Marine and Freshwater Resources Institute

Integrated Scientific Monitoring Program Development of a “design model” for an adaptive ISMP sampling regime

Final report to the
Australian Fisheries Management Authority

December 2001

Ian Knuckey
& Anne Gason

ARF Project R99/1502

State Government Victoria
Department of
Natural Resources
and Environment

Victoria
The Place To Be

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NON-TECHNICAL SUMMARY

R99/1502	Development of a "design model" for an adaptive ISMP sampling regime.

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OBJECTIVES:

1. To develop a "design model" for updating the ISMP sampling regime to reflect the most recent data available from the trawl and non-trawl sectors of the SEF.
2. To provide a statistically sound basis for maintaining a cost-effective sampling regime for estimating the total catch (retained and discarded) and length/age composition of quota species and other species caught by the trawl and non-trawl sectors of the SEF.

Non-Technical Summary

The South East Fishery (SEF) is a commonwealth-managed multi-species fishery comprising of both trawl and non-trawl vessels working in the waters off south eastern Australia. The Integrated Scientific Monitoring Program (ISMP) was established in 1994 to provide essential information on the species composition of the retained and discarded catch from the SEF and the size and age composition of selected quota and non-quota species.

Over the last three years, the original ISMP sampling design (Smith *et al.* 1997) has proven to be statistically robust, meeting virtually all of the target CVs for estimates of discard rates and length frequency distributions for all species (Knuckey and Sporcic 1999, Knuckey 2000, Knuckey *et al.* 2001). In each of these reports, however, it was noted that there were cases in which target sea-days for a particular strata were not achieved because of significant changes in the fleet dynamics of the fishery when compared to the data on which the ISMP design was originally based.

Due to changes in fleet dynamics, patterns of discarding, the addition of new strata in the trawl sector as well as the availability of data for the non-trawl sector, it became apparent that

there was a pressing need to review the ISMP sampling regime so that it was better able to reflect the dynamics of the fishery and include monitoring of the non-trawl fishery. It was recognised that in a complex and dynamic fishery such as the SEF, any revision would need to be undertaken on a regular basis to ensure that the monitoring program adequately sampled fishery, yet the ongoing process needed to be relatively automated to minimise the costs involved. The present study has addressed this need by developing an 'adaptive survey design strategy' that utilises past information as well as the most recent logbook and ISMP data to revise the ISMP sampling strategy on an annual basis.

A Bayesian framework was used to incorporate prior information and then apply these priors to update the sampling design, thereby providing a basis for adjusting the intensity and spatial distribution of the sampling to meet the level of precision required for the management needs of SEFAG, SETMAC and AFMA and for input into agreed stock assessment models.

BACKGROUND

The South East Fishery (SEF) is a commonwealth-managed multi-species fishery comprising of both trawl and non-trawl vessels working in the waters off south eastern Australia. Catch and effort logbook data (SEF1) has been collected by the Australian Fisheries Management Authority since 1986 and when quota controls were introduced in 1992, quota monitoring data also became available. The Integrated Scientific Monitoring Program (ISMP) was established in 1994 to augment these data with essential information on the species composition of the retained and discarded catch and the size and age composition of selected quota and non-quota species. To achieve this, the ISMP has two main data collection components: at-sea monitoring of the composition of trawl catches by on-board field scientists; and port-based collection of length frequency information on the landed catches of both trawl and non-trawl vessels.

The objective of the current ISMP sampling regime, designed by Smith *et al.* (1997), was to provide estimates (within specified error bounds) of the total catch (retained and discarded) of quota and non-quota species and the size and age composition of selected quota species. To enable this, the fishery was characterised using quota monitoring and logbook information from 1992 to 1996 inclusive, together with data from the ISMP's predecessor, the Scientific Monitoring Program. These extensive data sets provided the spatial and temporal information that allowed stratification of the fishery based on species composition, fishing methods and port groups. Three species-specific target fisheries were recognised (orange roughy, spawning blue grenadier and royal red prawn) but sections of the fishery targeting a mixed species catch were more difficult to categorise and required grouping into "inshore" and "offshore" (equivalent to shelf and slope) reflecting the difference in species assemblages with depth. A further factor considered was the size of vessel landings (high volume and low volume). Overall, 14 strata were defined (Table 1). The amount of sampling required in each stratum reflected the species composition and the relative discard rates (% of catch discarded) of these species. Significant emphasis was given to the estimation of discard rates as this is typically the most difficult and expensive component of such a program. Species were grouped by discard rate into three groups: low (<5%), moderate (5–20%), and high (>20%) for which the target coefficients of variation (CVs) were 1.5, 0.8 and 0.4 respectively. Simulation modelling was used to determine the number of trips required in each stratum to achieve these targets. Further, to account for seasonal variation in fishing effort, the annual number of trips per stratum were divided into months based on the monthly proportion of commercial fishing shots per stratum recorded in the SEF1 and SEF2 databases.

Over the last three years, the ISMP sampling design has proven to be statistically robust, meeting virtually all of the target CVs for estimates of discard rates and length frequency distributions for all species (Knuckey and Sporcic 1999, Knuckey 2000, Knuckey *et al*. 2001). In each of these reports, however, it was noted that there were cases in which target sea-days for a particular strata were not achieved because of significant changes in the fleet dynamics of the fishery when compared to the data on which the ISMP design was originally based. For example, the original sampling design did not reflect the increasing proportion of southern NSW and Lakes Entrance/Eden vessels that now move south to fish off eastern Tasmania over the summer period. Also, in the initial design there was both inshore and offshore strata for the Lakes Entrance/Eden vessels and these vessels often fished either one or the other in any given trip but current ISMP and SEF1 data indicated that vessels now often fished both strata within the one trip. Furthermore, patterns of discarding of many species have changed over time to an extent where the original discard classification (and target CVs) were no longer applicable.

Another issue was that when the ISMP sampling regime was designed, there was no on-board monitoring information available on the non-trawl sector. As such, the non-trawl sector could not be included as a statistically valid stratum within the design. To rectify this, a pilot monitoring program was undertaken during 1999/2000 to monitor the amount and composition of the retained and discarded catches of SEF non-trawl vessels. This program has now been completed and the data has been analysed (Knuckey *et al*. 2001a) so that on-board monitoring of non-trawl vessels can now be incorporated into a "unified" ISMP sampling design.

Overall, it was apparent that there was a pressing need to review the ISMP sampling regime so that it was better able to reflect the dynamics of the fishery and include monitoring of the non-trawl fishery. It was recognised that in a complex and dynamic fishery such as the SEF, any revision would need to be undertaken on a regular basis to ensure that the monitoring program adequately sampled fishery, yet the ongoing process needed to be relatively automated to minimise the costs involved. The present study has addressed this need by developing an 'adaptive survey design strategy' that utilises past information as well as the most recent logbook and ISMP data to revise the ISMP sampling strategy on an annual basis. A Bayesian framework was used to incorporate prior information and then apply these priors to update the sampling design, thereby providing a basis for adjusting the intensity and spatial distribution of the sampling to meet the level of precision required for the management needs of SEFAG, SETMAC and AFMA and for input into agreed stock assessment models.

OBJECTIVES

1. To develop a "design model" for updating the ISMP sampling regime to reflect the most recent data available from the trawl and non-trawl sectors of the SEF.
2. To provide a statistically sound basis for maintaining a cost-effective sampling regime for estimating the total catch (retained and discarded) and length/age composition of quota species and other species caught by the trawl and non-trawl sectors of the SEF.

METHODS

Data inputs

The data used to develop the 'design model' included: catch and effort logbook information from the trawl sector (SEF1) and non-trawl sector (GN01 and GN01a); catch landings information for quota species (SEF2), on-board scientific observer monitoring of trawl fishing during the 7-year period 1993-2000; on-board scientific observer monitoring of non-trawl fishing during the 15 months March 1999-May 2000; and port-based measuring for both sectors. Details of these datasets are provided below.

SEF1 and GN01(a)

These data were obtained from compulsory logbooks filled out by the skipper of each vessel permitted to operate in the SEF. The data were stored on the Australian Fishing Zone Information System (AFZIS), an INGRES relational database. SEF1 data were obtained for the period 1993 to 2000 and GN01(a) data were obtained from 1998 to 2000. The information used from each logbook record included:

Boatname
Date
Operation (shot) number
Fishing method
Fishing activity
Start position (latitude and longitude)
End position (latitude and longitude)
Species name
Estimated weight of species caught

SEF2

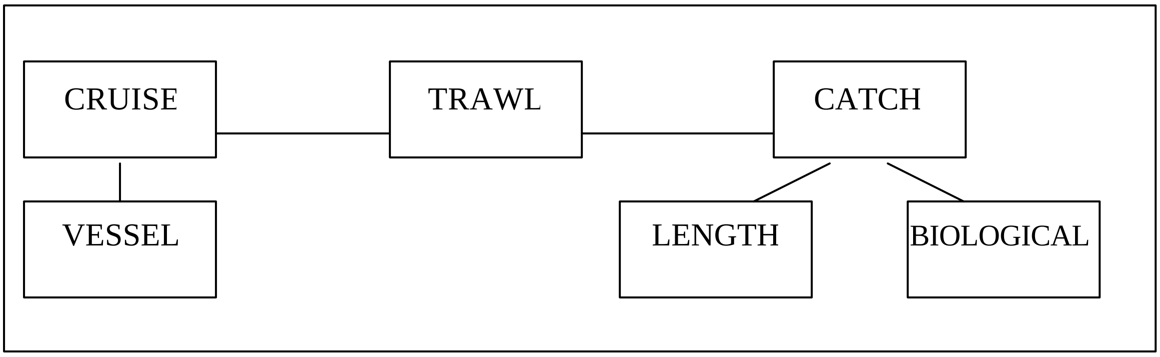
The SEF2 data, also stored on AFZIS, were used by AFMA to monitor the catch of species against their TAC's. The data were obtained from fishers at the end of each fishing trip.

SEF2 data for the period 1992 to 2000 were used. The information used from each SEF2 record included:

Boatname
Date
Port landed
Processor
Transport company
Species name
Weight of species caught

On board monitoring (trawl and non-trawl)

The trawl data collected by the on-board observers with the ISMP (and its predecessor, the SMP) were extremely detailed. They were stored in a relational database comprised of six tables as shown below. These ISMP data from trawlers were used for the period 1993 to 2000. The on-board data for the non-trawl vessels was very similar to that of the ISMP but it was only collected from the Pilot Non-trawl Monitoring Program that ran from March 1999 to May 2000.



The CRUISE table was the parent table to which all other tables refer. It contains information about each cruise or trip by a SEF vessel which has an observer on board. Each cruise is uniquely identified by two fields: Callsign and Cruisedate.

The VESSEL table contains information about the vessel, its skipper and the crew. All information on the specifications of the vessel, the electronic equipment, hold/freezer capacity, etc, was recorded, along with information on the experience of the skipper and crew. It was linked to the CRUISE table by Callsign.

The TRAWL table contains information on the time and position of each individual trawl or Danish seine shot as well as an estimation of the weight of the retained and discarded catch.

In addition, the table has information on the weather and substrate conditions during the shot and the specifications of the gear. Each record was linked to the CRUISE table by Callsign and Cruisedate and identified by Shotdate and Shotnumber.

The CATCH table contains information on the catch composition of each shot. The estimated retained and discarded weight of each species were recorded as well as the percentage of the catch of that species which was sampled and measured. Each record was linked to the TRAWL table by Callsign, Cruisedate, Shotdate and Shotnumber and was identified by Species (using its CSIRO code).

The LENGTH table contains information on the length frequency of the species measured. Each record was linked to the CATCH table by Callsign, Cruisedate, Shotdate, Shotnumber and Species.

The BIOLOGICAL table contains any biological information that may have been collected from individual fish. It includes information on sex, weight, gonad condition, and whether otoliths were collected. Each record was linked to the CATCH table by Callsign, Cruisedate Shotdate, Shotnumber and Species.

Port measuring

The port-measuring aspect of the ISMP was designed to collect length frequency and other biological information from the landed catch. The database included two tables, the OPERATIONAL table and the LENGTH table.

The OPERATIONAL table was the parent table. It contains information on the date, vessel, area fished and port landed as well as data on the weight and number of each species landed and sampled.

The LENGTH table contains information on the length of each fish that was sampled. Each record was linked to the OPERATIONAL table by Date, Vessel and Species.

Merging SEF1 and SEF2 datasets

In order to estimate the catch weight and composition of SEF trawl landings for any strata, it was necessary to match-merge data from both the SEF1 and SEF2 datasets. This was because only the SEF1 database has species composition together with the gear, position and depth information needed to allocate it to a certain strata, whereas the SEF2 database has the more accurate figures on the actual landed catch of quota species.

In theory, all of the landed quota catch information in one vessel's SEF2 record should match up with the sum of quota catches recorded for each shot of the vessel's most recent trip. In practice, however, this was often not the case. AFMA does not reconcile the SEF1 and SEF2 databases for validation and as a result, discrepancies between these datasets with respect to dates, boat names, ports and amount and type species landed prevent the match-merging of a significant number of records on a trip-by-trip basis. As a result, there was a "dropout" of records from one dataset which do not match up with records of the other dataset. It was beyond the scope of the current project to undertake any validation and correction of these datasets. Instead, we investigated various ways of match-merging on different spatial and temporal scales to reduce the proportion of dropouts without compromising the objectives of the project. The assumptions that were made with respect to these two datasets were that the landed weights of quota species in the SEF2 were correct and the relative catch composition of quota species and position and depth information recorded in the SEF1 logbooks were correct.

Stratification

The stratification of the fishery used for the ISMP design model was based on information derived from a number of different sources. Much of it came from the initial stratification developed by Smith *et al.* (1997) (Table 1). The ISMP had been operating under this stratification for over three years at the time of this study and there had been good feedback on its effectiveness and practical application. The problems that had become apparent over the last few years were reviewed using information contained in the annual ISMP reports presented to SEFAG (Knuckey and Sporcic 1999; Knuckey 2000; Knuckey *et al.* 2001) and the authors' detailed knowledge of the operation of the ISMP. Changes to the stratification prior to its incorporation into the ISMP design model were suggested.

Simulation modelling and estimation of discard rates and corresponding CVs.

Initially, ISMP data from 1993 to 2000 was used to investigate the variation of the discard rate CV and the probability of achieving the target CV for each species in each stratum for various sample sizes. All data manipulations, programming and simulations were carried out using the software package SAS.

Information on discard rates was available for each year from 1993 onwards. Each ISMP shot was assigned to a stratum based on its region x gear x depth x catch composition characteristics. The total number of shots observed by the ISMP in each stratum for each year is presented in Table 2. A standardised sample pool was created for each stratum by randomly selecting shots from the total observed in that stratum across all years. Due to the potential for changing discard practices over time (a feature that was evident in the ISMP data), greater weighting was placed on the discard rates of the more recent years. To do this, we compensated for differing annual sampling intensities and adjusted the number of shots available to be selected for each year so that the probability of selecting a shot from the most recent year was set to 1.0, and the probability of selecting a shot from the previous year (y-1) was set to 0.8 each preceding year. Table 3 displays the probability of selecting a shot from within a specific year and the expected final composition of yearly shots in the standardised sample pool. This random selection of shots for the sampling frame was newly created for each simulation. To undertake the simulations, shots, from 1 to the maximum available were randomly selected from the pool and the discard rate and CV were calculated for each sample. This procedure was repeated 500 times to estimate discard rates and CVs for the main quota species in each stratum for differing numbers of shots. For each quota species, calculations were made based on the defining strata as indicated by Table 4. Catches of quota species in non-defining strata were combined into an additional stratum 'Other' and were included in the calculations.

The mean discard rate and corresponding CV for each species in each stratum was calculated according to the following formulae:

The mean discard rate $\overline{D}_{si}$ for species s in stratum i is given by

$$\overline{D}_{si} = \frac{1}{k}\sum_{j=1}^{k}\frac{d_{sij}}{d_{sij}+r_{sij}}\times 100 \quad \text{where } i \in \{1,n\} \text{ and trip } j \in \{1,k\}.$$

The mean discard rate for species s was weighted up using landed SEF catches by

$$D_{s.} = \frac{\sum_{i=1}^{n}\overline{D}_{si}\times L_{si}}{\sum_{i=1}^{n}L_{si}}$$

, where L_{si} is SEF landed catch for species s and stratum i.

The variance of the discard rate $V(\overline{D}_{s.})$ for species s is given by

$$V(\overline{D}_{s.}) = \frac{\sum_{i=1}^{n}L_{si}^{2}V(\overline{D}_{si})}{\left(\sum_{i=1}^{n}L_{si}\right)^{2}}$$

, where $V(\overline{D}_{si})$ is the variance of the discard rate of species s, stratum i.

Due to the nature of the on-board observations, the number of shots in each individual stratum will be the same for each defining species in that stratum. The expected CV of discard rates will differ between species within a stratum and also between strata for each species.

Therefore, to estimate the appropriate number of shots across the fishery that was required to achieve the target CV for all species, it was necessary to achieve the optimal combination of shots from each stratum. This optimal combination of shots was achieved by calculating the standard deviation of the discard rate weighted by the SEF catch of each species in each stratum and then summing these values for each stratum. This provided a relative number of shots between strata that allocated more shots where variation of discard rate and SEF landed catches were greater.

Keeping this relative number of shots between each stratum constant, the discard rate and corresponding CV across all defining strata and well as the discard rate and corresponding CV across the entire fishery were calculated for each simulation.

All simulations were combined to estimate the minimum number of shots (S_{min}) required to achieve the target CV for each species across all strata with 95% probability. The target CVs were 1.5 if discard rate was <25%, 0.8 if discard rate was 25 - 40%, 0.4 if discard rate was >40%.

The number of shot-days was also calculated. Shot-days was defined as all days when a shot occurs.

For each species, the relative number of shots for each month within each stratum was in the same proportions as the landed weights for the strata as reported by the SEF logbook data.

Sampling for length and age

Sampling for length and age was discussed in detail in Smith *et al.* (1997). Broadly similar principles can be applied to length and age sampling as to sampling for discards. The approach taken here was to consider total length frequency distributions and age-length keys.

The at-sea component of the ISMP provided size distributions for retained and discarded catches by strata, which was supplemented by port-based sampling. Determining into which stratum to place a trip when sampling the landed catch for length and age frequency can be done after the trip has taken place. The same stratification as used for discard estimation was used for sampling for length. For age, the costs of ageing large numbers of fish prohibit individual age-length keys for each stratum unless, of course, there were known differences in growth. Generally, otolith samples for age estimation were taken from the landed catch during port-based activities.

Simulation modelling was used to assess the precision of sampling intensity for both lengths and age-length keys. Methods were similar to those described by Sullivan *et al.* (1994). For length frequency distributions, the data used for these simulations was taken from port-based sampling and for the age-length keys, from the Central Ageing Facility database.

The estimated sample sizes for both age and particularly length, should be regarded as a minimum.

Length frequency distributions.

The primary question when sampling catches to provide representative length frequency distributions is how many samples are required and how many fish should be in each sample. The simulation modelling was undertaken to provide a matrix of the number of samples required and the corresponding number of fish in each sample.

For each simulation, a number of samples were randomly selected from all port samples (each combination of callsign and date was considered one sample). The number of samples varied in steps of 20, from 20 to 200. From these samples, a number of fish were randomly selected. The number of fish per sample also varied in steps of 20, from 20 to 200. The mean weighted coefficient of variation (MWCV) was calculated for each combination of sample size and sample number.

A total of 500 simulations were completed for each combination and the MWCV calculated. Optimal sample sizes for each number of samples were taken at the point at which the change in MWCV was less than 1% for an increase of 20 in the number of fish in the sample. Larger sample sizes give only a small increase in precision of the length frequency distribution.

Age-length keys

Smith *et al.* (1997) used similar simulations as described above to estimate the optimum sample size for age-length keys for combined sexes and the sexes separately. These sample sizes were still relevant as age-length keys have not changed for the majority of species and because sample sizes were set by SETMAC as much on the basis of this information as on other information relating to management issues. The optimal sample sizes developed by Smith *et al.* (1997) were similar to those currently used by the Central Ageing Facility.

RESULTS & DISCUSSION

Data inputs

Merging SEF1 and SEF2 datasets

Due to errors and anomalies in the two datasets, data often could not be match-merged for a given trip. Consequently, SEF1 and SEF2 data for each vessel were summed over the period for which the vessel kept landing its catch at a given port to obtain a weighting factor for each species caught by each vessel at a given port over that period. This weighting factor was then applied to the SEF1 shot data to weight it up (or rarely down) to the SEF2 landings for each species caught by each vessel in each port. This enabled merging of 99.5% of the SEF1 data without the need to make subjective decisions in cases where SEF1 and SEF2 dates and landings did not correspond. In the few cases (eg. 0.37% - 672 records out of 178 000 during 1999) in which quota species from a SEF1 shot could not be matched to a SEF2 landing, those species catches for those shots were not included. This difference was then compensated by the weighting factors from other shots.

Stratification

Smith *et. al.* (1997) used 14 strata to define the trawl fishery (Table 1). They noted, however, that difficulties could result because the stratum into which a trip was placed was not finally determined until landing, and the future sampling plan would need to be updated as a consequence. We believe that the need for slight modifications to these strata have become apparent over the last three years, mainly due to practical considerations of running the ISMP and the changing dynamics of the fishery. The changes that we recommend and the underlying reasons for changing the strata are outlined below.

The primary sampling unit

In the current ISMP sampling regime Smith *et al.* (1997) made the decision to use “trip” rather than “shot” as the primary sampling unit because it was only practical for a sea-going observer to sample whole trips. Indeed this is true, but changes in the fishery – especially the tendency to target a larger variety of species for the markets – have resulted in a greater variety of shots within a single trip. Over the last three years, there have been a number of examples where stratification by trip rather than shot has resulted in “misclassification” of shots into a particular stratum. For example, Knuckey and Sporcic (1999) highlighted a particular case where increasingly, inshore and offshore shots were being made in the same trip off Eden/Lakes Entrance, but the trip then was classified as offshore. As a result, an increasing proportion of the shots were effectively being misclassified, thereby creating noise around the true estimates made for that stratum. Such noise reduced the effectiveness of the stratification and the potential for simulation modelling to predict the correct sampling intensity required to achieve target CVs for discard estimation. The use of shot as the primary sampling unit eliminates misclassifications of shot into a stratum but, the trade-off is that the observer has slightly less prior control over what strata may be sampled in any trip. Therefore, although we recognised that the only way to sample a shot was by undertaking a whole trip, we decided that shot was the more accurate and appropriate primary sampling unit for the present study.

Fishing zone vs port

Smith *et al.* (1997) acknowledged that the zone fished would be a natural stratification category but decided to reject it as impractical in favour of stratification by the port group in which the fish were landed. They identified four port groups: NSW (Sydney to Bermagui); EDEN/LAKES (Eden to Lakes Entrance); TAS (Tasmanian ports); and SW (Port Albert to Adelaide) whose ports were geographically contiguous and harboured vessels which fish similar species and areas. These groupings largely corresponded with the zones of fishing and Smith *et al.* (1997) noted that in most instances, this would allow good estimates of species by zone, if this was required. They further stated that practical difficulties with stratification by zone included the sampler's inability to determine where each vessel was intending to fish before trips were selected, and the potential for a single fishing trip to span two zones while the fish would only be landed and sampled on shore as a single group. Whilst this is true, recent changes in the fishery have rendered these difficulties to be less of a problem than using port as a stratification factor. The main reason for this was that in some areas of the fishery, the previously strong relationship between port of landing and fishing zone has tended to break down in recent years as fishers/owners make more dynamic decision about where their vessels catch and land fish. Their decisions were based on a number of factors including environmental conditions and their influence on catch rates, transport times and costs, best market prices (Sydney vs Melbourne) and personal considerations such as ensuring that crews regularly caught up with their families. Various examples of the problems of using port as a proxy for fishing zone have been highlighted in the ISMP progress reports and reports to SEFAG (eg. Knuckey and Sporcic 1999; Knuckey 2000). For the above reasons, we have decided to redefine the spatial aspect of the strata to reflect the fishing region (NB. we have not used the term "zone" to minimise confusion with the zones described by Klaer and Tilzey 1994) rather than port of landing and merge together the strata where unique sub-fisheries have been split by port of landing.

Zones and nomenclature

Regions used to summarise the spatial distribution of sub-fisheries were first described by Klaer and Tilzey (1994) and included Eastern Zone A, Eastern Zone B, Eastern Tasmania, Western Tasmania, Western Zone and Bass Strait. The strata described by Smith *et al.* (1997) were more detailed (including depth, port of landing and target fisheries), yet generally they still fitted well within the previous divisions by zone. One slight discrepancy was that the NSW strata of described by Smith *et al.* (1997) did not include Eden whereas the Eastern Zone A went down to the NSW / Victoria border (37^{o} 30'S), with Eastern Zone B being south of the border. The decision to move away from port as a strata definition meant that we needed to apply some division at the NSW / Victoria border. Analysis of effort data revealed that there was a natural division in the fishery between Eden and Bermagui and that Smith's NSW / EDL division better reflected current fishing practices and known biology of fish resources in the area. As a consequence it was decided that the dividing line for the new ISMP design should be between Bermagui and Eden at (36^{o} 45'S). To prevent confusion when drawing future comparisons, the group decided that changing the names of statistical zones would be sensible. Reference to Eastern Zone A and Eastern Zone B would now only relate to the historical analyses based on Klaer and Tilzey's 1994 fishery subregions, but would roughly correspond with the new NSW and Eastern Victoria zones respectively. The changes adopted are shown below:

Current zone name	New ISMP stratum name	Geographical change
Bass Strait	No change	No change
Eastern zone A	NSW	South to 36^{o} 45'S
Eastern zone B	Eastern Victoria	North to 36^{o} 45'S
Western zone	Western Victoria	No change
Eastern Tasmania	No change	No change
Western Tasmania	No change	No change

Vessel capacity

Based on a suggestion by an external referee, Smith *et al.* (1997) used size of vessel landings as a further stratification to increase sampling efficiency. SEF2 data were used to rank vessels in order of mean vessel landing per trip (all species, all fisheries). Vessels whose mean landing fell below 5 tonnes per trip were denoted low vessels (lv) and the others were denoted high vessels (hv). This division was used to subdivide two of the gear-fishery-port strata (SW Other and EDEN/LAKES Inshore). It was not considered necessary for any of the other strata. According to the observers, this has been the categorisation most difficult to apply in a practical sense, but it has also been the most difficult to justify in a theoretical sense. Part of the problem has been that, being based on an average, the hv/lv category did not necessarily apply for any particular trip even though the boat was categorised as one or the other. The other difficulty (especially in EDEN/LAKES) was that over the last few years, boats have tended to leave their local fishing grounds during summer to take advantage of better fishing conditions off the east coast of Tasmania. This has meant that they have been making longer trips and catching more fish which changes their hv/lv category. Thus, there was a temporal influence which could change a vessel's categorisation on both the short-term (months) and long-term (years). This, we believe, made the hv/lv categorisation too ephemeral to warrant its use in an ongoing stratification of the fishery and we have opted to remove the hv/lv category.

