps to follow are described here. They assume that you have downloaded and uncompressed the datasets (map layers) described above, and that QGIS is running. The preparatory work uses standard QGIS functionality. The actual transect generation uses the NIWA Survey tool.

1. Open the datasets.

Click *Layer* in the menu bar, then choose *Add Vector Layer.*
Click the *Browse* button, ensure that the file type is set to ESRI shapefiles, and navigate to where you put your copy of the nz_coasts_and_islands shapefile. Choose this and open it. Repeat for the STATAREA_2_4_5.shp shapefile you downloaded from NABIS (Figure 1).

The statistical areas are not clipped to the coastline, but extend inland. This allows the same statistical area polygons to be used with various versions of the coastline, and for coastlines to be updated and maintained without requiring all the statistical area maps to be rebuilt each time. You can select a layer in the right hand list of Quantum Map and change the order they are displayed in, so the coast layer can be moved above the statistical areas layer, which hides the inland part of the polygons and looks tidier.

If we are to use these statistical areas as survey strata, however, we need to clip them to the coastline, and ideally clip them just off the coastline, so the transects we generate just follow the coast. Paua are not found far from the coast and a dive survey cannot extend past shallow water.
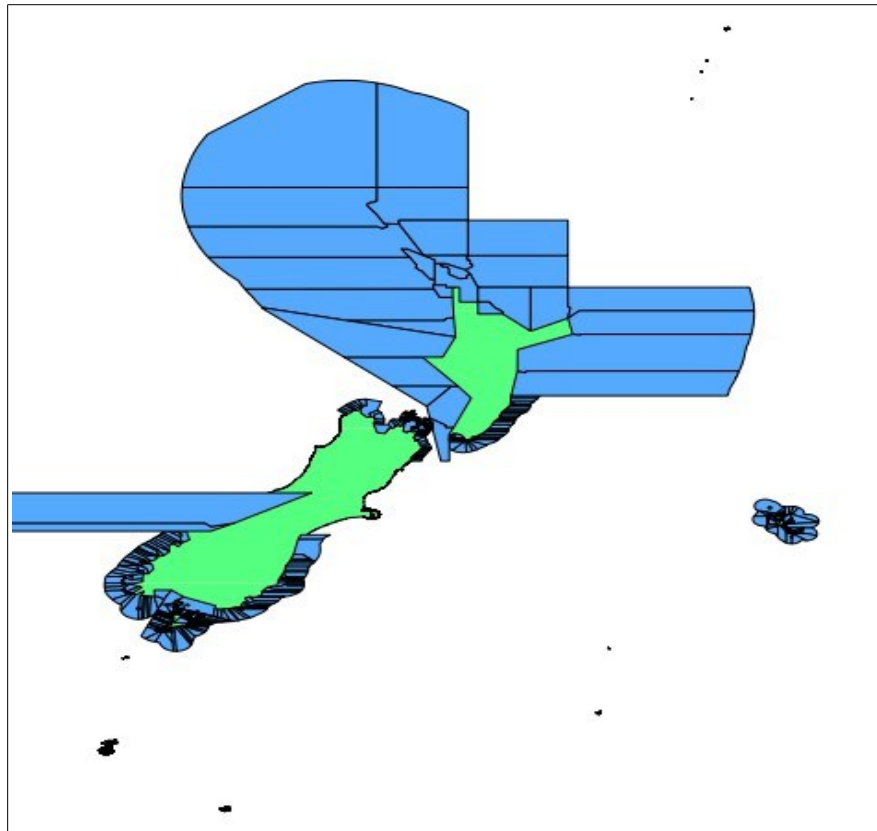
Figure 1: Base layers of coast polygons and Paua Statistical Areas downloaded from LINZ and NABIS respectively.

2. Create the survey coastline.

The survey tool uses a line as the base to propagate transects from. In this case, we will use the coastline, so we need to convert the polygon coastline of the South Island into a line instead of a polygon. We could convert the entire New Zealand coast, but will just use the South Island for this example.

