



## **Analyses of tag return data from the CCSBT SRP tagging program**

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**Table of Contents**

Abstract.....	1
Introduction.....	1
Methods.....	1
Data.....	1
Estimation Model.....	3
Reporting Rates.....	4
Tag Shedding .....	5
Natural Mortality Rates.....	5
Results and Discussion .....	6
Location of Longline Returns .....	6
Fishing Mortality Rate Estimates.....	7
Returns from the First Season for December Releases.....	9
Returns Per 1000 fish.....	10
Acknowledgements.....	11
Literature Cited .....	12

**Abstract**

Preliminary analyses of the release and recapture data from the CCSBT SRP tagging program are presented. A tag attrition model was used to estimate cohort and age-specific fishing mortality rates for different groups of tag releases conditional on estimates of natural mortality, tag shedding and reporting rates (the latter three derived from separate analyses). The estimated fishing mortality rates are independent of the catch and catch-at-age data. There appear to be substantial tagger and age of release effects in the return data. The results suggest high fishing mortality rates in 2003, 2004 and 2005 for ages 2 and 3 for those fish tagged at age 2 and above. However, rates based on age 1 releases, which primarily occurred in Western Australia, tend to be lower. High rates of recovery were obtained from age 3 fish released in December in the Great Australian Bight (GAB) during the same season they were released. Overall the results suggest high fishing mortality rates for fish in the GAB, but it is not clear to what extent this represents the overall juvenile population.

The number of returns from age 1 releases from the 2000 and 2001 cohorts were disproportionately low relative to returns from releases from other age classes and also relative to returns from the 1990s tagging experiments. This suggests either higher tagging mortality or natural mortality or changes in the spatial dynamics for age 1 fish. The spatial distribution of longline returns also suggest a possible change in spatial dynamics with few tagged fish moving into the Tasman Sea (but this may be confounded by reporting rate issues). Estimates of fishing mortality rates from the tag attrition model at age 2 were very near zero for the 2000 and 2001 cohorts, which appears inconsistent with the catch data from the surface fishery. Nevertheless, the estimates for age 2 indicate a large increasing trend between 2002 and 2005. Estimates of the number of tags returned per 1000 fish caught in the surface and longline fisheries also suggest possible inconsistencies with the catch data. In particular, not enough older fish appear to have been caught in the surface fishery relative to the number of tags returned from fish at older ages.

**Introduction**

As part of the Scientific Research Program (SRP), the CCSBT initiated a large scale tagging program to estimate juvenile fishing mortality rates beginning in 2000/2001 fishing season. The basic design of the tagging program was similar to that conducted in the 1990s as part of the CSIRO/NRIFS Recruitment Monitoring Program with the aim to tag multiple cohorts at different ages in several years. This paper provides some preliminary analyses of the data collected to date in the SRP tagging program, including some initial estimates of fishing mortality rates using a tag attrition model using similar approaches to those used in Polacheck and Eveson (2005).

**Methods*****Data***

Tagging in the first year was only done off Western Australia (WA) with 1 and 2 year old fish being tagged. In all subsequent years, tagging was conducted in both WA and South Australia (SA) with almost all of the fish being tagged being between ages 1 and 3 (i.e. less than 2% of the fish tagged are estimated to be older than age 3).

Some of the release and return data are considered unreliable for estimating mortality rates, therefore we applied the following screening process to the data prior to analysis.

For the release data:

- Only fish released into the wild were included (i.e., we excluded data from fish that were released into farms as part of a tag seeding program).
- Only releases where the fish was caught by pole and line were included. This method of catching fish is least likely to cause lasting injury to the fish.
- Only releases for which both tags were recorded as being inserted correctly were included to reduce the chance of tag shedding biasing our analyses.
- Only fish for which the injury due to tagging was regarded as slight were included to reduce the chance of fish mortality due to tagging biasing our analyses.
- Only fish whose length was recorded at the time of tagging were included because our analysis uses age of release, which is estimated based on length.

For the recapture data:

- Only recaptures corresponding to releases that met the above release criteria were included.
- Only recapture records from fish caught in the wild were included. For tagged fish that are harvested from the farms, the database has two records: one corresponding to the original capture from the wild and one corresponding to the harvest from the farm. For the purposes of estimating fishing mortality we are only interested in the information (date and location) for the capture from the wild.

A fish's age at tagging was estimated from its length using cohort slicing and the growth curve currently adopted by the CCSBT (Anon. 2001b). SBT grow rapidly as juveniles so there is good separation between length distributions at the ages being tagged, and therefore the number of aging errors should be small. All tagging was done between December and April, so the release ages were adjusted in order that fish tagged in December from a given year-class/cohort were assigned the same age as those tagged after December. The recapture age was calculated using the age of release and the time between release and recapture. Recapture ages were also adjusted so that fish from a given cohort caught in November or December were given the same age as those caught after December.

As discussed below, results from separate analyses of tag shedding rates performed by Dr. W.S. Hearn (CSIRO Marine and Atmospheric Research) are used in the estimation of mortality rates. In addition to the above data screening, Dr. Hearn excluded tag returns if the recapture year or month within year was uncertain, or if the day within month was uncertain for recaptures at liberty less than 270 days. Also, data sets associated with a tagger were only analysed if there were 30 or more acceptable recaptures in the set. Data associated with the remaining taggers were pooled into a set we call "tagger" Z.

In the current paper, we have included none of the releases from the 2005/2006 fishing season nor any of the recapture from tags returned in 2005/2006. This is because the data for this year are very still very incomplete because only a small fraction of fish had been harvested from the farms at the time the data were compiled for analysis.

### *Estimation Model*

A basic tag attrition model was used to estimate cohort and age-specific fishing mortality rates for different groups of tag releases. This model was chosen because it provides a direct estimate of the fishing mortality rate for those fish tagged independent of any assumptions about mixing. This is seen as a first step to evaluate the consistency of estimates from different releases prior to developing a more integrated estimation model (e.g. a Brownie model).

We define two seasons: season 1 runs from January 1 to June 30 and corresponds to the Australian surface fishery; season 2 runs from July 1 to December 31 and corresponds to the longline fishery. For convenience, the model assumes all releases occurred in season 1 on January 1. In addition, the model follows the convention used in the CCSBT Management Procedure operating model in which all fishing is assumed to occur either on January 1 (season 1) or July 1 (season 2). All returns from the Australian surface fishery were assumed to occur in season 1 and all longline returns were assumed to occur in season 2. Natural mortality is assumed to occur at a constant rate throughout the year (i.e., it is evenly split between the two seasons since they are of equal length).

Because there are two seasons per year, it is convenient to work in terms of time periods taking values  $t = 1, 2, 3, \dots$ , where season 1 corresponds to odd time periods, season 2 corresponds to even time periods, and a year consists of a consecutive odd and even time period.

Let

$$N_{c,a,g,t+1} = (N_{c,a,g,t} - \widehat{R}_{c,a,g,t})e^{-0.5m_{a^*}} \quad (1)$$

where

$$\begin{aligned} N_{c,a,g,t} &= \text{the number of tagged fish alive at the start of time period } t \text{ from} \\ &\quad \text{fish tagged from cohort } c \text{ at age } a \text{ by tagger group } g; \\ \widehat{R}_{c,a,g,t} &= \text{the estimated number of tagged fish caught in time period } t \text{ from} \\ &\quad \text{fish tagged from cohort } c \text{ at age } a \text{ by tagger group } g; \\ m_{a^*} &= \text{natural mortality for fish of age } a^* = y - c, \text{ where } y \text{ denotes the} \\ &\quad \text{year corresponding to time period } t. \end{aligned}$$

For reasons discussed below, it was important to examine results for different groups of taggers. In some cases this was all taggers pooled, in other cases it was a group of a few taggers, and in still others it was a single tagger – thus, the subscript  $g$  in the above equation.

The number of recaptured tagged fish,  $\widehat{R}_{c,a,g,t}$ , in equation 1 is not simply the number of tags actually returned but is estimated to take into account both tag shedding and non-reported tags. Specifically,  $\widehat{R}_{c,a,g,t}$  is estimated by

$$\widehat{R}_{c,a,g,t} = \frac{\sum_{k \in g} (R_{c,a,k,t} / \gamma_{c,a,k,t})}{\lambda_t}$$

where

- $R_{c,a,k,t}$  = the actual number of reported tag returns in time period  $t$  from fish tagged from cohort  $c$  at age  $a$  by a tagger in sub-group  $k$  of tagger group  $g$ ;
- $\gamma_{c,a,k,t}$  = the probability that a fish tagged from cohort  $c$  at age  $a$  by a tagger in sub-group  $k$  has at least one tag still attached at the beginning of time period  $t$ ;
- $\lambda_t$  = the tag reporting rate in time period  $t$ .

Recall that all fish have been double-tagged. The probability of a tagged fish still having at least one tag attached at the time of capture,

$\gamma_{c,a,k,t}$ , is given by

$$\gamma_{c,a,k,t} = 1 - [1 - Q_{a,k}(\tau)]^2$$

where

$Q_{a,k}(\tau)$  = the probability of a tag still being attached to a fish tagged at age  $a$  by a tagger in sub-group  $k$  after the fish has been at liberty for time  $\tau$ . Note that  $\tau$  is a function of  $c$  and  $a$  (which together define the time period of release) and  $t$  (the time period of recapture).

Finally, an estimate of the annual fishing mortality rate in year  $y$ , corresponding to time periods  $t$  and  $t+1$  (where  $t$  is odd), for fish from cohort  $c$  (i.e. age  $a^* = y - c$ ) can be calculated from the ratio of the estimated number of tagged fish alive at the start of year  $y+1$  (time period  $t+2$ ) to the estimated number of tagged fish alive at the start of year  $y$  (time period  $t$ ). A separate value can be calculated corresponding to fish tagged at age  $a$  by a tagger in tagger group  $g$ . Thus,

$$f_{c,a,g,y} = - \left[ m_{a^*} + \log \left( N_{c,a,g,t+2} / N_{c,a,g,t} \right) \right]$$

Bootstrap confidence intervals for  $f_{c,a,g,y}$  were calculated by sampling the releases at age  $a$  from cohort  $c$  by tagger group  $g$  along with the associated recapture data with replacement and calculating the estimates of  $f_{c,a,g,y}$  for each bootstrap sample. The confidence intervals presented are based on 1000 bootstrap replicates and treats each tag release as independent. This may underestimate the actual uncertainty if releases from the same school tend to stay together. The bootstrap estimates are also conditional on the estimates of reporting rates, shedding rates and natural mortality rates.

### **Reporting Rates**

Estimates of the reporting rate in the Australian surface fishery are available for the 2003, 2004 and 2005 fishing seasons from tag seeding experiments conducted in these years (Polacheck and Stanley 2004, 2005; Polacheck et al. 2006). Polacheck et al. (2006) provided estimates for the mean reporting rate for each year<sup>1</sup>. The mean estimates were 0.645, 0.482 and 0.363 for the 2003, 2004 and 2005 seasons respectively. In Polacheck and Eveson

<sup>1</sup> The rates quoted here are for the weighted mean estimates in Polacheck et al. (2006) as these are statistically more appropriate.

(2005), we used the mean of the then-available estimates for 2003 and 2004 because the two estimates were quite similar. However, the updated estimates in Polacheck et al. (2006) indicate a rather substantive difference between these two years (i.e. 0.16). In addition, there has been a decreasing trend overall and the difference in the reporting rates between 2003 and 2005 is clearly significant (Table 1). Consequently, in the analyses presented here we have used the season-specific rates.

Insufficient information was available to estimate reporting rates from the longline fisheries. Estimates of reporting rates from longliners were substantially below those in the surface fishery in the 1990s. Reporting rates for Japanese longliners in the 1990s ranged from 0.07 to 0.49 (Eveson and Polacheck 2005). There were no data to directly estimate reporting rates for Taiwanese vessels. In the absence of any direct data, a range of values was explored. Results are presented for two values, namely 0.65 (the same as the surface fishery in 2003) and 0.30, to provide an indication of the sensitivity of the results to the value assumed. The same value was used for all ages and years. Note, however, that unless the reporting rates were the same in the different longline fleets, the reporting rate would in fact vary with age and year even if the reporting rate was constant over time within a fleet; this is because the proportion of the total longline catch of a given age class by a given fleet varies among years (Pollock et al. 2001).

### ***Tag Shedding***

Tag shedding rates provided by Dr. Hearn were based on an analysis of the tag shedding data (number of recaptures with one tag versus two tags still attached) for taggers who participated in the SRP tagging program. Dr. Hearn applied the method of Kirkwood and Walker (1984) to estimate shedding parameters. The retention function (i.e., the probability of a tag still being attached after being at liberty for time  $\tau$ ) was assumed to have the form

$$Q_{a,k}(\tau) = \xi_{a,k} \exp(-\Omega_{a,k}\tau)$$

where  $\xi_{a,k}$  is the fraction of tags immediately retained (i.e.  $1 - \xi_{a,k}$  are immediately shed) for fish tagged at age  $a$  by a tagger in sub-group  $k$ , and  $\Omega_{a,k}$  is the continuous shedding rate. Thus, the model allows for tag shedding to vary between tagger groups (which may be individual taggers) and between fish released at different ages. The retention function was assumed to be the same for both tags on a given fish. Table 2 provides the estimates of the parameters for this retention function when fitted to the SRP tag return data. This table provides estimates for individual taggers as well as for groups of taggers with statistically insignificant differences in their tag shedding parameters. Only the estimates for the groups of taggers are used in the estimates of fishing mortality rates presented here, but the results are very similar if individual tagger estimates are used. In the notation above, each set of taggers constitutes a potential sub-group  $k$ .

In Polacheck and Eveson (2005), we also considered the potential effect of age-specific shedding. There were only sufficient data to meaningfully perform these calculations for two taggers. Only for one of these was the difference significant and the differences had only a minimal effect on the overall results. As such, we have not updated these estimates for this year's paper.

### ***Natural Mortality Rates***

Two age-specific natural mortality rate vectors were used in the calculation of the fishing mortality rates (Table 3) to provide a measure of the sensitivity of the estimates to

assumptions about natural mortality. These two vectors are two of the vectors being used in the conditioning and projections being undertaken with the SBT Management Procedure operating model.

## **Results and Discussion**

Table 4 provides a summary of the number of releases and recaptures by cohort. The low number of recaptures from the 2003 cohort and beyond reflect the fact that it is still too early to expect any substantial numbers of returns from these releases. Given the current fisheries, only significant numbers of recaptures are expected from age 3 and older. Since most of the returns from this year's Australian surface fishery are not yet available, even for releases from the 2002 cohort the tagging data are not yet informative. As such, results are only presented for the 1999-2002 cohorts (the number of releases for the 1998 cohort are too small to provide meaningful results).

Table 5 provides a breakdown of the release and recapture data by cohort, age at release and age at recapture. Evident in this table is the very low percent of returns from fish released at age 1 compared to the percent of returns from fish released at ages 2 and 3 from the same cohort. While the number of returns at a given age from age 1 releases would be expected to be less because of natural mortality rates, the differences are quite extreme and contrast markedly with the returns from the 1990s tagging (Figure 1). This feature of the SRP returns is explored and discussed further below.

