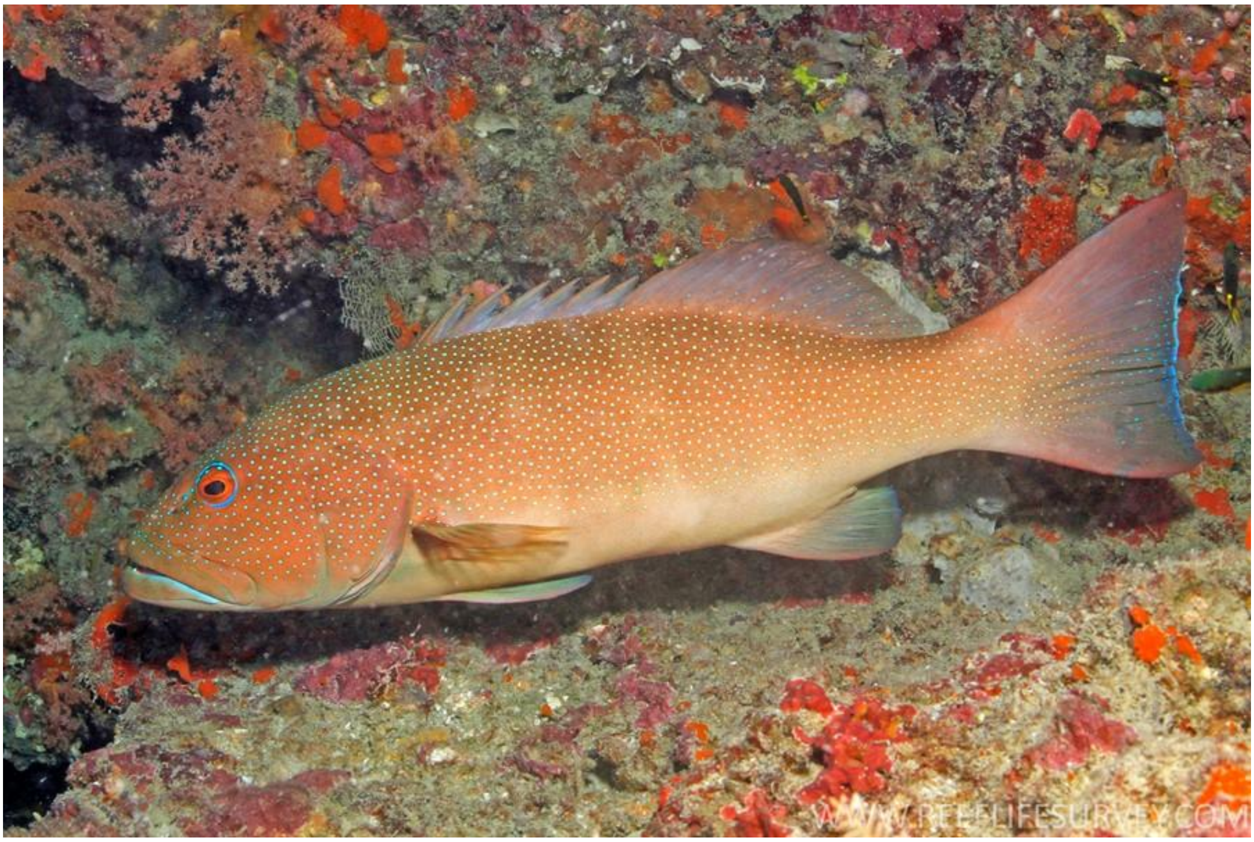

Stock assessment of the Queensland east coast common coral trout (*Plectropomus leopardus*) fishery

April 2019

Queensland Government

This publication has been compiled by Alexander Campbell[1], George Leigh[2], Pia Bessell-Browne[1] and Robyn Lovett[1] for the Department of Agriculture and Fisheries. It provides an assessment of the status of Queensland's population of common coral trout.

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Cover photo: *Plectropomus leopardus* on the Great Barrier Reef (source: Graham Edgar, www.reeflifesurvey.com, Creative Commons by Attribution, Non-commercial, Share-alike licence).

Executive summary

Queensland’s common coral trout, a species of grouper, is a line caught fish forming a single population (stock) across the Great Barrier Reef (GBR). Common coral trout are protogynous hermaphrodites (born female, many later changing sex to male) and aggregate to spawn during spring and summer. They can grow to 5 kg and 18 years of age.

The stock extends north from the GBR into the eastern Torres Strait where it is under Commonwealth jurisdiction. In financial year 2017-18, the Queensland jurisdiction accounted for around 90% of the total harvest.

Over the last five years, 2013-14 to 2017-18, the Queensland total harvest averaged 983 tonnes (t) per year. Sectoral shares were 82% commercial (806 t) and 18% recreational (177 t). Note that commercial harvest is based on logbook reporting, whereas recreational harvest is estimated and subject to greater uncertainty.

The previous stock assessment estimated that in July 2012 the stock was at 60% of unfished biomass (i.e. before fishing began) over the areas commonly fished by commercial fishers. This stock assessment updates the existing model to cover the full extent of the GBR in Queensland waters and includes harvest information from the recreational sector.

This stock assessment used a spatial age-structured model with a yearly time step based on financial years. The model considered twelve spatial sub-populations (“strata”) of fish based primarily on differences in coral reef habitat.

The model incorporated data spanning the period from 1961-62 to 2017-18 (including commercial harvest (1988-89 to 2017-18); historical commercial (1961-62 to 1981-82); recreational harvest (1996-97 to 2013-14); age monitoring (1994-95 to 2004-05); and underwater visual surveys (1982-83 to 2017-18)).

Model analyses suggested that biomass declined between 1951-52 and 2003-04 to 55% unfished biomass. In 2017-18, the stock level was estimated to be 68% unfished total biomass.

Maximum sustainable yield (MSY) was estimated at 1740 t per year, and the yield consistent with a biomass ratio of 68% (a proxy for maximum economic yield in this fishery) was estimated at 1398 t (all sectors, excluding Torres Strait).

While parameter estimation uncertainty has not been quantified, two key modelling assumptions have been explored through sensitivity tests. The relative increase in juvenile survival when the population has been reduced (“compensation ratio”), and the level of illegal fishing in green zones (some fishing has taken place in areas closed to fishing), were fixed at ‘base case’, upper and lower limits to determine the extent to which the results were dependent on these factors.

The current harvest in 2017-18 was 1002 t (all sectors, Queensland only).

The purpose of this report is to estimate biological reference points. It should be noted that the 2017-18 Total Allocated Commercial Catch is for all coral trout species combined, whereas this assessment is for common coral trout only.

Indicator	Value
Estimated current biomass (percentage of unfished state)	68%
2017-18 recreational harvest estimate	171 t
2017-18 reported commercial harvest, based on logbook data	829 t
Estimated Maximum Sustainable Yield	1740 t
Estimated harvest to achieve 68% biomass	1398 t

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Acknowledgements

The work was overseen by a project team committee that consisted of the authors and the following scientists and managers: Sian Breen, Sue Helmke, Ashley Lawson, Amanda Northrop, Michael O'Neill, Genevieve Phillips, Tom Roberts, Anthony Roelofs and James Webley. The role of the committee was collaborative to share interpretation and decision making on data inputs, assessment methods and results.

In addition to their role on the committee, the authors would like to thank Ashley Lawson and Genevieve Phillips who completed the extraction and supply of the Queensland commercial harvest data and were generous with their time in answering a number of questions about the data. James Webley and Jennifer Larkin are thanked for provision of the Queensland recreational harvest data.

The Australian Institute of Marine Science (AIMS) provided the underwater visual survey data from the AIMS Long Term Monitoring Project.

Tony and Avril Ayling (Sea Research) provided data from underwater visual surveys. Most of these surveys were funded by the Great Barrier Reef Marine Park Authority.

Data specialists and cartographers from the Great Barrier Reef Marine Park Authority also provided updated mapping data of the Great Barrier Reef, and made time to discuss these data. In particular, we thank Rhonda Banks for her time and expertise.

Much of the background information for this assessment came from fisher interviews conducted in 2012, many of which were facilitated by Darren Cameron of the Great Barrier Reef Marine Park Authority.

Researchers from the Effects of Line Fishing (ELF) Project, represented by Dr Bruce Mapstone and Dr Colin Simpfendorfer, provided age-frequency data from structured line surveys. The ELF Project field work ran every year from 1995 to 2005 and was undertaken by CRC Reef Research Centre with funding from the Australian Government's Fisheries Research and Development Corporation (FRDC, Project No. 97/124).

The authors would also like to acknowledge and thank the many fishers and scientists who contributed to past research on coral trout. They provided valuable information on the history of the fishery, and samples and measurements of fish as part of studies conducted by the Queensland Government, James Cook University, the University of Queensland and the Australian Government – through the Fisheries Research and Development Corporation (FRDC). Finally, we would like to thank Claire Anderson, Eddie Jebreen and Tony Courtney, in addition to members of the committee, for reviewing and providing comments on the draft report. The research was supported by the Queensland Department of Agriculture and Fisheries.

1. Introduction

Coral trout forms a species complex and is part of the family Epinephelidae. The complex is found throughout Australia and is comprised of common coral trout (*Plectropomus leopardus*), barcheek coral trout (*P. maculatus*), bluespotted coral trout (*P. laevis*), passionfruit coral trout (*P. areolatus*), highfin coral trout (*P. oligocanthus*), yellow-edge coronation trout (*Variola louti*) and white-edge coronation trout (*V. albimarginata*).

Common coral trout is the primary target species of the commercial Coral Reef Fin Fish Fishery (CRFFF) on Queensland's East Coast. It is also a popular species targeted by recreational line fishers able to travel offshore throughout the Great Barrier Reef (GBR). As common coral trout is the primary target species it is the focus of this assessment.

Research suggests that common coral trout forms one stock on the Qld east coast including the Torres Straight region (van Herweden et al. 2006, 2009). There is evidence to suggest that common coral trout stay on the same individual reefs after settlement as larvae, and furthermore that their larvae do not travel long distances (generally less than tens of km) after spawning (Bergenius et al. 2005, 2006; Harrison et al. 2012). Coral trout are also protogynous hermaphrodites, beginning life as a female, with many later changing sex to male (Ferreira 1995). They spawn in spring and summer months around the new moon (Samoilys 1997).

The CRFFF operates within the GBR Marine Park. It is a line-only fishery, except for a small amount of recreational spear fishing. The fishery targets mainly common coral trout for export live to Asia. Secondary target species include other coral trout species (see above), red throat emperor (*Lethrinus miniatus*), and a large number of reef fish species grouped together into an "Other Species" category for the purposes of management of the commercial fishery. Over 2000 tonnes of coral trout were landed annually by all sectors combined in the early 2000s, before Individual Transferable Quotas (ITQs) were introduced in 2004. Since this time, the estimated total harvest has reduced to around 1000 tonnes annually.

The previous stock assessment included data up until the end of calendar year 2011 (Leigh et al. 2014). The assessment suggested that the exploitable biomass in areas open to fishing (blue zones) was 60% of unfished biomass (Leigh et al. 2014). It is important to note that the previous assessment focused on the commercial sector of the fishery. The population model did not include the regions commonly fished by recreational fishers or the harvest that they took. The results from this assessment, along with updated standardised catch rates, have been used to set the annual total allocated commercial catch (TACC) for coral trout in the CRFFF since 2014.

There are various environmental variables that are thought to influence coral trout or the coral trout fishery, but which haven't been explicitly modelled, including: cyclones, coral bleaching and sea surface temperature. These are expanded upon in Section 4.

The GBR is separated into various zones in which different activities are permitted. Importantly, 'green zones' are areas in which fishing of any kind is not permitted. There is evidence that illegal fishing occurs within green zones (Davis et al. 2004; Arias and Sutton 2013; Leigh et al. 2014). To account for this, the previous assessment assumed areas closed to fishing were subject to fishing mortality equal to 20% of that estimated for component of the stratum open to fishing. It is important to note that this was set at a fixed level over the whole history of the fishery, whereas in reality it is likely that the degree of illegal green zone fishing has declined through time with the introduction of GPS. Because there was no reliable information from which to estimate green zone fishing, let alone how it has changed over time, a fixed level was used as it involved the fewest assumptions. It is also important to note that this green zone fishing mortality is based on total estimated harvest and does not distinguish between commercial and recreational fishing.

This assessment aimed to determine the status of the common coral trout stock on Queensland’s east coast. For this, harvests (both commercial and recreational), with standardised catch rates, underwater visual survey census results, and age structures were used to estimate the size of the stock. The assessment investigated the sensitivity of the model to the fishing mortality applied in green zones, testing 10% and 30% in addition to the 20% of the last assessment. It also improved on the previous assessment by incorporating recreational harvest and the full spatial extent of the GBR (the previous assessment focused on offshore reefs targeted by the commercial sector). Recommended biological harvest targets to support the implementation of Queensland’s Sustainable Fisheries Strategy 2017-2027 (the Strategy) are provided.

2. Methods

This report has been generated by KnitR (Xie 2019), a 'literate code' document generation system based on the R programming environment (R Core Team 2017). Segments of R language code that were used to generate the outputs are included in the report to increase transparency and guide continual improvement.

2.1 Data Sources

A number of data sources were used in the assessment. These are summarised in Table 1 and expanded on in the following sections.

Table 1 – Data sources

Code	Years	Reference
QFB	1963-1981	Halliday and Robins (2007)
Hundloe	1980	Hundloe (1985)
ABS	1985, 1991	ABS (1986), ABS (1994)
RFISH	1997, 1999, 2002, 2005	Higgs (1999), Higgs (2001)
NRIFS	2000	Henry and Lyle (2003)
SWIRFS	2011, 2014	Taylor et al. (2012)
CFISH	1989-2018	Fisheries Queensland
ELF	1995-2005	Mapstone et al. (2004)
AIMS	1997-2018	Emslie and Cheal (2018)
TAA	1983-1986	Ayling and Ayling (1986)
GBRMPA	1951-2018	GBRMPA (2014)
GL	1951-2018	Leigh et al. (2014)

2.1.1 QFB - Queensland Fish Board Data

Commercially caught fish were by law marketed through the Queensland Fish Board until 1981. Fish Board annual records compiled by Halliday and Robins (2007) provide information about the harvest size up until this date. For more detail see Section 4.2.1 of Leigh et al. (2014).

