Implementation of a Fishery Independent Survey for the Southern and Eastern Scalefish and Shark Fishery

Ian Knuckey, Mark Bravington, David Peel, Matt Koopman, Michael Fuller, Neil Klaer, Jemery Day, Judy Upston and Russell Hudson

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Table of Contents

List of Tables

List of Figures

2006/028 Implementation of a fishery independent survey for the Southern and Eastern Scalefish and Shark Fishery

Principle Investigator: Dr Ian Knuckey

Address: 27 Hesse Street
Queenscliff VIC 3225
Telephone: 03 5258 4399
ian@fishwell.com.au
www.fishwell.com.au

Objectives

1 Review the current fishery independent surveys that are operating in the SESSF and determine their efficacy and potential for use in a multi-species survey. Determine which survey methods are most suitable for the main species in the SESSF.

2 Design a suite of cost-efficient fishery independent surveys that will meet the needs of the fishery in providing indices of abundance for most major species in the SESSF. Determine the most practical way of undertaking the surveys and gain broad stakeholder acceptance of the survey design.

3 Determine the cost structure for the surveys and how funding and research quota will be allocated.

4 Undertake a full one-year trial of the survey design. Review the results of the survey with respect to cost-efficiency, practicality and provision of high quality (precise) indices of abundance and modify the design accordingly.

5 Implement a long-term (5 – 10 year) survey program that can be progressively funded by industry under standard AFMA CRIS (Cost Recovery Impact Statement) Policy.

Non-technical Summary

OUTCOMES ACHIEVED

In line with the objectives of the project, the following outcomes have been achieved:

Objective 1

A review of the main options for a design of the survey was conducted. The pros and cons of conducting standard randomized stratified surveys were compared with a model-based survey design; with the latter proving more suitable because it is more logistically flexible and gives abundance estimates with low bias and efficient CVs that make full use of the data.

Objective 2

The major outcome of this project has been the design and implementation of a broad, multi-species fishery independent survey that provides relative abundance indices for major quota and major non-quota species in the Southern and Eastern Scalefish and Shark Fishery (SESSF). Analysis of the 2010 survey results revealed that conducting just a winter survey would provide reasonable (<30%) CVs for 15 species which account for 87% of the catch weight of the GHaT and CTS sectors and 83% of the catch value.

Objective 3

Prior to the 2008 trial survey, considerable work was done to determine the most cost effective survey design that would deliver reasonable CVs for as many major quota and non-quota species as possible. Following the 2010 survey the issue of survey structure and funding was revisited. The survey definitely requires three industry vessels operating in the main areas of the fishery (NSW, east and west) to complete the survey within a month. Vessel charter is the main cost of the survey, accounting for about 70% of total project costs. Fish sales from the survey offset charter costs by 30 – 40 %. Analysis of CVs indicated that almost the same abundance index outcomes could be achieved by just conducting a winter survey, rather than running both a summer and winter survey. This produces an overall saving of about 44%.

During 2008 and 2010, the project operated with two methods of allocating research catch allowance (quota assigned to cover the survey catch). A post-survey allocation

which was then subtracted from the subsequent year's quota allocation was the most practical and easy to manage. A pre-survey prediction of research catch allowance was easily made, but variations from this figure were extremely difficult to manage: with under-prediction causing quota availability and reconciliation issues; and over-prediction viewed as a waste of industry's quota allocation.

Objective 4

A successful trial of the survey design was conducted during 2008. Only minor modifications were required for the 2010 survey. These included addressing: a lack of shallow sites sampled in the western region; clustering of sampling sites in shallow water in the NSW and eastern regions; and the use of a 'heavier' net in the western region that may have different selective properties to the other nets. Otherwise, the cost-effectiveness, practical implementation and provision of CVs were considered acceptable for ongoing surveys.

Objective 5

Importantly, the fishery independent survey has received strong support from industry, scientists and managers. As evidence of this, the South East Trawl Fishing Industry Association (SETFIA) took over as the project administrators to undertake the 2012 survey with funding directly from the Australian Fisheries Management Authority, largely cost-recovered from industry in line with the CRIS. During 2012, the SESSF Resource Assessment Group highlighted continuation of the time series of fishery independent surveys as one of the highest research needs for the fishery. A decision on the frequency and components of subsequent surveys will be made during 2013 dependent on species CV requirements and budget constraints. Based on three years of independent surveys, data can be used as an independent index of abundance in stock assessments.

There has been ongoing concern about the use of commercial catch rate data as the main index of abundance for species in the Southern and Eastern Scalefish and Shark Fishery. Apart from the well described problems of hyperstability and technology creep, the Commonwealth Trawl Sector (CTS) has a number of other factors that could affect the relationship between catch rates and abundance: as a quota managed fishery, operators have a large number of target species and modify their fishing practices to suit quota availability and market demands; species are sometimes discarded, and this is not regularly recorded in commercial logbooks; and further, targeting of some species is reduced and in some cases there is active avoidance of species for which there are very low, or 'bycatch' Total Allowable Catches (TACs). All of the above factors confound the assumed relationship between commercial catch rate and stock abundance. Recognizing this, during 2006 the SESSF Resource Assessment Group placed the highest priority on the need to implement fishery-independent methods for surveying relative abundance of SESSF fish stocks.

Traditionally, trawl surveys are designed and analysed as randomized stratified surveys (RSSs). In such cases sampling theory and parametric models are used to estimate variability around an assumed constant mean catch rate within each stratum. One of the issues facing traditional RSS design-based abundance indices is that any systematic trend within a stratum will be interpreted as random variability, which will inflate the CV. If there are several target species with different habitat requirements (such as in the SESSF), then it becomes even harder to choose strata that simultaneously give low within-stratum trend for all targets. In such circumstances, RSSs can be seriously inefficient. A second major problem with RSSs for fishery surveys is inflexibility over logistic constraints. These can be serious in regions that are far from ports and where it is hard to predict suitable spots for sampling. Unpredictable problems, such as bad weather and gear damage, can also make the realized design different from what was planned. Inevitably, the result is patchy coverage which, in an RSS, fundamentally compromises the integrity of the randomization assumption on which design-based estimates and variances are predicted. This can cause bias as well as incorrect variance estimates; for example, if sampling sites end up being clustered in different parts of a stratum in different years.

Model-based indices can potentially deal with these problems, to give abundance estimates with low bias and efficient CVs that make full use of the data. A model-based index and its variance are constructed in four steps: first, fit a parametric statistical model to the survey data to describe the effect of location and other covariates on catch rates; second, use the parameter estimates to predict mean catch rate under standardized conditions over each point in a fine grid across the region of interest; third, sum the predictions across the grid; finally, use the estimated parameter covariances to infer the uncertainty in the summed predictions.

A prerequisite for a model-based design approach was extensive existing data to which we fit a generalized additive model (GAM). The SESSF logbook data provided such information. A subset of about 50,000 shots from the logbook data between 2000 and 2005 were analysed for eleven important species for two distinct seasons: summer (January to March) and winter (July to September). The high number of zeros in such data was addressed within the GAM framework by using a Tweedie distribution.

After fitting a GAM to survey data, we estimated the relative abundance by predicting the catch rates under standardized conditions across the entire region of interest, and integrating the result across the region.

A workshop was held, in which designs were proposed and modified with the general goal of achieving reasonable precision (CV ≤ 30%) for eleven main species (Blue Warehou, Jackass Morwong, John Dory, Gemfish, Tiger Flathead, Pink Ling, Silver Trevally, Redfish, Blue-eye Trevalla, Mirror Dory and Silver Warehou). Other factors such as the ease of implementing the design were also considered and a final design was agreed. The components of the SESSF fishery independent survey (FIS) design that were not completely constrained by logistics were: depth, spatial location (e.g. position along coast), and the amount of effort per season. The time of day that samples were taken, and gear type, were fixed by the survey protocol, so not varied in the design.

The agreed survey design consisted of two seasons (summer and winter) and two depth strata (50 m – 200 m and 200 m – 700 m), while location was described by distance along the coast. Potential survey designs were evaluated using this logbook data to select and fit an appropriate GAM and then evaluate the likely variance of an abundance estimate. The model-based approach to design was found to be of particular use in this environment, since suggested designs or modifications could be evaluated quickly and quantitatively. Because the survey was conducted in summer and winter, the two independent abundance indices had to be combined to estimate the “overall equivalent CV” of the combined series.

Cost effective implementation was achieved by tendering for different vessels for each of three regions (NSW, eastern and western regions), and using proceeds raised from fish sales to subsidise the cost of the survey. To maximise profitability and ensure that crews maintained the catch to their usual high standards, an incentive of 10% of the revenue was returned to the vessels. Standard fishing nets were designed that were not specifically intended to capture any particular species, but were a good general fishing net. The survey nets were used in each region, with the only difference being that heavier ground gear was required in the western region because of the rougher bottom.

A pilot survey was conducted in 2008, during which 125 shots were conducted during summer, and 205 shots conducted during winter. As anticipated, a number of the prescribed shot locations could not be trawled due to rough ground — particularly in the western region. Alternative survey locations were used when that was the case; however this resulted in some areas and depths being under sampled, particularly in shallow depths in the western region. The 2008 survey caught 290 species, weighing 328 t, of which 107 t were quota species. In addition, nearly 24,000 length frequency measurements and 3,301 otolith samples were collected. Combined 2008 summer and winter survey CVs could be calculated for 25 different species, and good (<0.2) to reasonable (0.2 – 0.3) CVs were obtained for 14 quota and 3 non-quota species.

A review of the survey design, implementation and results was undertaken during a meeting with industry members, managers and scientists during 2009. Three issues highlighted during that meeting were the lack of shallow sites sampled in the western region, the clustering of sampling sites in shallow water in the NSW and eastern regions, and the potential implications of different selective properties of the net used in the western region. To resolve the first two issues it was decided that industry members would identify sampling locations in shallow locations of the western regions, and that 12 of those (six during summer and six during winter) would replace

12 of the tightly clustered shots in the NSW and eastern regions. It was also decided that the index of relative abundance on the western region should be kept separate from that in the NSW and eastern regions instead of trying to calibrate the different nets. This fits in with assessment of many fish stocks that are separated into eastern and western stocks. The boundary of the separation of the eastern and western indices of abundance was set as the Tasman Fracture Commonwealth Marine Reserve, where industry members reported an obvious change in species composition.

During the 2010 survey, a total of 119 shots were completed in summer and 202 during winter. A total of 274 species were caught totalling 244 t, of which 60 t were quota species. More than 26,000 length frequency measurements and 2,839 otolith samples were collected. Combined 2010 summer and winter survey CVs could be calculated for 20 different species, and good (<0.2) to reasonable (0.2 – 0.3) CVs were obtained for 14 quota and 3 non-quota species.

A review of the 2010 survey by industry representatives, managers and scientists found great support for the continuation of the survey, and identified options for cost savings and funding for the ongoing survey. Different scenarios were also outlined for redesigning the sampling to increase the number of species for which statistically robust estimates of relative abundance are obtained.

Analyses were undertaken to examine the effect on the number of useable abundance estimates (those with CVs ≤30%) of reducing sampling intensity and altering the survey design, and the approximate cost of obtaining those estimates. Various changes in the number and position of shots sampled would reduce the cost of the survey, however this would come at a disproportionate loss in the number of species with usable abundance estimates. Likewise, the alternative design scenarios all reduced the number of useable abundance estimates, with either no or very little reduction in total survey costs. The most cost effective survey design is the base case winter (200 shots) which achieved reasonable CVs for 14 quota species at a cost of $590,000 or about $42,200 per species. When combined together, the summer and winter base case survey achieved reasonable CVs for 13 quota species at a cost of ~$920,000, or ~$70,300 per species. Depending on available future funding and the number of species required to have reasonable CVs, it is recommended that ongoing surveys either comprise the winter only base-case survey or the combined summer and winter surveys.

A longer time-series of relative abundance indices are required before they can be incorporated into stock assessments. Experience from the GABTF survey suggests that at least three year's survey data are required before the data should be used in stock assessment. Under the current harvest strategy, indices of abundance produced from a longer time-series of the FIS can be directly used in Tier 1 and Tier 2 assessments, and there is potential for its use in Tier 4 assessments. Further, should a FIS become part of standard fishery monitoring, then there is potential to develop an alternative Tier assessment that primarily uses that FIS index. Such an alternative assessment would be useful for species where only the index and catch data are available, and fishery CPUE has been determined to not be a good indicator of abundance. It could potentially be applied to both quota and non-quota species where little information is available other than from the FIS.

Ultimately, it may be possible to use a FIS index of abundance as the primary indicator that is input directly into a harvest control rule as an alternative to regular standard stock assessment. Such an approach has clear advantages as it provides a data driven and transparent process for TAC setting. Implementation of such a system would ideally require management strategy evaluation of the harvest control rule prior to implementation, and intermittent full stock assessments to ensure that the process is operating as expected.

The implementation of a long-term survey program has been initiated, with surveys being conducted during 2012. A decision on the frequency and components of additional surveys will be made in the future. The planned outcome of that new project is to provide a robust alternative to standardised logbook CPUE for long-term use in SESSF stock assessments.

Keywords: Commonwealth Trawl Sector, Southern and Eastern Scalefish and Shark Fishery, fishery independent survey, catch rate, CPUE, survey design, trawl fishing.

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Background

The Southern and Eastern Scalefish and Shark Fishery (SESSF) is one of Australia's largest fisheries and supplies much of the fresh fish to our domestic markets. Landings from the fishery during 2009 were about 20,000 t with a gross value of production worth $95.5 million in 2008/09 (Wilson *et al.* 2009). The Commonwealth Trawl Sector (CTS) is a sub-fishery of the SESSF which ranges from Barranjoey Point (north of Sydney) to Cape Jervis in South Australia (Figure 1). The CTS is a multi-species trawl fishery managed mainly through annual Total Allowable Catches (TACs) which are applied to 34 species or species groups. These quota species comprise about 80% by weight of the 100+ commercial species that are landed. It is a limited entry fishery with 59 Statutory Fishing Rights (SFRs). Other management arrangements include trip limits, incidental catch limits, size limits, prohibited take, gear restrictions, and spatial and temporal closures.

The SESSF has a harvest strategy under which stock assessments are conducted for all quota species in order to set a recommended biological catch (RBC) and an annual TAC. Depending on the amount and quality of information available, these assessments range from fully quantitative integrated model-based assessments to simple assessments based on trends in standardised catch rate data. Nearly all of the SESSF assessments use some form of catch per unit effort (CPUE) time series data as the main index of stock abundance.

The problem with using commercial CPUE data as the main index of abundance largely stems from the critical assumption that there is a functional relationship between commercial catch rate and stock abundance (Shelton 2005). The veracity of this relationship has been questioned for numerous fish stocks around the world (e.g. Clark and Mangal 1979; Hutchings and Myers 1994; Hutchings 1996; Walters and Maguire 1996; Rose and Kulka 1999), and there has been significant doubt regarding that relationship for CTS species for some time. Apart from the well documented effects of hyperstability (Hilborn and Walters 1992) and technology creep (Marchal *et al*. 2007), the CTS has a number of other aspects that could readily affect the relationship between catch rates and abundance. With the large number of possible target species, fishers modify their fishing practices to suit quota availability and market demands. This means that it's often unclear what the target species of fishing effort is, and that effort may be expended on fishing grounds that are unsuitable for the species of interest. Compounding this problem is that patterns of fishing effort in the CTS change from year to year and within seasons (Tilzey 1994). Also, discarding of quota species occurs for a number of reasons including quota availability, size limits and market demands, and this also may change markedly from year to year (Liggins and Knuckey 1999). This discarding has only recently began to be reported in commercial logbooks, and the frequency and accuracy of reported discards is not at a standard that it can be included in analysis of catch rates. Further, several species such as Eastern Gemfish (*Rexea solandri*) and Blue Warehou (*Seriolella brama*) have low or 'bycatch' TACs, which prevents targeting of those species and undermines the use of commercial CPUE as a good index of abundance.

Many of the above problems can be largely addressed by the implementation of fishery independent surveys to provide a time series of abundance indices that can be used in addition to, or instead of, commercial CPUE data (e.g. Gunderson 1993; Pennington and Strømme 1998). Numerous fishery independent surveys for single species have operated in the SESSF over the last two decades. Many of these have focused on the high value, highly aggregated species such as Orange Roughy (*Hoplostethus atlanticus*) and Blue Grenadier (*Macruronus novaezelandiae*) but more recently they have broadened to a wider range of species. A review of these various FIS projects is provided below.

Orange Roughy

The boom of the Orange Roughy fishery off eastern Tasmania in the early 1990s saw the first fishery independent surveys begin in the SESSF. An Orange Roughy egg survey was conducted during 1992 to estimate the biomass of the Orange Roughy stock that spawns off north-eastern Tasmania (Koslow *et al.* 1995). A random stratified survey was designed around the St Helens Hill spawning site that used vertical tows from 1000 m to the surface to sample eggs during their first day of development. Although an estimate of the biomass of spawning fish was enabled, highly patchy egg distribution resulted in a high variance of the estimate. At about the same time, the first towed body acoustic surveys of spawning Orange Roughy were conducted (see Kloser *et al.* 1996). Single frequency and then multi-frequency deep-towed acoustic systems have successfully been undertaken on eastern zone

Orange Roughy during 1991, 1992, 1993, 1996, 1999, 2006, 2010 and again during 2012, and provide the longest time-series of fishery independent surveys available in the SESSF. The early acoustic surveys provided similar estimates of stock size as the egg survey but with lower variances. However, the acoustic surveys had greater non-statistical sources of uncertainty surrounding the target strength of Orange Roughy and interference from the acoustic signals of other species aggregating in the area. Improvement in the in situ target strength estimates, and accounting for acoustic signals from fish other than Orange Roughy has been the focus of ongoing work in these fishery independent surveys. The most recent development has been the use of a multi-frequency Acoustic-Optical System (AOS) that is mounted on a trawl headline and towed directly above the fish aggregations. The AOS system (see Ryan *et al.* 2009) consists of 38 and 120 kHz transceivers with seven degree split-beam transducers, together with single-beam 18 and 70 kHz transceiver/transducer combinations to improve species discrimination. This system can now provide very accurate biomass estimates of Orange Roughy and can discriminate and compensate for the acoustic signals from other species in the area, making it one of the most useful fishery independent survey tools available for highly aggregated species.

Since 1990, in parallel with the towed body acoustic surveys (and in many years between), hull-based single frequency (38 kHz) acoustic surveys have been used to provide snapshot biomass estimates of spawning Orange Roughy aggregations. Although there is a very good time series of these surveys, their accuracy is compromised by the large distance between the vessels hull-mounted transducer and the fish aggregations at around 700 m depth, as well as the motion of the vessel, the acoustic dead zone and weather induced noise. Most importantly, the effectiveness of species discrimination enabled from a single frequency transducer has led to positive biases in biomass through the inclusion of gas bladdered fish that swim within, or near the Orange Roughy aggregations. Ultimately, due to the above mentioned reasons, it is unlikely that the single frequency hull-mounted acoustic surveys will be used in a quantitative manner in future stock assessments. There are current proposals to continue the multi-frequency towed-body AOS surveys for eastern Orange Roughy.

Hull-mounted acoustic surveys have also been conducted over a number of years on the Cascade Plateau Orange Roughy stock. This is the only survey data available for the Cascade Plateau, but again the ability of this information to be used in a quantitative fashion for Orange Roughy stock assessment is questionable. There is consideration to conduct a multi-frequency AOS survey at Cascade, but the cost and unpredictability of the timing and position of aggregations on the Cascade has prevented this being approved to date.

Blue Grenadier

Similar egg surveys and towed body acoustic survey methods as used for Orange Roughy have also been applied to Blue Grenadier in the SESSF. Bulman *et al*. (1999) conducted an egg survey of the Blue Grenadier spawning stock off western Tasmania during winter in 1994 and 1995. Biomass estimates ranged 60,000 – 100,000 tonnes; the CV for the egg production estimate for the survey at the peak of the 1995 season was 14%.

Acoustic surveys of Blue Grenadier spawning aggregations off western Tasmania have been running annually since 2002 (Kloser *et al*. 2007; Ryan *et al*. 2007; Ryan and Kloser 2009). The aim of these surveys is to provide data that can be used by CSIRO to estimate the peak biomass of Blue Grenadier. This index represents a minimum estimate of spawning stock biomass because it does not include fish outside schools, or fish turnover on the grounds. With CSIRO guidance, the surveys rely entirely on skippers and vessel managers to correctly follow the standard operating procedure, and collect and record all of the required acoustic information. There are three aspects to the surveys: 1) a broad-scale survey of the entire spawning region at peak biomass; 2) parallel transect surveys at Pieman Canyon throughout the season; and, 3) opportunistic parallel transect surveys of localised aggregations during fish processing time. These surveys have been very successful and their biomass estimates now form an important input into the stock assessment modelling and subsequent setting of Blue Grenadier quota (Tuck *et al*. 2011). CVs from acoustic survey sampling have ranged ~15 – 46% depending on the year, but there has been an overall improvement over time. Similar to Orange Roughy, much of the recent work has focussed on experiments to improve the measure of Blue Grenadier target strength, and the development of the AOS has been critical to this goal (e.g. Kloser *et al*. 2011). There is a commitment for ongoing acoustic surveys of the Blue Grenadier spawning aggregation.

Eastern Gemfish

Eastern Gemfish comprised a very significant proportion of trawl landings off south-eastern Australia during the 1970s and 1980s, with trawling targeting aggregations of mature fish as they undertook a winter spawning run north. During the late 1980s the spawning stock was significantly reduced by heavy fishing pressure and a series of very poor cohorts. As a result, the TAC was progressively reduced and by 1993 a zero TAC was in place. A low bycatch TAC has been in place for almost two decades now. The stock assessment for Eastern Gemfish relied heavily on the use of the targeted catch rate during the winter spawning run as the index of stock abundance. With no targeted fishing allowed, the assessment was deprived of the primary index of abundance and the fishery had no way of measuring recovery.

To address this issue, industry developed a form of fishery independent trawl survey that allowed targeted fishing of the spawning run by a select group of traditional eastern gemfish fishermen, in an effort to obtain catch rates that could be comparable with historical targeted commercial fishing of spawning run. These were run during 1996 – 1998 (Prince 1996) and then again during 2007 – 2008 (Knuckey *et al*. 2009) and the data has been critical for recent stock assessments. Despite their necessity for assessments (Little and Rowling 2008), there are considerable concerns about the potential biases of these surveys as indices of abundance, particularly that the use of targeted fishing of the main spawning run as the main index of abundance may lead to hyperstability in CPUE and an overestimate of spawning stock abundance in the model. The ongoing use of this particular fishery independent survey is not certain.

Bight Redfish and Deepwater Flathead

The Great Australian Bight Trawl Sector (GABTS) targets two main species, Deepwater Flathead (*Neoplatycephalus conatus*) and Bight Redfish (*Centroberyx gerrardi*). Industry-based fishery-independent resource surveys of the Great Australian Bight have been conducted by the Great Australian Bight Industry Association (GABIA) since 2005 (Knuckey *et al*. 2006), with the primary goal of obtaining robust annual indices of relative abundance of these two main species. A random stratified survey design was chosen with particular specifications on depth, longitude, month, trawl duration and how the trawls were to be conducted. Shot allocation to each of the strata is proportional to the catch-weighted standard deviation of CPUE. The number of shots in the survey required to achieve a coefficient of variation of < 20% for the relative abundance index, was determined using power analysis to be 76 shots per annum, over two trips during February and March. The indices of relative abundance regularly achieve CVs of about 15% for Bight Redfish and 5% for Deepwater Flathead, and are incorporated into formal stock assessments. Successful surveys have now been conducted during 2005 – 2009 inclusive and in 2011 (Knuckey *et al*. 2011), and GABIA has committed to further surveys, although their frequency has yet to be decided.

Shark first shot survey

The Shark Gillnet and Shark Hook Sector (a part of the Gillnet, Hook and Trap Sector) of the SESSF consists of about 59 active operators fishing for shark on the continental shelf with bottom set gillnets and hooks (Woodhams *et al.* 2011). Until 2000, stock assessment models were based on standardised catch per unit effort data from logbooks. During 2000 TACs were introduced on Gummy Shark and School Shark, after which it was recognized that a new measure of abundance was required. A trial fishery independent survey was conducted during 2002 and 2003 on an analysis that suggested 126 shots per annum were required to achieve a statistically valid estimate of abundance. After initial attempts to charter vessels with observers onboard proved too expensive, the plan to use a subset of fishermen recording full information of the first (assumed most random) shot of a trip was developed. CVs of 40 – 70% were initially estimated for School Shark, which implied a larger number of shots would be needed over 10 – 15 years before significant trends were likely to become evident, but estimates for Gummy Shark were that CVs of 15 – 25% could be achieved with less than 40 shots. Despite the potentially cost-effective value of the first-shot surveys for the shark fishery, they have not continued beyond 2005.

Blue Warehou survey

Blue Warehou are found in continental shelf and upper slope waters throughout south-eastern Australia in depths to 500 m. Catches of Blue Warehou were as high as 2,500 t during the early 1990s, but concern over the state of the stock due to decreasing catch rates and a significant reduction in the proportion of large (>40 cm) fish in the catch, saw successive decreases in the TAC to 300 t in 2003 and ultimately a bycatch TAC of <200 t in recent years. Monitoring the abundance of a species at low stock size is difficult because CPUE data is impacted by low TACs, and from avoidance by fishers. A random stratified survey with 10 sites in each of three strata in the west and two in the east, was implemented during August and October 2005 (Hudson and Knuckey 2006). Results were compared to historical catch rates, and whilst there was good industry commitment to run the survey during 2005, stock abundance indices were extremely uncertain, and the value of further surveys was questioned. Efforts to repeat the survey during 2006 were thwarted by lack of industry participation. A repeat survey was undertaken during 2011 (Knuckey *et al*. 2012), but the results again showed extreme uncertainty and no evidence of recovery; consequently there is little commitment to conduct any further surveys in the near future.

Towards a multi-species FIS for the SESSF

Despite a history of single species fishery independent surveys in the SESSF, there has always been a level of industry concern about the practicalities and cost-effectiveness of undertaking a FIS for multiple species in the SESSF (Knuckey and Gason 2006). This has prevented their implementation. Following a project on the feasibility of industry-based fishery independent surveys for the SESSF (FRDC 2002/072), there was limited interest in their implementation by CTS operators, but the GABTS began a successful series of industry-based random stratified surveys over a number of years. The success of the GABTS surveys, together with increasing difficulties in using commercial CPUE as an index of abundance for a number of overfished SESSF species, alerted industry to the potential of an industry-based FIS for a broader suite of SESSF species. Implementation of a multi-species FIS for the SESSF then became the highest research priority for the SESSF.

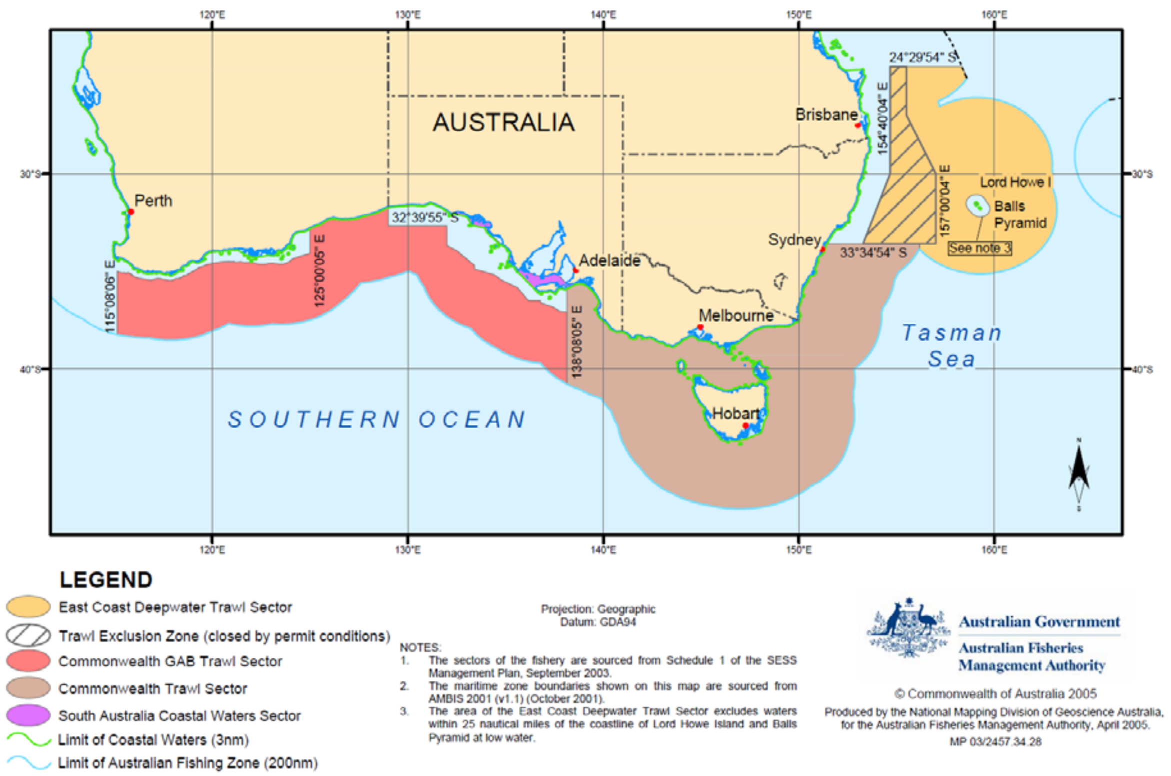


Figure 1. The Commonwealth Trawl Sector of the Southern and Eastern Scalefish and Shark Fishery.

Need

Catch and effort data obtained from commercial logbooks are the primary source of information used for an index of abundance in stock assessments of most SESSF quota species. The assumption underlying this is that commercial catch rates change in a linear fashion with abundance. This assumption, however, has little independent support for many SESSF species, and is frequently criticised by industry and scientists alike. One of the most significant problems with commercial CPUE data in the CTS is that fishers modify their fishing practices to suit quota availability and market demands. Also, many fishermen only report retained catches in logbook data, not the total catch. Furthermore, low or bycatch TACs cause avoidance by fishers, which undermines the use of CPUE used as a good index of abundance. Implementation of a FIS was considered by industry members, scientists and managers to be the most cost-effective and feasible means to obtain an independent index of abundance for the suite of SESSF species. Recognising this, the SESSF Resources Assessment Group (SESSFRAG) placed the highest priority on the need to implement fishery-independent methods for surveying relative abundance of SESSF fish stocks.

Objectives

1. Review the current fishery independent surveys that are operating in the SESSF and determine their efficacy and potential for use in a multi-species survey. Determine which survey methods are most suitable for the main species in the SESSF.
2. Design a suite of cost-efficient fishery independent surveys that will meet the needs of the fishery in providing indices of abundance for most major species in the SESSF. Determine the most practical way of undertaking the surveys and gain broad stakeholder acceptance of the survey design.
3. Determine the cost structure for the surveys and how funding and research quota will be allocated.
4. Undertake a full one-year trial of the survey design. Review the results of the survey with respect to cost-efficiency, practicality and provision of high quality (precise) indices of abundance and modify the design accordingly.
5. Implement a long-term (5 – 10 year) survey program that can be progressively funded by industry under standard AFMA CRIS (Cost Recovery Impact Statement) Policy.

Materials and Methods

The materials and methods section is divided into two major sections reflecting the major objectives of the project to first develop and test a survey design and then modify, implement and provide the results of that survey.

Survey Design

The survey area encompasses the entire area of the CTS (Figure 1), extending eastward from Cape Jervis (longitude 138° 08′ 05″ E) in South Australia, around the Victorian, Tasmanian and NSW coastlines to Barranjoey Point (latitude 33° 34′ 54″ S). Based on advice from SESSF Resources Assessment Group and the SESSF Management Advisory Committee, depths were restricted to 50 m – 700 m to encompass continental shelf and slope where most of CTS effort is concentrated, and these depths were stratified as “shallow” (<200 m) and “deep” (>200 m).

Randomised Stratified Survey Design

Traditionally, trawl surveys are designed and analysed as randomized stratified surveys (RSS). This is extensively described in the literature — notably in Jolly and Hampton (1990) — and simulation tools are available to assist with the design process (e.g. Schnute and Haigh 2003). Variances are estimated either by appeal to sampling theory (relying on the randomization assumption) or using parametric models that estimate variability around an assumed constant mean catch rate within each stratum. Although these two approaches to variance in stratified surveys are very different in principle and to a lesser extent in practice, the potential problems described next apply equally to both approaches, so we use the term RSS to cover both cases.

One of the issues facing traditional RSS design-based abundance indices is that any systematic trend within a stratum will be interpreted as random variability, which will inflate the CV. If there is only one dominant covariate, then fine-scale stratification by that covariate may be enough to make within-stratum trends unimportant. However, if there is more than one important covariate — for example, seabed depth and latitude — then it may not be possible to construct low-trend strata, given that each stratum needs to contain some minimum number of shots. There are more modern stratification methods, however, that aim to address the issue of multiple stratification variables — for example classification-tree stratification (Michaelsen *et al*. 1994). For some covariates such as time-of-day, which can significantly affect a species' depth preference and therefore its probability of being caught, it may not be possible to stratify at all, and if there are several target species with different habitat requirements, then it becomes even harder to choose strata that simultaneously give low within-stratum trend for all targets. In such circumstances, RSSs can be seriously inefficient.

A second major problem with RSSs for fishery surveys is inflexibility over logistic constraints. These can be serious in regions that are far from ports and where it is hard to predict suitable spots for sampling. Unpredictable problems, such as bad weather and gear damage, can also make the realized design different from what was planned. Inevitably, the result is patchy coverage, which in an RSS, fundamentally compromises the integrity of the randomization assumption on which design-based estimates and variances are predicated. This can cause bias as well as incorrect variance estimates — for example if sampling sites end up being clustered in different parts of a stratum in different years.

Model-based Survey Design

Model-based indices can potentially deal with both of the problems described for RSSs above, to give abundance estimates with low bias and efficient CVs that make full use of the data. A model-based index and its variance are constructed in four steps: first, fit a parametric statistical model to the survey data to describe the effect of location and other covariates on catch rates; second, use the parameter estimates to predict mean catch rate under standardized conditions over each point in a fine grid across the region of interest; third, sum the predictions across the grid; finally, use the estimated parameter covariances to infer the uncertainty in the summed predictions. No simulation or bootstrapping is required. Model-based indices can be constructed from any survey data, including a RSS; but if the analysis is to be model-based rather than design-based, then it makes sense to plan the survey with that in mind from the outset. This means model-based design, as opposed to analysis; sampling locations are chosen systematically (subject to logistic constraints) so as to keep the variance of the summed prediction as small as possible.

There is a growing literature in several disciplines on model-based designs (Brus and deGruijter 1997; Gao *et al.* 1996; Curtis 1999; van den Berg *et al.* 2003; Zhu and Stein 2006; Diggle and Lophaven 2006), and Petitgas (2001) and Rivoirard *et al.* (2000) used geostatistical models ("kriging") for model-based design and analysis of fisheries surveys. A key component to all spatial model-based design is the extent of spatial variability, summarized through quantities such as variogram**s** or spatial autocorrelation.

Our application, and therefore our methods, differ from most of the above examples in several respects:

- extensive prior data (from commercial CPUE);
- aim of aggregate prediction, not local prediction;
- logistic constraints, some known in advance and some not;
- exceedingly non-Gaussian response data;
- design of an ongoing annual survey programme, rather than a one-off survey;

- multiple species (hence multiple objectives), with no strictly-defined overall optimality criterion.

Model-based designs are potentially more efficient than conventional RSSs because they avoid confounding systematic trends with variability, and because they can be tuned to take advantage of logistic savings — via clustering some samples for example. However, the design is only as good as the underlying model. If there is little prior data, model-based design is fraught, and predictions of CVs may be misleading. In many fisheries however, there are often extensive CPUE data covering several years. While CPUE can be hard to interpret in assessments, it nevertheless can be highly informative about the effects of covariates such as depth, and about the nature and extent of between- and within-year spatial variability. The model can range from a very strong to very weak prior belief about how covariates relate to the quantity of interest (e.g. the catch of each shot).

A prerequisite for our model-based design approach is extensive existing data *H*, to which we fit a generalized additive model (GAM) (Hastie and Tibshirani 1986; Hastie and Tibshirani 1990; Xiao 2004) that describes expected catch in response to various covariates. From this model we can predict the precision (CV) of an abundance index estimate $\hat{A}$ that might arise from any given survey design *D*. In this section, we first describe the GAM framework we use in this work. This is followed by detail on how an abundance estimate and its variance can be derived from a GAM. Finally, we give an overall description of the steps involved in our approach to model-based design.

GAMs and penalized GLMs

There are several variants of GAMs in the literature. We use the penalized GLM framework of Wood (2006), where the smooth terms are represented parametrically via coefficients; this gives a straightforward route to prediction and inference. The general form of a GAM can be expressed schematically as

$$g(\mathrm{E}[Y_i]) = o_i + \sum_{j=1}^{J} s_j(z_{ji}), \qquad (1)$$

where the response Y_i comes from an exponential family distribution with dispersion parameter ϕ, so that $\mathrm{var}(Y_i) = \phi\, h(E[Y_i])$ for a pre-specified variance function $h(\ )$; the corresponding log-likelihood is denoted by $f(y_i \mid E[Y_i], \phi)$. As to the other terms: $g(\ )$ is a pre-specified link function, o_i is a fixed known offset, and s_j is a generic smooth or linear term that describes the effect of covariate(s) z_j. In the penalized GLM representation, which is computationally equivalent to a generalized linear mixed model (GLMM), this is operationalised as

$$g(\mathrm{E}[Y_i]) = o_i + X^T \beta, \tag{2}$$

where the design matrix *X* is based on the chosen *s* and *z* terms, and the β are coefficients to be estimated. Each term s_j corresponds to a subset of columns $X_{\bullet[j]}$ and coefficients $\beta_{[j]}$. Smoothing can be seen as implicitly placing an improper Gaussian prior on β (Silverman 1985), whereby the joint log density for data *y* and coefficients β can be written thus in terms of the smoothing parameters λ:

$$\Lambda(y, \beta \mid \phi, \lambda) = C(\lambda) + \sum_{i=1}^{n} f(y_i | o_i + X_i \beta, \phi) - \frac{1}{2} \sum_{j=1}^{J} \left\{ \lambda_j \beta_{[j]}^T S_j \beta_{[j]} + \log \left| \lambda_j S_j \right| \right\} \tag{3}$$

Here, each λ_j is a penalty that scales the *a priori* covariance of the coefficients $\beta_{[j]}$, the S_j are orthogonal unscaled covariance matrices determined by $s_j(\ )$, and $C(\lambda)$ is a normalizing constant. Unpenalized terms have $\lambda_j = 0$, but for each smooth term the λ_j must be estimated.

Several algorithms are available for fitting GAMs (i.e. for estimating ϕ, λ and β — collectively referred to as θ). We have used the “outer iteration” algorithm, which directly maximizes the Laplace approximation to the REML (marginal restricted log-likelihood) for (ϕ, λ). The posterior mode of β can be obtained by maximizing Equation (3) over β with ϕ and λ set equal to their MLEs, and its approximate covariance via inversion of the penalized Hessian. These computations are done automatically by recent versions of the mgcv package (Wood 2006) in R (R Core Development Team 2007) (see Wood 2010).

When applying GAMs to fisheries catch data, $g(\bullet) = \log(\bullet)$ in Equation (1) (i.e. a log-link) is the natural choice, since it corresponds to a multiplicative structure: if catch rates tend to double at midday compared to midnight in high-density areas, then this doubling is likely to apply in low-density areas too. If a fishing effort covariate *E* is available, such as the duration of each trawl shot (sample), then $\log(E)$ can be used as the offset term o_i for the full model, assuming that the effort is proportional to the swept area of the seabed.

The remaining issue for the application of GAMs in a fisheries context is the choice of distribution for the catch data *Y*, which can contain a high proportion of true zeros—over 80% for some SESSF species.

Tweedie distribution for catch data

Frequent zero catches have bedevilled much fishery modelling in the past. With modern software, however, zeros can be addressed straightforwardly within the GAM framework by using a Tweedie distribution — assuming of course, that the usual model-fitting diagnostics are satisfactory. Tweedie distributions (Jørgensen 1987; Jørgensen 1997; Smyth and Verbyla 1999) are the set of exponential family distributions indexed by a power parameter *p* such that

$$\mathrm{var}(Y) = \phi\, E(Y)^p \qquad (4)$$

The case $p = 1$ corresponds to a quasi-Poisson distribution, and the case $p = 2$ to a Gamma distribution. Intermediate cases have a finite probability that $Y = 0$, so can handle zeros naturally. Using a Tweedie distribution avoids the complexity of multi-stage zero-inflation modelling (Lambert 1992; Minami *et al.* 2007; Pennington 1986), and the need for *ad hoc* fixes, such as adding an arbitrary constant before taking logs. Examples of Tweedie distributions in fisheries work include Candy (2004) and Shono (2008), who noted its good performance in cross-validation compared to other more familiar approaches for data with a high proportion of zeros. The power parameter *p* must be either fixed a priori or estimated numerically. The latter is not directly possible within most estimation algorithms; however, inspection of residual plots can usually give a reasonable estimate.

Tweedie distributions have a long history of use in GLMs, where they can be fitted without needing to explicitly compute the probability density function. The latter has no closed form for general *p* and is difficult to compute, which has restricted the use of Tweedie distributions outside pure GLMs. While Tweedie GLMMs and GAMs can sometimes be fitted via Penalized Quasi-Likelihood (PQL) without ever calculating the probability density, in our experience this often failed to converge. Thanks to the algorithm of Smyth (1996), computation of the Tweedie density for the range $1 \le p \le 2$ has become reasonably straightforward, allowing the use of the more stable outer-iteration algorithm.

Our main motivations for using Tweedie distributions are pragmatic: accommodation within the GAM framework; ease of use with modern software; avoidance of ad hoc modifications to the data or awkward multi-stage models; and reasonable diagnostics in our example. Tweedie distributions, however, also have an attractive theoretical interpretation in a fisheries setting. A Tweedie distribution with $1 < p < 2$ is precisely the distribution of the total of a number of Gamma-distributed random variables, where the number of variables itself is Poisson-distributed; in particular, the number of variables has a finite probability of being zero, leading to a total of exactly zero. There is a natural analogy with a trawl shot that encounters a random number of schools, possibly zero, and catches a random positive amount from each one.

SESSF Model

In designing the SESSF FIS, we separately analysed CPUE data for eleven important species (see Table 1), for two distinct seasons: summer (January to March) and winter (July to September). Although the SESSF CPUE dataset is problematic for trend analysis, it is quite informative for model-based survey design, where we need only consider within-year comparisons. The data come from mandatory logbooks, where fishers record their catch by species and by shot, along with shot-specific covariates such as location, depth, date, time of day, and shot duration. To minimize any confounding from operational changes, we analysed only summer and winter CPUE data between 2000 and 2005, comprising about 50,000 shots.

Instead of using latitude and longitude to describe a location, we used depth, and distance along a coastline curve starting in South Australia (Figure 2). Depth at a location was interpolated from bathymetric maps. Distance along the curve (“coastal position”) was computed by projecting a location to the nearest point on the curve. Using this coordinate system, we were able to model the two dimensions independently and parsimoniously, without the need for complicated interaction terms.

Because a species' depth preference, spatial preference, and degree of aggregation can vary seasonally, we fitted separate GAMs for each species in each season. The model for the expected catch C_i was:

$$\log E[C_i] \sim s_{x:y}(x_i) : y_i + s_x(x_i) + f_d(d_i) : N_i + s_t(t_i) + y_i + N_i + offset(\log(e_i)) \quad (5)$$

where y_i indicates the year, t_i the time of day, N_i an indicator variable denoting whether the time is day or night, is the coastal location, d_i is the depth and e_i is the effort (i.e. duration of the shot) for sample *i*. The *s* terms denote smooth functions and the colon indicates a 'by' term, i.e., $s_{x:y}(x_i) : y_i$ means a separate smooth on coastal location for every year.

Table 1. Key species design considered in design process

Blue Warehou (*Seriolella brama*)
Jackass Morwong (*Nemadactylus macropterus*)
John Dory (*Zues faber*)
Western and Eastern Gemfish (*Rexea solandri*)
Tiger Flathead (*Neoplatycephalus richardsoni*)
Pink Ling (*Genypterus blacodes*)
Silver Trevally (*Pseudocaranx dentex*)
Redfish (*Centroberyx affinis*)
Blue-Eye Trevalla (*Hyperoglyphe antarctica*)
Mirror Dory (*Zenopsis nebulosis*)
Silver Warehou (*Seriolella punctata*)

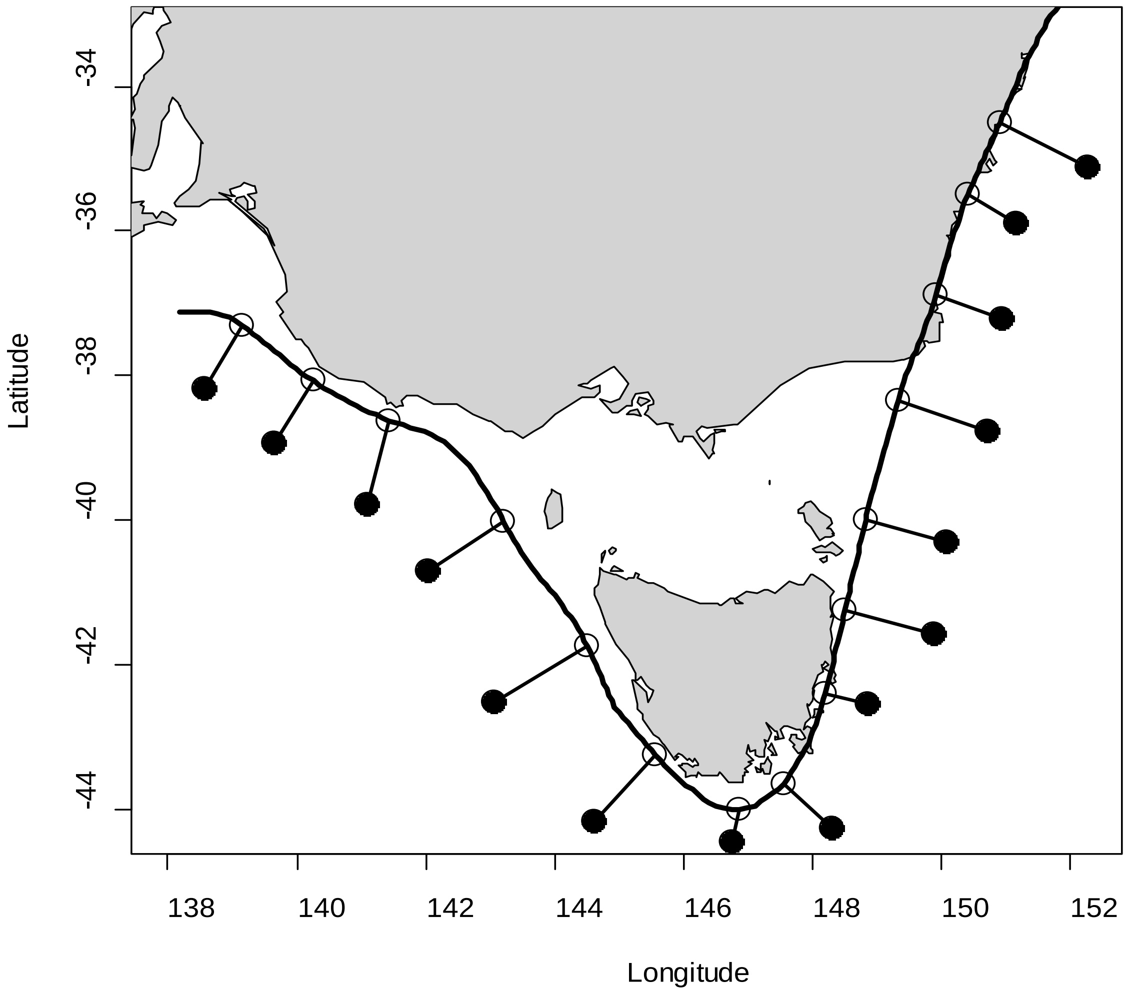


Figure 2. Plot demonstrating the formation of the spatial covariate in the SESSF FIS. The solid dots indicate hypothetical data points, the lines the projections and the open dots the corresponding coastal position.

Given the full model from the historical CPUE data, a 'cut-down' model was proposed for the survey data. We consider the voluminous historical CPUE data provides fairly precise estimates of the effect of depth, time and the common overall spatial distribution, so these terms were placed in the fixed offset (i.e. predicted from the prior fitted model (Equation 6)),

$$\log E[C_i] \sim s_{x:y}(x_i) : y_i + offset(\hat{s}_x(x_i) + \hat{s}_d(d_i) : N_i + \hat{s}_t(t_i) + \log(e_i)) \qquad (6)$$

where $\hat{s}_x(x_i)$ denotes the fitted function obtained from Equation 5. The model for survey data is thus modelling the change in spatial distribution of each species relative to the long term average. To maintain the same knot structure and basis as the original fit, the survey model was reparameterised using the model matrix and smooth matrix from the historical data fit. A new dispersion parameter was fitted to the survey data.

The appropriate value of the Tweedie power parameter *p* for each species and season was investigated using residual plots for a range 1.2-1.8. For all species, the optimal *p* lay in the range 1.4-1.6. We did not formally estimate *p* (as per Candy (2004)), as model fits seemed robust against minor variations in parameter values.

For many species in the SESSF, the CPUE data contains a few extremely large catch records which have a major distorting effect on the estimated shot-to-shot variance; the corresponding effect on the estimated density and spatial distribution are rather less. Since one major aim of analysing the CPUE data is to estimate spatial variability, which will be quite sensitive to shot-to-shot variance, we used the simple model below to prune some of the extreme values before analysis to allow for more stable estimation of spatial variability. Our interpretation of the extreme catches is not that they are recording errors necessarily, but rather that they likely reflect specific and unusual targeting practices aimed at large aggregations, which are unlikely to occur in the FIS itself. Pruning does affect the overall historical mean, but the overall historical mean is not very important for survey design or analysis. We do not apply any pruning to the survey data itself.

Estimating the abundance index

After fitting a GAM to survey data, we can estimate the relative abundance *A* by predicting the catch rates under standardized conditions across the entire region of interest, and integrating the result across the region. “Under standardized conditions” means fixing any detection-related covariates that affect only the proportion detected, not the amount present; since we assume a log-link and are interested in time series of relative abundance rather than in absolute abundance, the value chosen for the standardization simply induces a constant multiplicative factor that does not change between surveys and therefore does not matter.

The integral across the region can be approximated numerically using a finely-spaced prediction grid of say *m* points, each with an associated area. We first generate the “prediction design matrix” X^P for the given grid and standardized conditions, then use the estimated coefficients to predict the expected catch at each grid point, and finally sum the area-weighted predictions to give an estimated index $\hat{A}$:

$$\hat{A} = \sum_{i=1}^{m} w_i \exp\left(X_{i\bullet}^{P} \hat{\beta}\right), \quad (7)$$

where w_i is the proportion of the region's area that is represented by the *i* th grid point; this proportion will depend on the co-ordinate system of the grid. The exponential in Equation 7 is required to undo the log-link, so that we are predicting catch rate rather than its log. In multi-year surveys, abundance indices are sometimes taken directly from the coefficients of "year effects" in the design matrix, but the presence of the exponential term makes that inappropriate because of non-linear interactions with the within-year spatial distribution. The only safe way to construct an index is by spatially explicit prediction.

Variance of the abundance index

The variance of $\hat{A}$ can be approximated in terms of the variance of *β* via the Delta-method (see Oehlert 1992), as

$$V[\hat{A}] \approx \left(\frac{\partial A}{\partial \beta}\right)^{T} V[\beta | y] \left(\frac{\partial A}{\partial \beta}\right) \quad (8)$$

where $\partial A / \partial \beta$ can most simply be calculated numerically, by perturbing $\hat{\beta}$ in Equation 7. The linear approximation inherent to the Delta-method can be circumvented by simulating from the posterior distribution of *β* |*y* (in practice, from a Gaussian approximation to that posterior) and substituting each draw into Equation (7) to form a distribution for $\hat{A}$, as described in Wood (2006). In our application, we found this made little difference for CVs up to about 40%; CVs above 40% are probably too high to be useful anyway.

Equation (8) is trying to capture the sampling variance — i.e., the variability between abundance estimates that would be seen if the survey was repeated under identical conditions and with identical underlying animal densities. If the index forms part of a time series in which it has been necessary to fix the values of some detection-related covariates, then it is not appropriate to include the uncertainty associated with the corresponding parameters; even if those parameters are uncertain, the multiplicative factor induced by the standardization would not change under repeat samples, nor from survey to survey. The algorithm given in the following section correctly handles this.

Evaluating a survey design

A survey design *D* consists simply of a set of n_D "sample sites" (proposed values for all the covariates). In this section, we assume that all covariate values can in fact be controlled exactly, and that all proposed sites can in fact be sampled; these assumptions are not always appropriate in real surveys.

To evaluate a potential design we first use historical logbook data *H* to select and fit an appropriate GAM (as per Equation 5), and then evaluate the likely variance of an abundance estimate based on the same GAM, but fitted to typical data collected from *D*.

Let $\Gamma(x)$ denote a GAM that has been fitted to a dataset *X* (historical and/or survey), comprising of observations, Y_x, at covariate values Z_x. The vector $\hat{\theta}(\Gamma(x))$ is the point estimate of all the GAM parameters $\{\beta,\phi,\lambda\}$, and we write this as $\hat{\theta}(X)$ for brevity. θ can be divided into two parts: θ_F and θ_N, where θ_F denotes those parameters that should stay consistent across future surveys (e.g. the variance-related parameters λ and ϕ, plus the subset of β associated with environmental covariates), and θ_N denotes those parameters that are liable to change between surveys and will need to be re-estimated independently each time (e.g. "year effects", and parameters describing year-specific spatial density).

As discussed in the previous section, computations are simplified by assuming for now that θ_F is estimated reasonably well from the historical data alone by $\Gamma(H)$ and that little will be gained by re-fitting with additional survey data. We therefore distinguish between a "full model" $\Gamma(x)$ which fits both θ_F and θ_N, (e.g. Equation 5) and a "cut down model" $\Gamma(X|t_F)$ (e.g. Equation 6) which fits just θ_N given a fixed value t_F for θ_F.

The steps to predict the CV of an abundance index estimate $\hat{A}_D$ for a given survey design *D* are then as follows:

1. Fitting of the full model to the historical data

a. Fit the full model $\Gamma(H)$ to the existing historical data *H*, obtaining the point estimate $\hat{\theta}_F(\Gamma(x))$.

b. Select plausible values $\bar{\theta}_N$ for θ_N in a future survey. For example, this might entail setting year-specific spatial random effects to zero, and "year effects" to their overall mean.

2. Fitting of the cut-down model to the "design"

a. Compute the expected catches $\hat{Y}_D$ given z_D, $\hat{\theta}_F(H)$ and $\bar{\theta}_N$, to form an "exact" dataset $T = \{\bar{Y}_D, Z_D\}$.

b. Fit the cut-down model, $\Gamma(T|\hat{\theta}_F(H))$. Since there is no noise in $\bar{Y}_D$, the point estimate $\theta_N(T;\hat{\theta}_F(H))$ will be equal to $\bar{\theta}_N$, by construction (assuming that any random effects in $\bar{\theta}_N$ are set to zero, so that shrinkage has no effect); the main point of this step is to extract the covariance matrix $V[\beta|y]$, which is based on the dispersion parameter ϕ from step 1.

3. Variance calculation

a. Use $\Gamma(T|\hat{\theta}_F(H))$ (i.e., $\hat{\theta}_F(H)$ and $\bar{\theta}_N$) to form the abundance index estimate, $\hat{A}_T$, as per previous section.

b. Compute $dA_T(\theta_N)/d\theta_N \big|_{\hat{\theta}_N}$ numerically, by perturbing $\bar{\theta}_N$ and repeating step 3(a)

c. Infer $V[\hat{A}_T|T] = \left(dA_T(\theta_N)/d\theta_N \big|_{\hat{\theta}_N}\right)^T V[B|y]\left(dA_T(\theta_N)/d\theta_N \big|_{\hat{\theta}_N}\right)$, as per previous Section.

Note that variance parameters are fixed in the cut-down model, so the use of data free of measurement error causes no numerical or theoretical problem in fitting step 2. In particular, for an exponential-family, penalized-regression-style GAM, the

Fisher information of an average observation is equal to the average information of an observation.

We treat the smoothing parameters λ as fixed by the historical data; if λ describes the amount of spatial variability, then it is reasonable to assume that this will be consistent over time. However, the same may not apply to the dispersion parameter ϕ which reflects sampling variance, since the data collection protocols of the survey may differ from those in the historical data. Because this was likely in our example, we re-estimated ϕ from the survey data alone; with the package mgcv, some care is needed to vary ϕ while keeping λ fixed, since the smoothing parameters are interpreted relative to ϕ, not in absolute terms. For design purposes, it is still necessary to assume some value for ϕ, and unless a pilot survey happens to be available, the use of historical ϕ seems unavoidable.

SESSF Design

The components of the SESSF FIS design that were not completely constrained by logistics were: depth, spatial location (position along coast), and the amount of effort per season. The time of day that samples were taken, and gear type, were fixed by the survey protocol, so not varied in the design. Due to the additive nature of the model, terms can be adjusted orthogonally to test for the effect of each on precision. For example, the question of whether to survey at day or night could be examined independently of where to place survey effort in space. A number of design scenarios were investigated, based mainly on logistical constraints and some general sense of what a good design would entail (e.g. good spatial coverage). A workshop was then held, in which designs were proposed and modified with the general goal of achieving reasonable precision (CV below 30%) for the eleven species in Table 1. Other factors such as the ease of implementing the design were also considered and a final design was agreed. The model-based approach to design was found to be of particular use in this environment, since suggested designs or modifications could be evaluated quickly and quantitatively.

Depth sampling: In the SESSF, the gradient of the sea floor is highly variable, and it is therefore not possible to sample uniformly in the depth covariate space as well as uniformly in geographical space. A uniform sampling of depth covariate space would correspond to a deep water bias in the geographical space. Holding other survey design elements constant, we examined the effect on precision of a number of different depth sampling strategies. Some species give better CVs when sampling is predominantly shallow, and others when sampling is predominantly deep. In the end, two strategies were adopted, depending on season. In summer, a shallower depth sampling was used to boost the precision for Blue Warehou, Jackass Morwong, John Dory, Tiger Flathead, Redfish and Silver Warehou. In winter, deeper sampling was used to help with the precision of Gemfish, Blue-eye Trevalla, and Mirror Dory.

Spatial distribution: Fishing effort in the SESSF is higher near ports, and considerable time is needed to travel to some parts of the SESSF. From the logistical perspective of surveying 2,500 km of coastline, it makes sense to take advantage of the efficiency of sampling nearer ports where possible. The distribution of effort in the fishery, however, is not necessarily optimal for survey design, where slightly more uniform coverage is required. The survey spatial distribution was chosen to be an equal mixture of fisheries effort and a uniform distribution across the fishery.

Once a design was decided upon, further complications emerged relating to "untrawlable" ground. This problem occurred at two levels: First, during the design phase, it was obvious from maps that no "trawlable" ground was available at the required coastal position and depth for some proposed sample sites. To address this, we deterministically moved "untrawlable" sample sites to the closest nearby "trawlable" ground. Since the spatial scale of the coastal position coordinate was much larger than the depth coordinate, a distance metric that favoured retaining the specified depth more than the coastal position was used. Second, some sample locations still proved to be "untrawlable" during the initial survey itself, and had to be moved at the time on an ad hoc basis.

Figure 3 shows how the designs sit within the covariate space (i.e. coastal position versus depth). The top two plots correspond to the proposed designs for summer and winter. The different depth sampling strategies of the two seasons is clearly shown. The bottom two plots show the actual implemented design, resulting from the cumulative design changes. The comparison between the proposed (top) and implemented design (bottom) provides a perfect demonstration of how big the differences can be between planned and realised designs for fishery surveys.

Furthermore, these differences highlight why it is beneficial to use model-based method to analyse fisheries data. Model-based analysis is conditional on the real survey locations rather than those planned, and are therefore fairly robust to the unplanned changes.