Other trawl strata

Since July 2000, two extra trawl strata have been added to the ISMP in the SEF: East Coast Deep Water (ECDW) and Victorian Inshore Trawl (VIT). Data on the level of monitoring required in these strata was not available until September 2001. Nevertheless, as separate sub-fisheries within the SEF, both strata will need to be included in any ongoing long-term monitoring program for the SEF. At this stage we have simply opted to retain the sampling intensity that has been agreed to by AFMA for 2000/01: 40 days for ECDW and 10 days for VIT. Extra monitoring of the eastern gemfish spawning fishery was also undertaken by the ISMP during 2000/01, but with only a bycatch TAC allowed for spawning gemfish and the negligible catches of spawning fish taken during that year, this sub-fishery could not be analysed as a separate stratum and will be incorporated into the NSW Offshore stratum.

Non-trawl

At sea monitoring of discard rates in the non-trawl fleet was not included in the ISMP sampling regime designed by Smith *et al.* (1997) because data were limited for this sector and discard rates were thought to be small. Since then, the Pilot Non-Trawl Monitoring Program has been undertaken during 1999/2000 and information on the amount and composition of the retained and discarded catches of SEF non-trawl vessels was now available (Knuckey *et al.* 2001a). Compared to the trawl sector, non-trawl discard rates were generally low and precise estimates did not require an extensive on-board monitoring program (Knuckey *et al.* 2001a). Nevertheless, the South East Non-Trawl Management Advisory Committee (SENTMAC) determined that a base level of independent on-board monitoring of the non-trawl fishery should continue, at least to meet the requirements of strategic assessment.

The sampling plan used for the Pilot Monitoring Program was stratified by gear, region (port) and season. Based on the results of that Program, similar stratification has been adopted for the present study, except certain gear x region cells have been dropped because of negligible fishing activities. Gear has been categorised into mesh net, dropline and longline and the regional categories (similar to the trawl) of NSW, EDEN/LAKES, TAS and SOUTHWEST have been retained (Table 4). Seasonal sampling intensity was divided amongst these strata based simply on levels of fishing activity.

Stratification for the ISMP design model

The future stratification for on-board monitoring by the ISMP is presented in Table 4. It was generally based on the initial stratification by Smith *et al.* (1997), but included the modifications we have recommended after three years of ISMP operations, together with the inclusion of other trawl and non-trawl strata.

All shots of SEF logbook and ISMP data were assigned a stratum. Strata were defined by the fishing location, season, catch composition and/or gear. Any locations outside these geographic locations were not included in the analysis. Each stratum for trawl and nontrawl data were defined as presented in Table 4.

All of the proposed changes to the ISMP sampling regime highlighted above were presented at the 2001 SEFAG Plenary. The reasons for the changes were discussed by the managers, scientists and industry members present and were accepted.

Simulation modeling and estimation of discard rates and corresponding CVs

Simulations were performed on all years of the ISMP data but weighted so that shots from the more recent years had a higher probability of being selected (Table 3). The results for all the simulations were then used to investigate the distribution of the estimated discard rate CV for each species for each number of shots within each stratum and then across the entire fishery. The results for each species in their defining strata (see Table 4) are presented in Figures 1 to 20. Each plot shows the minimum and maximum values of the discard rate CV as well as the median and the interquartile range for different numbers of shots. The results for each species for the fishery (i.e. across all strata) are presented in Figures 21 to 40. The reference lines of target CVs 1.5, 0.8 and 0.4 were included in the figures to indicate the number of shots required to achieve the required target CV (as defined by discard rate – see Methods) with a high probability. Note the number of shots on the graphs does not include the 'Other' stratum.

The minimum number of shots for each species within each stratum is presented in Table 5. The proportion of successful shots (p_{succ}) within each stratum is also presented. This is the proportion of shots that contain each species. The actual number of shots required (S_{req}) to achieve the target CV for each species is therefore the number of shots necessary to achieve the number of successful shots. These are presented in Table 6.

$$S_{req} ? \frac{S_{\min}}{p_{succ}}$$

The number of shots required within a particular stratum was the maximum value of S_{req} across species within that stratum (Table 7). Based on the average number of shots completed in a single day in each stratum, this converts to approximately 420 shot days (Table 7). Note that this may not represent the total number of sea days because shots can be undertaken in more than one strata during any one day. Table 8 shows observed shots by month that would be required in each stratum.

Sampling for length and age

Length frequency distributions

Age-length keys

The optimal samples developed by Smith *et al.* (1997) have been modified according to decisions made by SETMAC and it is these modified sample sizes that are currently used by the Central Ageing Facility.

Implications of the design model for an adaptive ISMP sampling regime

In undertaking this project we have provided a means of efficiently updating the ISMP sampling regime on a regular basis (most practically annual) to proved statistically robust estimates of discard rates and length frequency distributions. By applying a relatively automated process, it is now possible to alter the sampling regime to best suit the current dynamics of the fishery. This will reduce most of the problems that were incurred previously when the initial ISMP sampling became outdated with respect to the current fishery practices.

One of the advantages in having developed the SAS code to undertake such analyses of the SEF data is that it can now be relatively easily altered to measure different fishery parameters to determine the optimum sampling regime. Currently it uses discard rate CVs, but it could easily be changed to optimise CVs for catch composition, CPUE, detection of listed species etc. In this manner, the ISMP can maintain a sampling regime that meets the changing requirement of management, scientists and industry. Furthermore, the required levels of precision can be altered depending on the requirements or to the available budget. Importantly for the current ISMP, the modified sampling regime determined in the current project is of a similar magnitude to that already operating. This means that it is possible to adopt the adaptive sampling regime without large changes to the current budget or operating procedures. It is important to note, however, that as a voluntary monitoring program the current and proposed ISMP sampling methods rely entirely on comprehensive coverage of most vessels operating in the SEF. To date this has been achieved to an extent where virtually all CVs have been achieved. A similar level of acceptance and coverage will be required of the adaptive sampling regime is to be successful.

Whilst there are a number of advantages in applying a relatively automated means of adapting the ISMP sampling regime on an annual basis, it is worth pointing out some possible pitfalls. The most obvious (and most concerning) would be the problems associated with “blindly” accepting the results of the analyses without endeavouring to understand the underlying dynamics of the fishery. The initial analysis undertaken for this project provides a good example. The extremely high predicted sampling required in NSW_OFF_TR is a result of the sampling requirements needed to estimate appropriate discard CVs for blue eye trevalla. It is important to consider the underlying reasons that may be potentially driving this requirement. Blue eye is one species for which there is often difficulty obtaining sufficient trawl quota. This is likely to have a significant effect on discard levels and may cause high variability in discard rates depending on the quota situation of the fisher. Also, blue eye trevalla are a species that typically exhibits high levels of spatial and temporal structuring of the stocks, so higher levels of length sampling are likely to be required to meet appropriate CV levels. How important is the need to meet the CVs for this particular species in the NSW_OFF_TR stratum – a stratum that only supplies a relatively small amount of the total blue eye catch? Sampling in this stratum could be reduced considerably without the blue eye requirement. Compromises are possible. A potential option would be to alter the CV required for this species in this stratum or to remove blue eye as one of the defining species for this stratum completely. It is important that such reasons and options for the ISMP adaptive sampling regime are discussed prior to implementation. Ultimately, it will be the decision of a combined industry/management/scientific group such as SEFAG how to approach and solve this type of issue.

One of the other issues associated with the implementation of the adaptive sampling regime is the level of flexibility and uncertainty it brings into the process. With a set number of sea days to achieve in each stratum, the current ISMP design is relatively easy to plan, cost and carry out. If the number of shots required in any one stratum can potentially change from year to year or changes across the entire fishery, it is far more difficult to plan the spatial and temporal requirements for human resources and to budget them accordingly. Costs associated with getting ISMP scientists out on vessels increases markedly the further afield from their own port they travel.

A table showing the achievement of the pro-rata (July to October 2001) target number of shots (compared to days) for each stratum against those predicted by the model using 2000 data is provided (Table 9 - from Knuckey and Berrie 2001). This indicated that monitoring of the NSW and Eastern Victoria offshore strata was tending to be greater than required, whilst there was a shortfall of monitoring around western Tasmania. Although the ISMP achieved all of the pro-rata target sea-days based on the initial design (against which the current ISMP contract is measured), the discrepancy between the target and achieved number of shots outlined using the design model highlighted the need for a dynamic approach to monitoring of the SEF. It also shows that an adaptive sampling regime will require ISMP staff to move around the fishery more than at present.

One important factor in the success of the current ISMP is the fact that field scientists generally work from their home ports where they are familiar with the local fishers that they go out with and have developed a level of trust over a period of years. As a voluntary monitoring program, this issue can not be under-estimated – trust is important. One option to allow for the flexibility in both staff numbers and location that may be required in an adaptive management regime would be to opt for casual employees. It is difficult to determine what impact this may have on the operational aspects of the ISMP and how well it would be accepted by the industry members. In a voluntary program, I tend to think that there may be benefits in retaining known and trusted onboard scientists based in the fishing ports, even if the costs of moving them around and maintaining them as full-time permanent staff is greater. It is a difficult thing to test, but previous experience with the people required to undertake the tasks required in the ISMP has shown that suitable people are few and far between.

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Tables

Table 1 The initial definition of SEF strata used in the original ISMP design. Stratification was based on gear type, main species caught, port group and size of landings (after Smith *et al*. 1997).

Stratum code	**Gear**	**Port group**	**Defining species**
OROSWall	O. Trawl	SW	Orange roughy
OROTASall	O. Trawl	TAS	Orange roughy
SBGSWall	O. Trawl	SW	Blue grenadier (spawning)
SBGTASall	O. Trawl	TAS	Blue grenadier (spawning)
OTHSWhv	O. Trawl, high catch vessels	SW	All species excl. roughy and spawning grenadier
OTHSWlv	O. Trawl, low catch vessels	SW	All species excl. roughy and spawning grenadier
OTHTASall	O. Trawl	TAS	All species excl. roughy and spawning grenadier
OFFSHEDLall	O. Trawl	EDEN LAKES	Blue grenadier (non-spawning), gemfish, ling, ocean perch, mirror dory
OFFSHNSWall	O. Trawl	NSW	Blue grenadier (non-spawning), gemfish, ling, ocean perch, mirror dory
INSHEDLhv	O. Trawl, high catch vessels	EDEN LAKES	Spotted warehou, blue warehou, tiger flathead, jackass morwong, silver trevally, John dory and redfish
INSHEDLlv	O. Trawl, low catch vessels	EDEN LAKES	Spotted warehou, blue warehou, tiger flathead, jackass morwong, silver trevally, John dory and redfish
INSHNSWall	O. Trawl	NSW	Spotted warehou, blue warehou, tiger flathead, jackass morwong, silver trevally, John dory and redfish
RRPall	O. Trawl		Royal red prawn
DSall	D. Seine		School whiting

Table 2 Annual breakdown of trawl shots within each strata recorded by observers from the ISMP.

Stratum name	1993	1994	1995	1996	1997	1998	1999	2000
BS_IN_TR	0	0	14	1	0	0	3	9
ECDW_TR	0	0	0	0	0	0	0	6
EDL_DS	27	261	183	0	0	23	42	24
EDL_IN_TR	0	52	42	44	150	94	98	75
EDL_OFF_TR	0	37	25	27	53	98	66	53
NSW_IN_TR	0	0	0	0	0	86	225	243
NSW_OFF_TR	0	0	0	0	0	76	131	111
NSW_RRP_TR	0	0	0	0	0	16	56	8
OTHER	103	295	266	163	254	442	618	508
SW_ORO_TR	0	36	0	0	11	10	2	4
SW_TR	0	104	137	203	164	141	144	102
TAS_BGS_TR	15	2	18	10	0	52	39	8
TAS_E_TR	124	44	0	46	28	52	89	114
TAS_ORO_TR	24	21	0	0	0	14	40	20
TAS_W_TR	85	32	57	0	4	17	15	5

Table 3 The probability of selecting a shot from each year from the shots available.

Year	Probability of selecting a shot from a specific year relative to the most recent year	Distribution of shots from each year in the final sample
1993	0.26	*10%*
1994	0.33	*11%*
1995	0.41	*13%*
1996	0.52	*14%*
1997	0.64	*16%*
1998 (y-1)	0.80	*17%*
1999 (y)	1.00	*19%*
Total		100%

Table 4 Proposed definition of SEF strata used in the ISMP for trawl and non-trawl sectors. Stratification was based on gear type, main species caught, fishing location.

Stratum name	Stratum code	Defining Species	Gear	depth	month	Region	Catch
Trawl Stratification							
Orange roughy South west	SW_ORO_TR	37255009	Otter trawl		6<=m <=9	South West	ORO >.5* total catch
Orange roughy Tasmania	TAS_ORO_TR	37255009	Otter trawl		6<=m <=9	Western Tasmania, Eastern Tasmania	ORO >.5* total cat ch
Spawning Blue Grenadier South west	SW_BGS_TR	37227001	Otter trawl		6<=m <=9	South West	
Spawning Blue Grenadier Tasmania	TAS_BGS_TR	37227001	Otter trawl		6<=m <=8	Western Tasmania, Eastern Tasmania	
Royal Red Prawn	NSW_RRP_TR	27701004	Otter trawl	<200 m		Eastern Zone A Eastern Zone B	Catch of RRP >50 kg
NSW Trawl Inshore	NSW_TR_IN	37445006, 37445005 37296001, 37377003 37337062, 37264004 37258003	Otter trawl	<200 m		Eastern Zone A Eastern Zone B	
NSW Trawl Offshore	NSW_TR_OFF	37439002, 37228002 37287093, 37287001 37264003, 37227001	Otter trawl	>=20 0m		Eastern Zone A Eastern Zone B	
East Coast Deepwater Trawl	ECDW_TR	37445001, 37258002	Otter trawl			ECDW	
Eden Lakes Entrance Trawl Inshore	EDL_TR_IN	37445006, 37445005 37296001, 37377003 37337062, 37264004 37258003	Otter trawl	<200 m		Eden, Lakes Entrance, Lake Tyers	
Eden Lakes Entrance Trawl Offshore	EDL_TR_OFF	37439002, 37228002 37287093, 37287001 23764003,	Otter trawl	>=20 0m		Eden, Lakes Entrance, Lake Tyers	
Eden Lakes Entrance Danish seine	EDL_DS	37330014 37296001	Danish seine			Eden, Lakes Entrance, Lake Tyers	
Victoria Trawl Inshore	VIC_TR_IN	37330014 37296001	Otter trawl			Bass Strait	
East Tasmania Trawl	ETAS_TR		Otter trawl			Eastern Tasmania	
West Tasmania Trawl	WTAS_TR		Otter trawl			Western Tasmania	
Southwest Trawl	SW_TR		Otter trawl			South West	

Table 4 cont. Proposed definition of SEF strata used in the ISMP for Trawl and Nontrawl sectors. Stratification was based on gear type, main species caught, fishing location.

Stratum name	Stratum code	Defining Species	Gear	depth	month	Region	Catch
Non-trawl Stratification							
NSW Longline	NSW_LL		Longline			Eastern Zone A Eastern Zone B	
Eden Lakes Entrance Meshnet	EDL_MN	37445005 37445006	Mesh net			Eden, Lakes Entrance, Lake Tyers	
East Tasmania Dropline	ETAS_DL	37445001	Dropline			Eastern Tasmania	
West Tasmania Dropline	WTAS_DL	37445001	Dropline			Western Tasmania	
Southwest Dropline	SW_DL	37445001	Dropline			South West	
Tasmania Longline	TAS_LL	37228002	Longline			Eastern Tasmania Western Tasmania	
		orot>bgt>otht, oros>bgs>oths, otht>edin, edoff,edlds>all,rrp>all					

Table 5 Minimum number of shots required (S_{min}) to achieve the target CV for each species in their defining strata. Numbers in parentheses are the proportion of shots that contain that species i.e. 'successful' shots (P_{succ}).

species	NSW INTR	EDL IN TR	NSW OFF TR	EDL OFF TR	NSW RRP TR	EDL DS	TAS E TR	TAS W TR	SW TR	TAS ORO TR	TAS BGS TR	TAS BGS TR	BS IN TR	ECDW TR	OTHER
Blue grenadier - nonspawning	0	0	1(.08)	14(.37)	0	0	11(.64)	13(.46)	19(.60)	0	0	0	0	0	1
Blue grenadier - spawning	0	0	0	0	0	0	0	0	0	0	0	26(1.0)	0	0	1
John dory	60(.93)	1(.93)	0	0	0	0	0	0	0	0	0	0	0	0	1
Mirror dory	0	0	7(.82)	8(.66)	0	0	7(.72)	5(.28)	3(.52)	0	0	0	0	0	4
Tiger flathead	3(.96)	10(1.0)	0	0	0	3(1.0)	1(.32)	1(1.0)	2(.16)	0	0	0	0	0	2
Eastern Gemfish	0	0	9(.65)	10(.53)	0	0	4(.30)	0	0	0	0	0	0	0	2
Western Gemfish	0	0	0	0	0	0	0	9(.13)	12(.57)	0	0	0	0	0	1
Pink Ling	0	0	6(.80)	13(.95)	0	0	20(.72)	8(.89)	12(.76)	0	0	0	0	0	10
Jackass morwong	4(.50)	14(.74)	0	0	0	0	8(.48)	1(.11)	4(.25)	0	0	0	0	0	5
Orange Roughy	0	0	0	0	0	0	0	0	0	31(1.0)	7(1.0)	0	0	0	9
Other	21(1.0)	21(1.0)	20(1.0)	20(1.0)	14(1.0)	20(1.0)	20(1.0)	19(1.0)	20(1.0)	14(1.0)	19(1.0)	21(1.0)	21(1.0)	22(1.0)	
Redfish	13(.76)	1(.55)	0	0	0	0	0	0	0	0	0	0	0	0	1
Ocean perch - inshore	6(.58)	4(.86)	0	0	0	0	0	0	0	0	0	0	0	0	1
Ocean perch - offshore	0	0	5(.92)	6(.85)	0	0	7(.60)	6(.49)	6(.48)	0	0	0	0	0	1
Royal red prawn	0	0	0	0	9(1.0)	0	0	0	0	0	0	0	0	0	1
Blue eye Trevalla	0	0	25(.08)	4(.18)	0	0	10(.35)	8(.15)	12(.34)	0	0	0	0	0	25
Silver trevally	163(.48)	4(.26)	0	0	0	0	0	0	0	0	0	0	0	0	1
Spotted warehou	0	0	7(.20)	17(.59)	0	0	9(.70)	22(.34)	16(.71)	0	0	0	0	0	24
Blue Warehou	17(.10)	15(.41)	0	0	0	0	4(.22)	1(.07)	6(.29)	0	0	0	0	0	3
School whiting	0	0	0	0	0	12(.63)	0	0	0	0	0	0	0	0	1

Table 6 Actual number of shots required (S_{req}) to achieve the target CV for each species in their defining strata.

spec	NSW IN TR	EDL IN TR	NSW OFF TR	EDL OFF TR	NSW RRP TR	EDL DS	TAS E TR	TAS W TR	SW TR	TAS ORO TR	SW ORO TR	TAS BGS TR	BS IN TR	ECDW TR	OTHER
Blue grenadier - nonspawning	0	0	7	36	0	0	17	28	30	0	0	0	0	0	1
Blue grenadier - spawning	0	0	0	0	0	0	0	0	0	0	0	26	0	0	1
John dory	64	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Mirror dory	0	0	8	11	0	0	10	17	5	0	0	0	0	0	4
Tiger flathead	3	10	0	0	0	3	2	1	10	0	0	0	0	0	2
Eastern Gemfish	0	0	14	17	0	0	13	0	0	0	0	0	0	0	2
Western Gemfish	0	0	0	0	0	0	0	69	20	0	0	0	0	0	1
Pink Ling	0	0	7	14	0	0	27	9	16	0	0	0	0	0	10
Jackass morwong	7	18	0	0	0	0	16	1	14	0	0	0	0	0	5
Orange Roughy	0	0	0	0	0	0	0	0	0	31	7	0	0	0	9
Other	21	21	20	20	14	20	20	19	20	14	19	21	21	22	
Redfish	16	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Ocean perch - inshore	9	4	0	0	0	0	0	0	0	0	0	0	0	0	1
Ocean perch - offshore	0	0	5	7	0	0	10	12	11	0	0	0	0	0	1
Royal red prawn	0	0	0	0	9	0	0	0	0	0	0	0	0	0	1
Blue eye Trevalla	0	0	321	21	0	0	28	54	35	0	0	0	0	0	25
Silver trevally	340	15	0	0	0	0	0	0	0	0	0	0	0	0	1
Spotted warehou	0	0	34	29	0	0	13	62	23	0	0	0	0	0	24
Blue Warehou	155	35	0	0	0	0	18	9	19	0	0	0	0	0	3
School whiting	0	0	0	0	0	18	0	0	0	0	0	0	0	0	1

Table 7 Number of shots required to achieve target CVs for all defining species in each stratum and the corresponding number of shot-days.

Stratum code	Minimum number of shots	Actual number of shots	Shots per day	Approximate number of shot-days
BS_IN_TR	22	22	4	6
ECDW_TR	23	23	3	8
EDL_DS	21	21	5	5
EDL_IN_T	22	36	3	13
EDL_OFF_	21	37	3	13
NSW_IN_T	164	341	3	114
NSW_OFF_	26	322	2	162
NSW_RRP_	15	15	2	8
OTHER	26	26	5	6
SW_ORO_T	20	20	2	11
SW_TR	21	36	3	13
TAS_BGS_	27	27	3	10
TAS_E_TR	21	29	4	8
TAS_ORO_	32	32	5	7
TAS_W_TR	23	70	2	36
Grand Total	**484**	**1057**		**420**

Table 8 Number of shots required to achieve target CVs for all defining species in each stratum within each month.

Stratum code	Jan	Feb	Ma	Apr	Ma	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
BS_IN_TR	2	1	2	0	0	2	1	1	0	5	5	2	22
ECDW_TR	0	0	0	0	0	14	7	0	0	0	0	2	23
EDL_DS	2	2	2	2	2	2	2	1	2	2	1	1	21
EDL_IN_TR	3	2	2	4	4	3	2	4	4	3	3	3	36
EDL_OFF_TR	3	2	1	3	5	4	5	3	3	3	2	2	37
NSW_IN_TR	38	24	31	31	20	24	20	27	27	44	27	31	344
NSW_OFF_TR	6	29	19	19	32	58	39	35	29	23	13	23	325
NSW_RRP_TR	2	2	2	2	2	2	0	0	1	1	0	0	15
OTHER	3	2	2	2	1	2	3	2	2	3	2	3	26
SW_ORO_TR	0	0	0	0	0	4	11	4	1	0	0	0	20
SW_TR	3	3	5	4	5	2	2	2	3	3	4	2	36
TAS_BGS_TR	0	0	0	0	0	8	11	8	0	0	0	0	27
TAS_E_TR	5	5	3	3	3	1	0	1	1	2	2	2	30
TAS_ORO_TR	0	0	0	0	0	6	18	6	3	0	0	0	32
TAS_W_TR	9	8	8	7	4	1	1	1	8	6	8	8	71

Table 9 Summary of the number of shots undertaken by on-board observers during July to October 2001 against pro-rata target shots as estimated using the ISMP design model for 2000 data.

Region	Strata	Annual Target No. of shots	Pro-rata Target No. of shots	Number of shots monitored	Difference
NSW	Inshore	239	89	86	-3
	Offshore	23* (615)	8*(262)	57	+49*(-205)
	Royal Red Prawn	18	3	3	0
	ECDW#	40 days	13	0	-13 days
VIC East	Inshore	210	79	75	-4
	Offshore	42	17	53	+36
	Danish Seine	45	14	14	0
Bass Strait	VIT#	20 days	7	1 day	-6 days
TAS	East	52	6	0	-6
	West	108	35	18	-17
	Orange roughy	20	17	22	+5
	Spawning grenadier	46	33	42	+9
VIC West	Other	66	21	29	+8
	Orange roughy	6	5	8	+3
TOTAL		875	314	366	+52

*Number of shots required if reduced sampling for blue eye trevalla in NSW_OFF_TR be accepted. Number in parentheses indicates shots required by ISMP design model if full blue eye coverage is estimated.

#The ECDW and VIT strata were not included in the ISMP design model estimations.

Table 10 The mean weighted CV of length frequencies (in parentheses) for each combination of sample number and sample size (i.e. number of fish within each sample).