Start by using the select tool to select the South Island (should show as yellow), then click *Layer* then *Save Selection as Vector File*. Browse to where you want to save the new shapefile, enter the name (something meaningful like South_is_coast, and save it. This will create a new shapefile containing just the South Island. Open this layer. We no longer need the nz_coasts_and_islands layer, so can remove it from the map

We now need to generate the linestring coast from the South Island polygon. Click *Vector; Geometry tools; Polygons to lines*. Select the south island polygon layer and browse to the location to save the new shapefile for storing the line data, then save it, you can add this to the TOC (table of contents) after saving it (Figure 2).
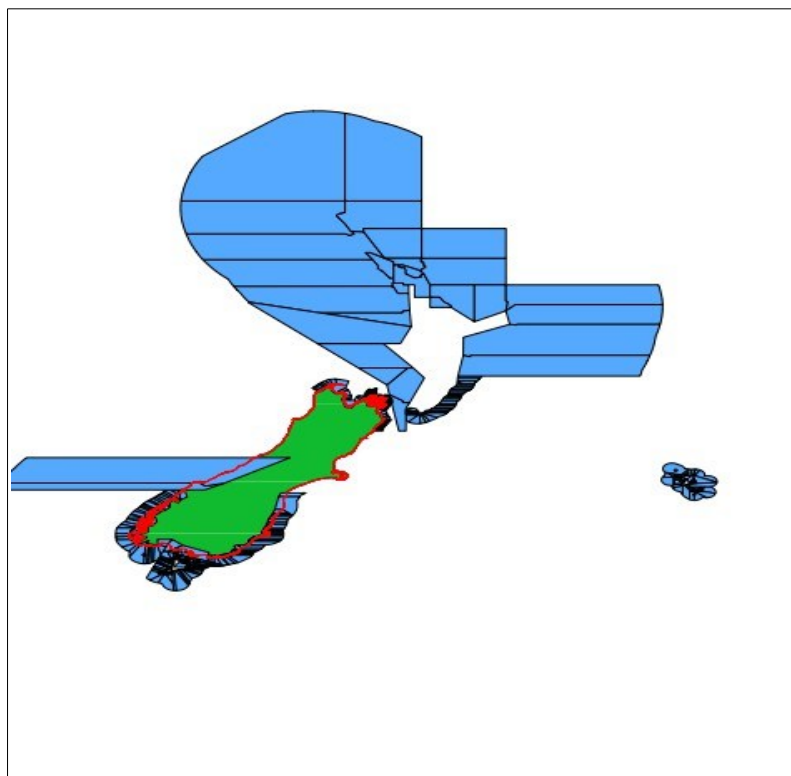
Figure 2: Statistical areas, South Island polygon and South Island coastline linestring in red.

3. Create the survey strata.

We now need to create a dataset containing just those statistical areas that we want to use to define the survey area. We will choose a few from the map and save those as a new shapefile. Make sure the statistical area map is the currently active layer in the map, choose the Select Features by Rectangle selection tool and select the required statistical areas for the survey (Figure 3).
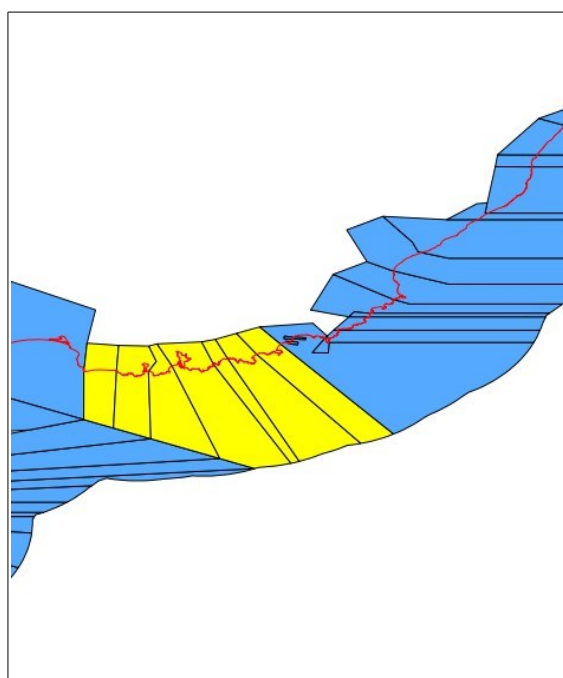
Figure 3: Statistical areas and coastline for the south eastern South Island, showing the selected statistical areas which comprise the survey area.