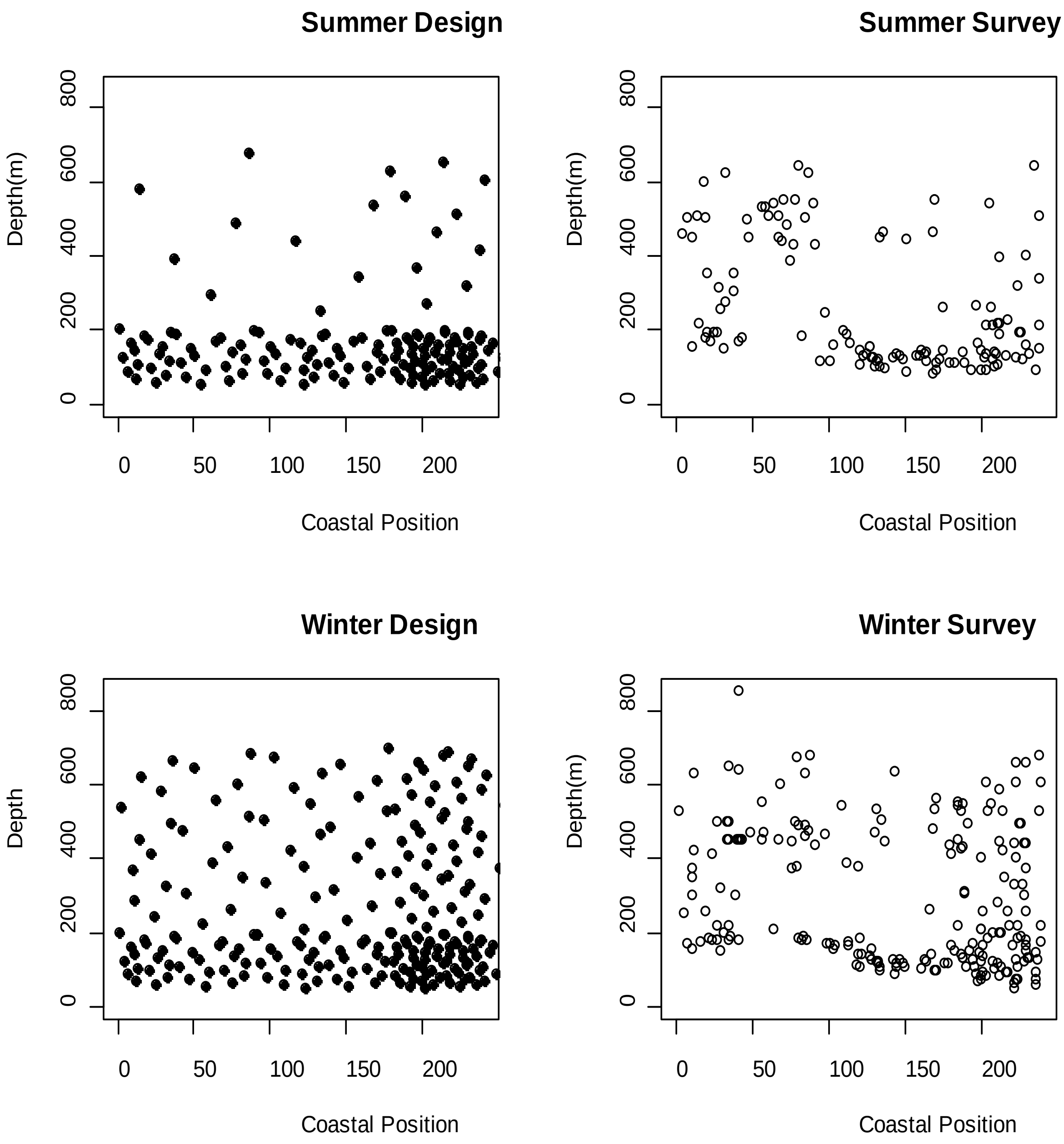


Figure 3. Comparison of the covariate coverage (i.e., depth versus coastal locations) for the proposed design for summer (top) and winter (bottom), and the actual survey.

Combining Seasonal CVs

Since the SESSF survey is actually two separate surveys, one in summer and one in winter, the survey produces two independent abundance index time series, each with associated CVs. For planning purposes it is useful to be able to estimate the "overall equivalent CV" of the combined series. If the two indices have the same "catchability", then the two series could be combined into one using inverse-variance-weighting with no loss of information, and the overall CV could be easily found. The "catchabilities", however, may not be the same between seasons, so this method does not apply directly.

Instead, suppose the two series are I_{1t} and I_{2t} where *t* is the year, with unknown "catchabilities" q_1 and q_2, and known CVs CV_1 and CV_2. If the true abundance in year *t* is N_t, then we have

$$\log I_{1t} = \log q_1 + \log N_t + \varepsilon_{1t}$$

$$\log I_{2t} = \log q_2 + \log N_t + \varepsilon_{2t}$$

where $V[\varepsilon_{1t}] \approx CV_1^2$ and $V[\varepsilon_{2t}] \approx CV_2^2$. Consequently $\log I_{1t} - \log I_{2t}$ is an estimate of $\log q_1 - \log q_2$ that is independent across *t* and does not require any underlying assessment model. By averaging these estimates across years, the uncertainty in our estimate of $\log q_1 - \log q_2$, $\log \overline{q}$, will eventually become negligible as the two series accumulate. We could therefore work with an adjusted second series $I_{2t}^* := I_{2t} + \log \overline{q}$ so that the two series have the same "catchability". Adding a constant does not affect the variance, and the optimally-weighted combination of I_1 and I_{2t}^* can be shown to have CV of $(CV_1 \times CV_2) / \sqrt{CV_1^2 + CV_2^2}$. Formally, this is the same as if the two series had the same "catchability", but it requires an asymptotic justification.

Predicted CVs for the 2008 summer, winter and combined surveys are shown in Table 2. Combined CVs ranged 0.11 for Tiger Flathead to 0.72 for Silver Trevally. Species for which usable (≤0.3) CVs in summer, winter and both seasons combined are Jackass Morwong, Tiger Flathead, Pink Ling, and Silver Warehou.

Table 2. CVs predicted by the survey design.

Species	Summer	Winter	Combined
Blue Warehou	0.78	0.84	0.34
Jackass Morwong	0.25	0.16	0.18
John Dory	0.39	0.26	0.20
Gemfish	0.46	0.33	0.28
Tiger Flathead	0.18	0.15	0.11
Pink Ling	0.24	0.19	0.15
Silver Trevally	0.98	N/A	0.72
Redfish	0.43	0.79	0.20
Blue-eye Trevalla	0.78	0.59	0.43
Mirror Dory	0.32	0.23	0.19
Silver Warehou	0.25	0.21	0.13

Survey Implementation

Numerous meetings with industry and managers occurred over the last six months of 2007, including critical meetings with the industry associations and MACs. This culminated in a presentation of the project and the survey design and costings at the joint SESSF Management Advisory Committee (MAC) meeting held on 20th November 2007 in Canberra. More information was required by the MAC in order for them to make a final decision on the intensity of the sampling that would be conducted during the preliminary survey during 2008. This was provided and the MAC agreed to fund a survey of 360 shots as recommended. At this point, there was general acceptance by all stakeholders of the need for a fishery independent survey for the SESSF and support for the preliminary survey to proceed during 2008.It was also agreed that all of the quota species caught during the survey would be covered using a “research catch allowance”. This allowance covers the catch of quota species likely to result from a particular research project — in this case, the fishery independent survey. Because this catch is a component of the total mortality for fish stock assessment purposes, it needs to be deducted from any sustainable catch in setting the TAC. For each of the 2008 and 2010 surveys, the likely catch of quota species was estimated and an agreed catch allowance was approved by the MAC during the TAC setting process. To ensure that the value of the research about the community resource is not compromised by the value of the research to the fishing industry, research allowances were used under strict scientific permits (see AFMA 2007).

Sampling Location and Duration

As mentioned above, sampling locations were randomly allocated within each strata, but because many areas are "untrawlable", some sampling locations were deterministically moved to the closest nearby "trawlable" ground. Coordinates for the sampling locations were pre-allocated and provided to the skippers and field scientist prior to departure. Together, they developed a voyage plan that sampled the survey area as efficiently as possible. Back-up sampling locations were also provided in case the first position was "untrawlable". Skippers could choose the path of the tow, with the requirement that the vessel passed within 500 m of the selected position (Appendix 5). Skippers were instructed to attempt to tow parallel with depth contours, and at a speed of 3 knots. To reduce diurnal bias, sampling was restricted to day-time (setting of shots from 0500 – 1800).

To cost effectively sample a large number of sites, short tow durations are preferable (Pennington and Volstad 1991). Tow duration was plotted against CVs for species considered in the survey design, and it was apparent that CVs were relatively stable for shots greater than 1 hr. Although this was considered as the minimum duration for survey shots for achievement of CVs, industry members were concerned that short tows could lead to avoidance by some strong, fast-swimming species including Silver Trevally, Blue Warehou and Silver Warehou and did not agree to shots as short as 1 hour. They were willing to accept 2 hour shots as the minimum and this was accepted into the survey design.

Tows of this duration reduce the chance of avoidance, but enable up to four shots a day to be conducted. Tow duration was timed from when the warps were fully deployed to when gear retrieval began. During each tow, operational and environmental details were noted. Door spread was estimated by measuring the distance between the warps at the block, and again one metre behind the blocks. Door spread was then calculated as follows:

$$d = (w_1 - w_2) \times WL + (w_1 - w_2)$$

where w_1 is the distance between the warps one meter down from the blocks, w_2 is the distance between the warps at the back of the blocks and WL if the warp length.

Survey Gear

For the FIS to provide a robust time-series of relative abundance indices, the survey design, fishing practices and net design need to remain constant over time (i.e. decades into the future). For this reason we required a standardised generalist net that was suited to the survey design and not biased to the capture of particular species. Although it would have been preferable to have the same net operating throughout the different areas of the survey, due to the prevalence of 'hard ground' (high relief reef) in the western region, a net with heavier ground gear was required. Initially it was envisaged that a different net size and design would be required for the type of survey vessel working off NSW to those working east and west of Bass Strait. The differences in the net design required in the east and west regions are shown in Table 3. Importantly, both nets needed to be hung on stainless steel combination rope or a similar alternative to ensure durability and long operating life (nets will not be used continually during the year and will be stored for long periods between surveys).

A tender was called to quote for the design and construction of the net from the doors to the codend, including: appropriate number of bubbles and leads, lazy line, lifting strops, codend strings etc. It was stipulated that a net plan (including all dimensions, mesh size, ply, doors, sweeps, bridles etc) will need to be provided as part of the tender to allow assessment of its suitability for the survey. It was advised that all details in the tender document would be made available for review and that the final design would be published at the completion of the project to enable them to be copied for ongoing use in the survey.

During the tendering process, further discussions were had with netmakers and industry on the design of the net. Ultimately it was agreed that a single net design would be used for both NSW and eastern regions and another net design would be used for the western region (Figure 4 and Figure 5). David Guillot was the successful tenderer for design and construction of the NSW and eastern nets and Hugh McKenna was the successful tenderer for design and construction of the western net. Designs of the nets are provided in Appendix 3.

Table 3. General survey net designs required in the different survey regions

SESSF Survey net	
NSW and Eastern Survey Regions	**Western Survey Region**
• Operating 50-600m depth	• Operating 100-600m depth
• A basic, generalist wing or diamond trawl net	• A basic, generalist wing or diamond trawl net
• 1800 – 2000 inch round net opening	• 2000-2400 inch round net opening
• To suit a vessel of minimum 350Hp towing at 3.0 knots average	• To suit a vessel of minimum 450Hp towing at 3.0 knots average
• Lengthener 100 mesh long 90mm single	• Lengthener 100 mesh long 100 mm single
• Codend 33 mesh long 100 mesh round 90mm single / double	• Codend 50 mesh long 100 mesh round 102mm double
• Approximate headline height 3-4 m	• Approximate headline height 4-5 m
• Rubber line with 6 inch discs and leads (70 kg)	• Rubber line with 9 inch discs and leads (100 kg)

Vessel Charter

Because of the vast survey area and large number of samples required, three different vessels were chartered for each sampling event. Vessels used and their specifications are shown in Table 4. Vessels were chartered through an open tender process, and the catch became property of the survey project, to offset costs. Details of the call for Expressions of Interest sent out to industry members are provided in Appendix 4. An outline of tender requirements is provided below. These were stipulated in more detail in the vessel charter contracts.

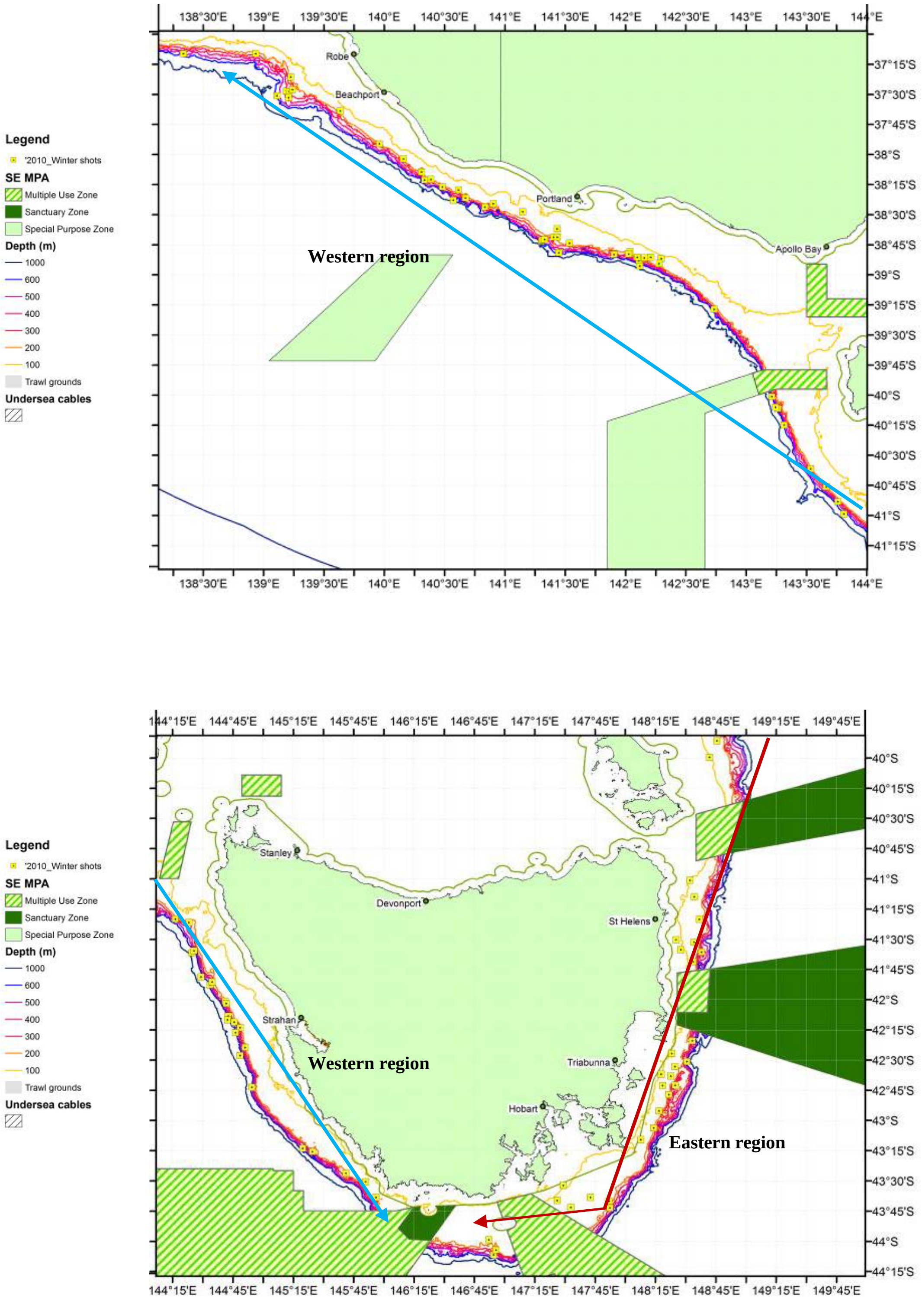
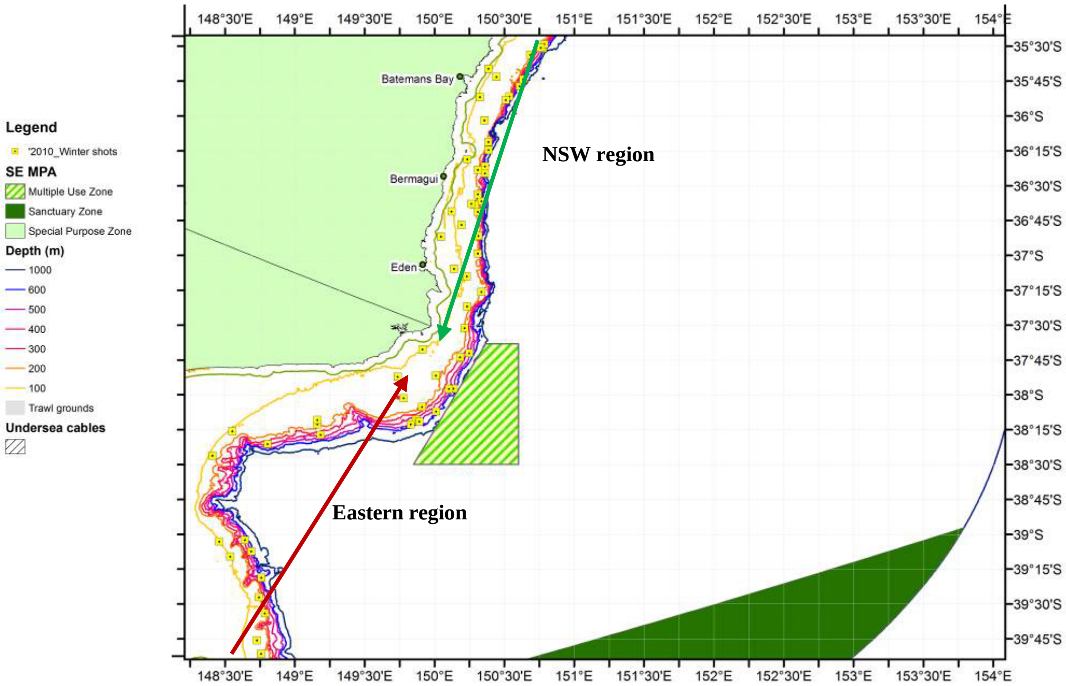


Figure 4. Survey area showing the western region and part of the eastern region.



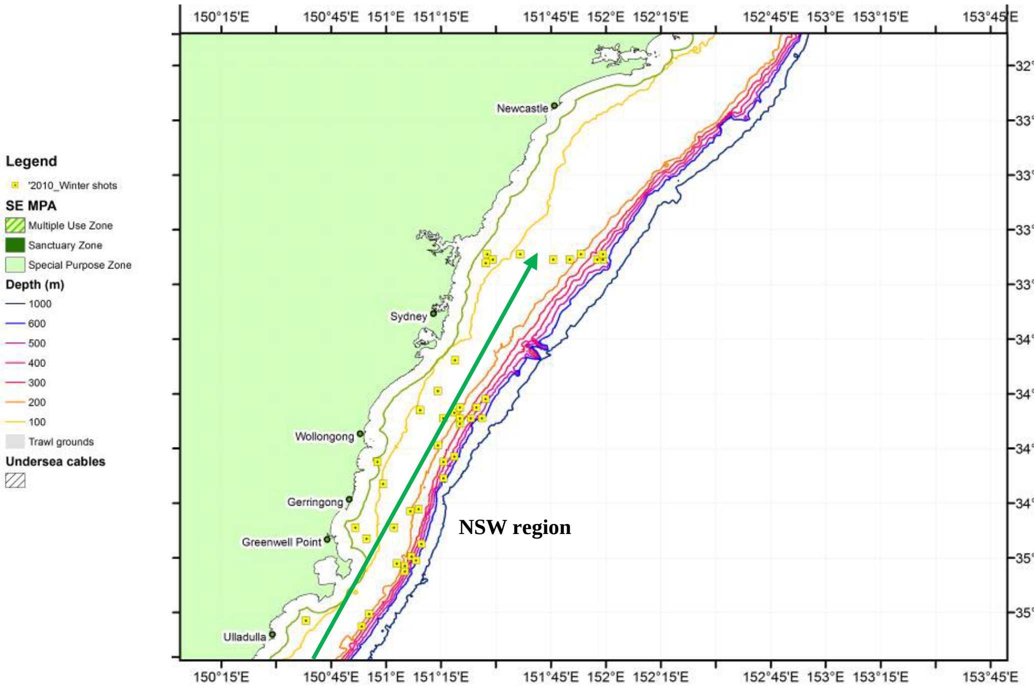


Figure 5. Survey area showing the part of the eastern region and the NSW region.

Catch / Charter arrangements:

- Survey vessels will be chartered on a daily rate to undertake valid survey shots;
- AFMA has agreed to a Research Allowance to cover all the catch of quota species taken while conducting the survey;
- All catch (quota and non-quota) taken during the survey will be the property of the survey project and proceeds from the sale will be used to offset the survey charter costs;
- Costs to transport and sell the fish caught during the survey (including commission) will be paid by the project;
- All other vessel operation costs required to participate in the survey will be covered by the vessel and should be allowed for in the vessel's daily charter rate;
- Sale of the fish caught during the survey will be entirely the responsibility of the vessel;
- Depending on the location of a survey trip, the project and skipper/owner will agree on an appropriate port of landing;
- A proportion of the proceeds from sale of the survey catch (up to 10%) may be returned to the vessel as an incentive to undertake the survey correctly and ensure appropriate fish handling and storage for commercial sale;
- A small proportion (<10%) of the catch will be sampled for scientific purposes and may need to be sold as damaged fish.

Vessel requirements

The vessel and fishing equipment must:

- be in proper good and workmanlike condition and suitable for use in the survey;
- be maintained in Marine Board Survey class 3 throughout the Survey Period;
- have adequate safety gear and survey requirements to carry one survey personnel in addition to the skipper and crew;
- have a stabilised 240 volt AC power supply;
- have sufficient accommodation for survey personnel in addition to the skipper and crew;

- have sufficient deck space to process and sort each catch of fish collected during each trip;
- have a fish room and sufficient ice/refrigeration to store at least twenty tons of fish;
- have space in the wheelhouse or other suitable dry area for the researchers to establish a laptop and process data, samples, and record sheets etc.

Owner requirements

The owner must:

- hold a Statutory Fishing Right for the Commonwealth Trawl sector of the SESSF under the Fisheries Management Act 1991 (Cwth);
- ensure that there is appropriate hull / public liability insurance;
- be able to make the vessel, skipper, crew and appropriate fishing gear available for the entire period of the survey;
- ensure that the survey personnel are provided with a satisfactory standard of accommodation, victualling, medical care and a safe and healthy working environment;
- ensure that survey personnel are given reasonable access to all required areas and facilities of the vessel to collect data, samples, and other information required and have reasonable daily access to the vessel's radio and satellite communication facilities.

Table 4. Specifications of vessels used during trawl surveys.

	Moira Elizabeth	Western Alliance	Francesca	Game Reason
Chartered survey	2008 – summer and winter 2010 – summer and winter	2008 – summer and winter 2010 – summer and winter	2008 – summer and winter 2010 – winter	2010 – summer
Region Surveyed	Western zone	Eastern zone	NSW	NSW
Length (m)	25.7	22	23.5	19.1
Gross tonnage	170	180	120	60
Power (hp)	500	620	1000	400

Catch Sampling Procedures

Each survey vessel carried a scientific observer who was responsible for sampling the catch. Once on board, fish were identified to the lowest taxonomic level possible, and their total weights estimated. Catches of commercial species were verified by comparing estimates to landing weights. Adjustments were made when large differences were found. Length frequency measurements and otoliths were taken for important commercial species. Data were entered and archived on Olfish Dynamic Data Logger (V5.0.1). The following information was recorded.

<u>Operational</u>

Trip Trip ID, Vessel, Skipper, Observer, Depart Harbour, Start Date, Start Time, Start Latitude, Start Longitude, Return Harbour, End Date, End Time, End Latitude, End Longitude

Set Start Set Date, Start Set Time, Start Set Latitude, Start Set Longitude, End Set Date, End Set Time, End Set Latitude, End Set Longitude, Set Direction, Set Speed, Valid Set

Start Haul Date, Start Haul Time, Start Haul Latitude, Start Haul Longitude, End Haul Date, End Haul Time, End Haul Latitude, End Haul Longitude, Haul Direction, Haul Speed, Door Spread

<u>Environment</u>

Wind Strength (Beaufort), Cloud Type, Cloud Cover, Moon Phase, Wind Speed, Wind Direction, Air Temperature, Swell height, Wave Height, Sea Surface Temperature, Surface Current Speed, Surface Current Direction, Bottom Temperature, Bottom Current Speed, Bottom Current Direction

<u>Biological</u>

Catch Species, Process, Length, Length Unit, Length code, Sex, Total Green Weight

Otoliths were collected from a subsample of the main quota species in the catch

<u>TEP Interaction</u>

Species, Sex, Weight, TEP Date, TEP Time, TEP Latitude, TEP Longitude, Interaction type, Life State

For summer and winter surveys in the eastern and western regions, Lotek LAT 1400 time, temperature and depth tags in stainless steel housings were attached to the survey nets (see Knuckey *et al*. 2010 for more details). Tags were set to record date, time, pressure (depth) and temperature at 10 minute intervals.

Results and Discussion

Survey implementation

Pilot survey - 2008

A survey based on the final design was successfully implemented during summer and winter of 2008. Three vessels were employed for the survey, each conducted both the summer and winter surveys in one region; the Moira Elizabeth sampled the western region, the Western Alliance sampled the eastern region while the Francesca sampled the NSW region (Table 4). A total of 125 shots were conducted over 52 vessel days during summer (38 in the NSW region, 43 in the eastern region and 44 in the western region), and 205 shots conducted over 87 vessel days during winter (71 in the NSW region, 65 in the eastern region and 69 in the western region) (Table 5, Appendix 7). The summer survey was completed in seven trips, during which an average of 2.4 shots were conducted during each of the 52 sea days, while the winter survey required 19 trips during which an average of 2.4 shots were conducted during each of the 87 sea days undertaken.

There were many cases where prescribed shot locations could not be trawled due to rough ground, requiring the use of back-up locations or some shots being missed altogether. This alteration for the sampling design resulted in under sampling of shallow (<200 m) depths in the western region (Figure 2). Another effect of avoidance of "untrawlable" ground was the bunching of shot locations. This was particularly noticeable in shallow depths of the NSW and eastern regions.

The 2008 survey caught 290 species of fish weighing 328 t, of which 26 were quota species of quota species baskets (Table 8, Figure 6). A full list of species caught during 2008 and 2010 surveys is shown in Appendix 6. A total of 107 t of quota species were caught during the two surveys, 38.7 t during summer and 68.6 t during winter. Totals of 149 t of non-quota teleosts, 51 t of non-quota chondrichthyans and nearly 10 t of cephalopods were also caught. Only a small portion of the non-quota species was of commercial value as byproduct, the rest were discarded as bycatch.

Main quota species caught during 2008 were Silver Warehou (27.3 t), Blue Grenadier (25.8 t), Tiger Flathead (15.1 t) and Jackass Morwong (8.6 t) (Table 8, Figure 7). Most Blue Grenadier and Jackass Morwong were caught during summer, while catches of most other species including Silver Warehou and Tiger Flathead were greater during winter. Quota species caught most frequently during the summer 2008 survey (Figure 8) were Jackass Morwong (49% of shots), Tiger Flathead (47%), Silver Warehou (42%) and Pink Ling (39%), while Common Sawshark (53%), Tiger Flathead (51%), Silver Warehou (47%) and Pink Ling (44%) were the most commonly caught quota species during winter. Rarely caught (<10% of shots in summer and winter) quota species were Alfonsino, Blue-eye Trevalla, Eastern School Whiting, Orange Roughy, Oreo basket, Ribaldo, Royal Red Prawn, Silver Trevally and Southern Sawshark (Figure 8).

More than 32 t of Frostfish were caught during the 2008 survey, nearly all of that during winter (Table 8, Figure 9). Other non-quota teleosts caught in large quantities were Barracouta (22.5 t), Ocean Jacket (16.8 t), Blacktip Cucumberfish (12.8 t), Silver Dory (6.6 t) and Gargoyle Fish (4.9 t). Spikey Dogfish (15.9 t), Greenback Stingaree (10.8 t) were the non-quota chondrichthyan species caught in greatest quantities (Table 8, Figure 10), followed by Melbourne Skate (2.5 t), Sydney Skate (2.5 t), Peacock Skate (2.0 t) and Draughtboard Shark (1.7 t). Much more Spikey Dogfish and 'Other chondrichthyan species' were caught during winter than summer. Of the other major taxonomic groups recorded, about 5 t of cephalopods were caught in each of summer and winter, 4.6 t of crustaceans were caught during summer and winter combined and over 4 t of echinoderms were caught during winter (Table 8, Figure 10).

A total of 3,301 otoliths were taken from nine different quota species during the 2008 survey (Table 6). These included otoliths from 726 Tiger Flathead, 445 Silver Warehou, 436 Pink Ling, and 434 Jackass Morwong. Some of those otoliths were aged, and the data included in 2009 stock assessments.

Nearly 24,000 length frequency measurements were recorded from 25 quota and non-quota species during 2008 (Table 7). Length frequency distributions for main species are shown in Figure 12 – Figure 28.

Review of pilot survey

An important aspect of this project was to keep key stakeholders informed, and to involve them with the planning and design of the survey. Operational aspects and results of the 2008 survey were reviewed during meetings with scientists, managers and industry members held in Melbourne over 21–22 September 2009 (Appendix 8). During the meetings, a summary of the survey methods, results and problems were presented and discussed with the aim of refining the survey for 2010.

Main problems/issues discussed were:

1. The lack of shallow sites sampled in the western region;
2. The clustering of sampling sites in shallow water in the NSW and eastern regions; and
3. The use of a 'heavier' net in the western region that may have different selective properties to the other nets.

The lack of shallow sampling sites in shallow water off Western Victoria and Western Tasmania prompted a call for the industry members to search harder for suitable sites. Industry members were supportive of this, and provided additional 12 "shallow shots" to be implemented during the 2010 survey. These replacement shots were randomly assigned between winter and summer surveys. To compensate for the addition of 12 extra sites, an equal number of sites were removed from the NSW and eastern regions to reduce clustering of sites, as data from clustered sites did not 'inform' the model as well as what those of a wider distribution would. The choice of which sites to remove was subjective, with preference given to tightly clustered sites off NSW and eastern Tasmania.

The implications of using a different net in the western region because of the 'heavy ground' was discussed at the meetings, and it was concluded that rather than calibrating the heavy net against the other two nets, it would be more appropriate to treat each region — east (NSW and eastern regions) and west (western region) — as separate indices of abundance. This was largely driven by the fact that assessments for most species are generally separated into eastern and western stocks. The location of the division between east and west was discussed, and rather than the traditional line at 147° E, observations of a distinct change in catch composition suggested that the line should be formed at the Tasman Fracture MPA (Figure 31).

2010 survey

The revised survey design was successfully implemented during the summer and winter of 2010. Four vessels were employed for the survey; the Moira Elizabeth sampled the western region during summer and winter, the Western Alliance sampled the eastern region during summer and winter, while the Game Reason sampled the NSW region during summer, and the Francesca sampled the NSW region during winter (Table 4). A total of 119 shots were conducted during summer (33 in the NSW region, 47 in the eastern region and 39 in the western region), and 202 shots conducted during winter (67 in the NSW region, 67 in the eastern region and 68 in the western region) (Table 5). The summer survey was completed in eleven trips, during which an average of 2.2 shots were conducted during each of the 55 sea days, while the winter survey required 19 trips during which an average of 2.4 shots were conducted during each of the 85 sea days undertaken.

The 2010 survey caught 274 species weighing 244 t, of which 25 were quota species or quota species baskets (Table 9, Figure 6). A total of 60 t of quota species were caught during the two surveys, 20.8 t during summer and 39.5 t during winter. Totals of 132 t of non-quota teleosts, 31 t of non-quota chondrichthyans and about 3.7 t of cephalopods were also caught.

Main quota species caught during 2010 were Tiger Flathead (12.9 t), Blue Grenadier (8.1 t), Silver Warehou (7.7 t) and Mirror Dory (6.9 t) (Table 9, Figure 7). As in 2008, most Blue Grenadier and Jackass Morwong were caught during summer, while catches of most other species including Tiger Flathead and Silver Warehou were greater during winter. Quota species caught most frequently during summer 2010 survey (Figure 8) were Tiger Flathead (53% of shots), Silver Warehou (48%), Jackass Morwong (48%), and Pink Ling (48%), while Tiger Flathead (58%), Silver Warehou (53%), Pink Ling (48%) and Mirror Dory (47%) were the most commonly caught quota species during winter. Rarely caught (<10% of shots in summer and winter) quota species were similar to those in 2008, Alfonsino, Blue-eye Trevalla, Eastern School Whiting, Orange Roughy, Oreo basket, Ribaldo, Royal Red Prawn, School Shark, Silver Trevally and Southern Sawshark (Figure 8).

More than 33 t of Frostfish were caught during the 2010 survey, nearly all of that during winter (Table 9, Figure 9). Other non-quota teleosts caught in large quantities were Barracouta (23.8 t), Blacktip Cucumberfish (14.2 t), Ocean Jacket (8.8 t), Silver Dory (5.1 t) and Australian Burrfish (6.8 t). Spikey Dogfish (6.6 t) and Southern Eagle Ray (3.6 t) were the non-quota chondrichthyan species caught in greatest quantities (Table 9, Figure 10), followed by Greenback Stingaree (2.8 t), Melbourne Skate (1.6 t), Sandyback Stingaree (1.4 t) and Whitefin Swell Shark (1.3 t). All of the Southern Eagle Ray, and about twice as much Spikey Dogfish and 'Other chondrichthyan species' were caught during the winter compared to the summer periods. Of the other major taxonomic groups recorded, 3.7 t of cephalopods, 3.2 t of crustaceans and 6 t of urochordata (mostly salps) were caught during 2010 (Table 9, Table 8, Figure 10).

A total of 2,839 otoliths were taken from nine different quota species during the 2010 survey (Table 6). These included otoliths from 907 Tiger Flathead, 321 Gemfish, 319 Jackass Morwong and 319 Silver Warehou.

More than 26,000 length frequency measurements were recorded from 25 quota and non-quota species during 2010 (Table 7). Length frequency distributions for main species are shown in Figure 12 – Figure 28.

Temperature-depth data collected from tags mounted on the survey nets used by the Western Alliance (eastern region) and Moira Elizabeth (western region) are shown in Figure 29 and Figure 30. Bottom temperatures of summer shots in less than 200 m depth in the eastern region ranged 10.5 – 14.2 ^{o}C, and off the shelf temperatures were 7.5 – 9.2 ^{o}C (Figure 29a). During winter the temperature remained more stable at 11.5 – 13.8 ^{o}C until depths of about 500 m, after which a wider range in temperatures were recorded (7.7 – 12.5 ^{o}C). Summer bottom temperatures were generally colder in the western region ranging 9.7 – 12.7 ^{o}C at depths less than 250 m, and 6.5 – 9.5 ^{o}C off the shelf (and Figure 30a). The four examples of temperature-depth profiles shown display clear trends of reduced temperature with increasing depth (Figure 29b and c and Figure 30b and c). These results can be used to get an indication of the time the net was on the bottom, and if tags were set to record information at more frequent intervals (for example every minute), accurate bottom times could be measured.

Review of 2010 survey

A meeting was held in Melbourne during 23 – 24 June 2011 to discuss the 2010 survey results and to plan the future direction of the SESSF independent survey (Appendix 9). The meeting was attended by fishery managers, industry representatives and scientists (including stock assessment scientists).

Review of the distribution of sampling effort showed that improvements had been made in increasing sampling in shallow depths in the western region, and reducing the clustering in the NSW and eastern regions. Another gap in sampling distribution became apparent however in depths 200 – 400 m off south-east Tasmania. Industry members agreed to look for available shots in that area.

There was general agreement that the methods and administrative processes used were appropriate, and should be continued in future surveys. An option for continuing the survey in each year during 2012 – 2015 was outlined and options discussed for improving efficiency (in terms of cost savings and increasing the number of species for which relative biomass estimates with useable CVs are achieved). These options are explored further in the section below.

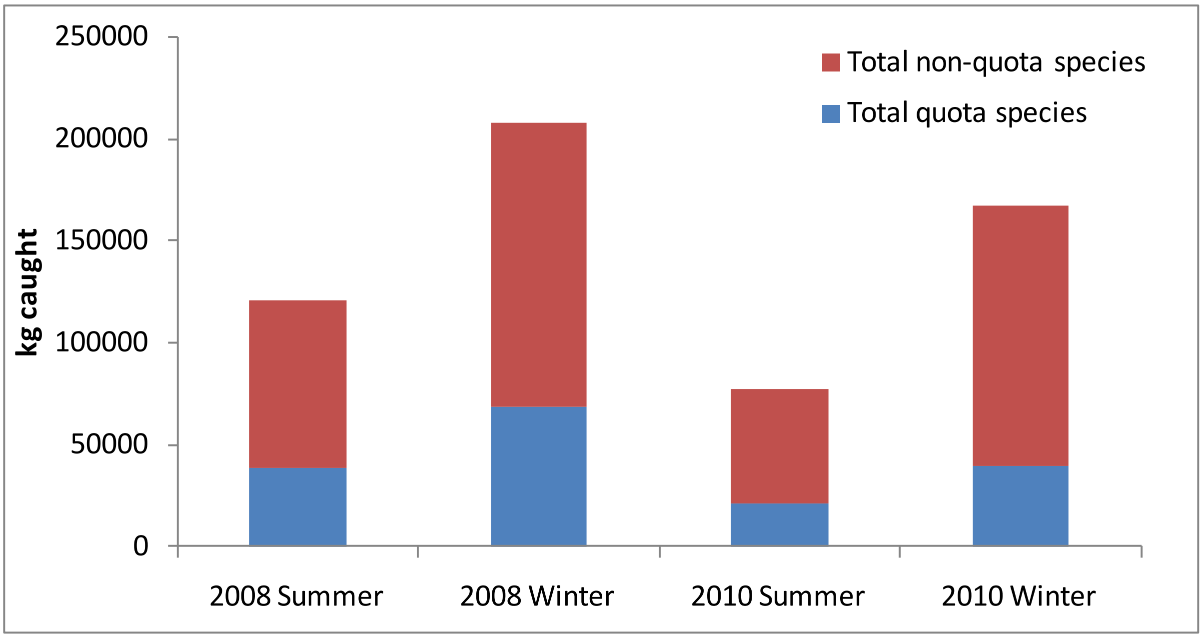
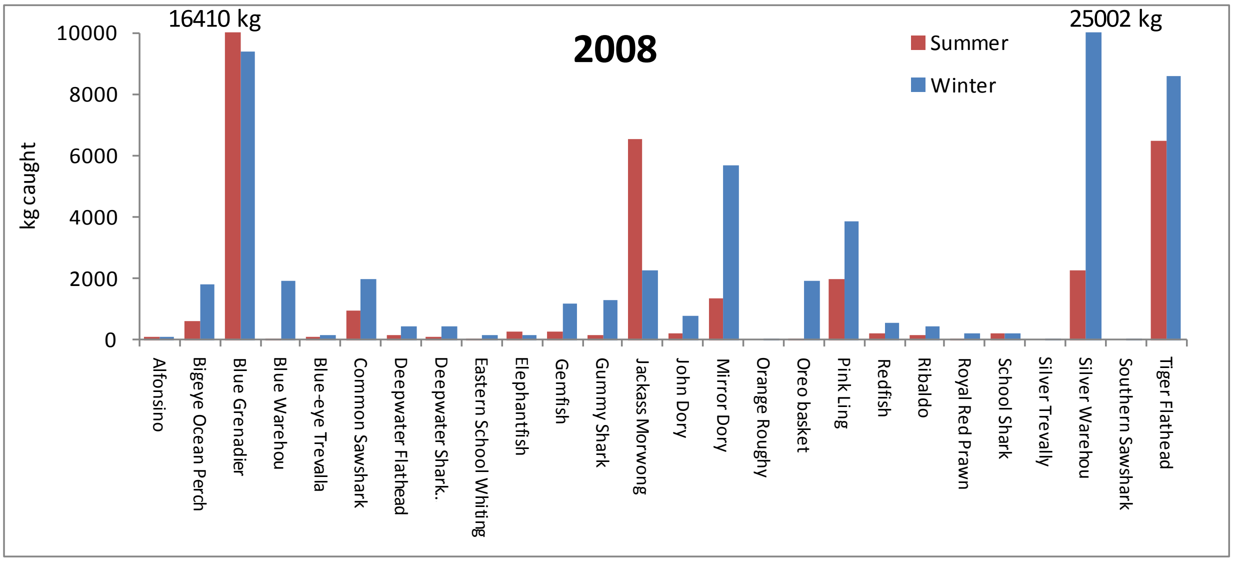


Figure 6. Total catch of quota and non-quota species during 2008 and 2010 summer and winter surveys.



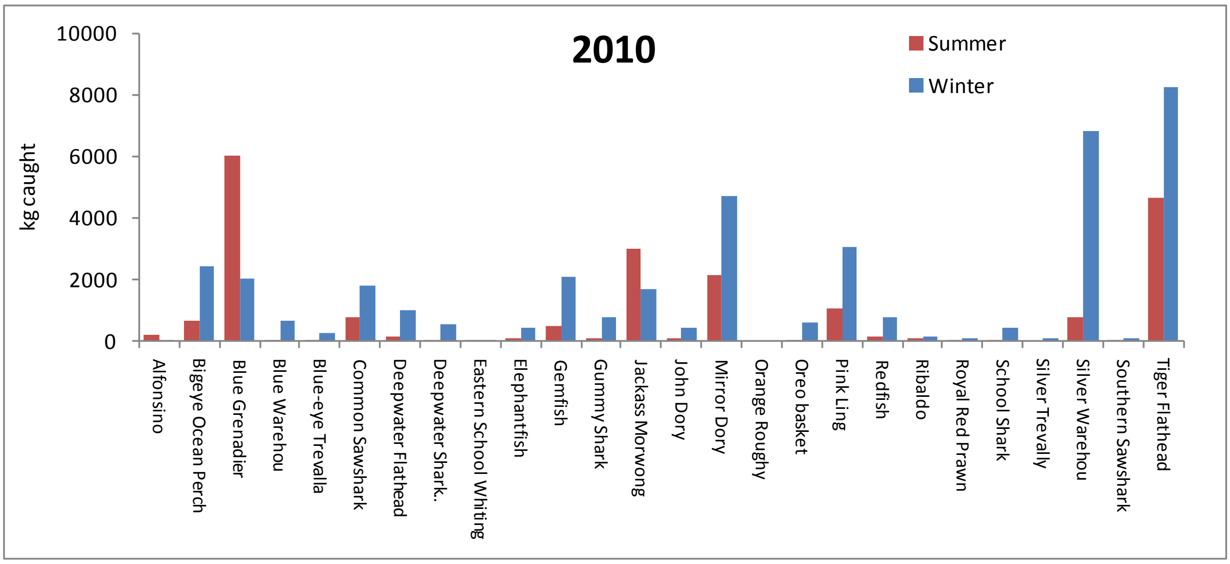
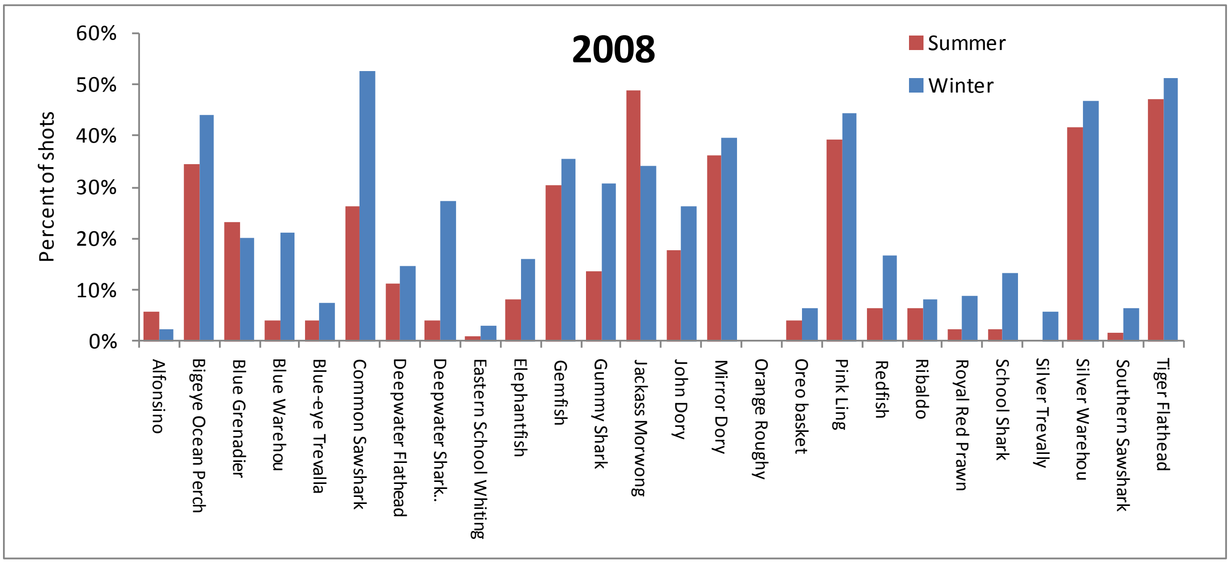


Figure 7. Catch of each quota species during 2008 and 2010 summer and winter surveys. Note Oreo and Deepwater Shark baskets are shown for brevity. Y-axis scale on 2008 chart abbreviated for display and catch of Blue Grenadier in winter and Silver Warehou in summer are displayed above chart.



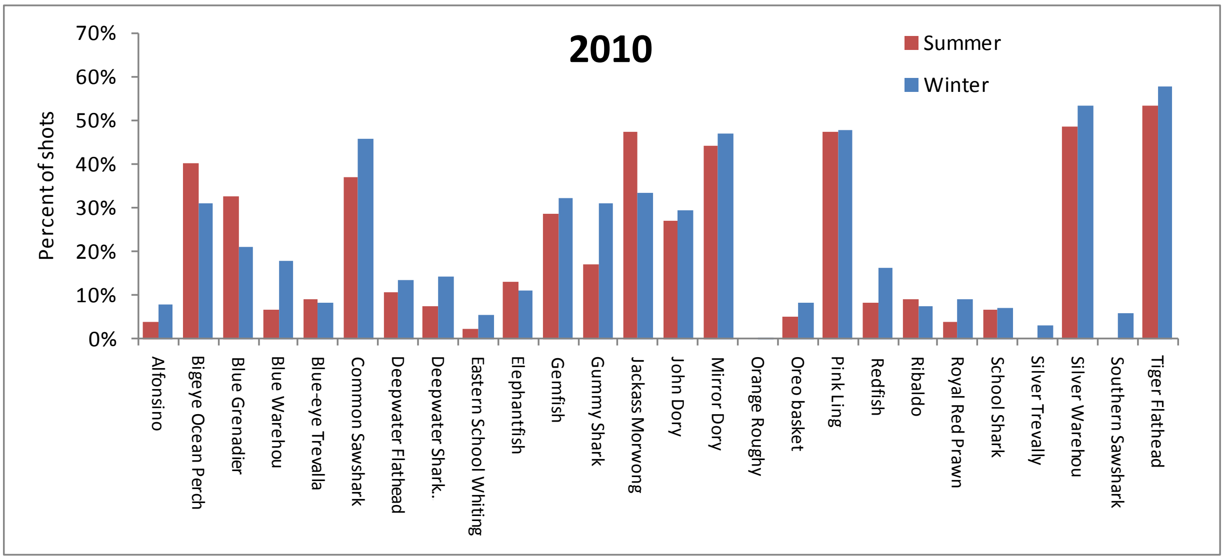


Figure 8. Percent of shots containing each quota species during 2008 and 2010 summer and winter surveys. Note that the figure for Deepwater Shark basket is the sum of the frequency of each component species.

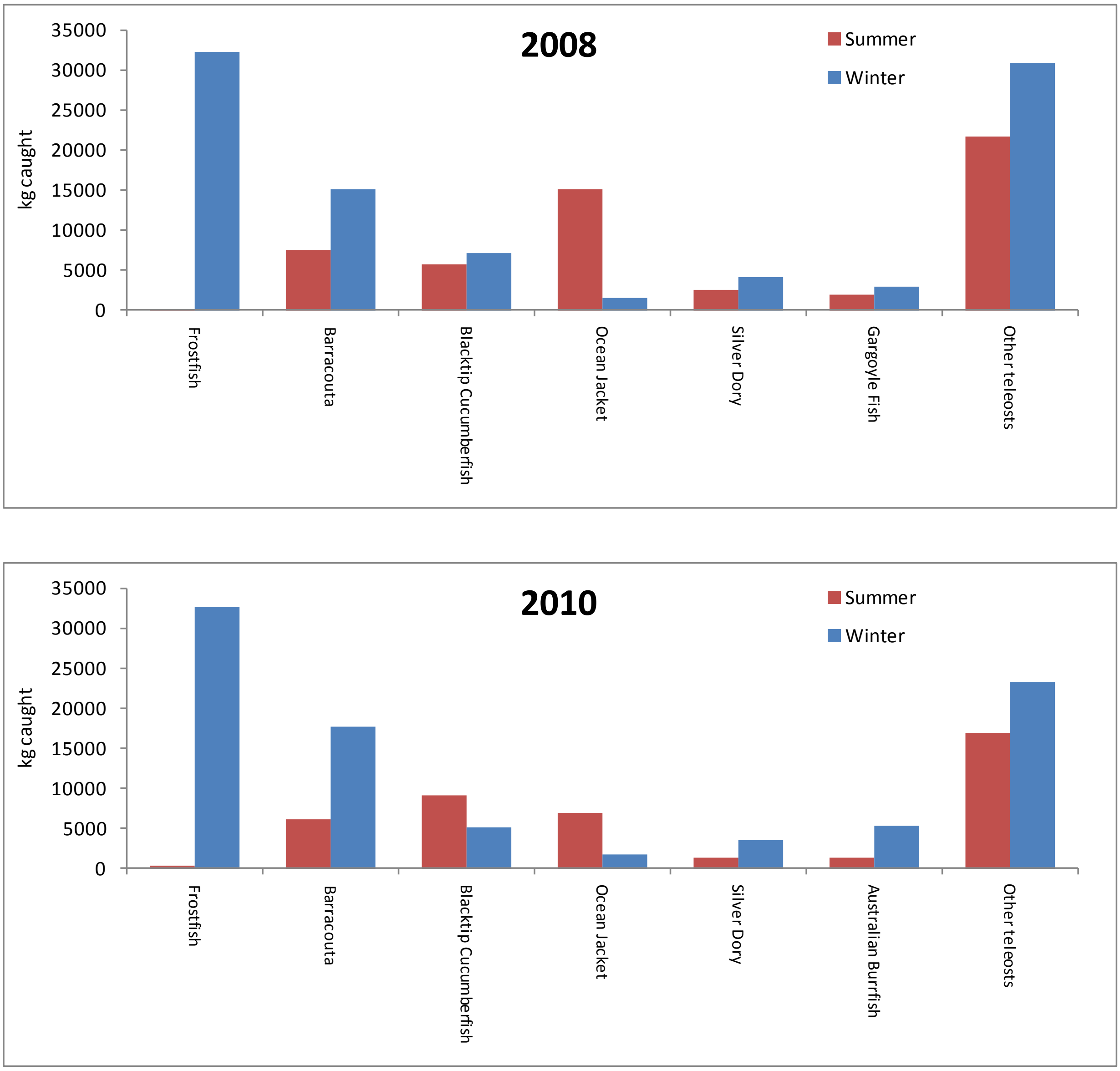


Figure 9. Catch of main non-quota teleosts species, and other non-quota teleosts combined, during 2008 and 2010 summer and winter surveys.

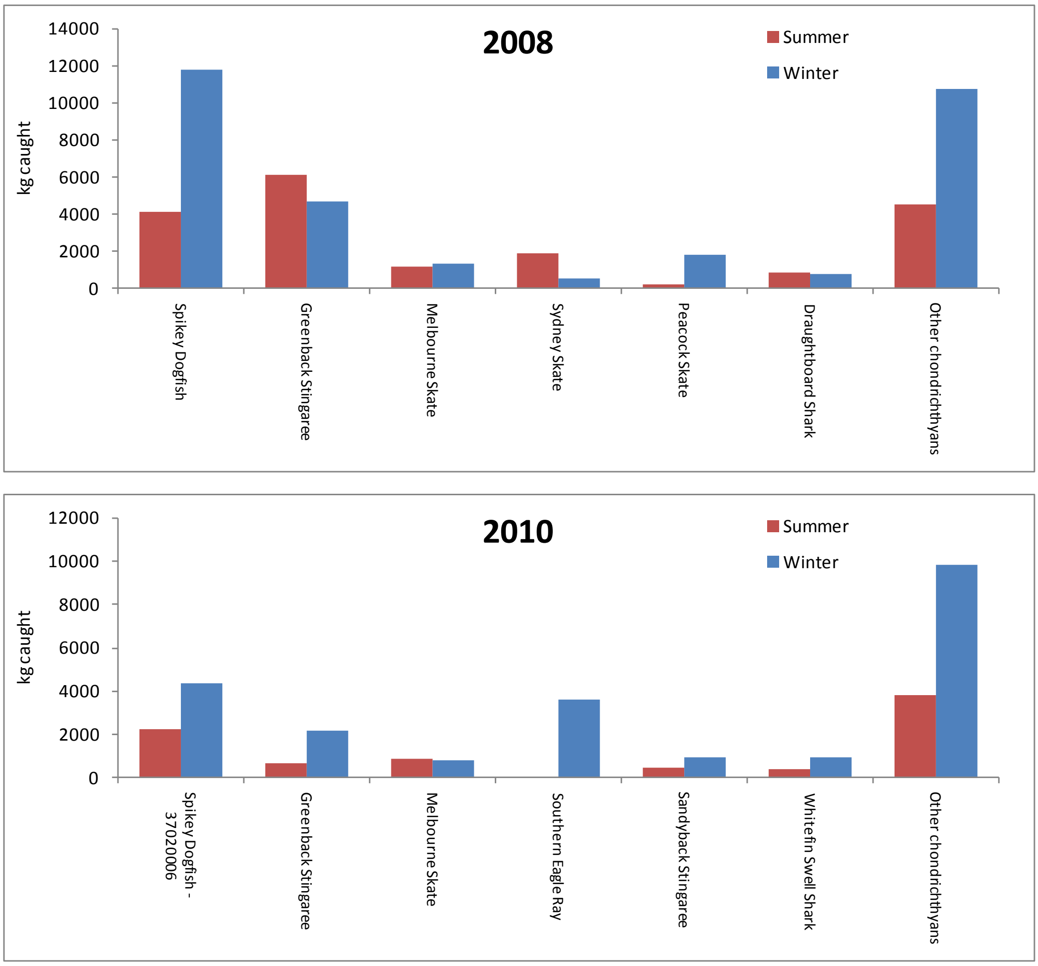


Figure 10. Catch of main non-quota Chondrichthyan species, and other non-quota Chondrichthyan species combined, during 2008 and 2010 summer and winter surveys.

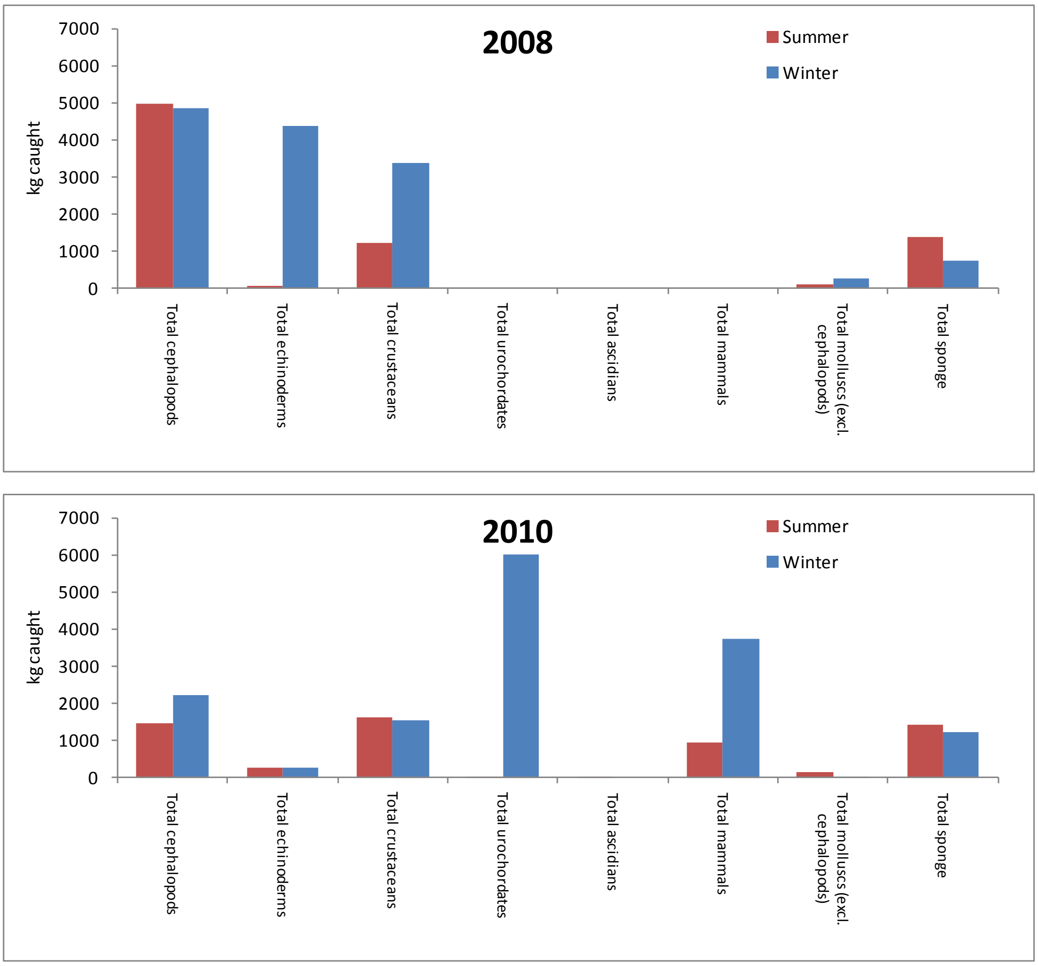


Figure 11. Catch of other taxonomic groups caught during 2008 and 2010 summer and winter surveys.

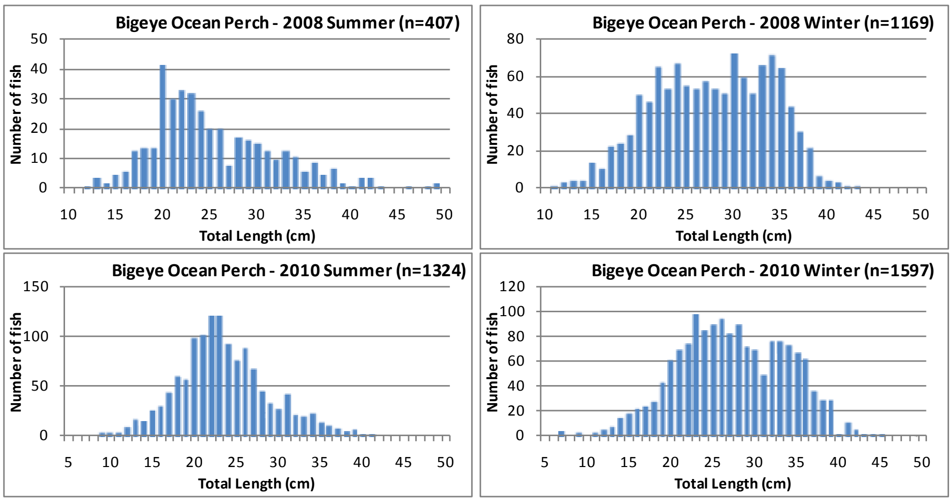


Figure 12. Length frequency distributions of Bigeye Ocean Perch sampled during 2008 and 2010 summer and winter surveys.