2.1.2 Hundloe - Tor Hundloe Surveys

The recreational survey by Hundloe (1985) estimated the total small-boat catch of fish (all species combined) off the coast opposite the Great Barrier Reef in the 1980 calendar year. For more detail see Section 4.3.1 of Leigh et al. (2014).

2.1.3 ABS - Australian Bureau of Statistics Data

A survey of participation in recreational fishing in Queensland in 1985 by the Australian Bureau of Statistics (ABS 1986) and an ABS survey of home food production (ABS 1994).

For further details see Sections 4.3.2 and 4.3.3 of Leigh et al. (2014).

2.1.4 RFISH, NRIFS and SWRFS Diary Surveys

Recreational catches of fish in Queensland have been measured by State-wide diary surveys since 1997. These included:

- Surveys conducted by Fisheries Queensland, known as RFISH, in 1997, 1999, 2002 and 2005 (Higgs 1999, 2001; Higgs et al. 2007; McInnes 2008).
- An Australian national survey (the National Recreational and Indigenous Fishing Survey, NRIFS) was conducted in 2000 (actually May 2000 to April 2001) and used different methodology. It was funded by the Australian Government's Fisheries Research and Development Corporation (FRDC, project number 99/158) (Henry and Lyle 2003).
- The NRIFS methodology was adopted by Fisheries Queensland for the State-wide surveys in 2011 and 2014, known as SWRFS (State-Wide Recreational Fishing Survey) (Taylor et al. 2012).

For further details see Sections 4.3.2 and 4.3.3 of Leigh et al. (2014).

2.1.5 CFISH - Fisheries Queensland Logbook Data

Logbook data from the CFISH database is maintained by Fisheries Queensland and began in 1988. The OperationEffortId, FishingMethodTypeID, LogTypeCode, FishingStartDate, MaximumFishingDayCount, AuthorityId, GridDerived, SiteDerived, NumberOfBoats and NumberOfCrew fields were extracted from the `LogEffort.OperationEffortView` table and stored in R data frame `Effort`. The OperationEffortId, CaabSpeciesID and RetainedWholeWeightDerived fields were extracted from the `LogCatch.OperationCatchView` table and stored in R data frame `Catch`. Finally the AuthorityID and AuthorityChainNumber fields were extracted from the `Authority.AuthorityView` table and stored in R data frame `Authority`. The `Data` data frame, representing the basis for catch history reconstruction and commercial catch rate standardisation was then obtained as:

```
Catch <- subset(Catch, CaabSpeciesID == 37311905)
Catch <- Catch[,!names(Catch) == 'CaabSpeciesID']
Effort <- subset(Effort, LogTypeCode == "LF" | LogTypeCode == "MI")
names(Effort)[which(names(Effort) == 'AuthorityId')] <- 'AuthorityID'
Effort <- merge(Effort, Authority)
Data <- merge(Effort, Catch)
Data <- subset(Data, !(GridDerived == ''))
Data$Month <- month(Data$FishingStartDate)
Data$Year <- ifelse(Data$Month<=6,year(Data$FishingStartDate), year(Data$FishingStartD
ate)+1)
Data <- subset(Data, Year >= 1989 & Year <= 2018)
```

2.1.6 ELF - Effects of Line Fishing Project

Fishery-independent age-frequencies and underwater visual survey (UVS) abundances of common coral trout obtained by the Effects of Line Fishing (ELF) Project, a major research project run by CRC Reef Research Centre and partly funded by the FRDC. The ELF Project ran from 1995 to 2005 and sampled 24 reefs in the GBR (four clusters each of six reefs) each year. For more details see Mapstone et al. (2004). This was the source of the age-frequency data input to the model.

2.1.7 AIMS - Australian Institute of Marine Science Underwater Visual Census

Fishery-independent underwater visual survey data collected by the Australian Institute of Marine Science's Long Term Monitoring Program (AIMS LTMP), 1992–2018, used as relative measures of abundance. For more detail see Emslie and Cheal (2018).

2.1.8 TAA - Tony and Avril Ayling underwater visual surveys

Fishery-independent estimates of abundance of coral trout from underwater visual surveys funded by GBRMPA. A major survey of hundreds of reefs was undertaken from 1983 to 1986 by the divers Tony and Avril Ayling (see Ayling and Ayling (1986)).

2.1.9 GBRMPA - Shapefiles

The *ZONING* and *Marine_Bioregions_of_the_Great_Barrier_Reef__Reef_* shapefiles were downloaded from *http://www.gbrmpa.gov.au/geoportal/catalog/main/home.page* on 10 December 2018. See also GBRMPA (2014).

2.1.10 GL - George Leigh Estimates of Habitat Area

Coral trout habitat area across the whole GBR by Bioregion was estimated by George Leigh; see Chapter 5 of Leigh et al. (2014). These estimates of habitat area involved a shapefile (“DRYREEF”) obtained from GBRMPA in 2012. The metadata for this shapefile contains the following disclaimer under the attribute accuracy: “DRYREEF has no usable attributes without further dataset development”. For this reason GBRMPRA no longer release it. The first author of the previous assessment cross referenced it with satellite imagery and is of the view that it is substantially accurate (Leigh et al. 2014).

2.2 Model Inputs

2.2.1 Spatial Structure

The population of common coral trout on the GBR is divided into twelve sub-populations belonging to one of twelve spatial strata. This division is based both on differences in habitat (guided by the Great Barrier Reef Marine Park Authority’s Marine Bioregions (see Figure 6 in Leigh et al. (2014)) and considerations related to the presence or absence of UVS data (Data Source ‘AIMS’). Where sufficient AIMS data existed within one of the GBRMPA Bioregions, the strata and the Bioregion are identical, and the strata name is the Bioregion name. Where multiple Bioregions had to be grouped together the strata was given the name of a coastal national park somewhere within the latitudinal range of the relevant Bioregions. The four northern strata are displayed in Figure 1 and eight remaining strata are displayed in Figure 2.

Within each stratum, two zones exist - a ‘blue’ zone, representing the commercially fishable portion of the stratum, and a ‘green’ zone, representing the portion closed to fishing. The strata, and zoning for the period 2005-2018, were determined from the GBRMPA shapefiles listed in Section 2.1.9. In the model strata are denoted with a subscript ‘s’ and zones with a subscript ‘z’.

Zoning and the associated coral trout habitat area has changed through time. This is handled in Section 2.2.5.

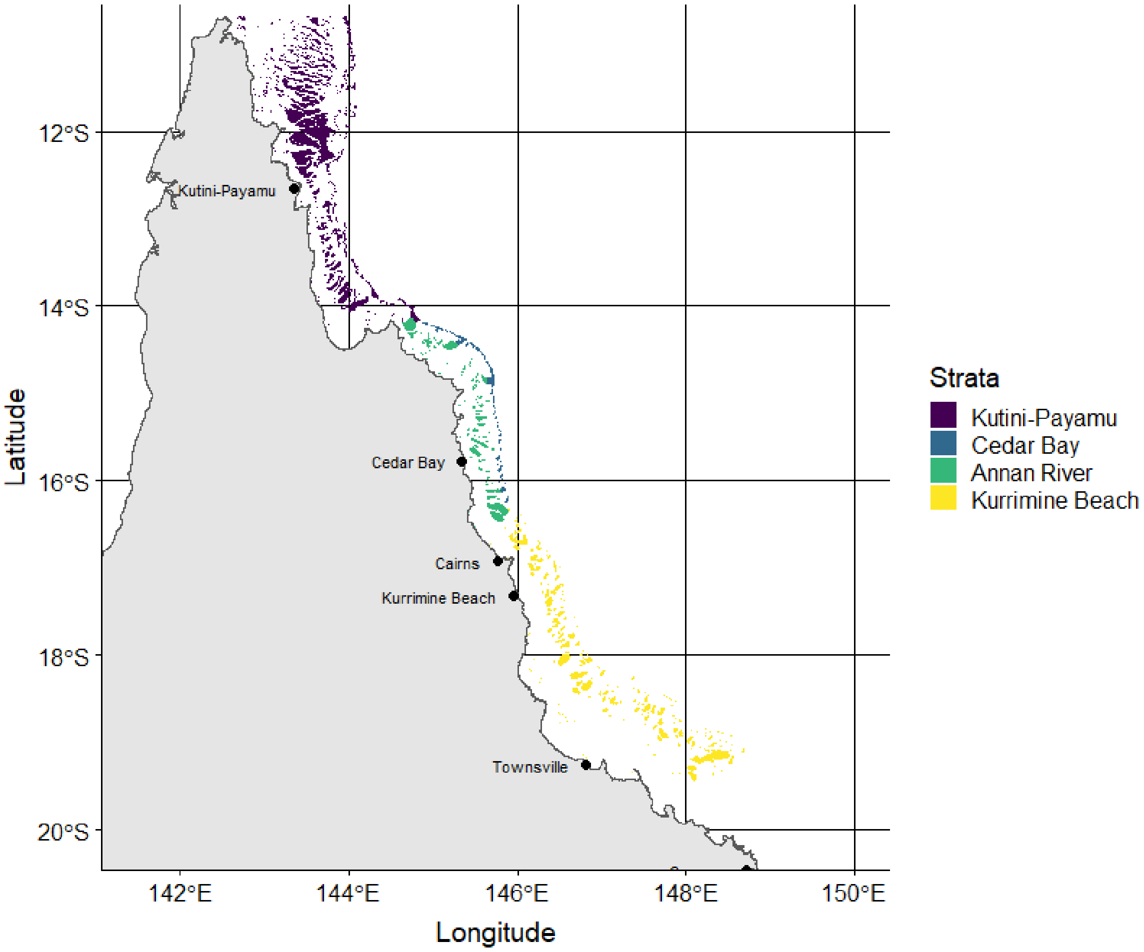

Figure 1 – Map of northern strata

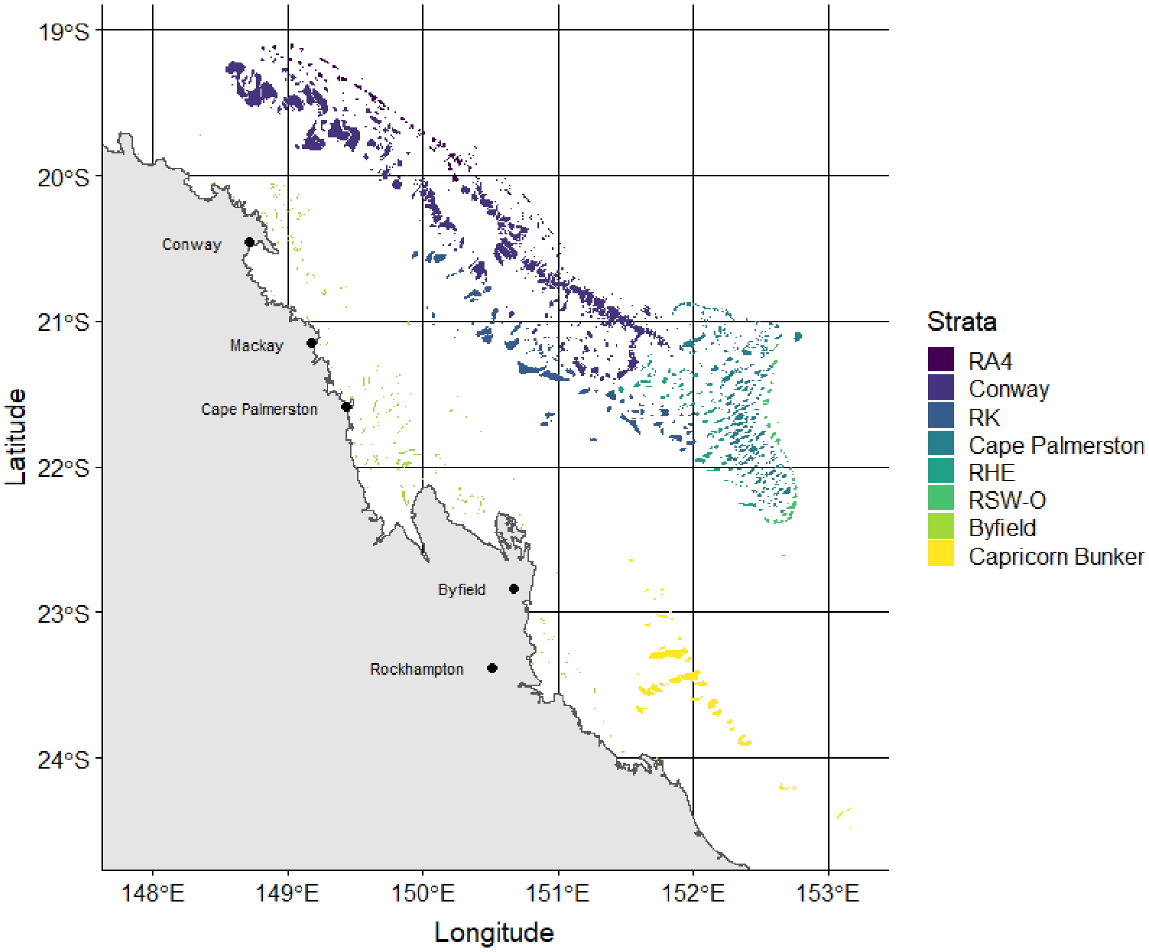

Figure 2 – Map of southern strata

2.2.2 Harvest Reconstruction

Commercial and recreational harvest was reconstructed from the last year of the assessment (Financial Year 2018), back to a presumed unfished (virgin) state in 1950. Data sources QFB, Hundloe, ABS, RFISH, NRIFS, SWRFS, CFISH and AIMS (see Table 1) were used in this procedure. For an overview of the reconstruction methodology as it pertains to the period between 1960 and 2011 and for the spatial structure used in that report see Sections 4.2.2 and 4.2.3 of Leigh et al. (2014). For the precise details of the reconstruction for the full time period and the spatial structure given in Figures 1 and 2 refer to Appendix B.