Use the *Layer; Save Selection as Vector File* tool again to save these areas as a new shapefile. Use a meaningful name (this makes things much easier when you come back to this after a few weeks and try to remember what all these shapefiles represent) such as survey_stat_areas.

4. Clip the coastline to the survey area.
Now we have a dataset defining the survey area, we can clip the South Island coastline we created previously to this area. Choose *Vector; Geoprocessing tools; Clip.* The Input vector layer is the South Island coastline linestring shapefile, browse to name the new file, perhaps survey_baseline (Figure 4).
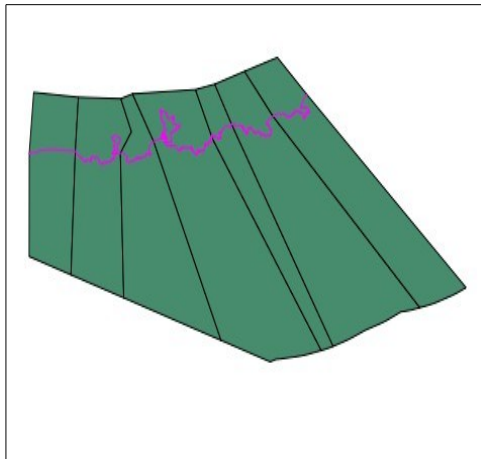
Figure 4: Statistical areas defining the initial area and the final survey baseline, from which the survey tool will propagate the transects.

5. Clip the stat area to the coastline.
The statistical areas include some land, inside the coastline. We do not want our survey transects to extend inland, so we can clip the areas with the coastline. Choose *Vector; Geoprocessing; Difference* with the input layer the new survey_stat_areas dataset and the South Island polygon as the difference layer (Figure 5).
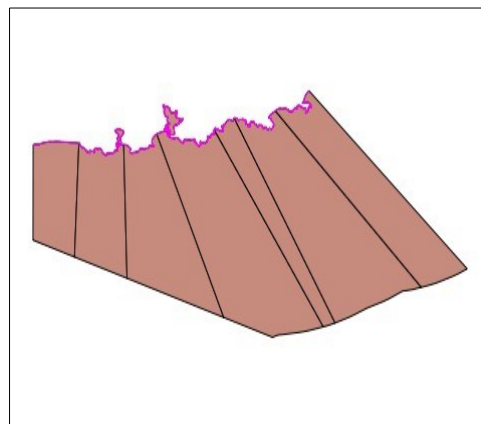

Figure 5: Statistical areas for the survey clipped to the coastline, by creating a new shapefile containing those parts of the statistical area polygons which are not part of the South Island polygon.

6. Create the final survey strata polygons.
This is a paua dive survey, and we want to restrict the survey area to a zone approximately 300 m wide along the coast, as divers will not be surveying outside of this area. There are two steps to this process:

      a. create a polygon defining the area approximately 300 m off the coastline (survey baseline)

      b. clip the survey area polygons based on the statistical areas to this new polygon.

The actual distance need not be accurate, so we are not going to reproject the data to make these calculations more accurate. We are working in a lat/long map, using degrees as the map unit, so given that 110 000 m are roughly one degree, 300 m = 300/110 000 (or 0.00273) degrees.

To create the buffer polygon, use *Vector; Geoprocessing tools; Buffer.* Use the survey baseline as the dataset to be buffered, enter: 0.00273 as the distance, click *Browse* to name the new shapefile and save it and add it to the map (Figure 6).
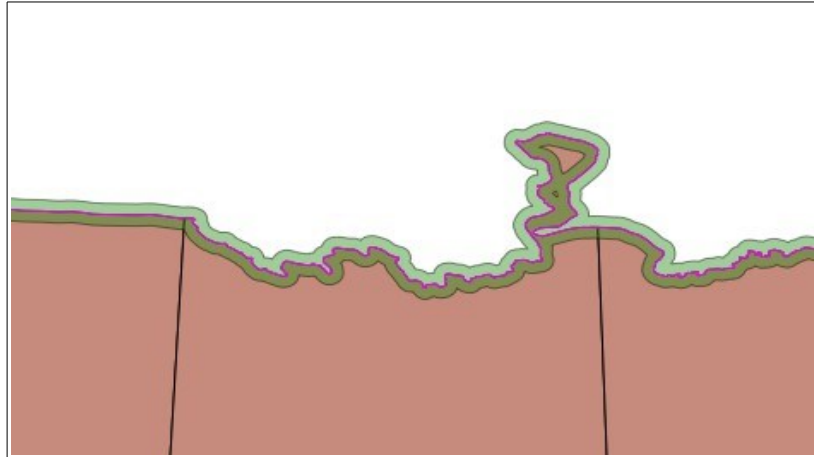
Figure 6: Zoomed in to show part of the survey area, with the statistical areas clipped to the coast, the coast baseline and the new buffer, shown partly transparent.