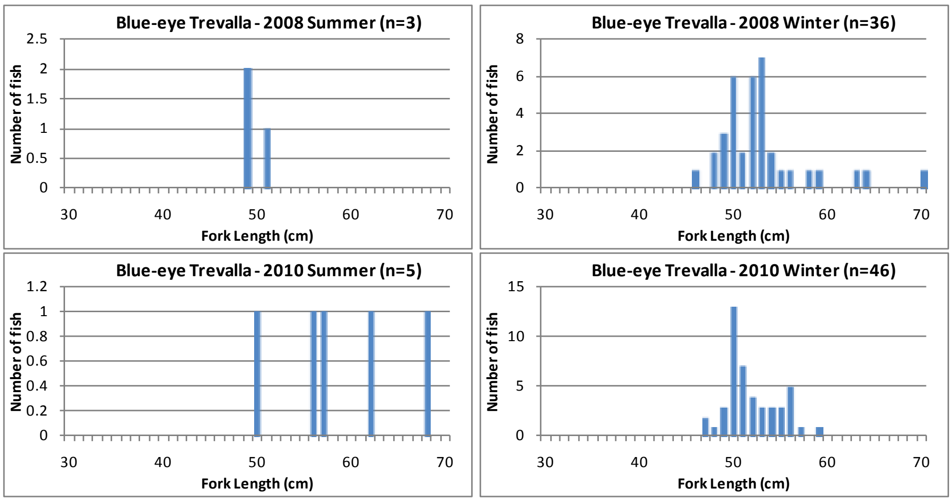


Figure 13. Length frequency distributions of Blue-eye Trevalla sampled during 2008 and 2010 summer and winter surveys.

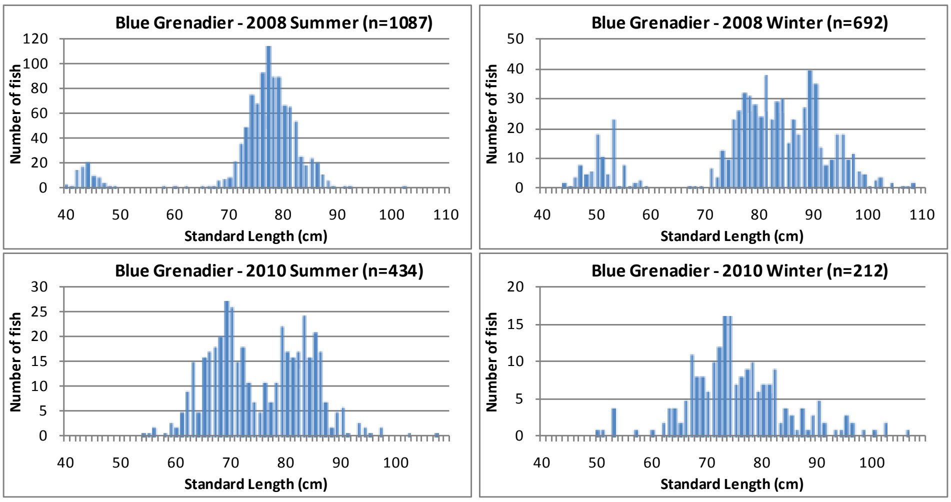


Figure 14. Length frequency distributions of Blue Grenadier sampled during 2008 and 2010 summer and winter surveys.

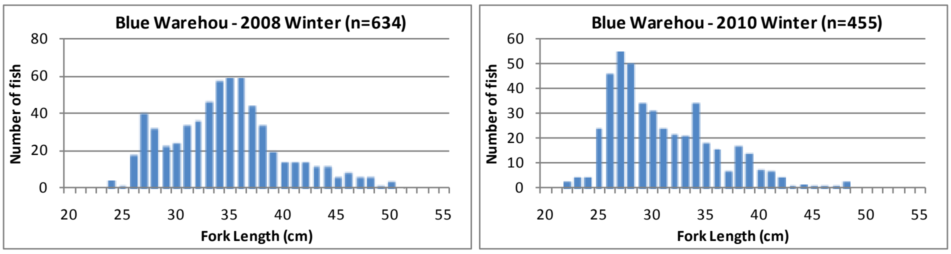


Figure 15. Length frequency distributions of Blue Warehou sampled during 2008 and 2010 summer and winter surveys.

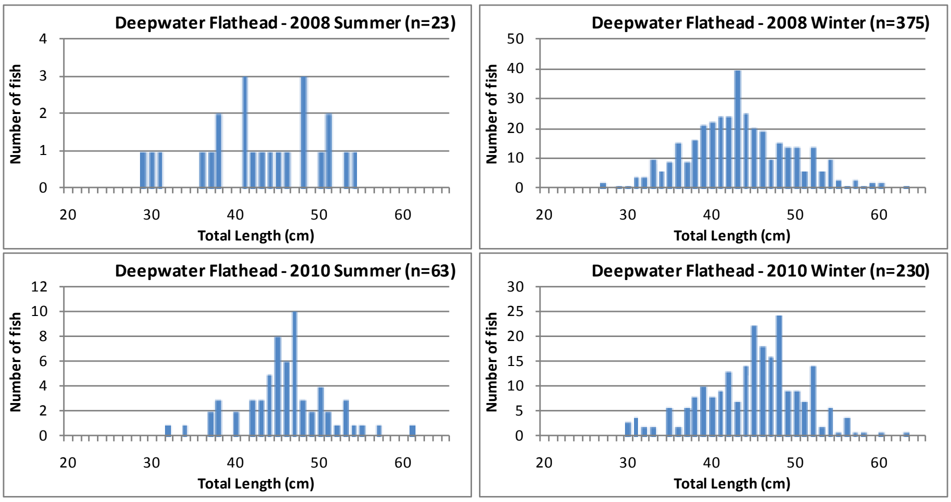


Figure 16. Length frequency distributions of Deepwater Flathead sampled during 2008 and 2010 summer and winter surveys.

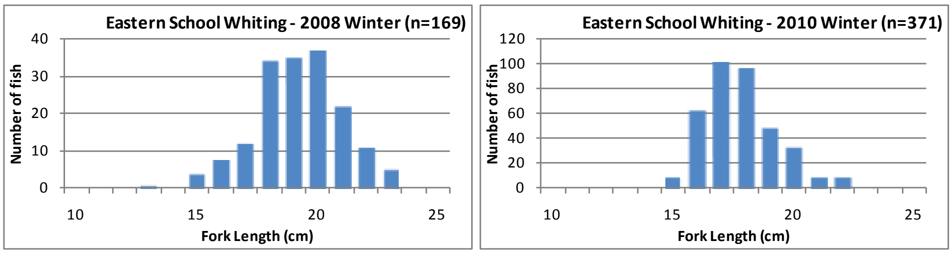


Figure 17. Length frequency distributions of Eastern School Whiting sampled during 2008 and 2010 winter surveys.

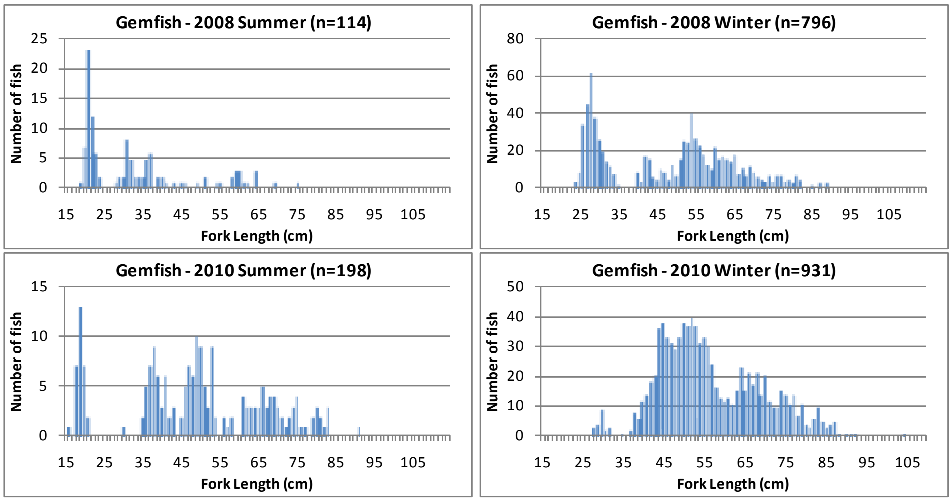


Figure 18. Length frequency distributions of Gemfish sampled during 2008 and 2010 summer and winter surveys.

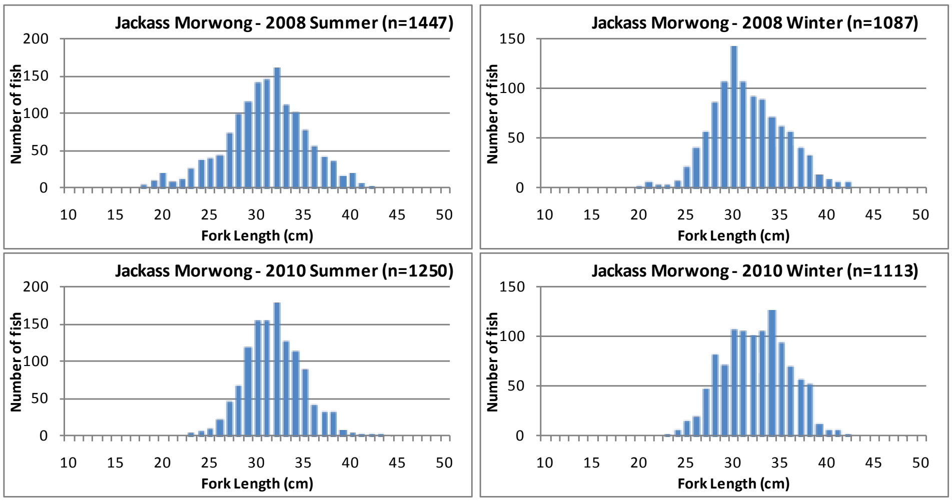


Figure 19. Length frequency distributions of Jackass Morwong sampled during 2008 and 2010 summer and winter surveys.

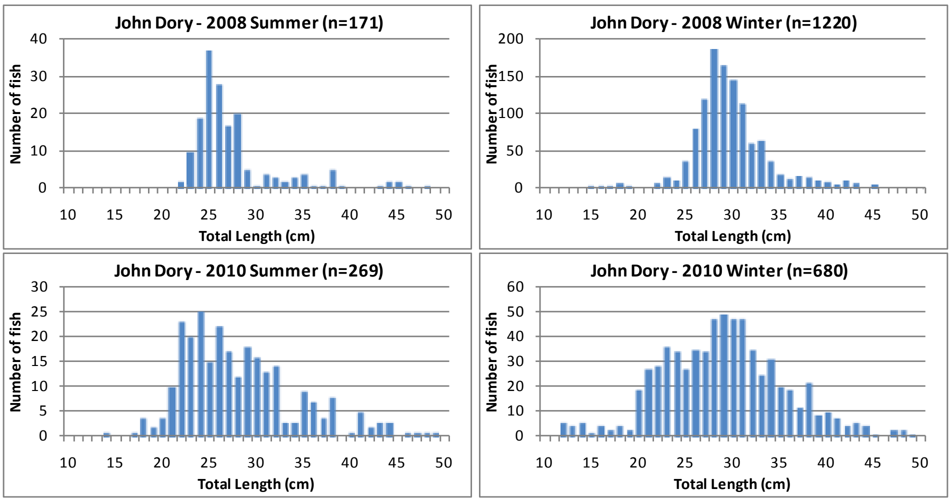


Figure 20. Length frequency distributions of John Dory sampled during 2008 and 2010 summer and winter surveys.

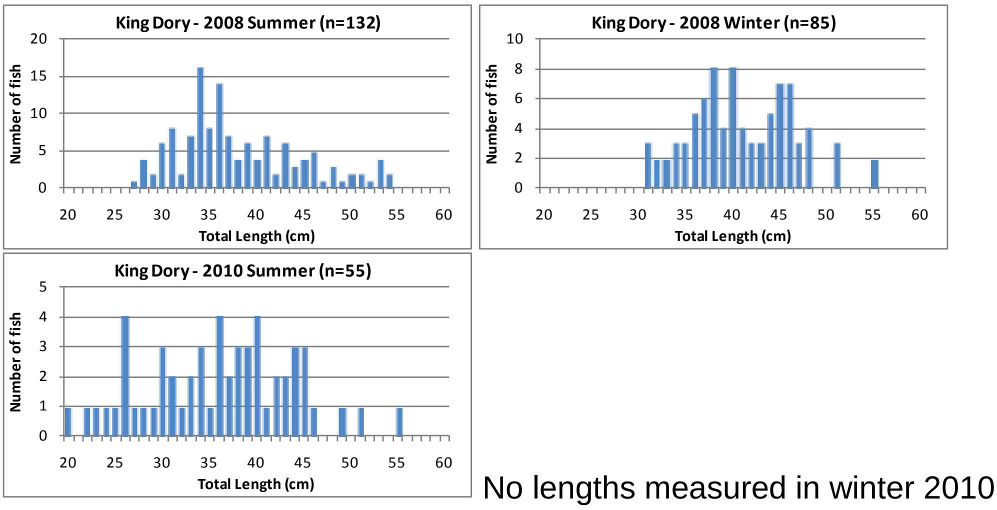


Figure 21. Length frequency distributions of King Dory sampled during 2008 and 2010 summer and winter surveys.

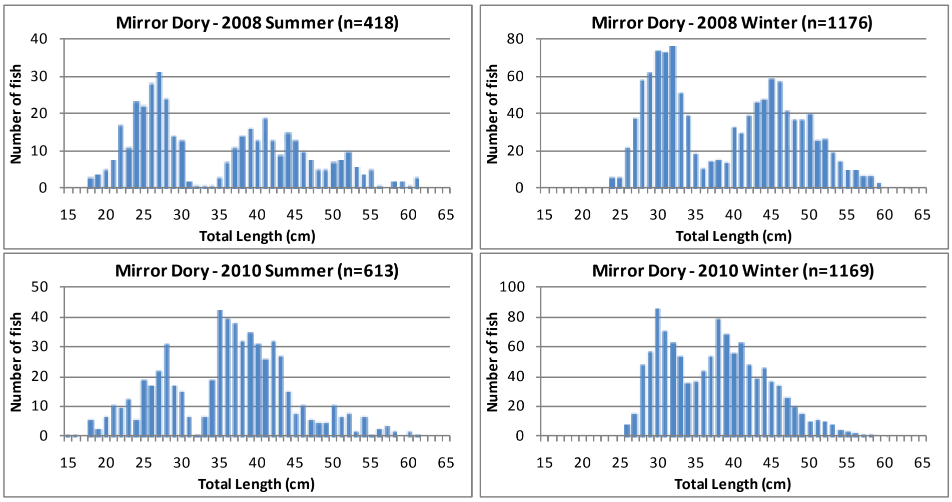


Figure 22. Length frequency distributions of Mirror Dory sampled during 2008 and 2010 summer and winter surveys.

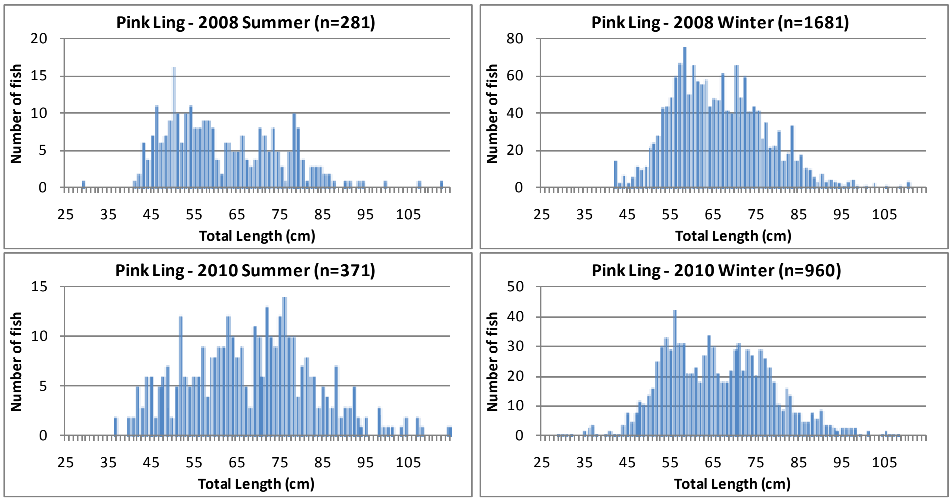


Figure 23. Length frequency distributions of Pink Ling sampled during 2008 and 2010 summer and winter surveys.

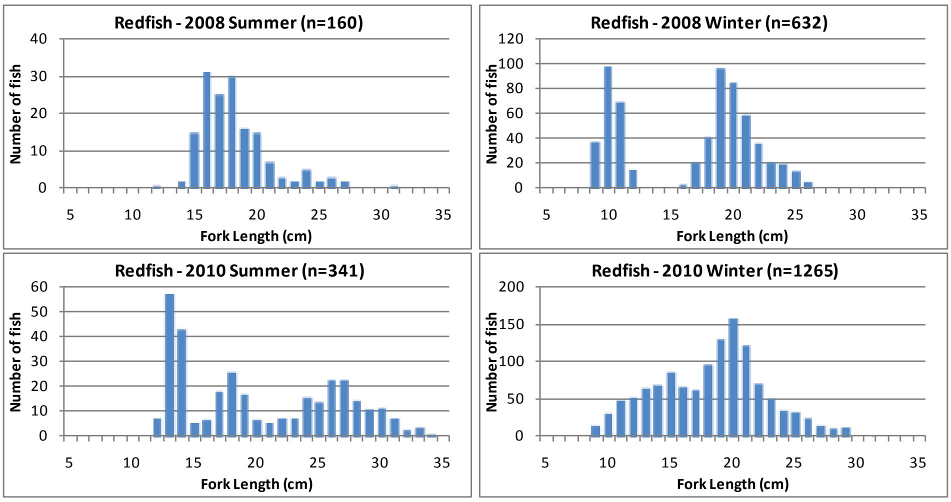


Figure 24. Length frequency distributions of Redfish sampled during 2008 and 2010 summer and winter surveys.

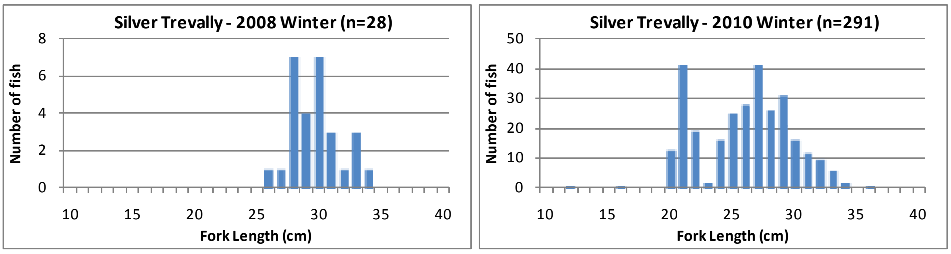


Figure 25. Length frequency distributions of Silver Trevally sampled during 2008 and 2010 winter surveys.

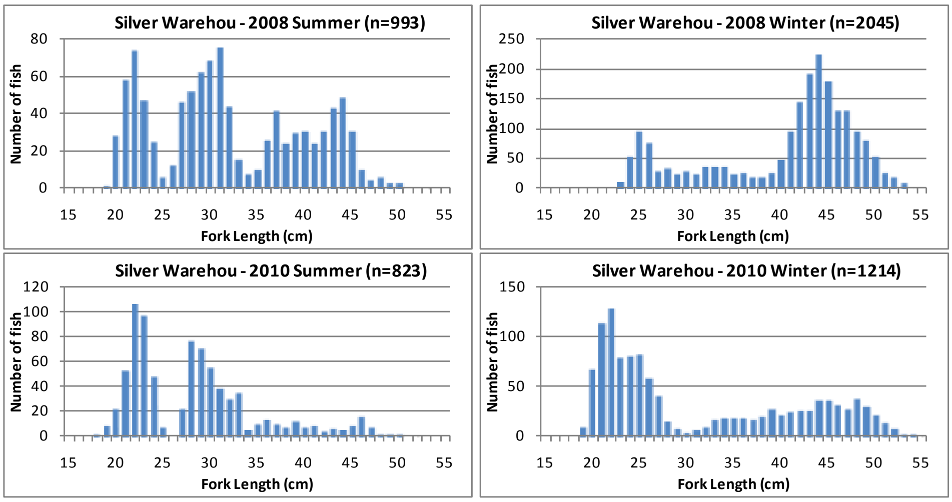


Figure 26. Length frequency distributions of Silver Warehou sampled during 2008 and 2010 summer and winter surveys.

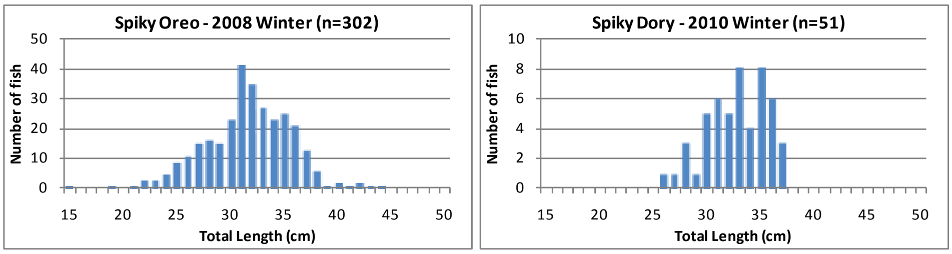


Figure 27. Length frequency distributions of Spiky Oreo sampled during 2008 and 2010 winter surveys.

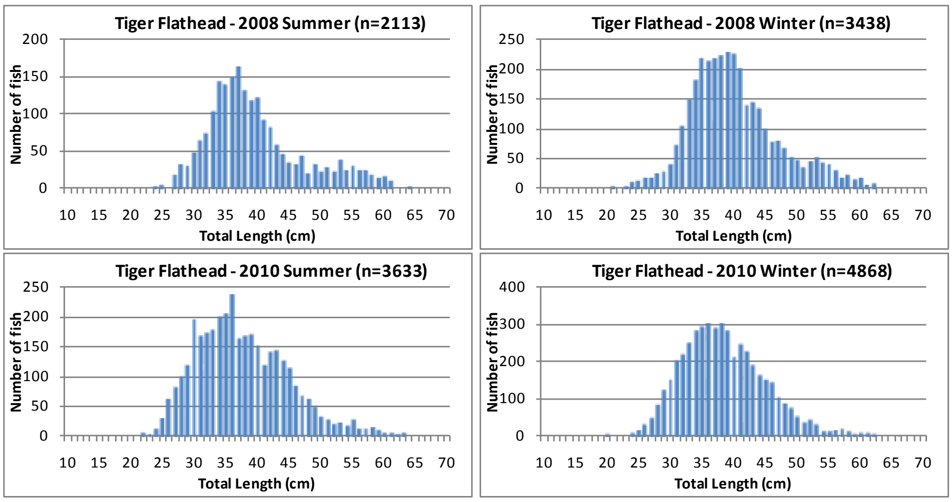
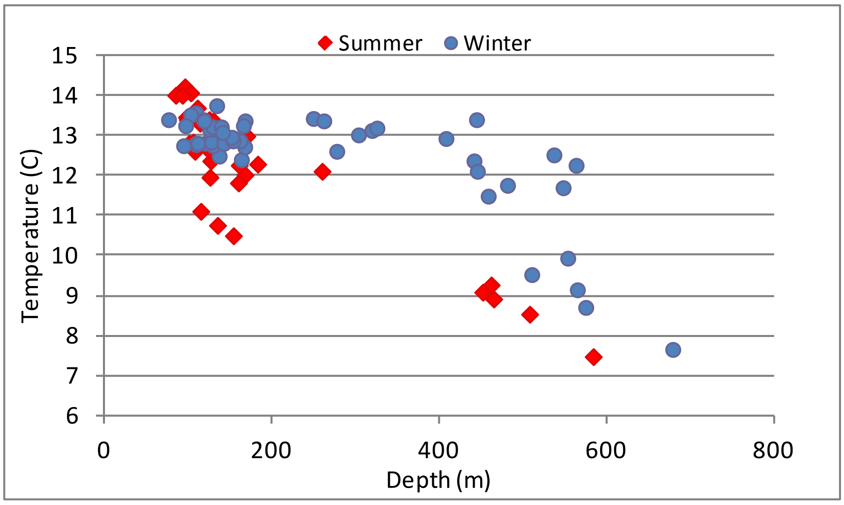
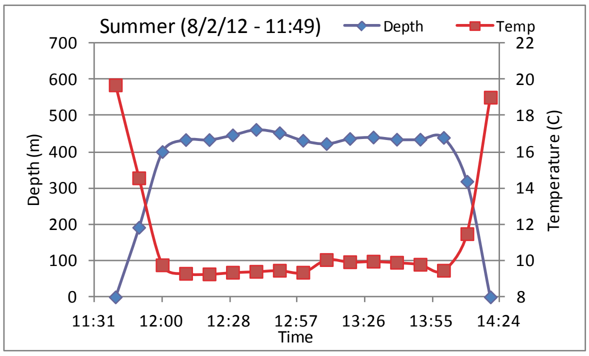


Figure 28. Length frequency distributions of Tiger Flathead sampled during 2008 and 2010 summer and winter surveys.

a)



b)



c)

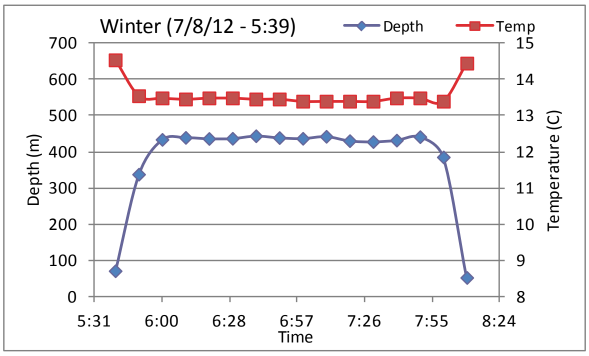


Figure 29. Temperature-depth data collected from tags attached to the survey trawl net of the Western Alliance during summer and winter 2010 surveys in the eastern region showing a) minimum temperature versus maximum depth of each shot, b) a typical temperature-depth profile from summer, and c) a typical temperature-depth profile from winter summer.

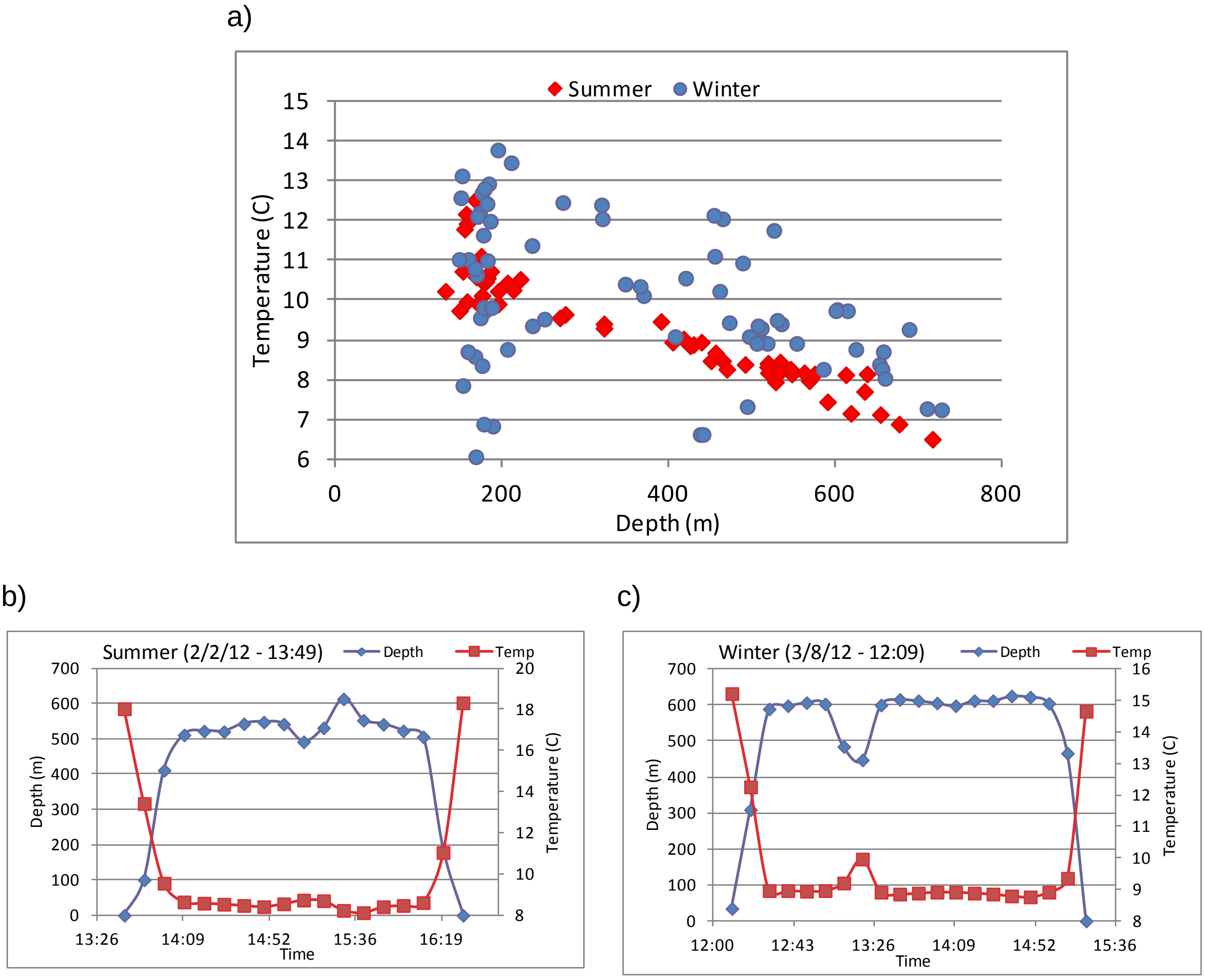


Figure 30. Temperature-depth data collected from tags attached to the survey trawl net of the Moira Elizabeth during summer and winter 2010 surveys in the western region showing a) minimum temperature versus maximum depth of each shot, b) a typical temperature-depth profile from summer, and c) a typical temperature-depth profile from winter summer.

Table 5. Number of trips, sea days and shots conducted during 2008 and 2010 summer and winter surveys.

Year	Season	Number of trips	Number of sea days	Number of shots				Mean shots per sea day
				NSW	East	West	Total	
2008	Summer	7	52	38	43	44	125	2.4
	Winter	19	87	71	65	69	205	2.4
2010	Summer	11	55	33	47	39	119	2.2
	Winter	19	85	67	67	68	202	2.4

Table 6. Number of otoliths collected during 2008 and 2010 summer and winter surveys.

Species	2008			2010		
	Summer	Winter	Total	Summer	Winter	Total
Bigeye Ocean Perch	146	233	379	138	154	292
Blue Grenadier	127	247	374	105	111	216
Blue Warehou		244	244	1	146	147
Deepwater Flathead		50	50	23	37	60
Gemfish	26	187	213	106	215	321
Jackass Morwong	211	223	434	223	96	319
Pink Ling	225	211	436	158	100	258
Silver Warehou	199	246	445	159	160	319
Tiger Flathead	428	298	726	545	362	907

Table 7. Number of length frequency measurements recorded during 2008 and 2010 summer and winter surveys.

Species	2008			2010		
	Summer	Winter	Total	Summer	Winter	Total
Alfonsino	0	58	58			
Blue Grenadier	1087	692	1779	434	212	646
Bigeye Ocean Perch	407	1169	1576	1324	1597	2921
Blue Morwong	0	1	1			
Blue Warehou	0	634	634	0	455	455
Blue-eye Trevalla	3	36	39	5	46	51
Deepsea Ocean Perch	0	175	175			
Deepsea Flathead				0	14	14
Deepwater Flathead	23	375	398	63	230	293
Eastern School Whiting	8	169	177	0	371	371
Gemfish	114	796	910	198	931	1129
Grey Morwong				0	3	3
Gummy Shark				27	0	27
Hapuku	0	7	7			
Inshore Ocean Perch	344	255	599	401	634	1035
Jackass Morwong	1447	1087	2534	1250	1113	2363
John Dory	171	1220	1391	269	680	949
King Dory	132	85	217	55	0	55
Latchet	38	0	38			
Mirror Dory	418	1176	1594	613	1169	1782
Orange Roughy	0	28	28			
Pink Ling	281	1681	1962	371	960	1331
Redfish	160	632	792	341	1253	1594
Ribaldo	0	69	69	0	14	14
School Shark	0	2	2			
Silver Dory	0	25	25			
Silver Trevally	0	28	28	0	291	291
Silver Warehou	993	2045	3038	823	1214	2037
Snapper				1	0	1
Southern Dogfish				6	0	6
Speckled Stargazer				0	239	239
Spikey Oreodory	0	302	302	0	51	51
Tiger Flathead	2113	3438	5551	3633	4868	8501

Table 8. Total catch weight (kg) during 2008 summer and winter surveys.

	Catch (kg)		
Species name	Summer	Winter	Total
Silver Warehou	2282.3	25002.1	27284.4
Blue Grenadier	16410	9379.5	25789.5
Tiger Flathead	6460	8592.5	15052.5
Jackass Morwong	6565.3	2293.4	8858.7
Mirror Dory	1351.2	5688.3	7039.5
Pink Ling	1988.9	3856.8	5845.7
Common Sawshark	958.7	1966.7	2925.4
Offshore Ocean Perch	627	1799.6	2426.6
Oreo Basket	69	1952.2	2021.2
Blue Warehou	13.8	1916.5	1930.3
Gummy Shark	164.6	1271.3	1435.9
Gemfish	266.2	1156.3	1422.5
John Dory	199.8	802.1	1001.9
Redfish	191.2	573.5	764.7
Deepwater Flathead	153.5	424.7	578.2
Ribaldo	138.2	439.9	578.1
Deepwater Shark Basket	103	422.3	525.3
School Shark	241	209	450
Elephantfish	266	174.5	440.5
Royal Red Prawn	17.4	229	246.4
Blue-eye Trevalla	95.3	136.6	231.9
Eastern School Whiting	30	185.8	215.8
Alfonsino	110.8	88.8	199.6
Southern Sawshark		52.5	52.5
Silver Trevally		11.1	11.1
Orange Roughy		10	10
Total quota species	**38703.1**	**68635**	**107338**
Frostfish	213	32237	32450
Barracouta	7503.5	15043.7	22547.2
Ocean Jacket	15187	1608.2	16795.2
Blacktip Cucumberfish	5673.5	7094.7	12768.2
Silver Dory	2555.8	4082.7	6638.5
Gargoyle Fish	2032.3	2887	4919.3
Other teleosts	21719.7	30932.8	52652.5
Total non-quota teleosts	**54884.7**	**93886**	**148771**
Spikey Dogfish	4154.6	11767.6	15922.2
Greenback Stingaree	6100	4706	10806
Melbourne Skate	1184	1320	2504
Sydney Skate	1931	525.5	2456.5
Peacock Skate	238.7	1807.2	2045.9
Draughtboard Shark	864	820.1	1684.1
Other chondrichthyans	4543	10739.9	15282.9
Total non-quota chondrichthyans	**19015.3**	**31686.3**	**50701.6**
Gould Squid	4618.4	4105.6	8724
Cuttlefish	185.7	287.9	473.6
Other cephalopods	157.5	462.6	620.1
Total cephalopods	**4961.6**	**4856.1**	**9817.7**
Total echinoderms	**83.6**	**4367.6**	**4451.2**
Total crustaceans	**1215.3**	**3372.7**	**4588.0**
Total molluscs (excluding cephalopods)	**125.5**	**253.1**	**378.6**
Total sponge	**1395.5**	**734.7**	**2130.2**
Total catch	**120385**	**207792**	**328176**

Table 9. Total catch weight (kg) during 2010 summer and winter surveys.

	Catch (kg)		
Species name	Summer	Winter	Grand Total
Tiger Flathead	4631.7	8228.3	12860
Blue Grenadier	6022.5	2033.5	8056
Silver Warehou	807.3	6846.4	7653.7
Mirror Dory	2163.8	4696.5	6860.3
Jackass Morwong	2991.1	1672.7	4663.8
Pink Ling	1087.2	3092.2	4179.4
Offshore Ocean Perch	690.5	2450.2	3140.7
Common Sawshark	788.8	1785	2573.8
Gemfish	478.4	2068.7	2547.1
Deepwater Flathead	157.5	1010	1167.5
Redfish	177.8	762.3	940.1
Gummy Shark	115.1	769.2	884.3
Blue Warehou	12	671.4	683.4
Oreo Basket	46.8	636	682.8
Deepwater Shark Basket	33.3	556.4	589.7
Elephantfish	119.8	463.8	583.6
John Dory	107	438.8	545.8
School Shark	44	456.5	500.5
Blue-eye Trevalla	29	253.5	282.5
Ribaldo	76.6	177.5	254.1
Alfonsino	199.5	23	222.5
Royal Red Prawn	18	126.3	144.3
Silver Trevally		125	125
Southern Sawshark	7	95	102
Eastern School Whiting	1	53.6	54.6
Total quota species	**20805.7**	**39491.8**	**60297.5**
Frostfish	285	32720.5	33005.5
Barracouta	6059.5	17747.3	23806.8
Blacktip Cucumberfish	9097.7	5097.2	14194.9
Ocean Jacket	6909	1853.7	8762.7
Australian Burrfish	1384.5	5384.8	6769.3
Silver Dory	1417.4	3642.7	5060.1
Other teleosts	16803.8	23237.6	40041.4
Total non-quota teleosts	**41956.9**	**89683.8**	**131640.7**
Spikey Dogfish	2236.5	4359.7	6596.2
Southern Eagle Ray		3576	3576
Greenback Stingaree	641	2204	2845
Melbourne Skate	844	785	1629
Sandyback Stingaree	442	942.5	1384.5
Whitefin Swell Shark	372.2	910.2	1282.4
Other chondrichthyans	3783.5	9859.6	13643.1
Total non-quota chondrichthyans	**8319.2**	**22637**	**30956.2**
Total crustaceans	**1641.3**	**1538.3**	**3179.6**
Gould Squid	1100.7	1437.3	2538
Cuttlefish	244.1	467.6	711.7
Other cephalopods	128.1	315.2	443.3
Total cephalopods	**1472.9**	**2220.1**	**3693**
Total echinoderms	**260.7**	**263.4**	**524.1**
Total urochordates	**4**	**6005.5**	**6009.5**
Total ascidians	**5**	**0**	**5**
Australian Fur Seal	640	3480	4120
Total mammals	**960**	**3750**	**4710**
Total molluscs (excluding cephalopods)	**137.6**	**23**	**160.6**
Total sponge	**1423.5**	**1224**	**2647.5**
Grand Total	**76987**	**166837**	**243824**

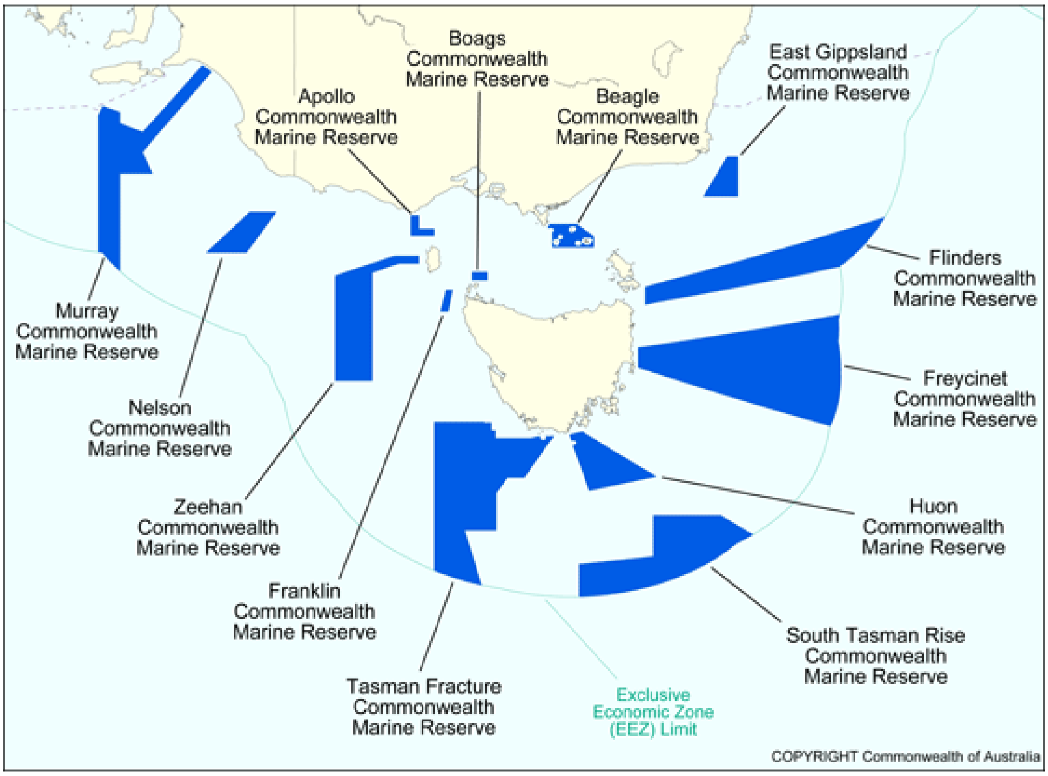


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Figure 31. Diagram of the Commonwealth marine protected areas.

Summer and winter results 2008

Abundance values could be calculated for 19 of the 27 quota species caught during summer and the same 19 species during winter plus Royal Red Prawn (Table 10). Results were also available for 14 non-quota species for the summer survey and 5 non-quota species for winter. Reasons for not calculating or presenting results for other species that were caught during the survey were that insufficient data were available to make calculations, the model failed to converge, the calculated CV was greater than 1.0, or the calculated abundance was greater than 300. Note that results are presented for the combined Gemfish stock and Eastern and Western Gemfish separately, so this has been counted as a single species for discussion purposes.

For quota species, CV values of 0.3 or less were achieved for 10 species for the summer survey and 13 species for the winter survey. The winter survey therefore produced reasonably precise values for a greater number of quota species than the summer survey in 2008, and allowed calculations to be made for one additional species. The highest precision of less than 0.2 was achieved for 4 species (Tiger Flathead, Jackass Morwong and Pink Ling and Latchet) during summer, and 9 species (Silver Warehou, Tiger Flathead, Mirror Dory, Pink Ling, Common Sawshark, Offshore Ocean Perch, John Dory, Deepwater Shark basket, and Southern Sawshark) during winter. For summer and winter surveys combined, the achieved CVs for 8 key species considered in the design were lower than those predicted by the design model (Table 11). This was likely due to the survey controlling many of the variables associated with commercial fishing such as net design, vessel power, skipper experience and species targeting.

For non-quota species, 5 had CV values of less than 0.3 in summer, while 2 had CV values of less than 0.3 in winter (Table 10). The summer survey allowed calculations to be made for considerably more non-quota species than the winter survey.

Table 10. Abundance indices and CV values for 2008 summer and winter surveys.

Species	Summer Abundance	CV	Winter Abundance	CV	Combined CV
Silver Warehou	30.37	0.21	106.69	0.14	0.12
Blue Grenadier	65.24	0.23	15.83	0.30	0.18
Tiger Flathead	113.63	0.15	93.06	0.11	0.09
Jackass Morwong	53.83	0.16	41.51	0.20	0.13
Mirror Dory	13.74	0.23	36.56	0.19	0.14
Pink Ling	17.20	0.19	18.16	0.15	0.12
Common Sawshark	7.77	0.23	11.62	0.17	0.13
Offshore Ocean Perch	17.66	0.22	6.90	0.14	0.12
Oreo Basket	*a*		*a*		
Blue Warehou	0.88	0.84	38.10	0.49	0.42
Gummy Shark	4.36	0.44	11.89	0.26	0.22
Gemfish	3.80	0.33	3.50	0.29	0.22
Gemfish east	3.13	0.62	0.30	0.69	0.46
Gemfish west	4.26	0.37	1.26	0.44	0.28
John Dory	9.45	0.26	13.99	0.14	0.13
Redfish	3.43	0.79	14.37	0.23	0.22
Deepwater Flathead	*c*		*c*		
Bight Redfish	*a*		*a*		
Ribaldo	1.07	0.57	2.62	0.52	0.38
Deepwater Shark Basket	74.34	0.41	25.81	0.19	0.17
School Shark	1.74	0.58	2.10	0.51	0.38
Elephantfish	NA		NA		
Royal Red Prawn	*b*		0.12	0.44	0.44
Blue-eye Trevalla	2.84	0.59	1.26	0.39	0.33
Eastern School Whiting	*b*		*a*		
Alfonsino	4.39	0.82	16.93	0.43	0.38
Southern Sawshark	7.77	0.23	11.62	0.17	0.13
Silver Trevally	*b*		*b*		
Orange Roughy	*b*		*b*		
Frostfish	15.59	0.97	41.73	0.43	0.39
Ocean Jacket	20.91	0.29	*a*		0.29
Barracouta	136.29	0.35	*a*		0.35
Silver Dory	*c*		*a*		
Latchet	49.98	0.18	*a*		0.18
Gould's Squid	20.75	0.24	*a*		0.24
Toothed Whiptail	15.41	0.30	*a*		0.30
Jack Mackerel	*c*		*a*		
Spikey Oreo	0.32	0.68	*a*		0.68
King Dory	4.95	0.30	4.68	0.29	0.21
Red Gurnard	19.33	0.25	1.76	0.34	0.20
Draughtboard Shark	7.46	0.32	*c*		0.32
Whitefin Swellshark	4.62	0.29	*c*		0.29
Green-eyed Dogfish	*a*		16.64	0.27	0.27
Triggerfish Leatherjacket	14.87	0.77	*b*		0.77
Speckled Stargazer	7.02	0.74	4.58	0.33	0.30
New Zealand Dory	1.91	0.50	*c*		0.50

Notes: *a* - not converged, *b* - CV>1.0, *c* – abundance >300, NA - not available.

Table 11. Predicted versus achieved CV values for 2008 summer, winter and combined surveys. CVs for combined surveys that are lower than predicted are in bold text.

	Summer		Winter		Combined	
Species	**Pred.**	**Real.**	**Pred.**	**Real.**	**Pred.**	**Real.**
Blue Warehou	0.78	0.84	0.38	0.49	0.34	0.42
Jackass Morwong	0.27	0.16	0.27	0.20	0.19	**0.12**
John Dory	0.36	0.26	0.24	0.14	0.20	**0.12**
Gemfish	0.50	0.33	0.36	0.29	0.29	**0.22**
Tiger Flathead	0.18	0.15	0.14	0.11	0.11	**0.09**
Pink Ling	0.24	0.19	0.18	0.15	0.14	**0.12**
Silver Trevally	NA	NA	1.00	1.09	NA	NA
Redfish	0.42	0.79	0.21	0.23	0.19	0.22
Blue-eye Trevalla	0.69	0.59	0.50	0.39	0.40	**0.33**
Mirror Dory	0.31	0.23	0.31	0.19	0.22	**0.15**
Silver Warehou	0.25	0.21	0.16	0.14	0.13	**0.12**

Summer and winter results 2010

Abundance values could be calculated for 17 of the 27 quota species during summer, and the same 17 species during winter plus Blue Warehou, Royal Red Prawn, Blue-eye Trevalla and Silver Trevally (Table 13). Compared to 2008, Blue Warehou and Blue-eye Trevalla results were unavailable for summer, and Silver Trevally results became available for winter. Results were also produced for 13 non-quota species for the summer survey (1 less than 2008) and 3 non-quota species for the winter survey (2 less than 2008).

For quota species, CV values of less than 0.3 were achieved for 10 species for the summer survey (same as 2008) and 15 species for the winter survey (2 more than 2008). The winter survey also produced reasonably precise values for a greater number of quota species than the summer survey in 2010. The highest precision of less than 0.2 was achieved for 4 species (Tiger Flathead, Jackass Morwong, Latchet and Gould's Squid) during summer, and 9 species (Silver Warehou, Tiger Flathead, Mirror Dory, Pink Ling, Common Sawshark, Offshore Ocean Perch, John Dory, Deepwater Shark basket, and Southern Sawshark) during winter. The only difference for the species with these highest precision estimates compared to 2008 was that Pink Ling was replaced by Gould's Squid for the summer survey. There is a high degree of correspondence of the CV values from 2008 and 2010 in both the summer and winter surveys per species. For summer and winter surveys combined, the achieved CVs for 8 key species considered in the design were lower than those predicted by the design model (Table 11).

For non-quota species, 4 had CV vales of less than 0.3 in summer and 1 in winter. As for 2008, the summer survey allowed calculations to be made for considerably more non-quota species than the winter survey.

Table 12. Predicted versus achieved CV values for 2010 summer, winter and combined surveys. CVs for combined surveys that are lower than predicted are in bold text.

	Summer		Winter		Combined	
Species	**Pred.**	**Real.**	**Pred.**	**Real.**	**Pred.**	**Real.**
Blue Warehou	0.82	1.04	0.39	0.23	0.35	**0.22**
Jackass Morwong	0.27	0.16	0.25	0.21	0.18	**0.13**
John Dory	0.35	0.30	0.24	0.17	0.20	**0.15**
Gemfish	0.47	0.28	0.36	0.21	0.29	**0.17**
Tiger Flathead	0.19	0.14	0.15	0.12	0.12	**0.09**
Pink Ling	0.25	0.20	0.18	0.15	0.15	**0.12**
Silver Trevally	NA	0.51	0.81	NA	NA	NA
Redfish	0.46	0.64	0.22	0.23	0.20	0.22
Blue-eye Trevalla	0.64	1.18	0.50	0.36	0.39	**0.34**
Mirror Dory	0.31	0.25	0.22	0.18	0.18	**0.15**
Silver Warehou	0.27	0.26	0.16	0.14	0.14	**0.12**

Table 13. Abundance indices and CV values for 2010 summer and winter surveys.

Species	Summer Abundance	CV	Winter Abundance	CV	Combined CV
Silver Warehou	15.06	0.26	32.87	0.14	0.12
Blue Grenadier	29.53	0.28	3.38	0.28	0.20
Tiger Flathead	101.01	0.14	91.06	0.12	0.09
Jackass Morwong	28.36	0.16	23.97	0.21	0.13
Mirror Dory	21.29	0.25	29.21	0.18	0.14
Pink Ling	11.47	0.20	19.72	0.15	0.12
Common Sawshark	6.28	0.29	12.94	0.14	0.13
Offshore Ocean Perch	22.56	0.22	14.34	0.13	0.11
Oreo Basket	*a*		*a*		
Blue Warehou	*b*		7.84	0.23	0.23
Gummy Shark	1.81	0.40	20.04	0.23	0.20
Gemfish	4.83	0.28	4.81	0.21	0.17
Gemfish east	2.39	0.62	0.92	0.66	0.45
Gemfish west	6.05	0.31	2.72	0.35	0.23
John Dory	4.77	0.30	9.46	0.17	0.15
Redfish	10.35	0.64	26.89	0.23	0.21
Deepwater Flathead	*c*		*c*		
Bight Redfish	*a*		*a*		
Ribaldo	0.57	0.57	3.28	0.46	0.36
Deepwater Shark Basket	100.08	0.43	12.83	0.14	0.13
School Shark	0.53	0.97	4.81	0.35	0.33
Elephantfish	NA		NA		
Royal Red Prawn	*b*		0.06	0.35	0.35
Blue-eye Trevalla	*b*		1.66	0.36	0.36
Eastern School Whiting	*b*		*a*		
Alfonsino	8.22	0.68	521.14	0.72	0.50
Southern Sawshark	6.28	0.29	12.94	0.14	0.13
Silver Trevally	*a*		6.53	0.51	0.51
Orange Roughy	*b*		*b*		
Frostfish	59.51	0.67	14.11	0.30	0.27
Ocean Jacket	21.50	0.28	*a*		0.28
Barracouta	87.38	0.34	*a*		0.34
Silver Dory	c		*a*		
Latchet	34.14	0.19	*a*		0.19
Gould's Squid	13.06	0.19	*a*		0.19
Toothed Whiptail	13.57	0.29	*a*		0.29
Jack Mackerel	18.31	0.36	*a*		0.36
Spikey Oreo	0.77	0.83	*a*		0.83
King Dory	2.69	0.33	5.64	0.27	0.21
Red Gurnard	2.17	0.34	2.08	0.48	0.28
Draughtboard Shark	4.20	0.32	*c*		0.32
Whitefin Swellshark	4.03	0.33	*c*		0.33
Green-eyed Dogfish	*a*		*b*		
Triggerfish Leatherjacket	*b*		*b*		
Speckled Stargazer	4.81	0.37	*b*		0.37
New Zealand Dory	*b*		*c*		

Notes: *a* - not converged, *b* - CV>1.0, *c* – abundance >300, NA - not available.

Combined results 2008 and 2010

The FIS takes place in both the first quarter (Jan – Mar) and the third quarter (Jul – Sep) of the year. This is useful logistically because it avoids excessive effort in any one season, and also biologically because some species are hard to catch in some seasons. Since catchability, patchiness, depth preference, and overall spatial distribution can vary greatly between seasons, the different seasons are analysed completely separately.

The separate analysis raises the question of how these two indices are to be used. It is not possible to combine the series at the present because we do not know the relative difference in summer and winter catchability for the FIS. However, for stock assessment purposes there is no need to combine them as in theory the stock assessment can accommodate multiple series. For the purposes of this project, it is possible to estimate the "equivalent CV" that an optimally combined series would have (see design methods chapter). In a sense, this combined CV gives a good overall idea of how informative the FIS indices will ultimately be for stock assessment purposes. This CV is given by

$$\left(CV_1 \times CV_2\right) / \sqrt{CV_1^2 + CV_2^2}$$

Combined results for 2008 and 2010 are only given for species where both summer and winter survey results were able to be calculated in both survey years. Results are therefore available for 19 quota species and 3 non-quota species (Table 10 and Table 13). Low CV values (less than 0.2) have been highlighted in green, medium (0.2 to less than 0.3) in yellow and high (0.3 or greater) in red. Low combined CV values of less than 0.2 were achieved for 10 quota species and 1 non-quota species in 2008, and 11 quota species (same species as 2008 plus Gemfish) and no non-quota species in 2010. Quota species towards the top of Table 10 and Table 13 were those with larger total catches during the surveys, and there is a general tendency for those species to have low CV values. Only Tiger Flathead achieved a CV of less than 0.1, which occurred in both survey years. Medium and high CV values were generally distributed across the same species for 2008 and 2010, with some changes of category between years.

Another issue is that these CVs do not incorporate "process error" (i.e. year-to-year variations in availability of a species). The process error is likely to be independent between the summer and winter surveys. For some species, the process error may dominate the pure measurement error given by our reported CVs; for others it may not be important.

After a time series of FIS has been established it should be possible to estimate the relative summer/winter catchability and the process error from the survey data, within the stock assessment.

Species that showed the greatest change (>50%) in abundance from 2008 to 2010 were Silver Warehou, Blue Grenadier, Blue Warehou, Redfish and Deepwater Shark basket (Figure 32 and Figure 33). Of these, only Blue Warehou had a CV values greater than 0.3, suggesting that some species do show large changes in abundance from year to year. As the biology of the species is unlikely to allow such large changes in the species populations, such changes are most likely due to changes in availability - i.e. the fish moving in and out of the survey area. Movement in and out of the survey area would most likely be for species that naturally move large distances, an attribute of schooling pelagic species in particular. Both Silver and Blue Warehou, and also Blue Grenadier would fall into this category, so high variability in abundance for those species may be explained.

For most species, the change in abundance was not very great between the 2008 and 2010 surveys, suggesting less effect of availability change for those. Species that show less availability effects are those that occur predictably in space and time — an attribute especially of demersal species that stay resident within a small habitat range. Species such as Tiger Flathead, Pink Ling or Jackass Morwong may fall into this category.

Across all species, the achieved CV values were remarkably consistent between survey years, while varying considerably among species (Figure 33).

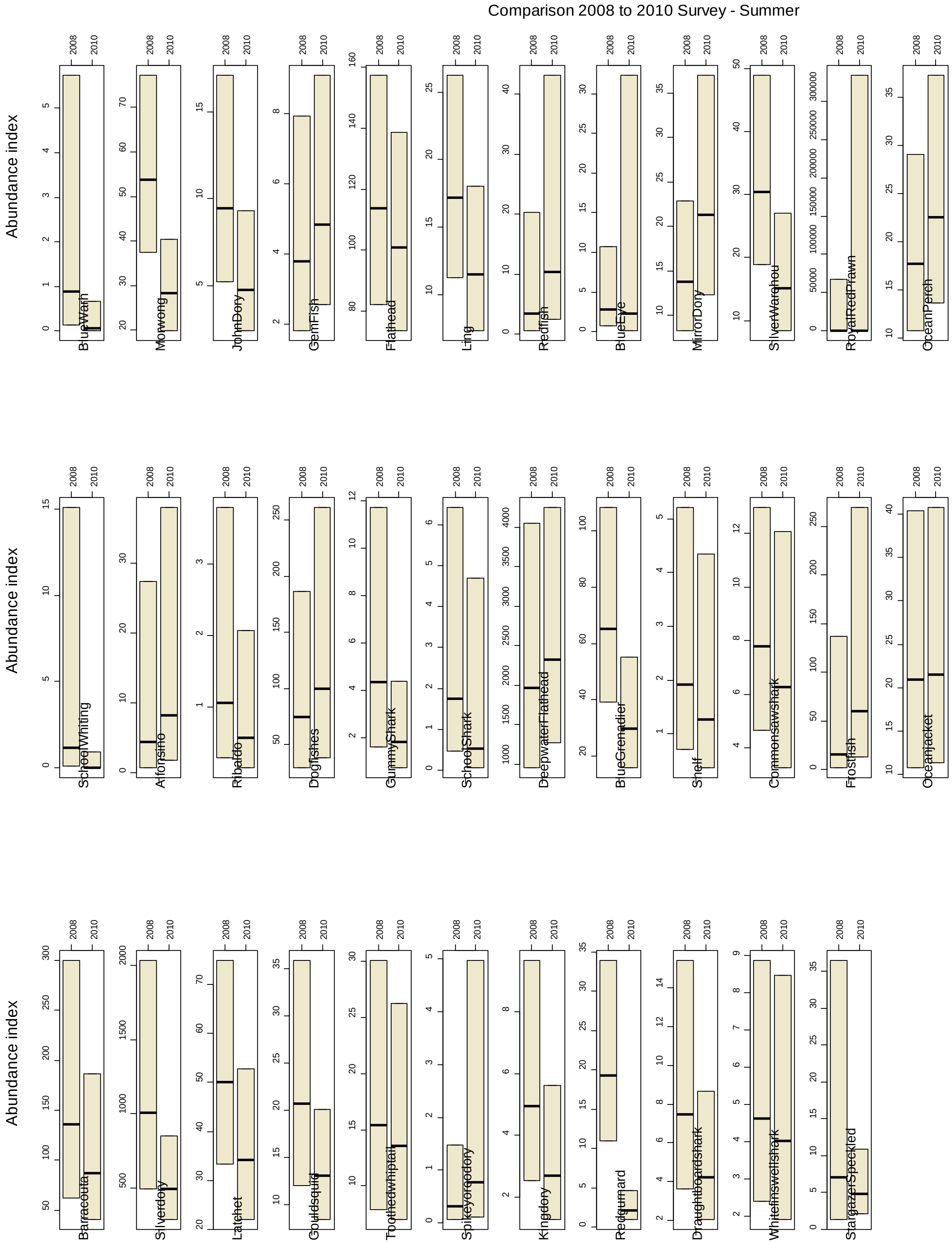

Figure 32. Comparison of combined survey abundance indices from 2008 to 2010.