### ***Location of Longline Returns***

The interpretation of results from tagging experiments depends upon the extent to which the tagged fish can be considered representative of the population. Lack of complete mixing is one factor that can bias results – particularly if it is systematic. Plots of release and recapture locations can provide one indication of this. Figures 2-5 show maps of the release and return locations for all longline returns from the SRP tagging experiments. Figure 6 provides a comparison with the 1990s tagging experiments. What is evident is the rapid spread of tagged fish from the surface fishery into all areas where longline fisheries occur, and there is no evident differential pattern for the tags released in Western Australia compared to South Australia.

Nevertheless, evident in these plots is very different spatial distribution of longline recoveries in the 2000s compared to the 1990s in terms of the low proportion of recoveries that come from the Tasman Sea. This is also evident when comparing the percentage of longline returns by age which came from the Tasman area in the 2000s (Table 6). This in part reflects differences in the spatial distribution of fishing effort within the Tasman Sea. Thus, in the 1990s, a substantial fraction of the longline effort was within the Australian Fishing Zone (AFZ) as a result of joint venture operations and bi-lateral access arrangements that allowed vessels to fish within the AFZ (i.e. smaller fish may be more concentrated in near shore waters) (Table 7). These arrangements ceased in 1998 and thus there has been little recent fishing effort in the areas where substantial numbers of the 1990s returns came from. In addition, there was more tag recovery opportunities for Japanese vessels in the AFZ than in some other areas due to a combination of observers and port visits by tag liaison officers. However, it is not clear whether these factors are sufficient to explain the large differences in the spatial distribution of longline returns in the 1990s compared to the 2000s. For example, there were still substantial numbers of longline returns outside of the AFZ in the 1990s



(Table 7). Moreover, in the 2000-2002 period, a substantial percentage (28-42%) of the Japanese longline catch of juveniles aged 3-4 came from the Tasman area (Figure 7), and all of this was outside of the AFZ. However, in 2004, these percentages decreased dramatically (~10% in 2004) without a decline of similar magnitude in the proportion of fishing effort in the Tasman area (Figure 7). There was some increase in 2005 to ~20%. Overall, the Japanese longline catch and effort data would also tend to suggest a shift in the spatial distribution of juveniles.

### ***Fishing Mortality Rate Estimates***

Sufficient release and return data (e.g. at least ~400 releases at a particular age and at least one year of full recoveries) exist to derive age-specific fishing mortality rate estimates for four cohorts, namely cohorts 1999, 2000, 2001 and 2002 (Table 8). Figures 8-10 compare estimates of fishing mortality rates based on different tagger groups and ages of release for the latter three cohorts (the number of releases within tagger groups for the 1999 cohort are insufficient for such comparisons). It should be emphasized that estimates of fishing mortality rates based on returns from the same year of release (e.g. the F estimates for age 2 based on age 2 releases) can be highly misleading in terms of being representative of the fishing mortality experienced by a cohort because the releases may have occurred before, during or after the main period of fishing, and the distribution of releases would also affect the number of returns. However, they do provide a measure of the fishing mortality rate experienced by the set of tagged fish and in this sense can still be informative.

Figures 8-10 suggest that there may be a consistent tagger effect in the fishing mortality rate estimates. Thus, in all cases where the rates were not essentially zero, the estimates for tagger group 1 were higher than those for tagger group 3 (the only two tagger groups with consistently enough releases to make such comparisons), while the estimates based on all taggers is between the two (as would be expected). For some ages (e.g. age 4 estimates based on age 2 releases for the 2000 cohort, and age 3 estimates based on age 1 releases for the 2001 cohort), the differences can be large (i.e. over 300%). The source of this tagger effect is not clear. It may be related to shedding rates because the shedding rates for tagger group 1 are substantially lower than for tagger group 3 (Table 2). These estimates are based on the assumption that the probability of shedding one tag is independent of the other. If this assumption were violated (i.e. shedding of tags tended to be correlated such that there was a greater probability of shedding both than indicated from the proportion that shed only one) then this could generate a consistent difference among taggers. Another possibility could be differences in tagging associated mortality.

Figure 11 provides examples of the sensitivity of the estimates of fishing mortality rates for the two reporting rate options considered for the longline component of the fishery. As would be expected, the option with the lower reporting rate for the longline component yielded higher mortality rates. The differences are not insubstantial and tend to increase with age. This is expected both because of the increasing proportion of the global catch which comes from longliners with age and the compounding effect of higher mortality rates at younger ages on the estimates for older ages. In some cases, the difference in reporting rate options yields differences in the trend in the estimates of fishing mortality rates with age (e.g. whether they continue to increase or decrease at ages 4 or 5) and would have implications for the reflective effects of the different fisheries and on the levels of future recruitment into the spawning stock from these cohorts. This emphasizes the importance of having direct estimates of the reporting rates from the longline fisheries. In addition, they suggest that

while the longline fisheries are not the primary source of fishing mortality rates on juveniles, they are nevertheless a contributing component.

Figure 12 provides examples of the sensitivity of the fishing mortality rates to assumptions about the natural mortality rates. Higher estimates are associated with higher estimates of natural mortality rates and increasingly so the longer the period between the age of release and age of the estimate. This is what would be expected since with higher natural mortality rates, the number of fish that would have survived to any age is less, and thus the number of returns at that age will constitute a higher fraction of those still alive. It should be noted that any consideration of the implications of the estimates of fishing mortality rates for the conditioning of the MP operating model will need to be done in the context of the natural mortality vector used in specific scenarios.

Figures 13 to 15 provide the trends in the estimated annual age-specific fishing mortality rates for ages 2 to 4. Note that in these figures, estimates derived from releases in the same year have not been included as they are not directly comparable as noted above. For ages 3 and 4, comparisons are provided for estimates derived from tags released at different ages (for age 2, such comparative estimates are not possible since only age 1 releases can provide estimates for age 2 fishing mortality rates). While the number of comparisons is small, the estimates derived from age 1 releases are always lower than those for age 2 or 3 releases. The differences in some cases are significant based on the bootstrap confidence intervals and are substantive enough (particularly for the age 3 and 4 estimates in 2004 and 2005; i.e. for the 2001 and 2002 and 2000 and 2001 cohorts respectively) to affect interpretations of the strength of recent cohorts and implications of current harvest levels. Possible sources for the differences are: (1) higher tag shedding rates for age 1 fish; (2) higher tagging associated mortality for age 1 fish; (3) a greater differential in the combined natural mortality rates for ages 1 and 2 compared to older ages than was assumed in the values used for natural mortality<sup>2</sup>; (4) an unreported catch or discarding of age 2 fish; (5) incomplete mixing of 2 and 3 year old tagged fish (i.e. these fish return preferentially to the GAB).

With respect to the first of these possible factors, the potential for age-specific tag shedding to be a substantial factor was examined in Polacheck and Eveson (2005). For tagger group 1, the fishing mortality rate estimates were essentially the same whether age-pooled or age-specific shedding rates were used.

With respect to the other four factors, there are no direct data or information that could be incorporated into the estimation to evaluate their effect. Comparison of the distributions of the length at release for recaptured fish versus the distribution for all tagged fish within an age class suggest that there is a marked tendency for the largest fish tagged to be recovered for age 1 releases but not for age 2 releases (Figures 16-21). This could indicate that either the larger age 1 fish have lower mortality rates (either natural or tag induced) or that they have a great propensity to return to the GAB. Similarly, there is also somewhat of a tendency for age 1 fish tagged further to the east to have a higher recovery rate (Figures 22-27), which might suggest incomplete mixing. However, whichever of these factors or combination of factors may be contributing to the difference, it would constitute a substantial difference from the 1990s tagging where such effects were not evident. For example, there was no apparent

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<sup>2</sup> The reason it would be sufficient for it to be the combined age 1 and 2 natural mortality is that the estimated fishing mortality rates for age 2 are essentially zero.

size effect in the 1990s (Figure 1) and the tagging of 1 year olds in WA was generally further to the west than in the more recent SRP tagging.

Another anomaly in these return data are the lack of returns at age 3 from the releases of the 1999 cohort at age 2. Only 11 out of the 750 age 2 releases were recovered at age 3 while 50 were recovered at age 4. This results in a very low estimate of fishing mortality rate at age 3 for this cohort (0-0.08) and a relatively high rate at age 4 (0.25-0.45). It should be pointed out that all of these fish were tagged in WA. Given that most of the surface fishery catch in 2002 (i.e. the year when these fish were age 3) is estimated to be comprised of 3 year old fish, this would suggest that either reporting rates in 2002 were very low or that very few of these fish went to the GAB at age 3 but that a large fraction came back at age 4. There is no direct information on reporting rates in 2002 (i.e. there were no tag seeding experiments). This was also the first year that any substantial numbers of SRP tags would have been expected to have been recaptured and promotional activities were minimal.

The estimates of fishing mortality rate for age 2 are always low relative to those for older ages. However, the estimates indicate a large increasing trend between 2002 and 2005. The increasing estimates of fishing mortality rates on age 2 are roughly consistent with the estimated increase in 2 year old catches in the Australian surface fishery (e.g. a nine fold increase in catch between 1992 and 1995 and a seven to eight fold increase in the estimates of F). These increases could reflect increasing targeting on or availability of smaller fish in the surface fishery or declining recruitments or a change in movement patterns (i.e. a higher fraction of 1 year olds are beginning to return to the GAB). If the latter is the case, then the differences in the mortality rates at older ages for age 1 releases versus older releases should diminish. The factors discussed above need to be kept in mind when interpreting the absolute magnitude of the fishing mortality rate estimates for age 2 as these are all based on age 1 releases.

Table 9 provides the range of estimates of expected age-specific fishing mortality rates in years 2002, 2003, 2004 and 2005 based on different ages of release. The range encompasses the range of expected values over the two reporting rate options and two mortality vectors considered. Also, separate ranges are presented based on estimates using the releases from all taggers and only those from tagger group 1. Overall, they suggest relatively high to extremely high fishing mortality rates for ages 3, 4 and 5 in 2004 and 2005 for fish tagged at age 2. However, it is not clear to what extent this represents the overall juvenile population given the differences in the returns and estimated fishing mortality rates between the age 1 releases and older age releases. Nevertheless, even the rates based on age 1 releases for age 3 in 2004 is 0.47-0.58 for tagger group 1 and 0.22-0.29 for all taggers. This suggests high rates of exploitation on the 2001 year-class irrespective of the age of release. Overall, the range of estimates for age 3 based on age 1 releases in years 2003-2005 range from 0.12-0.58.

### ***Returns from the First Season for December Releases***

Tag returns released near the beginning of the fishing season in the GAB can provide an indication of localized exploitation, particularly if tagging does not take place in the immediate vicinity of fishing operations. In 2003, 2004 and 2005, some SRP tagging operations took place in December in the GAB in inshore areas, while fishing operations are concentrated near the shelf edge. Over the next four months, tags were recovered from 10%-38% of the age 3, 4 or 5 year old fish (Table 10). These recapture rates suggest very high exploitation rates for fish found in the GAB in December – particularly in 2004, where over

50% of the tagged age 3 and 4 fish are estimated to have been caught within the fishing season, taking into account the estimates of reporting rates from tagging seeding experiments (Table 10). The estimated rates decline for 2005, but nevertheless are high (i.e. 29% and 23% for age 3 and 4 respectively). In 2005, 68 age 5 fish were tagged in December and an estimated 49% were caught within the season, taking into account the estimated reporting rate for 2005. This is almost twice as high as the rate for either age 3 or 4 fish and would suggest that the surface fishery may be quite successful at capturing those larger/older fish that happen to enter into the GAB during a year.

It should be noted that the times of recapture and locations of recapture relative to where the tags were released indicate that these large recapture estimates are not the result of tagging in very close spatial or temporal proximity to where fishing operations were occurring (Figures 28-29). Overall, the return rates during the first season suggest high rates of exploitation of fish within the GAB, particularly in 2004. The extent to which these may represent global rates depends in part on the proportion of the age 3 and 4 fish that are in the GAB during the summer months.

Perhaps somewhat surprising in these data are the low levels of returns from age 2 fish tagged in the same location and time period (Table 10). Less than 5% of the fish tagged at age 2 were estimated to have been recovered during the fishing season in spite of the fact that there were sizable catches of 2 year olds in all three years (particularly in 2004 where the catch of 2 year olds was estimated to comprise 31% of the catch and 7 times the number of 4 year olds).

### ***Returns Per 1000 fish***

The returns by age from releases of a cohort at a given age can provide an estimate of the catch at age for that cohort for a commercial fleet. There are only sufficient returns from the purse seine fleet to undertake such estimates. Comparison of the percent by age of a cohort's catch for the surface fishery based on catch data from the commercial fishery and on tag returns for different ages at release indicates substantive and consistent differences (Table 11 – note that the figures exclude recaptures from the first year of recovery). The comparisons in Table 11 indicate that relative to the tag return data the estimated number of age 2 fish in the commercial fishery is consistently too high and the number of age 4 and 5 fish is too low. It should be emphasized that the estimates for the tag return data have not been corrected for tag shedding and tag reporting rates. As the effect of tag shedding increases over time and since reporting rates appear to have also declined over time, the results in Table 11 are an underestimation of the actual differences between the commercial fishery and tagging results. If the commercial estimates are in fact representative of the actual catch at age, this would mean that tagged fish, as they age, become differentially and increasingly more vulnerable to the surface fishery than those fish not tagged. This seems unlikely given the location of where the fish were tagged.

Table 12 compares estimates of the number of tags returns per 1000 fish caught by age and year in the surface fishery and longline fishery. Note that the estimates in this table exclude the recaptures during the first year to avoid short term effects associated with the timing and location of releases. While the number of returns is relatively small for 2 year old fish, the return rates at this age in the longline fishery have been consistently 4-5 times higher than those in the purse seine fishery. This is in sharp contrast to the return rates for ages 4 and 5 in which the return rates from the surface fishery have been 13-100 times higher than in the longline fishery. Interpretation of these differences is confounded by a number of factors including differences in reporting rates, under-reporting of catch, biases in the estimates of

the catch-at-age and differential mixing. The same patterns are seen in the estimates if they are considered by age at release (Tables 13 and 14) and within a cohort (i.e. the appropriate diagonals in these tables).

For the surface fishery, the sharply increasing estimates of the fraction of individuals with tags at older ages would tend to suggest that not enough older fish have been caught in the surface fishery relative to the number of tags returned from fish at these older ages. For example, for the 2000 cohort at age 5, over 5% of the estimated surface catch is estimated to have tags (Tables 12 and 14). Given that the total number of tags released from this cohort is 5722 (Tables 4 and 5 – excluding 5 year old releases), this would suggest that the size of this cohort at the time of tagging (at least the portion that mixed with the tagged fish) was very small (i.e. ~20 times or ~100,000 fish). In contrast, for the longline fisheries, estimates of the number of tags returned per 1000 fish tend to suggest that not enough young fish have been caught relative to the number of tags returned (Tables 12 and 13). For the Japanese longline fisheries, the estimated number of returned tags tends to decrease with age for a cohort (but the number of years of returns is small). If there was complete mixing, the expectation would be that it should be increasing given the increased number of releases. If the estimated catches at age are accurate, then in order for the actual percentages to decrease, the fraction of a cohort represented by the tagged fish would have to have become increasingly less vulnerable to that fishery with age (e.g. the juvenile fish from a cohort in WA and SA initially have a preference for the areas where the longline fisheries operate relative to other members of a cohort and this preference diminishes with age). It should be emphasized that the interpretation of the returns per 1000 fish is confounded by reporting rates. Nevertheless, they suggest inconsistencies with the estimated catch at size/age data.