One important difference between the reconstruction methodology in Leigh et al. (2014) and this report is that we use data from the AIMS UVS census data to estimate the proportion of the recreational catch that is common coral trout as opposed to other species in the coral trout species complex (detailed in Section 1). The section of code (repeated in context in Appendix B) that estimates this proportion and then applies it to split out the common coral trout catch for the recreational sector is:

```
# adjustment for non-CCT observations
names(uvs)[names(uvs)=='GENUS_SPECIES'] <- 'Species'

uvs$Species[uvs$Species=='Plectropomus leopardus'] <- 'CCT'
uvs$Species[!uvs$Species=='CCT'] <- 'Other'
```

```
uvs$ID <- 1:nrow(uvs)

uvs <- st_as_sf(uvs, coords = c('SITE_LONG','SITE_LAT'), crs=st_crs(bio)) # make spatial

uvs$idx <- st_nearest_feature(uvs, strata) # get spatial index

uvs$Strata <- strata$Strata[uvs$idx] # assign population

step_one <- uvs  per cent> per cent group_by(Strata,Species)  per cent> per cent summarise(ab = mean(ABUNDANCE))
step_two <- step_one  per cent> per cent group_by(Strata)  per cent> per cent summarise(ab = sum(ab))
step_three <- step_one  per cent> per cent filter(Species=='CCT')
step_four <- step_three$ab / step_two$ab

CatchMatOut.Recr[,'Annan River'] <- step_four[1] * CatchMatOut.Recr[,'Annan River']
CatchMatOut.Recr[,'Byfield'] <- step_four[2] * CatchMatOut.Recr[,'Byfield']
CatchMatOut.Recr[,'Cape Palmerston'] <- step_four[3] * CatchMatOut.Recr[,'Cape Palmerston']
CatchMatOut.Recr[,'Capricorn Bunker'] <- step_four[4] * CatchMatOut.Recr[,'Capricorn Bunker']
CatchMatOut.Recr[,'Cedar Bay'] <- step_four[5] * CatchMatOut.Recr[,'Cedar Bay']
CatchMatOut.Recr[,'Conway'] <- step_four[6] * CatchMatOut.Recr[,'Conway']
CatchMatOut.Recr[,'Kurrimine Beach'] <- step_four[7] * CatchMatOut.Recr[,'Kurrimine Beach']
CatchMatOut.Recr[,'RA4'] <- step_four[8] * CatchMatOut.Recr[,'RA4']
CatchMatOut.Recr[,'RHE'] <- step_four[9] * CatchMatOut.Recr[,'RHE']
CatchMatOut.Recr[,'RK'] <- step_four[10] * CatchMatOut.Recr[,'RK']
CatchMatOut.Recr[,'RSW-O'] <- step_four[11] * CatchMatOut.Recr[,'RSW-O']

CatchMatOut.Recr[,'Kutini-Payamu'] <- step_four[1] * CatchMatOut.Recr[,'Kutini-Payamu'] # using annan river
```

where `bio` is the spatial object created from the GBRMPA bioregions shapefile and `uvs` is the data object created from the AIMS UVS data set.

It is assumed that all the commercial catch is common coral trout (*Plectropomus leopardus*).

2.2.3 Standardised commercial catch rates

Catch rates are assumed to follow a Poisson quasi-likelihood so that the contribution to the total log likelihood for a catch c_i is given by:

$$-\frac{1}{2}\sum_i c_i - \frac{n-1}{2}\log\left(\sum_i\left[c_i\left(\log(c_i)-\log(\mu_i)+\log\left(\sum_i \mu_i\right)-\log\left(\sum_i c_i\right)\right)\right]\right)$$

where

$$\mu_i = (1+\beta_1 x_i + \beta_2 y_i + \beta_3 z_i)\exp\left(\gamma_{D_\gamma[i]} + \delta_{D_\delta[i]} + \iota_{D_\iota[i]}\right)$$

where, for the $\imath$th record, x_i is the number of dories (`Data$Dories <- with(Data, pmin(NumberOfBoats, NumberOfCrew))`), y_i is an indicator variable for the number of dories being zero (`Data$ZDories <- as.numeric(Data$Dories==0)`), and z_i is the number of 'excess' crew (`Data$ExcessCrew <- with(Data, NCrew - Dories)`). γ_i is the parameter for the $\imath$th vessel, δ_i is the parameter for the $\imath$th bioregion, and ι_i is the parameter for the $\imath$th unique year-month-strata combination. D_γ, D_δ and D_ι are design vectors for the respective parameter sets, mapping the $\imath$th data record to the corresponding parameter.

For input to the standardisation model, the logbook catch data was subset using the following code:

```
Data <- subset(Data, !is.na(NumberOfBoats) & !is.na(NumberOfCrew) & SiteDerived != 0
& MaximumFishingDayCount==1)
```

This model is identical to the commercial catch rate standardisation model in Leigh et al. (2014), substituting strata for subregion, however, the data preparation differs. The previous assessment used a suite of co-caught species to define a broader dataset which included 'zero-catches': i.e. records where one or more of these other species were caught but not *Plectropomus leopardus*. This is an approach to attempt to account for the lack of recording of zero catches in fishery logbooks when fishers could reasonably be expected to catch the species being assessed. However the approach can introduce spurious signals and, because this fishery is highly targeted to common coral trout, it was decided that the dangers of zero-catch modelling probably outweighed the benefits.

A relative index by year and stratum was generated from the year-month-stratum parameter set to be used as input to the population model according to the following procedure. First an aggregation of catch over constant year-month-stratum was defined by:

$$\overline{c}_a = \sum_{\{i|D_\iota[i]=a\}} c_i$$

and then a catch-weighted transform of the year-month-stratum parameter set by:

$$\psi_a = \frac{\overline{c}_a}{\iota_a}$$

Then let $\langle\psi_j\rangle_s$ and $\langle\psi_j\rangle_t$ identify the stratum and year of the $\jmath$th transformed parameter. Giving:

$$\eta_{t,s} = \frac{\sum_{\{a|\langle\psi_a\rangle_s=s,\langle\psi_a\rangle_t=t\}}\overline{c}_a}{\sum_{\{a|\langle\psi_a\rangle_s=s,\langle\psi_a\rangle_t=t\}}\psi_a}$$

The maximum quasi-likelihood parameter estimates were found using the *optimizing()* function in Stan version 2.18.0 (Carpenter et al. 2017).

2.2.4 AIMS UVS Encounter Rates

The underwater visual survey data was standardised assuming the same Poisson quasi-likelihood error structure. As the number of parameters for this analysis was small compared to the catch rate standardisation, the quasi-likelihood was not coded directly and instead the `glm()` function of R (version 3.5.2) was used (R Core Team 2017). In R, the model was given by:

```
glm(Encounter ~ -1 + Strata:Zone:Year, family = quasipoisson(link = 'log')
, offset = log(Effort))
```

where `Encounter` was the total number of *Plectropomus leopardus* sighted over all transects of each reef-site sampling unit (three sites were sampled per reef) in the relevant stratum, zone and year, and `Effort` was the number of transects performed for the sampling unit. The estimated coefficents we denote $\omega_{t,s,z}$ and pass as input to the population model. For details of the sampling design and standard operational procedures see Emslie and Cheal (2018).

2.2.5 Habitat Areas and Ayling Abundance

Habitat area and abundance density estimates were also input to the population model. Table 2 is drawn from Leigh et al. (2014) and mapped onto the twelve spatial strata used in this report.

Table 2 – Abundance and habitat area estimates. Abundance is measured in units of number of fish greater than or equal to 38cm length per hectare. Habitat area estimates are in hectares.

Stratum	Bioregion	Blue	Green	Abundance
Kutini-Payamu	RA1	2893	2582	5.92
Kutini-Payamu	RB1	24913	7160	16.98
Kutini-Payamu	RC1	3065	1195	9.38
Kutini-Payamu	RC2	37062	27375	10.38
Kutini-Payamu	RD	17810	9081	5.95
Kutini-Payamu	RE1	7656	2405	1.03
Kutini-Payamu	RA2 North	7285	11503	8.71
Annan River	RG1	24680	7518	13.52
Annan River	RE2	1161	1358	8.49
Cedar Bay	RA2 South	8699	7318	8.71
Annan River	RF1 North	2656	1819	9.23
Kurrimine Beach	RG2	33041	14261	16.44
Kurrimine Beach	RA3	4241	4141	13.65
Kurrimine Beach	RF1 South	156	137	9.23
RK	RK	18877	4880	30.66
RA4	RA4	6004	2286	15.81
Conway	RHW	41011	14294	18.04
Conway	RHL	35119	9864	16.93
RHE	RHE	7282	2987	16.36
Cape Palmerston	RSW-M	14865	5918	35.55
Cape Palmerston	RSW-N	1974	2152	11.35
RSW-O	RSW-O	3229	2029	21.05
Capricorn Bunker	RCB1	5094	3384	33.30
Capricorn Bunker	RCB2	1014	745	33.30
Kurrimine Beach	RE3	2305	429	0.00
Kurrimine Beach	RF2	205	42	16.44
Kurrimine Beach	RHC North	2121	0	6.04

Stratum	Bioregion	Blue	Green	Abundance
Byfield	RE4	3044	442	3.10
Byfield	RE5	1836	543	4.57
Byfield	RE6	1656	990	4.57
Byfield	RE7	427	110	4.57
Byfield	RE8	1213	215	4.57
Byfield	RHC South	3074	772	6.04

The blue-zone abundance density estimates were multiplied by blue Bioregion area to produce an estimated total blue Bioregion abundance and then summed over the Bioregions in each stratum to produce an estimated blue stratum abundance, ζ_s. This was input to the population model to compare against 1986 model predictions of abundance of fish aged 3+ and above.

The habitat estimates were post 2004, i.e. after the implementation of a rezoning which took the total area of the GBR closed to commercial fishing from around 5 per cent to around 33 per cent. A full history of management changes, including those related to zoning, is given in Table 1 of Leigh et al. (2014). Based on this history, and Table 2 a year-by-year estimate of habitat in the blue and green zones of every stratum was reconstructed, and denoted $G_{t,s,z}$. These areas are given in Section 7.

The 1986 habitat areas were used to calculate ζ_s.

2.2.6 Age Frequencies

From the ELF project ‘observed’ age frequencies were generated by year (1995-2005) and strata (Annan River, Conway and Kurrimine Beach). These were denoted $P_{t,a,s}$ representing the proportion of fish aged a in year t and stratum s. The observations along with the model predictions can be seen in Section 6.2.

2.2.7 Fish Weight and Fecundity at Age

Mid-year weight and fecundity at age were taken from the methodology described in Section 1.5.3 of Leigh et al. (2014). They are denoted w_a and f_a and are illustrated in Figure 3.

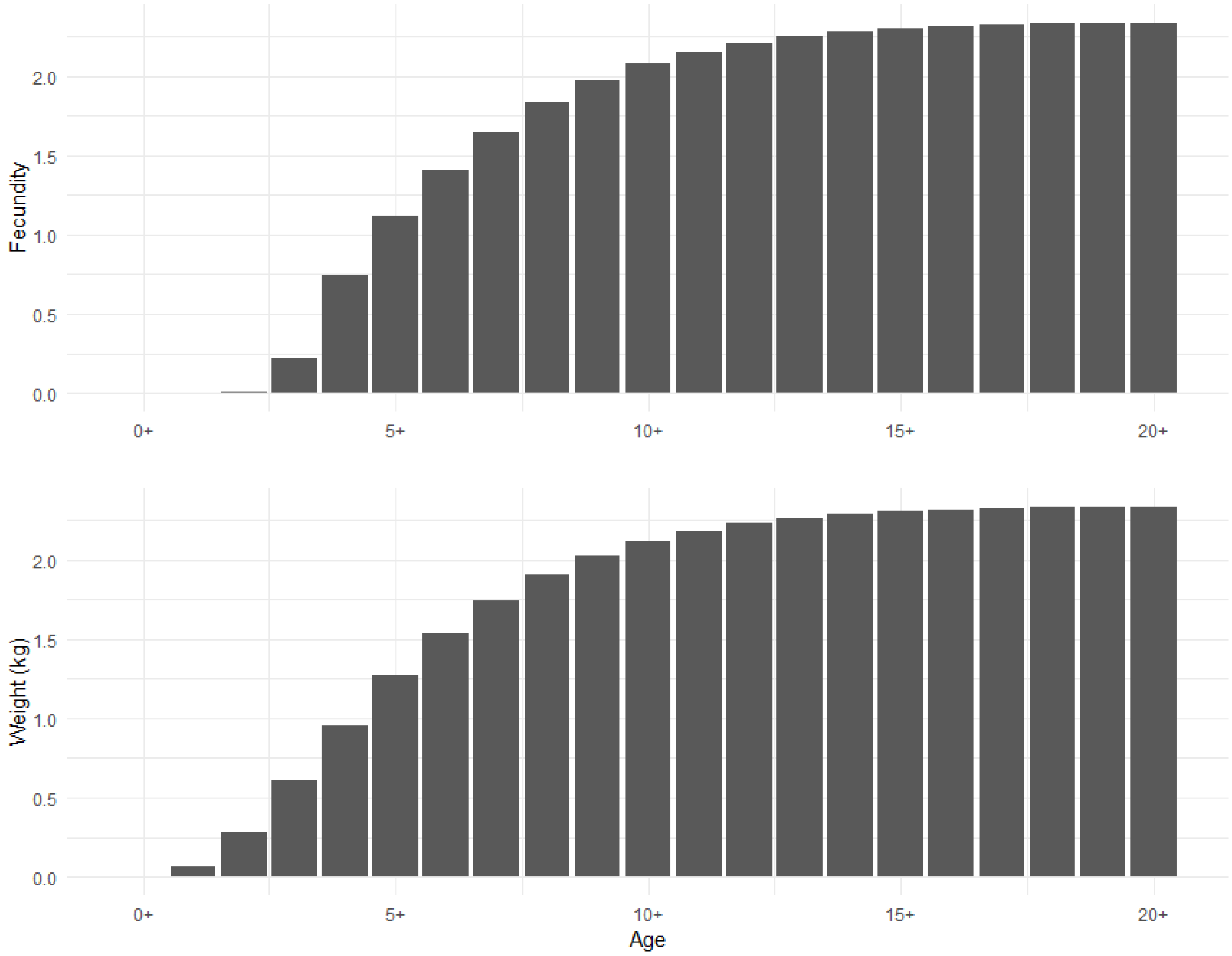

Figure 3 – Mid-year weight (kilograms) and fecundity at age (dimensionless).