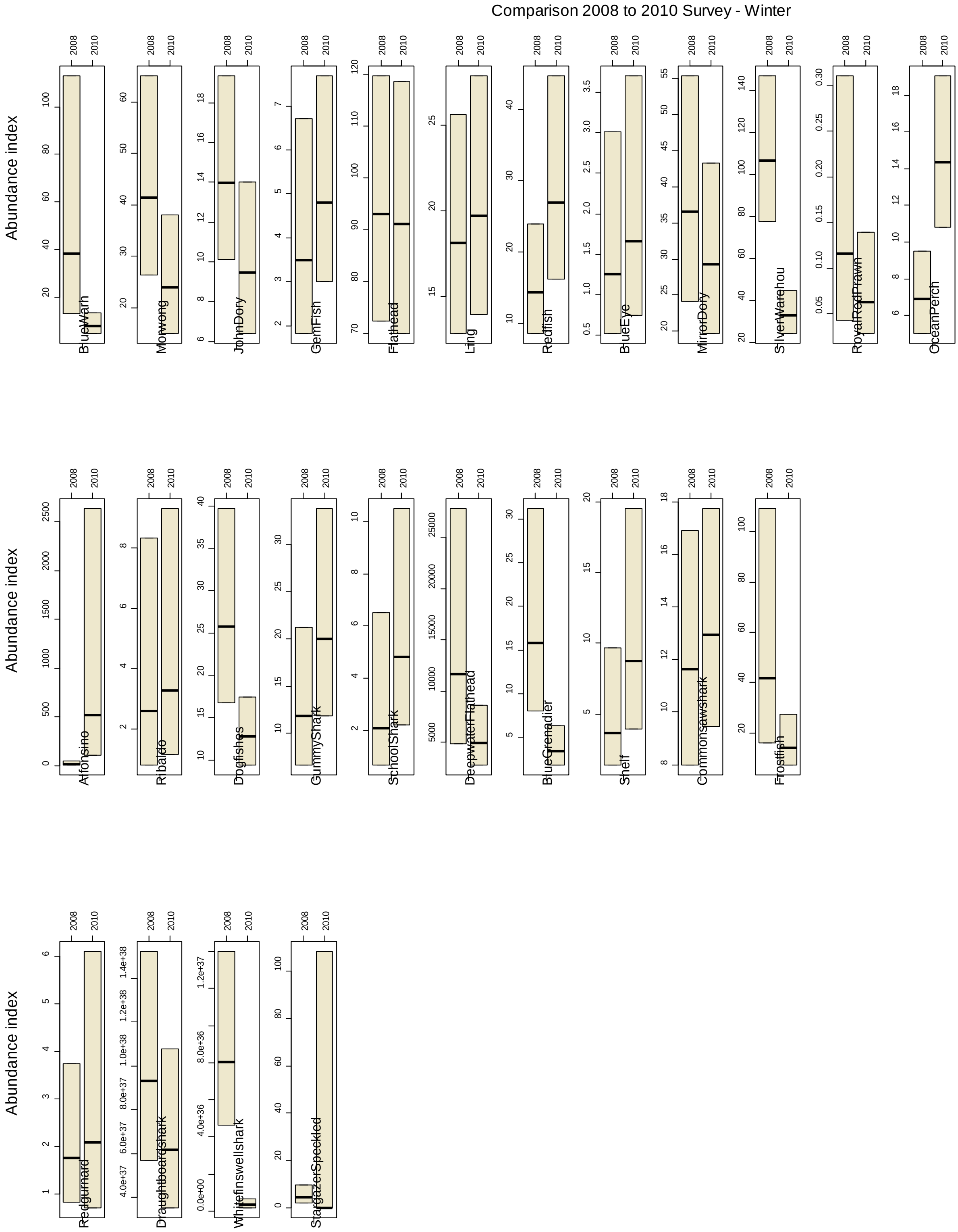

Figure 33. Comparison of combined survey CVs from 2008 to 2010.

Survey Design

This work has developed a model-based approach to designing a fishery trawl survey, and has demonstrated it in a pilot fishery independent survey design for the SESSF. The method was tailored to the SESSF, but we believe that the approach is general enough to have much wider scope for abundance surveys, and the facilities now available in the mgcv package in *R* make the computational tasks very feasible.

Model-based design obviously hinges on one underlying assumption: that the model is in fact correct. This has two direct repercussions. First, the model-based approach requires there to be enough historical data to build a suitable model and produce good estimates of the model parameters. Second, as the survey continues, care needs to be taken that the system has not changed enough to invalidate the model built on historical data. In the SESSF FIS, this relates to our use of the prior data to quantify the common underlying spatial smooth, depth, and time-of-day effects. Diagnostics from the surveys should be monitored for deviations from the underlying assumptions.

Despite the assumption of model validity, we would argue our approach is generally robust, since GAMs are suitably flexible and are based on reasonable and general assumptions. Furthermore, in situations such as our SESSF example, we are not focused on outright optimal design, but rather have simply used the model to make informed general design decisions. Therefore, since the design has not been overly 'fine-tuned' its performance will not be very sensitive to departures from the model.

Although there are model-based designs that aim to collect enough information on spatial variability during the survey itself (e.g., Diggle and Lophaven 2006), predicting the CV beforehand in that situation is a far harder problem than we have addressed. Even if historical data is voluminous, it may not yield very precise estimates of environmental effects for the purposes of index construction. For example, the historical data may be concentrated in a different part of covariate space to the survey data. It may then be worth using the survey data to improve the estimates of environmental effects, particularly if many surveys are to be done. However, even if there is substantial uncertainty about environmental effects, the utility of re-fitting depends largely on how much the distribution of the environmental covariate will change between surveys. If little change is expected, then the only gain from re-fitting might be a modest reduction in the measurement error variance, which will otherwise be absorbing some model error from the mis-specified offset. However, if major change in the covariates is expected then errors in the estimate of environmental effects can substantially affect year-to-year comparisons, and re-fitting obviously becomes important. If there is some uncertainty about environmental effects from the historical data, and these effects are not re-estimated for the survey, then there is some further value in estimating a survey-specific ϕ, since it can absorb the model error arising from inaccurate specification of the offset.

Providing an underlying model can be obtained, the model-based framework provides many benefits for wildlife abundance surveys. A model-based approach allows great flexibility in handling unbalanced and non-random designs. In parts of covariate space where sampling coverage is poor, the model can borrow strength from nearby well-sampled areas to estimate abundance, and can reflect this in the CV. This makes the approach particularly suited to the design of a FIS, where logistical issues and practicalities often cause considerable constraints on the design and impede on the final survey sampling, making balanced and/or random designs difficult. For example, Figure 34 clearly demonstrated the reality of conducting ground trawl surveys in imperfectly-known terrain, in that the final implemented design was quite different to the original plan. If a randomized design had been attempted it would have been compromised and a stratified model-based design could have suffered from bias due to uneven within-stratum sampling.

In a model-based analysis, it is easy to include important but uncontrollable covariates, such as time-of-day or weather conditions. In the SESSF, for example, time-of-day has a substantial effect on catch rates and, since it is easy to record, it should certainly be included in the model. However, the actual time-of-day at which a particular sample site gets visited is dictated by short-term logistic considerations and cannot be predicted at design time. Nevertheless, for a covariate such as time-of-day, the distribution of values across the survey can sometimes be predicted well, even if individual values cannot be. The CV of a design in which time-of-day is allocated randomly, according to that distribution, is likely to be close to the CV of the realized survey; this can be checked by using several different realizations.

The model-based approach avoids the issue of systematic trends within strata inflating the estimates of precision; this will generally be an issue for traditional RSSs where it is not possible to "design out" the trend using suitable strata unless some model assistance is used in the subsequent estimation. In this sense, it would be expected that using a model-based design and analysis would give greater precision than a completely traditional stratum-based approach. Gains in precision will be modest when covariate effects are weak, and are likely to be biggest when (as in the SESSF) two or more covariates all have strong effects, and cannot be "stratified out" simultaneously.

We have not proposed any formal method for searching through design space to choose a final design. There are applications where an optimal design can be found by maximizing the expected precision subject to logistic constraints (see van Groenigen and Stein 1998; Brus and Heuvelink 2007; Zhu and Stein 2006; Arbia and Lafratta 2002), and we are investigating a similar extension of our approach. However, even when no optimality criterion is given and general compromise must be sought between multiple objectives, as with the SESSF FIS, our model-based approach can quickly evaluate the likely precision of any proposed design. This speed and flexibility can be very valuable in the decision-making process, which for a FIS inevitably entails many aspects besides statistics.

Sensitivity analyses: Uniform survey reductions

To investigate the effect of reduced sampling, either uniformly distributed or restricted to specific areas, we examined a range of scenarios which are detailed in Table 14. The effect on CV for the key species was calculated when 10%, 20% and 50% of the sample shots were removed for each of the reduction strategies.

Table 14. Sample reduction strategies

Scenario	Description	Coastal position	Depth (m)
A	Uniform reduction	138° 08′ 05″ E to 33° 34′ 54″ S	100 - 700
B	NSW Shelf reduction	149° 48′ 53″ E to 33° 34′ 54″ S	100-200
C	Western Tas. reduction	138° 08′ 05″ E to 146° 58′ 58″ S	100-700

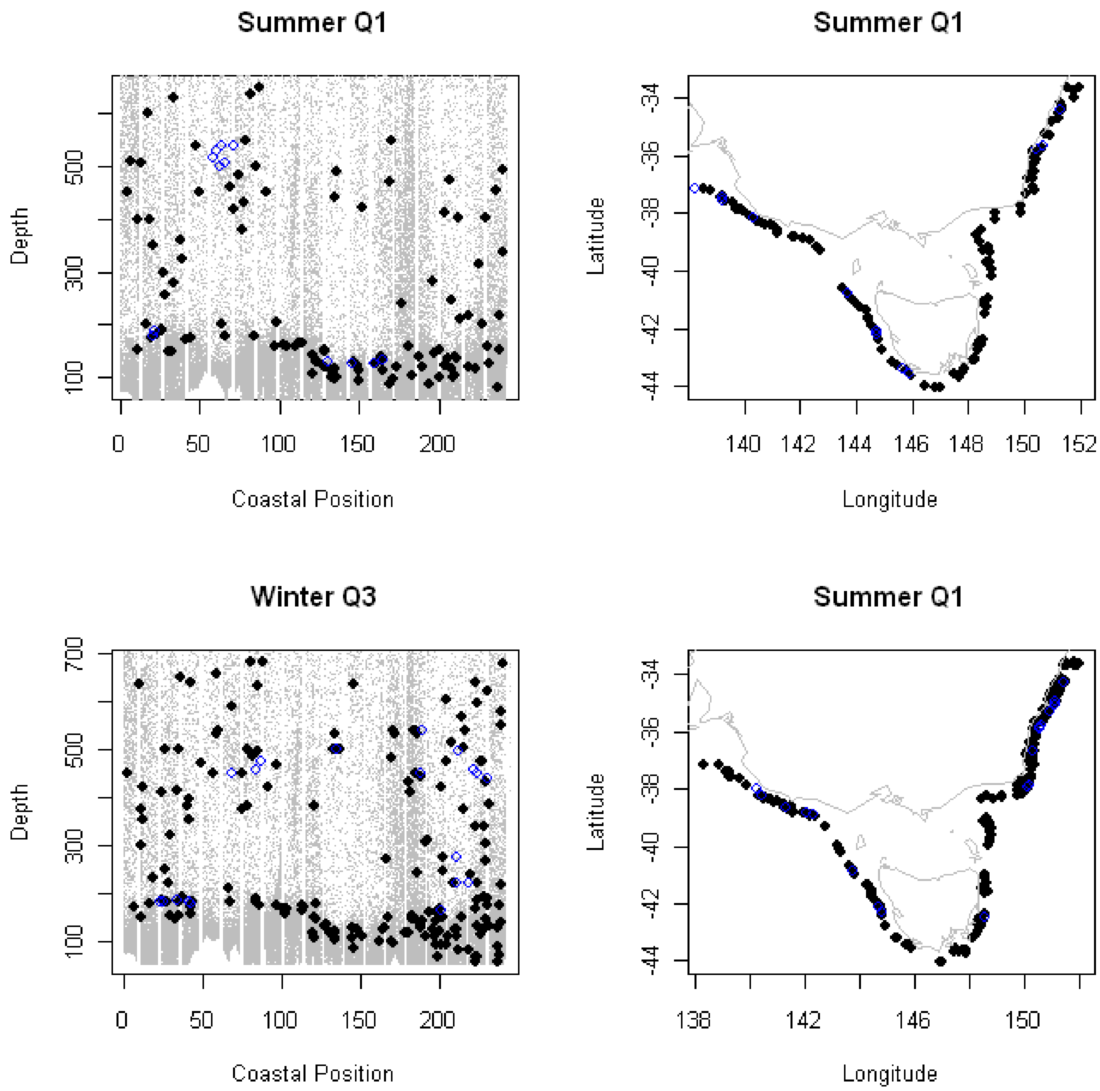

Figure 34. Plot in covariate space and real space of the design for Scenario A, blue circle= samples removed, black dots= remaining samples, grey dots= prediction grid.

The results for the summer and winter surveys are shown in Table 15 and Table 16, where the CVs are calculated for the seasonal surveys only. For those species where it is possible to combine the CVs, a combined CV is listed in Table 17. Results in the tables are separated into the target 11 species and the additional species, with the results sorted by the value of the base case CV.

The CVs obtained are colour coded, with CVs < 0.2 coloured in green, between 0.2 and 0.3 coloured yellow and those greater than 0.3 coloured red, with the suggestions that for stock assessment purposes, abundance estimates with CVs in the green range are good, in the yellow range are marginal but still useable and greater than 0.3 are not able to be used.

Table 15. Baseline CVs for the summer 2010 survey and for scenarios A10-C50. See Table 14 for a description of sensitivities.

Species	Summer Base	A10	A20	A50	B10	B20	B50	C10	C20	C50
Tiger Flathead	0.14	0.20	0.21	0.23	0.20	0.20	0.20	0.20	0.22	0.22
Jackass Morwong	0.16	0.26	0.27	0.32	0.26	0.26	0.26	0.26	0.30	0.32
Pink Ling	0.20	0.26	0.28	0.34	0.27	0.27	0.27	0.26	0.28	0.28
Mirror Dory	0.25	0.33	0.35	0.44	0.33	0.34	0.34	0.33	0.35	0.37
Silver Warehou	0.26	0.27	0.30	0.37	0.28	0.29	0.29	0.27	0.30	0.32
Gemfish	0.28	0.45	0.46	0.90	0.45	0.45	0.45	0.45	0.46	0.47
John Dory	0.30	0.41	0.42	0.45	0.41	0.42	0.42	0.41	0.45	0.45
Redfish	0.64	0.47	0.48	na	0.47	0.47	0.47	0.48	0.50	0.50
Blue Warehou	1.04	0.85	0.91	1.10	0.85	0.85	0.85	0.92	0.96	0.97
Blue-Eye Trevalla	1.18	0.84	0.89	1.35	0.87	0.88	0.88	0.89	0.93	0.96
Gould Squid	0.19	0.28	0.30	0.37	0.28	0.28	0.28	0.28	0.29	0.30
Latchet	0.19	0.56	0.57	0.70	0.55	0.56	0.56	0.56	0.60	0.63
Ocean Perch	0.22	0.38	0.39	0.45	0.38	0.38	0.38	0.39	0.41	0.42
Silver Dory	0.24	0.70	0.72	0.83	0.71	0.71	0.71	0.72	0.79	0.82
Deepwater Flathead	0.27	0.71	0.72	0.99	0.69	0.69	0.69	0.66	0.66	0.66
Blue Grenadier	0.28	0.28	0.30	0.43	0.28	0.28	0.28	0.29	0.30	0.31
Oceanjacket	0.28	1.07	1.10	1.36	1.07	1.10	1.10	1.15	1.22	1.22
Common Sawshark	0.29	na	na	na	na	na	na	na	na	na
Kingdory	0.33	0.46	0.47	0.74	0.45	0.46	0.46	0.46	0.47	0.49
Barracouta	0.34	0.98	1.02	1.18	0.99	1.00	1.00	1.05	1.13	1.15
Redgurnard	0.34	0.66	0.68	0.76	0.67	0.67	0.67	0.68	0.79	0.86
Jackmackerel	0.36	1.30	1.40	1.85	1.30	1.30	1.30	1.35	1.44	1.45
Stargazer Speckled	0.37	0.63	0.64	0.70	0.63	0.64	0.64	0.66	0.69	0.75
Gummy Shark	0.40	0.67	0.70	0.88	0.66	0.66	0.66	0.67	0.71	0.73
Dogfishes	0.43	1.64	1.69	1.97	1.67	1.67	1.67	1.71	1.74	1.75
Ribaldo	0.57	1.11	1.15	1.46	1.12	1.12	1.12	1.13	1.15	1.15
Frostfish	0.67	2.60	2.65	2.87	2.61	2.62	2.62	2.63	2.71	2.73
Alfonsino	0.68	2.16	2.15	2.86	2.16	2.16	2.16	2.39	2.49	2.49
Spikey Oreodory	0.83	1.02	1.08	1.37	1.00	1.01	1.01	0.98	1.04	1.11
School Shark	0.97	1.13	1.19	1.45	1.13	1.14	1.14	1.12	1.19	1.22

na – did not converge

For the summer surveys, only two species, Silver Warehou and Blue Grenadier, showed no change in classification when points were reduced. For Silver Warehou this was for the uniform reduction of 10% only (A10) and for Blue Grenadier it was the same scenario or any scenario with a reduction in points in the NSW shelf region, where Blue Grenadier is not caught in any case.

Table 16. Baseline CVs for the winter 2010 survey and for scenarios A10-C50. See Table 14 for a description of sensitivities.

Species	Winter Base	A10	A20	A50	B10	B20	B50	C10	C20	C50
Tiger Flathead	0.12	0.14	0.14	0.16	0.14	0.14	0.14	0.14	0.15	0.15
Silver Warehou	0.14	0.16	0.18	0.25	0.16	0.17	0.17	0.17	0.18	0.18
Pink Ling	0.15	0.20	0.21	0.28	0.20	0.20	0.20	0.20	0.21	0.21
John Dory	0.17	0.24	0.24	0.25	0.24	0.24	0.24	0.24	0.24	0.24
Mirror Dory	0.18	0.27	0.28	0.36	0.26	0.28	0.28	0.26	0.28	0.28
Jackass Morwong	0.21	0.26	0.27	0.31	0.26	0.26	0.26	0.26	0.31	0.31
Gemfish	0.21	0.35	0.36	0.52	0.35	0.35	0.35	0.41	0.41	0.41
Redfish	0.23	0.26	0.26	0.43	0.27	0.28	0.28	0.25	0.26	0.26
Blue Warehou	0.23	0.40	0.42	0.65	0.39	0.39	0.39	0.44	0.45	0.45
Blue-Eye Trevalla	0.36	0.57	0.62	0.79	0.55	0.58	0.58	0.56	0.59	0.59
Silver Trevally	0.51	0.90	0.90	0.99	0.90	0.93	0.93	0.92	0.92	0.92
Ocean Perch	0.13	0.23	0.24	0.31	0.23	0.24	0.24	0.23	0.23	0.23
Dogfishes	0.14	1.10	1.17	1.61	1.12	1.12	1.12	1.11	1.18	1.18
Common Sawshark	0.14	na	na	na	na	na	na	na	na	na
Gummy Shark	0.23	0.39	0.40	0.49	0.39	0.39	0.39	0.40	0.41	0.41
Deepwater Flathead	0.25	0.53	0.57	0.82	0.51	0.51	0.51	0.53	0.53	0.53
Kingdory	0.27	0.53	0.55	0.79	0.55	0.55	0.55	0.57	0.57	0.57
Blue Grenadier	0.28	0.27	0.31	0.42	0.26	0.26	0.26	0.29	0.30	0.30
Frostfish	0.30	0.74	0.84	1.15	0.76	0.76	0.76	0.69	0.70	0.70
School Shark	0.35	0.79	0.83	1.07	0.79	0.79	0.79	0.81	0.84	0.84
Royal Red Prawn	0.35	0.38	0.42	0.64	0.38	0.39	0.39	0.38	0.39	0.39
Ribaldo	0.46	0.68	0.71	0.92	0.68	0.70	0.70	0.74	0.75	0.75
Redgurnard	0.48	0.57	0.59	0.80	0.57	0.57	0.57	0.63	0.67	0.67
Alfonsino	0.72	1.91	2.16	2.78	1.84	1.94	1.94	1.85	1.94	1.94
Greeneye Dogfish	1.38	0.99	1.11	1.57	1.01	1.11	1.11	1.00	1.05	1.05

na – did not converge

For the winter surveys, five species, Tiger Flathead, Silver Warehou, Jackass Morwong, Redfish and Blue Grenadier, showed no change in classification when points were reduced. For Tiger Flathead, estimates of CV for all scenarios were < 0.2. For Silver Warehou, the only scenario that produced a CV > 0.2 was a uniform 50% reduction in shots (A50). Jackass Morwong and Redfish both started with a base case CV in the range 0.2 to 0.3. For Redfish, only one case (A50) results in an increase to > 0.3 while for Jackass Morwong, 3 cases showed an increase to > 0.3, (A50, C20 and C50). Blue Grenadier also started with a base case CV in the range 0.2 to 0.3 and in only 4 cases the CV increased to > 0.3.

Table 17. Combined baseline CVs for the 2010 survey and for scenarios A10-C50. See Table 14 for a description of sensitivities.

Species	2010 Base	A10	A20	A50	B10	B20	B50	C10	C20	C50
Tiger Flathead	0.09	0.12	0.12	0.13	0.12	0.12	0.12	0.12	0.13	0.13
Silver Warehou	0.12	0.14	0.15	0.21	0.14	0.14	0.14	0.14	0.15	0.16
Pink Ling	0.12	0.16	0.17	0.22	0.16	0.16	0.16	0.16	0.17	0.17
Jackass Morwong	0.13	0.18	0.19	0.22	0.18	0.19	0.19	0.18	0.22	0.22
Mirror Dory	0.14	0.21	0.22	0.28	0.21	0.21	0.21	0.21	0.22	0.22
John Dory	0.15	0.21	0.21	0.22	0.21	0.21	0.21	0.21	0.21	0.21
Gemfish	0.17	0.28	0.28	0.45	0.28	0.28	0.28	0.30	0.31	0.31
Redfish	0.21	0.22	0.23	0.43[w]	0.23	0.24	0.24	0.22	0.23	0.23
Blue Warehou	0.23	0.36	0.38	0.56	0.35	0.35	0.35	0.40	0.40	0.41
Blue-Eye Trevalla	0.34	0.47	0.51	0.68	0.47	0.49	0.49	0.48	0.50	0.50
Silver Trevally	0.51[w]	0.90[w]	0.90[w]	0.99[w]	0.90[w]	0.93[w]	0.93[w]	0.92[w]	0.92[w]	0.92[w]
Ocean Perch	0.11	0.20	0.21	0.26	0.20	0.20	0.20	0.20	0.20	0.20
Dogfishes	0.13	0.91	0.96	1.25	0.93	0.93	0.93	0.93	0.97	0.98
Common Sawshark	0.14[w]	na	na	na	na	na	na	na	na	na
Deepwater Flathead	0.18	0.42	0.45	0.63	0.41	0.41	0.41	0.41	0.42	0.41
Blue Grenadier	0.20	0.19	0.21	0.30	0.19	0.19	0.19	0.21	0.21	0.22
Gummy Shark	0.20	0.34	0.35	0.43	0.34	0.34	0.34	0.34	0.36	0.36
King Dory	0.21	0.35	0.36	0.54	0.35	0.35	0.35	0.36	0.37	0.37
Frostfish	0.27	0.71	0.80	1.07	0.73	0.73	0.73	0.67	0.68	0.68
Redgurnard	0.28	0.43	0.45	0.55	0.43	0.44	0.44	0.46	0.51	0.53
School Shark	0.33	0.65	0.68	0.86	0.65	0.65	0.65	0.65	0.68	0.69
Stargazer Speckled	0.35	0.53	0.55	0.64	0.54	0.55	0.55	0.55	0.58	0.61
Royal Red Prawn	0.35[w]	0.38[w]	0.42[w]	0.64[w]	0.38[w]	0.39[w]	0.39[w]	0.38[w]	0.39[w]	0.39[w]
Ribaldo	0.36	0.58	0.60	0.78	0.58	0.59	0.59	0.62	0.63	0.63
Alfonsino	0.50	1.43	1.52	1.99	1.40	1.44	1.44	1.46	1.53	1.53
Spikey Oreodory	0.83[s]	1.02[s]	1.08[s]	1.37[s]	1.00[s]	1.01[s]	1.01[s]	0.98[s]	1.04[s]	1.11[s]

[w] value obtained from winter survey only
[s] value obtained from summer survey only
na – did not converge

Combined CVs on the abundance estimate could only be calculated for 24 species listed in Table 17 (if available, CVs from either summer or winter are shown for quota species who's combined abundance estimates could not be calculated). These CVs are combined from the CVs on the separate seasonal abundance surveys conducted in both summer and winter 2010. These combined CVs were obtained for 10 of the target species and an additional 12 species.

In most cases the CVs increase monotonically as the number of points included in the survey reduces. In some cases, 20% or 50% of the total number of points from the 2010 survey cannot be removed from particular areas (NSW shelf or west coast Tasmania) so in this case the number of points removed is capped by the number of survey points that are available in that region.

The following seven target species have a CV <0.2 in the base case: Tiger Flathead, Silver Warehou, Pink Ling, Jackass Morwong, Mirror Dory, John Dory and Gemfish. As points are removed, Tiger Flathead is the only species to maintain a CV<0.2 for all shot reduction scenarios considered. Silver Warehou and Pink Ling maintain a CV<0.2 for eight of the nine scenarios, with the one exception (A50) in the range 0.2 to 0.3. Jackass Morwong maintains a CV<0.2 for six of the nine scenarios, with the exception (A50, C20, C50) in the range 0.2 to 0.3. Mirror Dory and John Dory produce a CV in the range 0.2 to 0.3 for all of the nine scenarios, with the one exception (A50) in the range 0.2 to 0.3. Gemfish (combined eastern and western) produce five out of nine scenarios in the range 0.2 to 0.3 with the remaining 4 scenarios with a CV >0.3.

Of the non-target species, three species have a baseline CV<0.2. Of these three species Ocean Perch results in a change of CV from <0.2 to between 0.2 and 0.3 for all nine shot reductions scenarios. For the other two species, Deepwater Flathead and Dogfishes, the CV changes from <0.2 with the full survey to > 0.3 in all shot reduction scenarios.

Blue Grenadier has a baseline CV of 0.2 and most shot reduction scenarios produce a CV in the range 0.19 to 0.22, with only one scenario (A50) resulting in a CV of 0.3. Gummy Shark and King Dory, Frostfish and Red Gurnard all move from a CV in the range 0.2 to 0.3 for the baseline CV with CV's exceeding 0.3 for all shot reduction scenarios.

While reductions in shots may reduce survey costs, this will result in a disproportionate loss of useable abundance estimates. This is probably due to the design of the current survey being optimised for these 11 target species.

Sensitivity analyses: Alteration of the survey design

We report on the effect on the estimated CVs of altering the independent survey design. The sensitivities investigated involved either replacing samples (10%, 20% or 40%) or adding more samples (10% or 20% more) to achieve a survey with a different emphasis - either shallow or deep water, or a more western or a more eastern survey (see Table 18 for a description of sensitivities).

Estimated CVs for the summer and winter re-designed surveys are shown in Table 19 and Table 20 respectively. Combined CVs across both seasons are reported in

Table 21 for those species where CVs were able to be estimated for both seasons (if available, CVs from either summer or winter are shown for quota species who's combined abundance estimates could not be calculated). Results in the tables are separated into the main 11 species that we report on and the additional species.

We report on changes to CVs associated with each species and sensitivity and compare with the optimised (base) survey using the criterion CVs < 0.2 are "good" or acceptably low to provide a reasonable estimate of abundance (colour = green); CVs > = 0.2 and < 0.3 deemed "marginal" (colour = yellow) and CVs > 0.3 deemed "unacceptable" (colour = red).

For the summer surveys with an emphasis on either shallow or deep depths, and for main species that had either "good" or "marginal" CVs estimated for the optimised survey, there was no notable change in the CV classification across the sensitivities. An exception was for Jackass Morwong; the estimated CV under a re-design changed from "good" to "marginal". The CVs for Tiger flathead reverted from "good" to "marginal" for the deeper survey scenarios. Similarly, for the additional species with either "good" or "marginal" CVs for the optimised survey, the CVs under a re-design on the basis of depth reverted to "unacceptable" (e.g. Ocean Jacket, Silver Dory, Latchet, Table 19).

Following from the above results relating to summer, using a survey design that has either a more western or eastern emphasis again resulted in the CV for Jackass Morwong reverting from "good" to "marginal". The CV classifications for the main species tended to remain as classified under the optimised design. This was also the case for most of the other species, however there were exceptions including Deepwater Flathead, Silver Dory, and Latchet, where the CVs got larger than those for the optimised design, these tended to go from "marginal" to "unacceptable" (Table 19).

For winter surveys with an emphasis on either shallow or deep depths, or more eastern or more western, the outcomes were similar to those observed for the summer scenarios. More of the main species tended to stay within their original classifications. More obvious than the summer scenarios, was an incremental effect of the different levels of the scenarios. For example the CV estimated for John Dory was 0.6 under the scenario with 40% more shots in deeper depths, whereas the CV was estimated to be 0.25 for the scenario with only 10% more shots in deep water. In both instances the CV had reverted from “good” to either “marginal” or “unacceptable”.

For the combined summer and winter surveys, with an emphasis on either shallow or deep depths, the CVs for most of the species remained classified as per the optimised (base) survey. Exceptions included Blue Warehou, John Dory (depending on the sensitivity), Gemfish, Dogfishes, School Shark, Deepwater Flathead, Frostfish, and King Dory. In all cases the CVs changed in the direction of “marginal” or “unacceptable” (Table 21). In the case of a survey with a more western or eastern emphasis, again if CVs did change in terms of their category then CVs tended to get larger and were categorised as either “marginal” or “unacceptable”, whereas previously they were either “good” or “marginal” (e.g. Blue Warehou; Table 21). An exception was Blue Grenadier for scenarios with an emphasis on deep depths or a more western survey, where there was a slight improvement in the estimated CVs and the category for CVs changed from “marginal” to “good”. Adding more survey shots (either deep, shallow, west or east) did not notably improve the CVs.

In summary, the CVs estimated for a survey design with a different emphasis, either more deep or more shallow, or more western or more eastern, did not make notable differences when compared to the CVs under the optimal design. There were some subtle differences in the CVs that were estimated under the different scenarios, but for the main species that were categorised under the optimal design as “good” there was a tendency to revert to a “marginal” or “unacceptable” CV in the alternative design scenarios. For the main and other species that had “unacceptable” CVs under the optimised design, the situation usually did not improve under the alternative design scenarios.

Table 18. Description of sensitivities — survey designs with different emphasis on either shallow or deep water, or a more western or a more eastern survey.

Sensitivity	Description	Depth1	Depth2	CoastPos1	CoastPos2
D1	Shallower Survey 10% replace shots	201 - 700	1 - 200	1 - 240	
D2	Shallower Survey 20% replace shots	201 - 700	1 - 200	1 - 240	
D3	Shallower Survey 40% replace shots	201 - 700	1 - 200	1 - 240	
D4	Shallower Survey 10% more shots	201 - 700	1 - 200	1 - 240	
D5	Shallower Survey 20% more shots	201 - 700	1 - 200	1 - 240	
E1	Deeper Survey 10% replace shots	100 - 199	200 - 700	1 - 240	
E2	Deeper Survey 20% replace shots	100 - 199	200 - 700	1 - 240	
E3	Deeper Survey 40% replace shots	100 - 199	200 - 700	1 - 240	
E4	Deeper Survey 10% more shots	100 - 199	200 - 700	1 - 240	
E5	Deeper Survey 20% more shots	100 - 199	200 - 700	1 - 240	
F1	More Western 10% replace shots			115 - 240	1 - 114
F2	More Western 20% replace shots			115 - 240	1 - 114
F3	More Western 40% replace shots			115 - 240	1 - 114
F4	More Western 10% more shots			115 - 240	1 - 114
F5	More Western 20% more shots			115 - 240	1 - 114
G1	More Eastern 10% replace shots			1 - 114	115 - 240
G2	More Eastern 20% replace shots			1 - 114	115 - 240
G3	More Eastern 40% replace shots			1 - 114	115 - 240
G4	More Eastern 10% more shots			1 - 114	115 - 240
G5	More Eastern 20% more shots			1 - 114	115 - 240

Depth1 = depth (m) from which shots were removed; Depth2 = depth (m) for replacement/ more shots; CoastalPos1 = coastal position (tx) from which shots were removed; CoastalPos2 = coastal position (tx) for replacement/ more shots. Coastal position is numbered from 1 – 240, starting in the West and running along the coast, towards the East.

Table 19. Comparison of CVs for Base (optimised) summer 2010 survey and each of the sensitivities listed in Table 18.

Species	Summer Base	Shallow					Deep					Western					Eastern				
		D1	D2	D3	D4	D5	E1	E2	E3	E4	E5	F1	F2	F3	F4	F5	G1	G2	G3	G4	G5
Blue Warehou	1.04	0.74	0.73	0.62	0.74	0.73	0.90	0.90	1.01	0.79	0.76	0.88	0.96	1.00	0.80	0.80	0.79	0.76	1.07	0.79	0.77
Jackass Morwong	0.16	0.27	0.25	0.23	0.26	0.24	0.27	0.27	0.29	0.26	0.25	0.25	0.25	0.25	0.25	0.23	0.28	0.29	0.35	0.26	0.26
John Dory	0.30	0.31	0.27	0.24	0.31	0.27	0.36	0.40	na	0.35	0.35	0.36	0.38	na	0.35	0.35	0.35	0.34	0.36	0.35	0.34
Gemfish	0.28	0.46	0.48	0.57	0.46	0.46	0.45	0.44	0.39	0.44	0.41	0.42	0.39	0.49	0.41	0.38	0.47	0.50	1.00	0.46	0.45
Tiger Flathead	0.14	0.17	0.15	0.14	0.17	0.16	0.20	0.21	0.25	0.19	0.18	0.20	0.21	0.39	0.19	0.19	0.19	0.18	0.18	0.19	0.18
Pink Ling	0.20	0.24	0.24	0.25	0.23	0.21	0.22	0.21	0.19	0.22	0.20	0.26	0.27	1.38	0.24	0.24	0.22	0.23	0.28	0.21	0.20
Silver Trevally	0.98	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	0.95	0.77	0.99	0.93	na
Redfish	0.64	0.43	0.37	0.35	0.41	0.36	0.46	0.48	na	0.46	0.46	0.49	na	na	0.46	0.46	0.46	0.45	0.40	0.46	0.45
Blue-Eye Trevalla	1.18	0.63	0.69	1.15	0.59	0.58	0.58	0.52	0.51	0.56	0.50	0.59	0.56	0.60	0.57	0.52	0.62	0.74	1.59	0.57	0.55
Mirror Dory	0.25	0.32	0.32	0.34	0.30	0.28	0.28	0.26	0.25	0.27	0.25	0.26	0.25	0.96	0.26	0.23	0.32	0.35	0.48	0.30	0.29
Silver Warehou	0.26	0.28	0.32	0.33	0.26	0.25	0.24	0.22	0.22	0.24	0.22	0.22	0.20	0.68	0.22	0.19	0.28	0.36	0.44	0.26	0.26
Ocean Perch	0.22	0.31	0.29	0.30	0.30	0.28	0.27	0.27	0.24	0.27	0.25	0.35	0.40	1.23	0.32	0.32	0.27	0.25	0.25	0.26	0.24
School Whiting	2.24	1.05	0.99	0.82	1.04	0.97	1.22	1.24	1.44	1.18	1.18	1.23	1.26	2.31	1.18	1.18	1.18	1.18	0.98	1.18	1.18
Alfonsino	0.68	1.45	1.50	1.76	1.46	1.43	1.24	1.03	0.93	1.21	0.98	1.63	1.77	1.43	1.58	1.57	1.12	0.99	1.38	1.12	0.93
Ribaldo	0.57	1.36	1.48	1.57	1.35	1.35	0.87	0.75	0.62	0.87	0.75	1.34	1.41	2.19	1.32	1.31	0.86	0.76	0.94	0.86	0.72
Dogfishes	0.43	1.59	1.55	1.51	1.59	1.55	1.71	1.54	1.55	1.66	1.49	1.69	1.71	2.66	1.64	1.64	1.61	1.59	2.08	1.60	1.59
Gummy Shark	0.40	0.65	0.64	0.57	0.64	0.62	0.68	0.69	0.73	0.63	0.61	0.66	0.66	0.70	0.62	0.60	0.66	0.68	0.99	0.64	0.63
School Shark	0.97	1.17	1.19	1.08	1.11	1.07	1.14	1.10	1.10	1.09	1.03	1.09	1.06	0.93	1.06	0.99	1.19	1.25	1.54	1.11	1.09
Deepwater Flathead	0.27	0.77	0.79	0.58	0.77	0.77	0.80	0.86	0.73	0.77	0.77	0.74	0.70	0.61	0.73	0.70	0.80	0.82	1.13	0.77	0.77
Blue Grenadier	0.28	0.29	0.32	0.37	0.28	0.27	0.23	0.19	0.17	0.22	0.19	0.22	0.23	0.27	0.22	0.21	0.27	0.31	0.44	0.26	0.25
Common Sawshark	0.29	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0
Frostfish	0.67	1.43	1.34	1.51	1.41	1.31	1.18	1.14	1.04	1.18	1.09	1.69	1.72	>4.0	1.59	1.57	1.14	1.00	0.89	1.13	0.99
Oceanjacket	0.28	1.34	1.29	1.01	1.35	1.21	1.64	1.91	1.52	1.46	1.47	1.66	1.75	3.63	1.48	1.48	1.47	1.46	1.05	1.46	1.46
Barracouta	0.34	0.90	0.87	0.89	0.87	0.82	0.93	0.99	1.07	0.89	0.87	0.88	0.85	1.12	0.87	0.82	0.97	1.03	1.73	0.91	0.90
Silverdory	0.24	0.62	0.59	0.60	0.61	0.57	0.61	0.60	0.73	0.59	0.56	0.59	0.57	0.66	0.57	0.54	0.63	0.64	0.84	0.62	0.61
Latchet	0.19	0.60	0.59	0.50	0.59	0.58	0.59	0.59	0.63	0.57	0.55	0.55	0.53	0.50	0.54	0.51	0.61	0.63	0.79	0.60	0.60
Gould Squid	0.19	0.25	0.24	0.24	0.24	0.22	0.26	0.26	0.26	0.25	0.24	0.27	0.27	0.51	0.26	0.25	0.26	0.27	0.39	0.25	0.23
Toothed Whiptail	0.29	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0
Jack Mackerel	0.36	1.19	1.18	1.06	1.15	1.14	1.38	1.39	1.53	1.19	1.15	1.39	1.48	1.28	1.21	1.20	1.21	1.18	1.59	1.18	1.14
Spikey Oreodory	0.83	1.02	1.24	1.43	0.93	0.91	0.81	0.72	0.65	0.79	0.70	0.89	0.88	0.69	0.86	0.80	0.95	1.27	1.50	0.85	0.80
King Dory	0.33	0.44	0.46	0.68	0.42	0.42	0.39	0.33	0.30	0.39	0.32	0.35	0.34	0.36	0.34	0.32	0.43	0.47	0.87	0.41	0.40
Red Gurnard	0.34	0.59	0.55	0.56	0.57	0.53	0.57	0.54	0.66	0.56	0.53	0.53	0.52	1.08	0.51	0.50	0.60	0.63	0.81	0.58	0.58
Speckled Stargazer	0.37	0.61	0.60	0.55	0.61	0.60	0.59	0.50	0.53	0.57	0.49	0.53	0.52	0.42	0.51	0.49	0.61	0.60	0.78	0.61	0.60

na – did not converge

Table 20. Comparison of CVs for Base (optimised) winter 2010 survey and each of the sensitivities listed in Table 18.

Species	Winter Base	Shallow					Deep					Western					Eastern				
		D1	D2	D3	D4	D5	E1	E2	E3	E4	E5	F1	F2	F3	F4	F5	G1	G2	G3	G4	G5
Blue Warehou	0.23	0.23	0.40	0.39	0.41	0.39	0.41	0.41	0.41	0.38	0.37	0.34	0.31	0.30	0.35	0.31	0.46	0.55	1.39	0.39	0.39
Jackass Morwong	0.21	0.21	0.25	0.25	0.23	0.25	0.25	0.27	0.25	0.25	0.25	0.25	0.24	0.22	0.25	0.24	0.27	0.31	1.34	0.25	0.25
John Dory	0.17	0.17	0.20	0.18	0.15	0.21	0.25	0.28	0.61	0.24	0.23	0.24	0.24	0.35	0.24	0.24	0.24	0.23	0.22	0.24	0.23
Gemfish	0.21	0.21	0.35	0.35	0.48	0.35	0.31	0.30	0.27	0.31	0.30	0.30	0.32	0.49	0.29	0.27	0.41	0.47	1.23	0.35	0.34
Tiger Flathead	0.12	0.12	0.12	0.11	0.10	0.12	0.14	0.14	0.16	0.14	0.13	0.15	0.15	0.19	0.15	0.15	0.13	0.12	0.13	0.13	0.12
Pink Ling	0.15	0.15	0.17	0.18	0.21	0.17	0.17	0.15	0.15	0.16	0.15	0.19	0.20	0.36	0.18	0.18	0.17	0.21	0.62	0.16	0.15
Silver Trevally	0.51	0.51	0.70	0.62	0.58	0.69	0.81	0.90	na	0.81	0.81	0.81	0.81	1.13	0.81	0.81	0.81	0.81	0.90	0.81	0.81
Redfish	0.23	0.23	0.20	0.20	0.19	0.20	0.25	0.29	0.30	0.22	0.22	0.23	0.30	0.55	0.22	0.22	0.22	0.20	0.19	0.22	0.20
Blue-Eye Trevalla	0.36	0.36	0.52	0.54	0.59	0.48	0.45	0.41	0.36	0.44	0.40	0.53	0.53	0.59	0.47	0.46	0.48	0.61	2.18	0.43	0.42
Mirror Dory	0.18	0.18	0.22	0.22	0.24	0.21	0.21	0.20	0.18	0.20	0.19	0.23	0.27	0.59	0.22	0.21	0.20	0.22	0.74	0.19	0.18
Silver Warehou	0.14	0.14	0.16	0.17	0.21	0.16	0.15	0.15	0.14	0.15	0.14	0.15	0.14	0.17	0.15	0.14	0.19	0.31	1.55	0.15	0.15
Royal Red Prawn	0.35	0.43	0.48	1.11	0.39	0.39	0.40	0.37	0.34	0.39	0.36	0.44	0.58	2.65	0.40	0.40	0.38	0.64	>4.0	0.38	0.34
Ocean Perch	0.13	0.20	0.22	0.24	0.19	0.18	0.19	0.17	0.18	0.18	0.17	0.22	0.28	0.56	0.20	0.20	0.18	0.17	0.34	0.17	0.16
Alfonsino	0.72	1.50	1.61	1.87	1.38	1.37	1.28	1.16	0.94	1.25	1.14	1.61	1.79	1.77	1.40	1.37	1.23	1.26	1.18	1.17	1.13
Ribaldo	0.46	0.76	0.80	0.98	0.75	0.74	0.49	0.44	0.38	0.49	0.43	0.57	0.60	0.89	0.54	0.51	0.72	0.84	3.01	0.68	0.68
Dogfishes	0.14	1.07	1.09	1.19	1.03	1.01	1.02	1.01	0.94	0.98	0.95	0.98	0.97	1.11	0.97	0.93	1.17	1.54	>4.0	1.02	1.01
Gummy Shark	0.23	0.38	0.37	0.33	0.37	0.35	0.39	0.41	0.38	0.37	0.36	0.40	0.39	0.34	0.39	0.38	0.39	0.40	0.87	0.37	0.36
School Shark	0.35	0.72	0.72	0.80	0.70	0.68	0.70	0.69	0.63	0.67	0.65	0.67	0.63	0.55	0.66	0.62	0.76	0.93	2.17	0.69	0.68
Deepwater Flathead	0.25	0.52	0.52	0.52	0.51	0.50	0.54	0.57	0.63	0.50	0.50	0.47	0.44	0.43	0.48	0.44	0.61	0.68	2.00	0.52	0.52
Blue Grenadier	0.28	0.26	0.28	0.38	0.26	0.25	0.26	0.25	0.25	0.25	0.24	0.24	0.19	0.21	0.23	0.19	0.35	0.66	3.59	0.28	0.28
Common Sawshark	0.14	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0
Frostfish	0.30	0.65	0.76	1.05	0.55	0.53	0.57	0.54	0.61	0.55	0.52	0.74	1.08	3.21	0.57	0.57	0.54	0.51	1.30	0.54	0.50
King Dory	0.27	0.51	0.52	0.78	0.49	0.49	0.41	0.39	0.37	0.40	0.38	0.39	0.36	0.34	0.37	0.34	0.54	0.74	3.22	0.49	0.49
Red Gurnard	0.48	0.57	0.54	0.62	0.56	0.53	0.58	0.58	0.56	0.57	0.55	0.55	0.50	0.48	0.53	0.49	0.64	0.80	3.60	0.59	0.59
Green-eyed Dogfish	1.38	1.02	1.04	1.13	0.96	0.95	1.19	1.08	1.15	0.98	0.89	1.05	1.29	2.85	0.98	0.97	0.94	0.85	0.80	0.94	0.83
New Zealand Dory	0.01	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	>4.0	3.05	>4.0	3.92	3.10	>4.0	>4.0	>4.0	>4.0	>4.0

na – did not converge

Table 21. Combined CVs (summer and winter) for each of the sensitivities listed in Table 18.

Species	2010 Base	Shallow					Deep					Western					Eastern				
		D1	D2	D3	D4	D5	E1	E2	E3	E4	E5	F1	F2	F3	F4	F5	G1	G2	G3	G4	G5
Blue Warehou	0.23	0.35	0.34	0.34	0.35	0.34	0.37	0.37	0.38	0.34	0.33	0.32	0.30	0.29	0.32	0.29	0.40	0.45	0.85	0.35	0.35
Jackass Morwong	0.13	0.18	0.18	0.16	0.18	0.17	0.18	0.19	0.19	0.18	0.18	0.18	0.17	0.17	0.18	0.17	0.19	0.21	0.34	0.18	0.18
John Dory	0.15	0.17	0.15	0.13	0.17	0.15	0.21	0.23	na	0.20	0.19	0.20	0.20	na	0.20	0.20	0.20	0.19	0.19	0.20	0.19
Gemfish	0.17	0.28	0.28	0.37	0.28	0.27	0.26	0.25	0.22	0.25	0.24	0.24	0.25	0.35	0.24	0.22	0.31	0.34	0.78	0.28	0.27
Tiger Flathead	0.09	0.10	0.09	0.08	0.10	0.09	0.11	0.12	0.13	0.11	0.11	0.12	0.12	0.17	0.12	0.12	0.11	0.10	0.11	0.11	0.10
Pink Ling	0.12	0.14	0.14	0.16	0.14	0.13	0.13	0.12	0.12	0.13	0.12	0.15	0.16	0.35	0.14	0.14	0.13	0.16	0.26	0.13	0.12
Silver Trevally	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	0.62	0.56	0.67	0.61	na
Redfish	0.21	0.18	0.18	0.17	0.18	0.17	0.22	0.25	na	0.20	0.20	0.21	na	na	0.20	0.20	0.20	0.18	0.17	0.20	0.18
Blue-Eye Trevalla	0.34	0.40	0.43	0.52	0.37	0.37	0.36	0.32	0.29	0.35	0.31	0.39	0.38	0.42	0.36	0.34	0.38	0.47	1.28	0.34	0.33
Mirror Dory	0.14	0.18	0.18	0.20	0.17	0.16	0.17	0.16	0.15	0.16	0.15	0.17	0.18	0.50	0.17	0.16	0.17	0.19	0.40	0.16	0.15
Silver Warehou	0.12	0.14	0.15	0.18	0.14	0.13	0.13	0.12	0.12	0.13	0.12	0.12	0.11	0.16	0.12	0.11	0.16	0.23	0.42	0.13	0.13
Ocean Perch	0.11	0.17	0.18	0.19	0.16	0.15	0.16	0.14	0.14	0.15	0.14	0.19	0.23	0.51	0.17	0.17	0.15	0.14	0.20	0.14	0.13
Alfonsino	0.50	1.04	1.10	1.28	1.00	0.99	0.89	0.77	0.66	0.87	0.74	1.15	1.26	1.11	1.05	1.03	0.83	0.78	0.90	0.81	0.72
Ribaldo	0.36	0.66	0.70	0.83	0.66	0.65	0.43	0.38	0.32	0.43	0.37	0.52	0.55	0.82	0.50	0.48	0.55	0.56	0.90	0.53	0.49
Dogfishes	0.13	0.89	0.89	0.93	0.86	0.85	0.88	0.84	0.80	0.84	0.80	0.85	0.84	1.02	0.83	0.81	0.95	1.11	1.91	0.86	0.85
Gummy Shark	0.20	0.33	0.32	0.29	0.32	0.30	0.34	0.35	0.34	0.32	0.31	0.34	0.34	0.31	0.33	0.32	0.34	0.34	0.65	0.32	0.31
School Shark	0.33	0.61	0.62	0.64	0.59	0.57	0.60	0.58	0.55	0.57	0.55	0.57	0.54	0.47	0.56	0.53	0.64	0.75	1.26	0.59	0.58
Deepwater Flathead	0.18	0.43	0.43	0.39	0.43	0.42	0.45	0.48	0.48	0.42	0.42	0.40	0.37	0.35	0.40	0.37	0.49	0.52	0.98	0.43	0.43
Blue Grenadier	0.20	0.19	0.21	0.27	0.19	0.18	0.17	0.15	0.14	0.17	0.15	0.16	0.15	0.17	0.16	0.14	0.21	0.28	0.44	0.19	0.19
Frostfish	0.27	0.59	0.66	0.86	0.51	0.49	0.51	0.49	0.53	0.50	0.47	0.68	0.91	2.53	0.54	0.54	0.49	0.45	0.73	0.49	0.45
King Dory	0.21	0.33	0.34	0.51	0.32	0.32	0.28	0.25	0.23	0.28	0.24	0.26	0.25	0.25	0.25	0.23	0.34	0.40	0.84	0.31	0.31
Red Gurnard	0.28	0.41	0.39	0.42	0.40	0.37	0.41	0.40	0.43	0.40	0.38	0.38	0.36	0.44	0.37	0.35	0.44	0.49	0.79	0.41	0.41
Common Sawshark	0.14[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]	>4.0[w]
Royal Red Prawn	0.35[w]	0.43[w]	0.48[w]	1.11[w]	0.39[w]	0.39[w]	0.40[w]	0.37[w]	0.34[w]	0.39[w]	0.36[w]	0.44[w]	0.58[w]	2.65[w]	0.40[w]	0.40[w]	0.38[w]	0.64[w]	>4.0[w]	0.38[w]	0.34[w]
School Whiting	2.24[s]	1.05[s]	0.99[s]	0.82[s]	1.04[s]	0.97[s]	1.22[s]	1.24[s]	1.44[s]	1.18[s]	1.18[s]	1.23[s]	1.26[s]	2.31[s]	1.18[s]	1.18[s]	1.18[s]	1.18[s]	0.98[s]	1.18[s]	1.18[s]
Spikey Oreodory	0.83[s]	1.02[s]	1.24[s]	1.43[s]	0.93[s]	0.91[s]	0.81[s]	0.72[s]	0.65[s]	0.79[s]	0.70	0.89[s]	0.88[s]	0.69[s]	0.86[s]	0.80[s]	0.95[s]	1.27[s]	1.50[s]	0.85[s]	0.80[s]

[w] value obtained from winter survey only
[s] value obtained from summer survey only
na – did not converge

Sensitivity analysis: cost-benefit

Scenarios examined in the previous two sections were costed out to examine implications on CVs of quota species and potential cost saving. Standard values used for costs and assumptions were used for cost-benefit analysis in each scenario (Table 22). For each scenario, the number sea days required to complete sampling was calculated from the number of shots required in each zone and the mean number of shots sampled per sea day. This enabled total charter costs and observer costs to be calculated. It was assumed that 33% of charter costs would be covered by fish sales, and this was subtracted from charter costs. Final charter and observer costs were added to the base cost for administration to provide the total cost of running each scenario. Results are provided in terms of total survey cost, cost per quota species with a useable abundance estimates (CV $\leq$30%) and number of quota species with a useable abundance estimates.

Of all scenarios examined, the three base case scenarios provide the best results in terms of number of quota species with useable abundance estimate and the cost per species of obtaining that CV estimate (Figure 35 and Figure 36). Reductions in overall cost of surveys would be realised in some scenarios (Table 23), however they would come at significant loss in number of species with useable abundance estimates. The most cost effective scenarios overall are the summer and winter base cases, which would both provide useable abundance estimates at about $38,900 and $42,200 per species respectively. These scenarios would also yield the largest number of quota species useable abundance estimates (11 for summer and 14 for winter) from any single season survey. The combined base case survey would yield 14 quota species with useable abundance estimates, but be less cost effective at about $65,300 per species. The next most cost efficient scenario is D1 for the winter survey which would provide useable abundance estimates for quota species at about $53,700 per species (Figure 36). However, the total cost of this scenario is the same as for the base case, and it would provide useable abundance estimates for 3 less quota species. Scenarios that provide overall cost savings come at significant cost of reducing the number of quota species with useable abundance estimates, particularly for the summer and combined surveys. For example, the cheapest alternative scenario for combined surveys would be A50, that that would reduce the number of quota species with useable abundance estimates from 14 to 8. One of the most cost effective scenarios while retaining useable abundance estimates for a high number of quota species is the B50 winter survey (Figure 36). Total cost of that scenario would be about $53,400 less than the base case, but provide useable abundance estimates for 5 less quota species. The cost per species with useable abundance estimates would also about $17,500 more than the base case.

Table 22. Standard rates and values of costs and assumptions used in cost-benefit analysis.

Parameter	Value
Base cost (summer or winter only)	$150,000
Base cost (combined summer and winter)	$200,000
Observer cost (per sea day)	$800
NSW vessel caster cost (per sea day)	$4,500
East vessel charter cost (per sea day)	$7,300
West vessel charter cost (per sea day)	$7,300
NSW shots per sea day	2.5
East shots per sea day	2.6
West shots per sea day	2.1
% of charter costs covered by fish sales	33%

Based on the above, the option of the base case winter survey offered the most cost effective achievement of CVs for the highest number of quota species. Using data from Woodhams et al. (2011), cumulative catch and catch value figures were applied to the quota species sampled in the 2010 survey. This revealed that conducting just a winter survey would provide reasonable CVs for 15 species which account for 87% of the catch of the GHaT and CTS sectors and 83% of the value (Table 24). Omission of the summer survey, while having little effect on the overall results of the survey, reduced costs by about 44%.

Table 23. Total cost of survey for each scenario. Scenarios are described in Table 14 and Table 18.

		Season	
Scenario	Summer	Winter	Combined
Base Case	**$427,298**	**$590,713**	**$914,196**
A10	$402,595	$550,813	$847,717
A20	$372,201	$505,222	$771,732
A50	$294,340	$377,955	$562,789
B10	$419,668	$579,268	$898,936
B20	$412,038	$567,823	$879,861
B50	$396,778	$537,303	$830,266
C10	$421,607	$573,640	$885,741
C20	$404,534	$556,567	$851,595
C50	$370,388	$499,657	$766,230
D1	$427,298	$590,713	$914,196
D2	$427,298	$590,713	$914,196
D3	$427,298	$590,713	$914,196
D4	$453,877	$641,995	$986,366
D5	$484,271	$678,080	$1,056,660
E1	$427,298	$590,713	$914,196
E2	$427,298	$590,713	$914,196
E3	$427,298	$590,713	$914,196
E4	$453,877	$641,995	$986,366
E5	$484,271	$678,080	$1,056,660
F1	$431,050	$607,723	$938,773
F2	$440,493	$613,351	$953,844
F3	$455,627	$639,804	$987,801
F4	$438,680	$613,477	$948,342
F5	$455,753	$630,550	$976,797
G1	$427,298	$588,837	$904,753
G2	$419,731	$585,085	$889,619
G3	$410,288	$564,260	$874,548
G4	$442,495	$619,231	$952,220
G5	$455,816	$638,243	$994,059

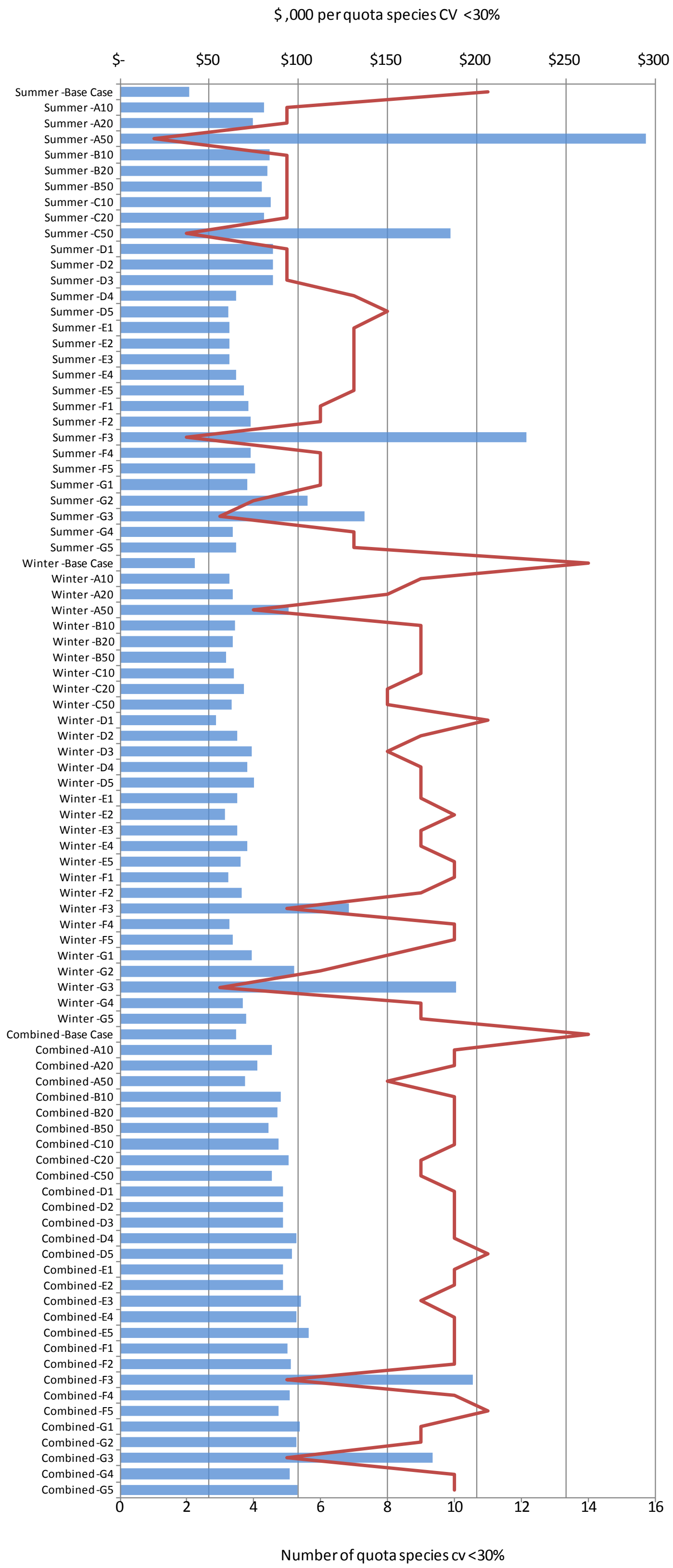

Figure 35. Cost-benefit analysis of sampling scenarios described in previous section. Solid bars are cost of obtaining useable abundance estimates (CVs ≤30%) per quota species and line is the number of quota species for which useable abundance estimates would be obtained.

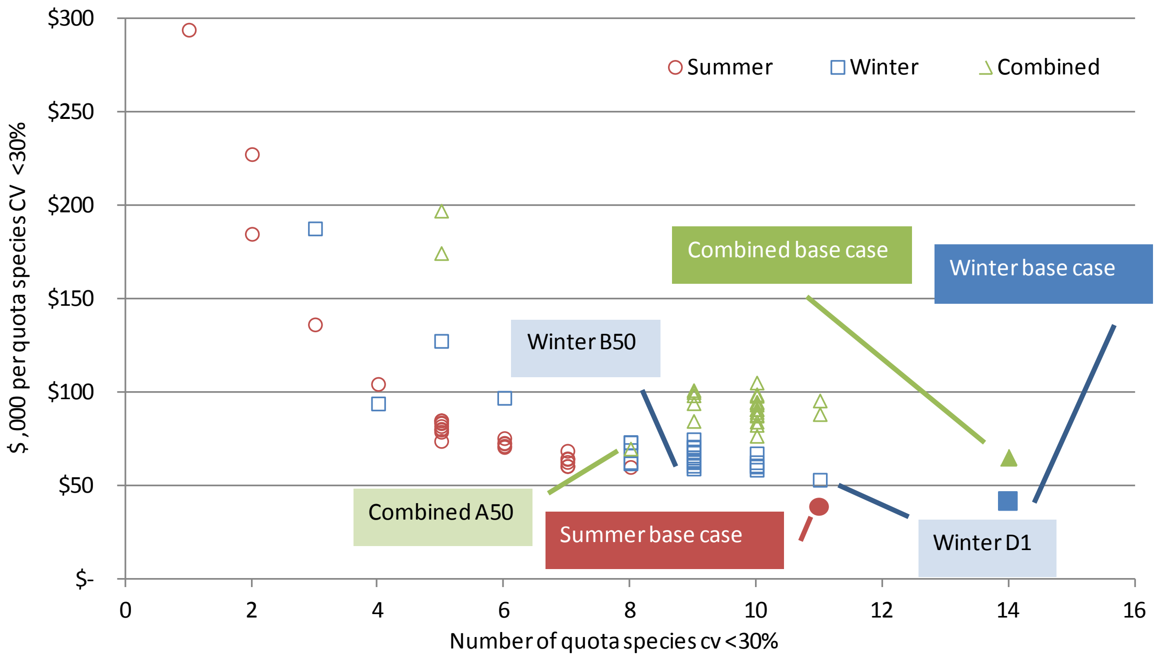

Figure 36. Cost-benefit analysis of sampling scenarios described in previous section showing cost of obtaining useable abundance estimates (CVs ≤30%) per quota versus the number of quota species for which useable abundance estimates would be obtained. Base case scenarios are shown as solid symbols

Table 24. 2010 cumulative catch (t) and value ($ million) of SESSF quota species (adapted from Woodhams et al. (2011) and CVs achieved during the summer, winter and combined 2010 fishery independent surveys.