### **Acknowledgements**

We wish to acknowledge the large number of individuals that have contributed to the CCSBT SRP tagging program include the taggers, the crews of the tagging vessels, those involved in promotion and tag recovery activities, and those responsible for the data process and management aspects. A special thanks to Bill Hearn for his analyses and provision of the tag retention parameters used in this paper.

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Table 1: Estimates of reporting rates, their variances and standard errors for the Australian surface fishery for years 2002/2003 to 2004/2005 from Polacheck et al. (2006).

Year	Weighted			
	$\hat{\lambda}$	$\text{Var}(\hat{\lambda})$	$\text{SE}(\hat{\lambda})$	CV
2002/2003	0.645	0.00369	0.061	9.5
2003/2004	0.482	0.00272	0.052	10.8
2004/2005	0.363	0.00076	0.028	7.7

Table 2: Shedding rate estimates by individual taggers and by tagger groups (results provided by Dr. Hearn, CSIRO Marine and Atmospheric Research).

Tagger ID	Initial retention fraction ( $\xi$ )	Continuous shedding rate ( $\Omega$ )	Recaptures with 2 tags	Recaptures with 1 tag	Total number recaptures	
2	0.979	0.099	1420	514	1934	
4	1.000	0.264	561	515	1076	
418	0.682	0.000	44	41	85	
419	1.000	0.293	62	79	141	
444	1.000	0.203	38	31	69	
1439	1.000	0.247	33	27	60	
Z	1.000	0.313	67	41	108	
<b>Tagger Group</b>						
1	2	0.979	0.099	1420	514	1934
2	418+444	1.000	0.181	82	72	154
3	4+419+507+Z	1.000	0.269	723	662	1385
4	1439	0.818	0.124	197	166	363

Table 3: Age-specific natural mortality rates used in the estimation of fishing mortality rates.

Vector	Age				
	1	2	3	4	5
1	0.3401	0.3028	0.2700	0.2420	0.2153
2	0.4202	0.3703	0.3278	0.2894	0.2538

Table 4: The number of tag releases and reported recaptures by cohort.

Cohort	Number releases	Number recaptures	Percent
1998	50	7	14.0
1999	1190	134	11.3
2000	5790	848	14.6
2001	9899	1893	19.1
2002	10291	903	8.8
2003	11353	153	1.3
2004	7084	4	0.1

Table 5: The number of releases by age and recaptures by age for the 1999-2002 cohorts

Cohort	Age at release	Number released	Number recaptured by age						Total	Percent recaptured
			1	2	3	4	5	6		
1999	2	750		0	11	50	10	3	74	9.9
	3	23		0	0	1	0	1	2	8.7
	4	414			0	34	16	8	58	14.0
2000	1	1921	0	4	84	19	3		110	5.7
	2	492		1	51	36	12		100	20.3
	3	3277			295	255	63		613	18.7
	4	32				7	3		10	31.3
	5	68					12		12	17.6
2001	1	2748	0	9	128	17			154	5.6
	2	5869		28	1085	263			1376	23.4
	3	1147			253	93			346	30.2
	4	135				12			12	8.9
2002	1	3315	1	26	65				92	2.8
	2	6255		87	666				753	12.0
	3	721			51				51	7.1

Table 6: Percent of longline returns that occurred in the Tasman Sea (defined as east of 142°E). Note that the RMP results have not been updated for returns in 2005/2006.

		Age at recapture							
		2	3	4	5	6	7	8	
1990s RMP	All longline returns	39.6	46.7	53.8	58.6	60.3	64.1	45.7	
	Japanese returns	39.1	48.3	51.7	56.3	58.9	63.3	48.4	
2000s SRP	All longline returns	6.0	5.0	3.3	-	-	-	-	
	Japanese returns	16.7	16.3	6.3	-	-	-	-	

Table 7: Percent of longline returns from the Tasman Sea (defined as east of 142°E) that occurred in the Australian Fishing Zone (AFZ) for the 1990s RMP tag releases. Note that the results have not been updated for returns in 2005/2006.

		Age at recapture						
		2	3	4	5	6	7	8
% in AFZ		90.7	77.5	67.8	51.4	42.2	34.7	21.6



Table 8: Estimates of age-specific fishing mortality rates for different cohort derived from tags released in the waters around southern Australia. Results are presented separately for tags released at different ages. Lower and upper 5% refer to the lower and upper 5% percentiles from the bootstrap estimates (i.e. the 90% confidence interval). The results shown are for releases from all taggers using the tagging group shedding rates in Table 2.

Cohort	Age at release	Number of releases	Age	F		Lower 5%	Upper 5%	
1999	2	750	2		0.000	0.000	0.000	
			3		0.035	0.018	0.055	
			4		0.251	0.189	0.315	
			5		0.107	0.056	0.172	
			6		0.078	0.000	0.166	
	4	414	4		0.137	0.103	0.176	
			5		0.127	0.076	0.180	
			6		0.117	0.055	0.191	
	2000	1	1921	1		0.000	0.000	0.000
2					0.005	0.001	0.010	
3					0.160	0.132	0.193	
4					0.076	0.047	0.110	
5					0.019	0.004	0.037	
2		492	2		0.004	0.000	0.011	
			3		0.260	0.200	0.329	
			4		0.467	0.321	0.641	
3		3277	3		0.415	0.206	0.732	
			4		0.151	0.136	0.166	
			5		0.290	0.258	0.326	
2001		1	2748	1		0.000	0.000	0.000
				2		0.008	0.003	0.012
				3		0.222	0.189	0.260
				4		0.057	0.035	0.081
	5				0.008	0.006	0.011	
	2	5869	2		0.773	0.720	0.827	
			3		0.741	0.635	0.873	
			4		0.615	0.542	0.695	
	3	1147	3		0.817	0.616	1.063	
			4					
	2002	1	3315	1		0.001	0.000	0.002
				2		0.023	0.016	0.030
				3		0.119	0.095	0.146
		2	6255	2		0.029	0.024	0.035
				3		0.543	0.500	0.587
3		721	3		0.210	0.158	0.265	
2003		1	2662	1		0.000	0.000	0.000
				2		0.042	0.030	0.056
		2	8691	2		0.027	0.022	0.031

Table 9: Summary of the range of age-specific fishing mortality rates in years 2002 to 2005 from tags released at different ages. Results are presented for all tags released and those released only by tagger group 1. The two values presented give the range of expected values over the two reporting rate options and two mortality vectors considered.

Year	Release		All Taggers			Tagger Group 1		
	Age	Age	# Tagged	F range		# Tagged	F range	
2002	2	1	1921	0.01	0.01	401	0.02	0.10
	3	2	750	0.04	0.06	-	-	-
2003	2	1	2748	0.01	0.01	1015	0.01	0.14
	3	1	1921	0.16	0.20	401	0.20	0.24
		2	492	0.26	0.33	242	0.29	0.32
	4	2	750	0.25	0.36	-	-	-
2004	2	1	3315	0.02	0.03	1028	0.04	0.05
	3	1	2748	0.22	0.29	1015	0.47	0.58
		2	5869	0.77	0.96	2301	0.98	1.11
	4	1	1921	0.08	0.14	401	0.12	0.19
		2	492	0.47	0.69	242	0.89	1.16
		3	3277	0.29	0.35	1655	0.30	0.33
	5	2	750	0.11	0.25	-	-	-
		4	414	0.13	0.16	215	0.12	0.13
2005	2	1	2662	0.04	0.05	1127	0.06	0.07
	3	1	3315	0.12	0.15	1028	0.21	0.25
		2	6255	0.54	0.63	2986	0.64	0.70
	4	1	2748	0.06	0.09	1015	0.20	0.28
		2	5869	0.74	1.44	2301	1.30	2.76
		3	1147	0.82	1.05	637	0.89	1.03
	5	1	1921	0.02	0.06	401	0.02	0.14
		2	492	0.41	1.10	242	1.19	inf
		3	3277	0.16	0.20	1655	0.17	0.20
	6	2	750	0.08	0.13	-	-	-
4		414	0.12	0.15	215	0.22	0.24	

Table 10: First year recaptures of fish released in December in the Great Australian Bight by age of release and fishing year. Estimated percent caught is based on reporting rate estimates of 0.645, 0.482 and 0.363 for the 2003, 2004 and 2005, respectively, with no allowance for tag shedding.

Fishing Year	Release Age	Number Released	Number Returned	Percent Returned	Est. Percent Caught
2003	1	17	0	0.0	0.0
	2	894	14	1.6	2.4
	3	3004	285	9.5	14.5
	4	242	32	13.2	20.2
	5	8	3	37.5	57.3
2004	1	622	0	0.0	0.0
	2	3186	76	2.4	5.3
	3	979	234	23.9	52.9
	4	27	7	25.9	57.4
	5	3	0	0.0	0.0
2005	1	52	0	0.0	0.0
	2	2760	30	1.1	3.0
	3	308	32	10.4	28.6
	4	130	11	8.5	23.3
	5	68	12	17.6	48.6

Table 11: Comparison of the percent by age of a cohort's catch for the surface fishery based on catch data from the commercial fishery and based on tag returns for different ages at release. Recaptures from the first year of recovery are not included. Percent of a commercial catch by age are based on the corresponding ages from which tag return data are available for a cohort and age at release.

Cohort	Release Age		Catch/Recapture Age				# Caught/ # Returned
			2	3	4	5	
2000	1	Catch	7.5	70.6	21.5	0.5	250152
		Tag	2.1	83.3	13.5	0.0	96
	2	Catch		76.3	23.2	0.5	231499
		Tag		51.1	36.7	10.0	90
	3	Catch			97.8	2.2	54950
		Tag			79.3	19.7	295
2001	1	Catch	16.5	74.7	8.8		258716
		Tag	4.3	84.9	10.1		139
	2	Catch		89.5	10.5		216055
		Tag		80.6	19.2		1265
2002	1	Catch	42.5	57.5			216270
		Tag	23.8	75.0			80

Table 12: Comparison of the number of recaptured tags, estimated catch and number of tags return per 1000 fish caught by age and year for the SBT longline and surface fisheries. No adjustment has been made to the number of tags recaptured to account for tag shedding and reporting rates. The estimates of the catch by age are based on those provided by the CCSBT secretariat and take no account of possible over-catches. Note that tags recaptured in the year of release have been excluded from the number of tags recaptured.

Year	Gear		Recapture/Catch Age			
			2	3	4	5
2003	LL	# Tags	3	8	6	0
		# Catch	3658	7772	16380	30898
		Tags/1000	0.82	1.03	0.37	0.00
	PS	# Tags	6	126	45	0
		# Catch	42662	176549	53742	3847
		Tags/1000	0.14	0.71	0.84	0.00
2004	LL	# Tags	6	72	30	5
		# Catch	4654	13655	19411	23550
		Tags/1000	1.29	5.27	1.55	0.21
	PS	# Tags	19	1138	280	5
		# Catch	91879	193378	12912	292
		Tags/1000	0.21	5.88	21.69	17.12
2005	LL	Tags	5	34	25	10
		Catch	6089	12259	22848	17898
		Tags/1000	0.82	2.77	1.09	0.56
	PS	Tags	24	696	347	67
		Catch	168669	124391	22677	1209
		Tags/1000	0.14	5.60	15.30	55.42

Table 13: Estimates of the number of tags returned per 1000 fish caught by age, age of release and year for the SBT longline fisheries (all fleets combined). No adjustment has been made to the number of tags recaptured to account for tag shedding and reporting rates. The estimates of the catch by age are based on those provided by the CCSBT secretariat and take no account of possible over-catches. Note that tags recaptured in the year of release have been excluded from the number of tags recaptured.

Year	Release Age	Recapture Age			
		2	3	4	5
2003	1	0.82	0.51	0.00	
	2		0.51	0.37	0.00
2004	1	1.29	0.59	0.31	0.00
	2		4.69	0.15	0.21
	3			1.08	0.00
2005	1	0.82	0.41	0.13	0.17
	2		2.37	0.83	0.11
	3			0.13	0.28

Table 14: Estimates of the number of tags returned per 1000 fish caught by age, age of release and year for the SBT surface fisheries. No adjustment has been made to the number of tags recaptured to account for tag shedding and reporting rates. The estimates of the catch by age are based on those provided by the CCSBT secretariat and take no account of possible over-catches. Note that tags recaptured in the year of release have been excluded from the number of tags recaptured.

Year	Release	Recapture Age			
	Age	2	3	4	5
2003	1	0.14	0.45	0.00	
	2		0.26	0.82	0.00
	3			0.02	0.00
2004	1	0.21	0.61	1.01	0.00
	2		5.27	2.56	17.12
	3			18.12	0.00
2005	1	0.14	0.48	0.62	0.00
	2		5.11	10.72	7.44
	3			3.97	47.97

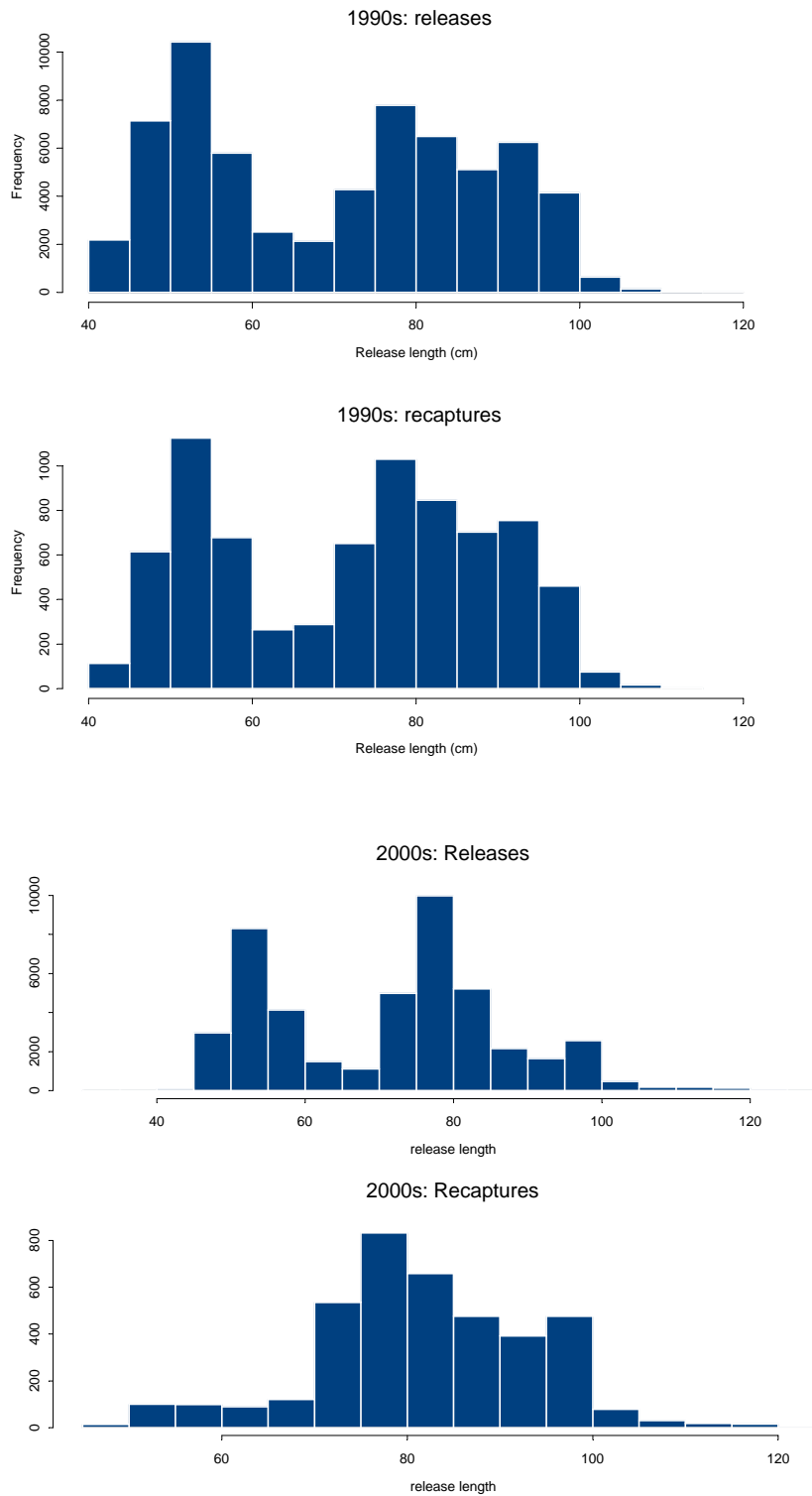


Figure 1: Comparison of the release length distribution for all fish released and for those fish that were recaptured. The upper two panels are for the 1990s releases and the lower two are for the 2000s releases.