Species	_20	40	_60	_80	_100	_140	_200
Blue Warehou	125(.07)	100(.04)	75(.03)	75(.02)	50(.02)	50(.02)	50(.01)
Blue eye Trevalla	125(.10)	125(.05)	75(.04)	75(.03)	75(.02)	50(.02)	50(.01)
Blue grenadier - nonspawning	125(.08)	100(.04)	75(.03)	75(.03)	75(.02)	50(.02)	50(.01)
Blue grenadier - spawning	175(.12)	150(.06)	100(.05)	75(.04)	75(.04)	75(.03)	50(.02)
Eastern Gemfish	200(.14)	150(.08)	100(.06)	100(.05)	100(.04)	75(.03)	75(.02)
Jackass morwong	125(.08)	100(.04)	75(.03)	75(.02)	75(.02)	50(.02)	50(.01)
John dory	150(.12)	125(.06)	100(.04)	100(.03)	75(.03)	75(.02)	50(.02)
Mirror dory	175(.16)	125(.10)	100(.07)	100(.05)	75(.05)	75(.03)	75(.02)
Ocean perch - inshore	0	175(.10)	125(.08)	100(.07)	100(.05)	75(.04)	75(.03)
Ocean perch - offshore	200(.13)	125(.08)	125(.05)	100(.04)	75(.04)	75(.03)	75(.02)
Orange Roughy	150(.07)	100(.05)	75(.03)	75(.03)	50(.03)	50(.02)	50(.01)
Pink Ling	150(.13)	100(.07)	100(.05)	75(.04)	75(.03)	75(.02)	50(.02)
Redfish	175(.12)	125(.07)	100(.05)	75(.04)	75(.03)	75(.02)	50(.02)
Royal red prawn	0	200(.14)	125(.12)	125(.09)	100(.08)	100(.06)	75(.04)
School whiting	175(.08)	100(.06)	75(.04)	75(.03)	75(.03)	50(.02)	50(.02)
Silver trevally	0	150(.10)	125(.08)	100(.06)	100(.05)	100(.04)	75(.03)
Spotted warehou	125(.07)	100(.04)	75(.03)	50(.03)	50(.02)	50(.01)	50(.01)
Tiger flathead	125(.07)	75(.04)	75(.03)	75(.02)	50(.02)	50(.01)	50(.01)
Western Gemfish	150(.09)	100(.05)	75(.04)	75(.03)	75(.02)	50(.02)	50(.01)

Figures

Figure 1 Nonspawning blue grenadier for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

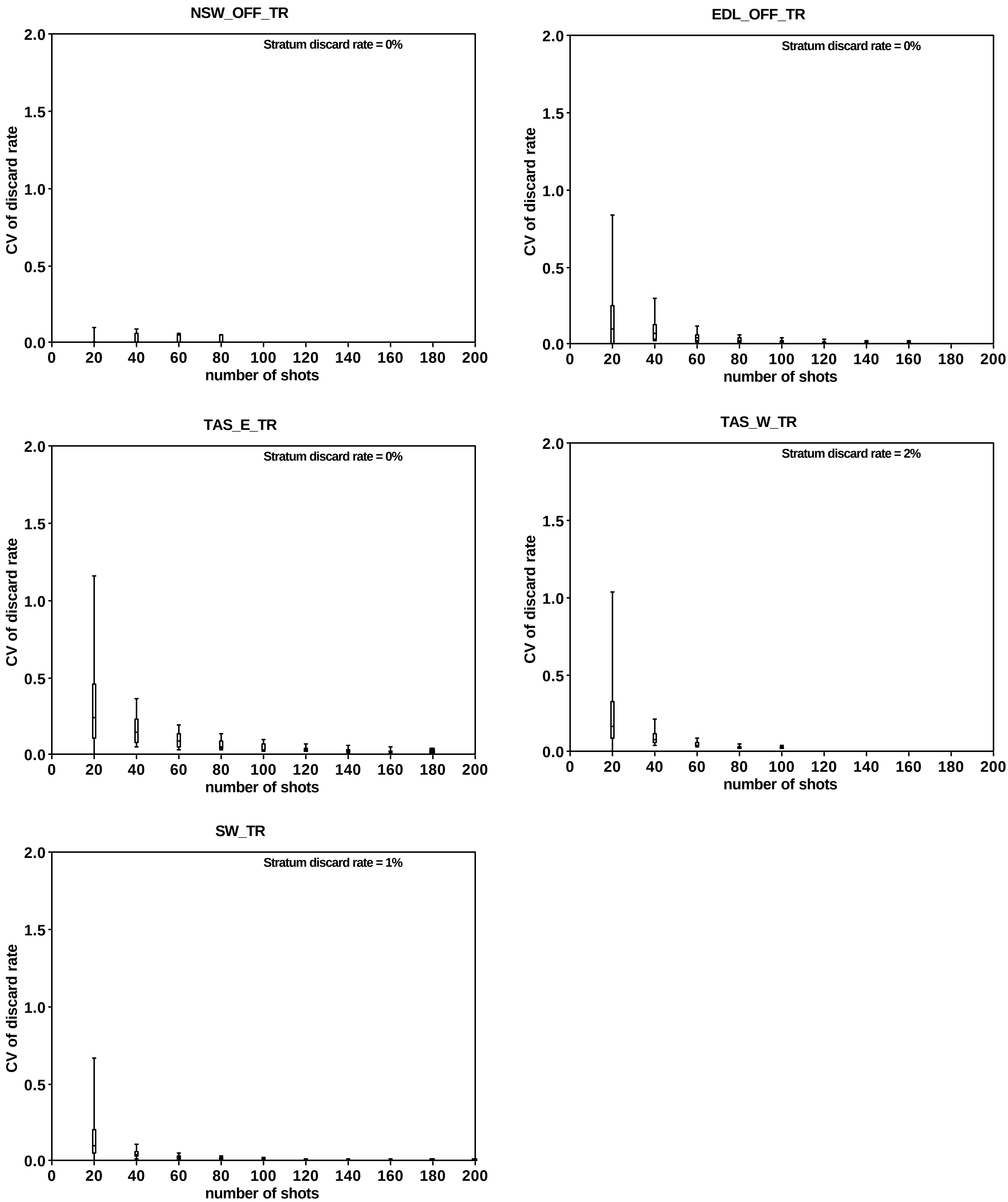
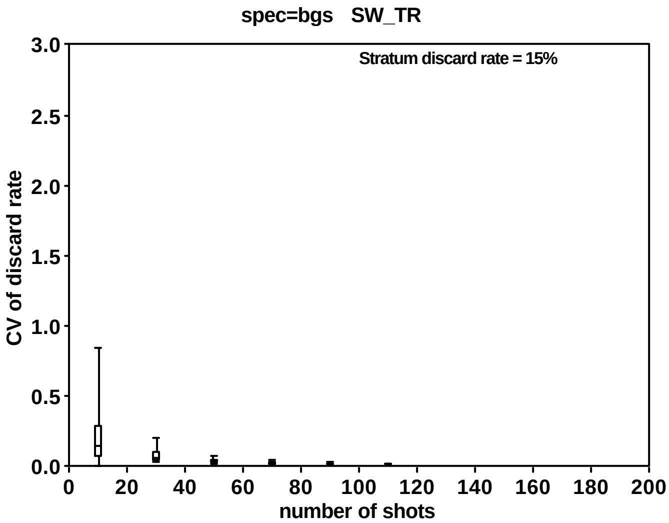


Figure 2 Spawning blue grenadier for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.



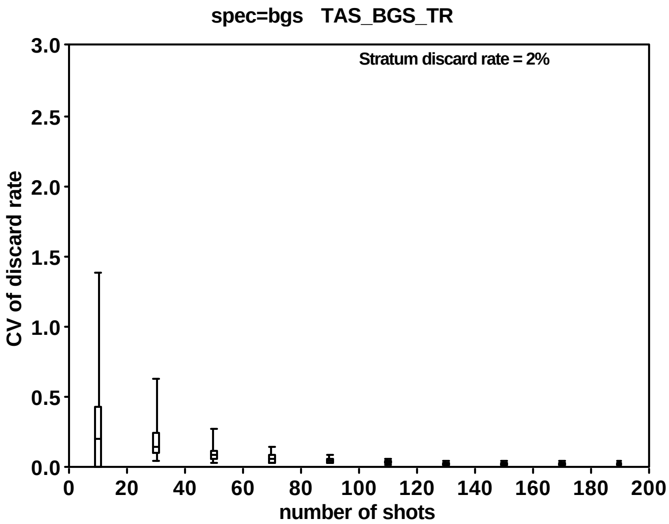


Figure 3 John dory for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

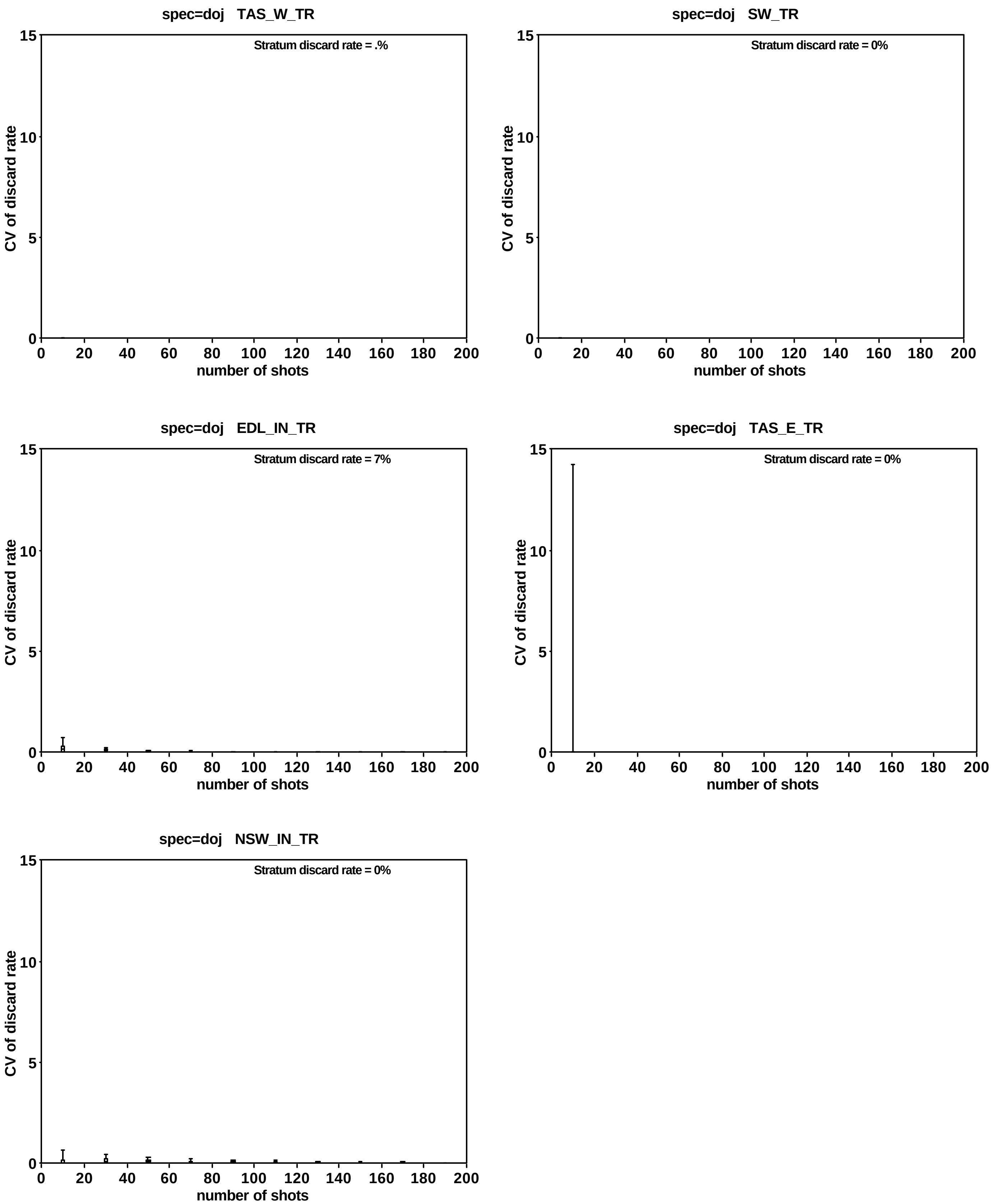


Figure 4 Mirror dory for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

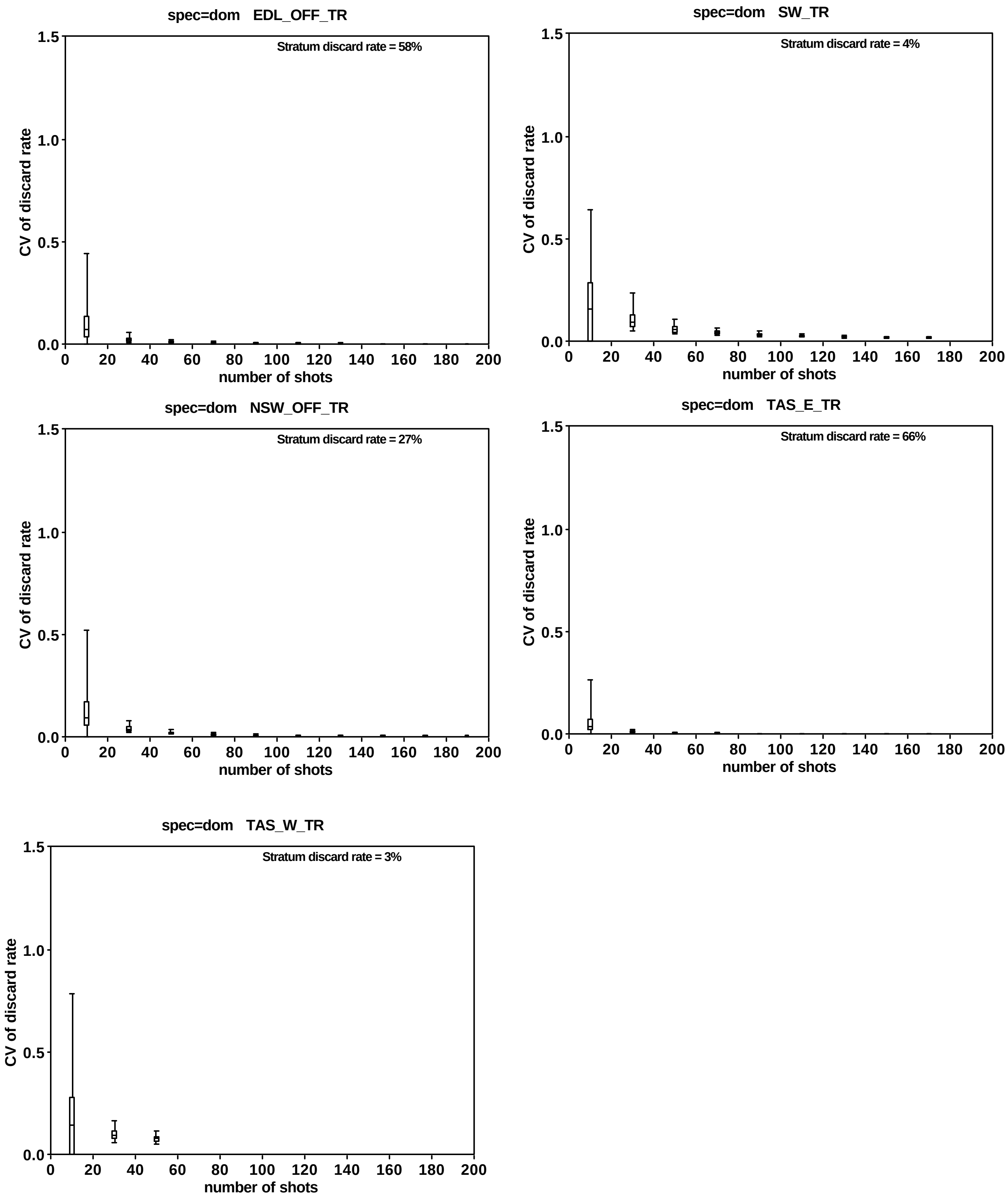


Figure 5 Flathead for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

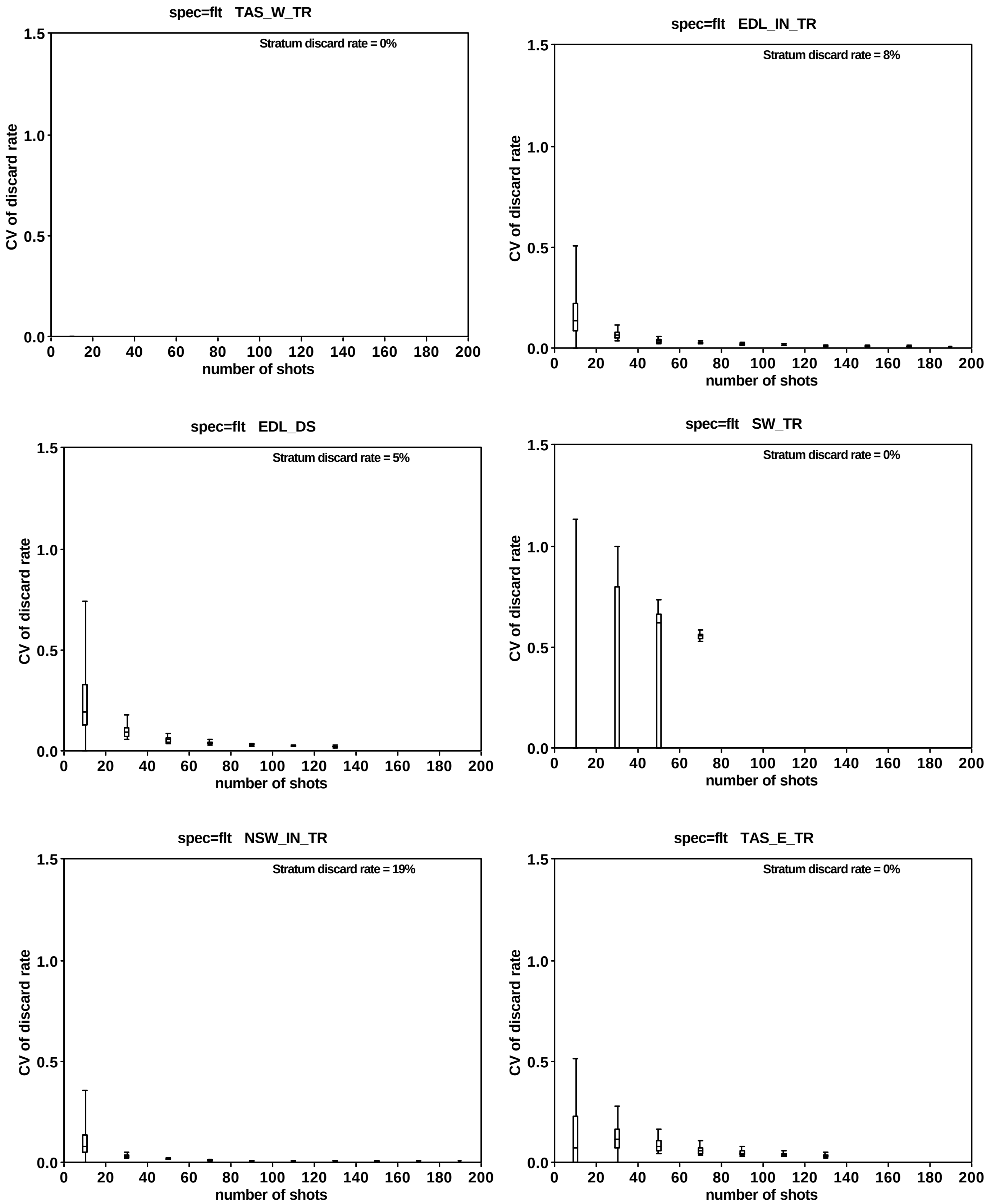
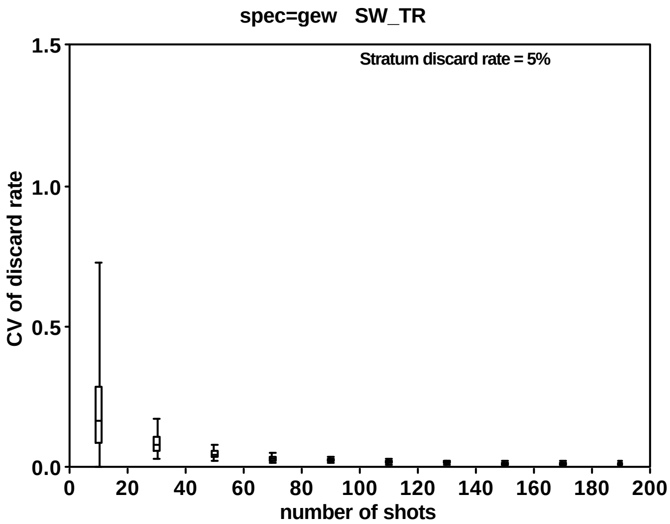


Figure 6 Western gemfish for each defining stratum. Coefficient of variation of discard rates from from simulations for 20 to 200 shots within the stratum.



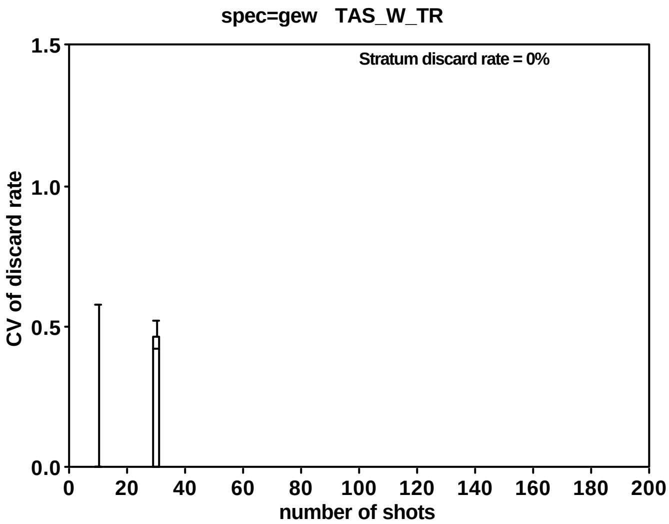


Figure 7 Eastern gemfish for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

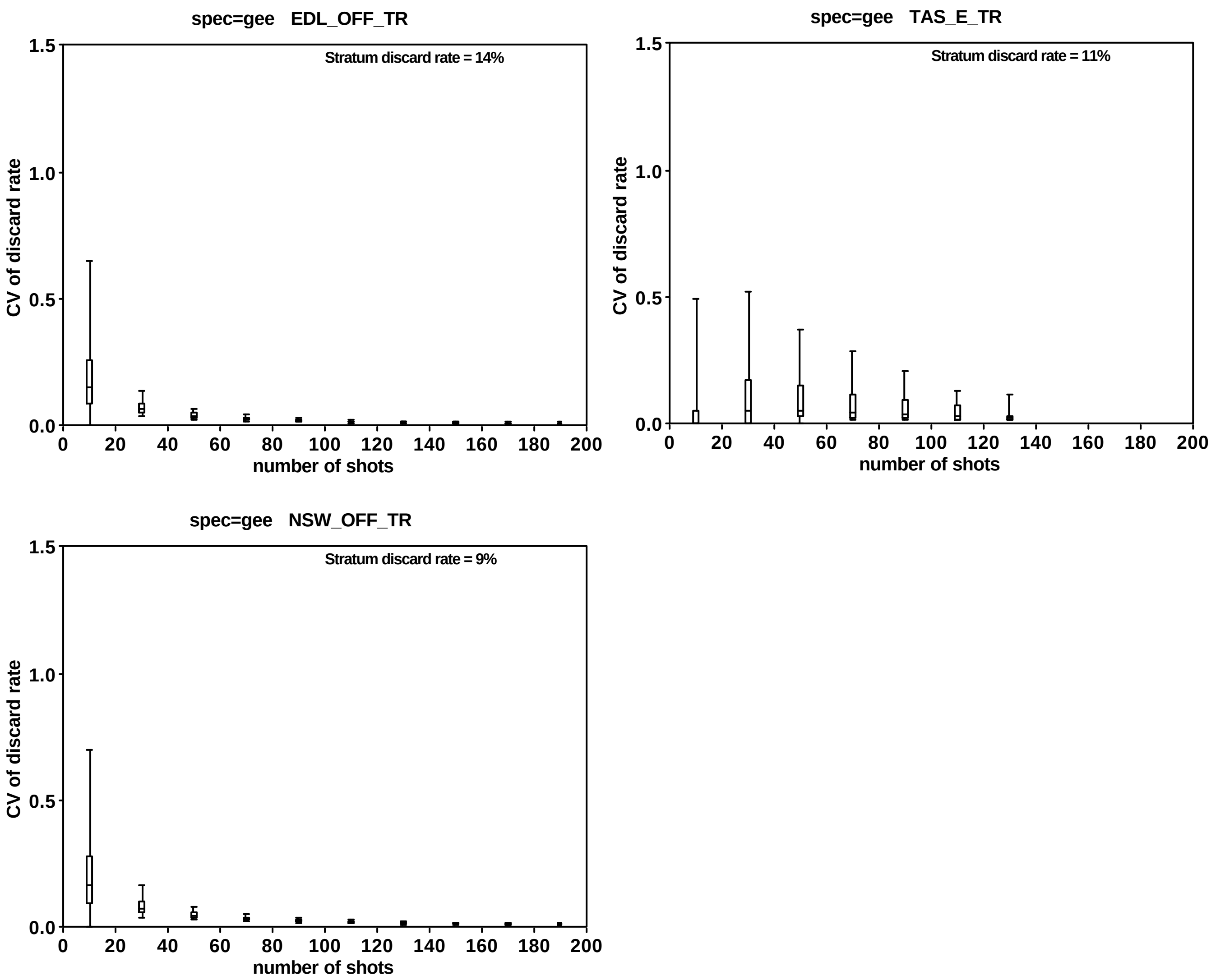


Figure 8 Ling for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

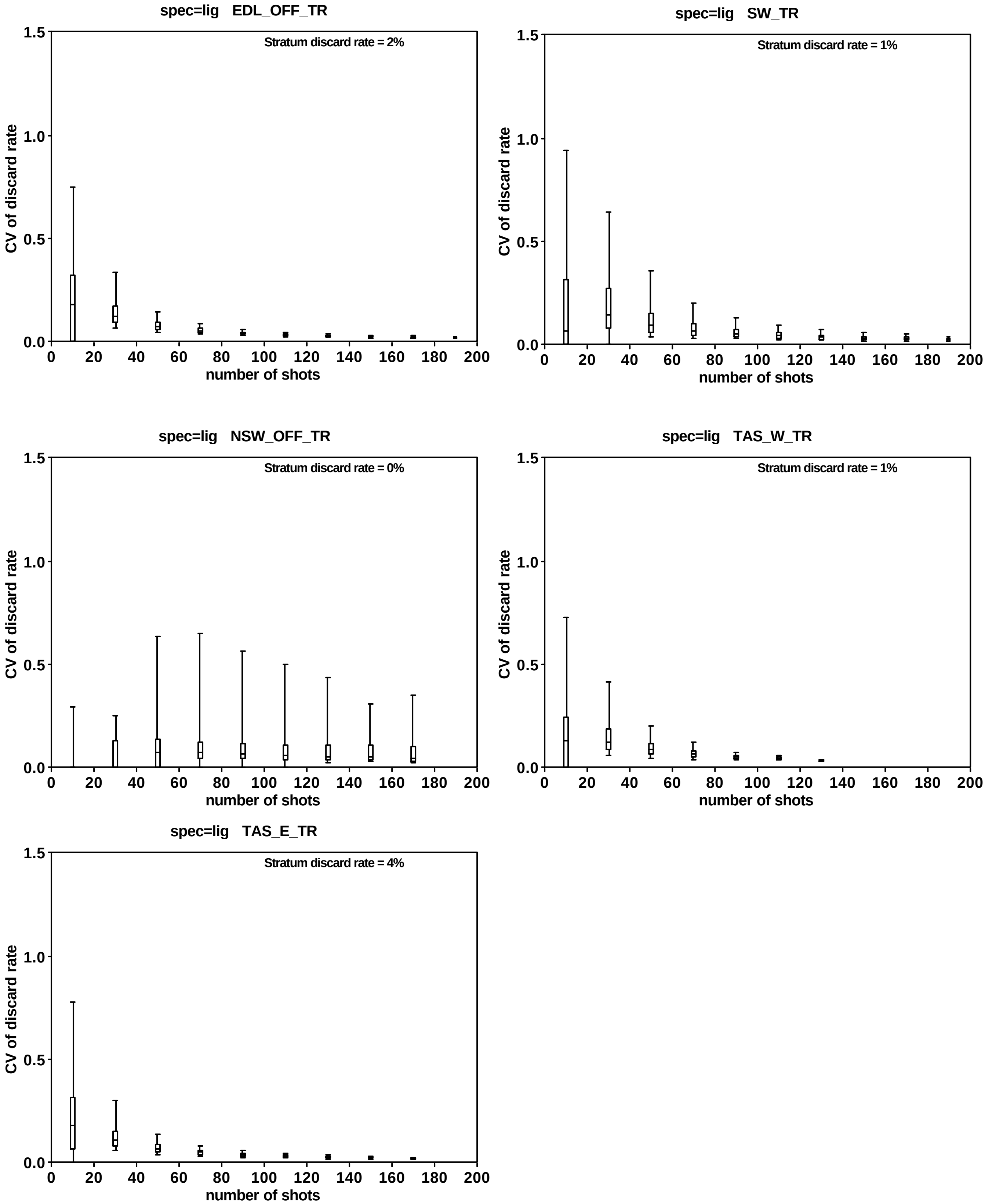


Figure 9 Jackass morwong for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