2.3 Model

A population dynamic model was fit to the data to determine the number of common coral trout in each year and each age group from the start of fishing in 1951 to the current year (2017–18). Model equations are given in Section 2.3.2. The model was coded in Stan (Carpenter et al. 2017) and used Stan's *optimizing()* function to find the maximum likelihood estimate (Stan version 2.18.0). The negative log likelihood is defined by the equations in Section 2.3.3.

R (R Core Team 2017) was used to prepare data for the model (version 3.5.2), and plot inputs and output.

2.3.1 Model Assumptions

Some of the key assumptions that underpin the model are:

- Fish do not move from the reef on which they settle as juveniles, so they remain in the same stratum and do not move between blue zones and green zones.
- Adult spawners in green zones contribute to recruitment in blue zones.
- Sex ratio is socially controlled so the sexes can be combined, and sex ratio as a function of age does not need to be included.
- Minimum legal size is not modelled explicitly and all fish that are selected by the (model-estimated) selectivity function die.

2.3.2 Population Model Equations

The population model indexes the population matrix by time (t), age (a), strata (s) and zone (z). The zone can be 'blue' (open to fishing, coded $z = 0$) or 'green' (closed to fishing, coded $z = 1$).

Table 3 – Equations used to describe coral trout population dynamics.

Population Dynamics

Logistic selectivity function

$$S_a = -\log(1 + \exp[-\ln(19)(a - A_{50})/(A_{\mathrm{dif}})]) \tag{1}$$

where A_{50} represents the age at 50 per cent selection and A_{dif} represents the additional age between 50 per cent and 95 per cent selection.

Initial age structure

$$N_{0,a,s,z} = \begin{cases} \exp(\chi_s) G_{0,s,z} & \text{for } a = 0 \\ N_{0,a-1,s,z} \exp(-M) & \text{for } a = 1,2,\dots,a_{max} - 1 \\ N_{0,a-1,s,z} \exp(-M)/((1 - \exp(-M)) & \text{for } a = a_{max} \end{cases} \tag{2}$$

where χ_s represents log fish density in 1950 in stratum s and $G_{0,s,z}$ represents the area of zone z in stratum s in 1950.

Vulnerable biomass

$$B^V_{t,s} = \exp(-\frac{1}{2}M) \sum_a (N_{t,a,s,0} + \alpha_{\mathrm{green}} N_{t,a,s,1}) \, S_a \, w_a \tag{3}$$

where α_{green} represents the fraction of fishing in green zones and w_a denotes mid-year weight at age.

Harvest rate

$$H_{t,s} = C_{t,s}/B^V_{t,s} \tag{5}$$

Spawning biomass

$$B^{Sp}_t = \sum_z f_a \, N_{t,1,a} \qquad \text{for } t > 0 \tag{6}$$

where f_a denotes fecundity at age.

Beverton-Holt recruitment

$$R_{t,s,z} = G_{t,s,z} \exp(\chi_s) \frac{r_{\mathrm{comp}} (B^{Sp}_t / B^{Sp}_0)}{1 + (r_{\mathrm{comp}} - 1)(B^{Sp}_t / B^{Sp}_0)} \tag{7}$$

where r_{comp} is the recruitment compensation ratio (Beverton and Holt 1957; Goodyear 1977).

Age structure

$$N_{t,a,s,z} = \begin{cases} R_{t,s,z} & \text{for } a = 0, t > 0 \\ \dfrac{G_{t,s,z}}{G_{t-1,s,z}} \exp(-M)(1 - H_{t-1,s} \, S_a) N_{t-1,a-1,s,z} & \text{for } a = 1,2,\dots,a_{max} - 1, \ t > 0 \\ \dfrac{G_{t,s,z}}{G_{t-1,s,z}} N_{t-1,a-1,s,z} \exp(-M)(1 - H_{t-1,s} \, S_a) & \\ \qquad + \dfrac{G_{t,s,z}}{G_{t-1,s,z}} N_{t-1,a,s,z} \exp(-M)(1 - H_{t-1,s} \, S_a) & \text{for } a = a_{max}, t > 0 \end{cases} \tag{8}$$

Predicted mid-year vulnerable biomass

$$B^{V_{mid}}_{t,s} = \frac{e^{-M/2} \sqrt{1 - H_{t,s}} \sum_a \big(S_a w_a (N_{t,a,s,0} + \alpha_{\mathrm{green}} N_{t,a,s,1})\big)}{G_{t,s,0} + \alpha_{\mathrm{green}} G_{t,s,1}} \tag{9}$$

This equation is used to match catch rates in the negative log likelihood (equation 13).

Predicted number density

$$N_{t,s,z}^{dens} = \frac{1}{G_{t,s,z}} \sum_{a=1}^{a_{\max}} N_{t,a,s,z} \tag{10}$$

This equation is used to match encounter rates in the negative log likelihood (equation 14).

Predicted numbers for Ayling comparison

$$N_{t,s}^{\mathrm{Ayl}} = \sum_{a=4}^{a_{\max}} N_{t,a,s,0} \tag{11}$$

This equation is used to match abundance in the negative log likelihood (equation 15).

Predicted sample numbers at age

$$\hat{P}_{t,a,s} = \frac{S_a N_{t,a,s,0}}{\sum_a S_a \, N_{t,a,s,0}} \tag{12}$$

This equation is used to match age frequency data in the negative log likelihood (equation 16).

2.3.3 Matching Predictions to Data

Table 4 – Negative log-likelihood equations used for model fitting

Negative log-likelihood functions

Standardised commercial catch rates

$$\ell^{CR} = y^{CR} \times \ln(\hat{\sigma}^{CR}) + \frac{y^{CR}\sqrt{A_1/y^{CR}}}{2\,\hat{\sigma}^{CR}} \tag{13}$$

where y^{CR} is the number of years and strata in the catch rate series -1.

$$\hat{\sigma}^{CR} = \frac{1}{2}\left(\sqrt{A_1/y^{CR}} + 1\right) + \sqrt{\frac{1}{4}\left(\sqrt{A_1/y^{CR}} - 1\right)^2 + \phi}$$

where $\phi = 0.01$ is a smoothing constant.

$A_1 = \sum_{t,s}\left(\left(\ln\left(c_{t,s}/B_{t,s}^{V_{mid}}\right) - A_2\right)/\sigma_t^{CR}\right)^2,$

where $\eta_{t,s}$ is the input catch rate for each year and stratum (Section 2.2.3). $\sigma_{t,s}^{CR}$ is the standard error for $\eta_{t,s}$ from the catch-rate analysis.

$A_2 = \sum_{t,s}\left(\ln\left(\eta_{t,s}/B_{t,s}^{V_{mid}}\right)/(\sigma_{t,s}^{CR})^2\right) / \sum_t\left(1/(\sigma_{t,s}^{CR})^2\right).$

Standardised AIMS UVS encounter rates

$$\ell^{UVS} = y^{UVS} \times \ln(\hat{\sigma}^{UVS}) + \frac{y^{UVS}\sqrt{A_1/y^{UVS}}}{2\,\hat{\sigma}^{UVS}} \tag{14}$$

where y^{UVS} is the number of years and strata in the encounter rate series -1.

$$\hat{\sigma}^{UVS} = \frac{1}{2}\left(\sqrt{A_1/y^{UVS}} + 1\right) + \sqrt{\frac{1}{4}\left(\sqrt{A_1/y^{UVS}} - 1\right)^2 + \phi}$$

$A_1 = \sum_{t,s,z}\left(\left(\ln\left(\omega_{t,s,z}/N_{t,s,z}^{dens}\right) - A_2\right)/\sigma_t^{UVS}\right)^2,$

where $\omega_{t,s,z}$ represents the input AIMS UVS encounter rate for each year, stratum and zone. $\sigma_{t,s,z}^{UVS}$ is the standard error for $\omega_{t,s,z}$ from the encounter-rate analysis.

$A_2 = \sum_{t,s,z}\left(\ln\left(\omega_{t,s,z}/N_{t,s,z}^{dens}\right)/(\sigma_{t,s,z}^{UVS})^2\right) / \sum_t\left(1/(\sigma_{t,s,z}^{UVS})^2\right).$

Matching to Ayling abundance data

$$\ell^{Ayl} = y^{Ayl} \times \ln(\hat{\sigma}^{Ayl}) + \frac{y^{Ayl}\sqrt{A_1/y^{Ayl}}}{2\,\hat{\sigma}^{Ayl}} \tag{15}$$

where y^{Ayl} is the number of strata in the series -2 (it would normally be -1 but the Byfield stratum was removed).

$$\hat{\sigma}^{Ayl} = \frac{1}{2}\left(\sqrt{A_1/y^{Ayl}} + 1\right) + \sqrt{\frac{1}{4}\left(\sqrt{A_1/y^{Ayl}} - 1\right)^2 + \phi}$$

where $\phi = 0.01$ is a smoothing constant.

$A_1 = \sum_s \left(\left(\ln\left(\zeta_s/N_{38,s}^{\mathrm{Ayl}}\right) - A_2\right)/\sigma_t^{Ayl}\right)^2$,

where ζ_s represents the observed abundance in each stratum. σ_s^{Ayl} is the standard error for ζ_s.

$A_2 = \sum_s\left(\ln\left(\zeta_s/N_{38,s}^{\mathrm{Ayl}}\right)/(\sigma_s^{Ayl})^2\right) / \sum_t\left(1/(\sigma_s^{Ayl})^2\right)$.

Age structures

$$\ell^{(AF)} = -\sum_{t,s} T_{t,s} \ln Q_{t,s} \tag{16}$$

where $T_{t,s} = \frac{1}{2}\left[\left(\sum_a \mathcal{H}\,(P_{t,a,s})\right) - 1\right]$

where $\mathcal{H}()$ is the Heaviside step function

and where $Q_{t,s} = T_{t,s}\left[\sum_a \left(\mathcal{H}(P_{t,a,s})P_{t,a,s}\ln\left(\frac{P_{t,a,s}}{\hat{P}_{t,a,s}}\right)\right)\right]^{-1}$

where $P_{t,a,s}$ represents the observed input proportions at age indexed by year and stratum.

Crash penalty

$$\ell^{Pen} = \begin{cases} \sum_{t,s}(\,0.0001(C_{t,s} - B_{t,s}^V))^2 & \text{if } C_{t,s} >= B_{t,s}^V \\ 0 & \text{else} \end{cases} \tag{17}$$

2.3.4 Estimated Parameters

Table 5 lists the parameters estimated by the model.

Table 5 – Estimated parameters.

Symbol	Units	Interpretation
M	Years^{-1}	Natural mortality
$\exp(\chi_s)$	Numbers $\mathrm{Hectare}^{-1}$	Initial recruitment density
A_{50}	Years	Age at 50 per cent selectivity
A_{dif}	Years	Age difference 50-95 per cent selectivity

2.3.5 Sensitivity Analyses

There was insufficient information in the data to estimate the recruitment compensation ratio (r_{comp}) in addition to the other parameters. The recruitment compensation ratio is a key parameter in stock assessment which governs the "productivity" of the stock. Specifically it refers to the relative increase in juvenile survival when the population has been reduced almost to zero. Stocks with a higher compensation ratio are more robust and can support higher fishing pressure. A number of runs of the model of Leigh et al. (2014) with data updated through to calendar year 2018 estimated r_{comp} at around 4, so this value was chosen for the base case (also referred to as the "preferred" or "recommended" case). Sensitivity to this important parameter was explored with two values that were considered to be at the lower and upper plausible limits: 2.0 and 10.0.

Another unknown factor was the extent of fishing in green zones (α_{green}). As discussed above, this is the fraction of the total (i.e. all sectors) fishing mortality calculated for the blue (open to fishing) component of the stratum that is applied to the green component. This was fixed in the previous assessment at 20%. For this assessment values of 10% and 30% were also considered.

3. Results

3.1 Reconstructed harvest

Figure 4 shows low commercial harvest initially, with a sharp increase in the 1980s. Harvest remained high from 1990 to mid-2004 with a peak of 2185t in 2002. Following the Representative Area Program rezoning and the setting of a TACC in July 2004, reported harvest dropped to around 800t. A further decline in harvest occurred between 2009 and 2012 during which the weather events Cyclone Hamish (2009) and Cyclone Yasi (2011) occurred. The largest harvests occurred in the strata of Conway and Kurrimine Beach.

Recreational harvest (Figure 5), shows an increase from 1950 to 1970. With the exception of 1977 and 1978 harvest remained above 600t per year from 1969 to 1989 with a peak of 780t in 1980. Harvest dropped to around 400t during the 1990s. A further decline in harvest occurred between 2002 and 2011 resulting in reported harvests under 200t. The largest harvests occurred in the strata of Byfield, Kurrimine Beach and Capricorn Bunker.

Total harvest (Figure 6) steadily increase to peak at 2570t in 2002 with a fall to around 1300t following the introduction of additional green zones and the setting of a TACC in mid-2004. Following this, harvest declined again and leveled off at around 1000t from 2010 onwards.