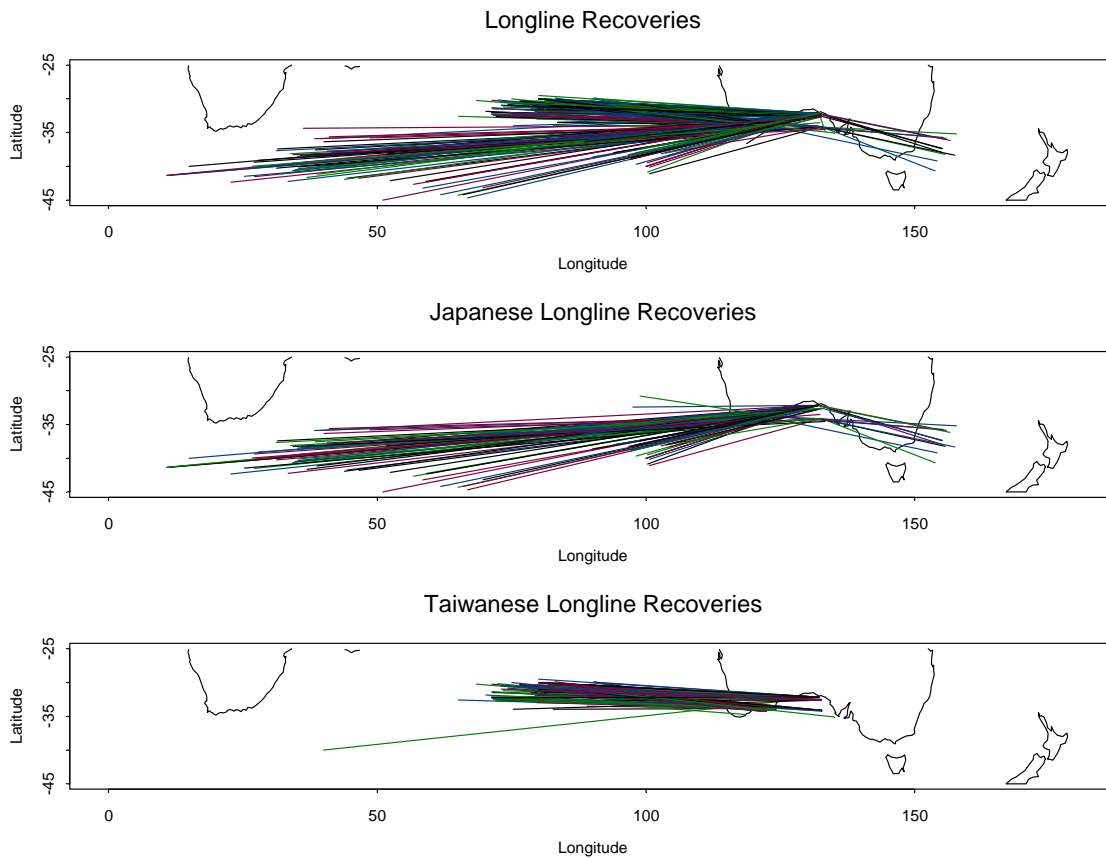


Figure 2: Release and recapture locations for longline returns from the SRP conventional tagging in WA and SA.

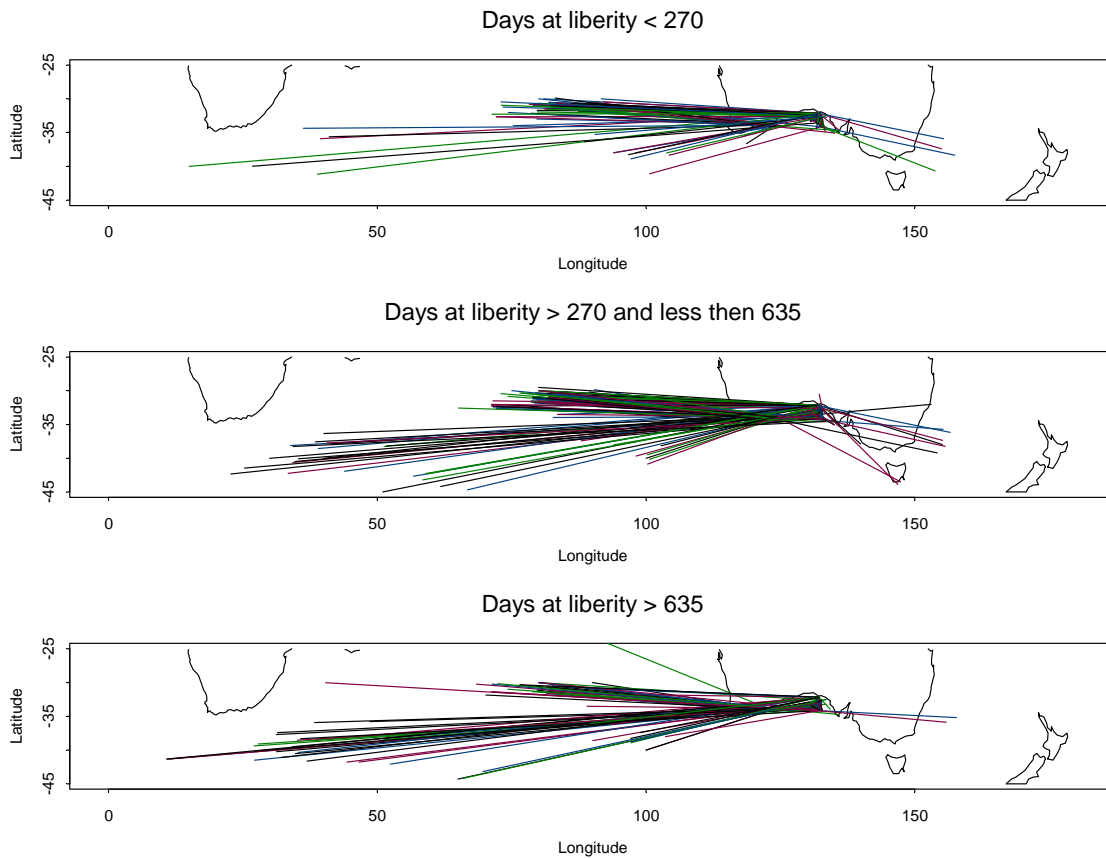


Figure 3: Release and recapture locations for longline tag returns for different times at liberty from the SRP conventional tagging in WA and SA.



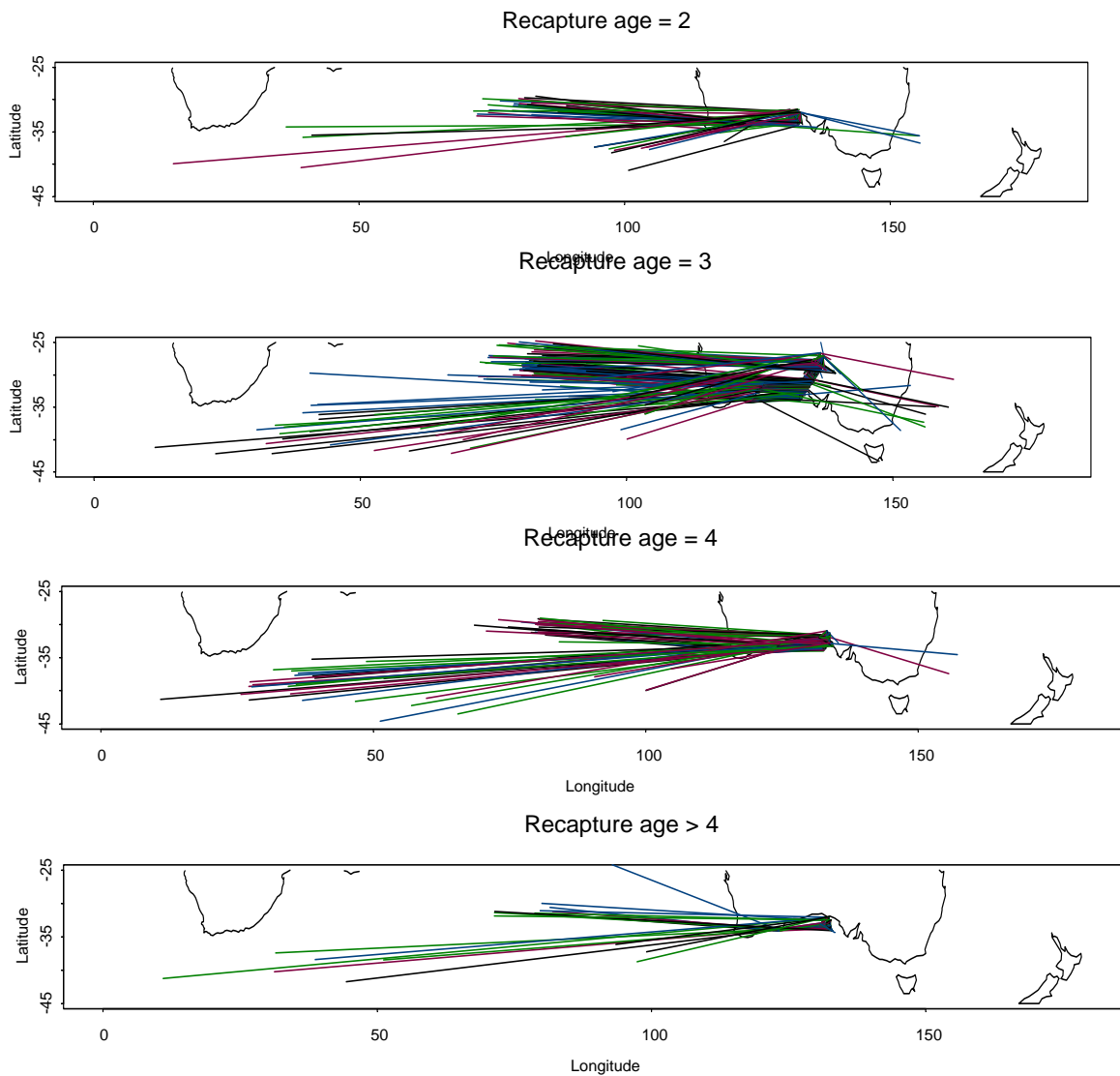


Figure 4: Release and recapture locations for longline tag returns for different ages at recapture from the SRP conventional tagging in WA and SA.

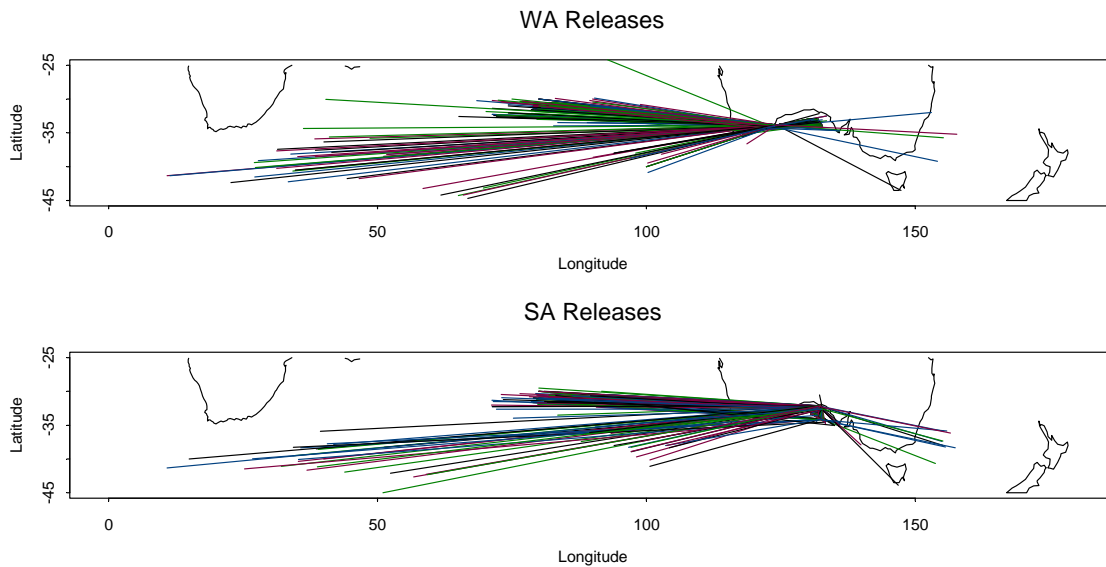


Figure 5: Comparison of release and recapture locations for longline tag returns released in Western Australia (WA) versus South Australia (SA) as part of the SRP conventional tagging.