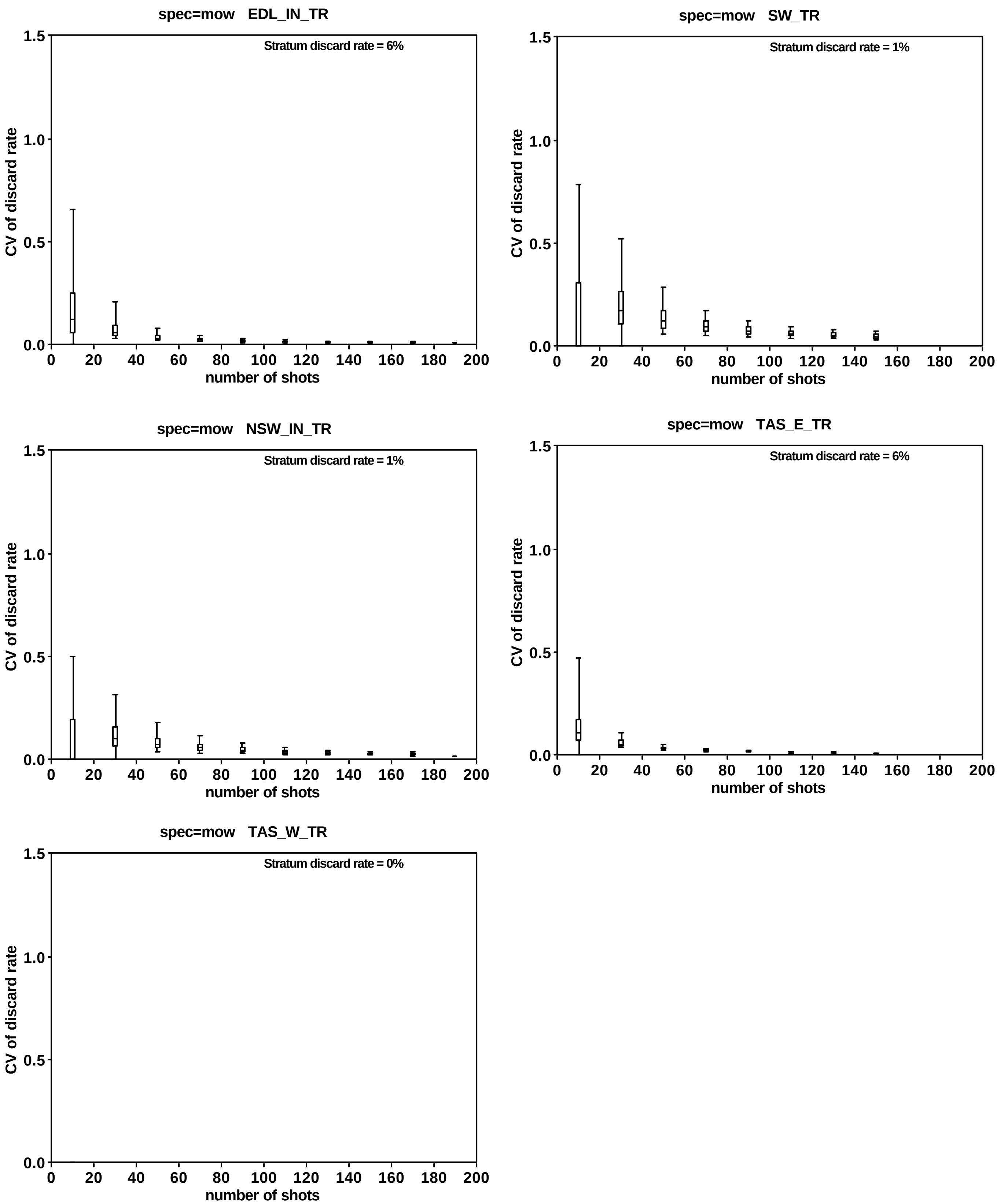
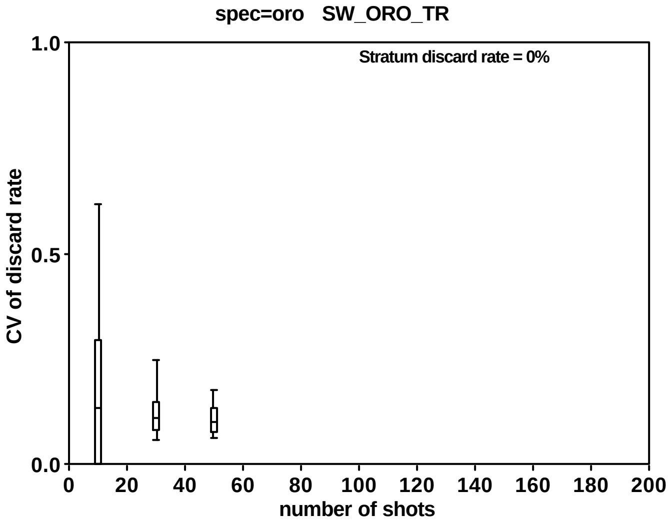


Figure 10 Orange roughy for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.



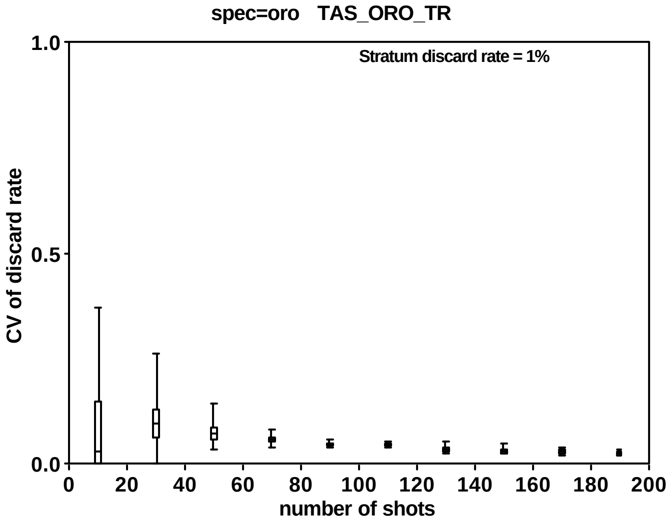
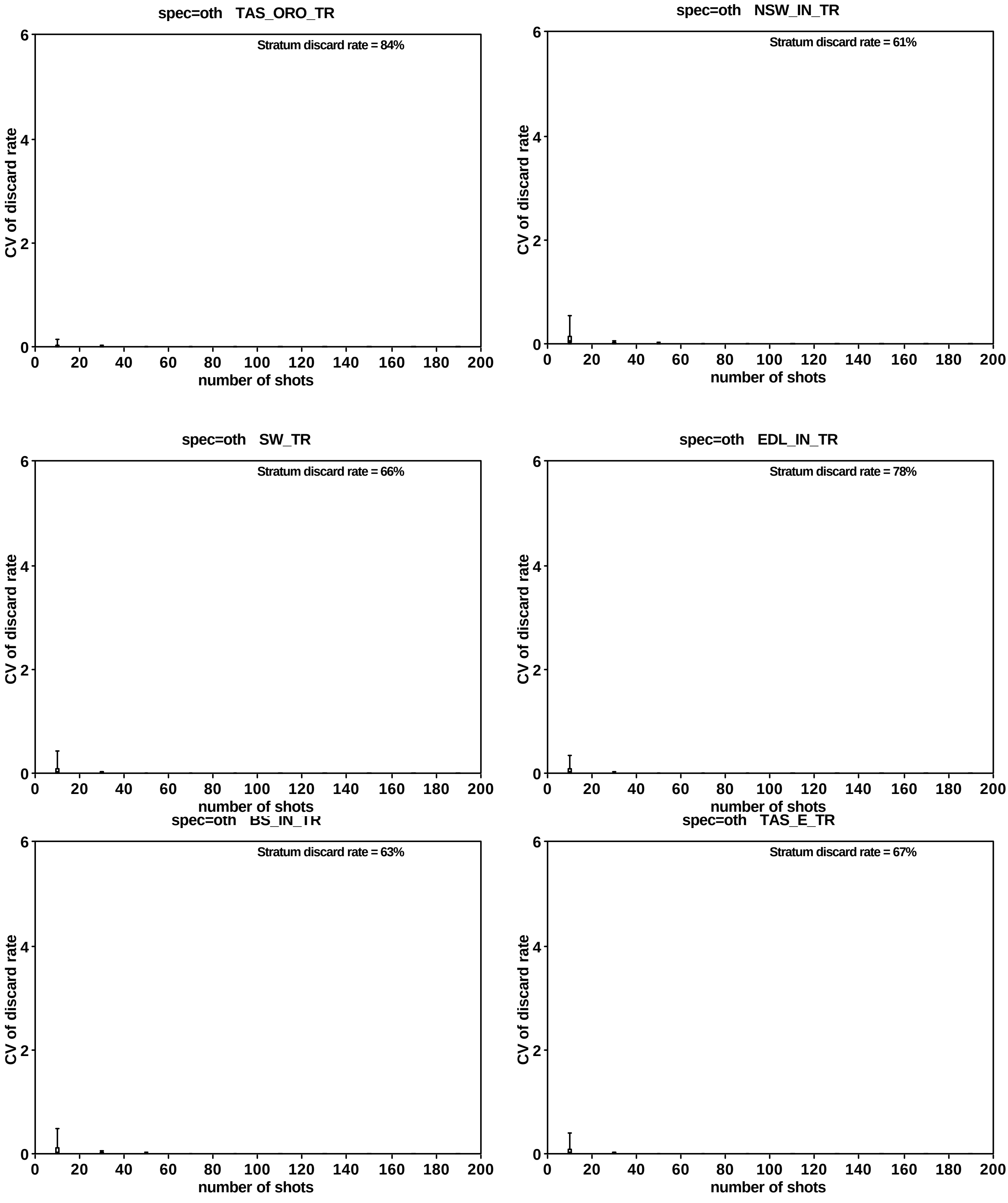
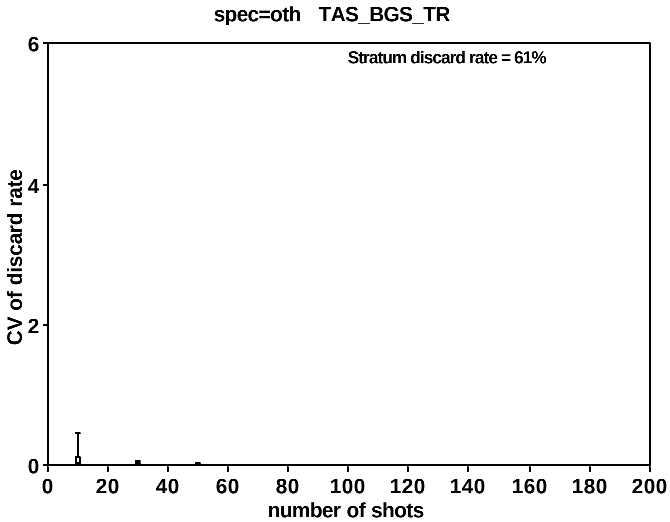
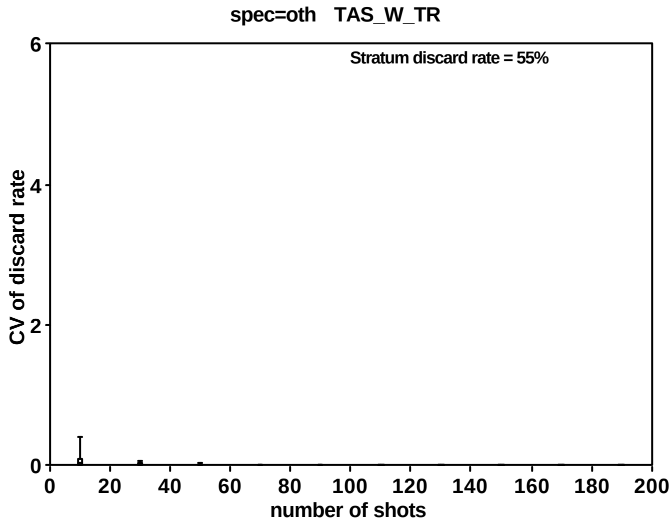
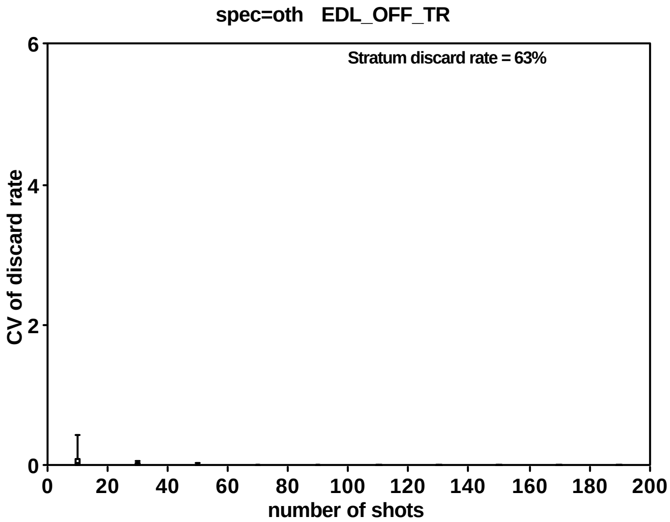


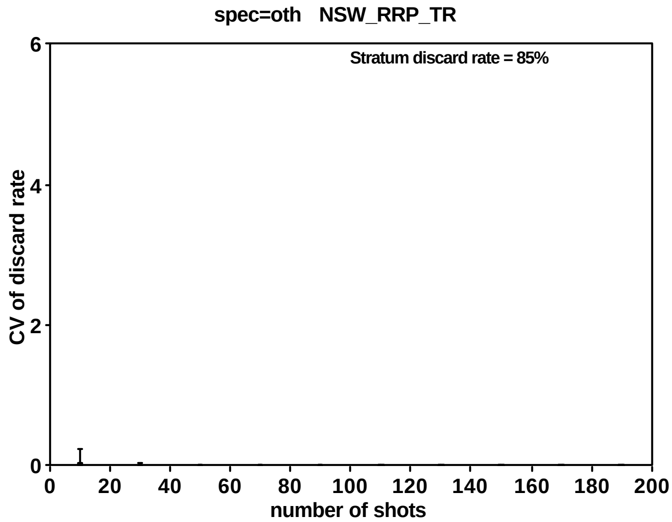
Figure 11 Other species for each stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

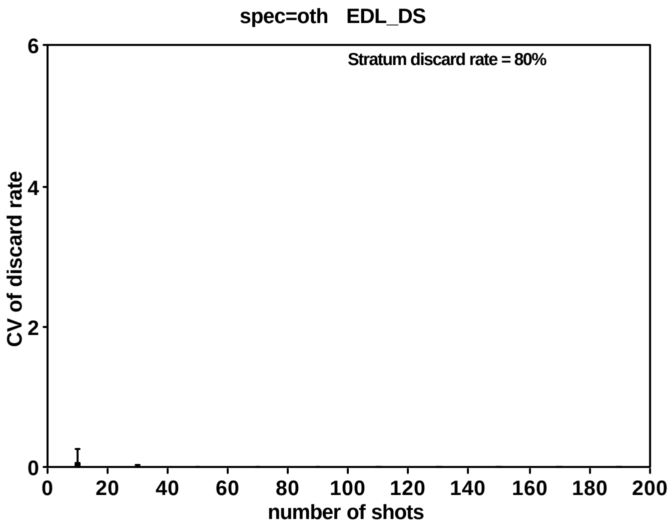


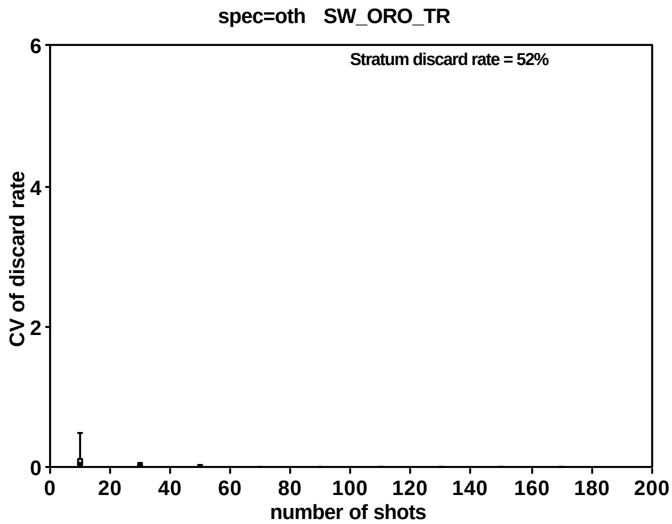

spec=oth TAS_BGS_TR
Stratum discard rate = 61%
CV of discard rate
number of shots
0
2
4
6
0 20 40 60 80 100 120 140 160 180 200

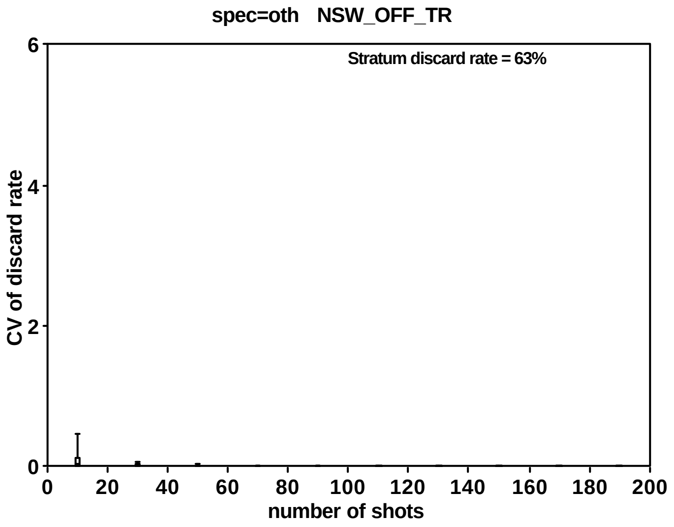

spec=oth TAS_W_TR
Stratum discard rate = 55%
CV of discard rate
number of shots
0
2
4
6
0 20 40 60 80 100 120 140 160 180 200


spec=oth EDL_OFF_TR
Stratum discard rate = 63%
CV of discard rate
number of shots
0
2
4
6
0 20 40 60 80 100 120 140 160 180 200


spec=oth NSW_RRP_TR
Stratum discard rate = 85%
CV of discard rate
number of shots
0
2
4
6
0 20 40 60 80 100 120 140 160 180 200


spec=oth EDL_DS
Stratum discard rate = 80%
CV of discard rate
number of shots
0
2
4
6
0 20 40 60 80 100 120 140 160 180 200


spec=oth SW_ORO_TR
Stratum discard rate = 52%
CV of discard rate
number of shots
0
2
4
6
0 20 40 60 80 100 120 140 160 180 200


spec=oth NSW_OFF_TR
Stratum discard rate = 63%
CV of discard rate
number of shots
0
2
4
6
0 20 40 60 80 100 120 140 160 180 200

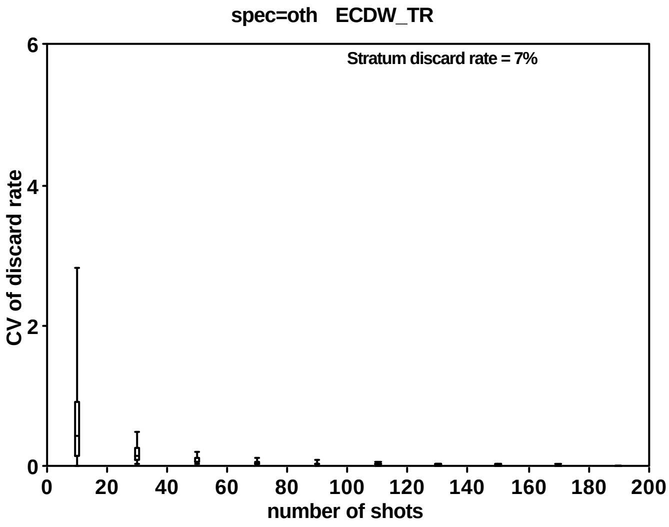
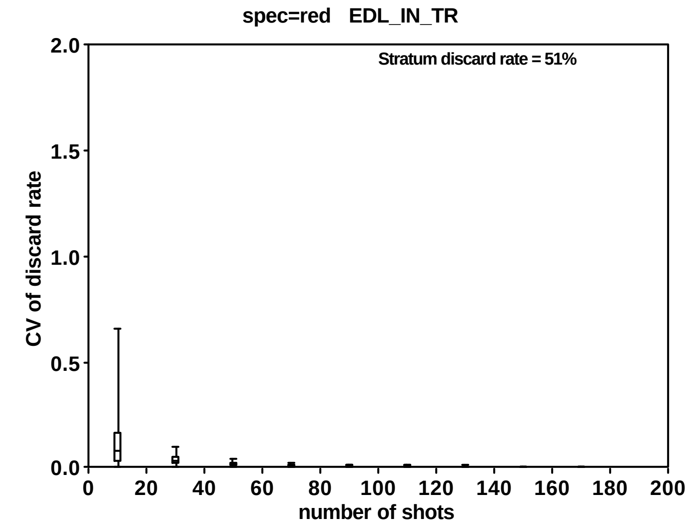
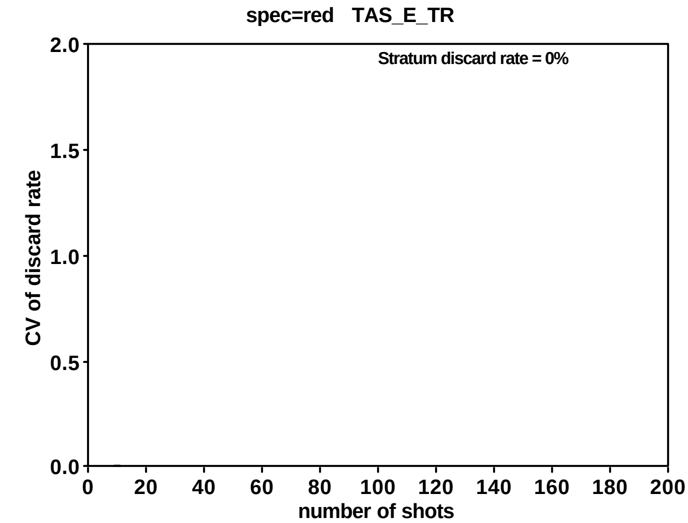

spec=oth ECDW_TR
Stratum discard rate = 7%
CV of discard rate
number of shots
0
2
4
6
0 20 40 60 80 100 120 140 160 180 200

Figure 12 Redfish for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.





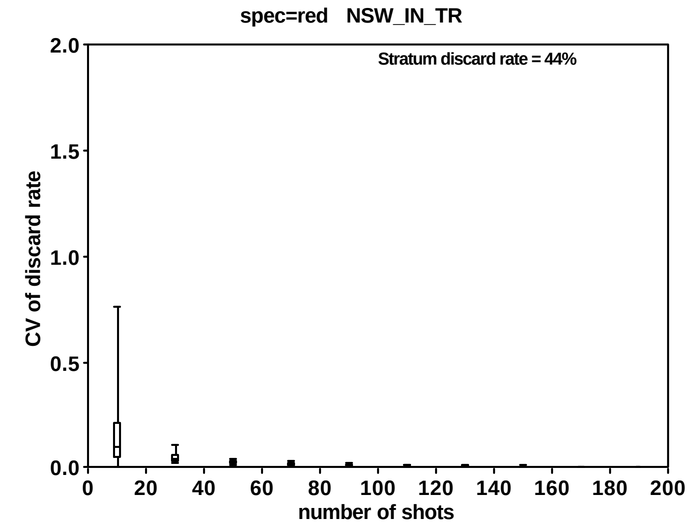


Figure 13 Inshore ocean perch for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

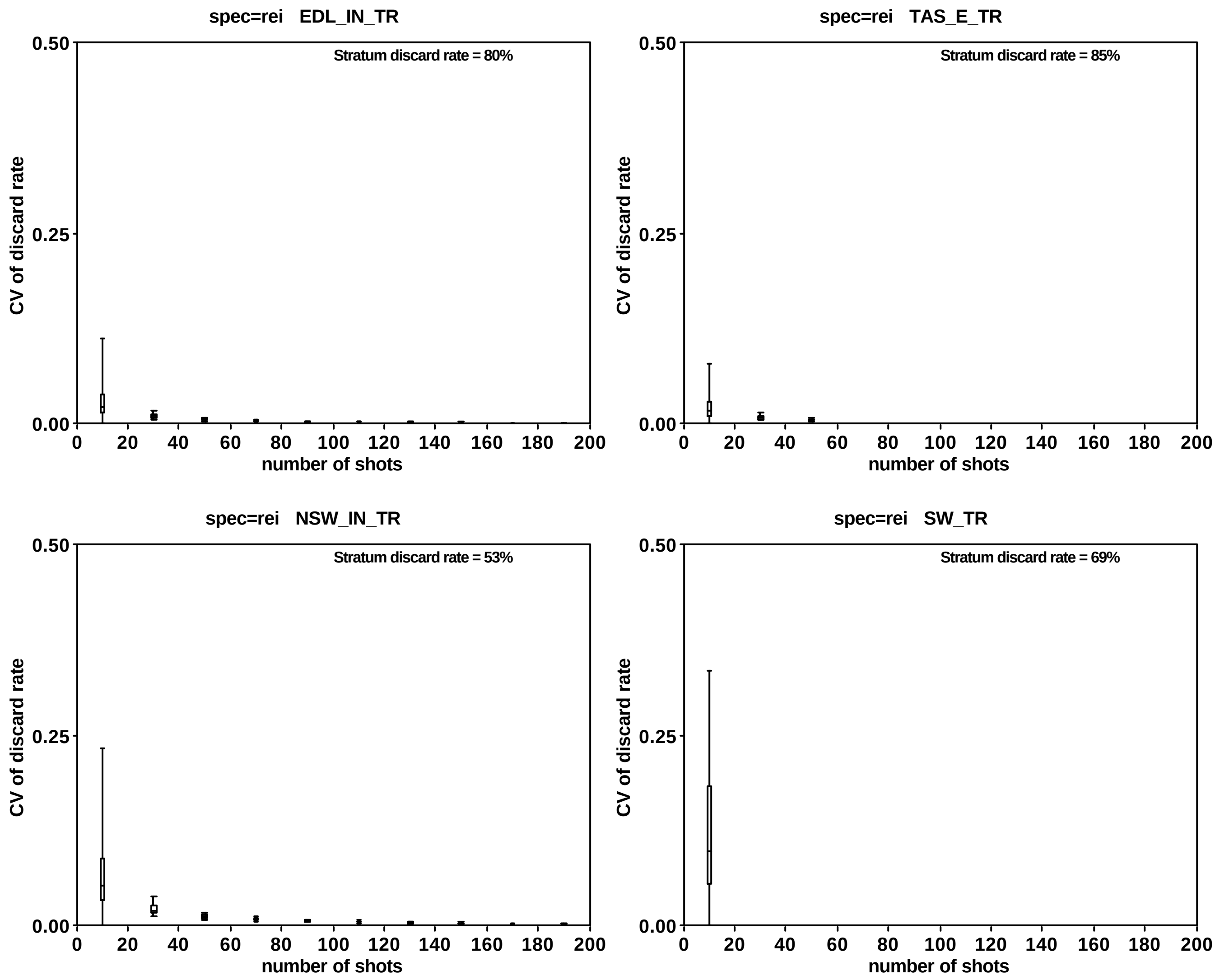


Figure 14 Offshore ocean perch for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