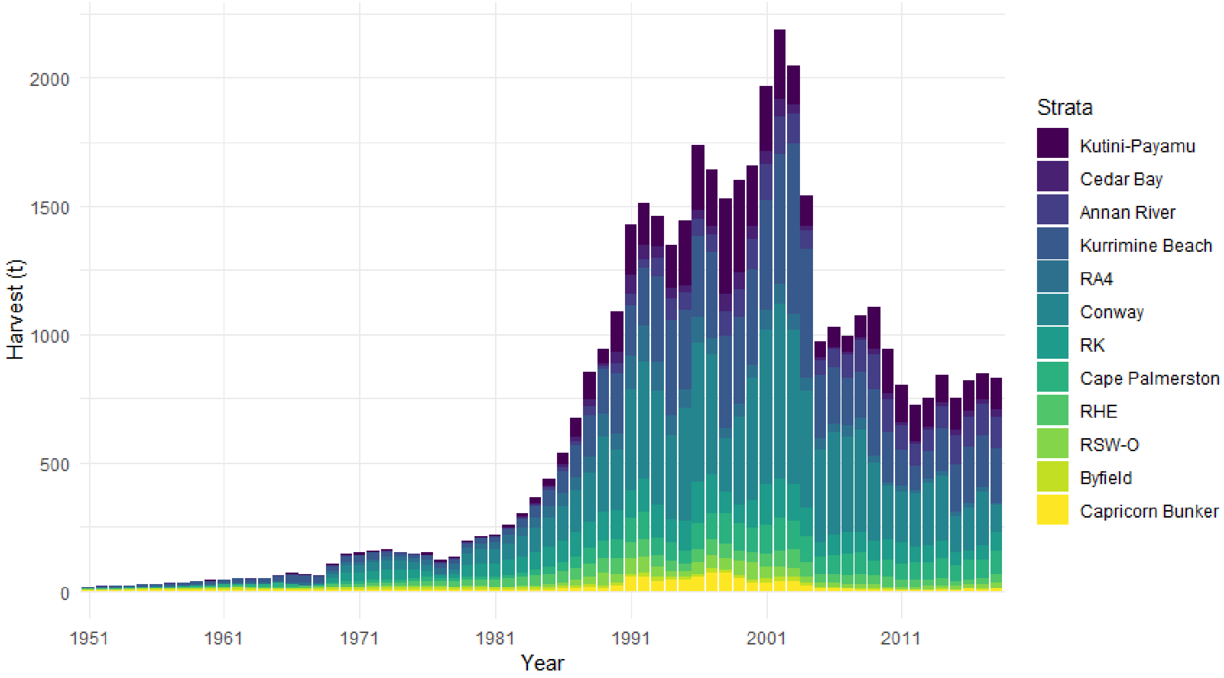

Figure 4 – Reconstructed harvest from the commercial sector between 1951 and 2018 for each of the 12 strata included in the model

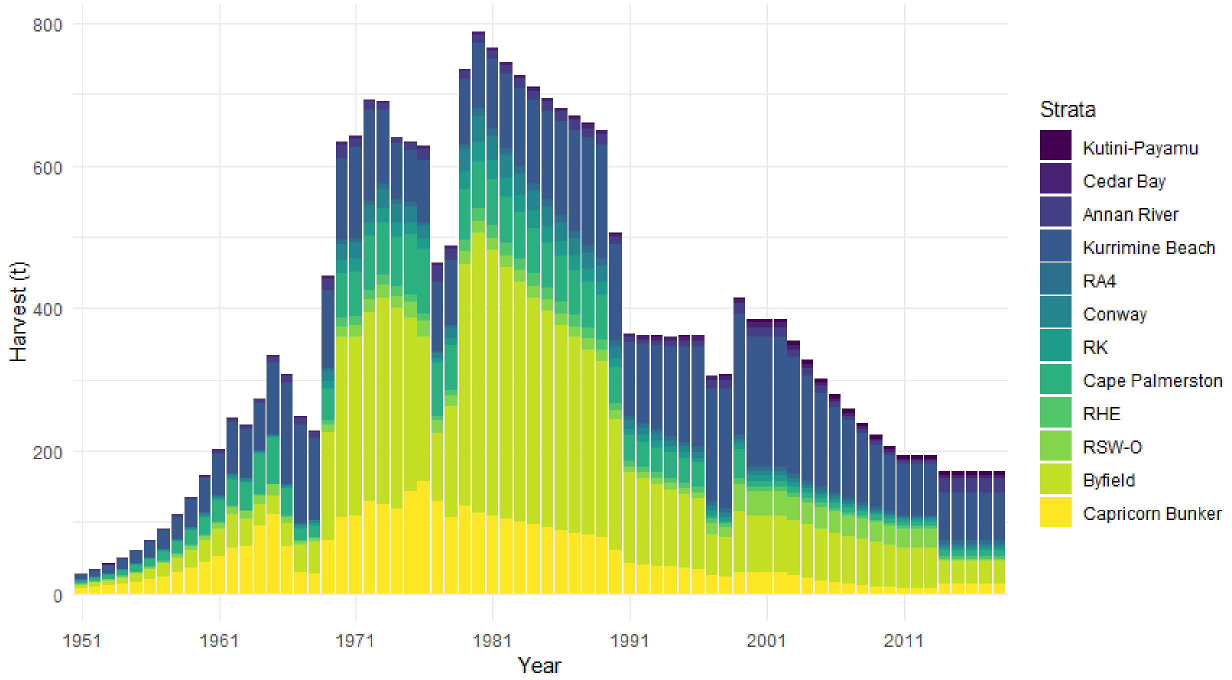

Figure 5 – Reconstructed harvest from the recreational sector between 1951 and 2018 for each of the 12 strata included in the model

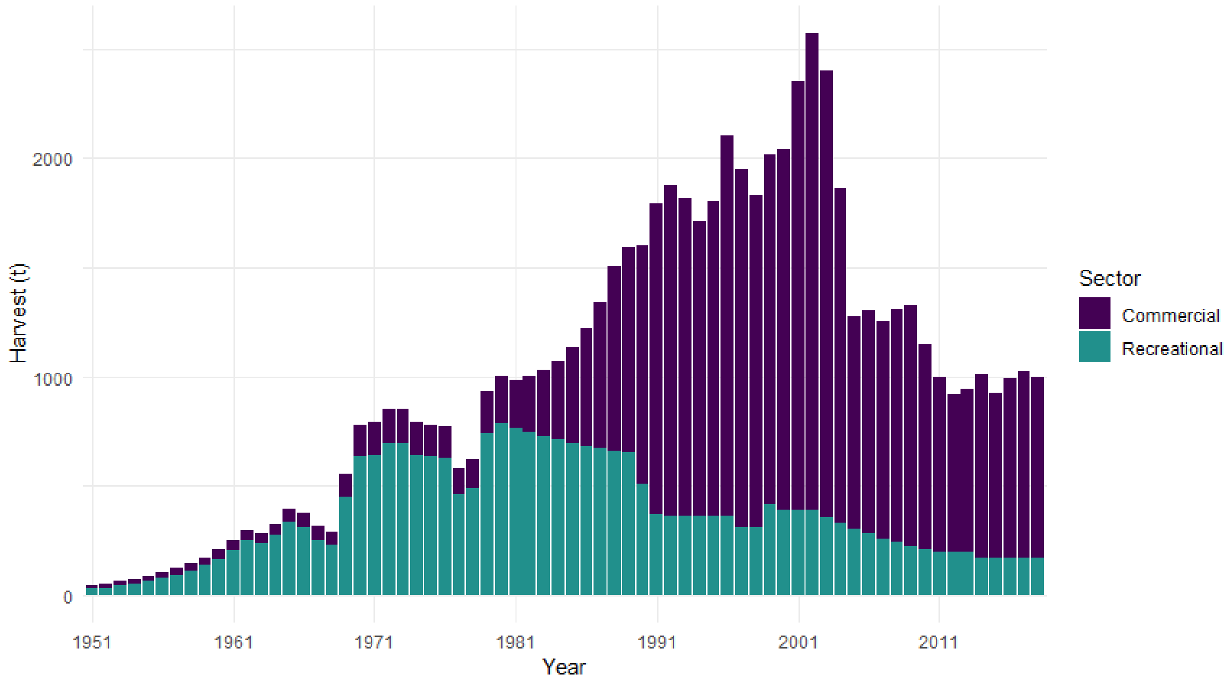

Figure 6 – Reconstructed harvest from the commercial and recreational sectors between 1951 and 2018 for each of the 12 strata included in the model

3.2 Standardised catch rates

Standardised catch rates for common coral trout were calculated separately for each stratum from commercial catches along with underwater visual surveys from both areas open and closed to fishing (see Figures 7 and 8). These catch rates were normalised such that the last year of each catch rate series is equal to 1.

Underwater visual survey (UVS) information was not available for the Kutini-Payamu stratum. In Cedar Bay the standardisation model failed to produce a sensible output, probably due to the preponderance of zero-sightings. Commercial catch rates for these strata show a slight decrease from the mid-1990s to 2011 followed by an increase. Annan River and Kurrimine Beach commercial catch rates show the same trend whereas UVS catch rates for these strata show a slight increase (Figure 7).

Commercial catch rates for RA4 show a decline to around 2011 and then a slight increase. UVS catch rates for this stratum showed an overall increase with peaks at around 2004 and 2013. Conway, RK and Cape Palmerston showed an overall decline in commercial catch rate and relatively steady UVS catch rates (Figure 7).

RHE and RSW-O strata commercial catch rates trended slightly downwards until the early-2010s where a slight increase was observed (Figure 8). For the RHE stratum, the UVS catch rates fluctuated, with UVS open showing an overall upward trend and UVS closed trending down until the late-2000s and then rising again (Figure 8). The RSW-O UVS open catch rate displayed a relatively steady state until rising from around 2010 onwards (Figure 8). The UVS closed catch rate for RSW-O fell to a trough in 2010, rose to a peak in 2016 and then fell again (Figure 8).

Commercial catch rates for Byfield and Capricorn Bunker were relatively steady, although Byfield displayed a slight initial decline and a strong peak in 2017 (Figure 8). For Byfield, the UVS closed catch rate had an initial slight decline to 2001 and then increased plateauing from 2007 onwards (Figure 8). The UVS open catch rate for Byfield showed large fluctuations with an overall decline (Figure 8). A sharp trough was noted in 2005 which preceded a sharp peak in 2006 (Figure 8). Capricorn Bunker UVS catch rates rose until the late-2000s (with a sharp peak for UVS closed in 2007) these catch rates then fell until 2011 after which they displayed a slight increase (Figure 8).

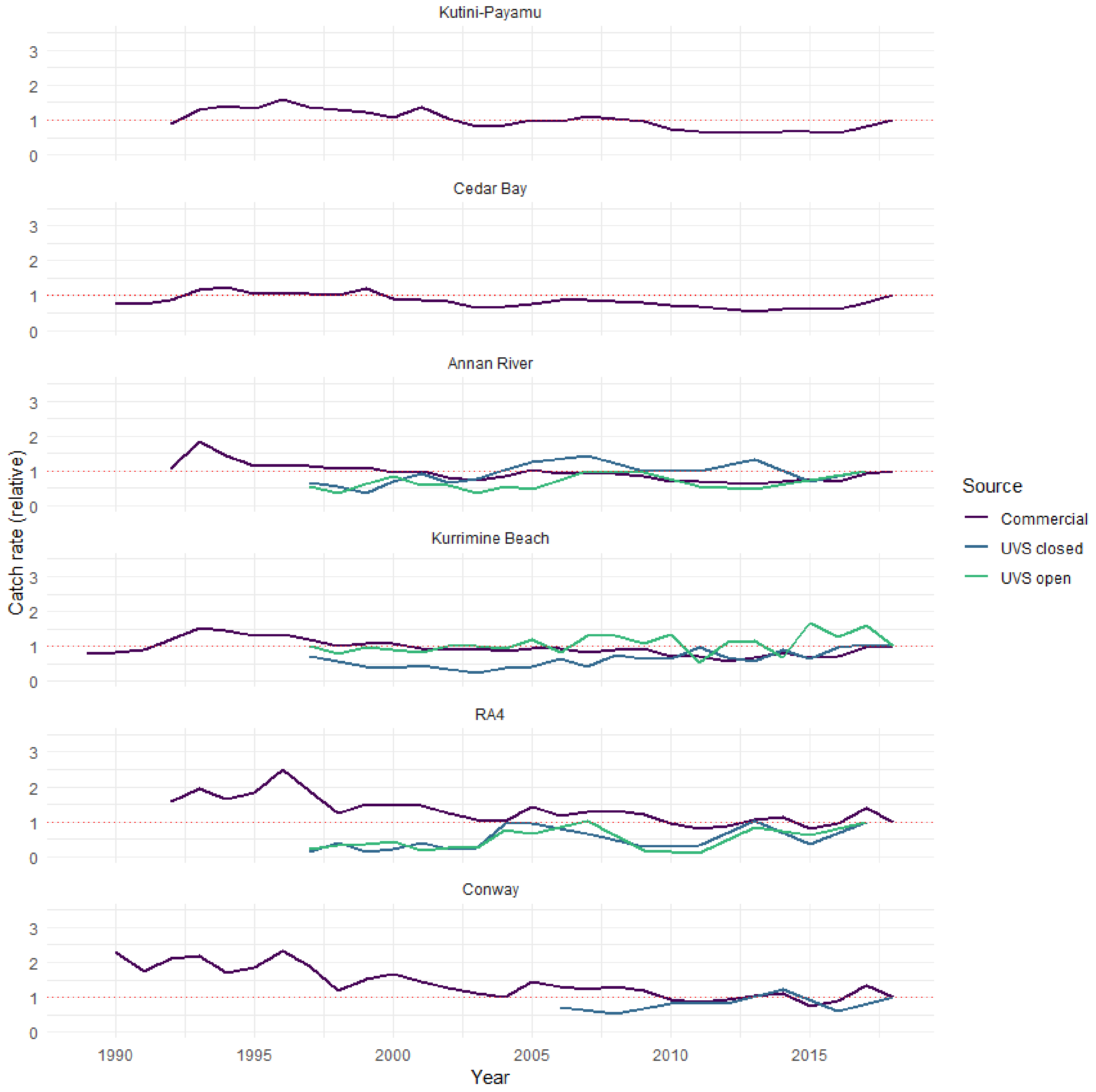

Figure 7 – Catch rates for coral trout from commercial catches along with underwater visual surveys from both areas open and closed to fishing. These catch rates have been normalised such that the last year of each series is equal to 1. Plots illustrate the six northernmost strata, between 1988 and 2018.