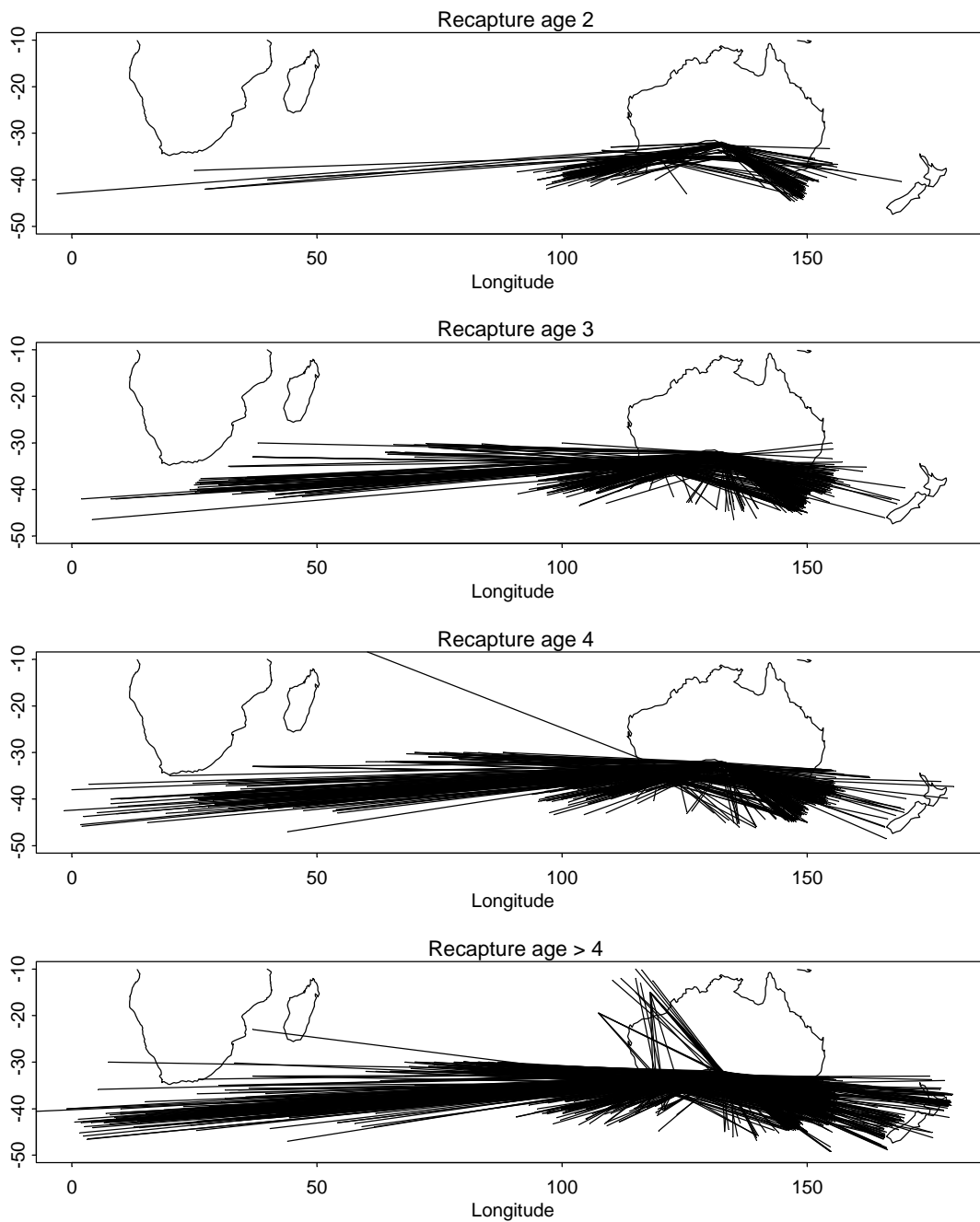


Figure 6: Release and recapture locations for longline tag returns for different ages at recapture from the RMP conventional tagging in WA and SA in the 1990s.

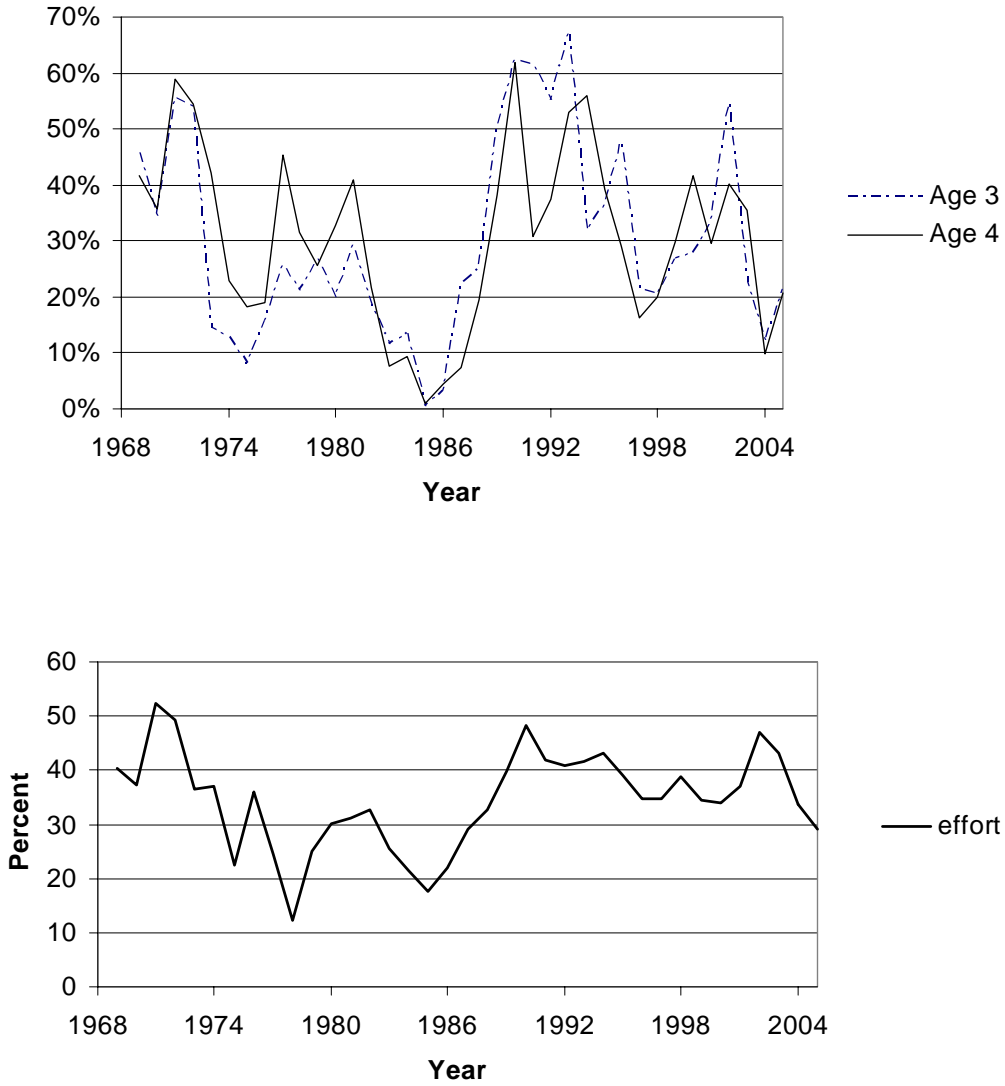


Figure 7: The percentage of age 3 and 4 Japanese longline SBT caught that were taken from the Tasman area (east of 140°) and percent of Japanese longline effort in this area. Note the figures are for quarters 2 and 3 and only include data for statistical areas 4-9.

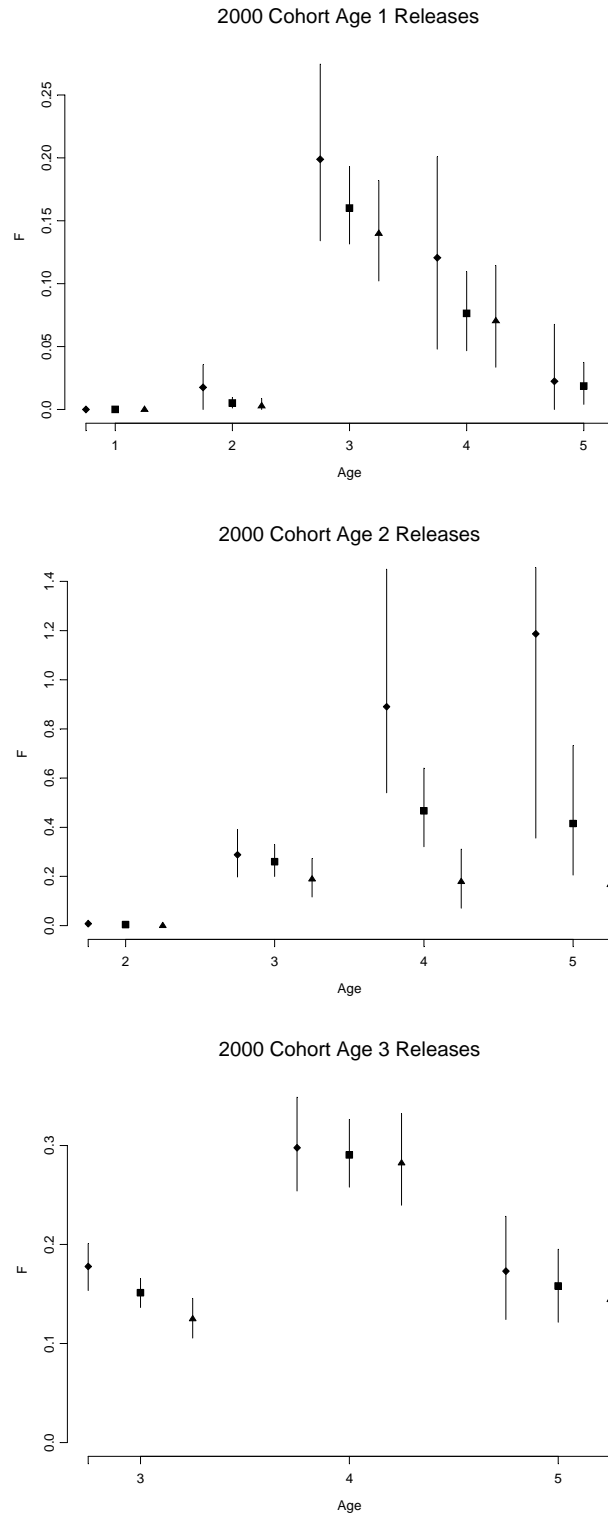


Figure 8: Comparison of fishing mortality rates for different tagger groups and different release ages for the 2000 cohort. Squares are for all taggers; diamonds are for tagger group 1; and triangles are for tagger group 3. All estimates are for natural mortality rate vector 1 and for a reporting rate of 0.65 for the longline fisheries. Error bars are 90% bootstrap confidence intervals conditional on the estimates of mortality, shedding and reporting rates.

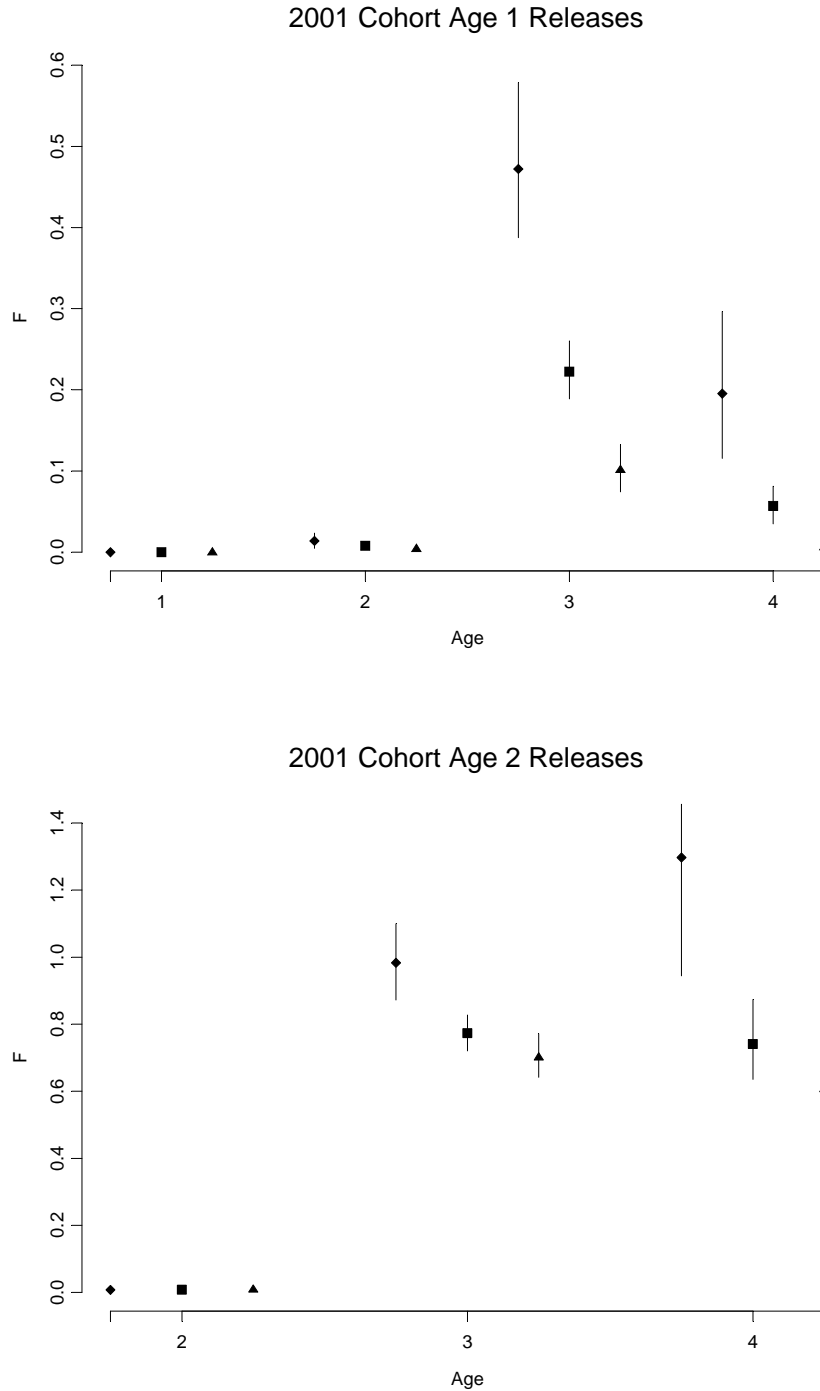


Figure 9: Comparison of fishing mortality rates for different tagger groups and different release ages for the 2001 cohort. Squares are for all taggers; diamonds are for tagger group 1; and triangles are for tagger group 3. All estimates are for natural mortality rate vector 1 and for a reporting rate of 0.65 for the longline fisheries. Error bars are 90% bootstrap confidence intervals conditional on the estimates of mortality, shedding and reporting rates.