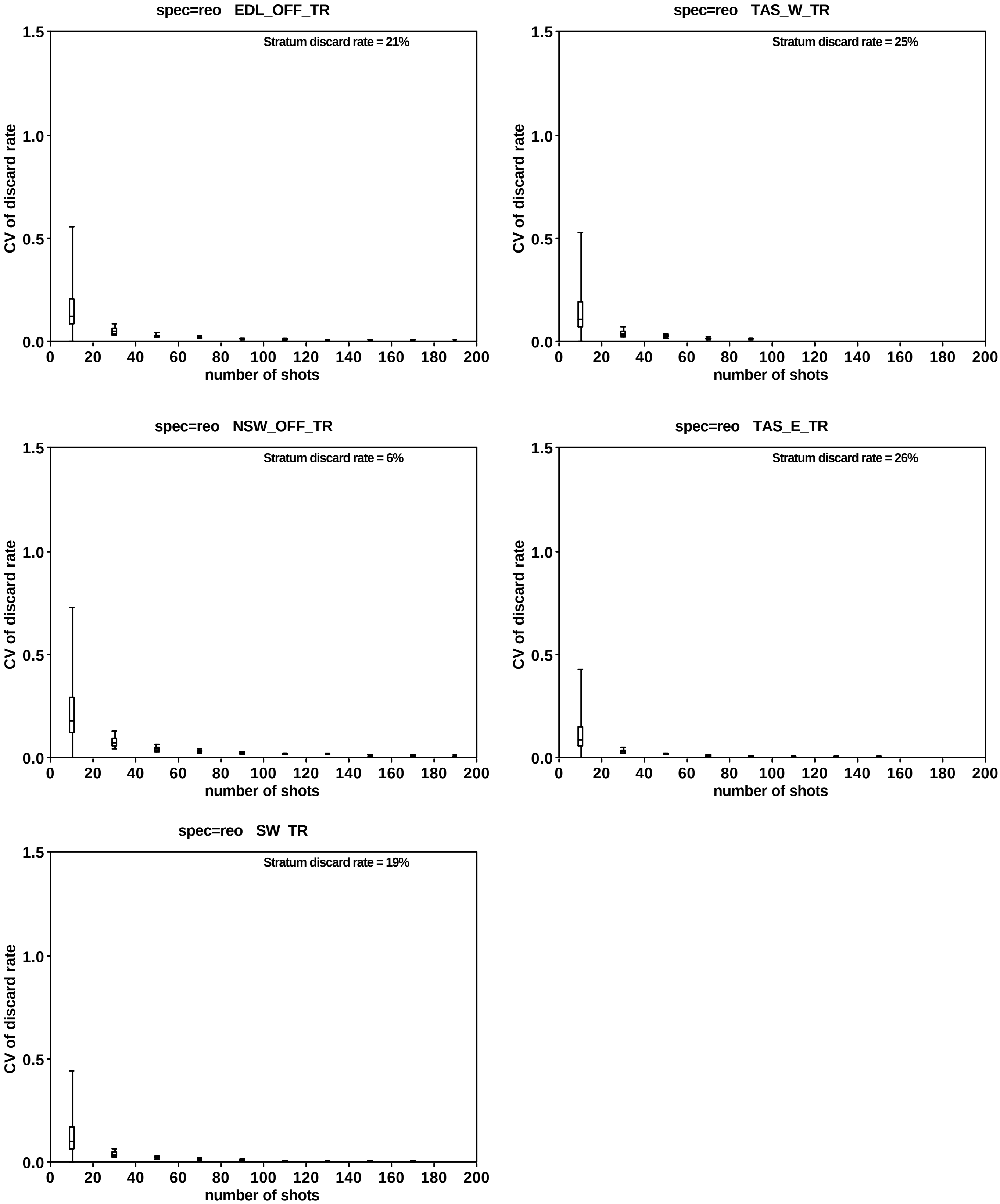


Figure 15 Royal red prawn for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

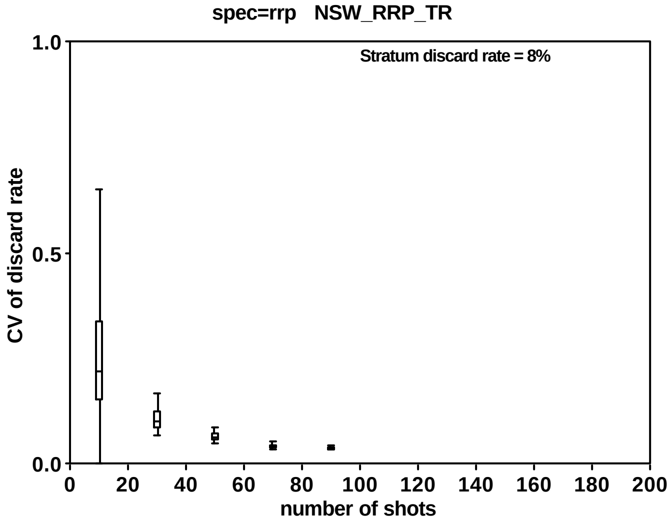


Figure 16 Blue eye trevalla for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

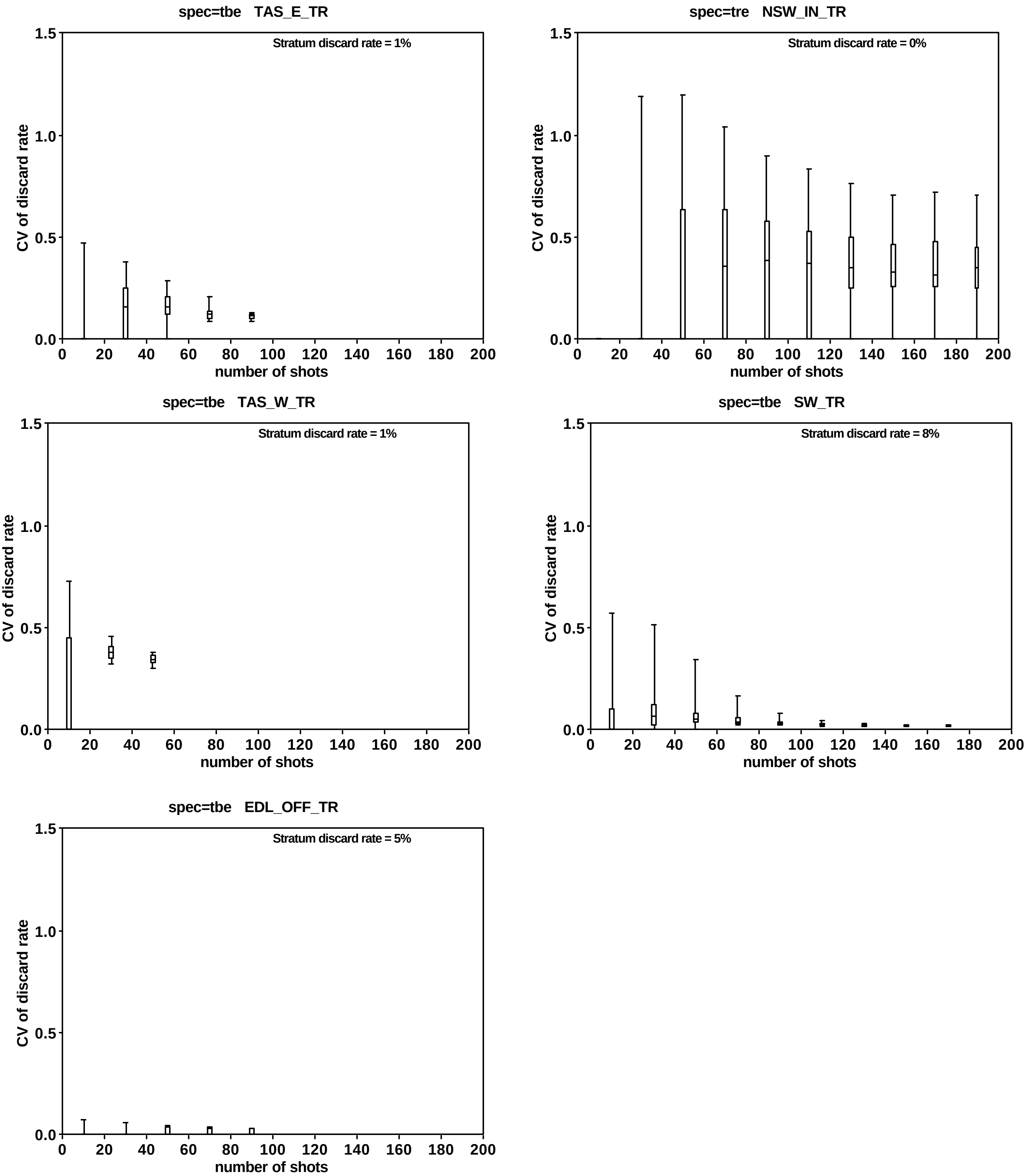
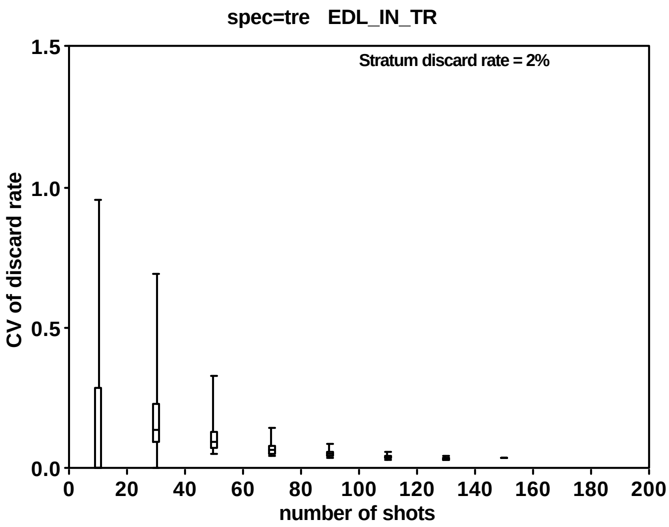


Figure 17 Silver Trevally for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.



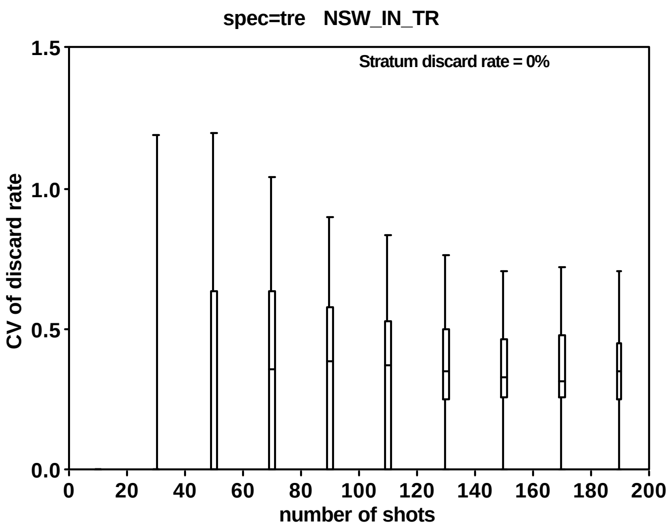


Figure 18 Spotted warehou for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

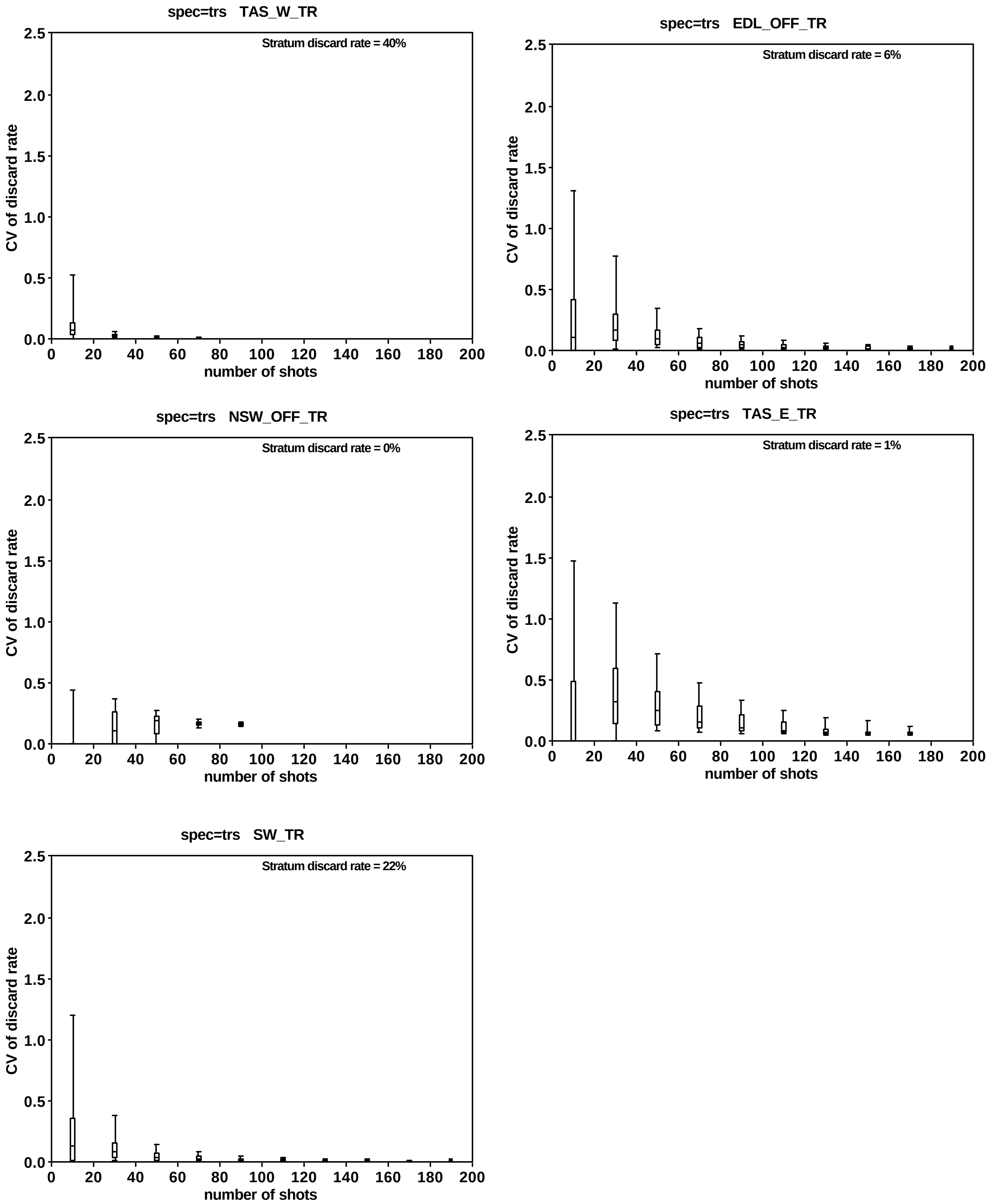


Figure 19 Blue warehou for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

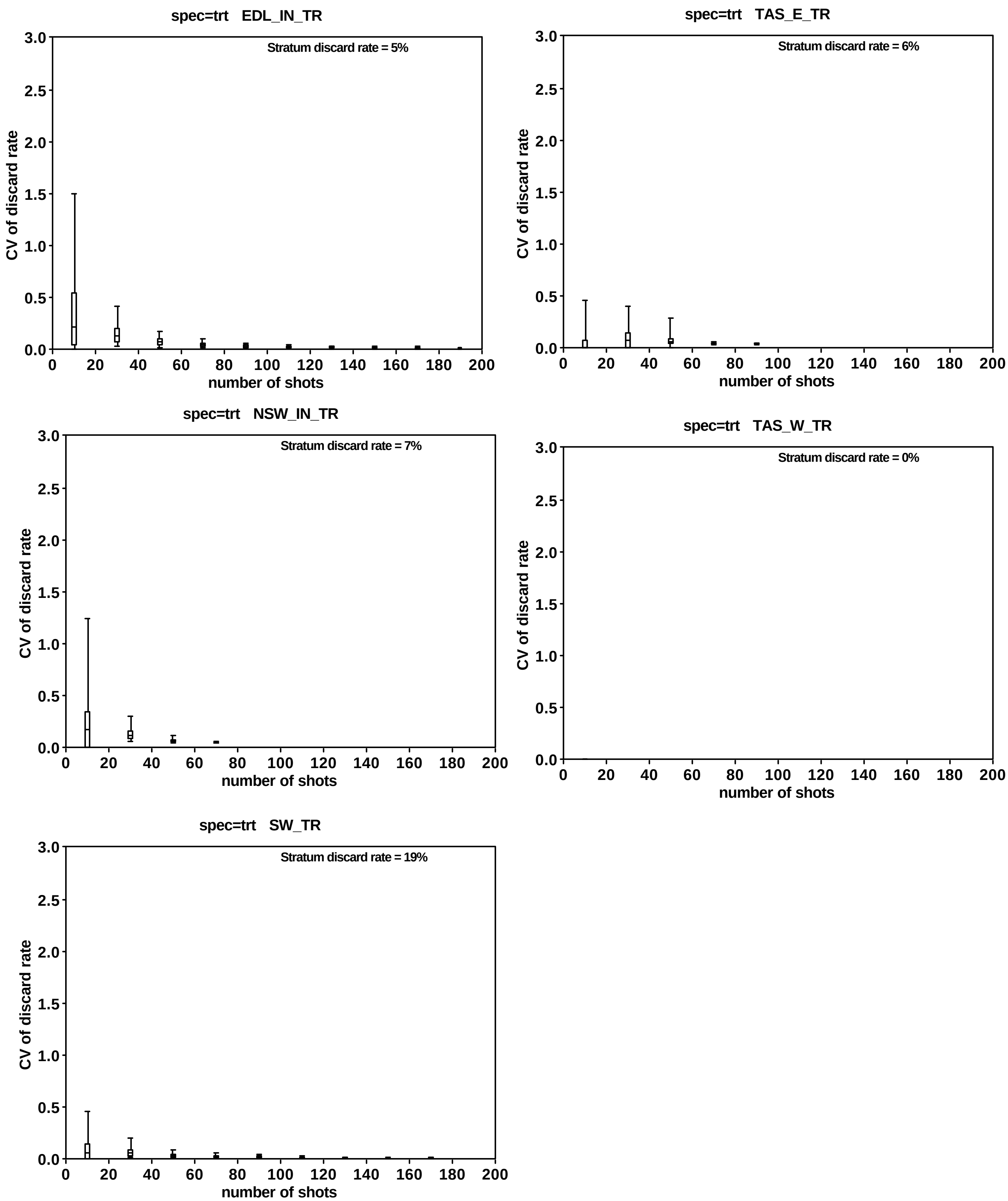


Figure 20 School whiting for each defining stratum. Coefficient of variation of discard rates from simulations for 20 to 200 shots within the stratum.

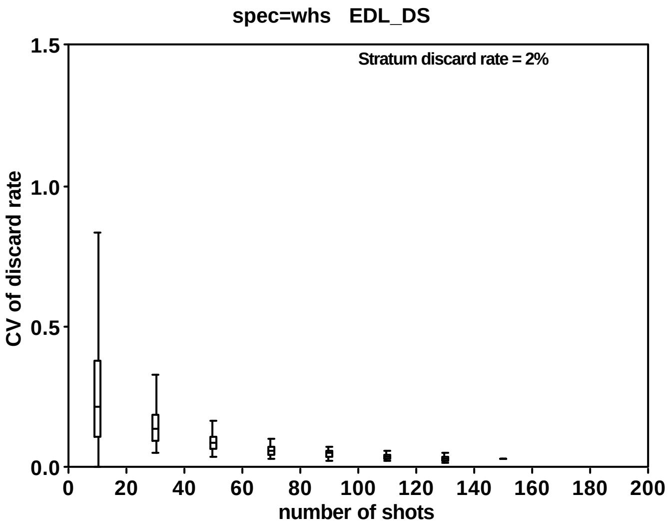


Figure 21 Spawning blue grenadier for all strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

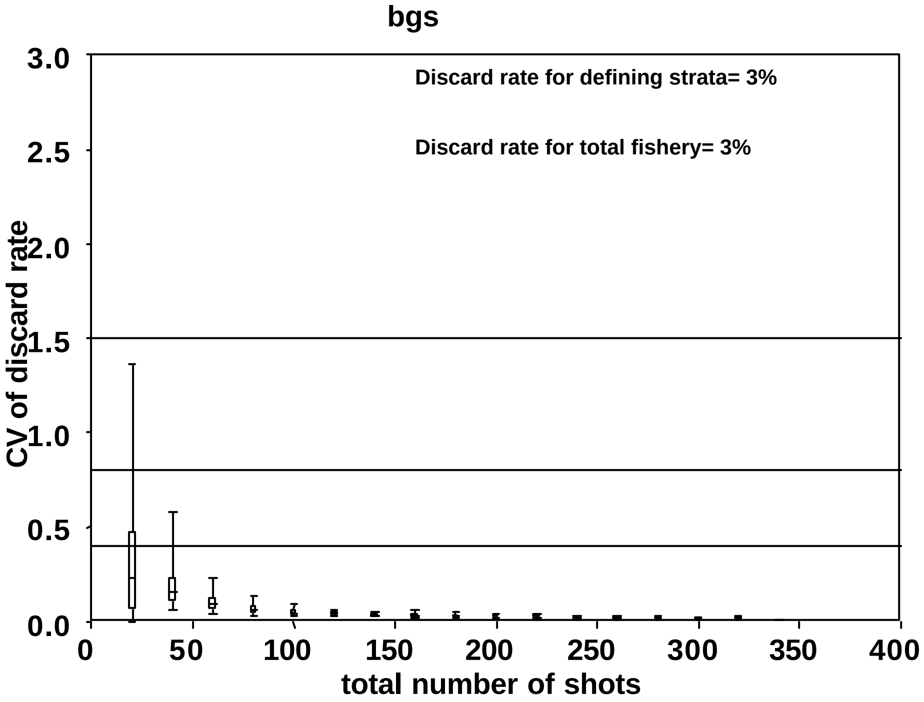


Figure 22 Nonspawnimg blue grenadier for all strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

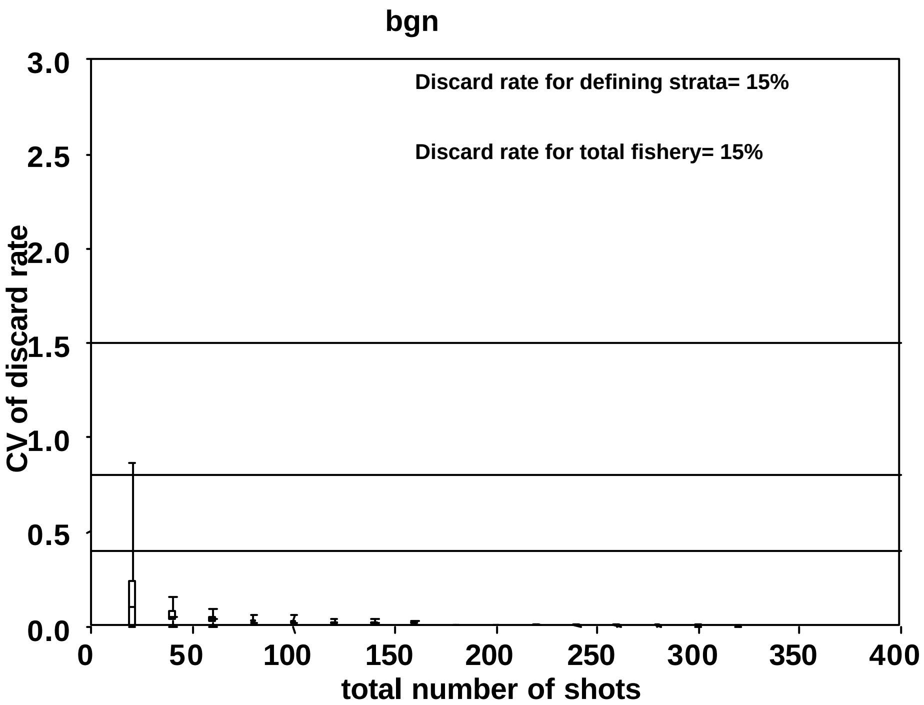


Figure 23 John dory for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

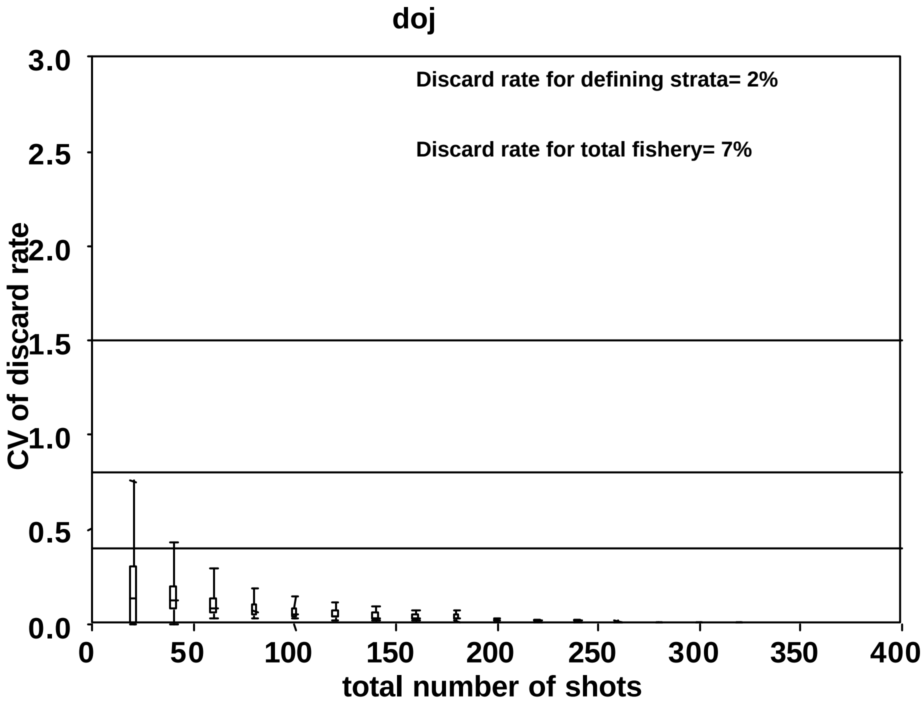


Figure 24 Mirror dory for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

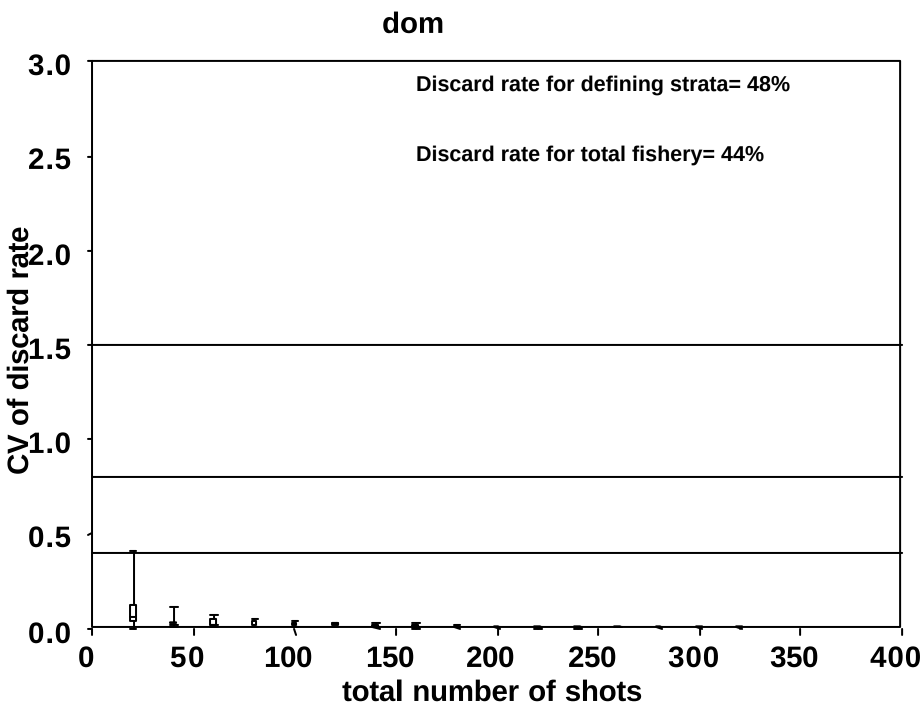


Figure 25 Tiger flathead for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