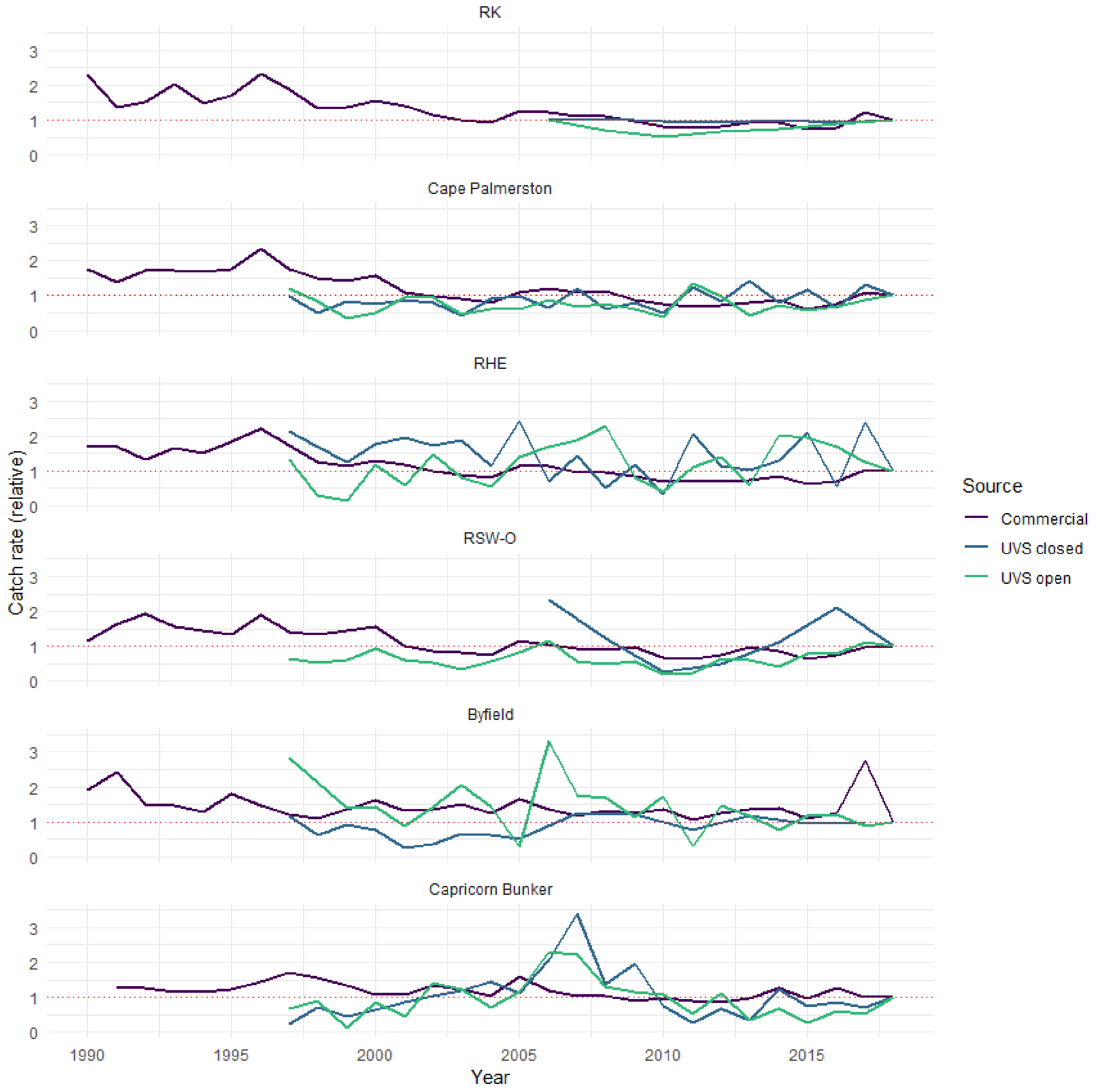

Figure 8 – Catch rates for coral trout from commercial catches along with underwater visual surveys from both areas open and closed to fishing. These catch rates have been normalised such that the last year of each series is equal to 1. Plots illustracte the six southernmost strata, between 1988 and 2018.

3.3 Population dynamics model

3.3.1 Parameter estimates

Parameters estimated by the population model are shown in Table 6. Five model scenarios are displayed each using a different combination of fixed values for recruitment compensation (r_{comp}) and assumed fishing in green zones (α_{green}). Values obtained for natural mortality (M) range between 0.18 and 0.25. These values obtained were sensitive to the fixed r_{comp} value used in each model.

On the natural (non-logarithmic) scale, the estimated density of zero-plus fish in 1950 ranged from 14.4 recruits per hectare (Kutini-Payamu stratum) to 73.0 recruits per hectare (Byfield stratum).

Results show that a fish at age ≈ 2.3 years is 50 per cent likely to be vulnerable to fishing and 95 per cent likely at 3.2 years.

Table 6 – Parameter estimates from each of the model scenarios investigated. Each model uses a different combination of fixed values for recruitment compensation (r_{comp}) and assumed fishing in green zones (α_{green}). M is measured in $year^{-1}$, χ is measured in log numbers per hectare and Age parameters are measured in years.

Parameter	r_{comp} = 2, α_{green} = 0.2	r_{comp} = 4, α_{green} = 0.2	r_{comp} = 10, α_{green} = 0.2	r_{comp} = 4, α_{green} = 0.1	r_{comp} = 4, α_{green} = 0.3
M	0.18	0.22	0.25	0.22	0.23
$\chi_{\mathrm{Annan\ River}}$	2.85	2.98	3.38	3.07	2.88
χ_{Byfield}	4.29	4.35	4.42	4.35	4.36
$\chi_{\mathrm{Cape\ Palmerston}}$	3.32	3.38	3.70	3.45	3.31
$\chi_{\mathrm{Capricorn\ Bunker}}$	3.90	3.90	3.90	3.90	3.90
$\chi_{\mathrm{Cedar\ Bay}}$	2.78	2.91	3.30	2.99	2.82
χ_{Conway}	3.20	3.29	3.67	3.38	3.20
$\chi_{\mathrm{Kurrimine\ Beach}}$	3.49	3.58	3.79	3.61	3.55
$\chi_{\mathrm{Kutini-Payamu}}$	2.67	2.82	3.20	2.93	2.68
χ_{RA4}	3.71	3.78	3.97	3.81	3.76
χ_{RHE}	3.42	3.49	3.80	3.55	3.43
χ_{RK}	3.35	3.43	3.77	3.50	3.36
$\chi_{\mathrm{RSW-O}}$	3.84	3.91	4.02	3.94	3.90
A_{50}	2.22	2.34	2.39	2.32	2.37
A_{dif}	0.85	0.91	0.93	0.89	0.93

3.3.2 Biomass

Biomass relative to 1950 is shown in Figures 9 and 10.

Figure 9 shows relative biomass falling to a minimum in 2004 at just over 50 per cent and then increase to a level of around 68 per cent in 2018 for the preferred model ($r_{\text{comp}} = 4$). With r_{comp} equal to 2 and 10 the relative biomass returns to 54 per cent and 85 per cent in 2018 respectively. A 20 per cent level of fishing in green zones is assumed in this figure.

A fixed level of $r_{\text{comp}} = 4$ is then used for the models shown in Figure 10. These models explore different levels of fishing in the zones that are closed to fishing. Green zone fishing levels (α_{green}) of 10 per cent, 20 per cent and 30 per cent have been displayed (see the Methods section for a more precise definition of this variable). The same overall trend is shown as in Figure 9, however the sensitivity to α_{green} is smaller than r_{comp} with a range of 62 per cent - 73 per cent relative biomass in 2018 when α_{green} is adjusted.

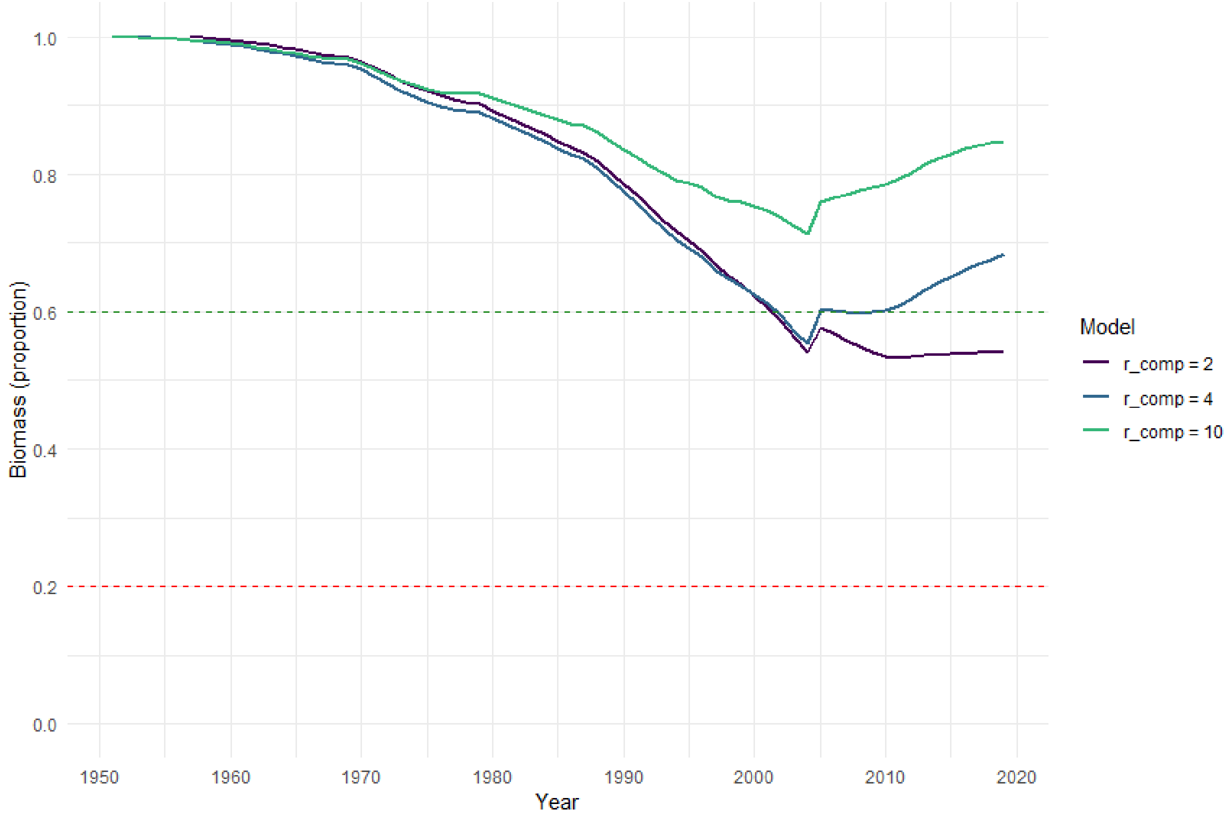

Figure 9 – Predicted biomass trajectory relative to virgin biomass for each model with different fixed recruitment compensation (r_comp) values and an assumed level of 20 per cent fishing in green zones closed to fishing.

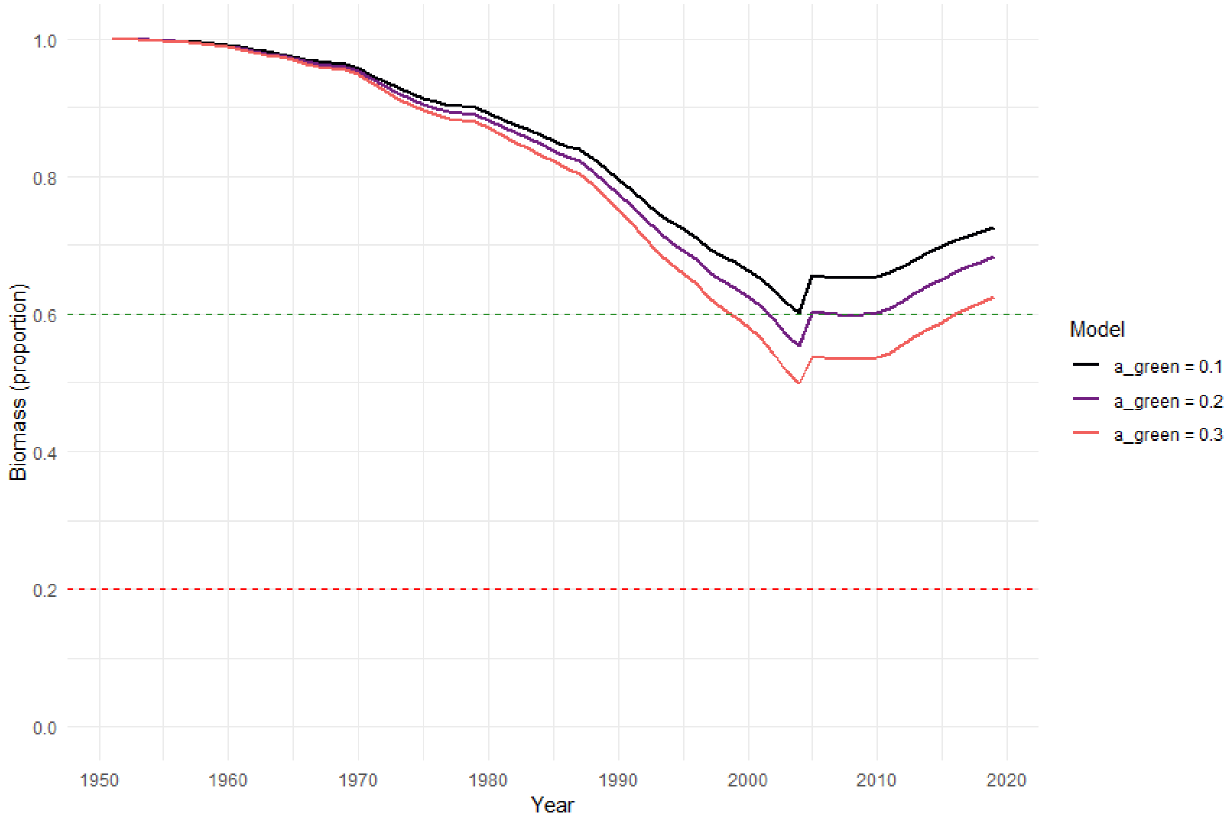

Figure 10 – Predicted biomass trajectory relative to virgin biomass for each model with a fixed recruitment compensation (r_comp) value of 4 and three levels of assumed fishing in green zones closed to fishing (a_green).

3.3.3 Yield predictions

Harvest yields were calculated for MSY and an equilibrium biomass ratio of 68 per cent (see Figure 11). To aid in the readability of equilibrium yields, Table 7 details the actual values.