QUOTA	Summer CV	Winter CV	Combined CV	Catch: Tonnes	Catch: % Total quota	Catch: Cum. %	Value: $ million	Value: % Total quota	Value: Cum. %
Tiger Flathead	0.14	0.12	0.09	2677	18%	18%	13.7	19%	19%
Offshore Ocean Perch	0.22	0.13	0.11	236	2%	20%	1.2	2%	20%
Silver Warehou	0.26	0.14	0.12	1347	9%	29%	3.4	5%	25%
Pink Ling	0.2	0.15	0.12	1112	8%	37%	4.7	6%	31%
Jackass Morwong	0.16	0.21	0.13	400	3%	39%	1.6	2%	33%
Common Sawshark	0.29	0.14	0.13	125	1%	40%	0.3	0%	34%
Deepwater Shark Basket	0.43	0.14	0.13	81	1%	41%	0	0%	34%
Southern Sawshark	0.29	0.14	0.13	130	1%	42%	0.3	0%	34%
Mirror Dory	0.25	0.18	0.14	646	4%	46%	1.3	2%	36%
John Dory	0.3	0.17	0.15	73	0%	47%	0.6	1%	37%
Gemfish (All)	0.28	0.21	0.17	92	1%	47%	0.6	1%	38%
Blue Grenadier	0.28	0.28	0.2	4031	27%	75%	16.3	22%	60%
Gummy Shark	0.4	0.23	0.2	1511	10%	85%	15.9	22%	81%
Redfish	0.64	0.23	0.21	158	1%	86%	1	1%	83%
Blue Warehou		0.23	0.23	145	1%	87%	0.2	0%	83%
Gemfish west	0.31	0.35	0.23	123	1%	88%		0%	83%
School Shark	0.97	0.35	0.33	216	1%	89%	1.6	2%	85%
Royal Red Prawn		0.35	0.35	113	1%	90%	0.2	0%	86%
Ribaldo	0.57	0.46	0.36	114	1%	91%	0.3	0%	86%
Blue-eye Trevalla		0.36	0.36	394	3%	94%	3.8	5%	91%
Gemfish east	0.62	0.66	0.45		0%	94%	0.6	1%	92%
Alfonsino	0.68	0.72	0.5		0%	94%		0%	92%
Silver Trevally		0.51	0.51	231	2%	95%	1.0	1%	93%
Oreo Basket				108	1%	96%	0.2	0%	94%
Deepwater Flathead					0%	96%		0%	94%
Bight Redfish					0%	96%		0%	94%
Elephantfish				65	0%	96%	0.3	0%	94%
Eastern School Whiting				388	3%	99%	1.4	2%	96%
Orange Roughy				197	1%	100%	3	4%	100%
TOTAL QUOTA				14713			73.5		
TOTAL SPECIES	3	9	13			88%	81.3		83%
	8	6	3						
	11	15	16						

Practical implementation

Prior to the 2008 trial survey, considerable work was done to determine the most cost effective and practical survey design that would deliver reasonable CVs for as many major quota and non-quota species. Following the 2010 survey the issue of survey structure and funding was revisited.

The survey definitely requires three vessels operating in the main areas of the fishery (NSW, east and west) to complete the survey within a month. If fewer vessels were used, the survey would extend over a longer time period and it could be more difficult to reconcile changes in weather or oceanic conditions over that time. While enough vessels tender to conduct the survey concurrently across the three regions, this would be the preferred approach. The value of using industry vessels for the survey is that vessels are appropriately equipped; skippers have an excellent knowledge of the grounds; and the crews are efficient and effective in undertaking survey shots and handling and storing the survey fish. In all cases, only one filed scientist was required onboard and a good working relationship was established was established with the crew. The allocation of 10% of the sale of the fish back to the vessel as an incentive for crew's cooperation with the survey requirements, and good handling and storage of the fish appeared to work well and was appreciated, but it is not clear if it was entirely necessary and may have been achieved simply through good will.

Vessel charter was the main cost of the survey, accounting for about 70% of total project costs. While there remain enough vessels interested in conducting the survey to allow competition in the tender process, charter costs are not expected to change dramatically as most operators considered the charter amounts were a "fair" cost for their involvement. The main risk to not meeting budget expectations for the surveys is the potential for bad weather to reduce the number of shots that can be achieved in a survey day, thereby prolonging the survey period and associated charter costs. This could be possibly addressed by changing the charter rate from a per-day fee to a per-shot fee. A change in the fuel price is seen as another factor that could considerably alter charter costs.

Over the entire project, fish sales from each survey offset charter costs by 30 – 40 % (average ~ 33%). There was considerably more variation on a trip by trip basis where sales from survey catches sometime offset charter costs by up over 80% or less than 20% but these instances were rare. The arrangement whereby the survey vessel owner and/or skipper organised all transport and sale of the survey product worked well because it did not upset their regular market arrangements. It also meant that the project supervisor did not need to get involved in day-to-day marketing and sale of the fish – an aspect of the project for which specialist skills and experience are required to get the best price in an efficient manner.

During 2008 and 2010, the project operated with two methods of allocating research catch allowance (quota assigned to cover the survey catch). During 2008, a post-survey calculation of research allowance was made that was then subtracted from the subsequent year's quota allocation. This worked wll and was both practical and easy to manage. During 2010, a pre-survey prediction of research catch allowance was made, and it was endeavoured to build this into the current years' quota allocation. Not only was it more difficult to estimate predicted survey catches, but the summer and winter surveys operate in different quota years. Further, problems were associated with under-prediction causing quota availability and reconciliation issues. For example if five tonnes of research allowance is pre-allocated to a species for the survey, what happens when this figure is reached and how is this coordinated across three survey vessels? Over-prediction is also viewed as problematic because if the research allowance is not caught, quota holders view it as a waste of industry's quota allocation. The alternative is that it is then put back into the allocation during the following year, which is also complicated. Overall, it was determined that post-allocation of research allowance to the survey was the easiest and most feasible system to implement.

Diagnostics

Historical fits

A range of diagnostic plots can be produced to examine the fits of the historical model, for each species and for summer and winter. Example plots of flathead in summer follow. The fitted line is in red and the data is the black dots. These fits can be assessed visually as a check to make sure that the model is fitting the data adequately. Poor fits to the data would be indicated by large spikes not fitting data, odd shapes or ballooning out at the edges.

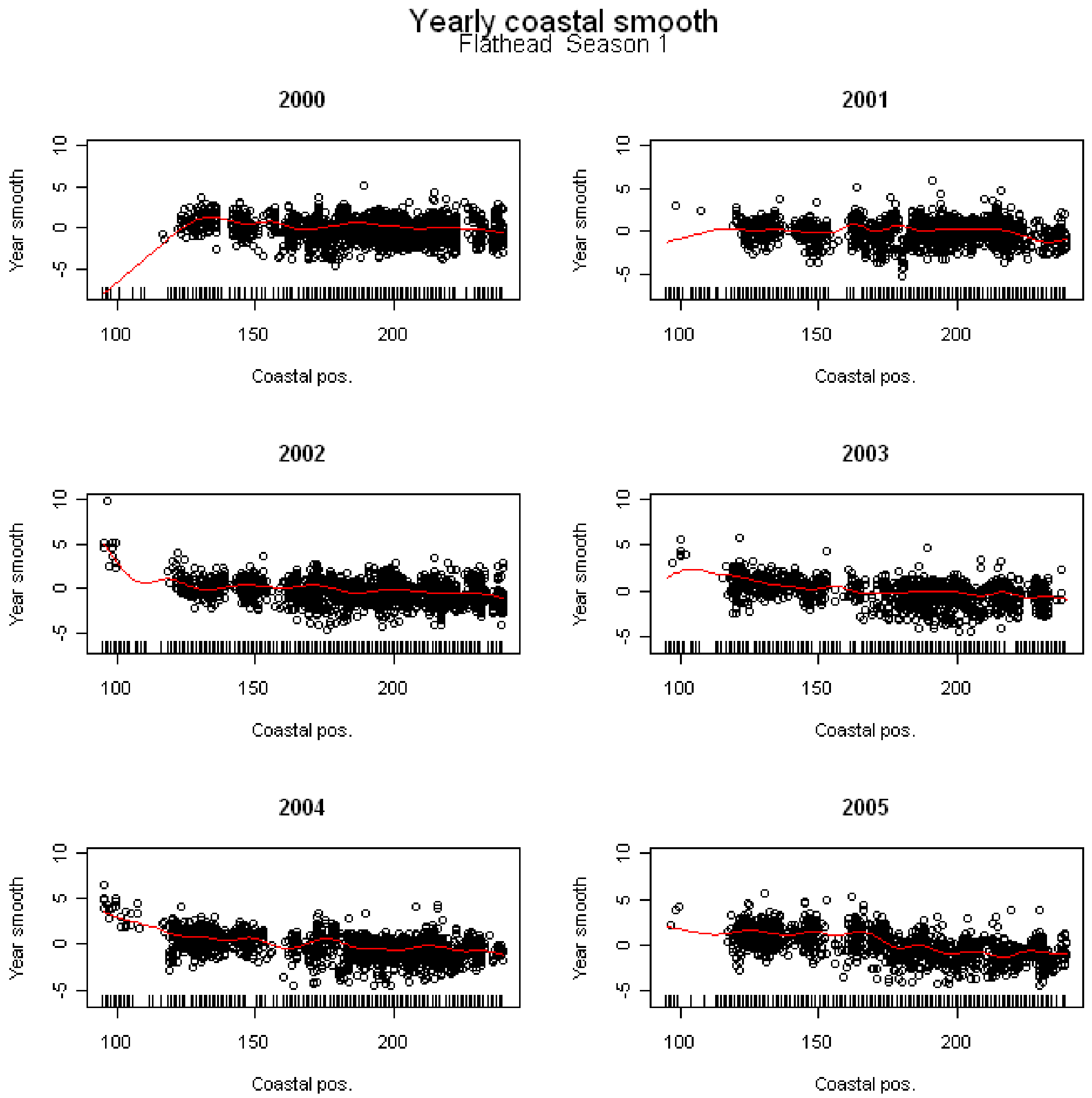

Figure 37. The coastal year effect for each year, e.g. deviation from the long-term smooth for flathead in summer.

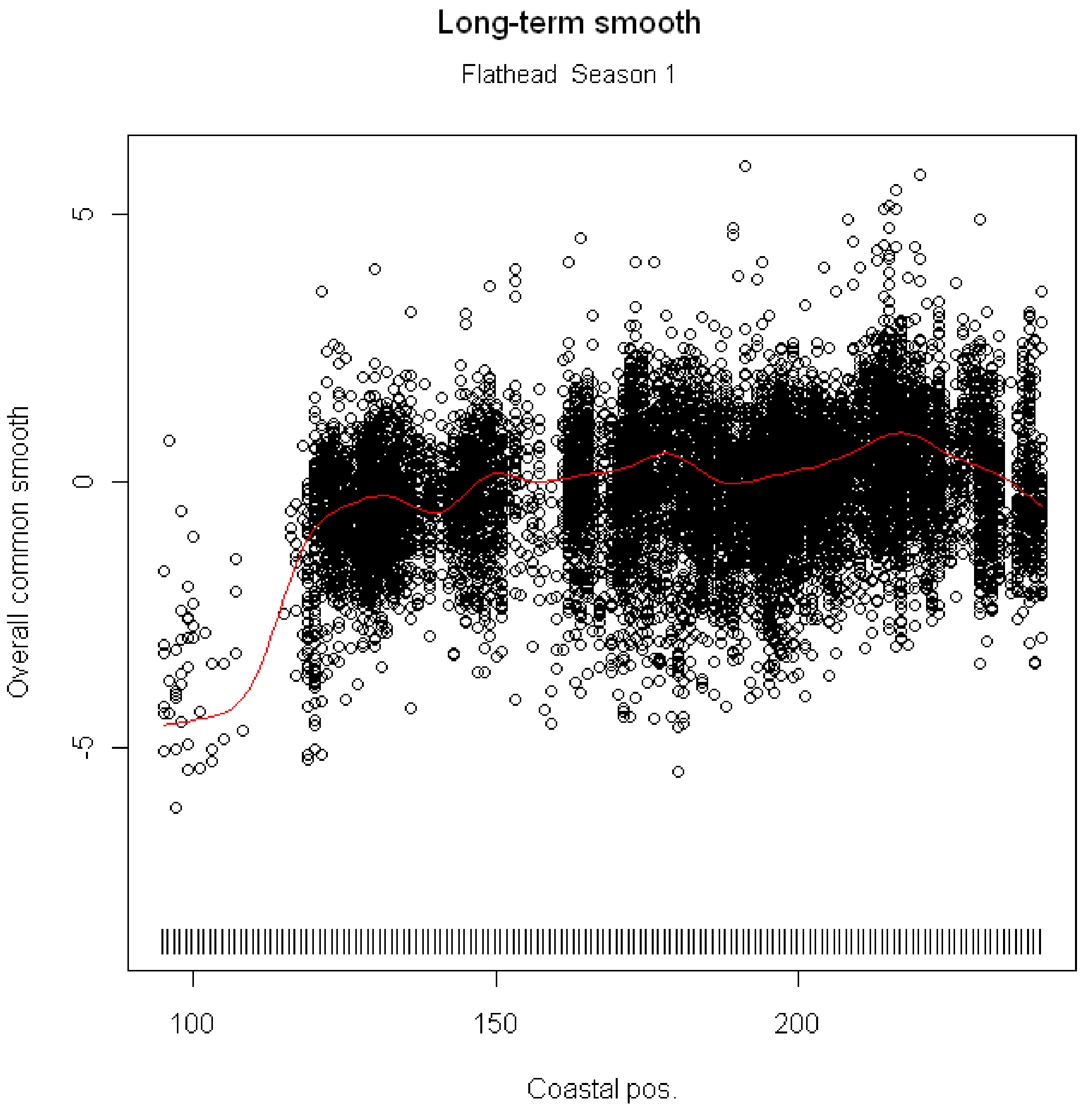

Figure 38. The long-term coastal effect for flathead in summer.

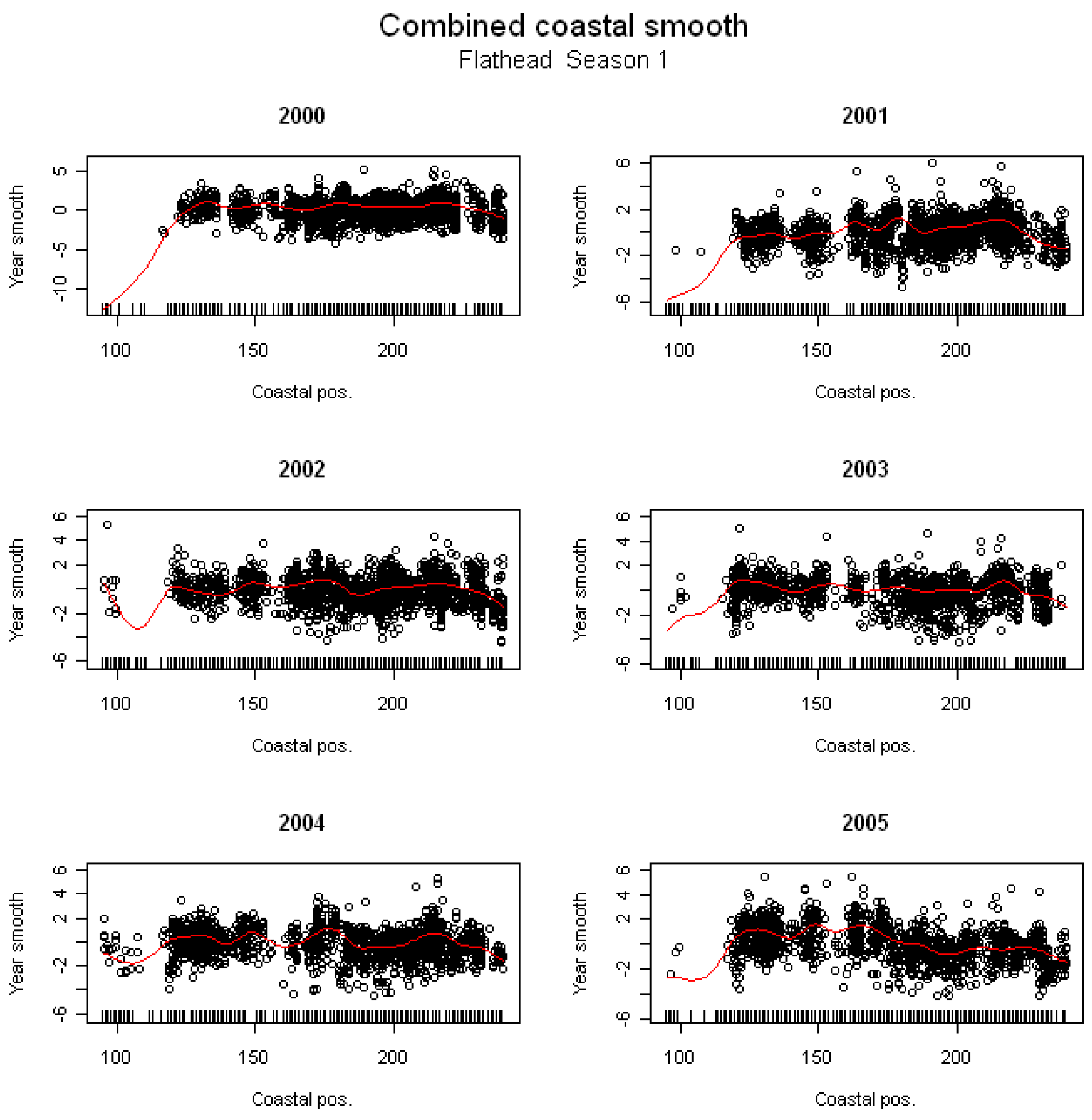

Figure 39. The overall combined coastal effect (i.e. the long-term effect + year effect) for each year for flathead in summer.

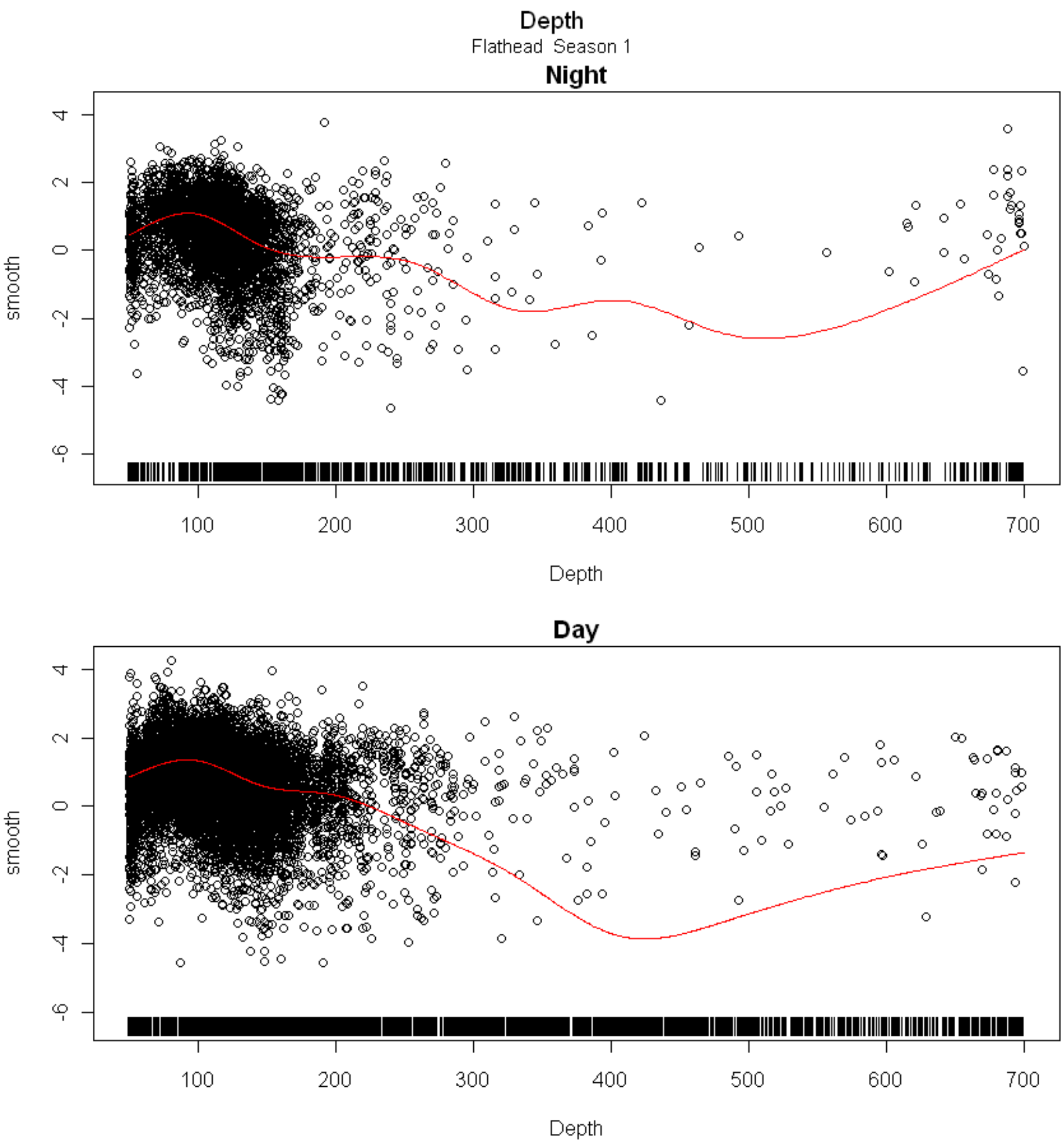

Figure 40. The depth by time of day (night at the top and day at the bottom) for flathead in summer.

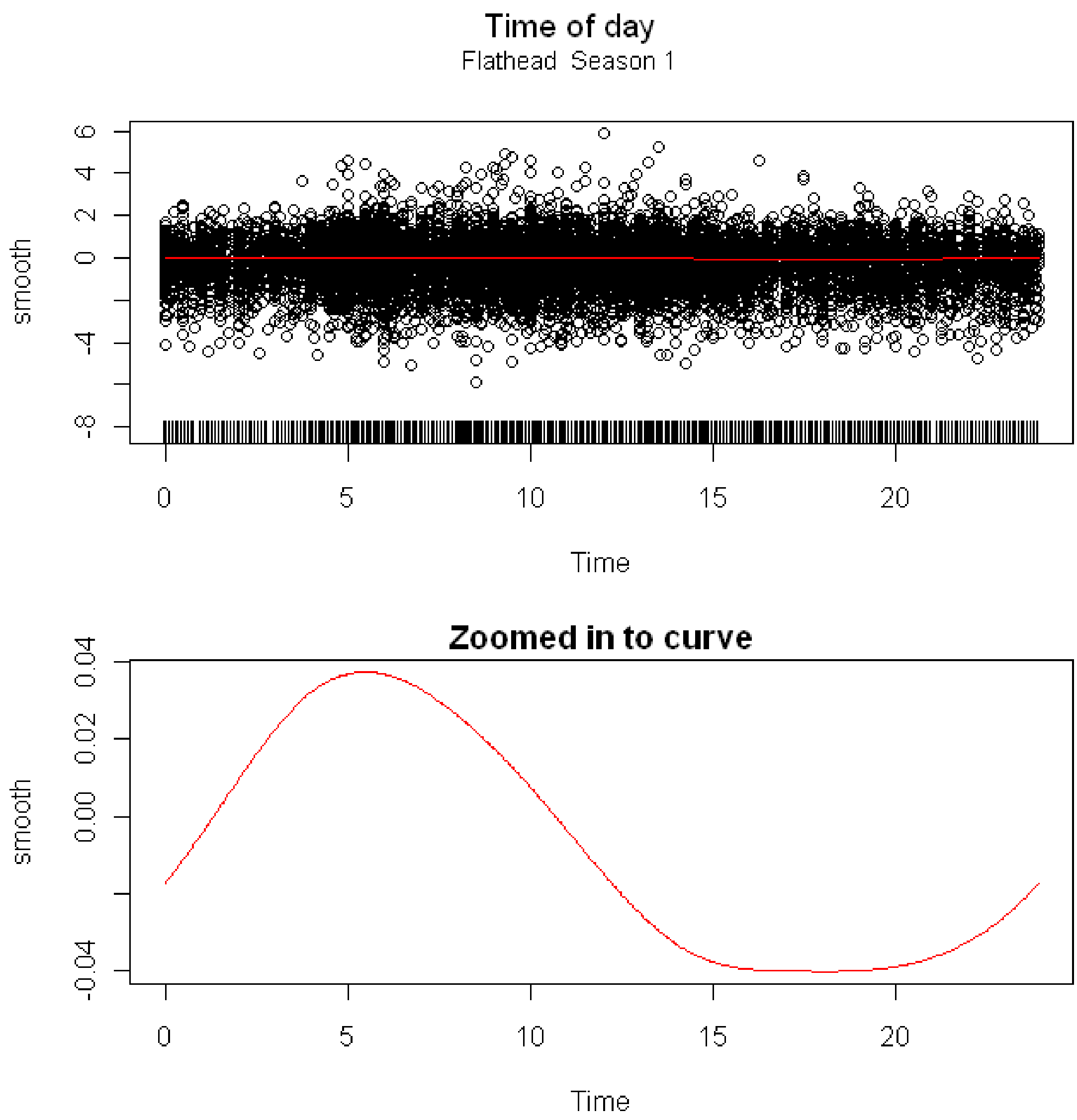

Figure 41. The time of day model for flathead in summer.

In Figure 41, the upper plot shows a comparison to the data and the lower plot shows the fit by itself, with an expanded scale to emphasize the differences between different times of day. In this case the differences due to time of day are very minor, as can be seen from the scale on the lower plot or from the plot relative to the data on the upper plot.

2010 Survey fits for Tiger Flathead:

The plots shown from Figure 42 to Figure 49 are diagnostic plots showing fits to both the summer and the winter survey from 2010 for Tiger Flathead, which is a target species with good CVs (<0.1 for both the 2008 and 2010 surveys) and which is caught in a wide range of locations.

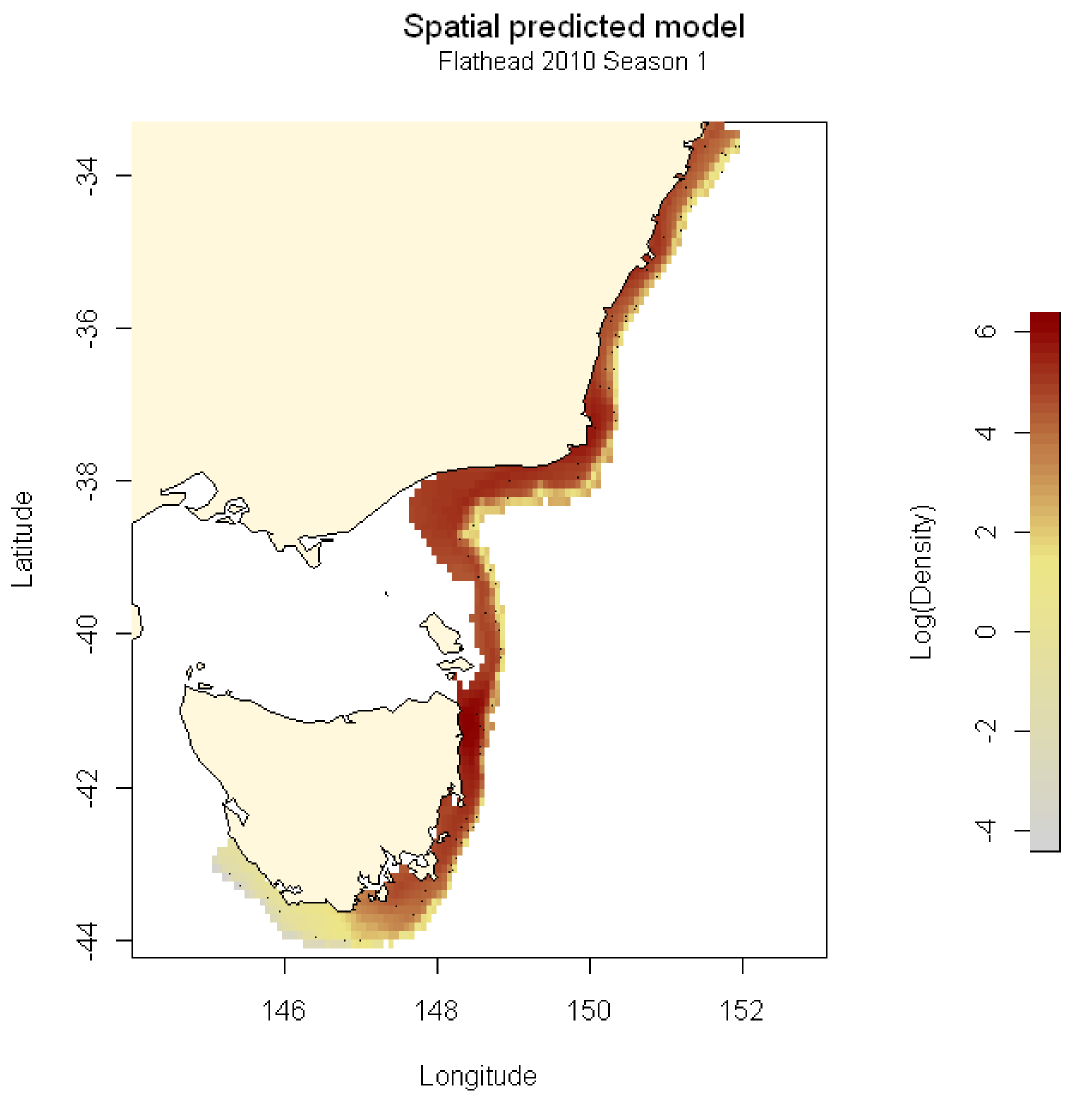

Figure 42. Predicted abundance index for the summer 2010 survey for Tiger Flathead.

Figure 42 and the similar subsequent predicted abundance plots show the model predicted abundance for fixed conditions (e.g. set time of day, length of tow).

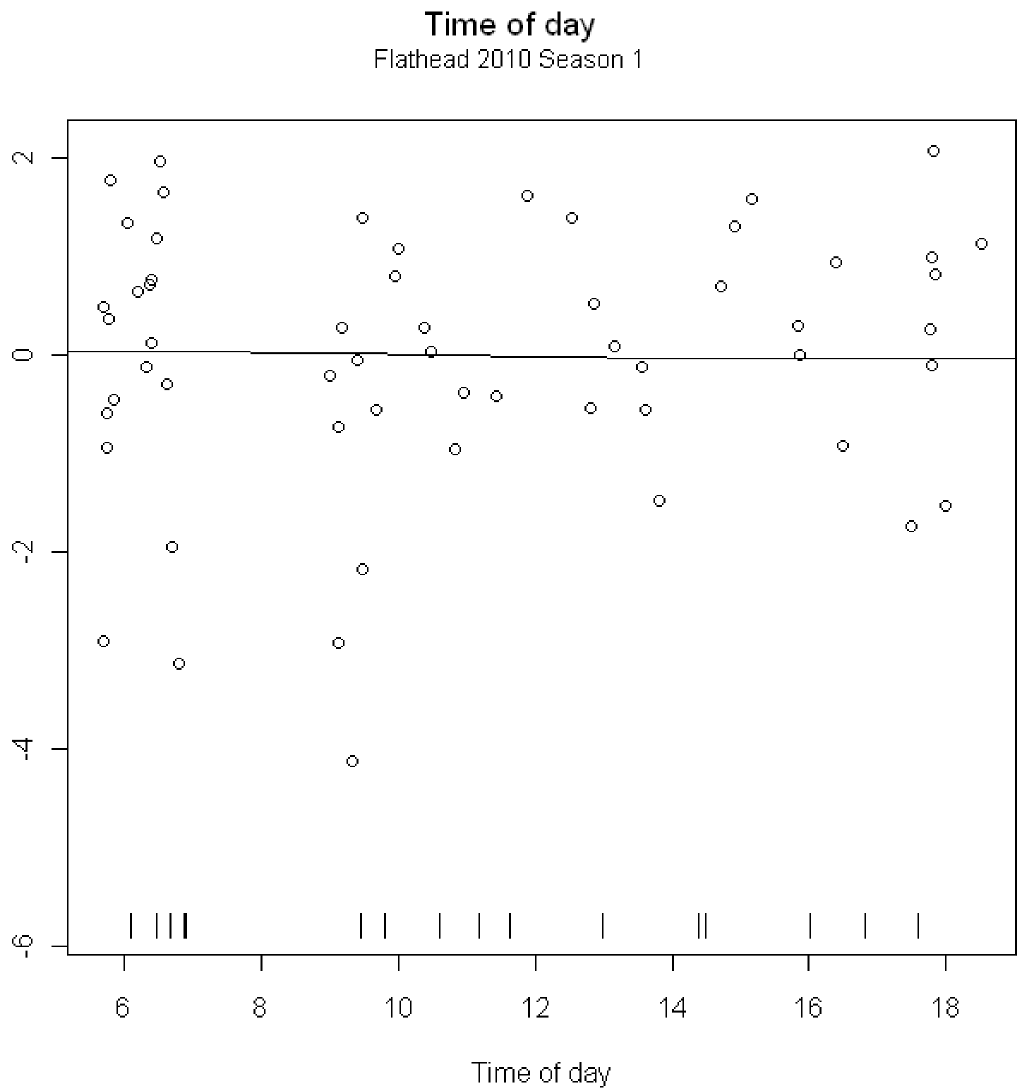

Figure 43. Time of day effect for the summer 2010 survey for Tiger Flathead.

Figure 43 and the similar subsequent time of day plots show the time of day effect plotted against the data with other effects removed (depth, coastal position, . shot length). The lines on the axis denote zero catch. The time of day model is taken from the historical model so poor fits in this plot would indicate a difference between the historical data and the species caught in the particular survey.

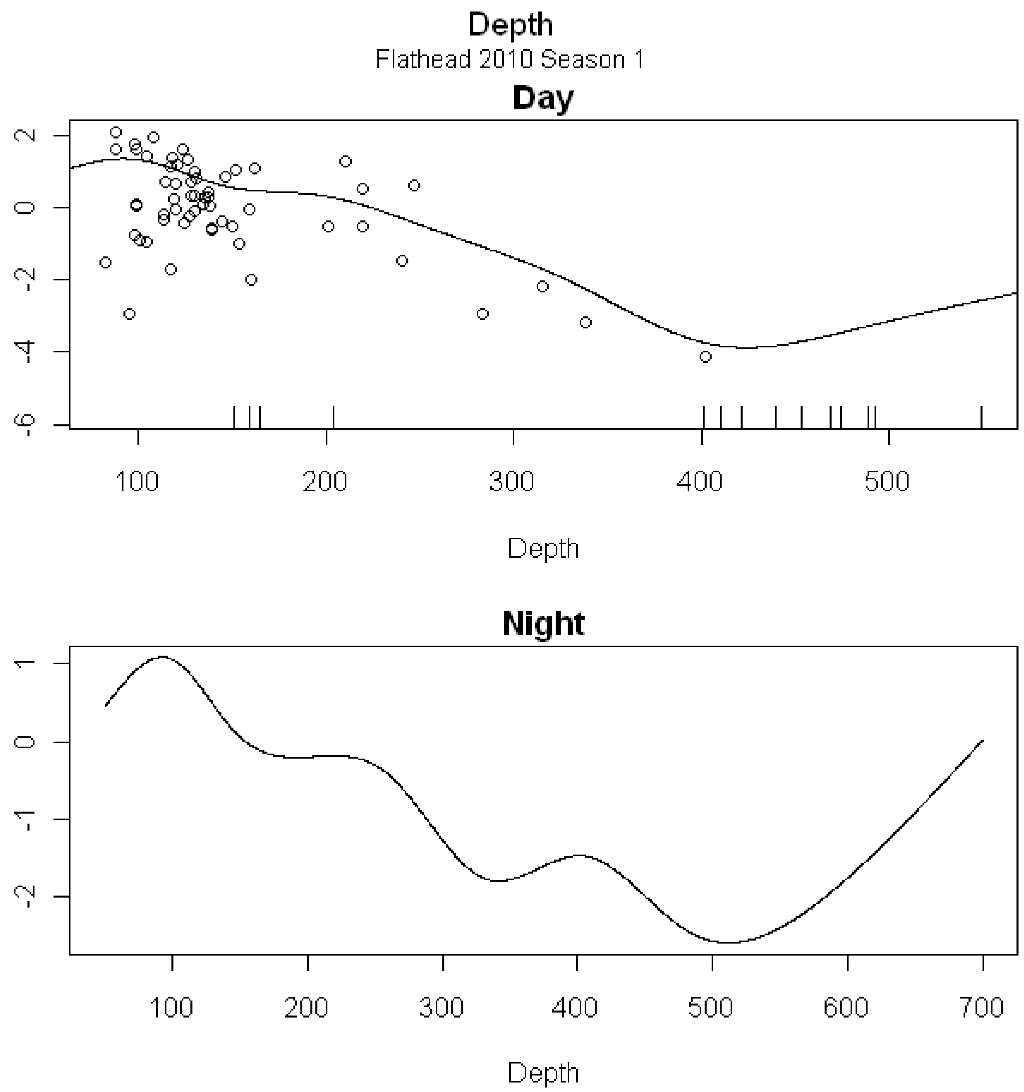

Figure 44. Depth model for the summer 2010 survey for Tiger Flathead.

Figure 44 and the similar subsequent depth model plots show the depth model separated into day or night with the standardised data overlayed (with the other terms removed). The lines on the axis denote zero catch. The depth model is taken from the historical model so poor fits in this plot would indicate a difference between the historical data and the species caught in the particular survey. The survey did not operate during the night, so there is no night time data to overlay on the night plots.

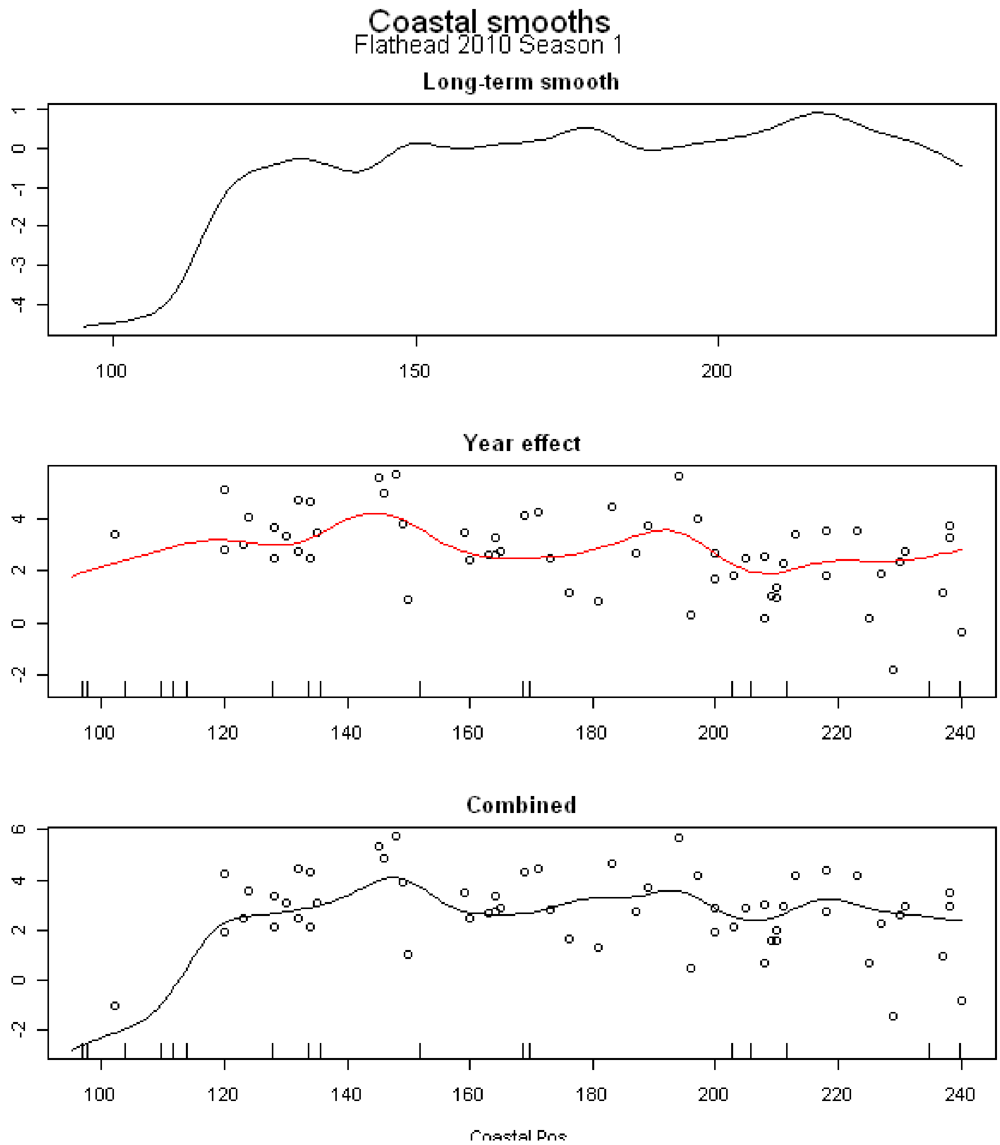

Figure 45. Coastal position for the summer 2010 survey for Tiger Flathead.

Figure 45 and the similar subsequent coastal position plots show the coastal position component of the model. The top plot is the long-term prediction from the historical data. The middle plot shows the year effect fitted to the survey data and the data (with all other effects removed). This shows how this particular survey deviates from the long-term distribution. The bottom plot shows the combined year and longer smooth as well as plotting the data, so this shows the actual coastal distribution for this survey. The lines on the axis denote zero catch.

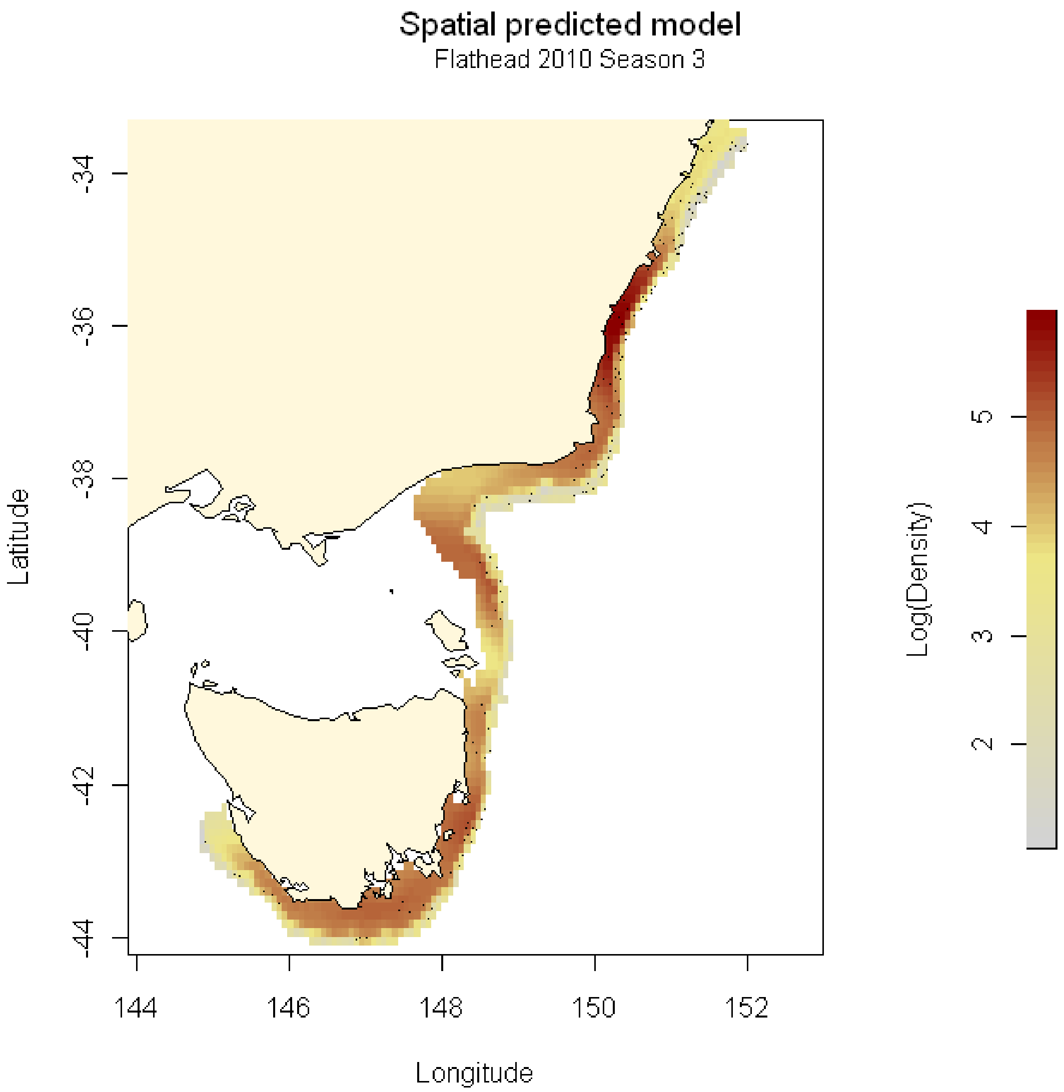

Figure 46. Predicted abundance index for the winter 2010 survey for Tiger Flathead.

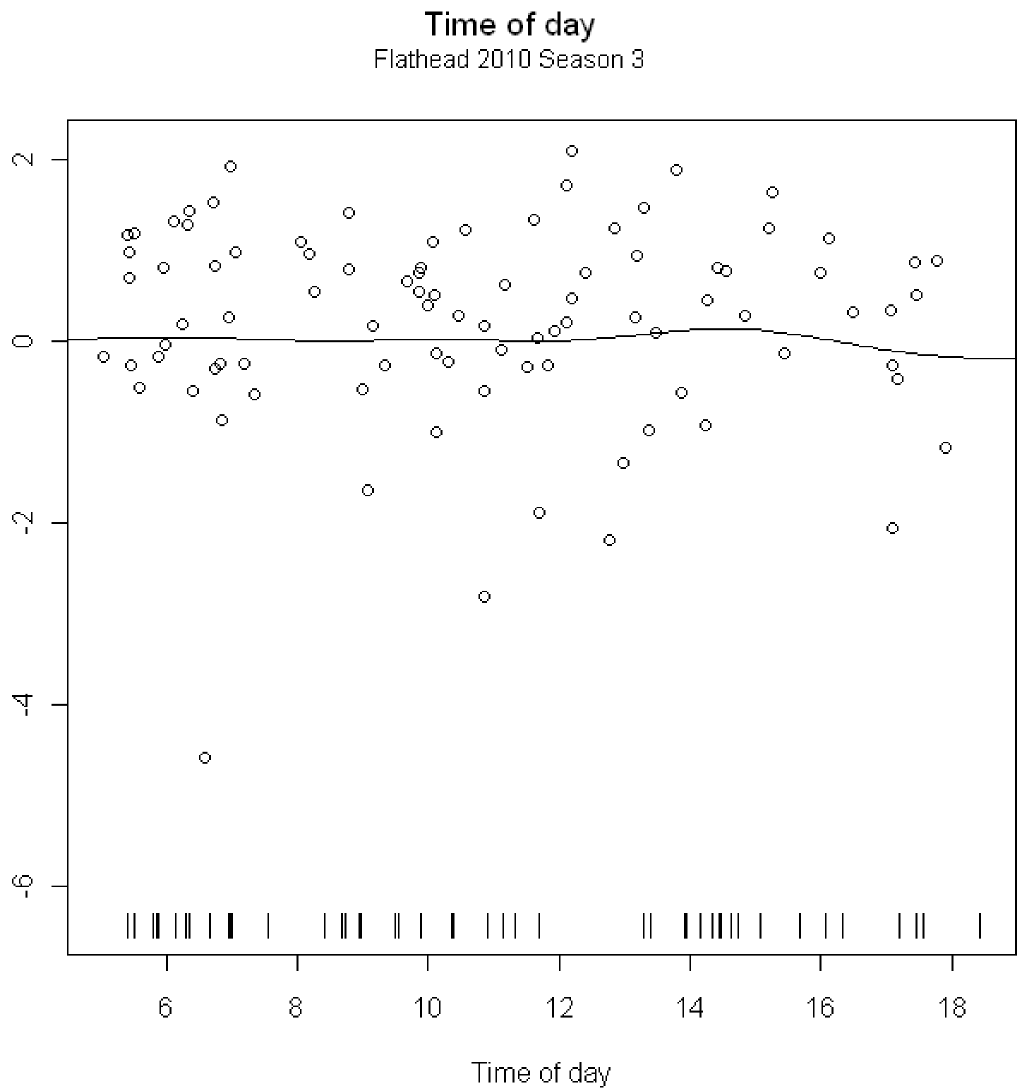

Figure 47. Time of day effect for the winter 2010 survey for Tiger Flathead.

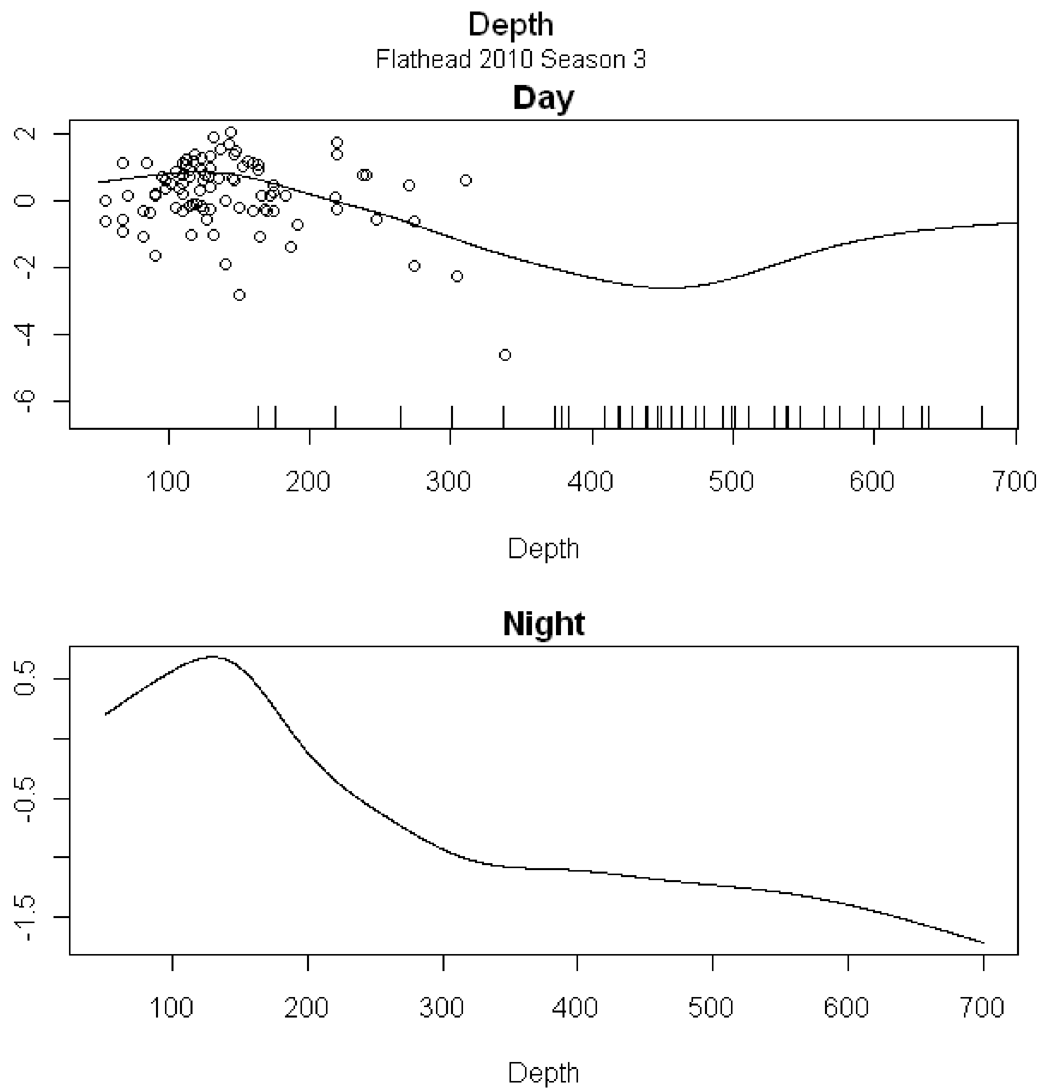

Figure 48. Depth model for the winter 2010 survey for Tiger Flathead.

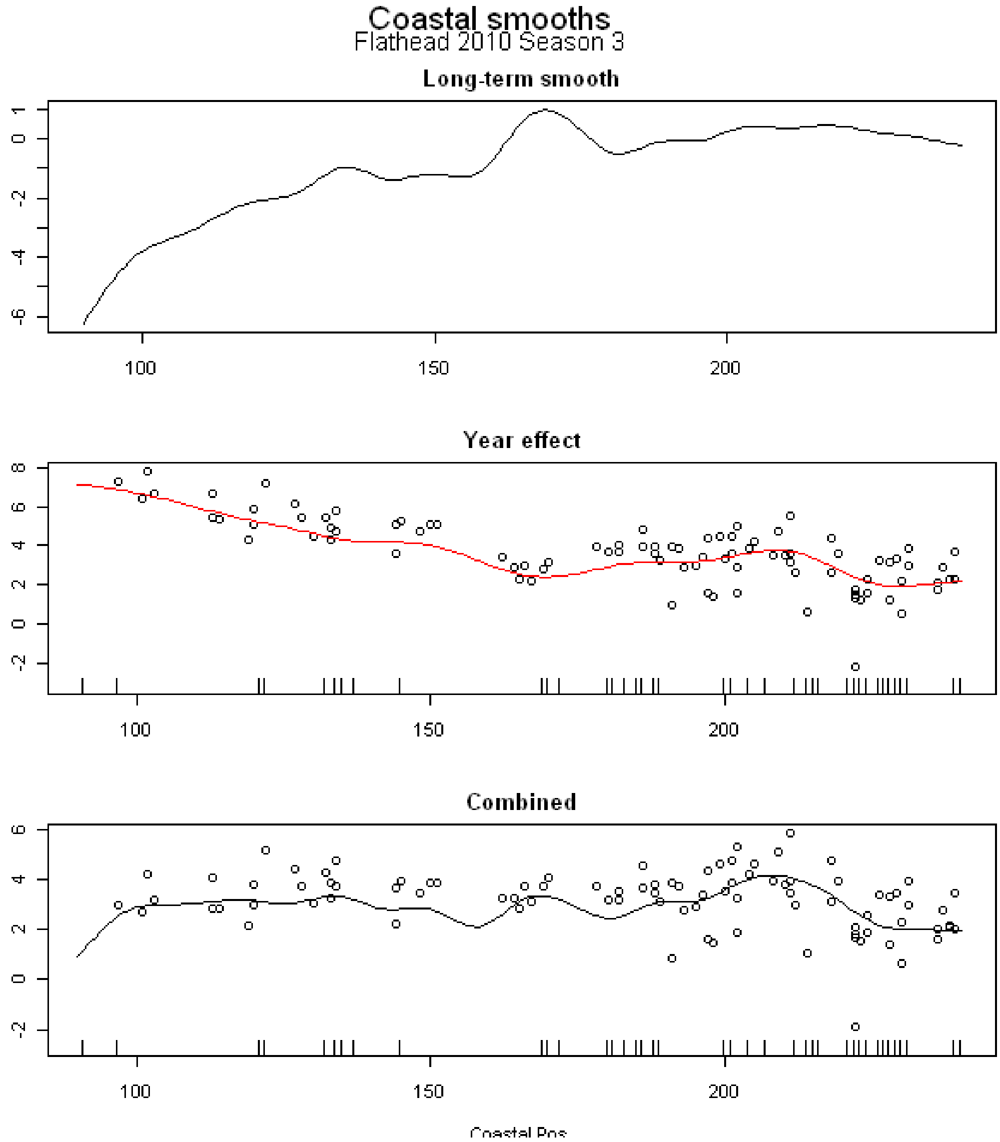

Figure 49. Coastal position for the winter 2010 survey for Tiger Flathead.

2010 Survey fits for Blue Warehou:

The plots shown from Figure 50 to Figure 57 are diagnostic plots for Blue Warehou showing fits to both the summer and the winter survey from 2010. Blue Warehou, which is a target species with poor CVs (>0.75 for both the 2008 and 2010 surveys) and which is not caught in a wide range of locations. The number of summer shots which caught Blue Warehou was very small (three) which explains why the CV is poor. The combined baseline CV for Blue Warehou of 0.23 shown in Table 17 is an underestimate. When the differences in abundance estimate is taken into account between the summer and winter surveys, this resulting combined CV is much larger (much greater than 0.3).

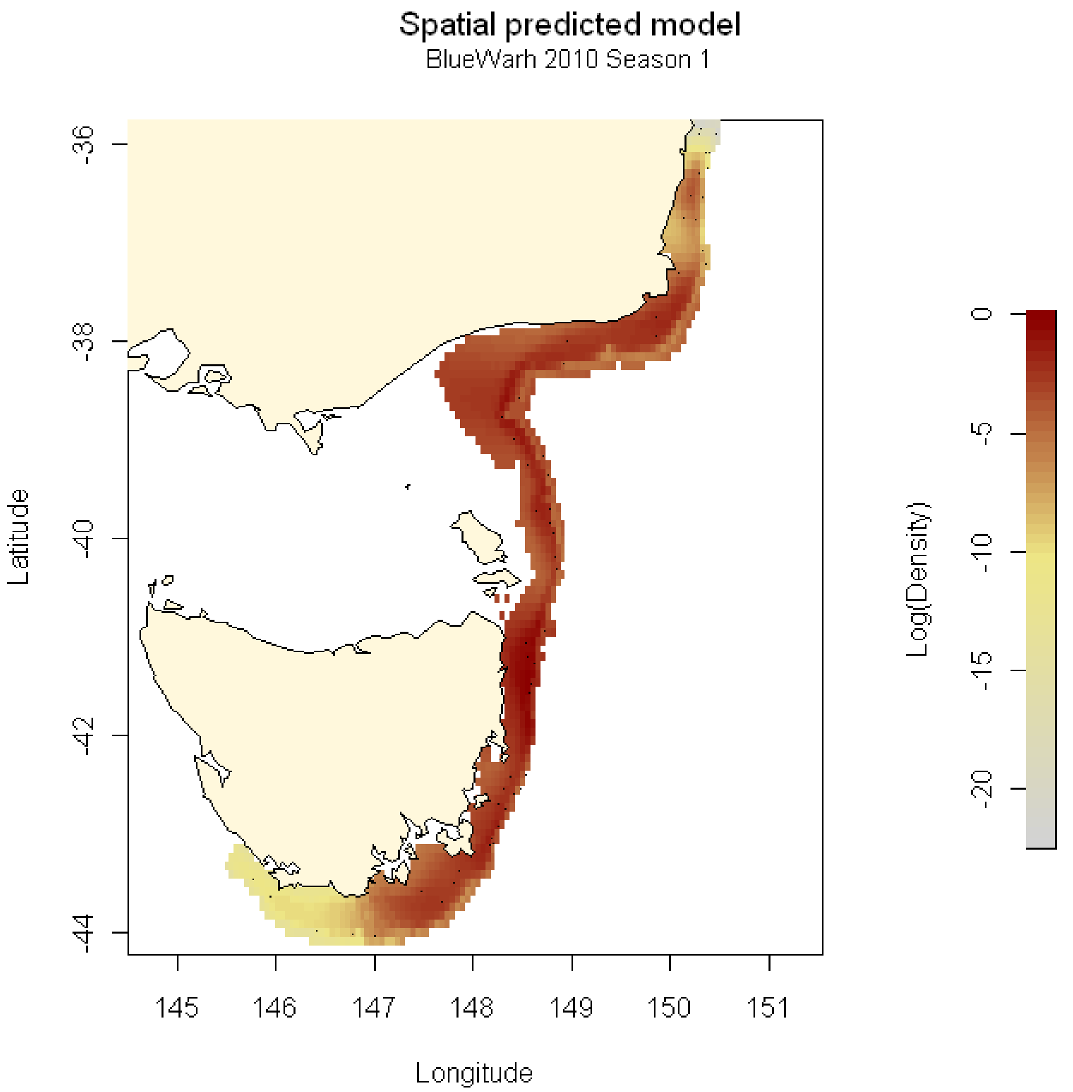

Figure 50. Predicted abundance index for the summer 2010 survey for Blue Warehou.