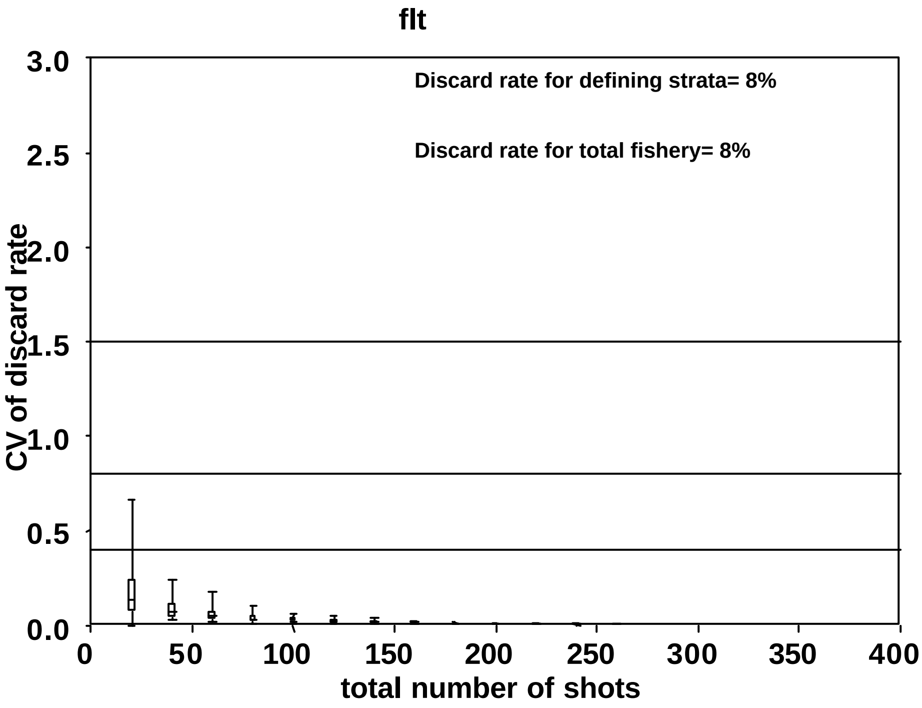


Figure 26 Eastern gemfish for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

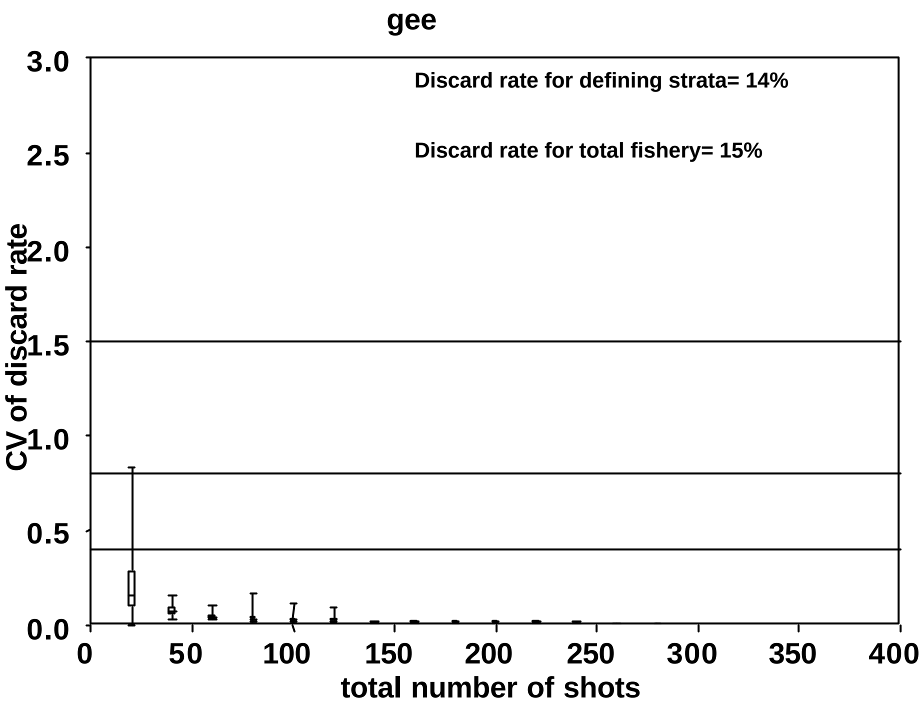


Figure 27 Western gemfish for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

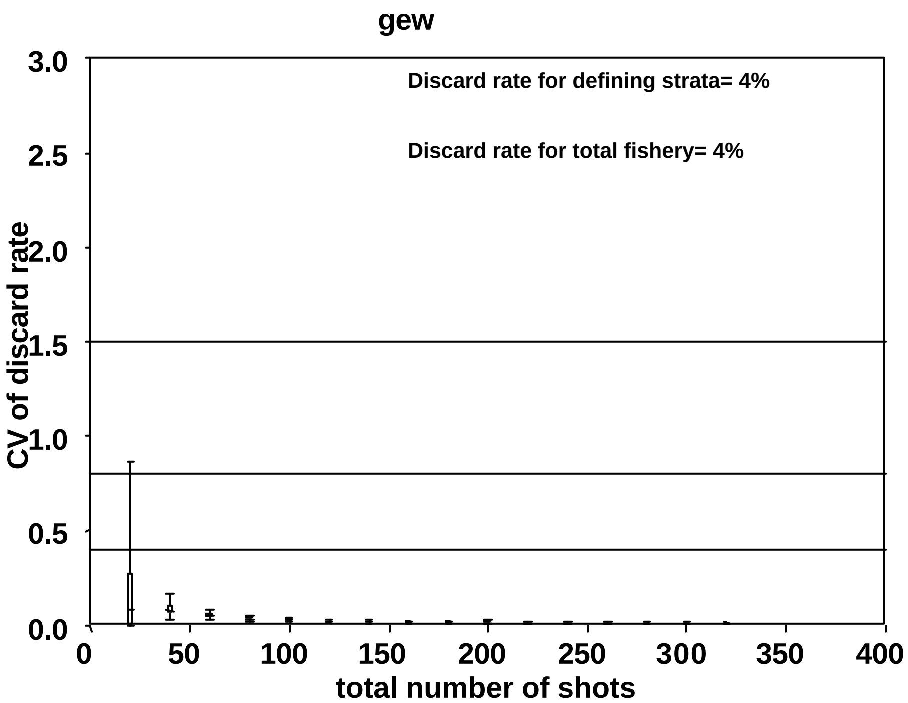


Figure 28 Ling for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

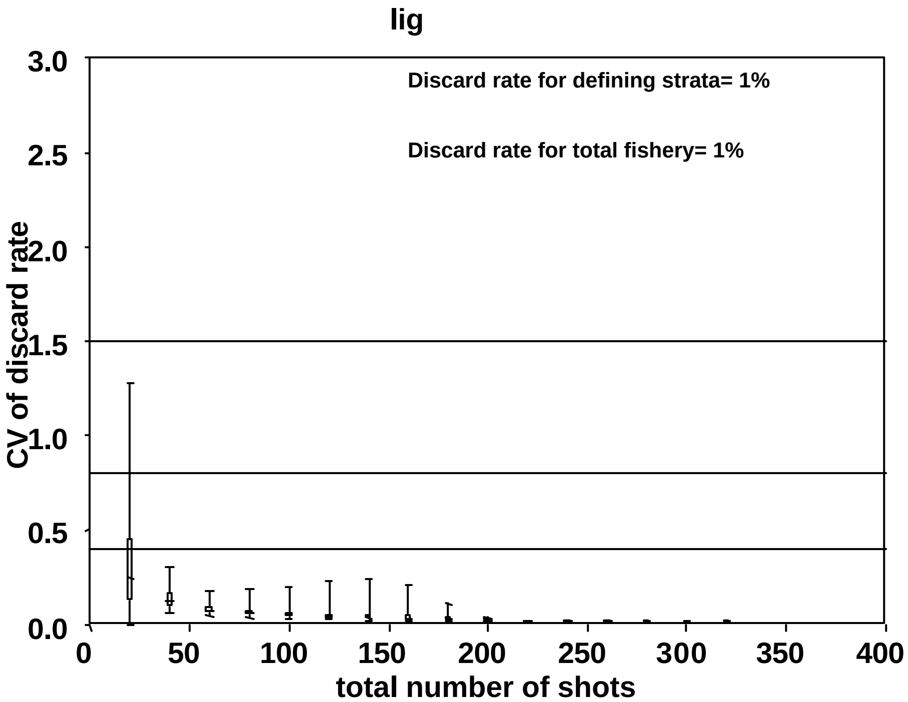


Figure 29 Morwong for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

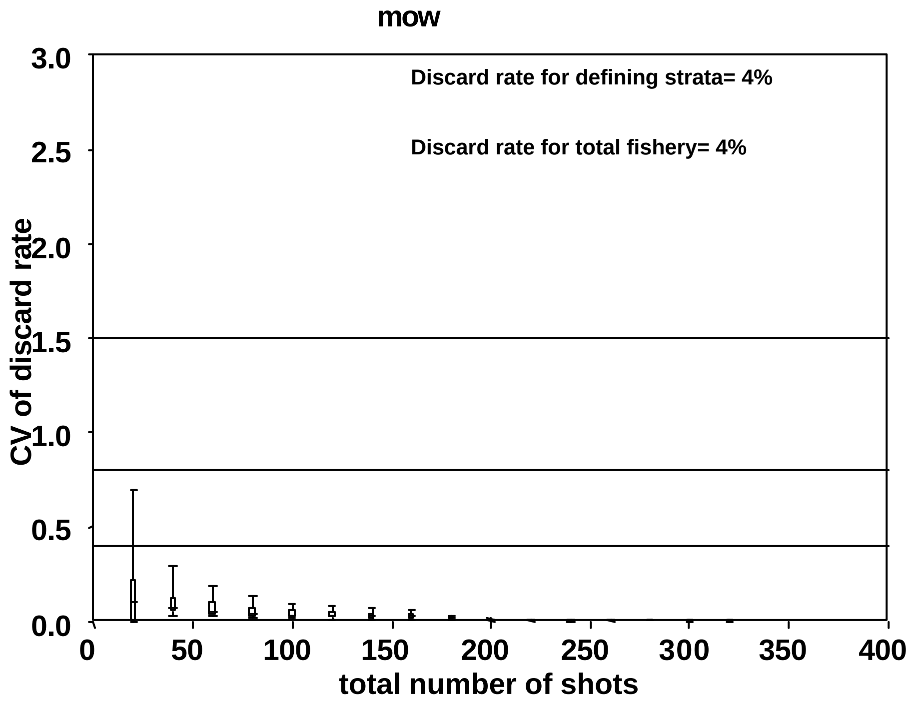


Figure 30 Orange roughy for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

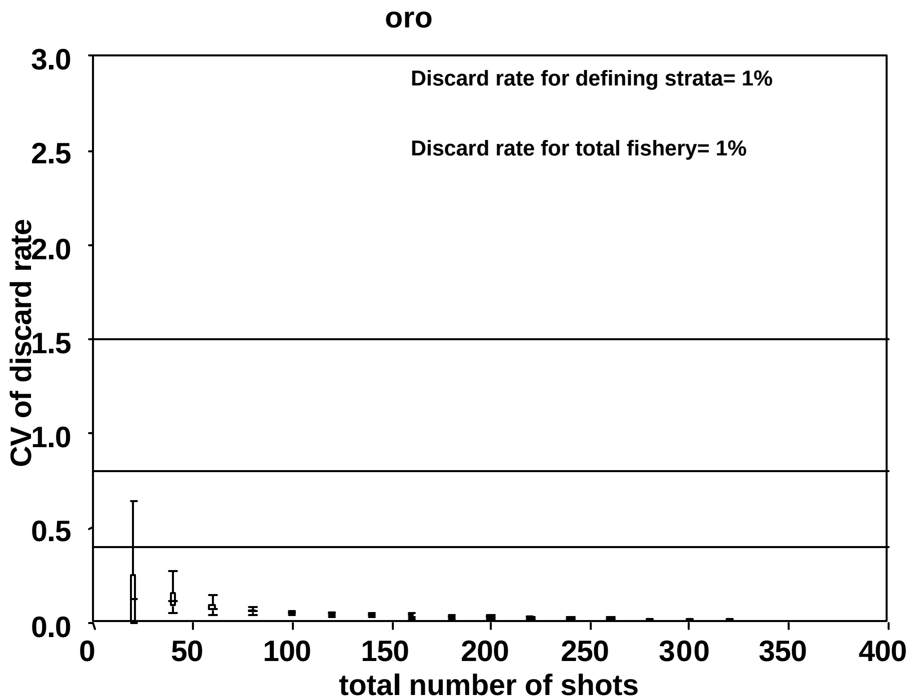


Figure 31 All other species for all strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

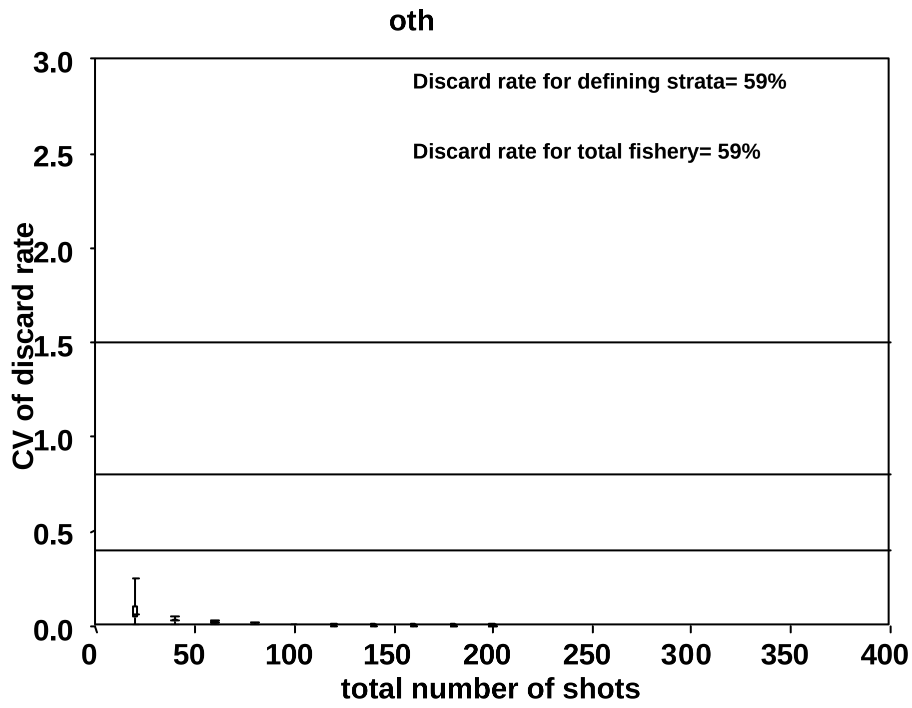


Figure 32 Redfish for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

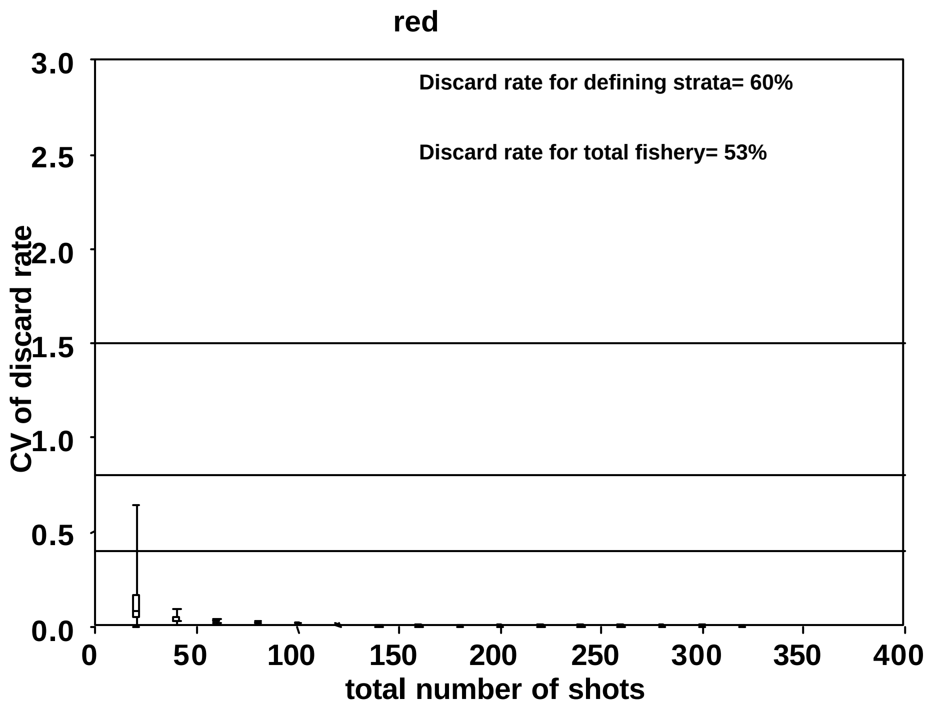


Figure 33 Inshore ocean perch for all strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

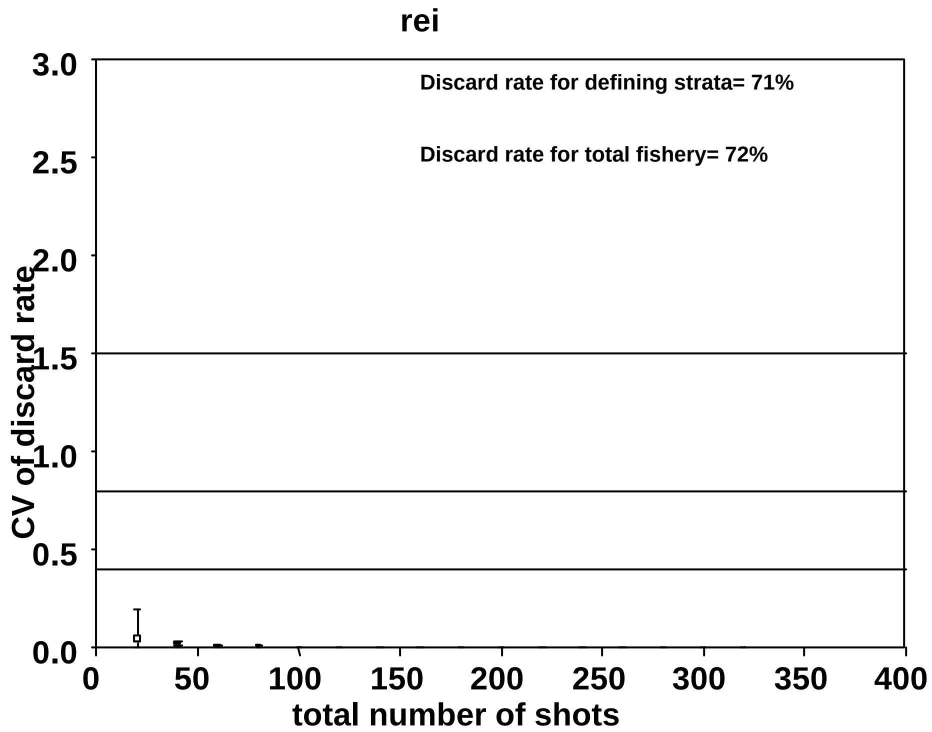


Figure 34 Offshore ocean perch for all strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

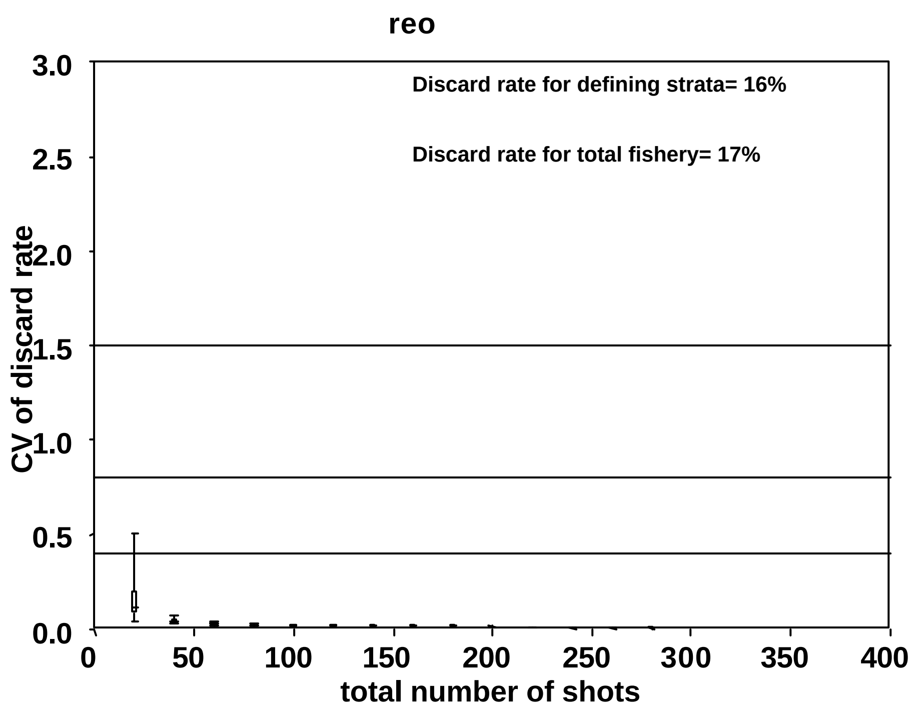


Figure 35 Royal red prawn for all strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

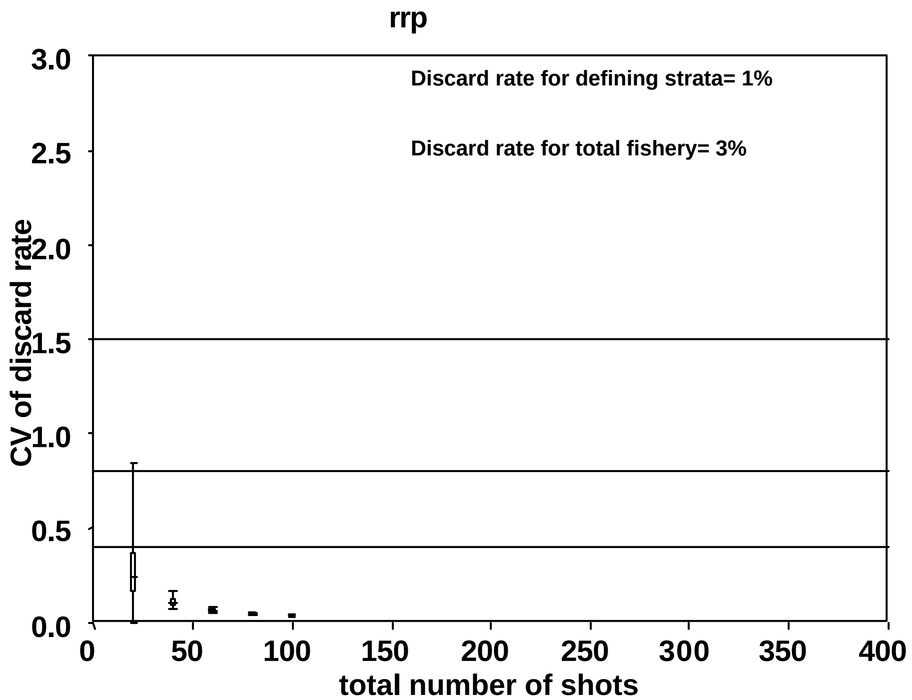


Figure 36 Blue eye trevalla for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

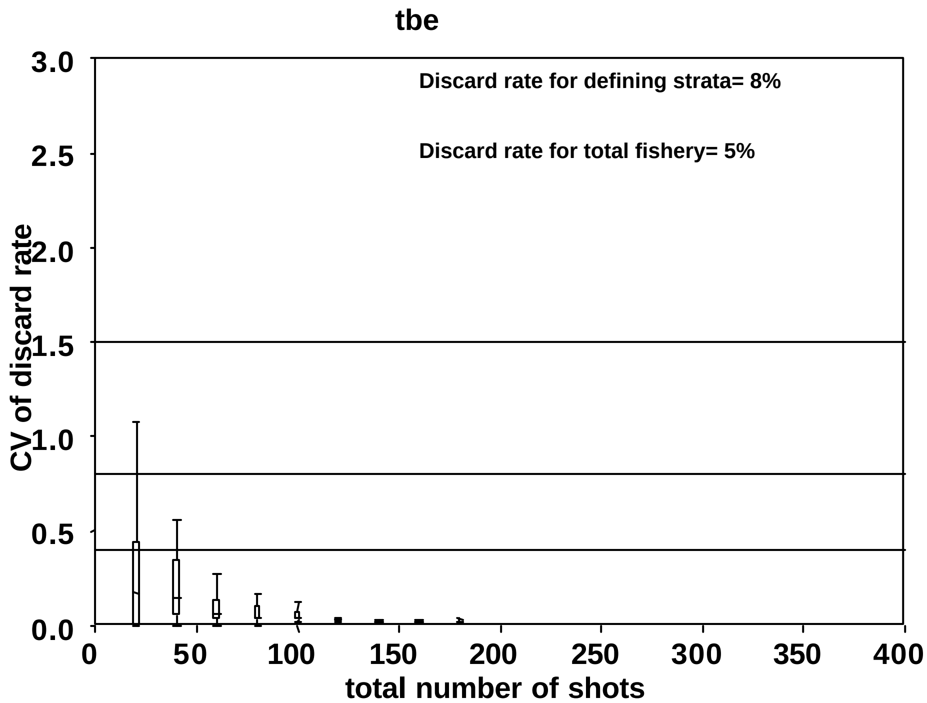


Figure 37 Silver trevally for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