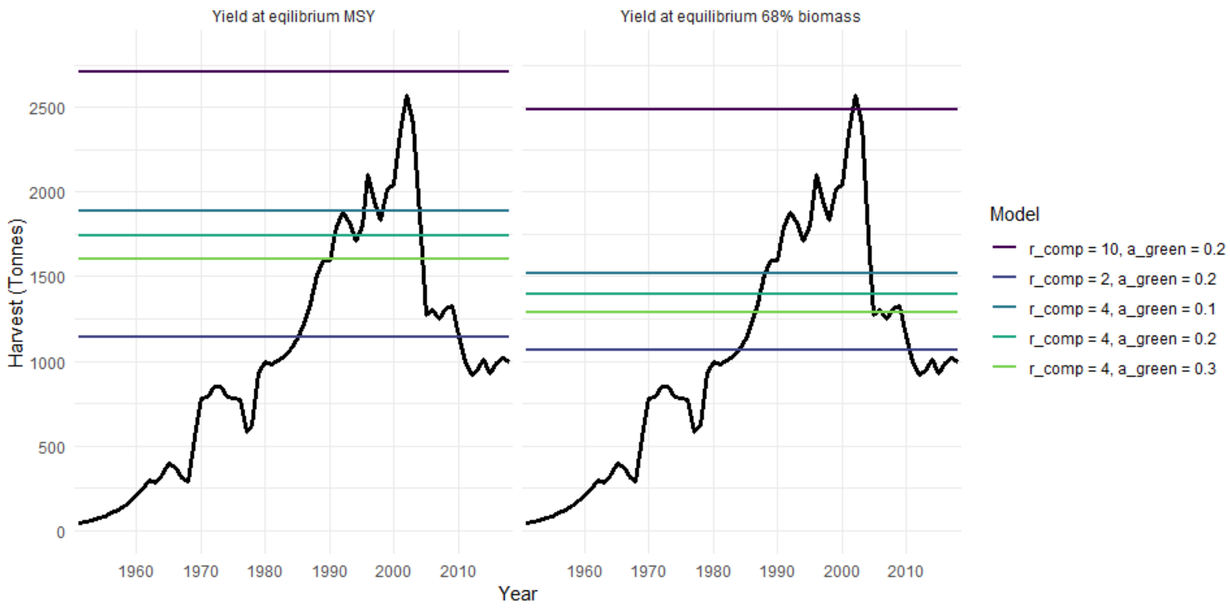

Figure 11 – Annual harvest (t) of coral trout with harvest yield predictions estimated from each of the five models with different recruitment compensation ratio (r_comp) and green zone fishing level (a_green) estimates.

Table 7 Predictions of equilibrium yields for MSY and 68 per cent biomass for each model.

Model	Yield at MSY (t)	Yield at 68 per cent biomass (t)
$r_{\text{comp}} = 2, \alpha_{\text{green}} = 0.2$	1145	1066
$r_{\text{comp}} = 4, \alpha_{\text{green}} = 0.2$	1740	1398
$r_{\text{comp}} = 10, \alpha_{\text{green}} = 0.2$	2711	2489
$r_{\text{comp}} = 4, \alpha_{\text{green}} = 0.1$	1887	1515
$r_{\text{comp}} = 4, \alpha_{\text{green}} = 0.3$	1601	1286

3.3.4 Model fits

Model fits to the Ayling abundance estimates, age-frequency data and most of the catch/encounter rates can be found in section 6 Appendix A. The exception is the fit to standardised commercial catch rates for the base case scenario and the green zone fishing sensitivity scenarios which is presented in this section.

Fits to the observed Ayling abundance data show the same overall trend however model predictions were higher (Figure 13). The Byfield stratum was not included in the model fitting, but the abundance estimate and model prediction are shown here for reference (Figure 13). Preliminary model runs indicated much poorer fit in Byfield than the other strata, and the attempt to fit this region was problematic for estimating other parameters (Figure 13).

Model fits to age structures show a good general fit (Figure 14 to 19).

The fitting of the model to catch rates for each stratum was not always successful, in particular the Byfield stratum (Figure 20 to 24).

Figure 12 presents model fits to catch rates for each stratum for models with differing r_{comp} levels and green zone fishing at 20%. Byfield and Capricorn Bunker strata do not fit well. The other 10 strata show a better fit with overall model trends showing similar trends to each stratum's catch rate (Figure 12).

Both the Ayling data and the standardised catch rates indicate a fundamental disagreement with model predictions in the Byfield stratum. This is expanded upon in the discussion.

The AIMS UVS time series are quite noisy at this spatial scale (large inter-annual fluctuations). The model fits reasonably to the average trend in most strata, but some fits are poor.

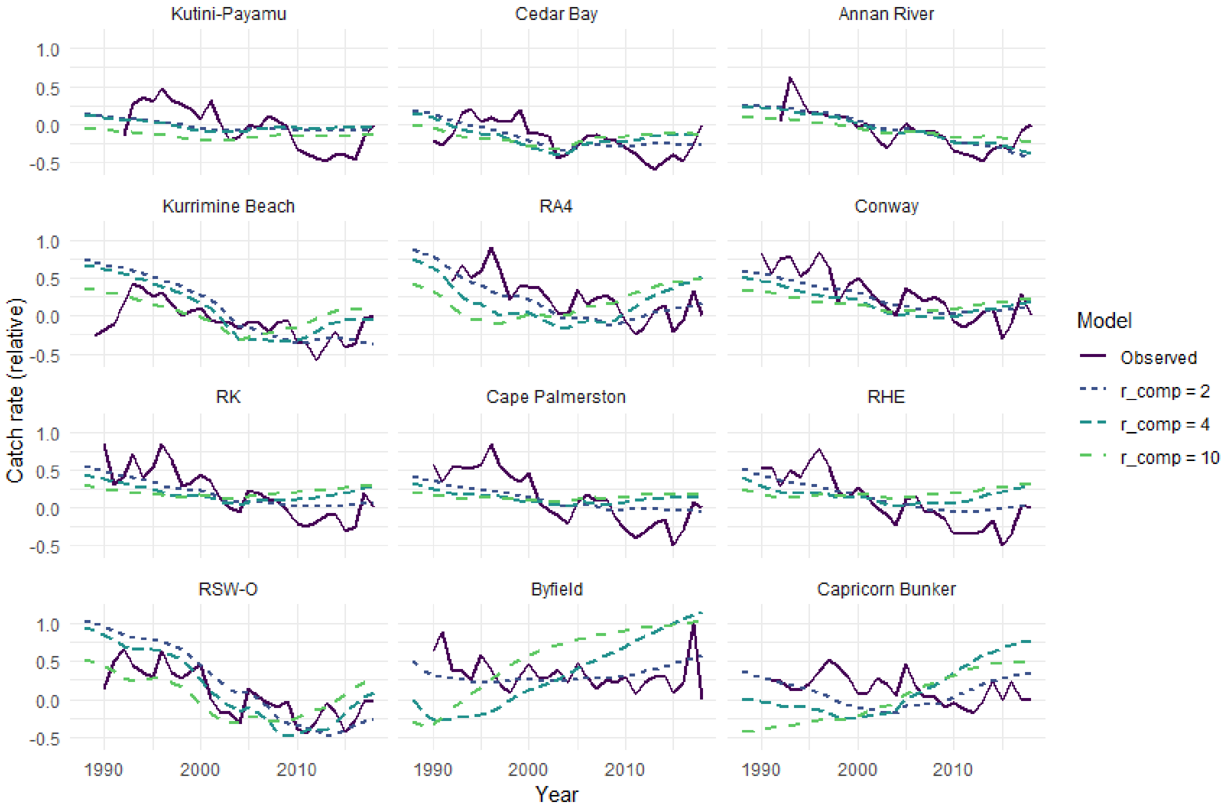

Figure 12 – Stock model fitted values to the standardised commercial catch rates (observed) for each of the model scenarios with different recruitment compensation (r_comp) values for each of the 12 strata.

4. Discussion

4.1 Assumptions and limitations

As with any stock assessment, there are a number of assumptions and limitations. Here we expand on the major ones and discuss their implications.

4.1.1 Data source conflict

The Byfield stratum, an inshore region not included in the previous assessment (Leigh et al. 2014), highlighted inconsistencies in the input data. As noted in Section 3, the Ayling abundance data suggested relatively low coral trout density in this region, whereas the model required a high density in order to support the quantity of harvest estimated to have been extracted from this area based on the data sets involved in the harvest reconstruction. While there are many perspectives on the relative weight to place on each of these data inputs, there is little evidence and no obvious resolution. One possibility is that because the Byfield stratum consists of a large number of small reefs, the inter-reef abundance variability may be high and the Ayling survey may have missed high density reefs. Because of this possibility, combined with the model estimation problems caused by an attempt to fit to this data set in this stratum, a decision was made to remove Ayling data in this stratum from the fitting process. This amounts to a preference for the harvest reconstruction data (in particular the Queensland Fish Board, Tor Hundloe and ABS data sets) over the Ayling data. However, this preference is not strongly justified, and the catch rate fits also indicate a discrepancy with the reconstruction data. Harvests in this stratum for both commercial and recreational sectors have been much lower following the early 1990s, when data recording has improved. Model outputs should be considered in light of this conflict and investigating this issue should be high on the list of priorities for the next assessment.

4.1.2 Unmodelled environmental influences

Since 2014, there have been two mass coral bleaching events, one tropical cyclone that severely impacted the GBR, and two crown of thorns outbreaks on the GBR (AIMS 2018). These have reduced coral cover, which in turn reduces habitat and prey availability for coral trout (Tobin et al. 2010; Pratchett et al. 2014; Rogers et al. 2017). Loss of coral reef habitat extent and complexity have been found to result in reductions in fisheries productivity of approximately 35% (Rogers et al. 2017). Bleaching events can also influence coral trout growth rates and spawning output (Hughes 2010; Johnson and Welch 2010; Pratchett et al. 2014).

It is anticipated that increases in sea surface temperature (SST) will affect recruitment, by impacting the timing and duration of spawning events, along with increasing larval growth rates (Welch et al. 2010). In a review of the potential environmental variables impacting common coral trout, SST and nutrient changes were ranked as high risks to common coral trout, while upwelling and wind/current changes were ranked as medium risks (Welch et al. 2010). More specifically SST over 28°C negatively impacts development of early life stages (Pratchett et al. 2014). While common coral trout in southern areas may be able to spawn at different times when water is cooler, this will be more difficult in northern regions.

Tropical cyclones may also affect the catchability of the fish. Catch rate declines are correlated with anomalous wave heights resulting from cyclone activity (Callaghan 2011, 2014; Leigh et al. 2014; Courtney et al. 2015). These declines are most likely not associated with declines in stock size, as UVS data do not show the same pattern and catch rates come back strongly one or two years after the cyclone. Currently, information is lacking on the cause of this although there are various theories.

One theory is that common coral trout seek refuge in deeper water while coral cover is reduced in shallower areas due to cyclone damage to branching corals, reducing habitat availability. These fish then return to the reef once corals have begun to grow back and habitat availability is restored. Another hypothesis is that the broken branching coral reduces habitat complexity and refuge for common coral trout prey species. Common coral trout can then more easily prey on these species and are less inclined to feed on the bait provided by fishers, therefore reducing catch rates.

None of these environmental factors have been explicitly modelled in this assessment as the mechanisms that connect them to common coral trout abundance are not well understood and require further investigation. This is a major limitation if these variables are changing systematically over time. In addition to the aforementioned impacts of rising SST, there is evidence to suggest that climate change will cause cyclones to increase in intensity (Walsh et al. 2016) and bleaching events will become more extensive and more severe (Hughes et al. 2017). Associated declines in coral cover may reduce the carrying capacity of the GBR for coral trout and threaten the sustainability of the fishery.

4.1.3 Parameter estimation uncertainty not quantified

It was not possible to obtain meaningful estimates of parameter uncertainty in the time allocated. Monte-carlo Markov Chain simulations were run using the Stan software package (Carpenter et al. 2017), however despite many hours of computation the key convergence statistic (a multi-chain analysis of variance known as “R-hat”) was not satisfied. It is likely that this is related to the difficulty of fitting a large number (twelve) of initial recruitment density parameters, and the way this interacted with the requirement that the predicted biomass be able to support the observed harvest in every strata (enforced through the penalty function). Regardless of the cause, it is a limitation of the current assessment and the results should be interpreted accordingly.

4.1.4 Unmodelled biological phenomenon

There is a biological phenomenon which may prove important both in understanding the aforementioned mechanisms, and in better understanding the relationship between catch rates and coral trout abundance. This is the concept of ‘social learning’ (Brown and Laland 2011). When a population of coral trout is fished individuals may quickly learn to not take bait, causing the catch rate to fall even when the population size has barely changed. Anecdotal evidence for this behaviour is strong. Social learning may take place by fish directly observing their fellows being hooked, or perhaps heeding a chemo-sensory cue emitted by fish that are hooked. Further detail is available in (Leigh et al. 2014). With this behaviour not modelled, catch rates may be misleading as indicators of abundance, particularly when new fishing grounds are being explored. This may have introduced a bias to the results, but the directionality is unknown (the phenomenon is spatio-temporally complex).

4.2 Recommendations

4.2.1 Data and Monitoring

- Improved mechanisms implemented to report daily common coral trout harvests (as opposed to simply the coral-trout species-group), precise fishing location, and fishing effort per operation (important for standardised catch rates).
- Restart monitoring of fish age structure of common coral trout. See (Northrop et al. 2018) for analysis and practical suggestions regarding how this could be done.
- Improved data sources to estimate coral-trout habitat area. Possibly computer vision applied to satellite imagery.
- We concur with (Northrop et al. 2018) that a one-off large-scale UVS similar to (Ayling and Ayling 1986) should be conducted.
- AIMS underwater visual census surveys continue, return to their original annual frequency, and expanded in the Byfield stratum.
- Expansion of the Boat Ramp survey of recreational fishers in line with the recommendations of (Northrop et al. 2018).