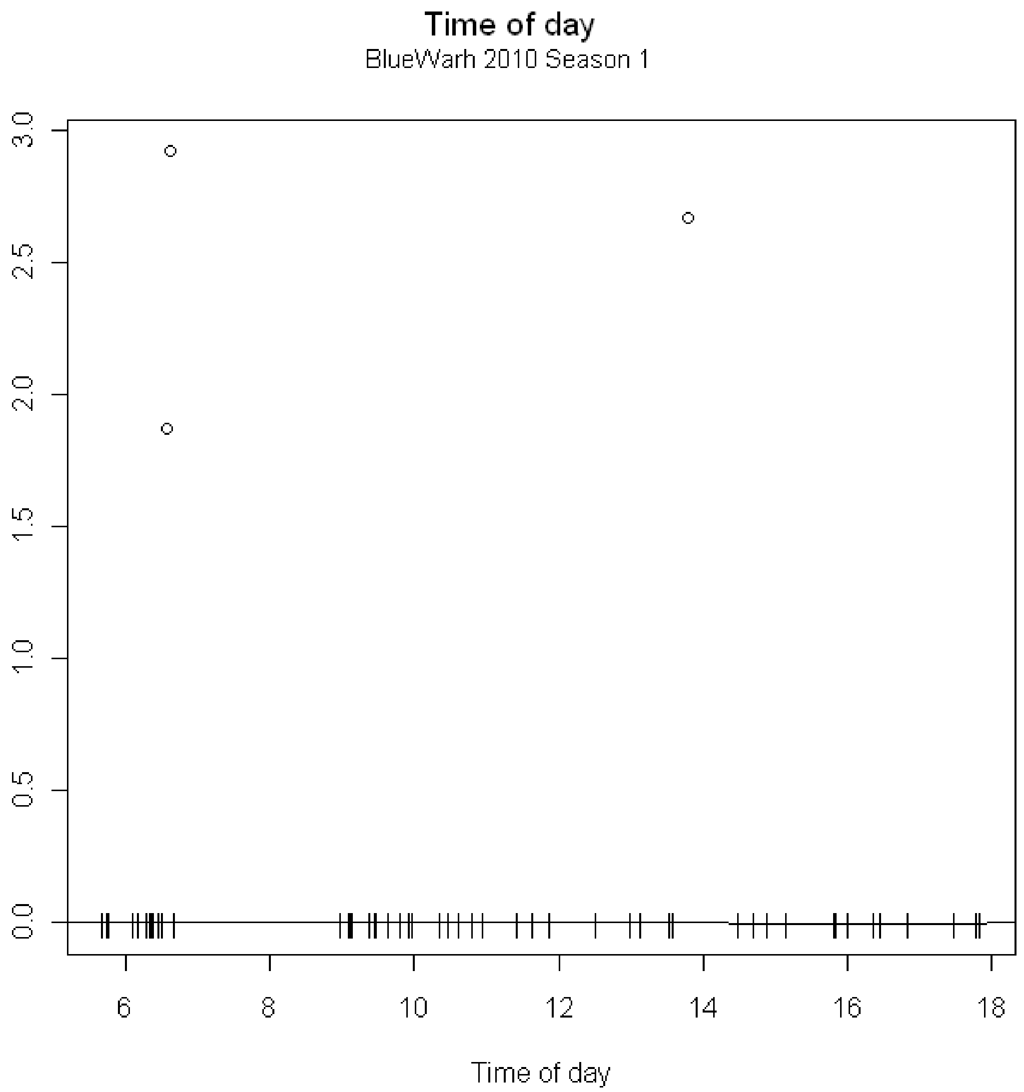

Figure 51. Time of day effect for the summer 2010 survey for Blue Warehou.

The major story in Figure 51 is the low number of shots (three) in which Blue Warehou was caught in the summer 2010 survey. The large number of zero shots suggests that this fit is reasonable, and matches the historical data – but with so few non-zero catches, reliable conclusions cannot be drawn.

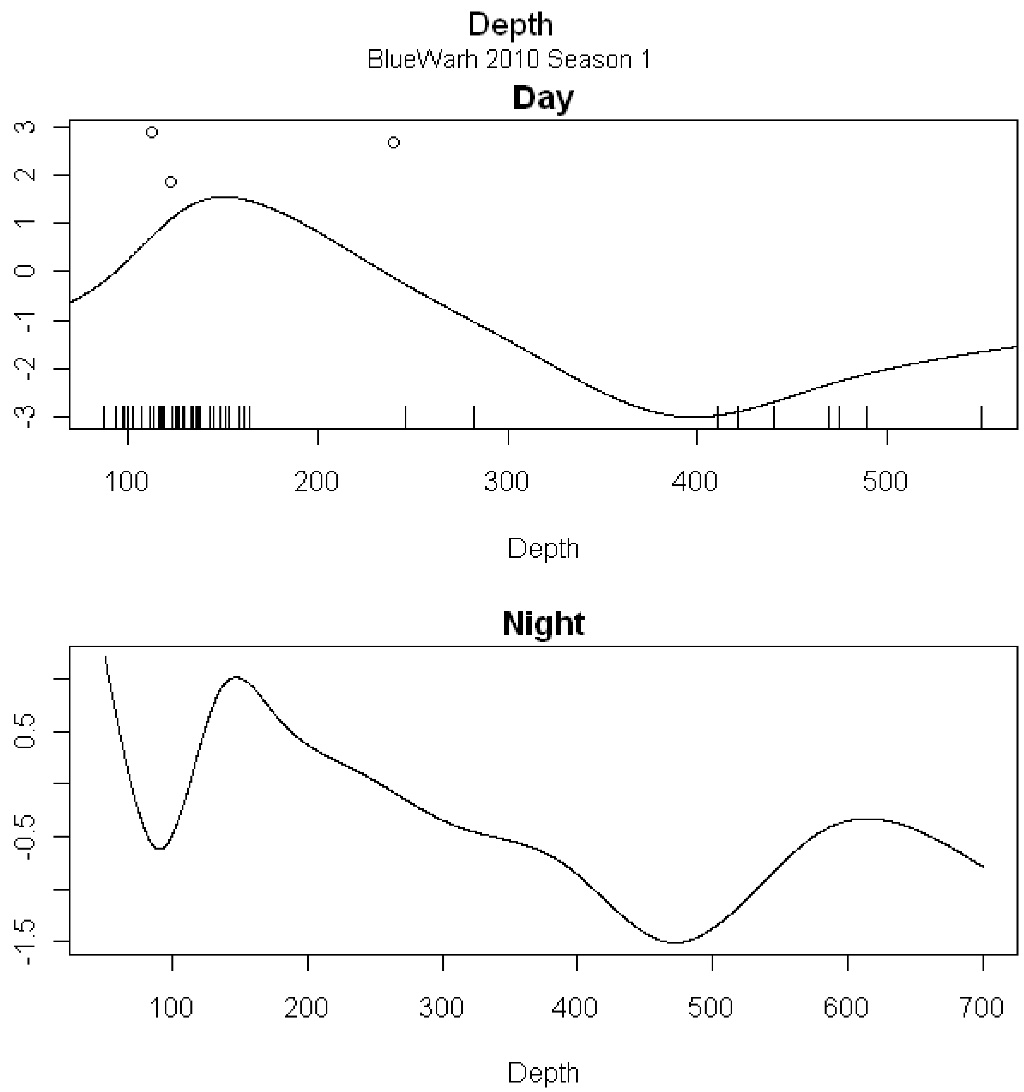

Figure 52. Depth model for the summer 2010 survey for Blue Warehou.

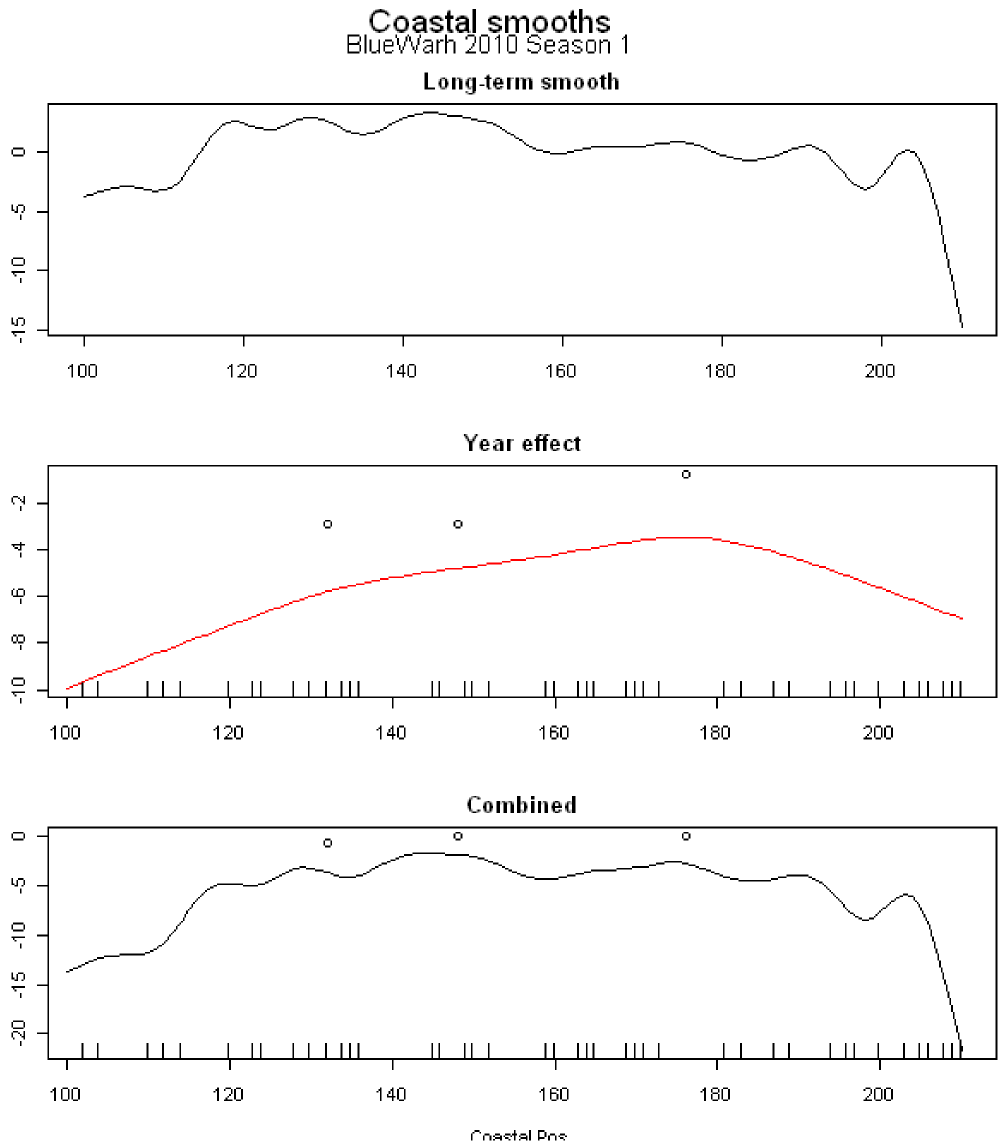

Figure 53. Coastal position for the summer 2010 survey for Blue Warehou.

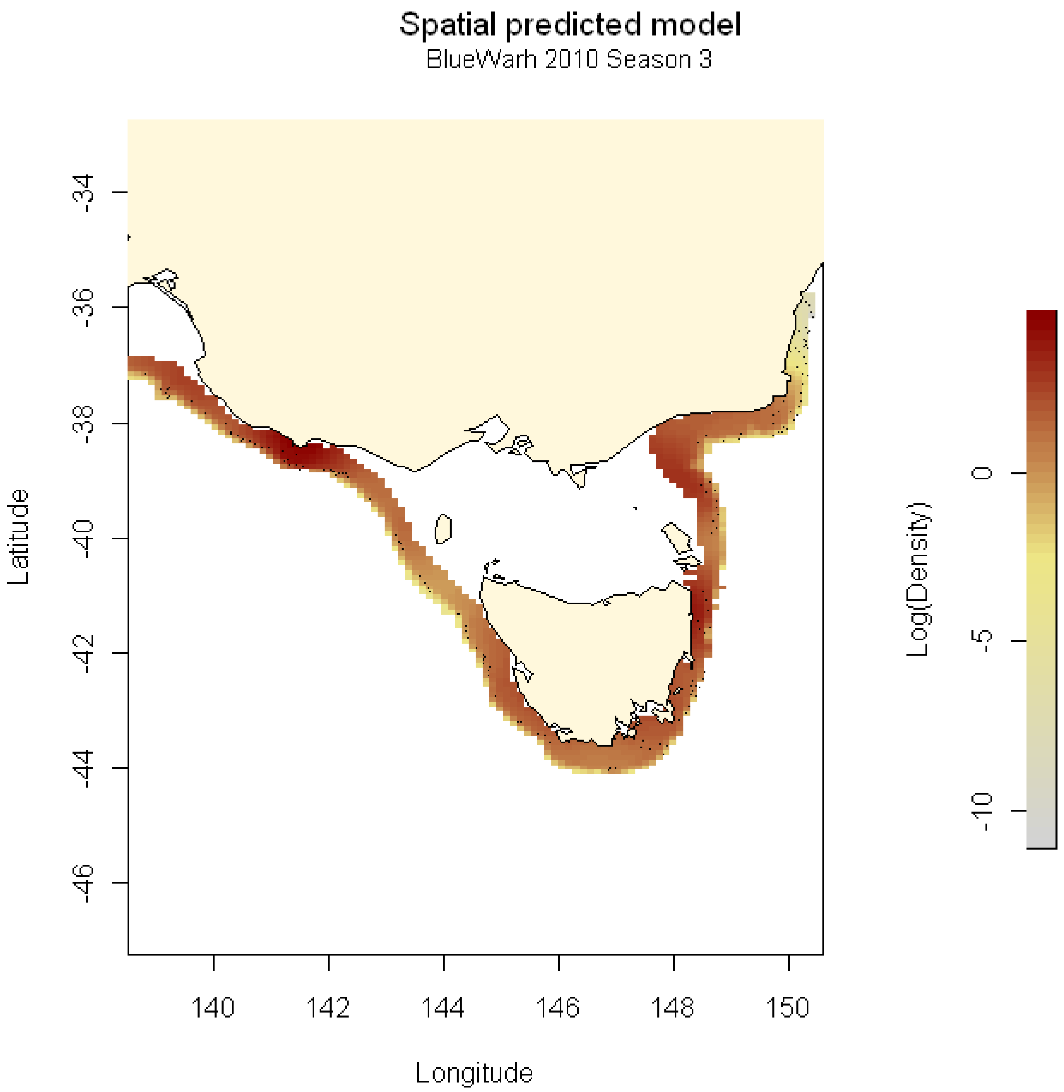

Figure 54. Predicted abundance index for the winter 2010 survey for Blue Warehou.

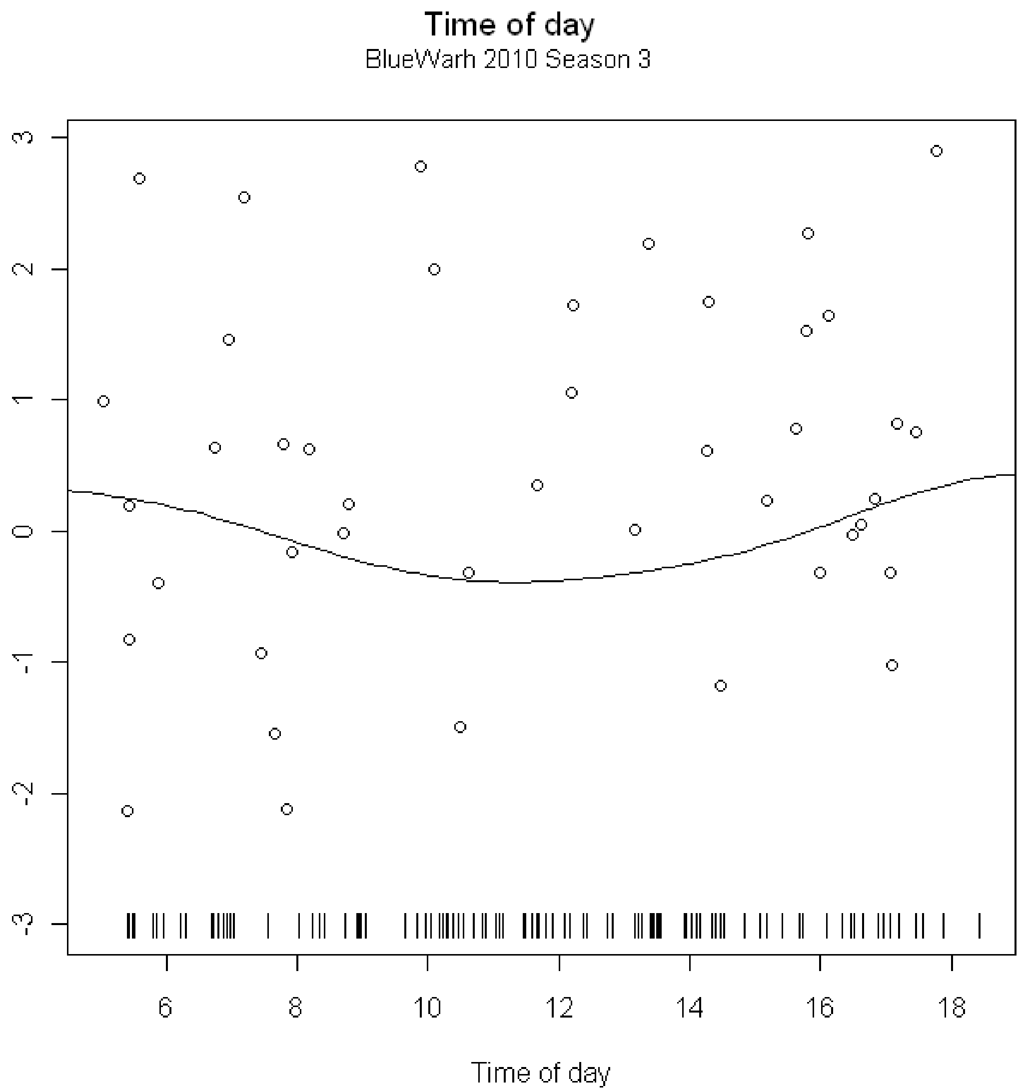

Figure 55. Time of day effect for the winter 2010 survey for Blue Warehou.

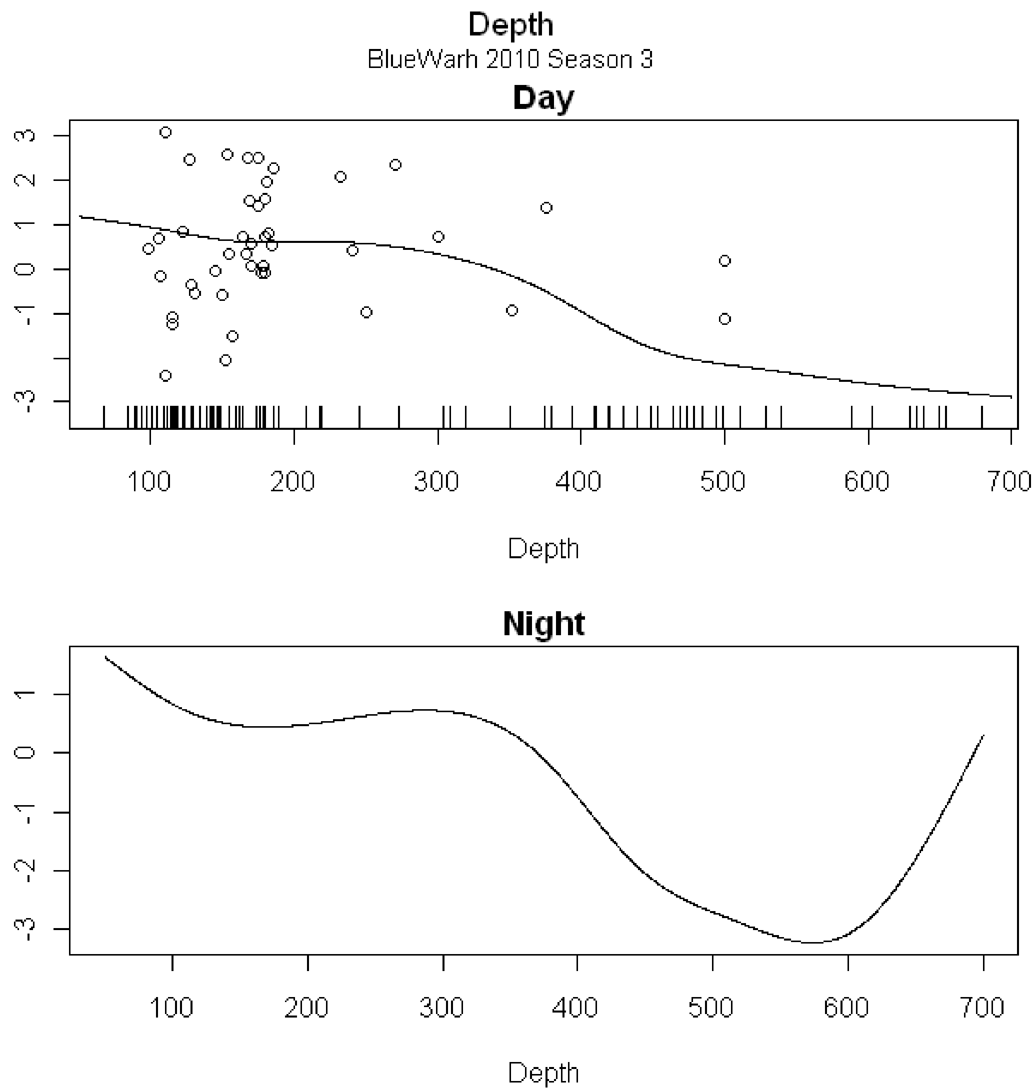

Figure 56. Depth model for the summer 2010 survey for Blue Warehou

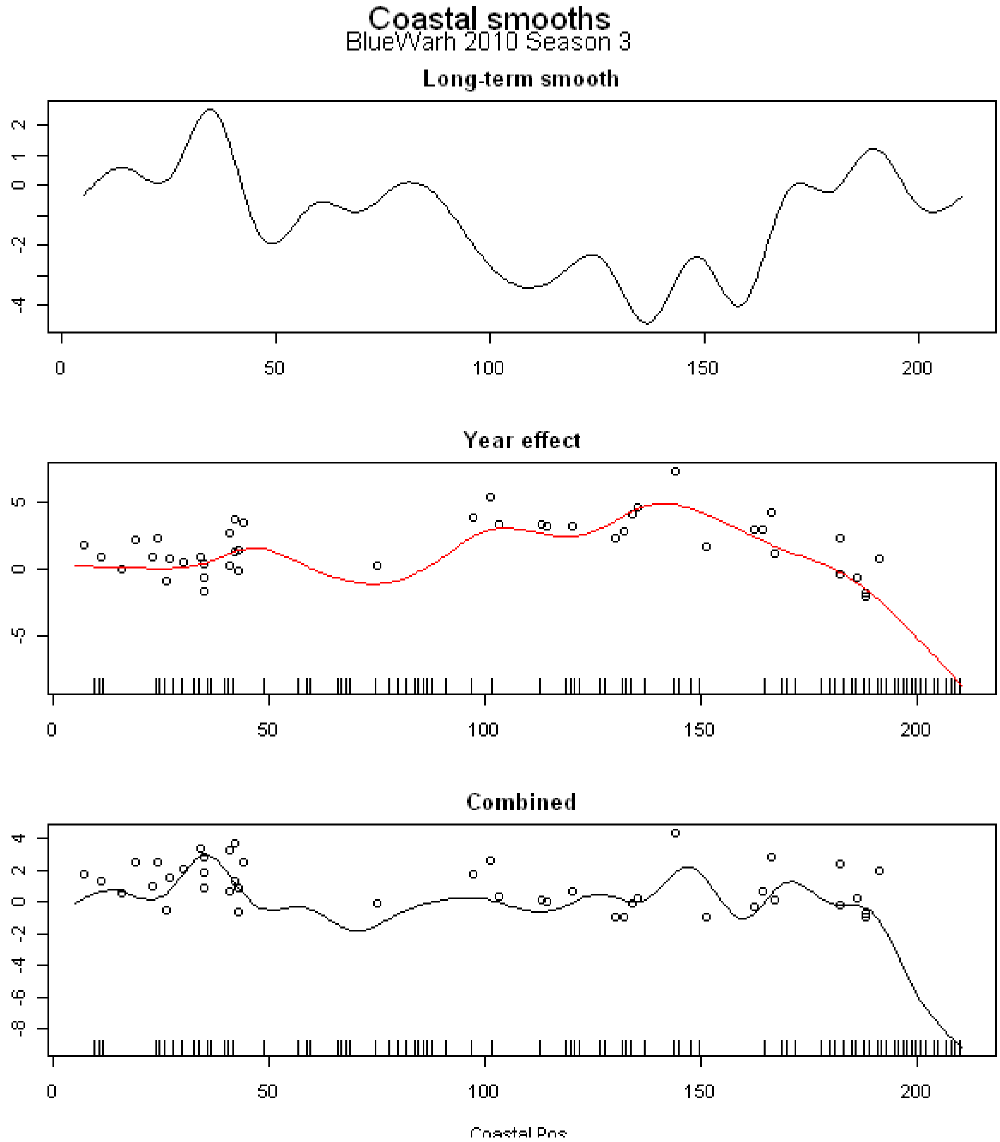

Figure 57. Coastal position for the winter 2010 survey for Blue Warehou.

Using FIS Data in SESSF Stock Assessments

The primary use of the survey is to provide an additional index of abundance that can be used for stock assessments. Stock assessments in the SESSF differ according to the Tier level of the species (Smith *et al*. 2008), with Tiers 1 and 2 being a fully integrated stock assessment, Tier 3 estimating current fishing mortality using catch curves (Wayte and Klaer 2010) and Tier 4 comparing recent CPUE with target CPUE from some period in the past (Little *et al*. 2011). Currently, fishery independent indexes of abundance would be useful for Tier 1 and 2 assessments, and there is potential application for Tier 4 assessments as a substitute for CPUE. Should a FIS become part of standard fishery monitoring in the SESSF, then there is also potential to develop an alternative Tier assessment that primarily uses that fishery independent index of abundance. Such an alternative assessment would be useful for species where only the index and catch data are available, and fishery CPUE has been determined to not be a good indicator of abundance. It could potentially be applied to both quota and non-quota species where little information is available other than from the FIS.

Current use of the index of abundance from the FIS, however, has direct use for Tier 1 and 2 fully integrated stock assessments. In the GABTS, stock assessments for Bight Redfish and Deepwater Flathead have included an index of abundance with up to six annual point estimates (Bight Redfish 2005 – 2009, 2011; Deepwater Flathead 2005 – 2009) (Klaer 2011, In prep.). It was agreed for those species, that the survey data would be used as a relative indicator of abundance once three points became available. Similar use would be expected to be made of data from the SESSF FIS. Initially, the data would be used as an additional abundance index to CPUE in fully integrated stock assessments. The Resource Assessment Groups (RAGs) would make decisions on how much relative weight should be placed on the FIS data, relative to the fishery CPUE, and available age and size measurements.

There are two main sources of error in the annual FIS index of abundance that cause departure of the index from true abundance of that species: measurement error and process error. Measurement error is primarily due to the sample size, and is the subject of the survey CV estimates examined in detail in this report. The survey design was conducted to reduce the measurement error (increase sample numbers), while at the same time attempting to minimise the survey cost (reduce sample numbers). Process error is mainly due to changes in fish availability (given that catchability should remain constant with similar vessels, gear, shot positions and times for all years). It may be that fish move into and out of the survey area in unpredictable ways from year to year. Such a case would lead to greater annual variability in the FIS index of abundance. How much of this variability may be due to change in fish availability can sometimes be determined with a longer time series of FIS indices of abundance, and is further informed by a knowledge of the population biology of the species at what extent of change is actually possible from one year to the next (greater changes can be expected from short-lived species with variable recruitment compared to long-lived species with stable recruitment). The extent of both measurement and process error will vary from species to species, and the combination of these errors can be estimated through integrated stock assessments, provided additional data (length and age composition, possibly CPUE) are available.

Ultimately, it may be possible to use a FIS index of abundance as the primary indicator that is input directly into a harvest control rule as an alternative to regular standard stock assessment. Such an approach has clear advantages as it provides a data driven and transparent process for TAC setting (e.g. Hilborn 2012). Implementation of such a system would ideally require management strategy evaluation of the harvest control rule prior to implementation, and intermittent full stock assessments to ensure that the process is operating as expected.

Benefits and Adoption

The survey design developed during this project has enabled the implementation of a fishery independent survey to cost effectively collect statistically robust estimates of relative abundance of main quota species and many non-quota species. The unique approach taken provided many benefits over traditional randomised stratified sampling by allowing greater flexibility in handling unbalanced and non-random designs (as required by the constraints brought about because of practical and logistical issues), avoiding the issue of systematic trends within strata inflating the estimates of precision, and providing a quick and flexible framework for investigating alternative survey designs. This provides benefit to AFMA management and the SESSF by providing a tool for long term collection of relative abundance data that can be used alongside, or instead of, commercial catch rate data for stock assessments.

This project has also provided two years of fishery independent estimates of relative abundance, length frequency and otoliths samples for many quota and non-quota SESSF species. While a longer times series of relative abundance estimates are required before they can be incorporated into stock assessments, otoliths samples have already been used to subsidise shortfalls in collections made, and length frequency data have been made available for stock assessment purposes. The value of relative abundance estimates in stock assessments of quota species will not be known until they can be used; however the precision of data for many species is very good. Estimates of relative abundance of many non-quota species is also proving very valuable, especially considering the increased emphasis of ecosystem based fisheries management.

Beyond the value to the SESSF, the FIS has far greater community value as a tool to monitor demersal fish assemblages across SE Australia. The key findings of the Report Card of Marine Climate Change for Australia (2009) were that: Australian ocean temperatures have warmed, with south-west and south-eastern waters warming fastest; The flow of the East Australian Current has strengthened, and is likely to strengthen by a further 20% by 2100; and Marine biodiversity is changing in south-east Australia in response to warming temperatures and a stronger East Australian Current. As a result, it is expected that the southward range of temperate fish species will expand in south-eastern waters. An important way to improve our understanding of these impacts was to expand ocean climate observations to validate other datasets, ground truth satellite observations, verify models and improve understanding of ocean processes and heat fluxes. Temperature depth recorders used on the survey vessels can meet this requirement. Another knowledge gap highlighted in the report was to provide baseline information on many fished stocks, and in particular non-commercial fish. Again, the FIS provides good time series information on the spatial and temporal distribution of a large number of non-commercial fish species. It also provides a platform from which biological information (length, sex, maturity, age etc) can be collected in a systematic way from these species.

The long-term outcome of this project will be information that helps demonstrate the sustainable nature of the fishery with respect to both target species and major byproduct and bycatch species. Specifically, indices of abundance produced from the FIS can be directly used in Tier 1 and Tier 2 assessments, and there is potential for its use in Tier 4 assessments. Further, should a FIS become part of standard fishery monitoring, there is potential to develop an alternative Tier assessment that primarily uses the index. This would be particularly useful for both quota and non-quota species where CPUE has been determined to not be a good indicator of abundance.

With regard to the ongoing adoption of a fishery independent survey for the SESSF, a pre-proposal was submitted to AFMA to continue the survey for another three years (2012 – 2014). At its 59th meeting on 22 September 2010, Commonwealth Fisheries Research Advisory Body (ComFRAB) advised that it endorsed this project as a high priority and accordingly supported the development of a full proposal. The full proposal was subsequently developed and submitted and the following response was received.

> "At its 60th meeting on 30 March 2011, the Commonwealth Fisheries Research Advisory Body (ComFRAB) supported this proposal for funding. The AFMA Research Committee (ARC) also supported this proposal for funding and has now been approved by AFMA's CEO.
>
> In considering this full proposal, the ARC noted the workshop being held to examine the results of the previous FIS and look at possible ways to reduce the budget. Noting the high budget for this project and given the current budgetary restrictions, an allocation of $500,000 for 2011/12 has been approved.
>
> In order to proceed, you will need to negotiate the budget for 2012/13 and 2013/14, liaising with Brad Milic and Beth Gibson. Please note that it is likely, although not guaranteed, that a similar amount of funds will be available in future years and budget discussions should focus around the contribution of the FIS to the assessment of the SESSF stocks and the overall strategic research and assessment needs of the SESSF".

Based on the ComFRAB is advice, particularly the budget restrictions, the proposal was significantly modified. In general terms, the amount required to conduct both the summer and winter survey is about $1.35 million per year although this is somewhat offset by proceeds from the sale of survey fish (~$250 thousand). Initial discussions with CSIRO and AFMA, suggested it was better to maintain the present design, with both the summer and winter surveys, but conduct it biennially rather than annually. During early 2012, however, the SESSF Resource Assessment Group considered the CVs achieved during just the winter survey and agreed that it may be better, given the cost restrictions, to conduct annual winter surveys, thereby achieving a good time-series of abundance estimates that could be used in stock assessments in a much shortened time period. Analysis of the 2010 survey results revealed that conduct of just a winter survey would provide reasonable CVs for 15 species which account for 87% of the catch of the GHaT and CTS sectors and 83% of the value. It has been agreed to conduct a survey during 2012, but a decision on the frequency and components of future surveys has yet to be made.

Further Development

A longer time-series of relative abundance indices are required before they can be incorporated into stock assessments. Experience from the GABTS fisheries independent surveys show that at least three years of data are required before they can be used, but that an even longer time-series is desirable. Funding remains the most critical aspect of continuing the time-series of SESSF fishery independent surveys. It is an expensive monitoring program that is largely cost-recovered from industry and will represent a significant proportion of the research budget if there is commitment to continue either the combined (summer and winter) surveys on an annual basis. Based on the SESSF Resource Assessment Group advice, if only the winter survey is continued, significant savings would be achieved. There is also some opportunity to get partial government funding (15%) for the survey under the AFMA Cost Recovery Impact Statement Policy based on the public good component. Justification for this is that the survey collects base level monitoring information on demersal fish assemblages (not just commercial species) along with a large range of environmental and oceanographic data. A proposal has been submitted to extend the time series, with surveys being conducted during 2012, and a decision on the frequency and components of additional surveys will be made in the future. The planned outcome of that new project is to provide a robust alternative to standardised logbook CPUE for long-term use in most SESSF stock assessments.

Planned Outcomes

The outcome of this project has been the implementation of a broad, multi-species fishery independent survey that provides relative abundance indices for many quota and major non-quota species in the SESSF. Estimates of relative abundance with good to reasonable CVs were obtained for 10 – 11 quota and 4 – 7 non-quota species during summer surveys, 14 – 15 quota and 2 non-quota species during winter surveys. A one year extension to this survey has been implemented which will increase the time series of relative abundance to three years. This will enable the data to be used in stock assessments alongside, or instead of commercial catch rate data. Stock assessment scientists have been engaged throughout this project to ensure they are familiar with the data collected, and that it can be used in the current assessment framework.

Conclusions

- Current fishery independent surveys operating in the SESSF were reviewed, and it was concluded that trawling was the most suitable survey method for sampling the main species in the SESSF.
- A model-based approach was taken to the survey design that enable evaluation of achieving an array of different outcomes in terms of obtaining statistically robust estimates of relative abundance for main quota species. Different designs were tested by changing sample weightings between strata and seasons. The design that would provide useable CVs for the most number of main quota species was used for the 2008 survey.
- A practical method of undertaking the survey was devised, which incorporated tendering different vessels for each of the three regions (NSW, eastern and western) and supplying those vessels with standard survey nets.
- The cost structure of the survey was arranged so that the vessels were chartered outright, and that fish caught during the survey became property of the survey. However, as an incentive for crews to take care with the fish to maximise market prices, 10% of sales was returned to the vessel.
- Research survey was allocated based on predicted catches, however implications of the survey over-catching or under-catching the research quota requires further discussion.
- The pilot survey was successfully undertaken during 2008. Over summer and winter, 330 survey shots were completed catching 290 species totalling 328 t, of which 107 t were quota species. Combined 2008 summer and winter survey CVs could be calculated for 25 different species, and good (<0.2) to reasonable (0.2 – 0.3) CVs were obtained for 14 quota and 3 non-quota species.
- After reviewing the survey design, implementation and results of the pilot survey, the survey was run again during 2010. A total of 321 survey shots were completed catching 274 species totalling 244 t, of which 60 t were quota species. Combined 2010 summer and winter survey CVs could be calculated

for 20 different species, and good (<0.2) to reasonable (0.2 – 0.3) CVs were obtained for 14 quota and 3 non-quota species.

- Achieved CVs were lower than predicted CVs in the summer and winter surveys combined for 8 and 9 of the key species considered in the design respectively. The lower than expected CVs were likely due to the survey controlling many of the variables associated with commercial fishing such as net design, vessel power, skipper experience and species targeting.
- Review of the surveys concluded that results obtained exceeded expectations in terms of precision for main quota species, and also obtained precise estimates of relative abundance for many non-quota species. Review of the cost-efficiency and practicality of the survey found that the arrangements were appropriate, and that it was feasible to continue a similar structure in the long-term.
- The South East Trawl Fishing Industry Association (SETFIA) took over as the project administrators to undertake the 2012 survey with funding directly from the Australian Fisheries Management Authority. During 2012, the SESSF Resource Assessment Group has highlighted continuation of the time series of fishery independent surveys as one of the highest research needs for the fishery.
- A decision on the frequency and components of subsequent surveys will be made during 2013 dependent on species CV requirements and budget constraints.

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Appendix 1 - Intellectual Property

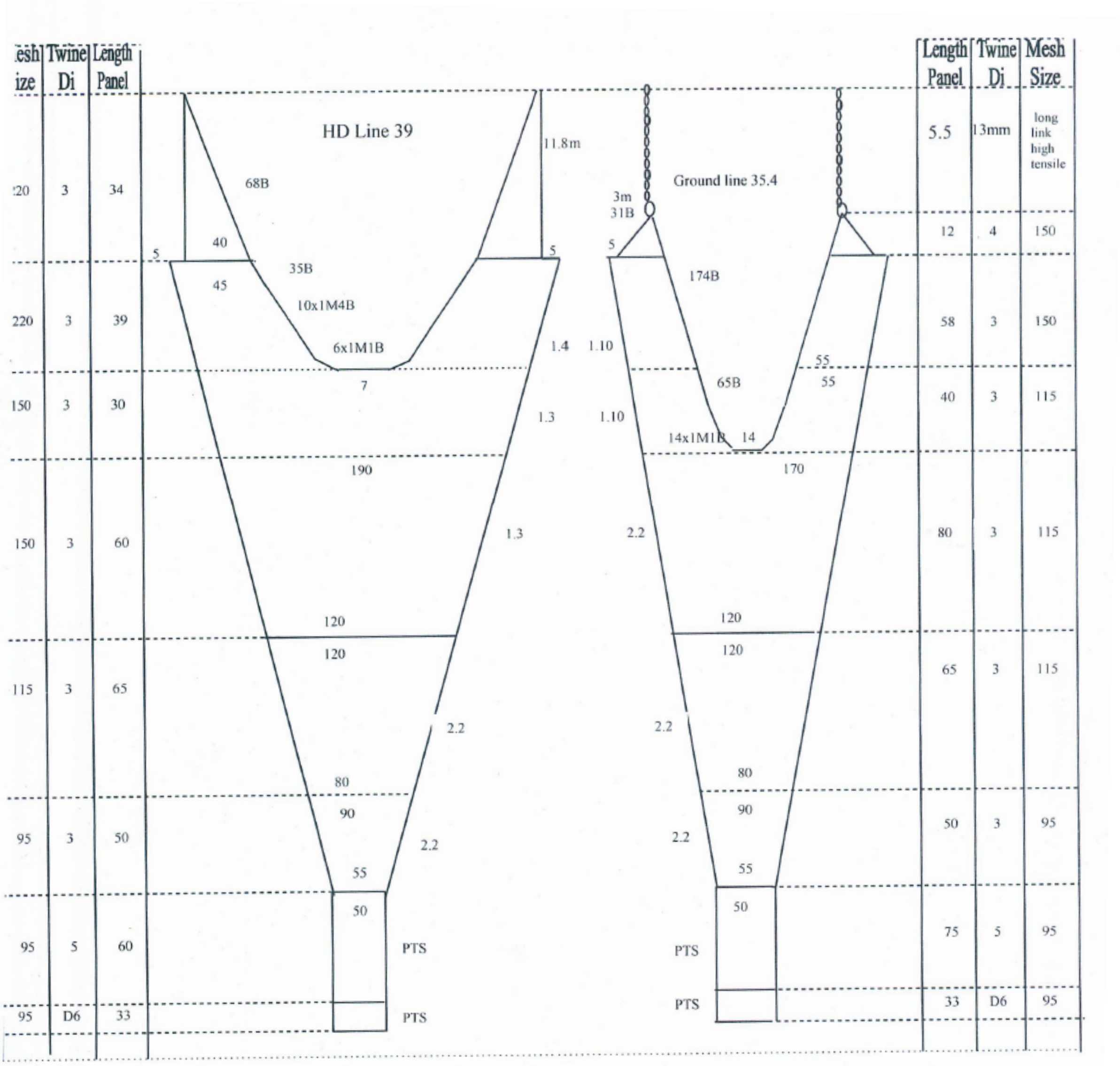
Intellectual property associated with this project includes the design on the survey nets for the western region (Mr Hugh McKenna) and for the NSW and eastern regions (Mr David Guillot) and the scientific papers produced on the survey methods.

Appendix 2 - Staff

Name	Organisation	Project Involvement
Ian Knuckey	Fishwell Consulting	Co-Investigator
Mark Bravington	CSIRO	Co-Investigator
David Peel	CSIRO	Modelling
Russel Hudson	Fishwell Consulting	Field Scientist
Matt Koopman	Fishwell Consulting	Analysis/Reporting

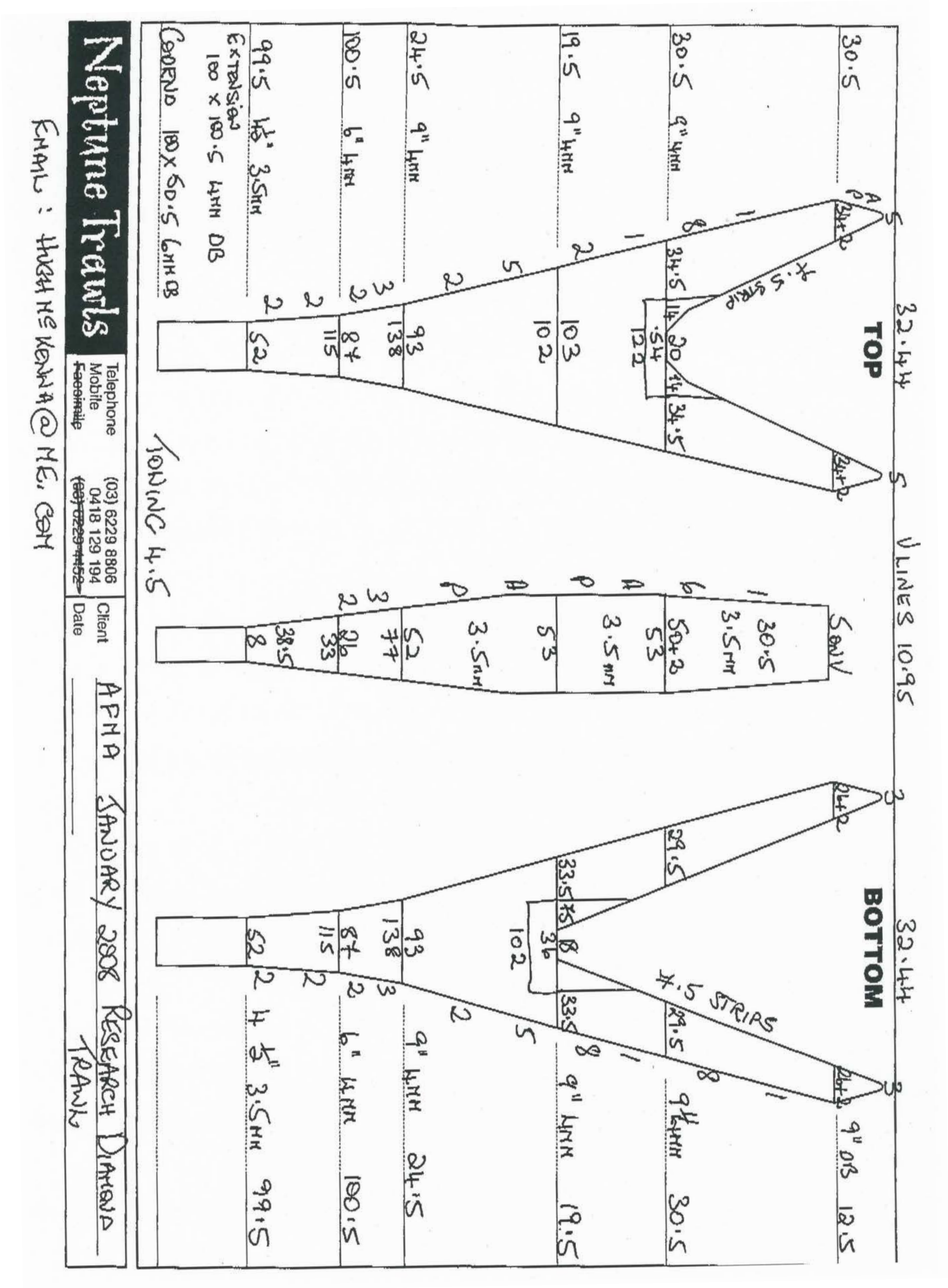
Appendix 3 - Survey Net Designs

Net design used in the NSW and eastern regions



HD LINE & GROUND LINE 14MM S/STEEL COMBI. DOVE TAIL 20MM S/STEEL
46 X 8” FLOATS EVENLY DISTRIBUTED STARTING 4 METERS BACK FROM WING END, ATTACH WITH 16MM SILVER ROPE.
ALL WING END MESHES SHOULD START 500MM BACK FROM CENTRE EYE
HD LINE SHOULD BE HUNG OVERTIGHT
FT ROPE SHOULD BE HUNG OVERTIGHT
DOVE TAIL SHOULD BE HUNG EVEN
16MM SIDE ROPES SHOULD FOLLOW ALL SEAMS, NO ADDED TENSION.

Net design used in the western region



Appendix 4 - Call for Expressions of Interest

Call for Expressions of Interest

SESSF Fishery Independent Survey

- 2008 Winter Survey -

Background

For many years now, stakeholders have recognised the problems associated with using CPUE data from commercial logbooks as the primary index of abundance for most SESSF species. It is generally agreed that the implementation of a Fishery Independent Survey (FIS) to provide a time series of abundance indices would overcome many of these problems. At a workshop run by AFMA in 2005, the implementation of a multi-species fishery independent survey was seen as one of the top research priorities. More recently, industry members in the SESSF have realised the potential value of a FIS to provide abundance indices for recovering species or for species which have a bycatch TAC or the TAC is limiting catch rates. The primary objective of the FIS is to obtain a time-series of relative abundance indices for many quota and some key non-quota species in the SESSF.

Recognising this need, Fishwell Consulting and CSIRO are undertaking a research project to design and implement a FIS for the SESSF. Over the last year, the logbook data has been extensively analysed in order to develop a design for a preliminary survey to be undertaken during 2008. The results of this survey will be analysed during 2009 in order to establish the long-term survey design to be implemented during 2010.

Expression of Interest

Expressions of Interest are now being sought from SESSF Commonwealth Trawl SFR holders who would like to make their vessel, skipper and crew available to undertake the 2008 winter survey. The final charter details will need to be determined after consultation with the tenderers, but the following outline is provided as a guide.

Please read the details provided below to help you decide whether you would be interested in being involved in this tender. If you are interested, please contact from Ian Knuckey at Fishwell Consulting for further information on 03 5258 4399 or 0408 581 599 or email fishwell@datafast.net.au.

Survey Design

The 2008 preliminary survey will operate in two seasons: “summer” (January to March inclusive); and “winter” (July to September inclusive). The 2008 summer survey has been successfully completed. Based on the characteristics of the fishery, the summer survey had greater coverage of shelf waters whilst the winter survey will be split more between shelf and slope waters.

It is anticipated that a total of about 370 shots will be undertaken across the fishery during the entire survey of which 220 (60%) will be conducted during the winter period. It is expected that at least three to four 2-hour survey shots will be conducted by the survey vessel during each survey day depending on the amount of steaming required between shots. Given the large geographical extent of the fishery, it is expected that three survey vessels will be required to complete the survey in the required time (See Figure 1).

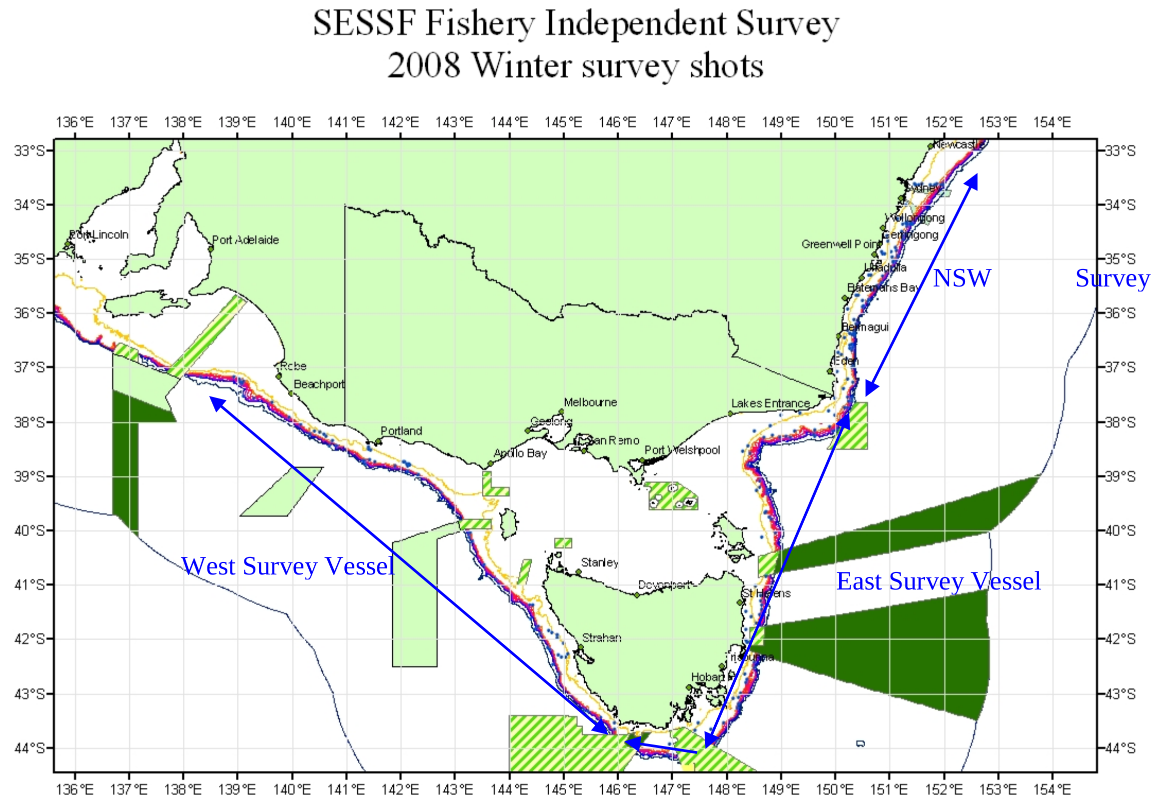


Figure 1. Indication of the number and position of 2008 winter survey shots to be undertaken by each of the three survey vessels. Note: shot locations are approximate and more detail on shot position and depth will be provided to those interested in being involved in the survey.

The details of how the winter survey shots are to be conducted over how many trips will need to be discussed further with individual operators. Regardless of the number of trips, each survey vessel will be required to perform about 60-80 survey shots. Inclusive of steaming time, this is likely to require 20-30 sea days. Further details of the survey shots are provided in the appendix. Whilst care has been taken in the placement of these shots, it is likely that some shots will need to be relocated because they might impinge on closed areas or fishing grounds of other sectors.

<u>Survey Details</u>

- It is anticipated that three vessels will be required for the survey during each period. Each survey vessel will be responsible for conducting survey shots in a specified area (NSW, East, West) as defined in Figure 1.
- A standardised survey trawl net (including doors) will be provided for use during the survey. Survey vessels would be expected to have a similar backup net stowed on board.
- The duration of each survey shot will be 2.0 hours bottom time.

- It is expected that 4 shots will be completed in any one fishing day beginning with a pre-dawn shot set at 0500-0600 hours, second shot set 0900-1000 hrs, third shot set 1300-1400 hrs and fourth shot set 1700-1800 hrs. These times are indicative only.
- Tow speed of the trawl net will need to be constant at 3.0 knots during the shot.
- Survey shots must be undertaken at prescribed locations in the manner outlined in Figure 2 in order to be considered valid.

<u>Catch / Charter arrangements:</u>

- Survey vessels will be chartered on a daily rate to undertake valid survey shots;
- AFMA has agreed to a Research Allowance to cover all the catch of quota species taken while conducting the survey;
- All catch (quota and non-quota) taken during the survey will be the property of the survey project and proceeds from the sale will be used to offset the survey charter costs;
- Costs to transport and sell the fish caught during the survey (including commission) will be paid by the project;
- All other vessel operation costs required to participate in the survey will be covered by the vessel and should be allowed for in the vessel's daily charter rate;
- Sale of the fish caught during the survey will be entirely the responsibility of the vessel;
- Depending on the location of a survey trip, the project and skipper/owner will agree on an appropriate port of landing;
- A proportion of the proceeds from sale of the survey catch (up to 10%) may be returned to the vessel as an incentive to undertake the survey correctly and ensure appropriate fish handling and storage for commercial sale;
- A small proportion (<10%) of the catch will be sampled for scientific purposes and may need to be sold as damaged fish.

<u>Vessel requirements</u>

The vessel and fishing equipment must:

- be in proper good and workmanlike condition and suitable for use in the survey;
- be maintained in Marine Board Survey class 3 throughout the Survey Period;
- have adequate safety gear and survey requirements to carry one survey personnel in addition to the skipper and crew;
- have a stabilised 240 volt AC power supply;
- have sufficient accommodation for survey personnel in addition to the skipper and crew;
- have sufficient deck space to process and sort each catch of fish collected during each trip;
- have a fish room and sufficient ice/refrigeration to store at least twenty tons of fish;
- have space in the wheelhouse or other suitable dry area for the researchers to establish a laptop and process data, samples, and record sheets etc.

<u>Owner requirements</u>

The owner must:

- hold a Statutory Fishing Right for the Commonwealth Trawl sector of the SESSF under the Fishing Management Act 1991 (Cwth);
- ensure that there is appropriate hull / public liability insurance;
- be able to make the vessel, skipper, crew and appropriate fishing gear available for the entire period of the survey;
- ensure that the survey personnel are provided with a satisfactory standard of accommodation, victualling, medical care and a safe and healthy working environment;
- ensure that survey personnel are given reasonable access to all required areas and facilities of the vessel to collect data, samples, and other information required and have reasonable daily access to the vessel's radio and satellite communication facilities.

Submissions

If you are interested in participating in the 2008 winter survey, please forward your expression of interest to:

Ian Knuckey
Fishwell Consulting
22 Bridge Street
Queenscliff VIC 3227
Fax: (03) 5258 4399 Email: fishwell@datafast.net.au

When forwarding your expression of interest, please include details of:

The name of the vessel and skipper and relevant experience in the SESSF;

Your preferred survey area (NSW, East, West);

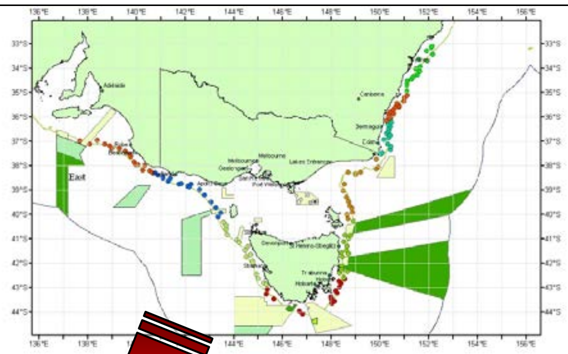
Daily charter costs.

PLEASE NOTE: Expressions of interest must be received by close of business Friday 13th June 2008.

Appendix 5 - Valid Survey shots

Further information on the exact position and depth of each shot can be provided on request. Note: whilst care has been taken in the placement of these shots, it is likely that some shots will need to be relocated because they might impinge on closed areas or fishing grounds of other sectors.

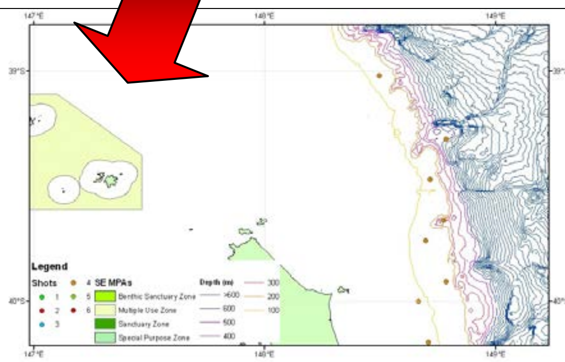
1



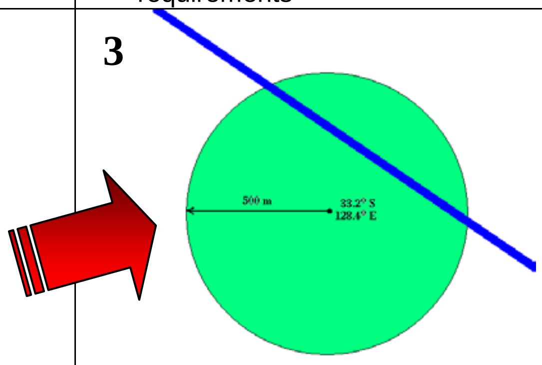
Conducting a valid survey shot

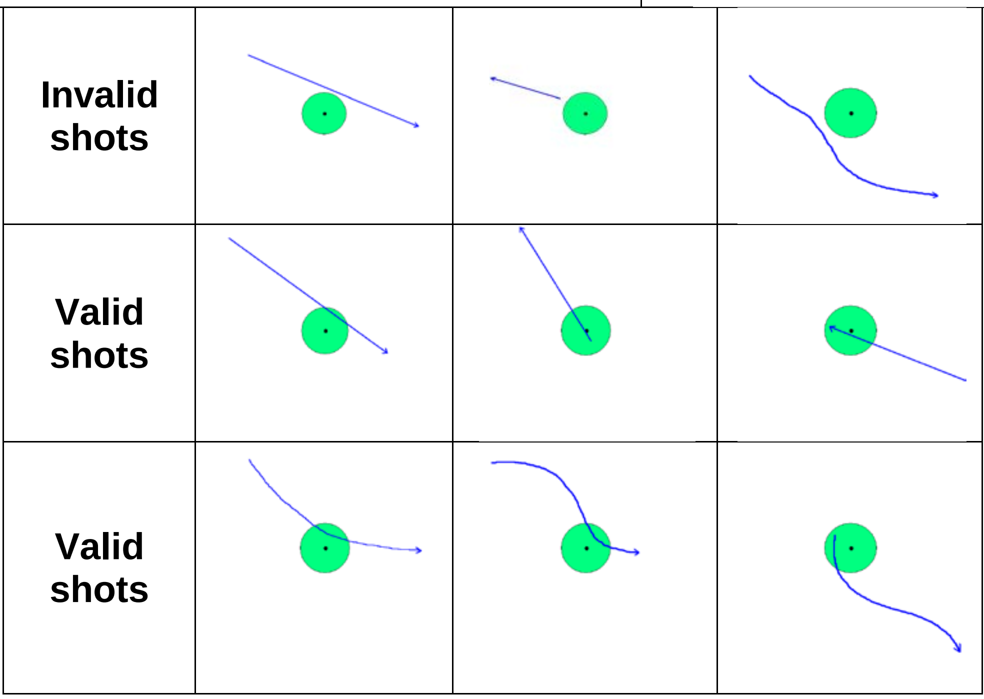
1. Each survey vessel will be responsible for a specific area
2. Within that area, 60-80 specific Lat/Long survey shot locations have been allocated
3. A valid survey shot must pass within 500m of the specific Lat/Long location
4. The skipper chooses any 2 hour shot that achieves these requirements

2



3





Appendix 6 - Species Sampled

Table 25. All species caught during summer and winter surveys showing CAAB codes, common name and species name.