We can now clip the stratum areas to this coastal buffer polygon to create a set of strata polygons representing the required statistical area polygons clipped to this buffer. Choose *Vector; Geoprocessing tools; Clip, as before,* but use the new layers. Use the statistical areas clipped to coast as the source layer, clipped by the baseline buffer polygon. Save it as a new shapefile (survey_strata). This is the final step in creating the survey strata polygons, but there a few things to do before we can generate the transects.
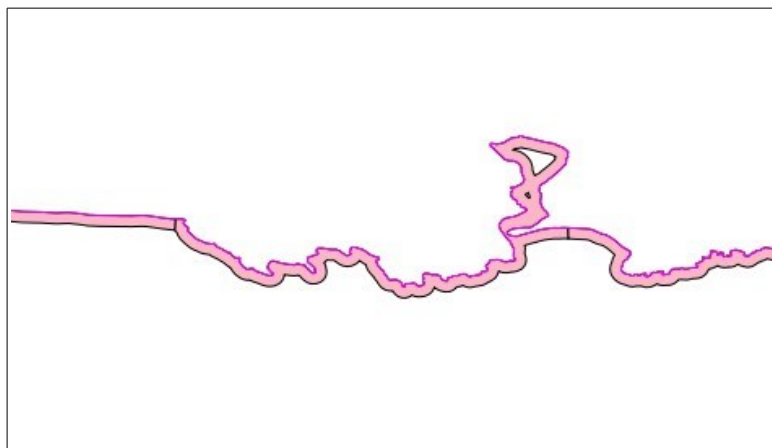

Figure 7: The same zoomed in extent but showing the final strata areas for the survey, running about 300 m along the coast.

7. Specify survey transect parameters.

For the survey tool to generate the transects in each stratum, it needs to know each stratum boundary and a baseline to propagate the transects from. We now have these, but the tool also needs to know how many transects you want in each stratum, and the minimum distance between neighbouring transects. You will now enter this information by editing the stratum shapefile, In the TOC, select the survey_strata layer and click the Edit tool (blue pencil). The layer will show in the map with each vertex (point) represented with a red cross, but we are not going to edit the spatial features, but the attribute data associated with each stratum. Right click the layer name in the TOC and choose *Open*

Attribute Table. You will see a spreadsheet-like listing (Figure 8) of the available columns and values for each stratum. These were inherited from the original statistical area data downloaded from NABIS.

Figure 8: The attribute edit window showing some of the existing attributes for each stratum.

We need to add at least two new columns, and optionally a third. The first column to add will be to define the number of transects we want created. The second column will specify the minimum distance (in either map units or meters). The third can contain the name for each stratum that we'd like to use as a label in a map. A column name cannot exceed 10 characters.

Press CTRL-W or click the New Column button to create each of the new columns you require (Figure 9).

Figure 9: Quantum Map attribute editor, showing the dialogue for adding a new column to the file.

Ensure you select the appropriate Type for each new column, the number of stations should be a whole number, the minimum distance could be a whole number (integer) if in meters, but should be a decimal if in degrees (map units). A stratum label should probably be a text value (Figure 10). Once the columns are added, click on each cell to enter a value. It is likely that for various reasons, a particular transect may be unsuitable for sampling, so having extra transects generated will allow those carrying out the survey to allocate a new transect from the available spare transects. Choosing a combination of minimum distance and number of transects which is not possible may cause no transects to be created, so choose realistic values.

Figure 10: Quantum Map attribute editor, showing the three new columns as created, without values.

8. Generate transects.

We have now entered all the information the survey tool requires to create the transects, so can start the survey tool to do just that. *Click Survey; Survey Init* to initialise the survey parameters. In this case, we do not have a specific survey area polygon dataset, so this is left as none, we have a baseline layer we created, in this case called survey_baseline, which is not divided into separate strata, so there is no stratum id field. The strata layer was saved as survey_strata, and has the columns we entered, with the distance expressed in metres (Figure 11). Click OK to save these settings.