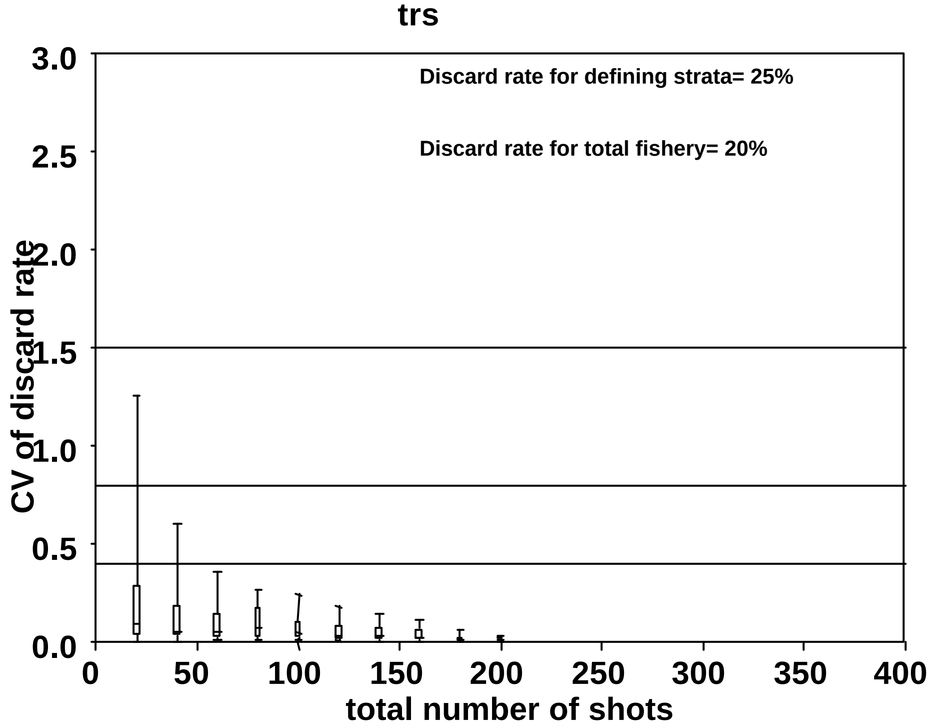


Figure 38 Spotted warehou for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

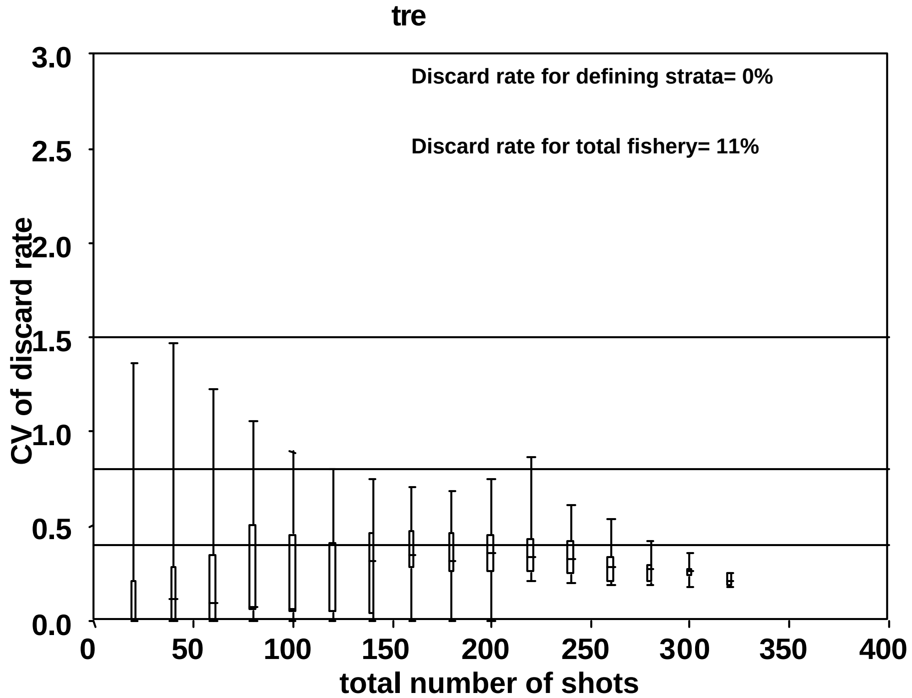


Figure 39 Blue warehou for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

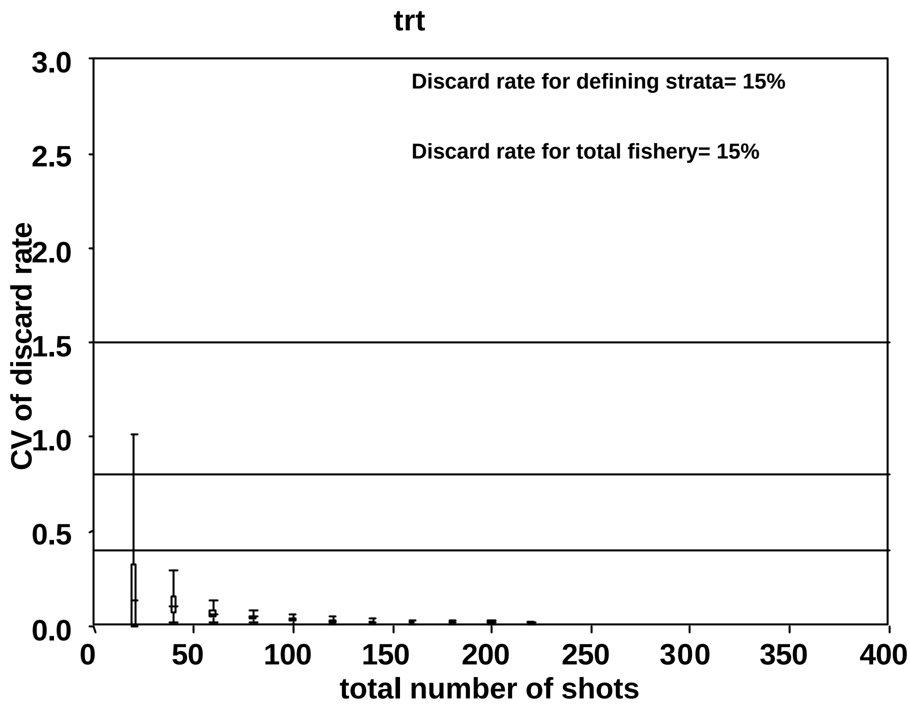


Figure 40 School whiting for all defining strata. Coefficient of variation of discard rates from simulations for total number of shots across all defining strata.

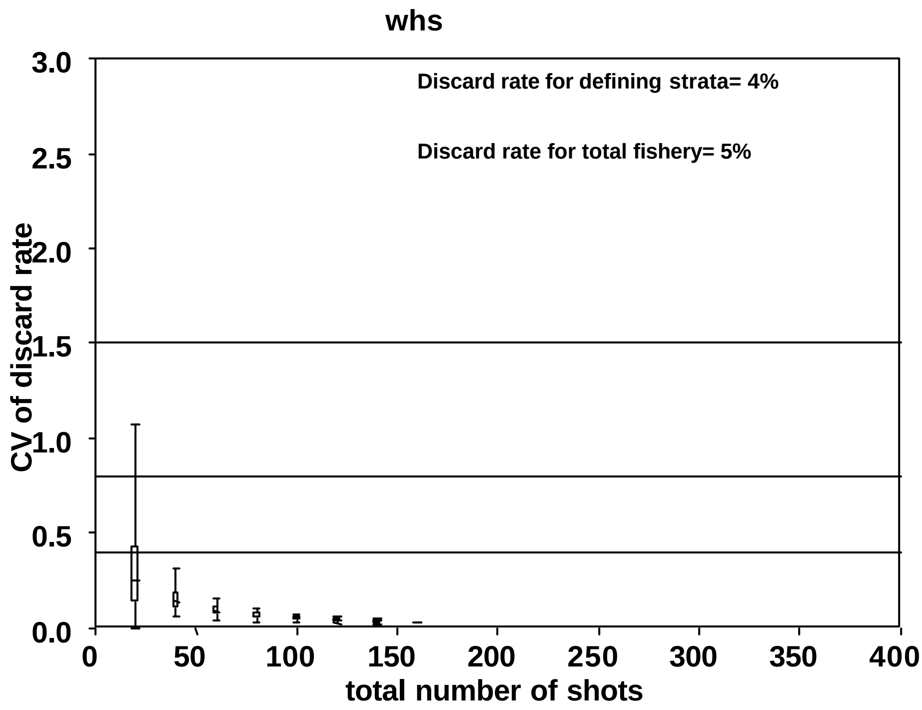
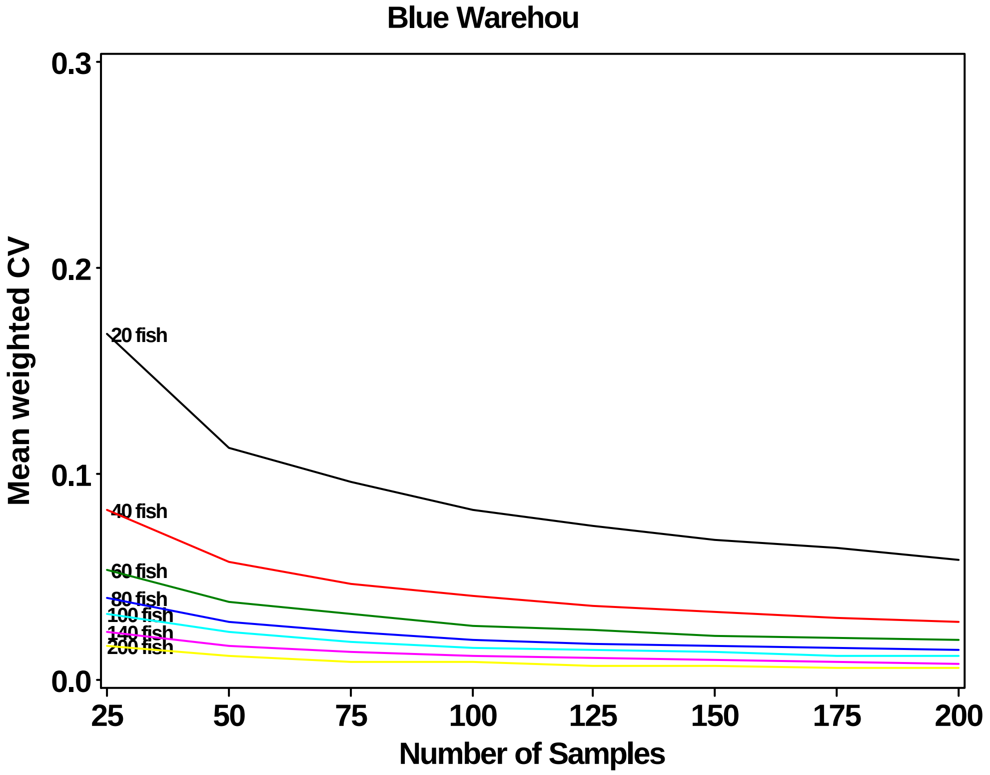
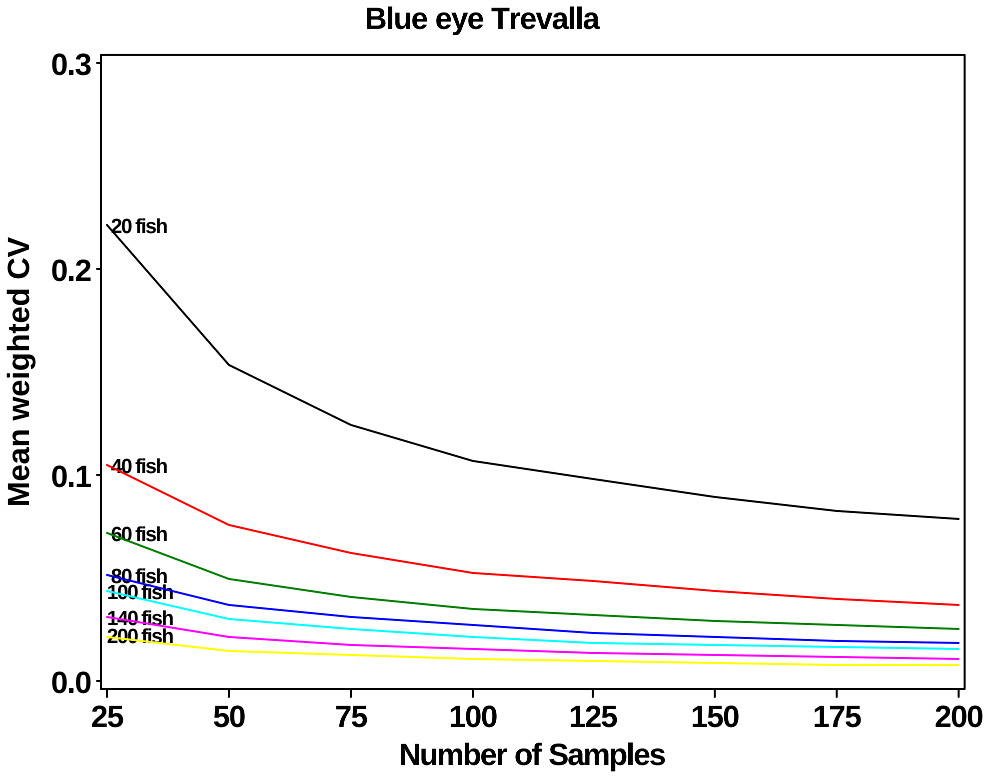
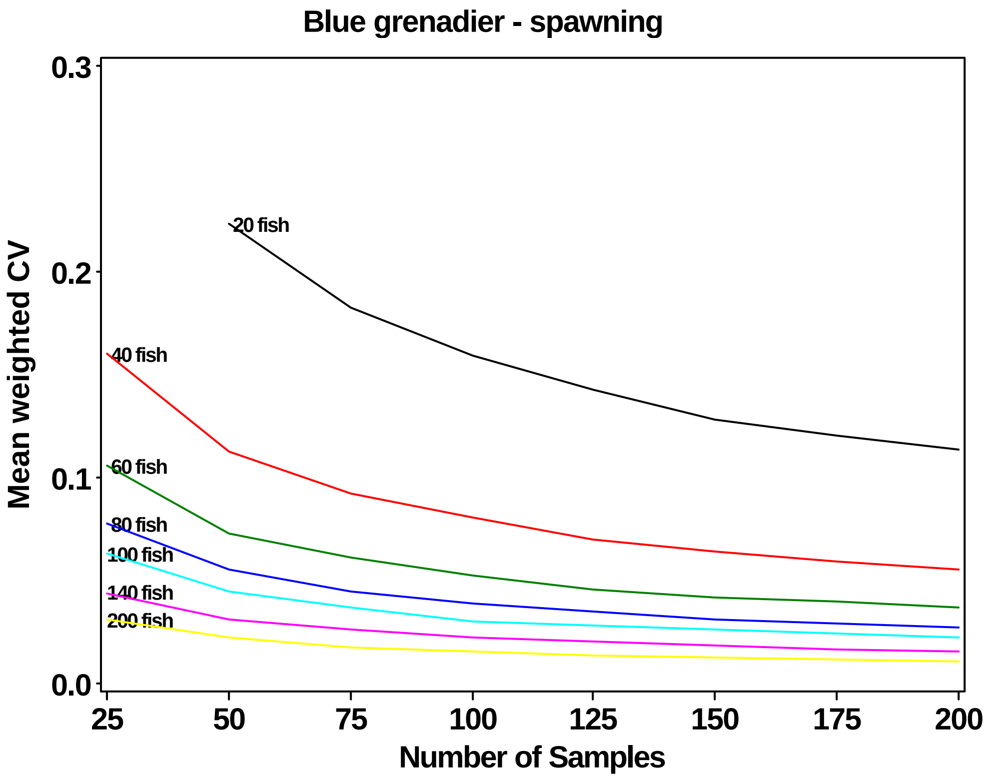
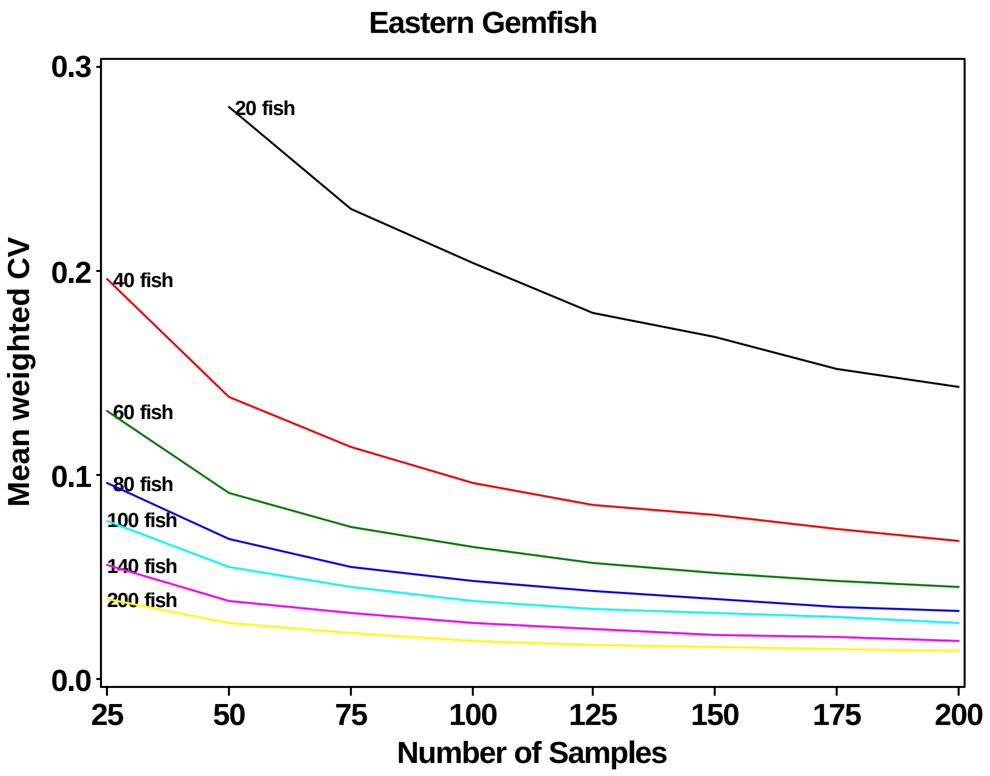


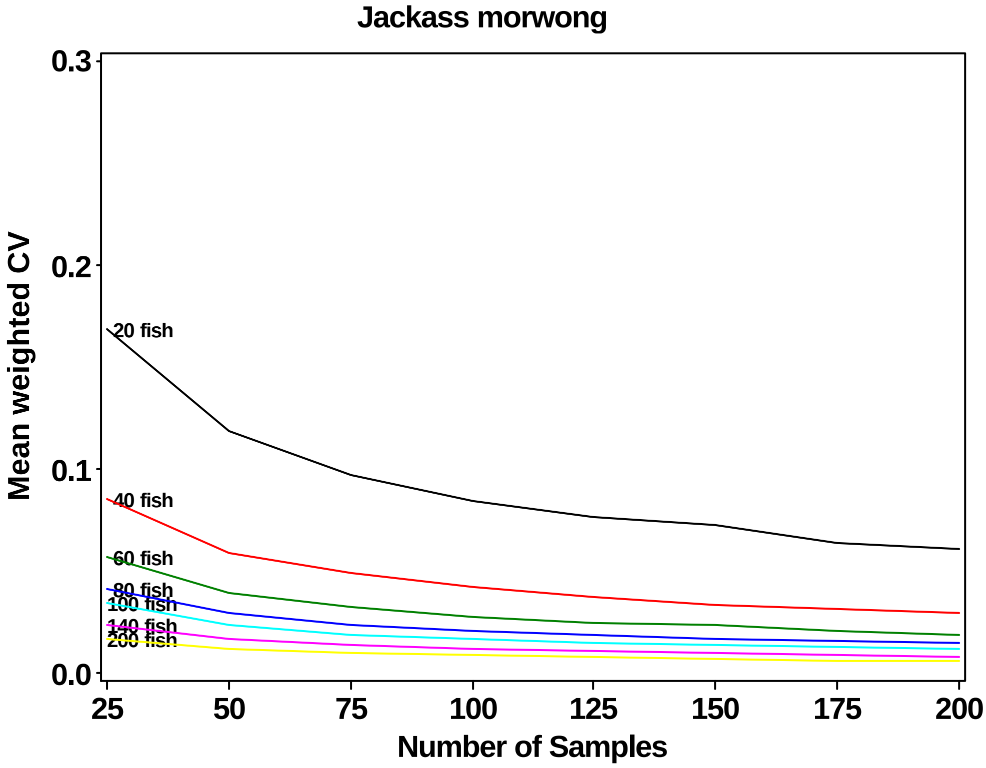
Figure 41 The mean weighted CV of length frequencies for each combination of sample number and sample size (i.e. number of fish within each sample).

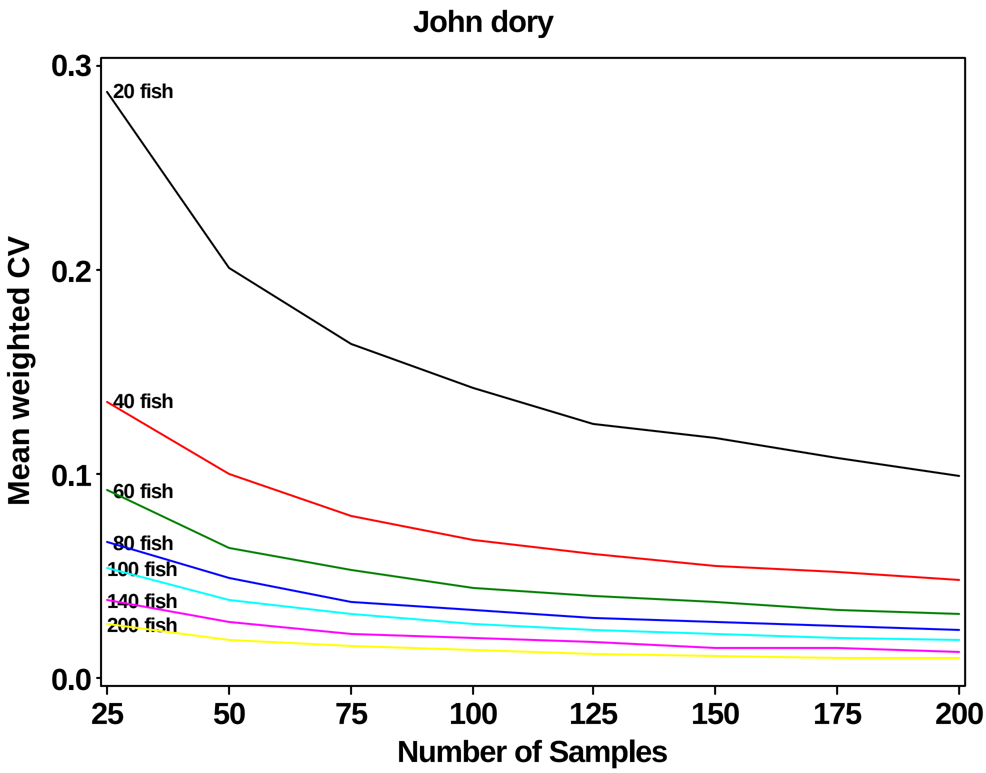


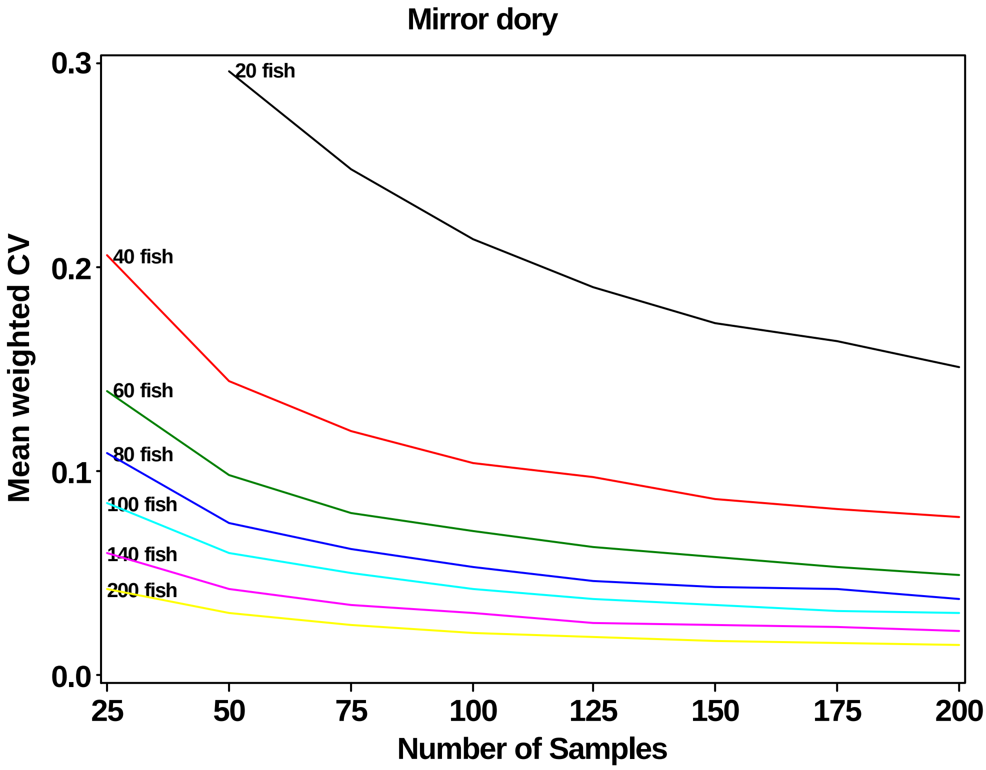


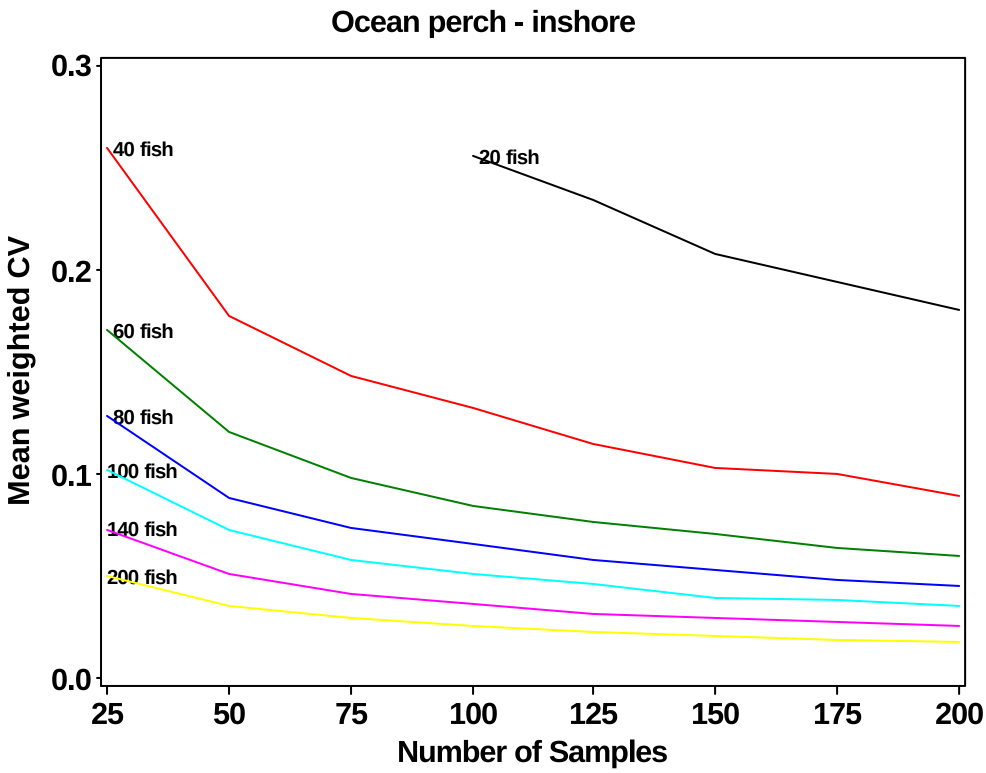

Blue grenadier - spawning
Mean weighted CV
0.0
0.1
0.2
0.3
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
25
50
75
100
125
150
175
200
Number of Samples