Caab code	Common name	Species name
10038000	Sponges (Coral)	*Corallistidae*
10216000	Sponge (U)	*Porifera (u)*
11120000	Jellyfish (U)	Class *Scyphozoa*
11229000	Anemones	*Cnidaria*
11305002	Hard Coral	*Cnidaria*
20027000	Hermit Crab (U)	*Diogenidae (u)*
23000000	Mollusc (U)	*Phylum Mollusca (u)*
23270000	Scallop (U)	*Pectinidae (u)*
23607000	Cuttlefish (U)	*Sepiidae (u)*
23607001	Giant Cuttlefish	*Sepia apama*
23617005	Southern Calamari	*Sepioteuthis australis*
23632000	Deepsea Squid (U)	*Bathyteuthidae (u)*
23636004	Gould Squid	*Nototodarus gouldi*
23636007	Red Ocean Squid	*Ommastrephes bartramii*
23636011	Southern Ocean Arrow Squid	*Todarodes filippovae*
23659000	Octopus (U)	*Octopodidae (u)*
23659004	Pale Octopus	*Octopus pallidus*
24000000	Gastropod (U)	Class *Gastropoda (u)*
24155000	Cowrie (U)	*Cypraeidae (u)*
24207000	Volute (U)	*Volutidae (u)*
24207001	False Bailer Shell	*Livonia mammilla*
25000000	Echinoderm (U)	*Echinodermata (u)*
25102000	Seastar (U)	Class *Asteroidea (u)*
25160000	Brittlestars (U)	Class *Ophiuroidea*
25200000	Sea Urchin (U)	Class *Echinoidea (u)*
25262000	Sand Dollar (U)	*Clypeasteridae (u)*
25415000	Beche-De-Mer (U)	*Holothuriidae & Stichopodidae (u)*
28710000	Prawn (U)	*Penaeoidea & Caridea (u)*
28712001	Red Prawn	*Aristaeomorpha foliacea*
28712008	Giant Scarlet Prawn	*Aristaeopsis edwardsiana*
28714005	Royal Red Prawn	*Haliporoides sibogae*
28820001	Southern Rock Lobster	*Jasus edwardsii*
28820002	Eastern Rocklobster	*Jasus verreauxi*
28821000	Shovel-Nosed / Slipper Lobster (U)	*Scyllaridae (u)*
28821001	Deepwater Bug	*Ibacus alticrenatus*
28821904	Bug	*Ibacus & Thenus spp*
28836003	Spiny King Crab	*Lithodes longispina*
28840000	Squat Lobster (U)	*Galatheidae (u)*
28850000	Crab (U)	*Brachyura (u)*
28860001	Antlered Crab	*Dagnaudus petterdi*
37228002	Pink Ling	*Genypterus blacodes*
37229003	Messmate Fish	*Echiodon rendahli*
37232000	Whiptail & Rat-Tail (U)	*Macrouridae & Bathygadidae (u)*
37232001	Southern Whiptail	*Caelorinchus australis*
37232002	Banded Whiptail	*Caelorinchus fasciatus*
37232003	Gargoyle Fish	*Caelorinchus mirus*
37232004	Toothed Whiptail	*Lepidorhynchus denticulatus*
37232005	Blackspot Whiptail	*Lucigadus nigromaculatus*
37232007	Smooth Whiptail	*Malacocephalus laevis*
37232014	Notable Whiptail	*Caelorinchus innotabilis*
37232017	Blueband Whiptail	*Caelorinchus matamua*
37232047	Little Whiptail	*Caelorinchus parvifasciatus*
37232067	Aloha Whiptail	*Nezumia propinqua*
37235005	Crocodile Longtom	*Tylosurus crocodilus*
37254001	Black Spinyfin	*Diretmichthys parini*
37255000	Roughy (U)	*Trachichthyidae (u)*
37255001	Blacktip Sawbelly	*Hoplostethus intermedius*
37255002	Palefin Sawbelly	*Hoplostethus latus*
37255003	Sandpaper Fish	*Paratrachichthys macleayi*
37255009	Orange Roughy	*Hoplostethus atlanticus*
37258000	Alfonsino (U)	*Berycidae (u)*
37258001	Imperador	*Beryx decadactylus*
37258002	Alfonsino	*Beryx splendens*
37258003	Redfish	*Centroberyx affinis*
37258004	Bight Redfish	*Centroberyx gerrardi*
37258005	Swallowtail	*Centroberyx lineatus*
37259001	Australian Pineapplefish	*Cleidopus gloriamaris*
37264001	King Dory	*Cyttus traversi*
37264002	Silver Dory	*Cyttus australis*
37264003	Mirror Dory	*Zenopsis nebulosus*
37264004	John Dory	*Zeus faber*
37264005	New Zealand Dory	*Cyttus novaezealandiae*
37266001	Spikey Oreodory	*Neocyttus rhomboidalis*
37267001	Sharpsnout Deepsea Boarfish	*Antigonia rubescens*
37269001	Common Veilfin	*Metavelifer multiradiatus*
37271001	Southern Ribbonfish	*Trachipterus arawatae*
37272000	Oarfish (U)	*Regalecidae (u)*
37277000	Trumpetfishes (U)	*Aulostomidae (u)*
37278001	Smooth Flutemouth	*Fistularia commersonii*
37278002	Rough Flutemouth	*Fistularia petimba*

Caab code	Common name	Species name	Caab code	Common name	Species name
28880000	Spider Crab (U)	*Majidae (u)*	37279000	Bellowsfish (U)	*Macroramphosidae (u)*
28911020	Swimmer Crab	*Ovalipes molleri*	37279001	Banded Bellowsfish	*Centriscops humerosus*
28925001	Giant Crab	*Pseudocarcinus gigas*	37279002	Common Bellowsfish	*Macroramphosus scolopax*
35102000	Salp (U)	*Doliolidae (u)*	37279003	Crested Bellowsfish	*Notopogon lilliei*
37004000	Hagfish (U)	*Myxinidae (u)*	37282000	Pipefish (U)	*Syngnathidae (u)*
37005001	Sharpnose Sevengill Shark	*Heptranchias perlo*	37282029	Spiny Pipehorse	*Solegnathus spinosissimus*
37005002	Broadnose Shark	*Notorynchus cepedianus*	37287000	Scorpionfish (U)	*Scorpaeniformes (u)*
37007001	Port Jackson Shark	*Heterodontus portusjacksoni*	37287001	Inshore Ocean Perch	*Helicolenus percoides*
37007003	Crested Hornshark	*Heterodontus galeatus*	37287002	Blackspotted Gurnard Perch	*Neosebastes nigropunctatus*
37008001	Grey Nurse Shark	*Carcharias taurus*	37287004	Gulf Gurnard Perch	*Neosebastes bougainvillii*
37010001	Shortfin Mako	*Isurus oxyrinchus*	37287005	Common Gurnard Perch	*Neosebastes scorpaenoides*
37010003	White Shark	*Carcharodon carcharias*	37287006	Thetis Fish	*Neosebastes thetidis*
37011001	Basking Shark	*Cetorhinus maximus*	37287046	Deepsea Ocean Perch	*Trachyscorpia eschmeyeri*
37012001	Thresher Shark	*Alopias vulpinus*	37287093	Offshore Ocean Perch	*Helicolenus barathri*
37012002	Bigeye Thresher	*Alopias superciliosus*	37288000	Searobin & Armour Gurnard (U)	*Triglidae & Peristediidae (u)*
37013001	Banded Wobbegong	*Orectolobus ornatus*	37288001	Red Gurnard	*Chelidonichthys kumu*
37013002	Collar Carpetshark	*Parascyllium collare*	37288003	Butterfly Gurnard	*Lepidotrigla vanessa*
37013003	Spotted Wobbegong	*Orectolobus maculatus*	37288004	Robust Amour Gurnard	*Peristedion picturatum*
37013005	Rusty Carpetshark	*Parascyllium ferrugineum*	37288005	Painted Latchet	*Pterygotrigla andertoni*
37013006	Zebra Shark	*Stegostoma fasciatum*	37288006	Latchet	*Pterygotrigla polyommata*
37015000	Catshark (U)	*Scyliorhinidae (u)*	37288007	Cocky Gurnard	*Lepidotrigla modesta*
37015001	Draughtboard Shark	*Cephaloscyllium laticeps*	37288008	Roundsnout Gurnard	*Lepidotrigla mulhalli*
37015009	Sawtail Catshark	*Galeus boardmani*	37288014	Bullhead Gurnard	*Bovitrigla leptacanthus*
37015013	Whitefin Swell Shark	*Cephaloscyllium sp A*	37288900	Sea Robin (U)	*Triglidae*
37015020	Pinocchio Catshark	*Apristurus sp G*	37296000	Flathead (U)	*Platycephalidae (u)*
37015024	Orange Spotted Catshark	*Asymbolus rubiginosus*	37296001	Tiger Flathead	*Neoplatycephalus richardsoni*
37015027	Grey Spotted Catshark	*Asymbolus analis*	37296002	Deepwater Flathead	*Neoplatycephalus conatus*
37017001	Gummy Shark	*Mustelus antarcticus*	37296003	Southern Sand Flathead	*Platycephalus bassensis*
37017008	School Shark	*Galeorhinus galeus*	37296007	Bluespotted Flathead	*Platycephalus caeruleopunctatus*
37018001	Bronze Whaler	*Carcharhinus brachyurus*	37296036	Longspine Flathead	*Platycephalus longispinis*
37019004	Smooth Hammerhead	*Sphyrna zygaena*	37296037	Southern Bluespotted Flathead	*Platycephalus speculator*
37020001	Endeavour Dogfish	*Centrophorus moluccensis*	37296038	Marbled Flathead	*Platycephalus marmoratus*
37020002	Black Shark	*Dalatias licha*	37296041	Mud Flathead	*Ambiserrula jugosa*
37020003	Brier Shark	*Deania calcea*	37297001	Deepsea Flathead	*Hoplichthys haswelli*
37020004	Longsnout Dogfish	*Deania quadrispinosa*	37298000	Pigfish	*Congiopodidae (u)*
37020005	Blackbelly Lanternshark	*Etmopterus lucifer*	37305001	Smooth-Head Blobfish	*Psychrolutes marcidus*
37020006	Spikey Dogfish	*Squalus megalops*	37311000	Temperate Bass & Rockcod (U)	*Percichthyidae & Serranidae (u)*
37020007	Greeneye Dogfish	*Squalus mitsukurii*	37311001	Eastern Orange Perch	*Lepidoperca pulchella*
37020008	Whitespotted Dogfish	*Squalus acanthias*	37311002	Butterfly Perch	*Caesioperca lepidoptera*
37020009	Leafscale Gulper Shark	*Centrophorus squamosus*	37311005	Harlequin Fish	*Othos dentex*
37020010	Harrisson Dogfish	*Centrophorus harrissoni*	37311006	Hapuku	*Polyprion oxygeneios*
37020011	Southern Dogfish	*Centrophorus uyato*	37311052	Slender Orange Perch	*Lepidoperca occidentalis*
37020012	Golden Dogfish	*Centroscymnus crepidater*	37311053	Threespine Cardinalfish	*Apogonops anomalus*
37020013	Plunket Dogfish	*Centroscymnus plunketi*	37311055	Splendid Perch	*Callanthias australis*
37020014	Smalltooth Cookiecutter Shark	*Isistius brasiliensis*	37311060	Convict Grouper	*Epinephelus septemfasciatus*
37020015	Slender Lanternshark	*Etmopterus pusillus*	37326001	Spotted Bigeye	*Priacanthus macracanthus*
37020019	Owston Dogfish	*Centroscymnus owstoni*	37326002	Longfin Bigeye	*Cookeolus japonicus*

Caab code	Common name	Species name
37020021	Southern Lanternshark	*Etmopterus granulosus*
37020025	Portuguese Dogfish	*Centroscymnus coelolepis*
37020033	Moller's Lanternshark	*Etmopterus molleri*
37020901	Greeneye Dogfish (U)	*Squalus spp*
37020907	Lantern Shark	*Etmopterus spp*
37021001	Prickly Dogfish	*Oxynotus bruniensis*
37023001	Southern Sawshark	*Pristiophorus nudipinnis*
37023002	Common Sawshark	*Pristiophorus cirratus*
37024001	Australian Angelshark	*Squatina australis*
37024002	Ornate Angelshark	*Squatina tergocellata*
37024004	Eastern Angel Shark	*Squatina sp A*
37024900	Angel Shark	*Squatina spp*
37027000	Guitarfish (U)	*Rhinobatidae (u)*
37027002	Southern Fiddler Ray	*Trygonorrhina fasciata*
37027006	Eastern Fiddler Ray	*Trygonorrhina sp A*
37027009	Eastern Shovelnose Ray	*Aptychotrema rostrata*
37028001	Coffin Ray	*Hypnos monopterygium*
37028002	Tasmanian Numbfish	*Narcine tasmaniensis*
37028003	Short-Tail Torpedo Ray	*Torpedo macneilli*
37028004	Western Numbfish	*Narcine lasti*
37028006	Longtail Torpedo Ray	*Torpedo sp A*
37031000	Skate (U)	*Rajidae (u)*
37031002	Sydney Skate	*Dipturus australis*
37031003	Whitespotted Skate	*Dipturus cerva*
37031005	Longnose Skate	*Dipturus sp A*
37031006	Melbourne Skate	*Dipturus whitleyi*
37031009	Peacock Skate	*Pavoraja nitida*
37031010	Bight Skate	*Dipturus gudgeri*
37031028	Grey Skate	*Dipturus sp B*
37031035	Deepwater Skate	*Dipturus sp J*
37031900	Skate	*Raja spp*
37035000	Stingray (U)	*Dasyatidae (u)*
37035001	Smooth Stingray	*Dasyatis brevicaudata*
37035002	Black Stingray	*Dasyatis thetidis*
37038001	Sandyback Stingaree	*Urolophus bucculentus*
37038002	Banded Stingaree	*Urolophus cruciatus*
37038004	Sparsely-Spotted Stingaree	*Urolophus paucimaculatus*
37038005	Yellowback Stingaree	*Urolophus sufflavus*
37038006	Common Stingaree	*Trygonoptera testacea*
37038007	Greenback Stingaree	*Urolophus viridis*
37038008	Wide Stingaree	*Urolophus expansus*
37038009	Brown Stingaree	*Urolophus westraliensis*
37038014	Eastern Shovelnose Stingaree	*Trygonoptera sp B*
37039000	Eagle Ray (U)	*Myliobatidae (u)*
37039001	Southern Eagle Ray	*Myliobatis australis*
37042001	Ogilby Ghostshark	*Hydrolagus ogilbyi*
37042003	Blackfin Ghostshark	*Hydrolagus lemures*

Caab code	Common name	Species name
37327001	Bigeye Deepsea Cardinalfish	*Epigonus lenimen*
37327010	White Deepsea Cardinalfish	*Epigonus denticulatus*
37327018	Robust Deepsea Cardinalfish	*Epigonus robustus*
37327900	Deepsea Cardinalfish	*Epigonus spp*
37330014	Eastern School Whiting	*Sillago flindersi*
37331001	Freckled Tilefish	*Branchiostegus sawakinensis*
37331006	Pink Tilefish	*Branchiostegus wardi*
37334002	Tailor	*Pomatomus saltatrix*
37337002	Jack Mackerel	*Trachurus declivis*
37337003	Yellowtail Scad	*Trachurus novaezelandiae*
37337006	Yellowtail Kingfish	*Seriola lalandi*
37337007	Samsonfish	*Seriola hippos*
37337025	Amberjack	*Seriola dumerili*
37337062	Silver Trevally	*Pseudocaranx dentex*
37345001	Redbait	*Emmelichthys nitidus*
37345002	Bigscale Rubyfish	*Plagiogeneion macrolepis*
37346014	Ruby Snapper	*Etelis carbunculus*
37353001	Snapper	*Pagrus auratus*
37353013	Tarwhine	*Rhabdosargus sarba*
37355000	Goatfish (U)	*Mullidae (u)*
37355001	Bluestriped Goatfish	*Upeneichthys lineatus*
37361002	Footballer Sweep	*Neatypus obliquus*
37367000	Boarfish (U)	*Pentacerotidae (u)*
37367001	Yellowspotted Boarfish	*Paristiopterus gallipavo*
37367002	Giant Boarfish	*Paristiopterus labiosus*
37367003	Longsnout Boarfish	*Pentaceropsis recurvirostris*
37367004	Bigspine Boarfish	*Pentaceros decacanthus*
37367005	Blackspot Boarfish	*Zanclistius elevatus*
37369002	Knifejaw	*Oplegnathus woodwardi*
37377002	Grey Morwong	*Nemadactylus douglasii*
37377003	Jackass Morwong	*Nemadactylus macropterus*
37377004	Blue Morwong	*Nemadactylus valenciennesi*
37378001	Striped Trumpeter	*Latris lineata*
37378002	Bastard Trumpeter	*Latridopsis forsteri*
37384000	Wrasse (U)	*Labridae (u)*
37384035	Yellowfin Pigfish	*Bodianus flavipinnis*
37384061	Eastern Pigfish	*Bodianus unimaculatus*
37390001	Barred Grubfish	*Parapercis allporti*
37400000	Stargazer (U)	*Uranoscopidae (u)*
37400001	Bulldog Stargazer	*Xenocephalus armatus*
37400005	Scaled Stargazer	*Pleuroscopus pseudodorsalis*
37400018	Speckled Stargazer	*Kathetostoma canaster*
37439001	Barracouta	*Thyrsites atun*
37439002	Gemfish	*Rexea solandri*
37439009	Longfin Gemfish	*Rexea antefurcata*
37439901	Escolar	*Ruvettus pretiosus*
37440002	Frostfish	*Lepidopus caudatus*

Caab code	Common name	Species name	Caab code	Common name	Species name
37042005	Southern Chimaera	*Chimaera sp A*	37441000	Mackerel (U)	*Scombridae (u)*
37042010	Black Ghostshark	*Hydrolagus sp A*	37441001	Blue Mackerel	*Scomber australasicus*
37043001	Elephantfish	*Callorhinchus milii*	37441020	Australian Bonito	*Sarda australis*
37067000	Conger Eel (U)	*Congridae & Colocongridae (u)*	37442001	Swordfish	*Xiphias gladius*
37067007	Southern Conger	*Conger verreauxi*	37445001	Blue-eye Trevalla	*Hyperoglyphe antarctica*
37067900	Conger Eel	*Conger spp*	37445004	Rudderfish	*Centrolophus niger*
37070001	Basketwork Eel	*Diastobranchus capensis*	37445005	Blue Warehou	*Seriolella brama*
37076000	Snipe Eel (U)	*Nemichthyidae (u)*	37445006	Silver Warehou	*Seriolella punctata*
37083001	Southern Spineback	*Notacanthus sexspinis*	37445011	White Warehou	*Seriolella caerulea*
37085002	Australian Sardine	*Sardinops neopilchardus*	37446010	Blue Cubehead	*Cubiceps caeruleus*
37086001	Australian Anchovy	*Engraulis australis*	37449001	Smalleye Squaretail	*Tetragonurus cuvieri*
37098000	Deepsea Smelt (U)	*Bathylagidae (u)*	37460000	Lefteye Flounder (U)	*Bothidae (u)*
37106000	Bristlemouth & Lightfish (U)	*Gonostomatidae & Phosichthyidae (u)*	37460002	Smalltooth Flounder	*Pseudorhombus jenynsii*
37106002	Silver Lightfish	*Phosichthys argenteus*	37460031	Slender Flounder	*Pseudorhombus tenuirastrum*
37114000	Slickhead (U)	*Alepocephalidae (u)*	37461002	Banded-Fin Flounder	*Azygopus pinnifasciatus*
37117001	Sergeant Baker	*Aulopus purpurissatus*	37465000	Triggerfish & Leatherjacket (U)	*Balistidae & Monacanthidae (u)*
37118001	Largescale Saury	*Saurida undosquamis*	37465003	Mosaic Leatherjacket	*Eubalichthys mosaicus*
37120001	Blacktip Cucumberfish	*Paraulopus nigripinnis*	37465005	Velvet Leatherjacket	*Meuschenia scaber*
37122000	Lanternfish (U)	*Myctophidae (u)*	37465006	Ocean Jacket	*Nelusetta ayraudi*
37141001	Beaked Salmon	*Gonorynchus greyi*	37465008	Brownstriped Leatherjacket	*Meuschenia australis*
37208000	Goosefish (U)	*Lophiidae (u)*	37465032	Fourspine Leatherjacket	*Eubalichthys quadrispinis*
37209005	Australian Handfish	*Brachionichthys australis*	37465036	Sixspine Leatherjacket	*Meuschenia freycineti*
37211000	Coffinfish (U)	*Chaunacidae (u)*	37465038	Modest Leatherjacket	*Thamnaconus modestoides*
37211003	Furry Coffinfish	*Chaunax endeavouri*	37465059	Yellowfin Leatherjacket	*Meuschenia trachylepis*
37212001	Shortfin Seabat	*Halieutaea brevicauda*	37466002	Eastern Smooth Boxfish	*Anoplocapros inermis*
37224000	Pelagic, Morid & Eucla Cod (U)	*Melanonidae, Moridae & Euclichthyidae (u)*	37466003	Shaw Cowfish	*Aracana aurita*
37224001	Eucla Cod	*Euclichthys polynemus*	37467000	Toadfish (U)	*Tetraodontidae (u)*
37224002	Ribaldo	*Mora moro*	37467002	Ringed Toadfish	*Omegophora armilla*
37224003	Bearded Rock Cod	*Pseudophycis barbata*	37467004	Balloonfish	*Sphoeroides pachygaster*
37224004	Chiseltooth Grenadier Cod	*Tripterophycis gilchristi*	37467005	Starry Toadfish	*Arothron firmamentum*
37224006	Red Cod	*Pseudophycis bachus*	37468000	Pufferfish (U)	*Triodontidae (u)*
37224009	Slender Cod	*Halargyreus johnsonii*	37469001	Globefish	*Diodon nicthemerus*
37227001	Blue Grenadier	*Macruronus novaezelandiae*	37469002	Australian Burrfish	*Allomycterus pilatus*
37228001	Tusk	*Dannevigia tusca*	41131003	Australian Fur Seal	*Arctocephalus pusillus doriferus*

Appendix 7 - Shot Locations

Table 26. Location and details of shots conducted during 2008 survey. Season (Win=winter, Sum=summer) and vessel (F=Francesca, ME=Moira Elizabeth, WA=Western Alliance) are abbreviated.

Season	Region	Vessel	Date	Start Time	End time	Start Latitude	Start Longitude	End Latitude	End Longitude	Speed (kts)	Depth (m)
Win	NSW	F	21/08/2008	04:54	07:29	36°38.50'	150°05.85'	36°45.64'	150°04.47'	3.0	75
Win	NSW	F	22/08/2008	04:55	07:22	36°05.57'	150°21.85'	35°58.45'	150°21.20'	3.0	120
Win	NSW	F	10/08/2008	05:30	07:35	35°28.65'	150°46.56'	35°33.80'	150°43.49'	3.0	347
Win	NSW	F	12/09/2008	05:31	07:27	33°35.49'	151°52.48'	33°40.05'	151°48.78'	3.0	173
Win	NSW	F	11/09/2008	05:33	07:45	33°43.32'	151°55.48'	33°38.21'	151°59.31'	3.0	676
Win	NSW	F	20/08/2008	05:39	07:25	36°43.55'	150°18.71'	36°38.13'	150°18.33'	3.0	210
Win	NSW	F	10/09/2008	05:50	07:57	33°43.62'	151°42.17'	33°38.43'	151°47.08'	3.0	146
Win	NSW	F	13/08/2008	05:55	08:03	35°55.50'	150°16.50'	35°48.37'	150°22.69'	3.0	104
Win	NSW	F	19/08/2008	05:59	08:23	36°20.80'	150°19.18'	36°27.29'	150°17.90'	3.0	183
Win	NSW	F	12/08/2008	06:07	08:55	35°45.83'	150°35.02'	35°53.45'	150°30.78'	3.0	200
Win	NSW	F	01/09/2008	06:10	08:39	34°34.31'	151°11.54'	34°28.24'	151°14.80'	3.0	190
Win	NSW	F	28/08/2008	06:11	08:52	34°53.39'	151°02.33'	34°45.57'	151°02.37'	3.0	128
Win	NSW	F	03/08/2008	06:16	08:26	34°03.57'	151°20.13'	34°08.14'	151°17.70'	3.0	131
Win	NSW	F	26/08/2008	06:19	08:55	35°02.64'	151°05.08'	34°55.72'	151°07.60'	3.0	329
Win	NSW	F	29/08/2008	06:20	09:15	34°34.63'	151°17.20'	34°26.54'	151°20.22'	3.0	493
Win	NSW	F	31/08/2008	06:21	07:49	34°49.07'	151°06.28'	34°45.47'	151°06.77'	3.0	183
Win	NSW	F	30/08/2008	06:22	08:43	34°30.39'	151°17.14'	34°36.48'	151°14.67'	3.0	329
Win	NSW	F	03/09/2008	06:26	08:31	34°19.05'	151°25.64'	34°13.98'	151°28.88'	3.0	442
Win	NSW	F	02/09/2008	06:30	08:32	34°11.50'	151°15.87'	34°16.74'	151°11.68'	3.0	131
Win	NSW	F	25/08/2008	06:38	08:55	35°02.51'	151°05.94'	34°56.79'	151°08.11'	3.0	439
Win	NSW	F	04/08/2008	06:45	09:12	34°17.15'	151°25.60'	34°22.84'	151°22.03'	3.0	374
Win	NSW	F	07/08/2008	06:50	09:28	35°18.50'	150°53.50'	35°12.39'	150°57.44'	3.0	256
Win	NSW	F	27/08/2008	07:15	09:31	34°56.17'	150°53.25'	34°49.58'	150°53.19'	3.0	64
Win	NSW	F	18/08/2008	07:16	09:31	36°05.89'	150°24.15'	36°12.06'	150°22.90'	3.0	201
Win	NSW	F	09/08/2008	07:35	09:42	35°34.38'	150°29.29'	35°39.89'	150°26.19'	3.0	109
Win	NSW	F	20/08/2008	08:08	09:53	36°38.11'	150°17.09'	36°43.09'	150°15.94'	3.0	164
Win	NSW	F	21/08/2008	08:16	10:36	36°44.72'	150°06.50'	36°37.71'	150°08.23'	3.0	84
Win	NSW	F	10/08/2008	08:17	10:12	35°33.50'	150°44.50'	35°28.80'	150°47.45'	3.0	420
Win	NSW	F	05/08/2008	08:41	10:59	35°16.03'	150°55.56'	35°21.66'	150°51.33'	3.0	219
Win	NSW	F	13/08/2008	08:50	11:00	35°46.50'	150°26.50'	35°40.00'	150°26.96'	3.0	119
Win	NSW	F	11/09/2008	09:03	11:11	33°37.14'	151°58.94'	33°41.57'	151°55.50'	3.0	603
Win	NSW	F	24/08/2008	09:18	11:56	35°44.99'	150°37.62'	35°39.14'	150°41.53'	3.0	585
Win	NSW	F	09/09/2008	09:23	11:23	33°40.40'	151°24.12'	33°36.17'	151°28.61'	3.0	58
Win	NSW	F	10/09/2008	09:33	11:42	33°35.78'	151°39.05'	33°40.27'	151°34.01'	3.0	128
Win	NSW	F	30/08/2008	09:49	12:26	34°38.37'	151°15.46'	34°45.32'	151°12.67'	3.0	493
Win	NSW	F	12/08/2008	09:50	12:04	35°52.81'	150°31.67'	35°46.84'	150°35.06'	3.0	283
Win	NSW	F	02/09/2008	09:53	12:06	34°17.86'	151°18.97'	34°23.26'	151°14.35'	3.0	151
Win	NSW	F	26/08/2008	10:01	12:28	34°57.41'	151°07.88'	35°03.84'	151°04.92'	3.0	402
Win	NSW	F	25/08/2008	10:13	12:28	34°57.64'	151°09.02'	34°52.15'	151°11.15'	3.0	603
Win	NSW	F	29/08/2008	10:14	13:09	34°24.57'	151°21.18'	34°17.43'	151°26.12'	3.0	439
Win	NSW	F	19/08/2008	10:16	12:30	36°29.34'	150°21.84'	36°23.64'	150°21.50'	3.0	603
Win	NSW	F	27/08/2008	10:32	12:39	34°49.69'	150°54.33'	34°55.57'	150°54.23'	3.0	75
Win	NSW	F	18/08/2008	10:36	12:34	36°12.29'	150°24.53'	36°17.15'	150°22.10'	3.0	548
Win	NSW	F	31/08/2008	10:45	13:11	34°41.00'	150°58.86'	34°34.33'	151°00.71'	3.0	109
Win	NSW	F	03/08/2008	10:47	13:14	34°16.66'	151°11.12'	34°22.41'	151°07.59'	3.0	124
Win	NSW	F	09/08/2008	10:48	12:30	35°40.21'	150°22.89'	35°35.72'	150°27.50'	3.0	82
Win	NSW	F	20/08/2008	10:58	12:58	36°41.84'	150°20.64'	36°36.26'	150°20.11'	3.0	402
Win	NSW	F	04/08/2008	11:01	13:20	34°22.53'	151°25.09'	34°16.91'	151°28.68'	3.0	658
Win	NSW	F	07/08/2008	11:37	13:59	35°12.45'	150°43.75'	35°17.53'	150°38.06'	3.0	91
Win	NSW	F	21/08/2008	11:51	14:37	36°31.79'	150°09.17'	36°23.93'	150°12.44'	3.0	95
Win	NSW	F	09/09/2008	12:00	14:06	33°36.58'	151°28.68'	33°41.78'	151°25.89'	3.0	73
Win	NSW	F	11/09/2008	12:19	14:05	33°39.85'	151°56.32'	33°35.70'	151°58.90'	3.0	530
Win	NSW	F	02/09/2008	13:24	15:43	34°25.85'	151°18.79'	34°20.43'	151°22.25'	3.0	301
Win	NSW	F	12/08/2008	13:27	15:56	35°47.70'	150°35.32'	35°41.41'	150°38.94'	3.0	448
Win	NSW	F	27/08/2008	13:36	15:14	34°53.09'	150°51.80'	34°48.69'	150°50.56'	3.0	47
Win	NSW	F	20/08/2008	13:56	15:49	36°36.13'	150°18.90'	36°30.71'	150°18.20'	3.0	256
Win	NSW	F	18/08/2008	14:01	16:33	36°22.81'	150°21.30'	36°29.35'	150°20.56'	3.0	530
Win	NSW	F	26/08/2008	14:03	16:00	35°04.00'	151°02.14'	34°59.29'	151°03.87'	3.0	164
Win	NSW	F	25/08/2008	14:04	16:38	34°57.71'	151°09.36'	35°04.18'	151°06.22'	3.0	658
Win	NSW	F	24/08/2008	14:38	16:38	35°33.43'	150°45.23'	35°28.61'	150°48.06'	3.0	530
Win	NSW	F	19/08/2008	14:40	17:10	36°34.14'	150°16.27'	36°41.59'	150°15.56'	3.0	137
Win	NSW	F	31/08/2008	14:45	17:10	34°40.82'	150°55.32'	34°33.90'	150°57.72'	3.0	73
Win	NSW	F	04/08/2008	14:50	17:16	34°17.50'	151°24.50'	34°23.13'	151°20.13'	3.0	256
Win	NSW	F	09/09/2008	14:58	17:11	33°41.93'	151°25.89'	33°37.38'	151°31.28'	3.0	91
Win	NSW	F	30/08/2008	14:59	16:00	34°47.95'	151°08.67'	34°45.41'	151°09.20'	3.0	219
Win	NSW	F	21/08/2008	15:10	17:12	36°23.49'	150°11.76'	36°18.59'	150°14.37'	3.0	82
Win	NSW	F	09/08/2008	15:15	17:32	35°37.07'	150°40.28'	35°31.26'	150°44.07'	3.0	201
Win	NSW	F	11/09/2008	15:20	17:15	33°35.48'	151°54.55'	33°39.87'	151°50.72'	3.0	219
Win	NSW	F	29/08/2008	15:30	18:04	34°19.18'	151°18.90'	34°25.34'	151°14.68'	3.0	166
Win	NSW	F	03/08/2008	15:58	18:20	34°17.73'	151°20.60'	34°23.68'	151°16.25'	3.0	179
Win	NSW	F	07/08/2008	16:30	17:54	35°19.18'	150°40.03'	35°15.85'	150°38.07'	3.0	91
Sum	NSW	F	4/03/2008	04:58	07:24	35°48.32'	150°34.65'	35°41.29'	150°37.68'	3.0	217
Sum	NSW	F	4/03/2008	04:58	07:24	35°47.79'	150°33.99'	35°41.29'	150°37.68'	3.0	217
Sum	NSW	F	28/02/2008	05:02	07:00	37°10.45'	150°21.09'	37°5.15'	150°20.3'	2.8	263
Sum	NSW	F	3/03/2008	05:28	07:28	35°58.19'	150°26.59'	35°52.48'	150°29.12'	3.0	139
Sum	NSW	F	7/03/2008	05:32	07:57	34°32.73'	151°12.24'	34°26.07'	151°14.65'	3.0	192
Sum	NSW	F	5/03/2008	05:38	07:34	35°20.23'	150°43.59'	35°16.32'	150°47.84'	3.0	128
Sum	NSW	F	10/03/2008	05:45	07:47	33°37.5'	151°30.72'	33°42.42'	151°25.42'	3.0	91
Sum	NSW	F	1/03/2008	05:46	07:57	36°25.42'	150°17.76'	36°18.7'	150°18.33'	3.0	135
Sum	NSW	F	27/02/2008	05:46	07:46	37°55.84'	149°56.29'	37°49.51'	149°57.83'	2.8	137
Sum	NSW	F	6/03/2008	05:46	07:49	34°43.02'	151°12.05'	34°35.72'	151°13.98'	3.0	316
Sum	NSW	F	9/03/2008	05:50	07:44	33°42.84'	151°53.47'	33°38.46'	151°56.66'	3.0	506
Sum	NSW	F	2/03/2008	05:58	07:59	36°8.95'	150°23.81'	36°3.22'	150°26.12'	3.0	261
Sum	NSW	F	29/02/2008	06:00	08:17	36°32.66'	150°13.49'	36°25.78'	150°13.73'	3.0	124
Sum	NSW	F	8/03/2008	06:38	08:50	34°20.78'	151°23.71'	34°15.35'	151°27.28'	3.0	402
Sum	NSW	F	26/02/2008	06:39	08:44	36°25.24'	150°20.51'	36°31.36'	150°20.23'	2.9	212

Season	Region	Vessel	Date	Start Time	End time	Start Latitude	Start Longitude	End Latitude	End Longitude	Speed (kts)	Depth (m)
Sum	NSW	F	9/03/2008	08:44	10:55	33°38.02'	151°55.04'	33°42.48'	151°50.63'	3.0	338
Sum	NSW	F	6/03/2008	08:59	10:59	34°36.3'	151°10.64'	34°30.85'	151°12.87'	3.0	190
Sum	NSW	F	27/02/2008	09:20	11:22	37°43.06'	149°53.67'	37°41.08'	149°54.13'	2.7	110
Sum	NSW	F	1/03/2008	09:35	11:50	36°14.37'	150°23.68'	36°8.7'	150°25.35'	3.0	539
Sum	NSW	F	5/03/2008	09:42	11:56	35°18.99'	150°53.46'	35°12.44'	150°57.27'	3.0	225
Sum	NSW	F	29/02/2008	09:45	11:57	36°25.99'	150°10.82'	36°19.47'	150°13.43'	3.0	88
Sum	NSW	F	7/03/2008	09:49	12:05	34°21.72'	151°8.01'	34°15.75'	151°10.69'	3.0	121
Sum	NSW	F	3/03/2008	09:54	12:19	35°47.54'	150°35.23'	35°42.12'	150°38.44'	3.0	396
Sum	NSW	F	2/03/2008	10:00	12:24	36°5.32'	150°24.59'	35°58.91'	150°27.84'	3.0	210
Sum	NSW	F	28/02/2008	10:35	12:36	36°46.06'	150°8.44'	36°40.5'	150°7.24'	2.5	90
Sum	NSW	F	9/03/2008	11:46	13:55	33°40.81'	151°50.36'	33°36.24'	151°53.9'	3.0	210
Sum	NSW	F	8/03/2008	12:04	14:04	33°57.61'	151°45.19'	33°52.83'	151°48.18'	3.0	640
Sum	NSW	F	26/02/2008	12:21	14:22	36°51.42'	150°17.27'	36°58.29'	150°18.1'	2.9	144
Sum	NSW	F	25/02/2008	13:17	15:19	35°42.63'	150°31.77'	35°47.99'	150°33'	2.9	185
Sum	NSW	F	7/03/2008	13:49	16:03	34°15.98'	151°20.82'	34°10.61'	151°24.42'	3.0	157
Sum	NSW	F	26/02/2008	15:35	17:38	36°59'	150°18.1'	37°6.09'	150°19.46'	2.9	163
Sum	NSW	F	25/02/2008	17:19	19:22	35°56.02'	150°27.14'	36°2.12'	150°24.26'	2.8	132
Sum	NSW	F	27/02/2008	17:32	19:37	37°18.99'	150°5.09'	37°13.13'	150°5.93'	2.8	88
Sum	NSW	F	7/03/2008	17:44	20:10	34°3.86'	151°20.21'	34°10.06'	151°15.57'	3.0	133
Sum	NSW	F	1/03/2008	17:46	19:51	35°57.94'	150°16.12'	35°52.37'	150°18.45'	3.0	100
Sum	NSW	F	2/03/2008	18:09	20:20	36°5.68'	150°21.35'	35°59.83'	150°21.92'	3.0	117
Sum	NSW	F	5/03/2008	18:09	19:41	34°48.46'	150°58.41'	34°44.7'	151°0.94'	3.0	122
Sum	NSW	F	9/03/2008	18:21	20:26	33°37.12'	151°49.61'	33°42.39'	151°45.07'	3.0	150
Sum	NSW	F	3/03/2008	18:23	20:40	35°47.65'	150°20.87'	35°42.14'	150°23.53'	3.0	104
Win	West	ME	18/08/2008	05:45	07:45	38°46.97'	141°58.79'	38°50.09'	142°05.84'	3.0	450
Win	West	ME	30/07/2008	05:45	07:45	38°01.37'	140°07.80'	38°05.63'	140°12.84'	2.8	185
Win	West	ME	26/07/2008	05:50	07:50	37°55.07'	139°57.79'	37°51.23'	139°52.27'	3.0	255
Win	West	ME	17/08/2008	05:55	07:55	38°44.11'	141°19.95'	38°40.71'	141°19.97'	3.0	220
Win	West	ME	09/08/2008	06:05	08:05	38°50.02'	142°06.04'	38°53.16'	142°12.77'	3.0	450
Win	West	ME	29/07/2008	06:06	08:05	37°23.42'	139°15.07'	37°19.35'	139°12.16'	3.0	155
Win	West	ME	10/08/2008	06:20	08:20	38°45.35'	141°32.20'	38°42.26'	141°26.13'	3.0	190
Win	West	ME	06/09/2008	06:30	08:30	41°38.40'	144°26.78'	41°33.14'	144°24.89'	3.0	379
Win	West	ME	07/08/2008	06:30	08:30	40°52.73'	143°44.28'	40°56.97'	143°49.27'	3.0	450
Win	West	ME	04/09/2008	06:33	07:49	42°44.92'	144°54.49'	42°42.08'	144°54.52'	2.7	435
Win	West	ME	29/08/2008	06:49	08:49	41°58.07'	144°39.57'	42°03.59'	144°00.00'	3.0	181
Win	West	ME	27/08/2008	06:51	08:51	43°17.77'	145°26.64'	43°13.23'	145°22.53'	3.0	168
Win	West	ME	16/08/2008	06:55	08:55	38°25.08'	140°47.89'	38°28.03'	140°54.46'	3.0	320
Win	West	ME	28/08/2008	07:06	09:00	42°08.66'	144°43.43'	42°13.04'	144°46.37'	3.0	461
Win	West	ME	24/08/2008	07:12	09:12	41°21.98'	144°23.39'	41°27.08'	144°23.44'	3.0	372
Win	West	ME	25/08/2008	07:22	09:22	42°28.46'	144°49.26'	42°23.44'	144°47.32'	3.0	678
Win	West	ME	06/07/2008	07:42	09:45	40°03.41'	143°13.35'	40°08.77'	143°16.28'	3.0	470
Win	West	ME	31/07/2008	07:45	09:45	38°41.60'	141°14.99'	38°00.00'	141°00.00'	3.1	500
Win	West	ME	08/08/2008	08:10	10:10	39°19.41'	142°44.89'	39°14.96'	142°40.93'	3.1	470
Win	West	ME	28/07/2008	08:25	10:25	37°36.08'	139°10.58'	37°32.29'	139°06.11'	3.0	630
Win	West	ME	26/08/2008	08:31	10:30	43°24.50'	145°40.28'	43°28.60'	145°45.50'	3.1	170
Win	West	ME	08/08/2008	08:35	10:35	38°50.97'	142°04.90'	38°48.47'	141°58.56'	3.0	180
Win	West	ME	05/07/2008	08:40	10:40	40°01.84'	143°00.00'	40°06.84'	143°15.81'	3.0	550
Win	West	ME	15/08/2008	08:45	10:45	22°00.00'	139°00.00'	'	'	3.0	250
Win	West	ME	27/07/2008	08:45	10:45	37°08.89'	138°16.12'	37°08.77'	138°23.56'	3.0	530
Win	West	ME	05/09/2008	09:12	11:12	41°50.09'	144°33.22'	41°55.46'	144°34.36'	2.9	488
Win	West	ME	17/08/2008	09:45	11:45	38°48.21'	141°23.77'	38°49.91'	141°30.24'	3.0	650
Win	West	ME	07/08/2008	09:50	11:50	40°58.10'	143°47.06'	41°02.66'	143°51.83'	3.1	600
Win	West	ME	30/07/2008	09:55	11:55	38°12.14'	140°17.82'	38°15.55'	140°24.08'	3.1	410
Win	West	ME	09/08/2008	10:05	12:05	38°53.84'	142°00.00'	38°52.06'	142°03.18'	2.8	850
Win	West	ME	24/08/2008	10:55	12:55	41°33.40'	144°23.42'	41°39.04'	144°25.59'	3.0	498
Win	West	ME	06/07/2008	11:00	13:00	49°12.19'	143°17.73'	40°17.71'	143°20.38'	3.0	540
Win	West	ME	26/07/2008	11:05	13:05	37°38.53'	139°37.51'	37°42.71'	139°41.44'	3.0	175
Win	West	ME	06/09/2008	11:11	13:10	41°21.49'	144°19.44'	41°18.54'	144°13.51'	2.9	444
Win	West	ME	27/08/2008	11:25	13:25	43°16.54'	145°22.87'	43°11.33'	145°16.84'	3.0	463
Win	West	ME	04/09/2008	11:49	13:41	42°18.65'	144°47.36'	42°14.25'	144°45.51'	2.7	473
Win	West	ME	04/07/2008	12:08	14:10	38°34.65'	141°27.84'	38°39.60'	141°24.41'	3.0	450
Win	West	ME	15/08/2008	12:08	14:10	38°21.47'	140°31.81'	38°24.00'	140°37.15'	3.0	500
Win	West	ME	09/08/2008	13:05	15:05	38°55.08'	142°03.98'	38°56.25'	142°10.60'	3.0	640
Win	West	ME	16/08/2008	13:18	15:18	38°40.75'	141°15.56'	38°44.28'	141°21.66'	3.0	450
Win	West	ME	05/07/2008	13:20	15:20	39°58.38'	143°11.80'	40°03.14'	143°13.86'	3.1	450
Win	West	ME	26/08/2008	13:48	15:48	43°40.77'	145°58.96'	43°36.06'	145°55.22'	3.0	165
Win	West	ME	14/08/2008	13:55	15:55	37°25.79'	139°10.43'	37°30.82'	139°12.46'	3.0	350
Win	West	ME	28/08/2008	13:59	15:00	42°14.94'	144°48.77'	42°12.94'	144°48.55'	3.0	178
Win	West	ME	05/09/2008	14:23	15:30	41°49.72'	144°34.73'	41°52.75'	144°34.82'	2.7	187
Win	West	ME	17/08/2008	14:30	16:30	38°49.45'	141°50.85'	38°50.35'	141°58.07'	3.1	300
Win	West	ME	30/07/2008	14:38	16:38	38°10.53'	140°20.30'	38°14.46'	140°26.42'	3.0	180
Win	West	ME	06/08/2008	14:40	16:40	40°33.36'	143°30.02'	40°38.39'	143°33.23'	3.0	210
Win	West	ME	08/08/2008	14:45	16:45	38°50.00'	142°20.81'	38°54.01'	142°14.84'	3.1	450
Win	West	ME	04/07/2008	14:55	16:56	38°40.10'	141°24.83'	38°44.90'	141°30.24'	3.0	500
Win	West	ME	15/08/2008	15:25	17:25	38°20.20'	140°37.36'	38°00.00'	140°00.00'	3.0	220
Win	West	ME	04/09/2008	15:48	17:47	42°12.37'	144°43.71'	42°07.70'	144°41.27'	2.7	630
Win	West	ME	24/08/2008	15:54	17:54	41°42.91'	144°26.47'	41°48.92'	144°29.24'	3.0	675
Win	West	ME	27/07/2008	16:10	18:10	37°09.15'	138°50.17'	37°10.38'	138°57.51'	3.0	170
Win	West	ME	28/07/2008	16:30	18:30	37°25.92'	139°11.28'	37°31.17'	139°14.43'	3.0	375
Win	West	ME	25/08/2008	16:35	18:35	42°11.17'	144°43.54'	42°06.05'	144°41.25'	2.7	491
Win	West	ME	26/08/2008	16:40	18:40	43°32.62'	145°53.67'	43°28.21'	145°48.38'	3.1	156
Win	West	ME	09/08/2008	16:45	18:45	38°52.60'	142°09.07'	38°50.12'	142°02.89'	3.0	450
Win	West	ME	26/07/2008	16:45	18:45	37°33.06'	139°15.64'	37°30.21'	139°09.43'	3.0	420
Win	West	ME	28/08/2008	17:22	19:22	42°04.59'	144°43.28'	42°59.20'	144°40.37'	3.0	188
Win	West	ME	16/08/2008	18:05	20:05	38°39.32'	141°22.08'	38°43.26'	141°26.93'	3.0	180
Win	West	ME	08/08/2008	18:10	20:10	35°52.78'	142°15.75'	38°49.79'	142°09.52'	3.0	200
Win	West	ME	30/07/2008	18:30	20:30	38°17.69'	140°33.61'	38°17.69'	140°40.48'	3.0	180
Win	West	ME	15/08/2008	18:43	20:45	38°23.96'	140°51.95'	38°25.31'	140°56.80'	3.0	150
Win	West	ME	14/08/2008	18:45	20:45	37°25.26'	139°14.47'	37°30.19'	139°14.62'	3.0	300
Sum	West	ME	21/02/2008	03:50	05:50	38°24.86'	140°47.53'	38°21.05'	140°44.72'	3.0	257
Sum	West	ME	2/03/2008	03:59	05:58	38°53.52'	142°13.55'	38°56.43'	142°19.87'	2.9	179
Sum	West	ME	26/02/2008	04:15	06:15	38°26.5'	141°3.04'	38°24.84'	140°34'	3.0	150
Sum	West	ME	10/03/2008	04:26	06:10	41°58.18'	144°39.44'	42°3.61'	144°42.97'	3.0	180
Sum	West	ME	27/02/2008	05:25	07:25	38°48.68'	141°43.86'	38°46.61'	141°36.9'	3.0	350
Sum	West	ME	11/03/2008	07:02	08:20	42°45.33'	144°54.54'	42°42.02'	144°54.56'	3.1	430
Sum	West	ME	3/03/2008	07:05	08:49	39°58.99'	143°11.4'	40°4.39'	143°14.33'	3.0	528
Sum	West	ME	9/03/2008	07:20	09:09	41°19.11'	144°15.51'	41°23.37'	144°21.73'	3.0	385
Sum	West	ME	24/02/2008	07:20	09:20	37°27.56'	139°9.95'	37°33.82'	139°12.7'	3.0	450

Season	Region	Vessel	Date	Start Time	End time	Start Latitude	Start Longitude	End Latitude	End Longitude	Speed (kts)	Depth (m)
Sum	West	ME	22/02/2008	07:25	09:50	37°53.31'	139°46'	37°49.52'	139°40.48'	3.0	600
Sum	West	ME	8/03/2008	07:28	09:12	40°52.66'	143°44.1'	40°56.99'	143°49.57'	3.0	450
Sum	West	ME	23/02/2008	07:30	09:30	37°12.11'	138°49.22'	37°11.49'	138°42.18'	3.0	500
Sum	West	ME	25/02/2008	07:30	09:30	37°54.13'	139°53.07'	37°51.51'	139°46'	3.0	500
Sum	West	ME	4/03/2008	07:34	09:19	40°46.89'	143°37.49'	40°41.44'	143°33.48'	3.0	507
Sum	West	ME	21/02/2008	08:20	10:20	38°22.85'	140°42.9'	38°20.1'	140°36'	3.0	315
Sum	West	ME	26/02/2008	09:00	11:00	38°19.04'	140°36.57'	38°16.04'	140°30.02'	3.0	190
Sum	West	ME	1/03/2008	09:03	11:04	38°41.31'	141°13.36'	38°45.47'	141°19.06'	3.3	620
Sum	West	ME	2/03/2008	09:44	11:30	39°8.39'	142°34'	39°12.11'	142°37.55'	2.9	497
Sum	West	ME	11/03/2008	10:37	12:20	42°34.94'	144°52.46'	42°29.49'	144°49.91'	3.1	540
Sum	West	ME	8/03/2008	10:58	12:43	41°0.59'	143°53.55'	41°5.11'	143°58.1'	3.0	440
Sum	West	ME	9/03/2008	11:22	13:07	41°30.1'	144°23.86'	41°36.22'	144°25.36'	3.0	430
Sum	West	ME	4/03/2008	11:31	13:17	40°35.49'	143°28.46'	40°30.4'	143°25.29'	2.9	538
Sum	West	ME	10/03/2008	12:03	13:30	42°23.03'	144°47.15'	42°27.26'	144°49.15'	2.8	620
Sum	West	ME	24/02/2008	12:48	14:28	37°36.03'	139°28.43'	37°34.21'	139°21.59'	3.0	506
Sum	West	ME	23/02/2008	12:55	14:55	37°10.35'	138°31.58'	37°11.42'	138°38.42'	3.0	460
Sum	West	ME	22/02/2008	13:10	15:10	37°37.55'	139°35.25'	37°34.84'	139°29.41'	3.0	215
Sum	West	ME	2/03/2008	13:50	15:34	39°15.86'	142°41.59'	39°20.33'	142°45.6'	2.9	450
Sum	West	ME	25/02/2008	14:00	16:00	38°6.06'	140°13.52'	38°10.12'	140°19.54'	3.0	170
Sum	West	ME	1/03/2008	14:14	16:06	38°47.44'	141°40.85'	38°48.78'	141°48.6'	2.9	305
Sum	West	ME	8/03/2008	14:24	16:08	41°3.49'	143°53.83'	41°8.18'	143°58.61'	3.0	550
Sum	West	ME	9/03/2008	14:33	16:19	41°37.51'	144°24.63'	41°43.18'	144°27.47'	3.0	550
Sum	West	ME	21/02/2008	15:40	17:40	37°59.86'	140°4.6'	37°55.96'	139°57.09'	3.0	350
Sum	West	ME	11/03/2008	15:52	17:35	42°9.24'	144°42.77'	42°3.57'	144°40.47'	3.0	500
Sum	West	ME	3/03/2008	16:34	18:28	40°18.14'	143°21.33'	40°23.81'	143°23.35'	3.0	505
Sum	West	ME	8/03/2008	17:53	19:40	41°11.03'	144°3.15'	41°14.34'	144°9.74'	3.0	480
Sum	West	ME	25/02/2008	18:00	20:00	38°14.99'	140°27.05'	38°17.64'	140°33.42'	3.0	190
Sum	West	ME	4/03/2008	18:20	20:02	40°7.29'	143°15.89'	40°1.71'	143°12.84'	3.0	530
Sum	West	ME	9/03/2008	18:42	20:27	41°52.36'	144°31.87'	41°57.99'	144°35.21'	3.0	640
Sum	West	ME	1/03/2008	20:22	22:06	38°48.62'	142°1.47'	38°51.24'	142°8.18'	3.1	167
Sum	West	ME	26/02/2008	20:25	22:25	38°34.04'	141°10.93'	38°38.2'	141°16.14'	3.0	275
Sum	West	ME	21/02/2008	20:30	22:30	37°51'	139°53.2'	37°46.6'	139°47.64'	3.0	178
Sum	West	ME	22/02/2008	20:40	22:40	37°23.61'	139°15.28'	37°18.57'	144°29.24'	3.0	154
Sum	West	ME	24/02/2008	21:50	23:50	37°59.01'	140°6.85'	38°5.55'	140°12.8'	3.0	190
Win	East	WA	05/08/2008	05:18	07:07	37°17.22'	150°18.79'	37°12.18'	150°20.63'	3.0	170
Win	East	WA	10/08/2008	05:33	07:40	39°00.48'	148°25.50'	39°05.85'	148°29.93'	3.0	96
Win	East	WA	04/08/2008	05:39	07:33	36°54.72'	150°02.74'	36°49.24'	150°03.00'	3.0	68
Win	East	WA	07/08/2008	05:46	07:49	37°37.79'	149°56.69'	37°43.32'	149°53.32'	3.0	106
Win	East	WA	11/08/2008	05:50	08:09	39°21.67'	148°46.32'	39°16.02'	148°43.89'	3.0	479
Win	East	WA	09/08/2008	05:58	08:28	38°09.26'	149°14.71'	38°12.46'	149°04.85'	3.0	152
Win	East	WA	13/08/2008	06:05	08:00	38°28.09'	148°23.68'	38°22.94'	148°25.73'	3.0	117
Win	East	WA	25/07/2008	06:22	08:33	43°39.74'	147°26.22'	43°34.13'	147°29.78'	3.0	112
Win	East	WA	06/08/2008	06:23	08:20	37°19.28'	150°15.12'	37°24.88'	150°13.08'	3.0	125
Win	East	WA	08/08/2008	06:27	08:38	38°04.99'	150°03.79'	38°09.35'	149°57.75'	3.0	529
Win	East	WA	01/08/2008	06:30	08:41	41°33.28'	148°25.70'	41°27.21'	148°24.95'	3.0	86
Win	East	WA	02/08/2008	06:33	08:42	40°02.67'	148°42.70'	39°56.69'	148°41.35'	3.0	103
Win	East	WA	03/08/2008	06:35	08:40	38°07.35'	149°48.99'	38°04.34'	149°55.25'	3.0	220
Win	East	WA	31/07/2008	06:35	08:40	41°41.61'	148°33.47'	41°35.90'	148°34.51'	3.0	127
Win	East	WA	30/07/2008	06:45	09:05	42°46.06'	148°23.57'	42°39.11'	148°26.30'	3.0	535
Win	East	WA	26/07/2008	06:55	09:10	43°46.57'	147°50.42'	43°40.22'	147°54.51'	3.0	380
Win	East	WA	28/07/2008	07:05	09:40	42°17.12'	148°34.32'	42°23.66'	148°32.58'	3.0	445
Win	East	WA	10/08/2008	08:03	10:10	39°06.93'	148°30.65'	39°12.35'	148°34.22'	3.0	98
Win	East	WA	05/08/2008	08:14	09:28	37°10.95'	150°14.24'	37°07.08'	150°13.75'	3.0	108
Win	East	WA	27/07/2008	08:15	10:15	43°03.76'	148°14.14'	42°58.61'	148°15.86'	3.0	156
Win	East	WA	13/08/2008	09:02	11:13	38°17.98'	148°30.36'	38°13.46'	148°36.28'	3.0	116
Win	East	WA	04/08/2008	09:05	11:05	36°44.13'	150°11.72'	36°49.75'	150°11.71'	3.0	121
Win	East	WA	09/08/2008	09:08	11:06	38°13.78'	149°06.39'	38°11.59'	149°13.28'	3.0	165
Win	East	WA	06/08/2008	09:10	11:17	37°28.54'	150°14.21'	37°34.08'	150°11.91'	3.0	152
Win	East	WA	25/07/2008	09:20	11:25	43°31.99'	147°30.10'	43°28.33'	147°36.40'	3.0	105
Win	East	WA	11/08/2008	09:22	12:20	39°11.48'	148°42.87'	39°03.24'	148°40.03'	3.0	534
Win	East	WA	02/08/2008	09:31	11:41	39°54.62'	148°45.47'	39°48.42'	148°45.81'	3.0	127
Win	East	WA	08/08/2008	09:35	11:40	38°10.27'	149°57.15'	38°12.75'	149°50.08'	3.0	553
Win	East	WA	03/08/2008	09:59	12:18	38°03.12'	150°02.70'	37°57.35'	150°06.57'	3.0	425
Win	East	WA	31/07/2008	10:05	12:15	41°39.42'	148°37.17'	41°33.54'	148°38.85'	3.0	633
Win	East	WA	30/07/2008	10:15	10:52	42°38.89'	148°22.17'	42°37.17'	148°23.29'	3.0	122
Win	East	WA	26/07/2008	10:20	11:20	43°40.98'	147°51.49'	43°39.08'	147°52.75'	3.0	185
Win	East	WA	07/08/2008	10:34	12:40	37°54.39'	150°07.77'	38°00.54'	150°04.88'	3.0	432
Win	East	WA	01/08/2008	10:37	11:43	41°22.74'	148°36.40'	41°17.42'	148°37.44'	3.0	128
Win	East	WA	27/07/2008	10:45	12:40	42°58.05'	148°16.19'	42°52.51'	148°17.76'	3.0	129
Win	East	WA	30/07/2008	11:15	13:15	42°36.41'	148°23.95'	42°30.06'	148°25.76'	3.0	119
Win	East	WA	28/07/2008	11:40	13:45	42°28.07'	148°31.29'	42°33.44'	148°28.97'	3.0	505
Win	East	WA	04/08/2008	12:15	14:10	36°49.16'	150°19.25'	36°54.23'	150°18.65'	3.0	207
Win	East	WA	10/08/2008	12:16	14:28	39°23.84'	148°43.55'	39°30.43'	148°45.88'	3.0	143
Win	East	WA	24/07/2008	12:24	14:24	44°05.06'	146°47.53'	44°07.15'	146°54.24'	3.0	386
Win	East	WA	09/08/2008	12:30	14:28	38°17.22'	149°10.67'	38°17.47'	149°03.89'	3.0	412
Win	East	WA	02/08/2008	12:35	14:45	39°48.35'	148°45.44'	39°42.92'	148°42.37'	3.0	123
Win	East	WA	06/08/2008	12:42	14:51	37°39.02'	150°16.36'	37°45.16'	150°13.71'	3.0	494
Win	East	WA	08/08/2008	13:07	15:17	38°11.58'	149°53.82'	38°13.93'	149°46.05'	3.0	544
Win	East	WA	25/07/2008	13:10	15:10	43°35.67'	147°44.82'	43°40.17'	147°39.78'	3.0	142
Win	East	WA	27/07/2008	13:25	15:40	42°50.80'	148°21.48'	42°44.67'	148°23.99'	3.0	471
Win	East	WA	31/07/2008	13:35	15:35	41°34.21'	148°33.70'	41°28.62'	148°34.87'	3.0	119
Win	East	WA	07/08/2008	13:41	15:54	38°00.57'	150°06.91'	37°54.26'	150°09.60'	3.0	546
Win	East	WA	11/08/2008	13:45	15:57	39°05.67'	148°39.47'	38°59.34'	148°38.03'	3.0	562
Win	East	WA	01/08/2008	13:48	15:41	41°11.76'	148°34.62'	41°06.24'	148°34.35'	3.0	118
Win	East	WA	03/08/2008	14:00	15:45	37°55.70'	149°58.09'	37°50.76'	150°00.22'	3.0	132
Win	East	WA	30/07/2008	14:10	16:10	42°30.01'	148°21.49'	42°23.56'	148°24.88'	3.0	106
Win	East	WA	04/08/2008	14:48	16:38	36°54.64'	150°18.01'	36°59.56'	150°18.19'	3.0	146
Win	East	WA	10/08/2008	15:12	17:18	39°30.87'	148°46.66'	39°37.18'	148°47.92'	3.0	263
Win	East	WA	28/07/2008	15:20	17:30	42°33.79'	148°19.21'	42°40.32'	148°16.53'	3.0	100
Win	East	WA	24/07/2008	15:42	16:16	44°03.94'	146°55.11'	44°04.82'	146°56.76'	3.0	176
Win	East	WA	26/07/2008	15:43	17:50	43°12.48'	148°06.49'	43°06.75'	148°09.32'	3.0	138
Win	East	WA	25/07/2008	15:58	18:10	43°40.84'	147°35.92'	43°45.45'	147°30.11'	3.0	142
Win	East	WA	06/08/2008	16:03	18:05	37°46.71'	150°09.70'	37°41.02'	150°12.44'	3.0	309
Win	East	WA	08/08/2008	16:19	18:22	38°11.92'	149°48.81'	38°09.11'	149°55.49'	3.0	450
Win	East	WA	09/08/2008	16:22	18:29	38°20.13'	148°52.20'	38°22.33'	148°44.73'	3.0	434
Win	East	WA	01/08/2008	16:31	18:41	41°02.51'	148°32.26'	40°56.70'	148°35.70'	3.0	108
Win	East	WA	31/07/2008	16:40	18:40	41°30.08'	148°28.59'	41°35.50'	148°27.65'	3.0	105
Win	East	WA	27/07/2008	16:50	18:20	42°45.92'	148°19.16'	42°39.47'	148°18.23'	3.0	121