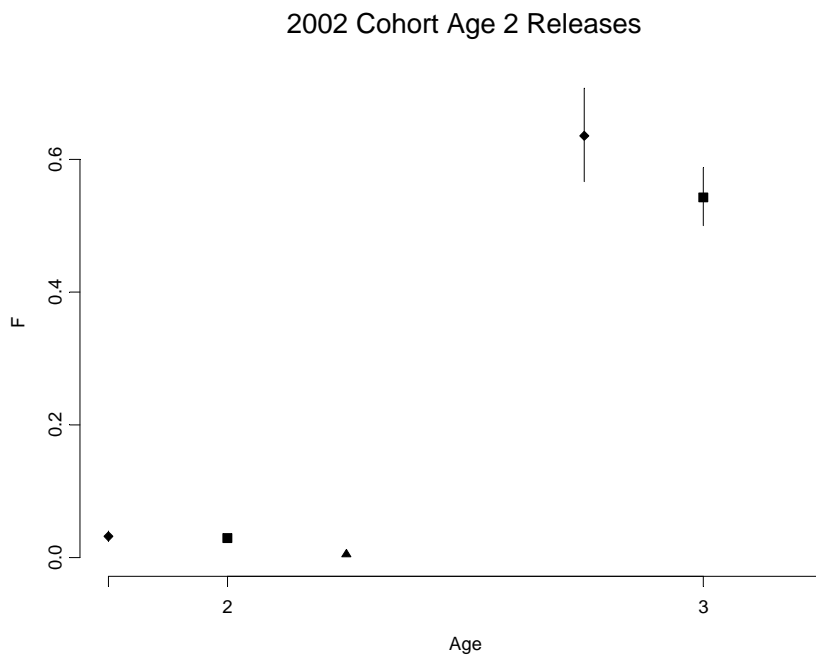
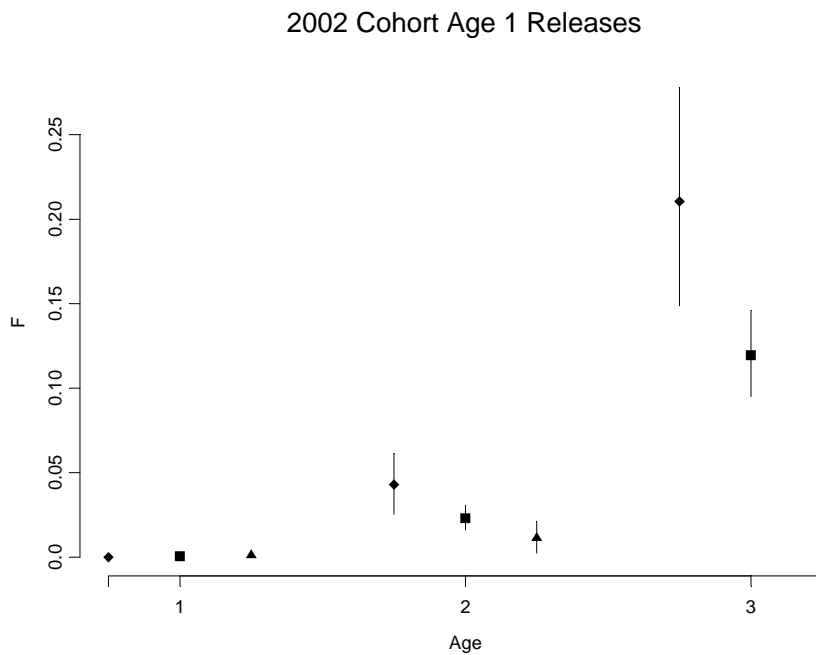


Figure 10: Comparison of fishing mortality rates for different tagger groups and different release ages for the 2002 cohort. Squares are for all taggers; diamonds are for tagger group 1; and triangles are for tagger group 3. All estimates are for natural mortality rate vector 1 and for a reporting rate of 0.65 for the longline fisheries. Error bars are 90% bootstrap confidence intervals conditional on the estimates of mortality, shedding and reporting rates.

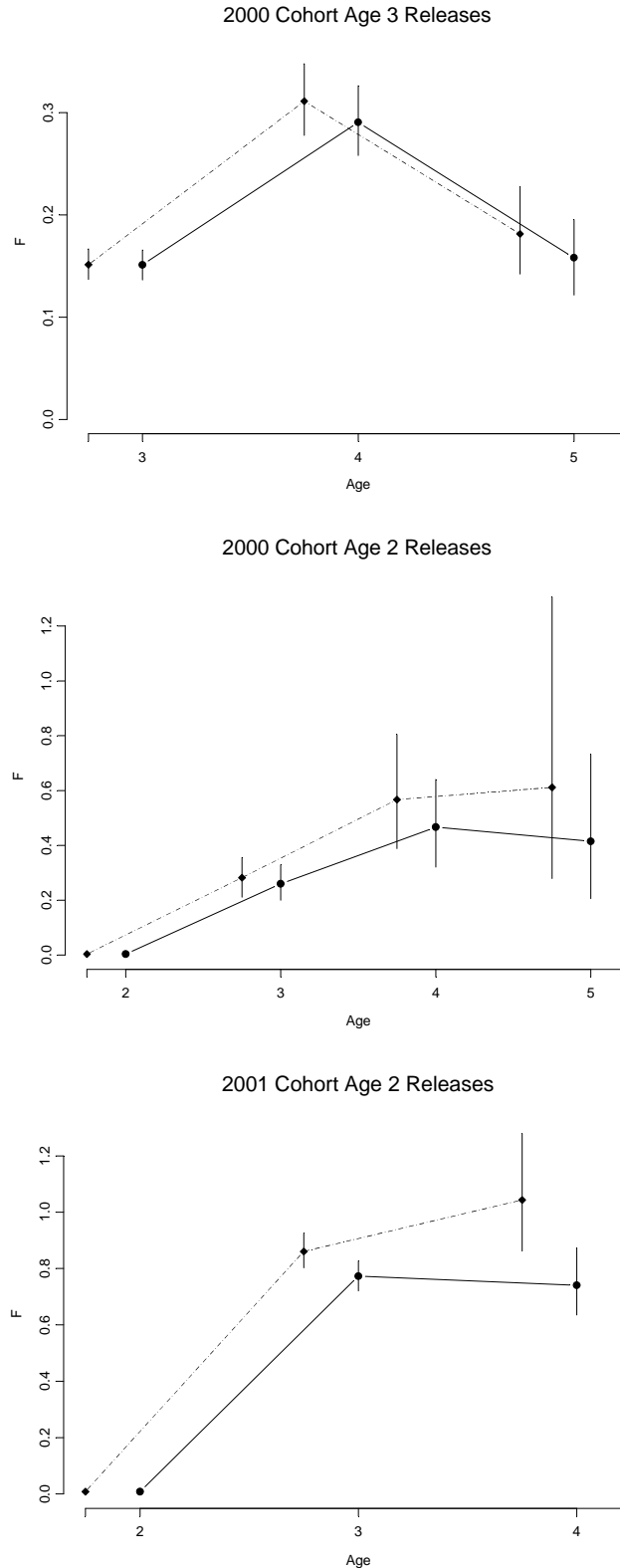


Figure 11: Examples comparing the estimates of fishing mortality rates for different reporting rates and different release ages. Diamonds are for a reporting rate of 0.65 in the longline fisheries and circles are for a reporting rate of 0.3 in the longline fisheries. All estimates include releases for all taggers and natural mortality rate vector 1. Error bars are 90% bootstrap confidence intervals conditional on the estimates of mortality, shedding and reporting rates.



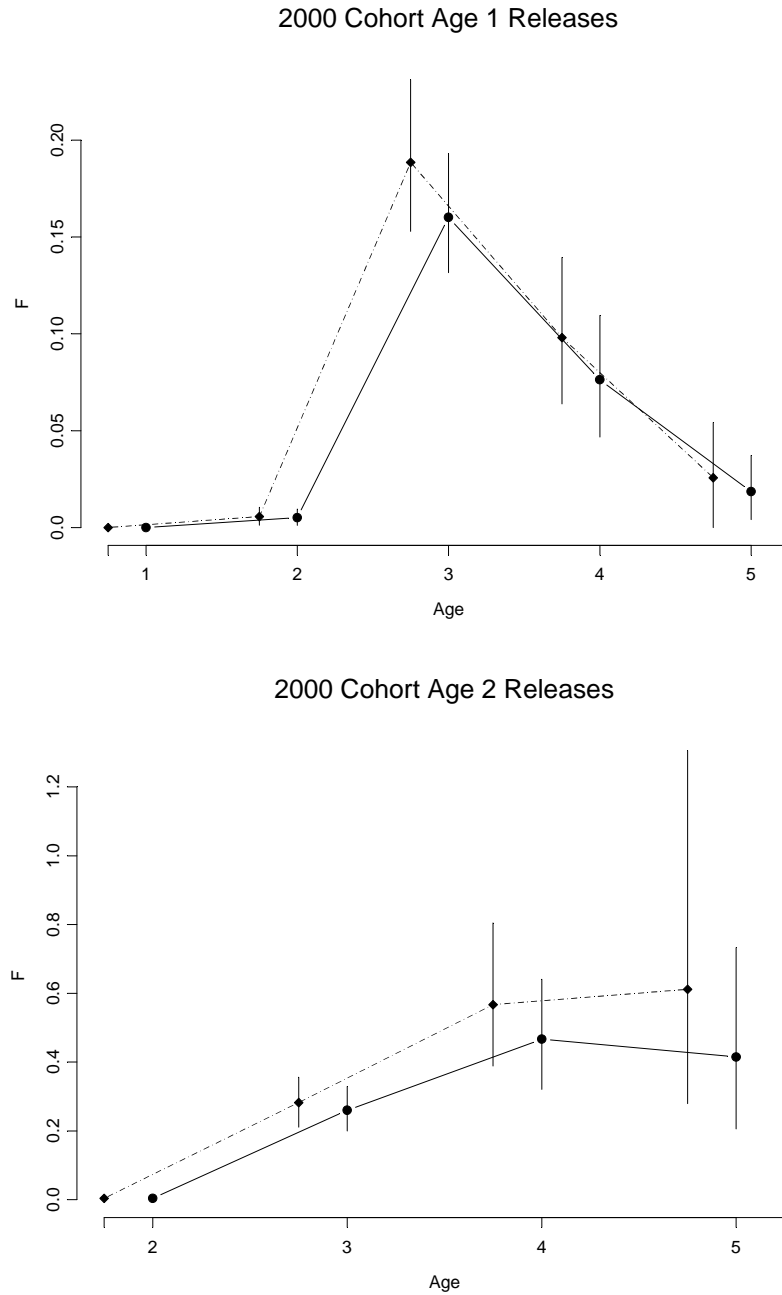


Figure 12: Examples comparing estimates of fishing mortality rates for different natural mortality rates and different release ages. Diamonds are for natural mortality vector 1 and circles are for vector 2. All estimates include releases for all taggers and a reporting rate of 0.65 for the longline fisheries. Error bars are 90% bootstrap confidence intervals conditional on the estimates of mortality, shedding and reporting rates.

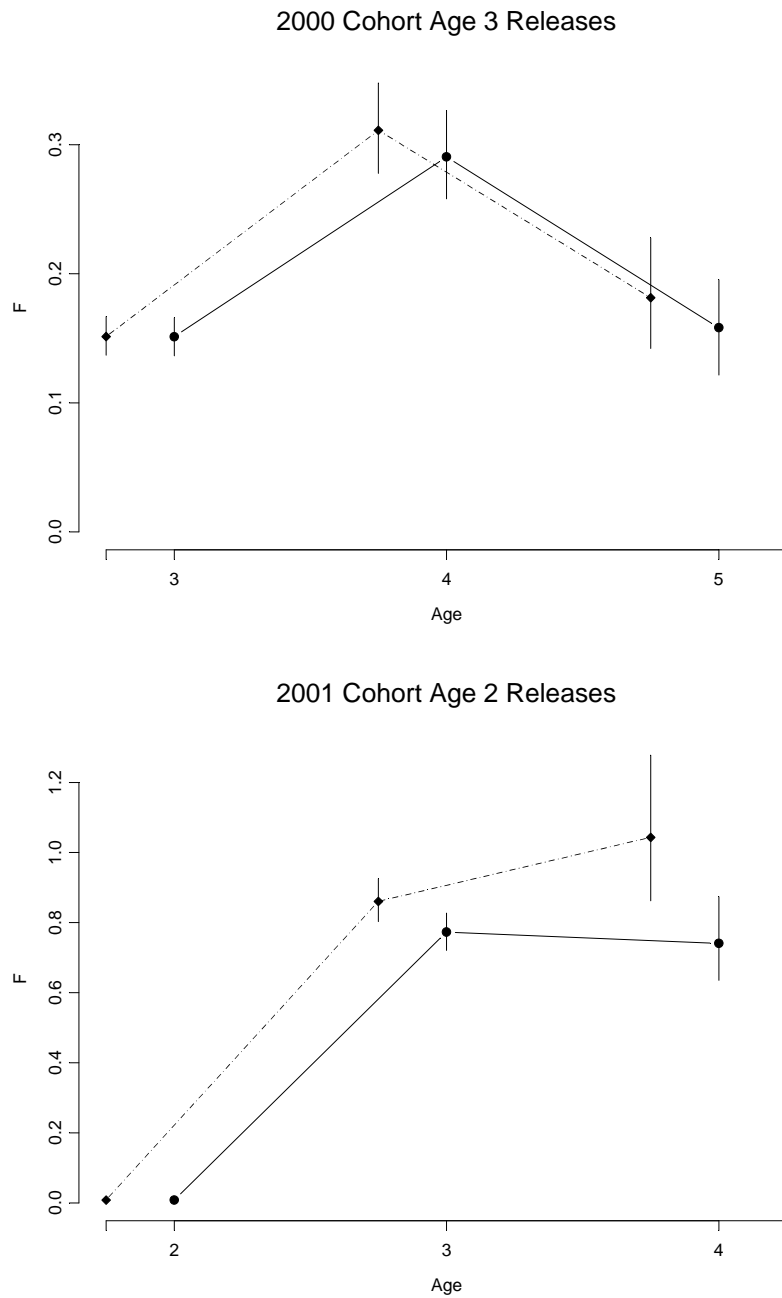


Figure 12 (continued)

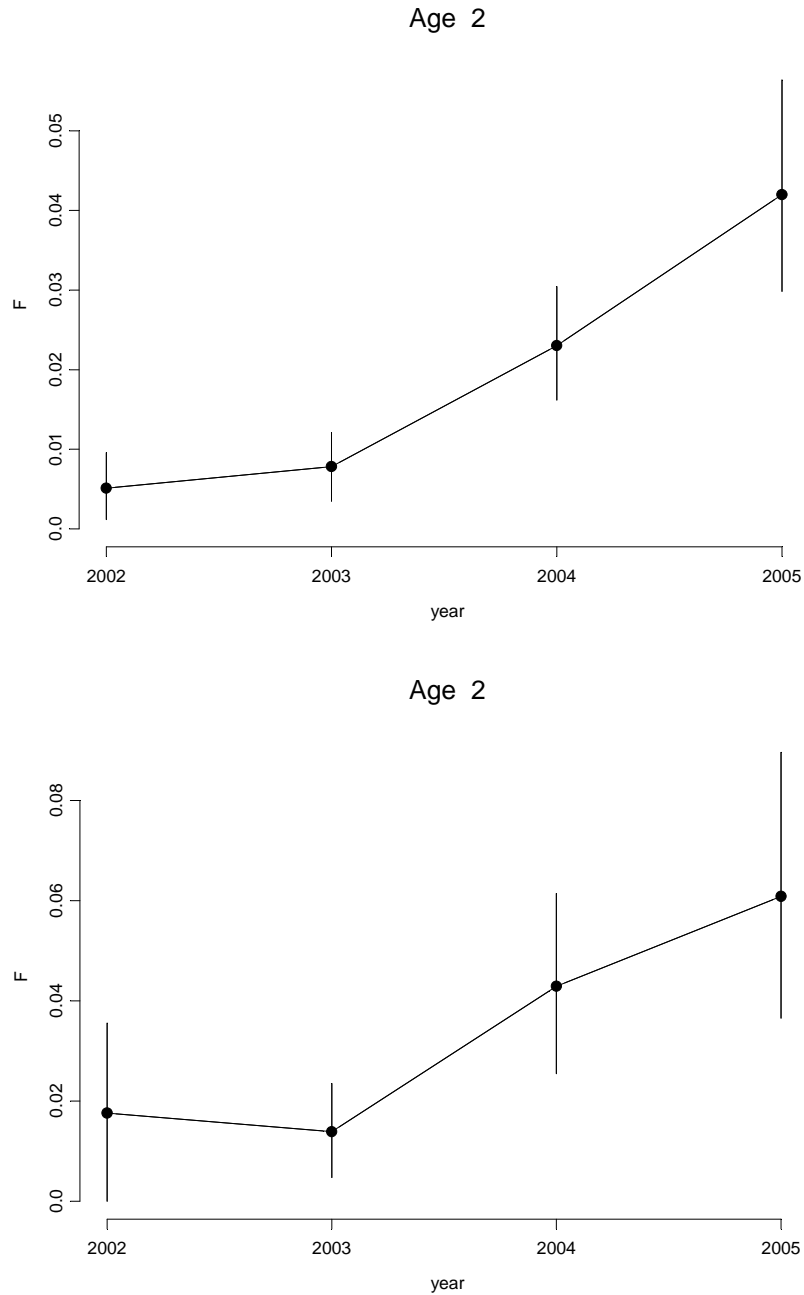


Figure 13: Estimates of fishing mortality rates for age 2 fish from 2002 to 2005. Estimates are all based on age 1 releases (the only one from which a valid estimate can be derived). The upper panel estimates are based on releases by all taggers and the lower panel estimates use only releases by tagger group 1. All estimates use natural mortality rate vector 1 and a reporting rate of 0.65 for the longline fisheries. Error bars are 90% bootstrap confidence intervals conditional on the estimates of mortality, shedding and reporting rates.