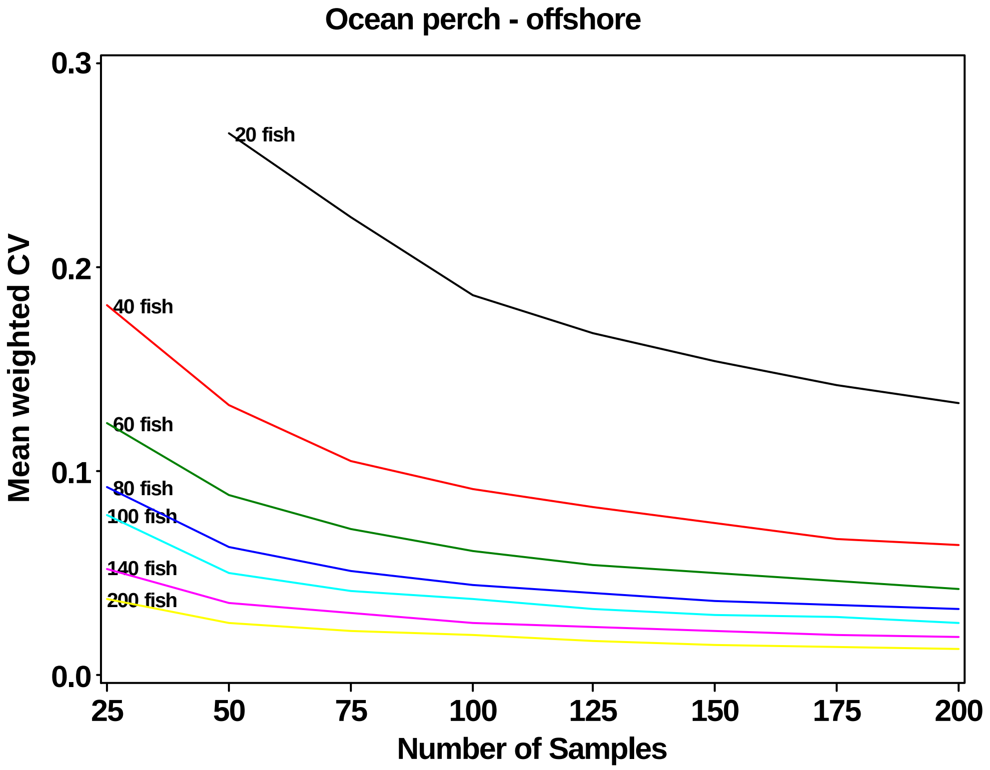

Eastern Gemfish
Mean weighted CV
0.0
0.1
0.2
0.3
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
25
50
75
100
125
150
175
200
Number of Samples

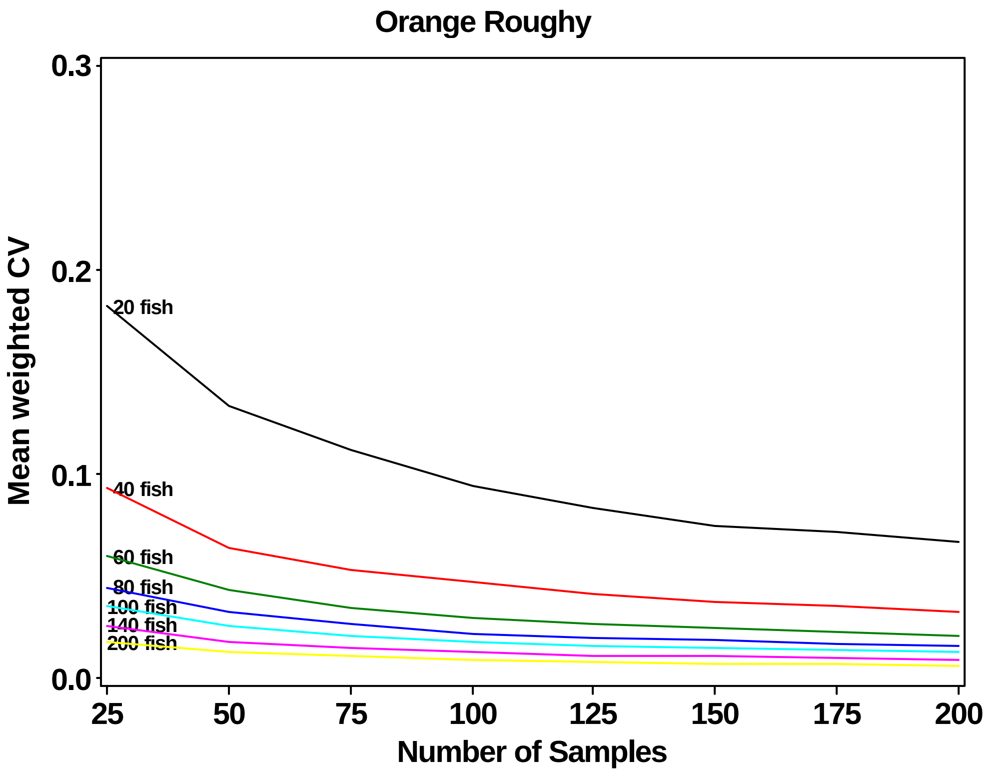

Jackass morwong
Mean weighted CV
0.3
0.2
0.1
0.0
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
25
50
75
100
125
150
175
200
Number of Samples

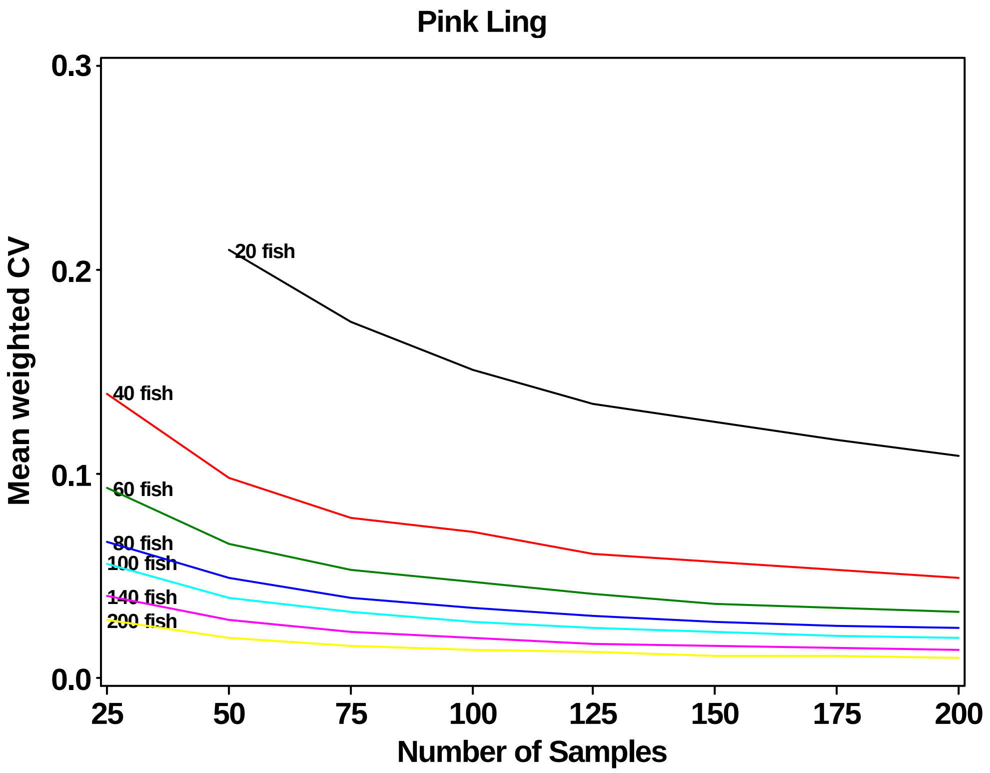

John dory
Mean weighted CV
0.3
0.2
0.1
0.0
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
25
50
75
100
125
150
175
200
Number of Samples

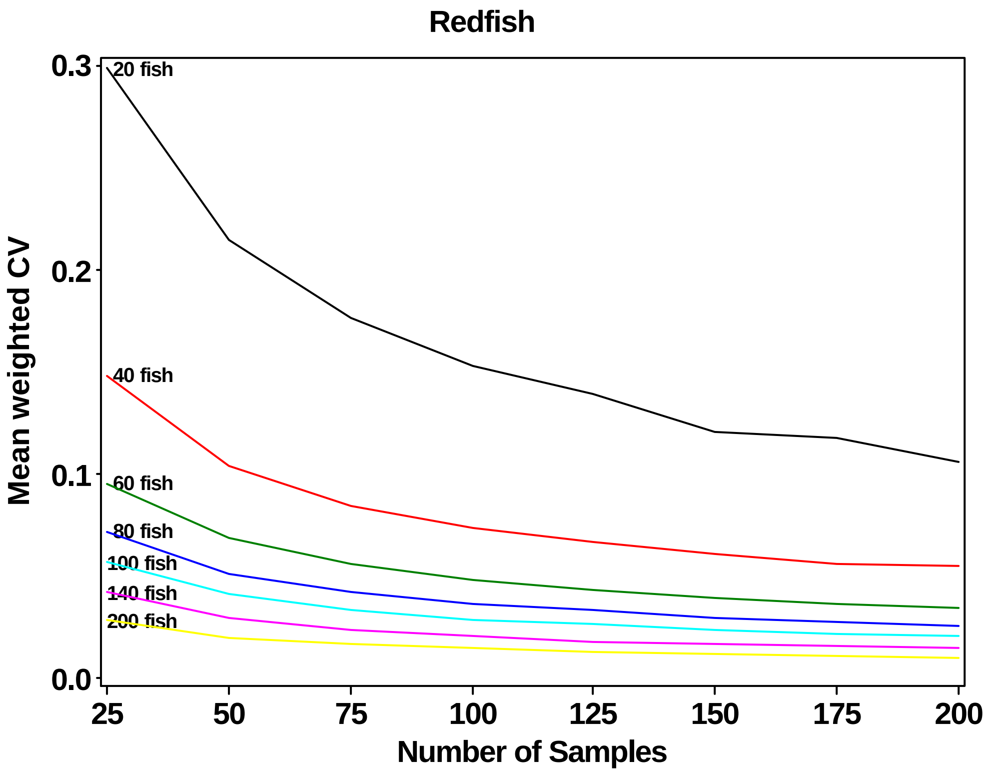

Mirror dory
Mean weighted CV
Number of Samples
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
0.0
0.1
0.2
0.3
25
50
75
100
125
150
175
200

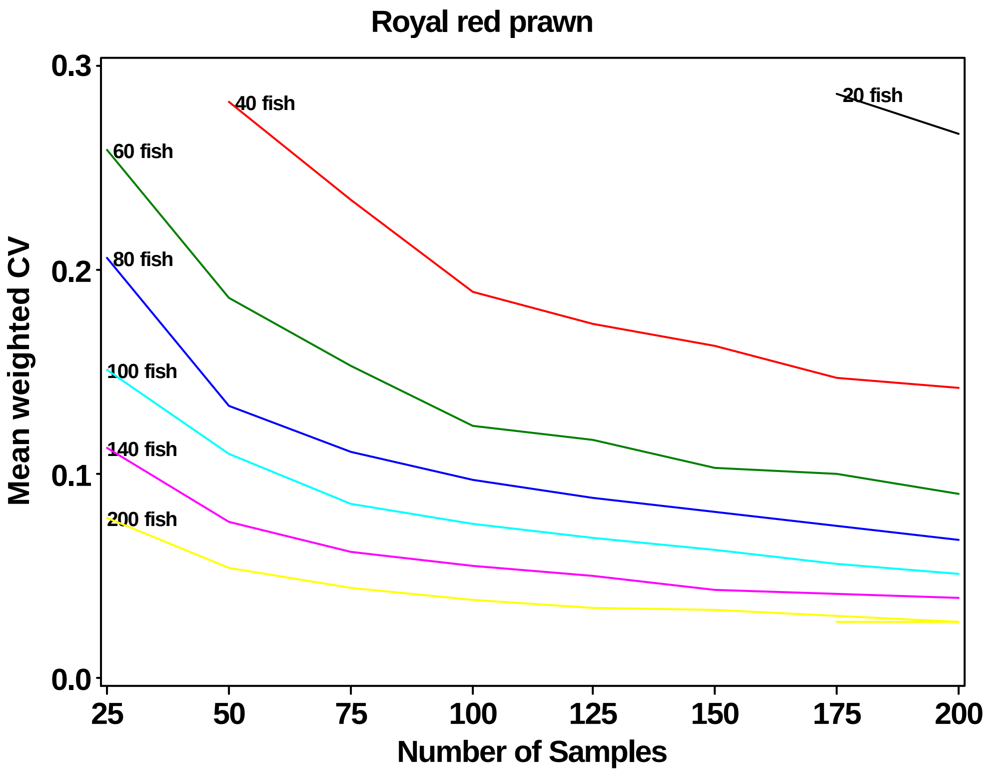

Ocean perch - inshore
Mean weighted CV
Number of Samples
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
0.0
0.1
0.2
0.3
25
50
75
100
125
150
175
200

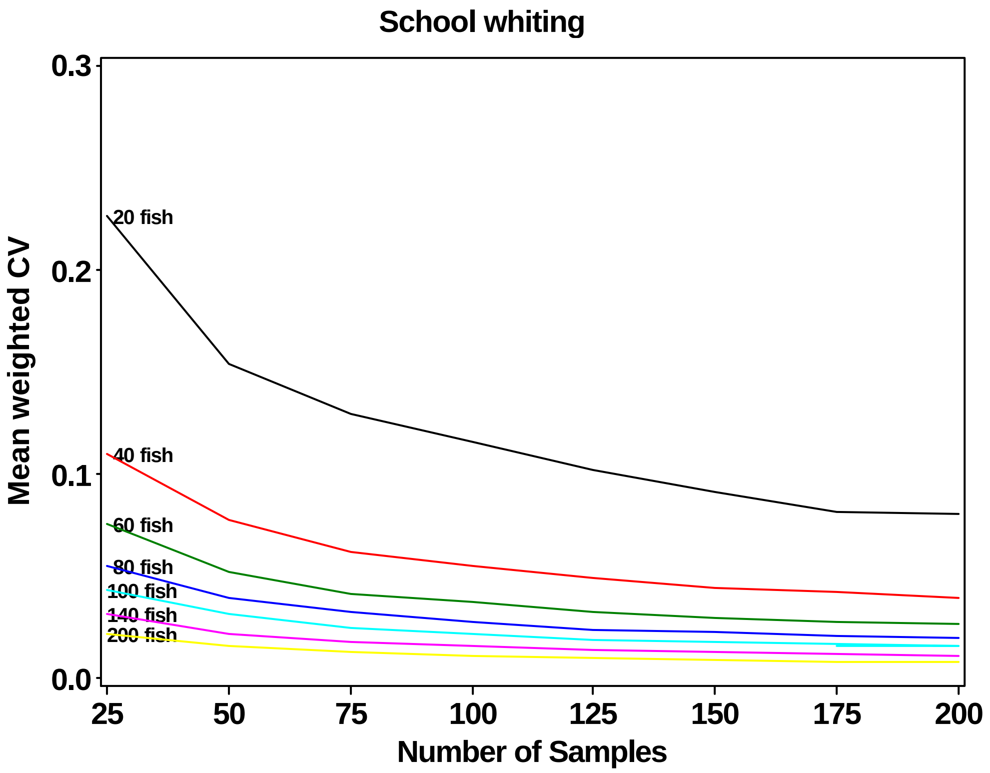

Ocean perch - offshore
0.3
0.2
0.1
0.0
Mean weighted CV
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
25
50
75
100
125
150
175
200
Number of Samples

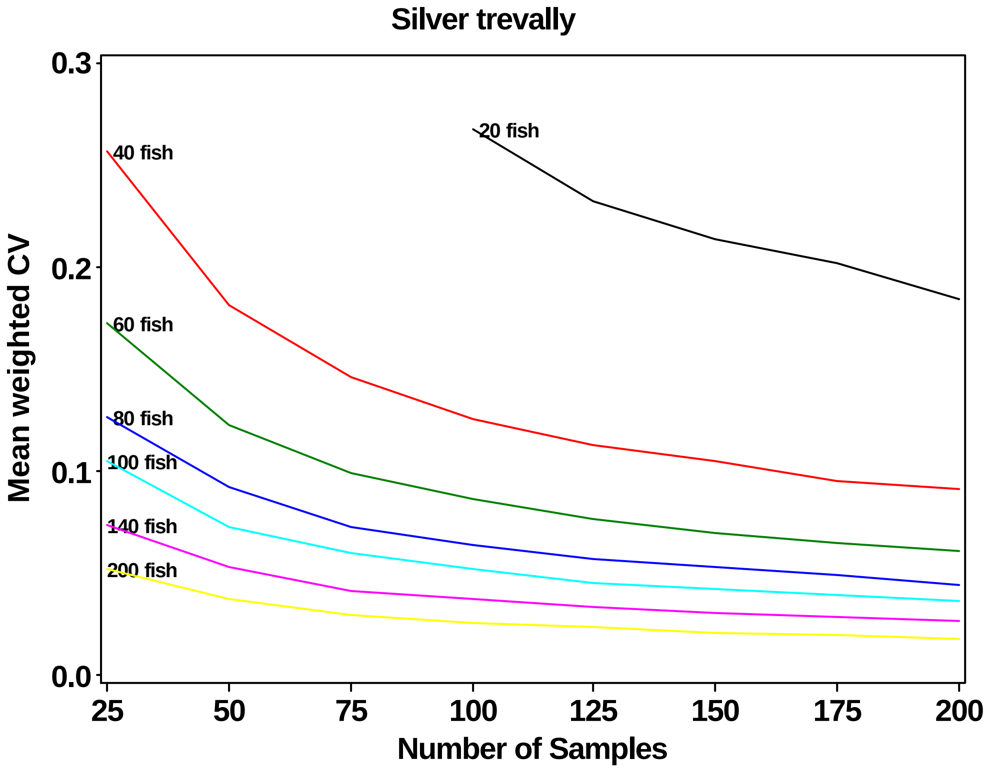

Orange Roughy
0.3
0.2
0.1
0.0
Mean weighted CV
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
25
50
75
100
125
150
175
200
Number of Samples

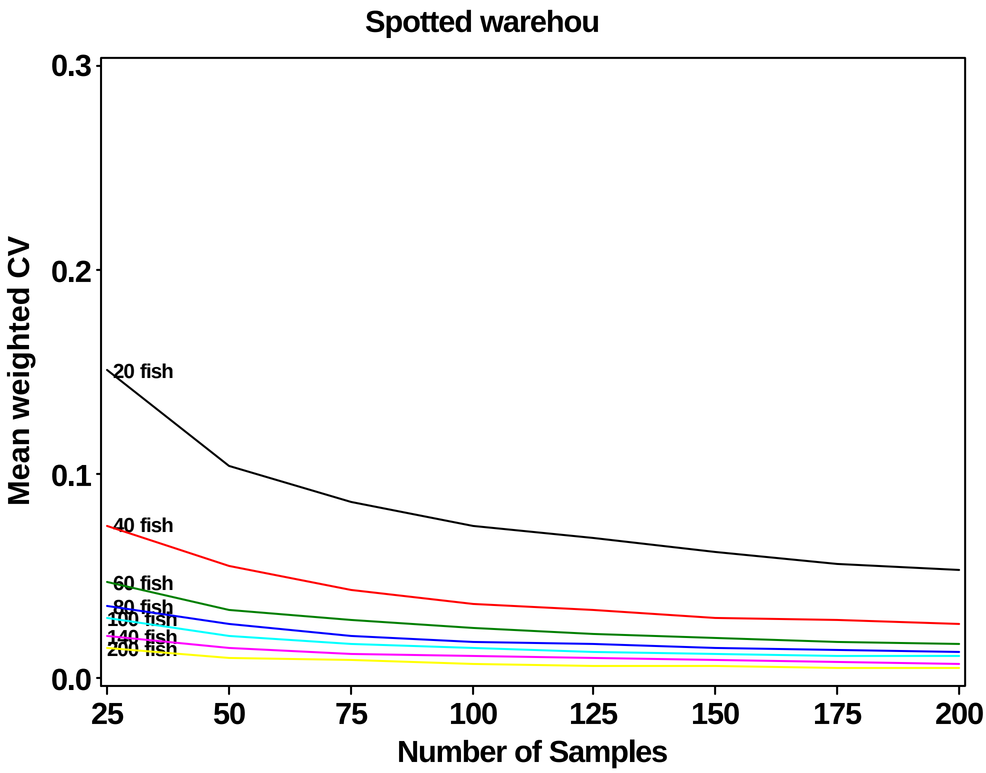

Pink Ling
Mean weighted CV
0.3
0.2
0.1
0.0
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
25
50
75
100
125
150
175
200
Number of Samples

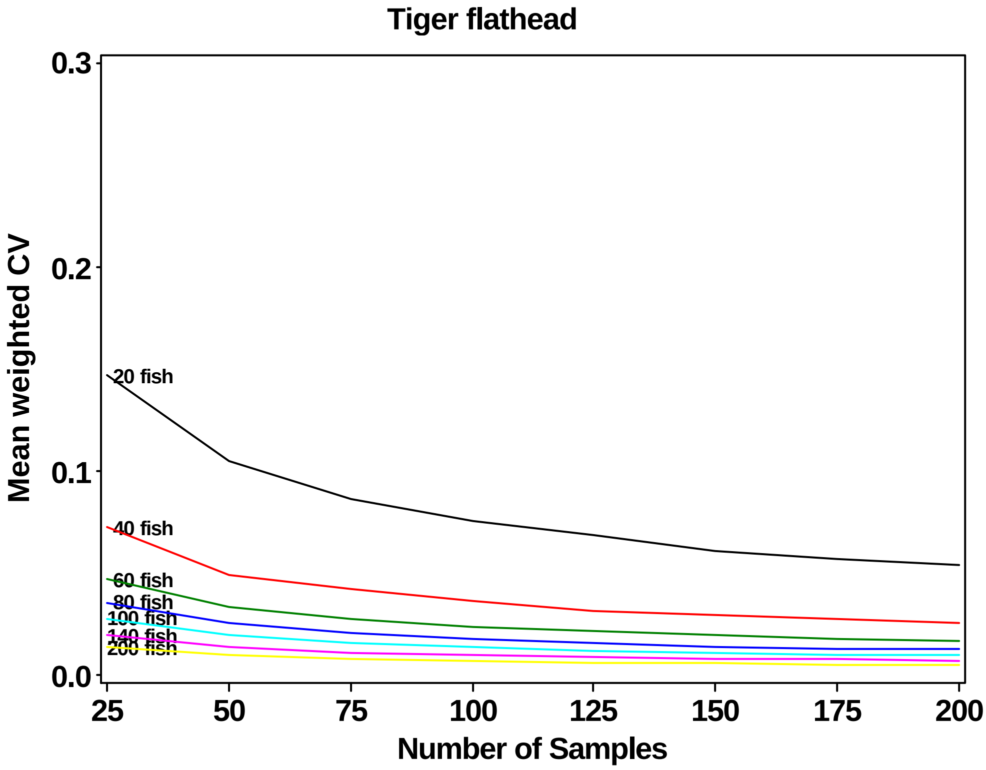

Redfish
Mean weighted CV
0.3
0.2
0.1
0.0
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
25
50
75
100
125
150
175
200
Number of Samples

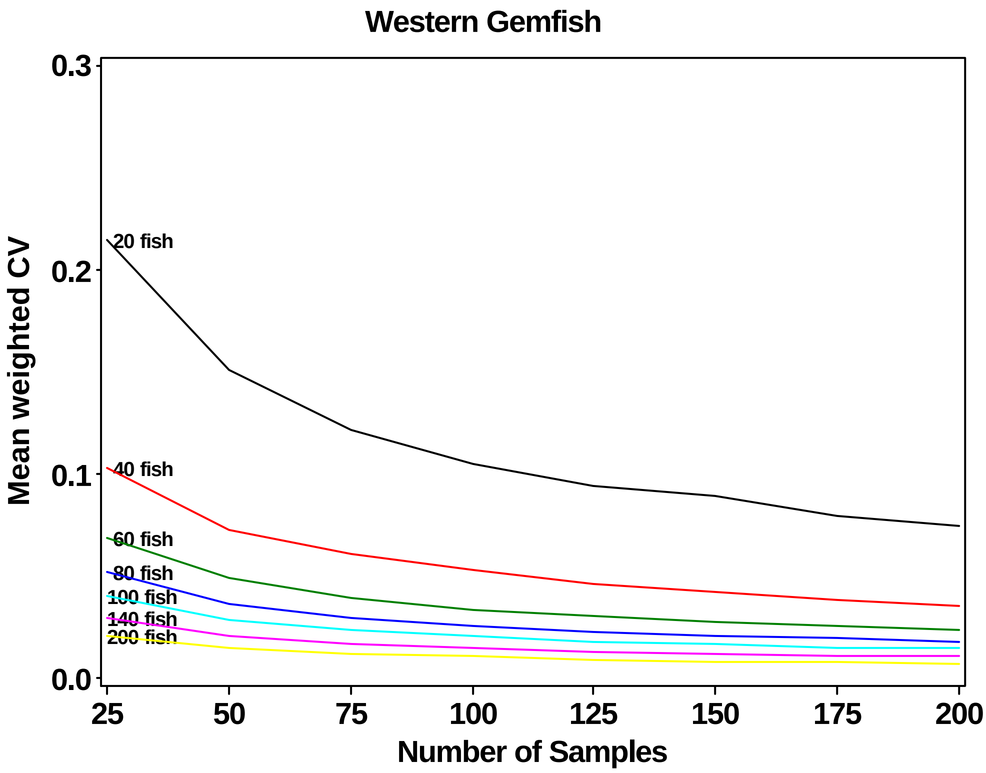

Royal red prawn
Mean weighted CV
0.0
0.1
0.2
0.3
25
50
75
100
125
150
175
200
Number of Samples
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish


School whiting
Mean weighted CV
0.0
0.1
0.2
0.3
25
50
75
100
125
150
175
200
Number of Samples
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish


Silver trevally
0.3
0.2
0.1
0.0
Mean weighted CV
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
25
50
75
100
125
150
175
200
Number of Samples


Spotted warehou
0.3
0.2
0.1
0.0
Mean weighted CV
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
25
50
75
100
125
150
175
200
Number of Samples


Tiger flathead
Mean weighted CV
0.3
0.2
0.1
0.0
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
25
50
75
100
125
150
175
200
Number of Samples


Western Gemfish
Mean weighted CV
0.3
0.2
0.1
0.0
20 fish
40 fish
60 fish
80 fish
100 fish
140 fish
200 fish
25
50
75
100
125
150
175
200
Number of Samples