Figure 11: The survey intialisation dialogue, with parameters entered to match the layers and columns we created.

The next step is to design the survey. Choose *Survey; Survey design* to set up the design (Figure 12). As we have specified the map layers to use, the Survey Design dialogue allows you to edit the datasets, which in this case we do not need to do. We will choose a shared baseline (our single baseline is shared by all the strata in the survey) and a transect survey (a point might be suitable for

divers undertaking a circular search or quadrant based survey, but in this example we want transect lines generated.
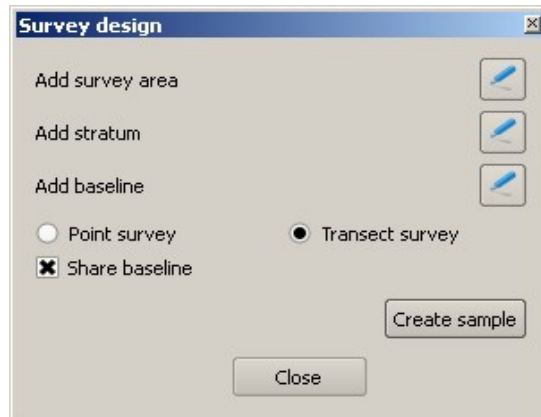

Figure 12: Survey design dialogue. Configured to use a shared baseline for all strata and to generate transect lines from the baseline as well as the start points along the baseline.

We need to enter names for the shapefiles to be created, for the transect start points, survey_p, for the transects, survey_l, for the new baseline (split by strata) survey_b2. The process can take a minute or so. When complete, the new layers: start points. transect lines and a baseline split into the strata, are automatically added to the map Figure 13).
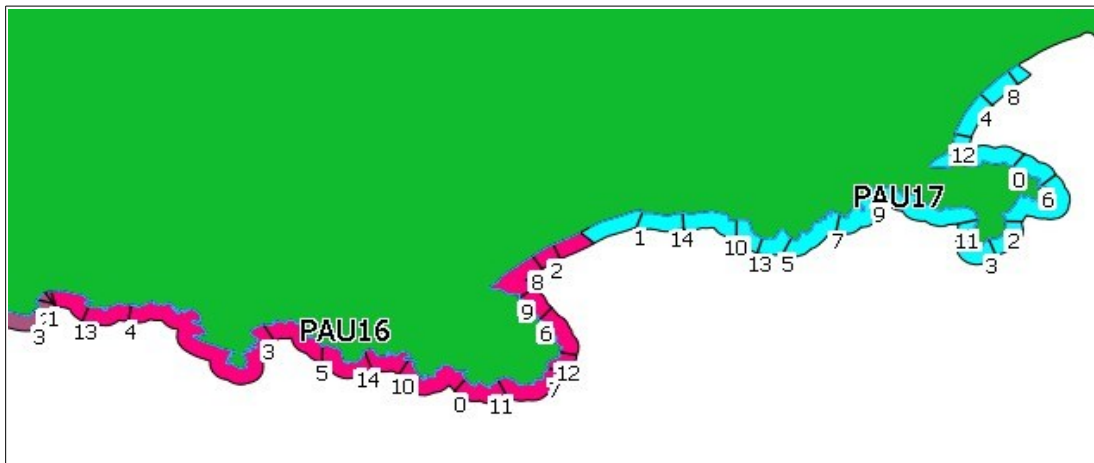

Figure 13: Zoomed in to the map, showing the South Island polygon (green), two labelled strata (PAU16 and PAU17) and the transects generated by the survey.

8. APPENDIX 2

Algorithms used to generate transects

The required input layers for transect generation are a stratum polygon layer and a baseline layer. The strata layer must have at least three attributes, a unique name or stratum identifier value, and two values specifying the required number of transects and the minimum distance allowed between two adjacent transects in that stratum.