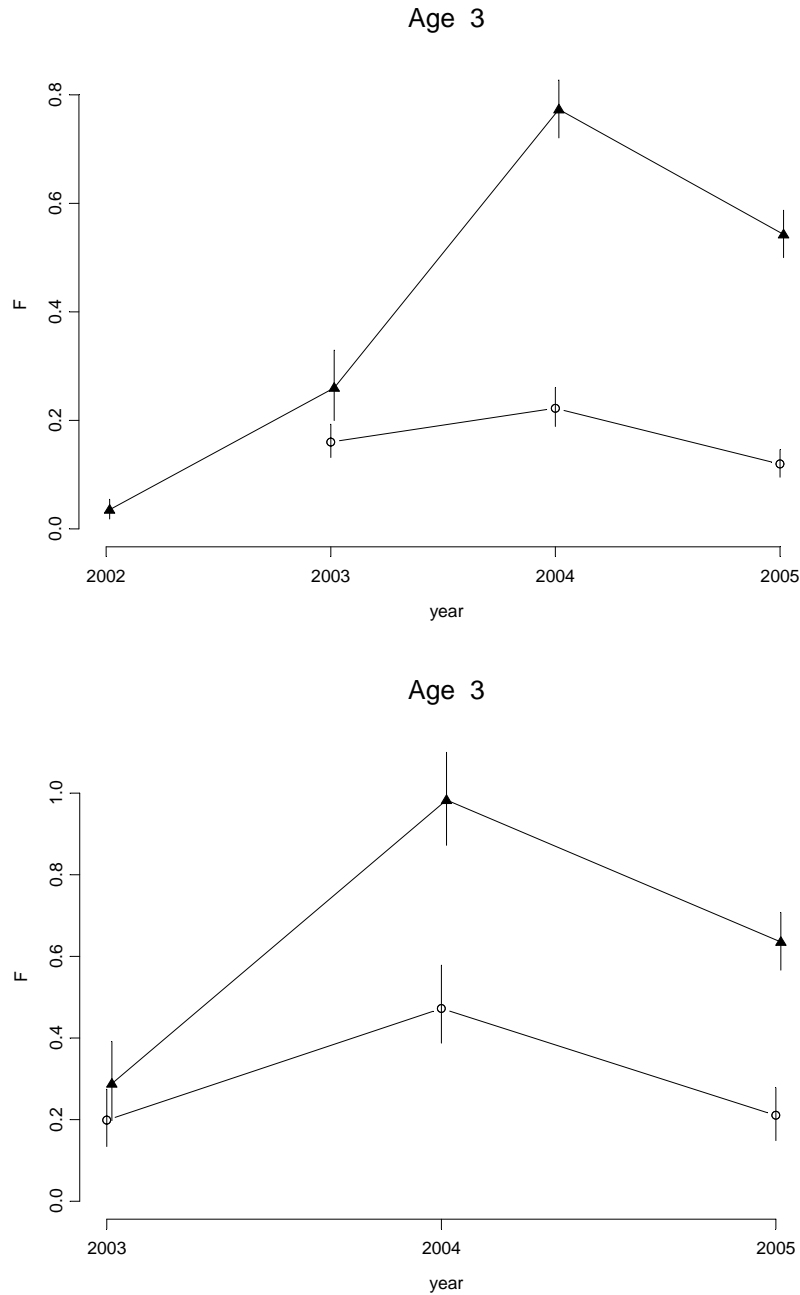


Figure 14: Estimates of fishing mortality rates for age 3 fish from 2003 to 2005. Estimates are based on age 1 releases (open circles) and age 2 releases (triangles). The upper panel estimates are based on releases by all taggers and the lower panel estimates use only releases by tagger group 1. All estimates use natural mortality rate vector 1 and a reporting rate of 0.65 for the longline fisheries. Error bars are 90% bootstrap confidence intervals conditional on the estimates of mortality, shedding and reporting rates.

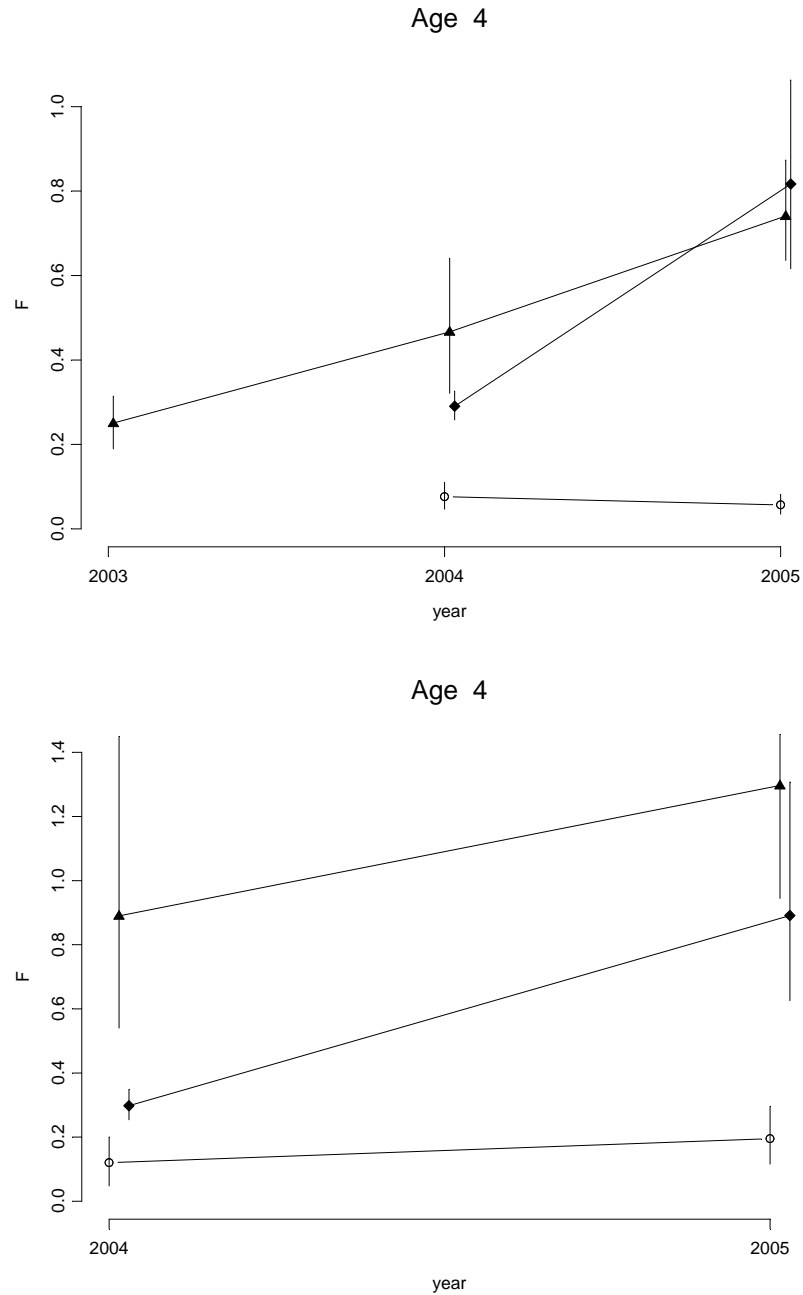


Figure 15: Estimates of fishing mortality rates for age 4 fish for 2004 and 2005. Estimates are based on age 1 releases (open circles), age 2 releases (triangles) and age 3 releases (diamonds). The upper panel estimates are based on releases by all taggers and the lower panel estimates use only releases by tagger group 1. All estimates use natural mortality rate vector 1 and a reporting rate of 0.65 in the longline fisheries. Error bars are 90% bootstrap confidence intervals conditional on the estimates of mortality, shedding and reporting rates.

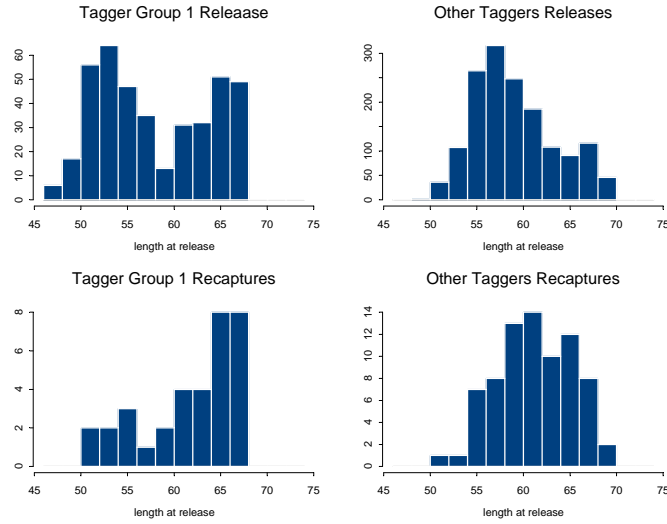


Figure 16: Comparison of the release length distribution for all fish released at age 1 from the 2000 cohort and for those fish that were recaptured.

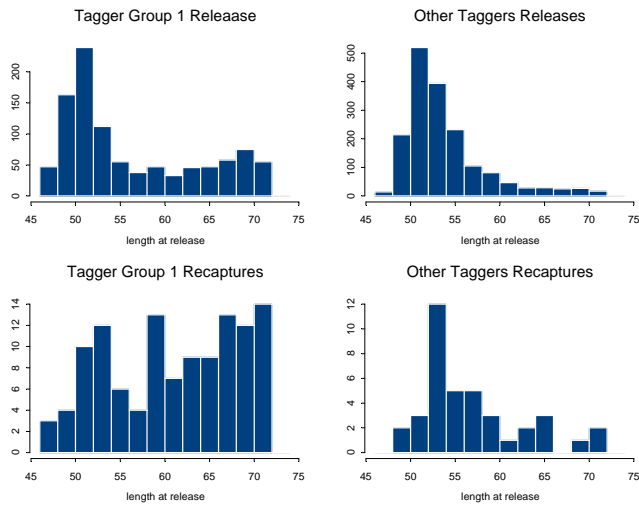


Figure 17: Comparison of the release length distribution for all fish released at age 1 from the 2001 cohort and for those fish that were recaptured

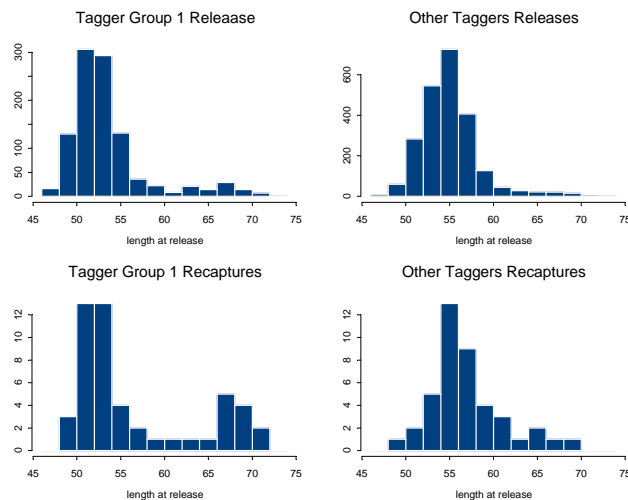


Figure 18: Comparison of the release length distribution for all fish released at age 1 from the 2002 cohort and for those fish that were recaptured

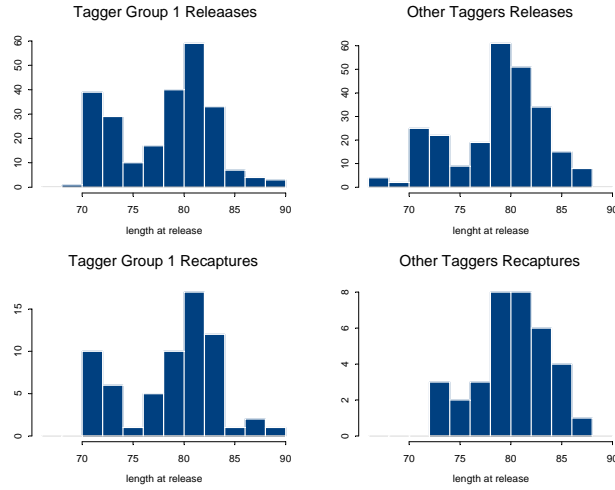


Figure 19: Comparison of the release length distribution for all fish released at age 2 from the 2000 cohort and for those fish that were recaptured.

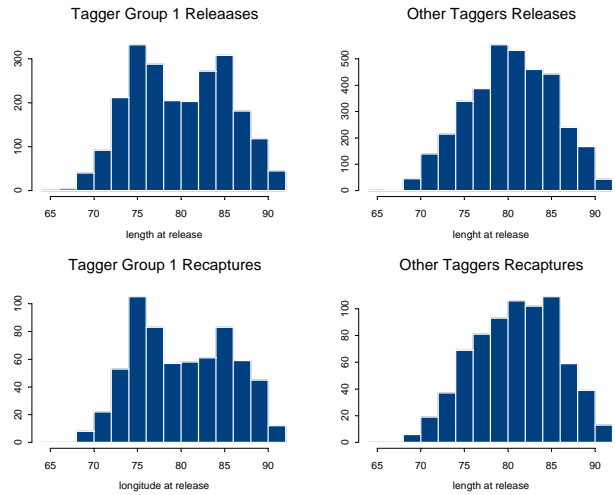


Figure 20: Comparison of the release length distribution for all fish released at age 2 from the 2001 cohort and for those fish that were recaptured.