Season	Region	Vessel	Date	Start Time	End time	Start Latitude	Start Longitude	End Latitude	End Longitude	Speed (kts)	Depth (m)
Win	East	WA	03/08/2008	17:01	19:02	37°48.14'	150°08.53'	37°42.71'	150°11.70'	3.0	304
Win	East	WA	24/07/2008	17:33	19:30	44°00.66'	146°55.30'	43°57.80'	146°49.39'	3.0	164
Win	East	WA	04/08/2008	17:59	19:45	37°03.31'	150°09.32'	37°08.39'	150°07.76'	3.0	90
Win	East	WA	07/08/2008	18:46	20:50	37°50.22'	149°46.88'	37°54.43'	149°41.66'	3.0	131
Win	East	WA	08/08/2008	20:09	22:08	38°00.74'	149°50.69'	38°02.18'	149°43.16'	3.0	143
Sum	East	WA	26/02/2008	05:17	08:10	43°30.69'	147°34.4'	43°36.47'	147°26.62'	3.0	104
Sum	East	WA	27/02/2008	05:20	08:10	43°13.27'	148°6.18'	43°6.26'	148°11.44'	3.0	154
Sum	East	WA	23/02/2008	05:26	07:59	42°59.56'	145°10.05'	43°5.97'	145°14.92'	3.0	113
Sum	East	WA	4/03/2008	05:40	08:25	39°56.97'	148°49.15'	39°49.68'	148°46.2'	3.0	132
Sum	East	WA	7/03/2008	05:43	07:39	39°21.41'	148°46.32'	39°16.13'	148°43.96'	3.0	462
Sum	East	WA	2/03/2008	05:45	08:15	41°41.88'	148°33.25'	41°35'	148°35'	3.0	126
Sum	East	WA	25/02/2008	05:46	08:31	43°34.55'	145°52.98'	43°40.94'	145°57.71'	3.0	160
Sum	East	WA	3/03/2008	05:50	08:30	40°58.27'	148°44.07'	40°52.17'	148°46.32'	3.0	445
Sum	East	WA	1/03/2008	06:00	08:20	42°34.48'	148°28.53'	42°26.43'	148°32.37'	3.0	450
Sum	East	WA	8/03/2008	06:08	08:05	38°45.79'	148°18.27'	38°40.43'	148°20.62'	3.0	117
Sum	East	WA	29/02/2008	06:30	09:30	42°49.2'	148°14.12'	42°39.72'	148°17.62'	3.0	101
Sum	East	WA	2/03/2008	08:45	11:15	41°33.63'	148°35.28'	41°26.47'	148°35.98'	3.0	133
Sum	East	WA	7/03/2008	08:45	11:21	39°11.7'	148°42.99'	39°4.21'	148°40.54'	3.0	550
Sum	East	WA	1/03/2008	09:00	11:30	42°25.47'	148°32.62'	42°18.05'	148°34.25'	3.0	465
Sum	East	WA	4/03/2008	09:00	11:30	39°48.54'	148°46.42'	39°41.49'	148°47.12'	3.0	138
Sum	East	WA	6/03/2008	09:18	11:14	38°0.55'	148°57.12'	38°4.47'	148°51.77'	3.0	112
Sum	East	WA	8/03/2008	09:22	11:26	38°37.89'	148°25.74'	38°33.1'	148°29.12'	3.0	260
Sum	East	WA	27/02/2008	09:30	11:59	43°11.43'	148°8.42'	43°5.82'	148°13.63'	3.0	155
Sum	East	WA	23/02/2008	09:48	12:33	43°13.35'	145°26.37'	43°19.48'	145°33.41'	3.0	245
Sum	East	WA	26/02/2008	10:10	12:40	43°40.62'	147°43.23'	43°34.23'	147°50.15'	3.0	144
Sum	East	WA	29/02/2008	10:40	13:15	42°44.53'	148°20.02'	42°37'	148°23.34'	3.0	116
Sum	East	WA	2/03/2008	11:50	14:18	41°23.88'	148°36.72'	41°17.41'	148°37.35'	3.0	130
Sum	East	WA	4/03/2008	12:30	15:00	39°45.12'	148°39.39'	39°37.38'	148°39.15'	3.0	116
Sum	East	WA	25/02/2008	12:51	15:06	43°59.47'	146°26.13'	44°0.62'	146°33.27'	3.0	197
Sum	East	WA	3/03/2008	13:00	15:31	40°22.13'	148°52.3'	40°10.86'	148°50.82'	3.0	130
Sum	East	WA	8/03/2008	13:00	15:02	38°39.03'	148°22.7'	38°44.42'	148°19.42'	3.0	145
Sum	East	WA	6/03/2008	13:09	15:09	38°15.94'	148°52.31'	38°16.61'	148°45.45'	3.0	109
Sum	East	WA	7/03/2008	13:30	15:30	39°14.46'	148°33.04'	39°8.62'	148°31.9'	3.0	83
Sum	East	WA	29/02/2008	13:40	16:10	42°36.5'	148°26.35'	42°30.3'	148°26.35'	3.0	118
Sum	East	WA	26/02/2008	13:45	16:15	43°28.55'	147°49.63'	43°23.05'	147°57.24'	3.0	128
Sum	East	WA	27/02/2008	14:30	17:00	42°55.33'	148°18.1'	43°2.67'	148°13.74'	3.0	126
Sum	East	WA	1/03/2008	15:30	18:08	42°15.53'	148°27.32'	42°7.43'	148°27.32'	3.0	95
Sum	East	WA	2/03/2008	15:30	18:02	41°12.73'	148°35'	41°4.64'	148°34.66'	3.0	119
Sum	East	WA	3/03/2008	16:00	18:31	40°12.28'	148°50.72'	40°10.84'	148°50.83'	3.0	128
Sum	East	WA	7/03/2008	16:45	18:29	39°4.61'	148°29.16'	38°59.82'	148°24.4'	3.0	90
Sum	East	WA	25/02/2008	17:00	19:08	44°1.66'	146°46.57'	44°1.56'	146°56.01'	3.0	185
Sum	East	WA	29/02/2008	17:00	19:45	42°32.07'	148°20.73'	42°24.95'	148°24.47'	3.0	100
Sum	East	WA	26/02/2008	17:15	19:30	43°19.1'	148°0'	43°22.63'	147°52.5'	3.0	132
Sum	East	WA	27/02/2008	17:30	20:00	43°3.3'	148°12.47'	43°9.48'	148°7.72'	3.0	124
Sum	East	WA	24/02/2008	17:50	20:20	43°25.36'	145°42.23'	43°29.84'	145°49.14'	3.0	116
Sum	East	WA	7/03/2008	18:45	20:23	38°59.01'	148°24.26'	38°54.59'	148°20.63'	3.0	110
Sum	East	WA	3/03/2008	19:00	21:30	40°4.02'	148°51.03'	39°56.43'	148°49.63'	3.0	143
Sum	East	WA	25/02/2008	19:30	22:00	44°1.45'	146°58.38'	44°5.77'	147°4.53'	3.0	165
Sum	East	WA	2/03/2008	19:56	22:07	40°57.62'	148°32.02'	41°4.17'	148°32.34'	3.0	87

Table 27. Location and details of shots conducted during 2010 survey. Season (Win=winter, Sum=summer) and vessel (F=Francesca, GR=Game Reason, ME=Moira Elizabeth, WA=Western Alliance) are abbreviated.

Season	Region	Vessel	Date	Start Time	End time	Start Latitude	Start Longitude	End Latitude	End Longitude	Speed (kts)	Depth (m)
Win	NSW	F	31/7/10	09:09	10:55	33°41.72'	151°47.44'	33°37.83'	151°50.78'	2.8	172
Win	NSW	F	31/7/10	11:56	13:51	33°39.36'	151°51.17'	33°35.06'	151°55.01'	2.8	218
Win	NSW	F	31/7/10	15:15	17:20	33°35.61'	151°48.68'	33°40.14'	151°43.94'	2.8	137
Win	NSW	F	1/8/10	06:45	09:03	33°42.51'	151°32.57'	33°37.33'	151°37.25'	2.8	126
Win	NSW	F	1/8/10	11:40	13:47	33°41.38'	151°24.19'	33°36.31'	151°28.05'	2.9	55
Win	NSW	F	1/8/10	14:50	16:57	33°35.83'	151°30.46'	33°39.54'	151°24.7'	2.9	71
Win	NSW	F	2/8/10	06:44	08:59	33°42.45'	151°25.24'	33°37.53'	151°30.95'	2.9	87
Win	NSW	F	5/8/10	07:02	09:21	34°14.46'	151°27.47'	34°19.68'	151°24.24'		384
Win	NSW	F	5/8/10	10:56	13:11	34°18.21'	151°25.98'	34°13.12'	151°29.27'		439
Win	NSW	F	5/8/10	17:26	19:34	34°11.29'	151°16.23'	34°16.17'	151°12.69'		130
Win	NSW	F	6/8/10	06:59	09:11	34°8.13'	151°17.77'	34°1.99'	151°20.61'		132
Win	NSW	F	8/8/10	07:01	09:10	33°42.42'	151°54.38'	33°37.82'	151°58.12'		549
Win	NSW	F	8/8/10	11:10	13:14	33°39.63'	151°57.02'	33°35.09'	152°0.41'		576
Win	NSW	F	8/8/10	14:46	17:02	33°37.08'	152°0.07'	33°41.82'	151°56.35'		677
Win	NSW	F	9/8/10	05:55	08:08	34°18.52'	151°27.97'	34°22.97'	151°23.99'		622
Win	NSW	F	9/8/10	09:31	11:24	34°23.36'	151°22.26'	34°19.01'	151°25.21'		430
Win	NSW	F	9/8/10	12:59	15:00	34°16.35'	151°21.95'	34°21.14'	151°18.38'		187
Win	NSW	F	9/8/10	16:06	18:06	34°23.7'	151°19.3'	34°19.08'	151°22.03'		265
Win	NSW	F	10/8/10	06:07	08:15	34°22.16'	151°7.84'	34°16.62'	151°10.47'		124
Win	NSW	F	15/8/10	06:42	08:46	34°24.41'	151°19.58'	34°19.88'	151°22.63'		302
Win	NSW	F	15/8/10	10:28	12:27	34°16.55'	151°21.06'	34°21.62'	151°17.75'		174
Win	NSW	F	15/8/10	13:53	16:07	34°28.08'	151°14.7'	34°34.18'	151°11.53'		192
Win	NSW	F	16/8/10	06:19	08:00	34°35.21'	151°0.42'	34°40.13'	150°59.1'		113
Win	NSW	F	16/8/10	09:00	11:19	34°40.9'	150°55.27'	34°34'	150°57.68'		68
Win	NSW	F	18/8/10	06:23	08:26	34°42.32'	151°13.74'	34°37.75'	151°15.99'		475
Win	NSW	F	18/8/10	09:35	11:46	34°36.15'	151°16.04'	34°31.43'	151°18.72'		475
Win	NSW	F	18/8/10	13:19	15:20	34°30.74'	151°17.04'	34°36.13'	151°14.65'		338
Win	NSW	F	19/8/10	06:51	08:42	34°54.99'	150°54.77'	34°50.06'	150°53.22'		68
Win	NSW	F	19/8/10	10:08	12:15	34°52.52'	151°2.38'	34°47.13'	151°2.35'		132
Win	NSW	F	22/8/10	06:59	09:02	34°57.3'	151°8.11'	35°2.21'	151°5.99'		448
Win	NSW	F	22/8/10	11:22	13:28	35°3.29'	151°6.63'	34°57.97'	151°9.11'		640
Win	NSW	F	22/8/10	14:39	16:41	34°56.32'	151°9.73'	34°50.79'	151°11.64'		594
Win	NSW	F	23/8/10	06:35	08:32	34°58.43'	151°6.67'	35°3.44'	151°4.77'		338

Season	Region	Vessel	Date	Start Time	End time	Start Latitude	Start Longitude	End Latitude	End Longitude	Speed (kts)	Depth (m)
Win	NSW	F	23/8/10	10:23	12:31	35°3.78'	151°5.25'	34°58.19'	151°8.07'		457
Win	NSW	F	23/8/10	14:14	16:15	34°59.93'	151°3.81'	35°4.86'	151°1.96'		165
Win	NSW	F	24/8/10	05:58	07:47	35°13.9'	150°57.16'	35°18.05'	150°53.96'		238
Win	NSW	F	24/8/10	08:47	10:54	35°17.82'	150°54.26'	35°22.41'	150°50.54'		219
Win	NSW	F	30/8/10	05:52	08:17	35°29.29'	150°47.99'	35°36.38'	150°43.5'		539
Win	NSW	F	30/8/10	09:55	11:58	35°33.95'	150°44.66'	35°29.03'	150°47.38'		502
Win	NSW	F	30/8/10	13:20	15:18	35°31.82'	150°45.14'	35°27.17'	150°47.95'		375
Win	NSW	F	31/8/10	06:10	08:03	35°40.52'	150°40.62'	35°45.77'	150°37.17'		566
Win	NSW	F	31/8/10	10:25	12:23	35°46.16'	150°36.3'	35°51.39'	150°33.36'		494
Win	NSW	F	31/8/10	13:48	15:41	35°51.69'	150°31.69'	35°57.01'	150°28.8'		219
Win	NSW	F	1/9/10	06:50	09:01	35°53.93'	150°19.11'	35°48.81'	150°22.3'		110
Win	NSW	F	1/9/10	10:08	12:13	35°46.93'	150°26.09'	35°41.72'	150°27.29'		124
Win	NSW	F	1/9/10	13:22	15:21	35°40.53'	150°22.74'	35°36.3'	150°27.14'		82
Win	NSW	F	2/9/10	09:20	10:48	35°15.53'	150°41.96'	35°17.05'	150°38.27'		82
Win	NSW	F	6/9/10	07:04	09:12	35°58.5'	150°22.19'	36°4.74'	150°21.94'		123
Win	NSW	F	6/9/10	10:19	12:39	36°5.61'	150°24.31'	36°12.1'	150°22.88'		219
Win	NSW	F	6/9/10	14:11	16:20	36°10.71'	150°24.84'	36°16.17'	150°22.59'		512
Win	NSW	F	7/9/10	06:43	08:55	36°33.81'	150°16.32'	36°40.22'	150°15.47'		148
Win	NSW	F	7/9/10	10:05	12:11	36°40.44'	150°16.81'	36°34.11'	150°17.07'		163
Win	NSW	F	8/9/10	06:20	07:51	36°24.81'	150°21.72'	36°28.43'	150°21.94'		604
Win	NSW	F	8/9/10	10:52	13:07	36°38.53'	150°18.85'	36°44.55'	150°18.87'		247
Win	NSW	F	8/9/10	14:22	16:15	36°42.15'	150°20.73'	36°36.77'	150°20.28'		421
Win	NSW	F	8/9/10	17:06	19:06	36°36.05'	150°19.1'	36°30.59'	150°18.16'		274
Win	NSW	F	9/9/10	06:15	08:26	36°42.4'	150°7.61'	36°36.01'	150°7.84'		91
Win	NSW	F	11/9/10	06:57	08:51	36°24.47'	150°11.34'	36°18.87'	150°14.19'		91
Win	NSW	F	11/9/10	09:51	11:54	36°21.16'	150°19.19'	36°26.51'	150°18.14'		110
Win	NSW	F	11/9/10	13:58	16:02	36°27.46'	150°20.42'	36°21.78'	150°21.74'		475
Win	NSW	F	12/9/10	06:24	08:36	35°52.8'	150°31.66'	35°47.01'	150°35.03'		274
Win	NSW	F	12/9/10	10:51	12:57	35°37.66'	150°38.46'	35°32.42'	150°41.84'		150
Win	NSW	F	13/9/10	07:21	08:54	34°52.79'	150°51.88'	34°48.62'	150°50.62'		55
Win	NSW	F	13/9/10	10:51	12:55	34°48.9'	151°6.37'	34°43.76'	151°7.51'		183
Win	NSW	F	13/9/10	14:29	15:19	34°47.69'	151°8.68'	34°46.11'	151°9.13'	2.2	219
Win	NSW	F	14/9/10	06:21	08:27	34°22.61'	151°14.8'	34°17'	151°17.82'		146
Sum	NSW	GR	8/2/10	06:02	08:00	35°42.27'	150°37.21'	35°47.06'	150°34.42'	2.8	210
Sum	NSW	GR	8/2/10	09:40	11:46	35°54.46'	150°28.61'	35°59.98'	150°25.8'	2.9	139
Sum	NSW	GR	8/2/10	16:29	18:53	35°54.37'	150°17.36'	36°1.08'	150°15.49'	2.9	101
Sum	NSW	GR	9/2/10	05:42	08:13	36°18.67'	150°17.72'	36°25.99'	150°17.78'	2.9	137
Sum	NSW	GR	9/2/10	11:26	13:31	36°32.29'	150°13.04'	36°26.39'	150°14.32'	2.9	124
Sum	NSW	GR	10/2/10	05:45	07:56	36°47'	150°16'	36°54.17'	150°18'	2.9	154
Sum	NSW	GR	10/2/10	10:29	12:40	36°45.83'	150°8.3'	36°51'	150°7'	2.9	99
Sum	NSW	GR	10/2/10	17:49	19:54	37°18.62'	150°4.83'	37°24.53'	150°3'	2.9	88
Sum	NSW	GR	11/2/10	05:45	07:41	37°57'	149°52'	37°52.16'	149°56.96'	2.9	139
Sum	NSW	GR	11/2/10	09:10	11:15	37°46.01'	149°51.72'	37°40.53'	149°54.51'	2.9	119
Sum	NSW	GR	11/2/10	17:51	20:20	37°5.64'	150°19.33'	36°59.07'	150°18.83'	2.6	146
Sum	NSW	GR	12/2/10	05:41	07:31	37°13.35'	150°21.58'	37°7.75'	150°20.88'	2.9	283
Sum	NSW	GR	13/2/10	06:42	09:09	36°32.65'	150°19.98'	36°26.1'	150°20.35'	2.8	411
Sum	NSW	GR	13/2/10	11:39	13:42	36°14.98'	150°22.78'	36°9.76'	150°24.9'	2.8	475
Sum	NSW	GR	13/2/10	17:30	19:35	36°5.83'	150°21.53'	35°59'	150°23'	2.8	117
Sum	NSW	GR	14/2/10	06:12	08:20	36°6.41'	150°24.38'	36°0.68'	150°27.07'	2.9	247
Sum	NSW	GR	14/2/10	10:50	12:55	35°51.26'	150°18.7'	35°45.62'	150°21.06'	2.9	104
Sum	NSW	GR	14/2/10	17:46	19:59	35°51.02'	150°29.26'	35°45.24'	150°32.28'	2.9	137
Sum	NSW	GR	18/2/10	06:54	09:02	35°45.97'	150°35.86'	35°40.14'	150°39.55'	3.1	402
Sum	NSW	GR	18/2/10	12:49	14:50	35°19.46'	150°53.24'	35°14.65'	150°56.65'	2.8	219
Sum	NSW	GR	18/2/10	18:31	20:17	35°15.01'	150°44.89'	35°19.94'	150°43.61'	2.9	121
Sum	NSW	GR	19/2/10	06:28	07:35	34°48.39'	150°58.29'	34°45.84'	151°0.5'	2.9	117
Sum	NSW	GR	19/2/10	09:28	11:29	34°43.73'	151°11.68'	34°38.66'	151°13.25'	2.7	315
Sum	NSW	GR	20/2/10	05:50	07:50	34°32.96'	151°12.51'	34°27.34'	151°14.96'	3.0	201
Sum	NSW	GR	20/2/10	09:20	11:26	34°25.16'	151°20.8'	34°20.38'	151°24.09'	2.7	402
Sum	NSW	GR	20/2/10	17:48	19:59	34°17.3'	151°19.78'	34°12.71'	151°23.52'	2.7	159
Sum	NSW	GR	21/2/10	05:46	07:47	34°9.44'	151°15.92'	34°4.43'	151°19.26'	2.8	128
Sum	NSW	GR	21/2/10	12:51	14:57	33°43.78'	151°47.27'	33°39.11'	151°51.69'	2.9	219
Sum	NSW	GR	21/2/10	17:48	19:56	33°43.29'	151°45.13'	33°38.23'	151°48.76'	3.0	152
Sum	NSW	GR	22/2/10	06:47	08:56	33°37.19'	151°55.92'	33°41.99'	151°51.48'	2.9	338
Sum	NSW	GR	22/2/10	11:13	13:33	33°37.18'	151°57.69'	33°42.72'	151°53.52'	2.9	494
Sum	NSW	GR	22/2/10	18:00	19:59	33°37.28'	151°30.42'	33°41.72'	151°25.95'	3.0	82
Sum	NSW	GR	23/2/10	06:55	08:55	33°57.91'	151°44.69'	33°52.75'	151°47.31'	2.7	454
Sum	West	ME	1/2/10	11:26	13:37	37°12.45'	138°50.15'	37°12.6'	138°43.89'	3.0	510
Sum	West	ME	1/2/10	15:50	17:51	37°9.69'	138°32.3'	37°9.65'	138°39.44'	3.0	450
Sum	West	ME	2/2/10	07:13	09:14	37°23.52'	139°15.21'	37°18.45'	139°11.89'	3.1	154
Sum	West	ME	2/2/10	11:02	13:05	37°27.04'	139°9.76'	37°31.83'	139°11.26'	3.0	400
Sum	West	ME	2/2/10	15:01	17:01	37°34.43'	139°21.38'	37°35.9'	139°28.35'	3.2	505
Sum	West	ME	2/2/10	19:07	21:08	37°38.65'	139°37.03'	37°42.73'	139°41.85'	2.8	200
Sum	West	ME	3/2/10	06:24	08:26	37°50.67'	139°41.69'	37°54.37'	139°47.51'	2.9	600
Sum	West	ME	3/2/10	10:17	12:16	37°54.81'	139°58.39'	37°51.06'	139°53.04'	3.0	180
Sum	West	ME	3/2/10	13:00	14:56	37°50.85'	139°53.22'	37°47.12'	139°48.56'	2.9	175
Sum	West	ME	3/2/10	16:00	17:59	37°51.24'	139°47.61'	37°54.74'	139°53.48'	3.0	400
Sum	West	ME	4/2/10	09:50	11:50	37°56.01'	139°56.71'	37°59.36'	140°2.22'	2.7	350
Sum	West	ME	4/2/10	13:00	15:00	38°1.03'	140°7.48'	38°5.38'	140°12.53'	2.9	188
Sum	West	ME	4/2/10	15:40	17:40	38°4.55'	140°12.67'	38°8.58'	140°18.2'	2.7	182
Sum	West	ME	5/2/10	06:18	08:18	38°15.15'	140°27.52'	38°18.33'	140°33.98'	3.0	188
Sum	West	ME	5/2/10	09:10	11:11	38°17.65'	140°32.42'	38°20.34'	140°38.83'	3.1	190
Sum	West	ME	5/2/10	11:50	13:50	38°21.41'	140°38.85'	38°24.02'	140°45.48'	3.2	300
Sum	West	ME	5/2/10	14:45	16:45	38°23.22'	140°44.73'	38°26.3'	140°51.63'	3.1	255
Sum	West	ME	6/2/10	06:40	08:40	38°24.53'	140°55.63'	38°26.34'	141°2.28'	3.1	150
Sum	West	ME	6/2/10	10:40	12:40	38°33.17'	141°9.75'	38°37.84'	141°14.02'	3.2	280
Sum	West	ME	6/2/10	13:38	15:38	38°40.1'	141°12.29'	38°44.21'	141°17.03'	2.8	629
Sum	West	ME	7/2/10	06:40	08:40	38°56.4'	142°19.84'	38°53.32'	142°13.02'	3.1	175
Sum	West	ME	7/2/10	09:28	11:05	38°50.72'	142°7.25'	38°49.33'	142°3.61'	3.1	172
Sum	West	ME	7/2/10	13:01	15:02	38°48.72'	141°48.79'	38°47.98'	141°41.27'	3.2	325
Sum	West	ME	7/2/10	16:11	18:11	38°48.36'	141°43.76'	38°46.37'	141°36.87'	3.0	360
Sum	West	ME	8/2/10	06:34	08:34	38°27.05'	141°5.69'	38°29.07'	141°11.89'	3.1	150
Sum	West	ME	12/2/10	06:54	08:55	42°9.94'	144°43.1'	42°4.75'	144°41.02'	3.0	500
Sum	West	ME	12/2/10	09:56	11:55	42°3.83'	144°42.97'	41°57.99'	144°39.36'	3.1	180
Sum	West	ME	12/2/10	13:13	15:13	41°55.6'	144°33.32'	41°50.45'	144°31.38'	2.9	636
Sum	West	ME	12/2/10	17:13	17:39	41°40.65'	144°25.9'	41°39.09'	144°25.28'	2.9	550
Sum	West	ME	13/2/10	06:48	08:31	41°34.74'	144°24.63'	41°29.92'	144°24.11'	2.9	433
Sum	West	ME	13/2/10	12:26	14:13	41°22.35'	144°21.8'	41°19.13'	144°16.58'	3.0	380
Sum	West	ME	13/2/10	15:46	17:46	41°14.31'	144°8.35'	41°10.65'	144°2.43'	3.1	485

Season	Region	Vessel	Date	Start Time	End time	Start Latitude	Start Longitude	End Latitude	End Longitude	Speed (kts)	Depth (m)
Sum	West	ME	14/2/10	07:17	09:16	41°5.02'	143°55.25'	41°0.29'	143°50.36'	3.1	540
Sum	West	ME	14/2/10	10:52	12:52	41°2.56'	143°55.47'	40°57.88'	143°50.35'	3.0	420
Sum	West	ME	14/2/10	14:00	15:59	40°54.77'	143°46.54'	40°51.08'	143°42.88'	2.9	460
Sum	West	ME	15/2/10	06:53	08:52	40°23.46'	143°22.81'	40°17.75'	143°20.64'	3.0	500
Sum	West	ME	15/2/10	10:00	11:59	40°13.45'	143°18.4'	40°7.39'	143°15.44'	3.1	530
Sum	West	ME	15/2/10	13:14	15:14	40°3.82'	143°13.9'	39°58.4'	143°10.89'	3.2	515
Sum	West	ME	16/2/10	06:57	08:57	39°17.67'	142°43.49'	39°12.93'	142°39.22'	2.9	450
Sum	West	ME	16/2/10	10:13	12:13	39°10.17'	142°35.95'	39°6.3'	142°31.46'	3.0	540
Sum	West	ME	19/2/10	11:32	13:33	40°31.64'	143°26.4'	40°36.96'	143°29.44'	2.9	540
Sum	West	ME	19/2/10	15:35	17:32	40°33.92'	143°30.3'	40°38.58'	143°33.47'	2.7	200
Sum	West	ME	19/2/10	18:40	20:39	40°43.79'	143°38'	40°48.24'	143°42.29'	2.9	178
Sum	West	ME	20/2/10	10:15	12:19	42°23.09'	144°47.08'	42°28.13'	144°49.32'	2.7	650
Sum	West	ME	20/2/10	17:11	18:24	42°45.3'	144°54.41'	42°42.11'	144°54.42'	2.8	450
Sum	West	ME	21/2/10	06:29	08:29	43°38.28'	145°57.11'	43°34.12'	145°52.44'	2.9	160
Sum	West	ME	21/2/10	10:00	12:00	43°28.09'	145°47.02'	43°24.72'	145°41.74'	2.8	162
Sum	West	ME	21/2/10	14:25	16:25	43°17.72'	145°26.51'	43°13.77'	145°22.55'	2.8	205
Sum	West	ME	21/2/10	17:37	19:38	43°8.97'	145°18.26'	43°4.83'	145°14.29'	2.9	160
Sum	West	ME	23/2/10	08:23	10:22	40°42.88'	143°33.99'	40°47.16'	143°37.97'	3.0	507
Win	West	ME	29/7/10	10:29	12:27	38°12.67'	140°18.7'	38°15.83'	140°24.22'	3.0	411
Win	West	ME	29/7/10	13:27	15:15	38°14.38'	140°26.37'	38°10.9'	140°21.02'	3.0	180
Win	West	ME	29/7/10	15:48	17:47	38°10.6'	140°20.35'	38°6.6'	140°14.02'	3.1	185
Win	West	ME	30/7/10	07:47	09:42	37°26.32'	139°13.78'	37°31.32'	139°14.93'	2.9	300
Win	West	ME	30/7/10	10:54	12:54	37°32.93'	139°15.83'	37°28.88'	139°10.67'	2.9	352
Win	West	ME	30/7/10	14:03	16:04	37°28.52'	139°11.02'	37°33.17'	139°13.35'	3.0	375
Win	West	ME	30/7/10	17:00	18:59	37°34.82'	139°14.12'	37°31.63'	139°8.78'	3.0	420
Win	West	ME	31/7/10	09:53	11:23	37°7.88'	138°16.2'	37°9.02'	138°20.88'	2.9	450
Win	West	ME	31/7/10	15:47	17:47	37°8.93'	138°49.78'	37°10.82'	138°56.82'	3.0	169
Win	West	ME	3/8/10	09:05	11:05	37°23.52'	139°15.17'	37°18.77'	139°11.97'	3.0	150
Win	West	ME	3/8/10	12:27	14:30	37°24.93'	139°5.48'	37°31.6'	139°5.62'	3.0	635
Win	West	ME	4/8/10	07:55	09:55	37°38.73'	139°37.6'	37°43.33'	139°42.78'	3.1	177
Win	West	ME	4/8/10	12:14	14:14	37°51.7'	139°52.73'	37°55.8'	139°58.75'	3.1	232
Win	West	ME	4/8/10	15:38	17:38	38°1.17'	140°13.5'	38°6.18'	140°13.5'	3.2	182
Win	West	ME	9/8/10	12:11	14:12	43°12.62'	145°21.92'	43°17.52'	145°27.03'	3.0	175
Win	West	ME	9/8/10	17:35	19:31	43°11.85'	145°17.23'	43°15.57'	145°22.47'	3.0	465
Win	West	ME	10/8/10	07:11	09:11	43°24.95'	145°39.9'	43°28.63'	145°45.68'	3.0	168
Win	West	ME	10/8/10	10:34	12:34	43°27.33'	145°46.47'	43°31.58'	145°52.67'	3.1	156
Win	West	ME	10/8/10	13:10	15:10	43°33.92'	145°52.47'	43°39.22'	145°56.55'	3.0	166
Win	West	ME	11/8/10	07:35	08:39	42°45.12'	144°54.33'	42°42.08'	144°54.5'	2.9	420
Win	West	ME	13/8/10	10:35	12:32	42°24.7'	144°47.61'	42°29.74'	144°48.78'	2.7	680
Win	West	ME	13/8/10	14:52	16:36	42°19.1'	144°47.46'	42°14.23'	144°46.02'	3.0	475
Win	West	ME	14/8/10	08:22	10:22	42°11.99'	144°42.93'	42°7.44'	144°40.97'	2.6	630
Win	West	ME	14/8/10	11:29	13:30	42°8.3'	144°42.64'	42°3.45'	144°40.15'	2.7	495
Win	West	ME	14/8/10	14:26	16:26	42°6.7'	144°41.76'	42°12.17'	144°44.42'	3.0	455
Win	West	ME	15/8/10	06:54	07:54	42°15.38'	144°49.02'	42°12.83'	144°48.53'	2.7	175
Win	West	ME	15/8/10	10:25	12:30	42°4.54'	144°43.25'	41°59.35'	144°40.39'	2.9	187
Win	West	ME	15/8/10	13:32	15:33	42°3.29'	144°42.82'	41°57.85'	144°39.19'	3.2	181
Win	West	ME	16/8/10	16:33	18:33	41°56.35'	144°35.03'	41°51.5'	144°32'	2.8	485
Win	West	ME	17/8/10	10:25	12:25	39°19.4'	142°44.66'	39°13.97'	142°40.34'	2.7	470
Win	West	ME	17/8/10	14:17	16:18	38°57.6'	142°20.85'	38°53.93'	142°15.23'	3.2	181
Win	West	ME	17/8/10	16:50	18:50	38°52.8'	142°15.9'	38°50.12'	142°10'	3.1	178
Win	West	ME	18/8/10	07:04	09:05	38°55.76'	142°8.84'	38°53.61'	142°2.93'	2.7	640
Win	West	ME	18/8/10	10:12	12:00	38°52.42'	142°4.58'	38°55.44'	142°11.09'	3.1	395
Win	West	ME	22/8/10	10:44	12:44	39°56.95'	143°10.7'	40°2.68'	143°13.58'	3.0	450
Win	West	ME	22/8/10	13:35	15:35	40°4.72'	143°14.35'	40°9'	143°14.35'	2.9	655
Win	West	ME	22/8/10	16:30	18:30	40°12.07'	143°17.73'	40°17.75'	143°20.85'	3.2	540
Win	West	ME	23/8/10	07:01	09:01	40°52.75'	143°44.37'	40°52.52'	143°49.92'	3.1	450
Win	West	ME	23/8/10	11:04	13:04	40°57.47'	143°46.73'	41°2'	143°51.43'	3.0	590
Win	West	ME	23/8/10	16:55	18:55	41°19.17'	144°15.28'	41°23.08'	144°20.72'	3.1	450
Win	West	ME	24/8/10	06:57	08:57	41°19.97'	144°17.52'	41°23.5'	144°23.03'	3.2	375
Win	West	ME	24/8/10	10:20	12:20	41°32.68'	144°24.93'	41°38.12'	144°26.67'	2.8	380
Win	West	ME	24/8/10	13:34	15:34	41°37.17'	144°24.6'	41°42.88'	144°27.93'	2.9	500
Win	West	ME	24/8/10	16:40	18:40	41°44.27'	144°26.73'	41°50'	144°29.42'	2.7	680
Win	West	ME	25/8/10	15:46	17:46	40°48.02'	143°42.12'	40°43.32'	143°37.6'	3.0	180
Win	West	ME	26/8/10	06:45	08:45	40°40.67'	143°35.53'	40°35.85'	143°31.52'	3.0	210
Win	West	ME	26/8/10	13:26	15:26	40°7.08'	143°15.78'	40°2.02'	143°13.03'	3.0	530
Win	West	ME	27/8/10	07:39	09:39	38°53.68'	142°18.87'	38°51.27'	142°12.58'	3.0	157
Win	West	ME	27/8/10	10:37	12:37	38°53.37'	142°12.9'	38°50.3'	142°6.67'	2.9	170
Win	West	ME	27/8/10	13:22	15:23	38°51.92'	142°7.63'	38°48.62'	142°1.28'	3.2	175
Win	West	ME	27/8/10	16:08	18:08	38°50.37'	142°3.2'	38°47.82'	141°56.72'	3.2	180
Win	West	ME	28/8/10	07:27	09:27	38°52.28'	142°4.85'	38°50.43'	141°57.48'	3.0	352
Win	West	ME	28/8/10	10:16	12:15	38°50.12'	141°56.57'	38°49.67'	141°49.68'	2.9	380
Win	West	ME	28/8/10	14:08	16:08	38°45.85'	141°34.52'	38°43.77'	141°27.23'	3.0	190
Win	West	ME	28/8/10	16:37	18:37	38°43.62'	141°27.1'	38°39.53'	141°22.42'	3.0	180
Win	West	ME	29/8/10	07:04	09:04	38°49.57'	141°31.48'	38°49.33'	141°25'	2.9	650
Win	West	ME	29/8/10	10:30	12:30	38°44.25'	141°20'	38°40.97'	141°14.23'	2.9	500
Win	West	ME	29/8/10	13:15	15:15	38°40.77'	141°15.78'	38°43.88'	141°22.67'	3.1	412
Win	West	ME	30/8/10	06:45	08:41	38°39.34'	141°18.75'	38°41.3'	141°26.17'	3.0	184
Win	West	ME	1/9/10	07:50	09:51	38°34.61'	141°27.83'	38°40.16'	141°24.27'	3.1	152
Win	West	ME	1/9/10	11:56	13:56	38°30.47'	141°12.91'	38°27.4'	141°7.19'	3.0	145
Win	West	ME	1/9/10	15:11	17:11	38°25.9'	140°58.25'	38°23.7'	140°51.18'	3.0	154
Win	West	ME	2/9/10	06:19	08:19	38°26.7'	140°51.83'	38°24.09'	140°45.1'	2.8	320
Win	West	ME	2/9/10	08:57	10:56	38°22.88'	140°44.48'	38°20.17'	140°37.86'	3.0	220
Win	West	ME	2/9/10	11:41	13:40	38°20.1'	140°38.98'	38°17.3'	140°31.93'	3.0	180
Win	West	ME	2/9/10	14:29	16:29	38°17.95'	140°32.23'	38°14.72'	140°26.02'	3.0	250
Win	West	ME	3/9/10	06:50	08:50	38°19.95'	140°30.58'	38°23.16'	140°37.02'	3.0	500
Sum	East	WA	1/2/10	10:23	12:23	39°42.84'	148°46.86'	39°48.93'	148°46.02'	3.1	135
Sum	East	WA	1/2/10	13:09	15:10	39°50.97'	148°46.66'	39°56.79'	148°49.17'	3.0	134
Sum	East	WA	1/2/10	15:52	17:57	39°57.17'	148°49.39'	40°2.77'	148°51.4'	3.1	138
Sum	East	WA	2/2/10	06:34	08:33	41°16.01'	148°37.21'	41°22.11'	148°36.45'	3.0	123
Sum	East	WA	2/2/10	09:57	11:59	41°29.06'	148°35.24'	41°35.62'	148°34.6'	3.2	131
Sum	East	WA	2/2/10	14:55	16:54	41°33.99'	148°34.99'	41°40.3'	148°33.32'	3.2	126
Sum	East	WA	3/2/10	06:24	08:30	42°24.94'	148°23.55'	42°30.97'	148°20.56'	3.0	99
Sum	East	WA	3/2/10	09:08	11:12	42°32.19'	148°19.44'	42°38.74'	148°17.45'	3.3	98
Sum	East	WA	3/2/10	11:53	13:56	42°41.61'	148°15.83'	42°48.33'	148°14.26'	3.3	99
Sum	East	WA	3/2/10	15:50	17:51	42°55.9'	148°16.1'	43°2.3'	148°14.41'	3.3	130
Sum	East	WA	4/2/10	06:22	08:22	43°2.56'	148°11.96'	43°8.19'	148°8.19'	3.2	120
Sum	East	WA	4/2/10	09:49	11:54	43°5.86'	148°12.43'	43°11.96'	148°9.18'	3.1	152
Sum	East	WA	4/2/10	13:36	15:41	43°6.76'	148°10.4'	43°12.61'	148°5.89'	3.3	150

Season	Region	Vessel	Date	Start Time	End time	Start Latitude	Start Longitude	End Latitude	End Longitude	Speed (kts)	Depth (m)
Sum	East	WA	5/2/10	06:31	08:31	43°34.76'	147°28.71'	43°29.89'	147°34.59'	3.2	108
Sum	East	WA	5/2/10	10:58	12:01	43°40.98'	147°41.55'	43°38.89'	147°44.93'	3.1	144
Sum	East	WA	5/2/10	13:33	15:32	43°30.37'	147°48.62'	43°25.69'	147°53.88'	3.1	130
Sum	East	WA	5/2/10	16:23	18:23	43°22.75'	147°51.9'	43°19.22'	147°58.66'	3.0	130
Sum	East	WA	6/2/10	06:29	07:30	43°59.17'	146°25.58'	44°0.36'	146°29.4'	3.1	160
Sum	East	WA	6/2/10	10:38	11:47	44°1.31'	146°47.66'	44°1.91'	146°52.21'	2.9	165
Sum	East	WA	6/2/10	16:51	18:20	44°1.9'	147°0.88'	44°5.74'	147°4.07'	2.9	165
Sum	East	WA	8/2/10	06:37	08:38	42°44.62'	148°19.63'	42°38.66'	148°21.95'	3.1	113
Sum	East	WA	8/2/10	09:29	11:29	42°35.38'	148°25'	42°29.37'	148°26.65'	2.9	118
Sum	East	WA	8/2/10	13:01	15:04	42°32.3'	148°29.14'	42°26.93'	148°31.48'	2.9	441
Sum	East	WA	8/2/10	16:02	18:02	42°24.49'	148°32.42'	42°19.6'	148°33.7'	2.5	490
Sum	East	WA	9/2/10	06:19	08:21	41°12.44'	148°34.01'	41°6'	148°34.2'	3.2	113
Sum	East	WA	9/2/10	09:07	11:11	41°3.58'	148°32.43'	40°56.93'	148°31.91'	3.2	95
Sum	East	WA	9/2/10	14:31	16:37	40°57.15'	148°43.92'	40°51.39'	148°46.21'	2.9	422
Sum	East	WA	10/2/10	06:23	08:23	40°18.88'	148°50.86'	40°12.79'	148°51.25'	3.2	128
Sum	East	WA	10/2/10	09:00	11:00	40°12.12'	148°50.23'	40°6.34'	148°51.01'	3.0	127
Sum	East	WA	10/2/10	14:43	16:46	39°43.5'	148°38.37'	39°37.65'	148°38.85'	3.2	114
Sum	East	WA	12/2/10	06:07	08:08	39°21.56'	148°46.43'	39°16.03'	148°43.7'	2.9	470
Sum	East	WA	12/2/10	09:28	11:42	39°10.79'	148°42.98'	39°2.92'	148°39.78'	3.1	550
Sum	East	WA	12/2/10	15:10	17:14	39°16'	148°33.21'	39°9.59'	148°32.24'	3.1	88
Sum	East	WA	13/2/10	05:47	07:48	38°59.76'	148°25.02'	38°54.7'	148°20.28'	3.1	98
Sum	East	WA	13/2/10	09:24	11:26	38°45.94'	148°18.1'	38°40.17'	148°20.94'	3.1	120
Sum	East	WA	13/2/10	13:48	15:50	38°34.52'	148°28.83'	38°39.6'	148°25.79'	3.0	240
Sum	East	WA	14/2/10	06:42	08:51	38°14.25'	148°55.63'	38°16.19'	148°47.95'	3.0	160
Sum	East	WA	14/2/10	12:32	14:22	38°0.03'	148°57.93'	38°1.81'	148°50.3'	3.4	104
Win	East	WA	27/7/10	11:50	13:51	39°43.46'	148°42.58'	39°49.59'	148°45.75'	3.1	129
Win	East	WA	27/7/10	14:16	16:16	39°50.41'	148°45.88'	39°56.31'	148°46.67'	3.1	122
Win	East	WA	27/7/10	17:28	19:29	39°56.35'	148°39.86'	40°2.37'	148°42.45'	3.1	98
Win	East	WA	28/7/10	05:25	07:26	40°57.38'	148°31.92'	41°3.63'	148°32.4'	3.3	110
Win	East	WA	28/7/10	08:03	10:07	41°5.37'	148°34.2'	41°12.31'	148°33.94'	3.3	113
Win	East	WA	28/7/10	11:11	13:10	41°16.73'	148°37.11'	41°23.09'	148°36.43'	3.2	125
Win	East	WA	29/7/10	05:33	07:34	42°20.12'	148°33.55'	42°25.91'	148°31.75'	3.2	500
Win	East	WA	29/7/10	08:43	10:43	42°27.77'	148°31.61'	42°37.2'	148°28'	3.0	500
Win	East	WA	29/7/10	13:25	15:25	42°36.22'	148°27.8'	42°43.45'	148°24.97'	3.2	530
Win	East	WA	29/7/10	17:13	19:20	42°45.75'	148°23.71'	42°51.61'	148°21.74'	3.2	500
Win	East	WA	30/7/10	08:11	10:11	44°0.65'	146°55.3'	43°57.28'	146°48.11'	3.1	164
Win	East	WA	30/7/10	11:31	12:59	44°2.81'	146°53.66'	44°5.77'	146°58.32'	3.0	175
Win	East	WA	30/7/10	17:10	18:47	44°1.73'	147°0.76'	44°6.06'	147°4.34'	3.1	170
Win	East	WA	31/7/10	05:52	07:55	43°45.78'	147°49.85'	43°40.81'	147°54.74'	3.1	380
Win	East	WA	31/7/10	08:59	10:35	43°38.54'	147°52.81'	43°42.88'	147°49.91'	3.0	177
Win	East	WA	31/7/10	12:12	13:12	43°35.57'	147°45.8'	43°37.63'	147°42.74'	3.1	144
Win	East	WA	31/7/10	14:33	16:31	43°41.55'	147°35'	43°45.99'	147°29.51'	3.1	147
Win	East	WA	31/7/10	17:54	19:55	43°39.23'	147°26.49'	43°34.28'	147°31.97'	3.1	116
Win	East	WA	2/8/10	05:02	07:03	43°32.6'	147°29.44'	43°28.52'	147°36.06'	3.2	105
Win	East	WA	2/8/10	11:37	13:42	43°10.65'	148°6.8'	43°4.77'	148°11.05'	3.2	130
Win	East	WA	2/8/10	14:25	16:25	43°4.36'	148°13.73'	42°58.34'	148°15.94'	3.2	135
Win	East	WA	2/8/10	17:06	19:10	42°56.49'	148°15.99'	42°50.13'	148°18.34'	3.1	115
Win	East	WA	3/8/10	05:26	07:27	42°44.76'	148°18.53'	42°38.39'	148°19.71'	3.1	115
Win	East	WA	3/8/10	08:16	10:17	42°35.59'	148°18.88'	42°41.35'	148°15.99'	3.1	102
Win	East	WA	3/8/10	11:07	12:21	42°40.94'	148°20.46'	42°37.58'	148°22.8'	3.0	117
Win	East	WA	3/8/10	13:17	15:18	42°35.22'	148°24.53'	42°28.85'	148°26.04'	3.1	119
Win	East	WA	3/8/10	16:29	18:30	42°30.4'	148°21.28'	42°24.36'	148°24.46'	3.1	107
Win	East	WA	4/8/10	05:36	07:36	41°40.08'	148°33.49'	41°33.71'	148°35.19'	3.1	127
Win	East	WA	4/8/10	08:46	10:46	41°33.95'	148°38.51'	41°40.86'	148°37.04'	3.0	635
Win	East	WA	4/8/10	13:11	15:03	41°35.28'	148°27.72'	41°29.32'	148°28.64'	3.1	105
Win	East	WA	4/8/10	16:07	18:07	41°27.64'	148°25.05'	41°33.56'	148°25.7'	3.1	85
Win	East	WA	5/8/10	10:06	12:14	39°36.91'	148°47.93'	39°30.69'	148°46.66'	3.1	270
Win	East	WA	5/8/10	13:57	15:57	39°21.41'	148°46.36'	39°15.81'	148°43.89'	3.1	480
Win	East	WA	5/8/10	17:30	19:30	39°10.85'	148°42.99'	39°3.55'	148°40.66'	3.1	540
Win	East	WA	6/8/10	05:53	08:03	39°29.27'	148°45.93'	39°23.06'	148°44.3'	3.1	150
Win	East	WA	6/8/10	10:00	12:00	39°13.7'	148°34.85'	39°7.8'	148°31.19'	3.1	98
Win	East	WA	6/8/10	12:25	14:26	39°6.35'	148°30.18'	39°1.09'	148°25.48'	3.1	95
Win	East	WA	6/8/10	16:21	18:23	39°1.88'	148°37.99'	39°6.72'	148°40.58'	3.0	530
Win	East	WA	7/8/10	05:50	07:51	38°20'	148°52.35'	38°22.4'	148°44.8'	3.1	430
Win	East	WA	7/8/10	09:52	11:53	38°14.73'	148°34.84'	38°18.8'	148°28.7'	3.1	115
Win	East	WA	7/8/10	12:51	14:51	38°21.76'	148°26.69'	38°27.72'	148°23.89'	3.1	117
Win	East	WA	9/8/10	15:07	16:29	38°17.38'	149°8.78'	38°17.25'	149°13.41'	2.8	410
Win	East	WA	9/8/10	17:46	19:46	38°12.36'	149°10.05'	38°8.91'	149°14.36'	2.8	153
Win	East	WA	10/8/10	05:52	07:52	38°14.13'	149°43.7'	38°12.68'	149°50.22'	3.0	540
Win	East	WA	10/8/10	08:27	10:27	38°11.19'	149°50.67'	38°8.2'	149°56.81'	3.1	450
Win	East	WA	10/8/10	11:43	13:43	38°11.37'	149°53.94'	38°7.85'	149°58.38'	3.1	540
Win	East	WA	10/8/10	14:30	16:31	38°7.7'	149°58.73'	38°4.27'	150°4.88'	3.0	530
Win	East	WA	11/8/10	05:59	07:41	36°45.86'	150°11.86'	36°51.2'	150°11.21'	3.0	120
Win	East	WA	11/8/10	09:00	11:03	36°51.41'	150°16.95'	36°57.59'	150°18.31'	3.2	165
Win	East	WA	11/8/10	11:42	13:59	36°59.21'	150°18.6'	37°6.46'	150°19.43'	3.1	140
Win	East	WA	11/8/10	15:13	17:13	37°10.92'	150°20.91'	37°17.26'	150°20.41'	3.0	160
Win	East	WA	12/8/10	05:31	07:31	36°47.17'	150°2.87'	36°53.64'	150°2.94'	3.0	68
Win	East	WA	12/8/10	09:05	11:05	37°2.9'	150°9.35'	37°9.23'	150°7.3'	3.1	90
Win	East	WA	12/8/10	12:07	14:09	37°9.12'	150°14.15'	37°15.02'	150°14.79'	3.0	110
Win	East	WA	12/8/10	15:26	17:28	37°19.82'	150°14.62'	37°23.93'	150°13.38'	2.4	125
Win	East	WA	13/8/10	05:27	07:32	37°30.19'	150°13.39'	37°35.25'	150°11.54'	2.7	160
Win	East	WA	13/8/10	09:54	11:54	37°38.71'	149°56.02'	37°43.77'	149°53.61'	2.8	110
Win	East	WA	13/8/10	13:29	15:32	37°49.35'	150°2.52'	37°54.5'	149°59.01'	2.6	140
Win	East	WA	13/8/10	17:04	19:05	37°48.95'	149°50.4'	37°52.22'	149°44.36'	3.0	130
Win	East	WA	14/8/10	09:40	11:47	37°38.97'	150°13.03'	37°44.69'	150°10.72'	3.1	310
Win	East	WA	14/8/10	12:46	14:46	37°43.96'	150°11.25'	37°48.77'	150°8.01'	3.1	305
Win	East	WA	14/8/10	15:42	17:42	37°53.25'	150°9.69'	37°59.06'	150°7.57'	3.1	540
Win	East	WA	14/8/10	18:27	20:31	37°58.33'	150°6'	37°53.25'	150°8.47'	3.0	440
Win	East	WA	15/8/10	05:26	07:26	37°57.58'	150°6.78'	38°4.04'	150°2.93'	3.0	450
Win	East	WA	15/8/10	08:47	10:47	38°4.42'	149°55.21'	38°7.54'	149°49.05'	3.0	240
Win	East	WA	15/8/10	12:07	14:07	38°2.07'	149°44.12'	38°0.39'	149°52.33'	3.0	143
Win	East	WA	15/8/10	15:59	17:59	37°51.92'	149°45.04'	37°55.57'	149°38.98'	3.0	128
Win	East	WA	16/8/10	05:26	07:26	38°12.67'	149°10.17'	38°12.61'	149°2.59'	3.0	145

Appendix 8 - Workshop Participants and Agenda 21–22 SEPT 2009

Day 1 Workshop Participants:

Attendees	
Mike Fuller (CSIRO) Russell Hudson (Fishwell) Neil Klaer (CSIRO) Ian Knuckey (Fishwell, PI) Matt Koopman (Fishwell)	David Peel (CSIRO) Mark Bravington (CSIRO) Tony Smith (CSIRO) Natalie Kelly (CSIRO) Jeremy Prince (Biospherics)

AGENDA - Day 1 - Scientific Details

Item / Topic	Speaker
Welcome / Introduction	Ian Knuckey
Design of 2008 survey - Sampling method - Use of logbook data for FIS design	Mark Bravington David Peel
Summary of 2008 survey results - Conducting the survey (theory vs. reality) - Fish capture and sales	Ian Knuckey
Re-analysis of 2008 survey - CVs achieved - statistical methods - 2010 design proposal	Mark Bravington David Peel
Proposed design for 2010 survey - Statistical design - Practical implementation	Workshop discussion
Way forward for ongoing survey - Final analyses - Appropriate CVs - Incorporation of results into assessments	Workshop discussion

Day 2 Workshop Participants:

Attendees	
Mike Fuller (CSIRO) Russell Hudson (Fishwell) Neil Klaer (CSIRO) Ian Knuckey (Fishwell, PI) Matt Koopman (Fishwell) David Peel (CSIRO) Mark Bravington (CSIRO) Tony Smith (CSIRO) Natalie Kelly (CSIRO) Jeremy Prince (Biospherics) Tanya Hughes (Workshop secretary)	Steve Auld (AFMA) Shane Gaddes (AFMA) Crispian Ashby *or Carolyn Stewardson* (FRDC) Sandy Morison (SlopeRAG) Simon Boag (SETFIA) Tom Bibby (SETFIA) Jeff Moore (GABIA) Semi Skoljarev (GABIA) Les Scott (SEFA) Will Mure (SEFA) David Guillot (SETFIA)

AGENDA - Day 2 - An Industry-based Fishery Independent Survey

Item / Topic	Speaker
Welcome / Introduction	Ian Knuckey
Design of the 2008 survey - Approach - Use of Industry vessels	Ian Knuckey Mark Bravington David Peel
Summary of 2008 survey results: - Conducting the survey (theory vs. reality) - Fish capture and sales - CVs achieved (What's in and what's out)	Ian Knuckey
Proposed design for 2010 survey - Design Improvements - Implementation	Ian Knuckey Mark Bravington David Peel
Way forward for ongoing survey - Final analyses - Appropriate CVs - Incorporation of results into assessments - Potential costs to industry - Is it worth it?	Workshop discussion

Appendix 9 - Workshop Participants and Agenda 23–24 JUNE 2011

Attendance at workshop and apologies received from invitees:

Attendees	Apologies
Mike Fuller (CSIRO)	Mark Bravington (CSIRO)
Russell Hudson (Fishwell)	Tony Smith (CSIRO)
Neil Klaer (CSIRO)	Crispian Ashby (FRDC)
Ian Knuckey (Fishwell, PI)	Tony Bagnato (SETFIA)
Matt Koopman (Fishwell)	Brian Bailey (SSFI)
David Peel (CSIRO)	Tom Bibby (SETFIA)
Simon Boag (SETFIA)	Anthony Ciconte (SSIA)
Neil Hughes (AFMA)	Beth Gibson (AFMA)
John Jarvis (SETFIA)	David Guillot (SETFIA)
Brad Milic (AFMA)	Jeff Moore (GABIA)
Jemery Day (CSIRO)	Sandy Morison (SESSFRAG)
Judy Upston (CSIRO)	Will Mure (Longline)
David Galeano (AFMA)	Joe Raschilla (SETFIA)
Shane Duggins (Industry)	Les Scott (Longline)

AGENDA - Day 1 - Scientific details and survey outputs

Item/Topic	Speaker
Welcome / Introduction	Ian Knuckey
Design of 2010 survey - Sampling method - Use of 2008 data to modify design - Final design	Ian Knuckey Mark Bravington David Peel
Summary of 2010 survey results - Conducting the survey (theory vs. reality) - Data obtained (Catch rates / length frequencies / other) - Budget and fish sales - Other issues	Ian Knuckey & Survey skippers Matt Koopman Ian Knuckey
Comparative analysis of 2008 and 2010 results - Statistical methods - CPUE CVs achieved - Species CV achievement - Areas for improvement - Implications for research / management	Mark Bravington David Peel Ian Knuckey
Overview of survey results - Data obtained - Potential use of data - Incorporation of results into assessments - Management implications	Workshop discussion

Agenda Day 2 – Ongoing SESSF Fishery Independent Surveys?

Item/Topic	Speaker
Welcome / Introduction Summary of Workshop Day 1	Ian Knuckey
FIS case study from the GABTF	Jeff Moore / Jim Raptis
Ongoing SESSF FIS surveys? - Project proposal 2010/817 - Value of information obtained (Target species / Bycatch & Byproduct) - Support for Industry-based surveys - Logistics and practical issues - Budget and costs - Finalisation of project proposal	Workshop discussion
Workshop summary	Ian Knuckey

Appendix 10 - A model-based approach to designing a fishery independent survey

A Model-Based Approach to Designing a Fishery-Independent Survey

D. PEEL, M.V. BRAVINGTON, N. KELLY, S.N. WOOD, and I. KNUCKEY

This paper uses Generalized Additive Models to evaluate model-based designs for wildlife abundance surveys where substantial pre-existing data are available. This is often the case in fisheries with historical catch and effort data. Compared to conventional stratified design or design-based designs, our model-based designs can be both efficient and flexible, for example in allowing uneven sampling due to survey logistics, and providing a general framework to answer specific design questions. As an example, we describe the design and preliminary implementation of a trawl survey for eleven fish species along the continental slope off South-East Australia.

Key Words: Fishery-independent surveys; Generalized additive models; Model-based design; Tweedie distribution.

1. INTRODUCTION

This paper describes a model-based approach to survey design for wildlife abundance estimation. Managing wild animal populations requires high-quality data on their abundance and distribution, and a great deal of consideration can go into designing and running surveys for that purpose. Marine fish stocks can be particularly difficult to monitor, as they cannot be counted directly and their spatial distributions can vary greatly over time. Fishery-independent surveys (FIS) are one of the most valuable tools for fish stock assessment, and underpin the provision of management advice in numerous major groundfish fisheries, e.g., Gulf of Alaska (Britt and Martin 2001), East Coast of North America (Doubleday 1981), and the North Sea (Cotter 2001). It is usually not possible to get an estimate of absolute abundance, and the objective is rather to obtain a time series of consistent relative abundance indices from repeat surveys. To demonstrate the model-based approach,

D. Peel (✉) is a Research Scientist (E-mail: *david.peel@csiro.au*), M.V. Bravington is a Senior Research Scientist, N. Kelly is a Research Scientist, Wealth from Oceans National Research Flagship and CSIRO Mathematics, Informatics and Statistics, Castray Esplanade, Hobart TAS 7001, Australia. S.N. Wood is Professor, Mathematical Sciences, University of Bath, Bath, BA2 7AY, UK. I. Knuckey is Director, Fishwell Consulting, 22 Bridge St., Queenscliff VIC 3225, Australia.

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