As described earlier, this tool attempts to reduce the number of generated transects which are not useable when propagated at the traditional right angle from the shoreline. Instead, a transect propagates from a point on the coast towards a point on the outer edge of the stratum nearer the shoreline start point. Initial trials showed that this approach generates fewer transects which are nearly parallel to the coast where the shoreline is convoluted. In Figure 15, the dotted line is perpendicular to the coast at the point of origin, but would result in a transect which is nearly parallel to the shoreline for the initial 1/3 of its length, and should be discarded (depending on scale). In contrast, the transect line (t), which is generated using the new algorithm from the same start point, is a viable survey transect.

The transect generation algorithm is contained in the function QgsTransectSample::createSample in the source file src/analysis/vector/qgstransectsample.cpp (QGIS analysis library). It comprises the following steps:

- For each stratum, a buffer line is created in a distance from the coastline. This buffer line is used to create the transect lines later. (Figure 15). Next the survey area baseline (b) is clipped to the stratum polygon (s) and a line buffer is generated from it. The buffer distance applied is the same as the baseline buffer distance mentioned above. This line buffer (lb) clipped to the stratum polygon (s) yields the buffer line (bl).

- Random points are then created along the baseline (coastline) of the stratum. Each point is a potential start point of a transect. The Mersenne Twister algorithm (Matsumoto & Nishimura 1998) has been used to create the pseudo-random numbers.

- To construct a transect, a ray is constructed from each random point passing through the closest point on the buffer line. The intersection between the ray and the stratum polygon is the potential new transect line (t in Figure 14). The new line has to fulfil some criteria to be retained as a valid transect, otherwise it is discarded and another random point is selected and transect generated. The new transect line has to:
  o have all segments start at the random point. If this is not the case, the transect most likely crosses land.
  o be longer than a specified minimum length. This prevents situations where very short transects are created, for example, within a bay.
  o be further away from existing transects than the minimum distance specified for the stratum.

  This process is repeated until the either desired number of transects for the stratum has been created or a threshold has been reached, making the assumption that there is no space left for more transects using the given criteria.
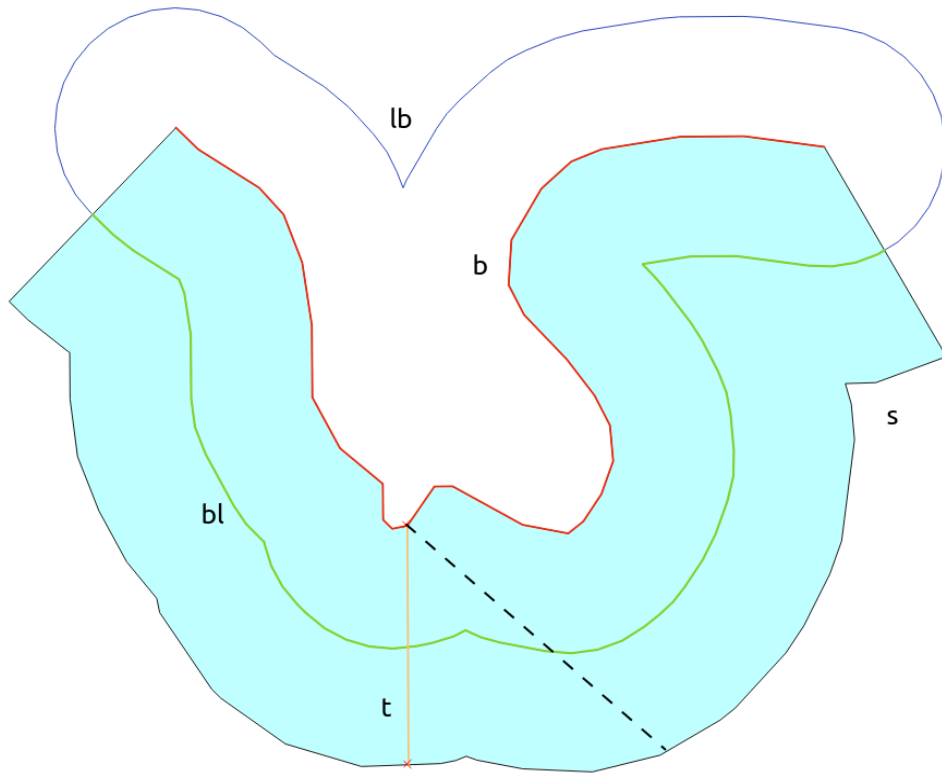
Figure 14: Showing how the plugin creates a viable random transect.