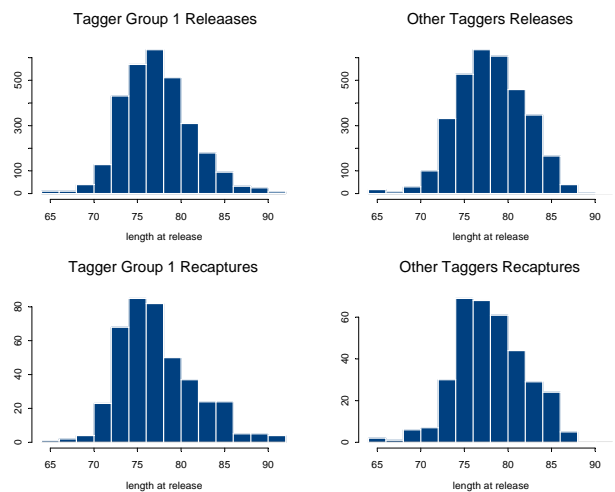


Figure 21: Comparison of the release length distribution for all fish released at age 2 from the 2002 cohort and for those fish that were recaptured.

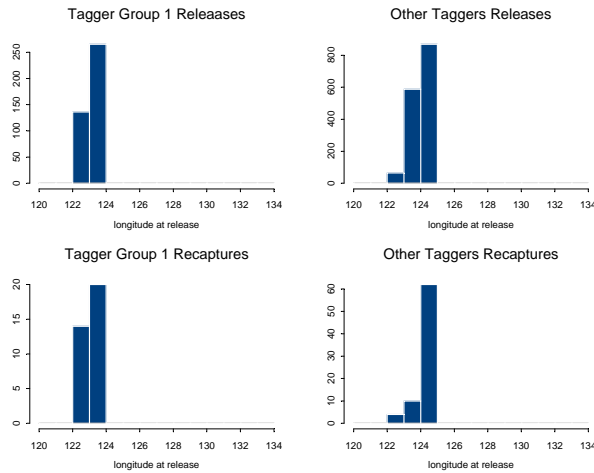


Figure 22: Comparison of the distribution of longitudes for all fish released at age 1 from the 2000 cohort and for those fish that were recaptured.

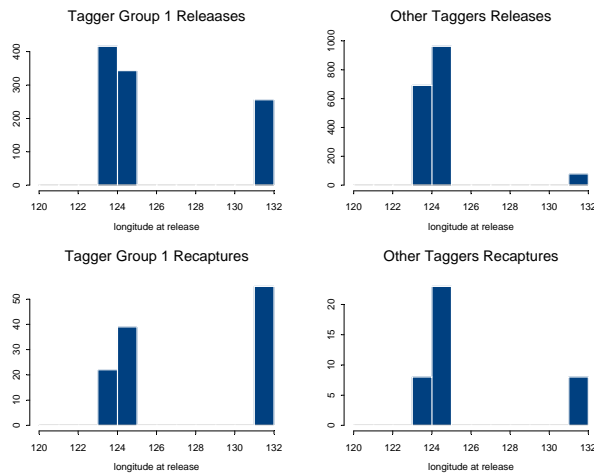


Figure 23: Comparison of the distribution of longitudes for all fish released at age 1 from the 2001 cohort and for those fish that were recaptured

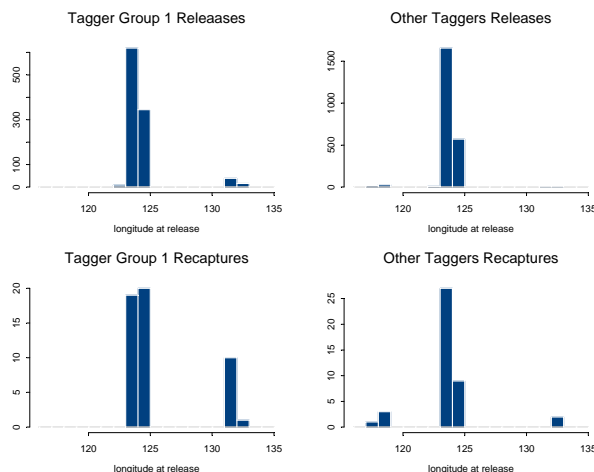


Figure 24: Comparison of the distribution of longitudes for all fish released at age 1 from the 2002 cohort and for those fish that were recaptured. Note that the apparent contradiction in recaptures from releases east of 130°E for “other taggers” when no tags appear to have been released simply reflects the scale of the release histogram and the fact that there were only 5 releases (two of which have been recaptured).



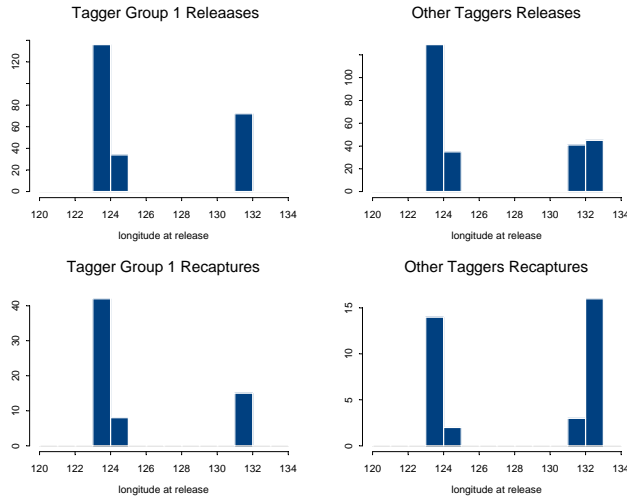


Figure 25: Comparison of the distribution of longitudes for all fish released at age 2 from the 2000 cohort and for those fish that were recaptured.

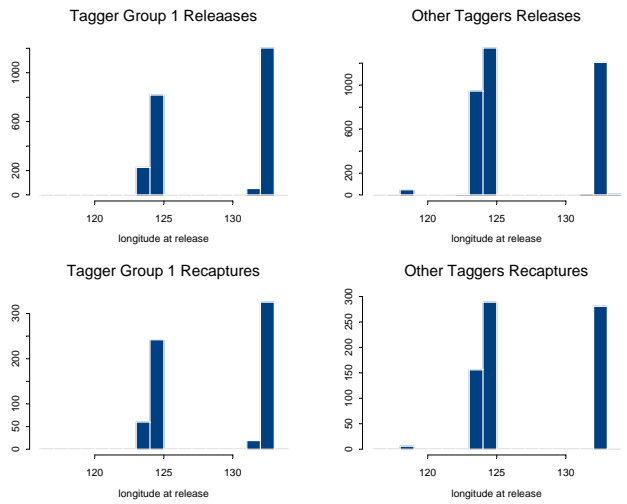


Figure 26: Comparison of the distribution of longitudes for all fish released at age 2 from the 2001 cohort and for those fish that were recaptured.

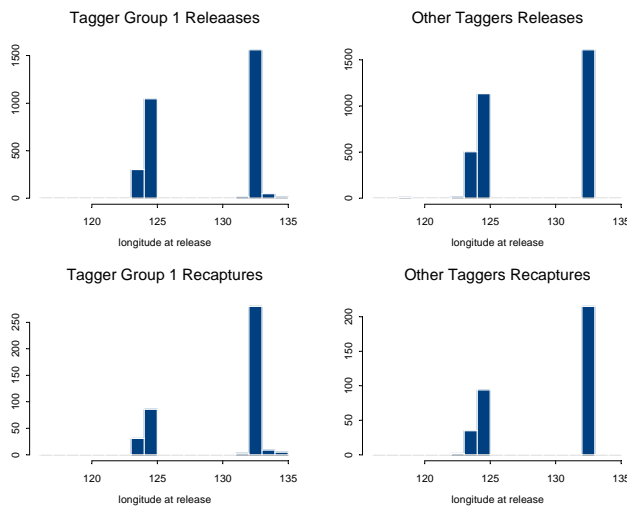


Figure 27: Comparison of the distribution of longitudes for all fish released at age 2 from the 2002 cohort and for those fish that were recaptured.

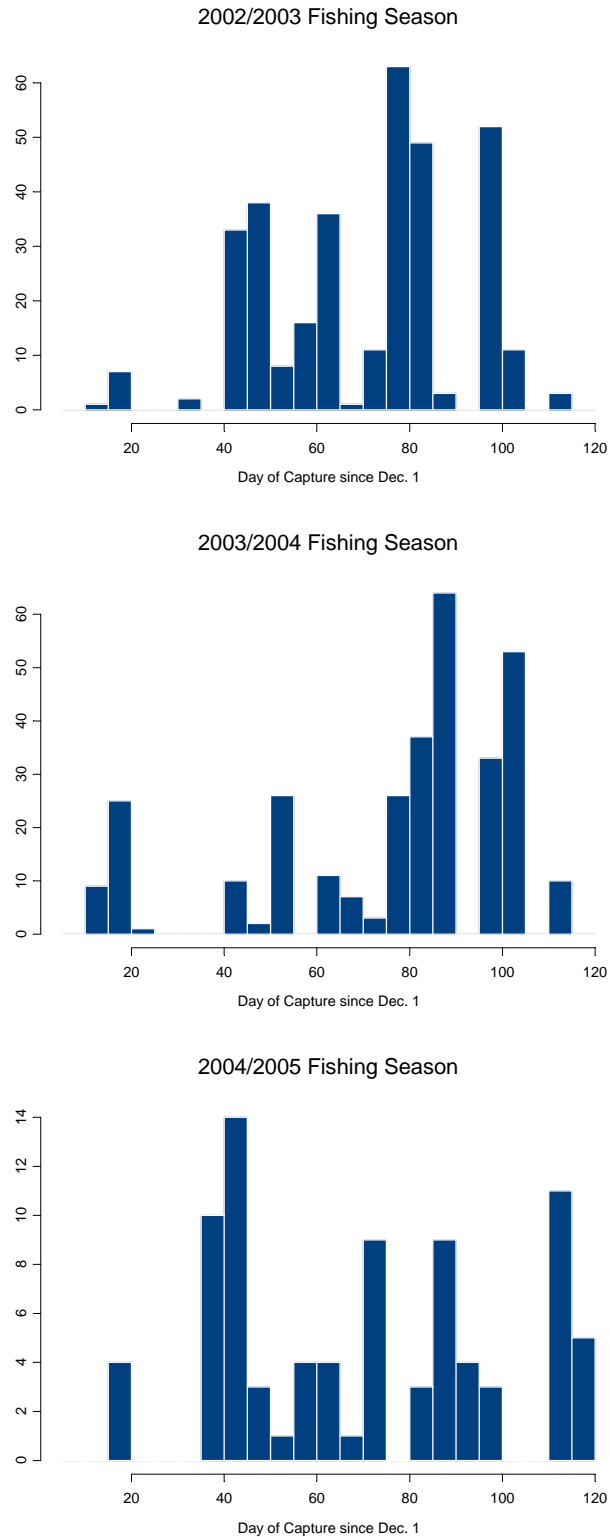


Figure 28: Number of days after December 1 in which a tagged fish released in December in the GAB in 2003, 2004 and 2005 was recaptured in the same fishing season. Note that day of recapture is approximate because all recaptures from a single tow cage are assigned the same date of recapture.

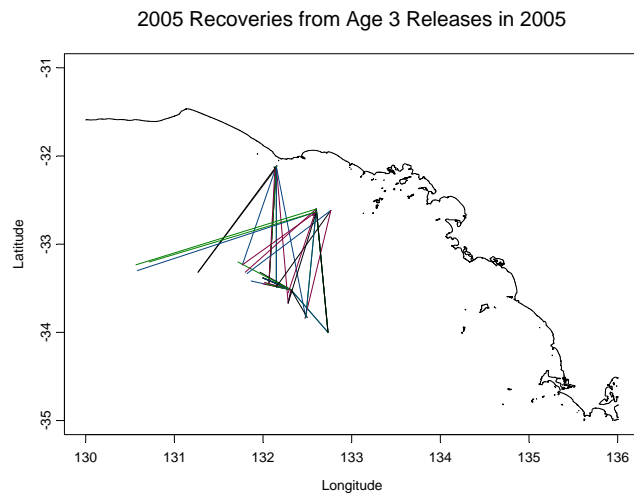
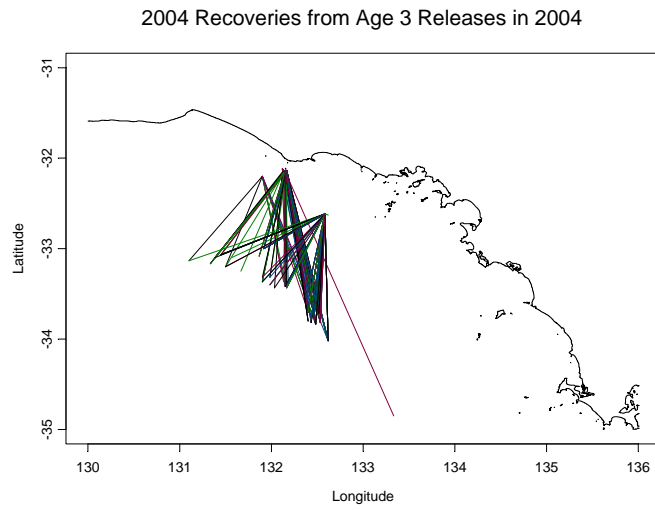
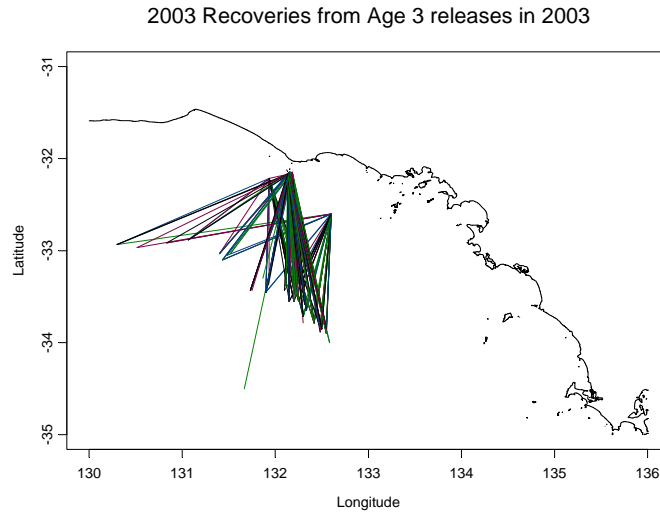


Figure 29: Release and recapture locations for returned tagged fish released in December in the GAB in 2003 and 2004 and recaptured in the same fishing season. Note that day of recapture is approximate because all recaptures from a single tow cage are assigned the same location of recapture.