4.2.2 Modelling and Research

- Conduct sensitivity analyses to resolve the conflict between the Ayling UVS and the harvest reconstruction history in the Byfield region.
- Rewrite the harvest reconstruction code to make sensitivity analysis of this component easier.
- Estimate the compensation ratio, or failing that, consider an informative prior.
- Calculate and report parameter estimation uncertainty.
- As discussed above, there are a number of environmental variables that are relevant and were not explicitly modelled in this assessment. Their likely evolution with changing climate raises concerns for the sustainability of the fishery. While there is some research investigating these phenomena, there is currently an insufficient understanding of the causal mechanisms that link them to coral trout life history. This means there is uncertainty about how common coral trout will respond to changes in their spatial extent, intensity and frequency. Research addressing this would improve future assessments and aid in the management of the fishery by ensuring harvest remains at sustainable levels when stock size is reduced due to factors that are not fishing related. Results from newly-approved project FRDC 2018-034 “Effects of climate change and habitat degradation on coral trout” may be of great help in this area.

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6. Appendix A - Model fits

6.1 Ayling abundance

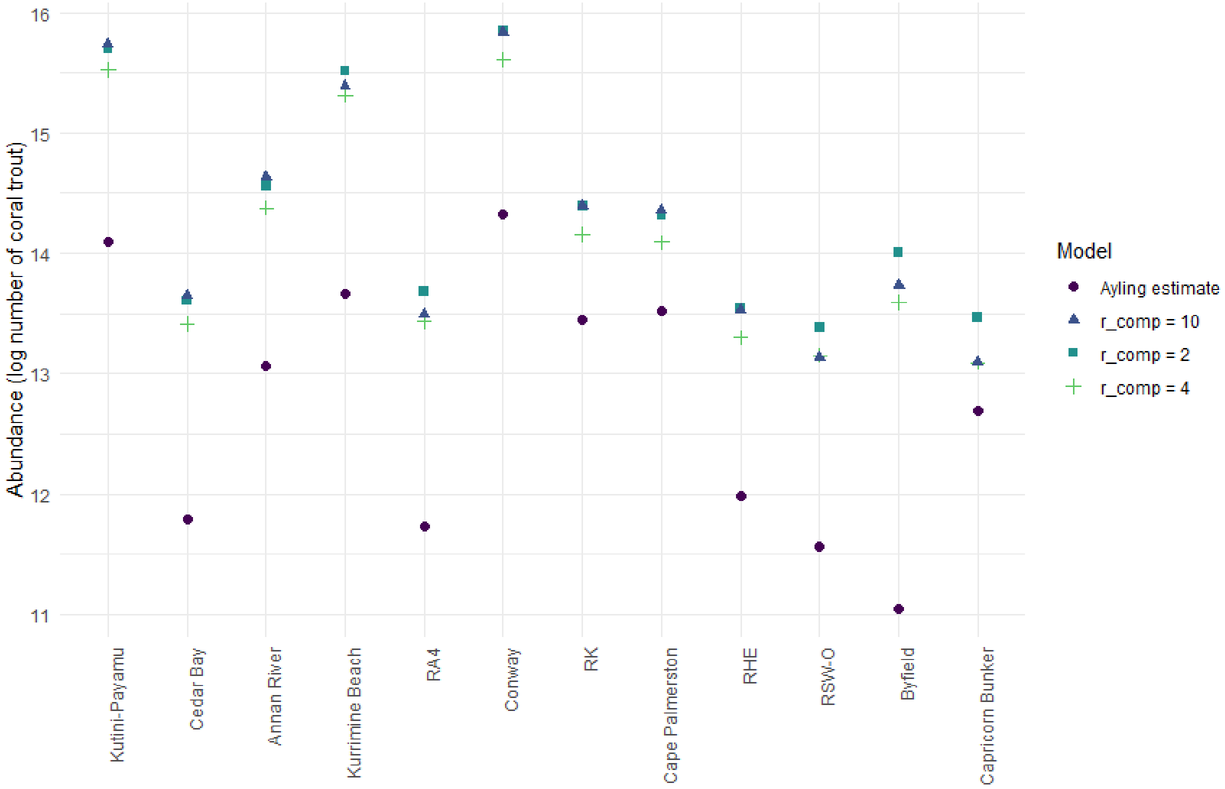

Figure 13 – Model fits to Ayling abundance estimates representing the number of coral trout 38 cm or greated in each habitat area displayed on a log scale. The observed data is fish 38 cm or longer, while the predicted includes fish of three years or older.

6.2 Age structures

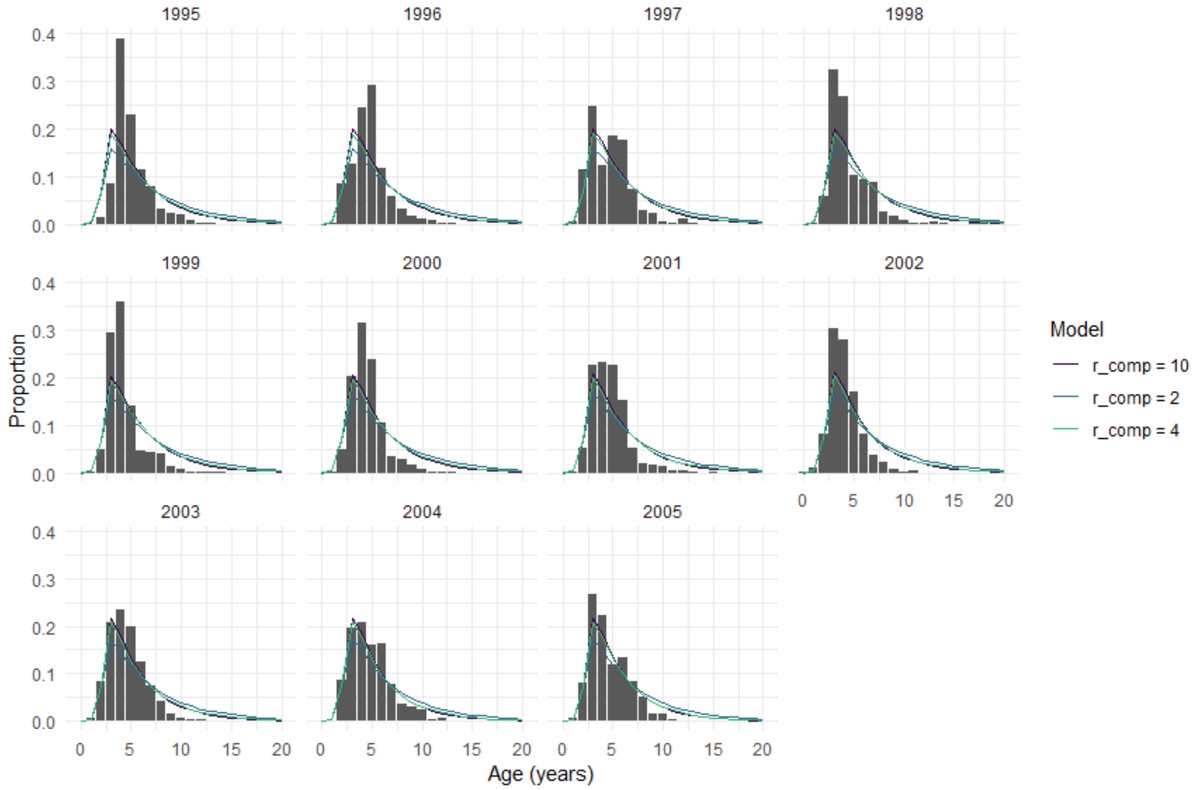

Figure 14 – Stock model predictions of common coral trout ages in the Annan River strata. Bars represent the measured values, while the coloured lines represents the model fit with different recruitment compensation (r_comp) values. The frequency of each observation is recorded as a proportion.

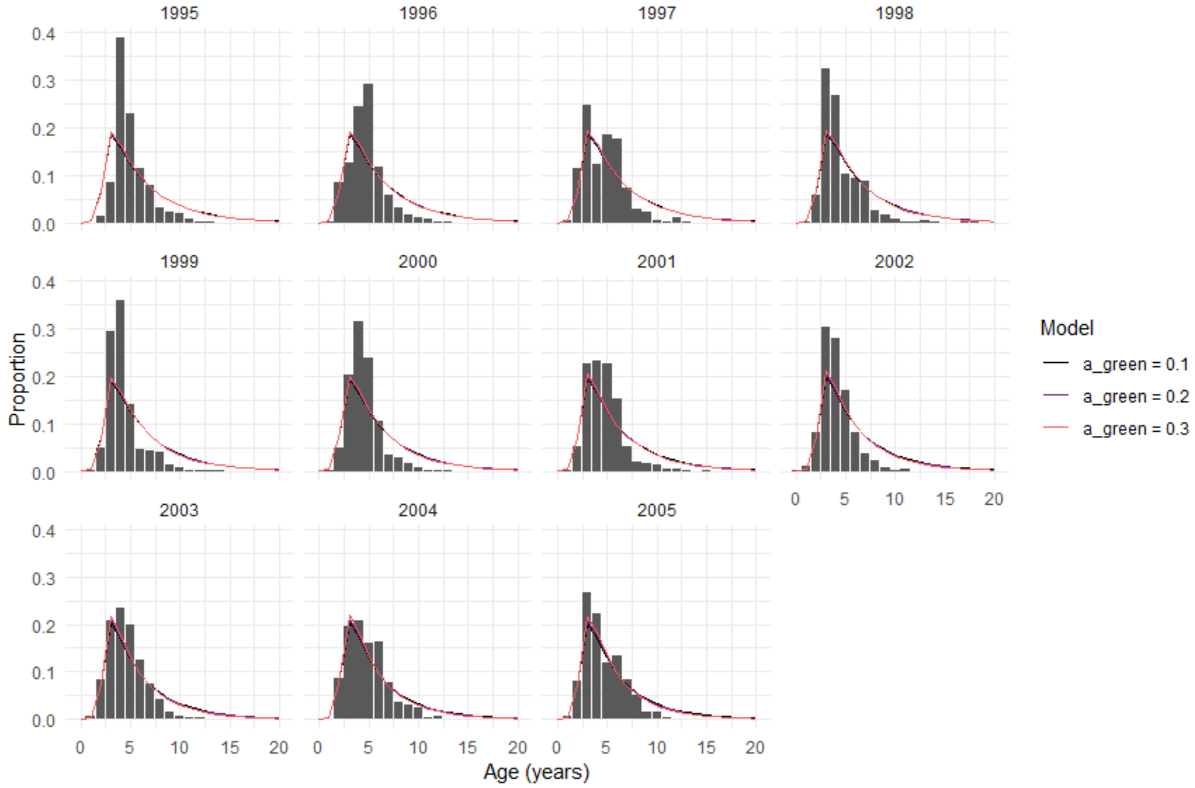

Figure 15 – Stock model predictions of common coral trout ages in the Annan River strata. Bars represent the measured values, while the coloured lines represents the model fit with different different values of assumed fishing in green zones (a_green). The frequency of each observation is recorded as a proportion.

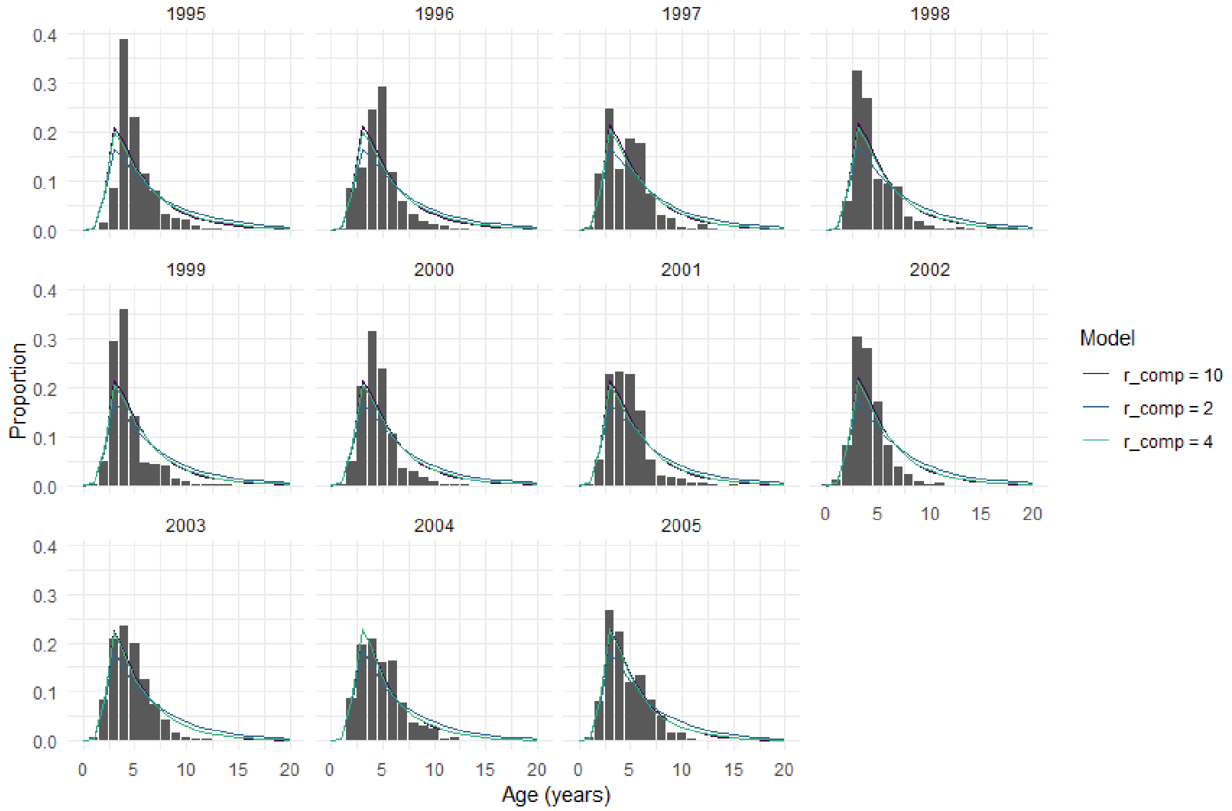

Figure 16 – Stock model predictions of common coral trout ages in the Conway strata. Bars represent the measured values, while the coloured lines represents the model fit with different recruitment compensation (r_comp) values. The frequency of each observation is recorded as a proportion.

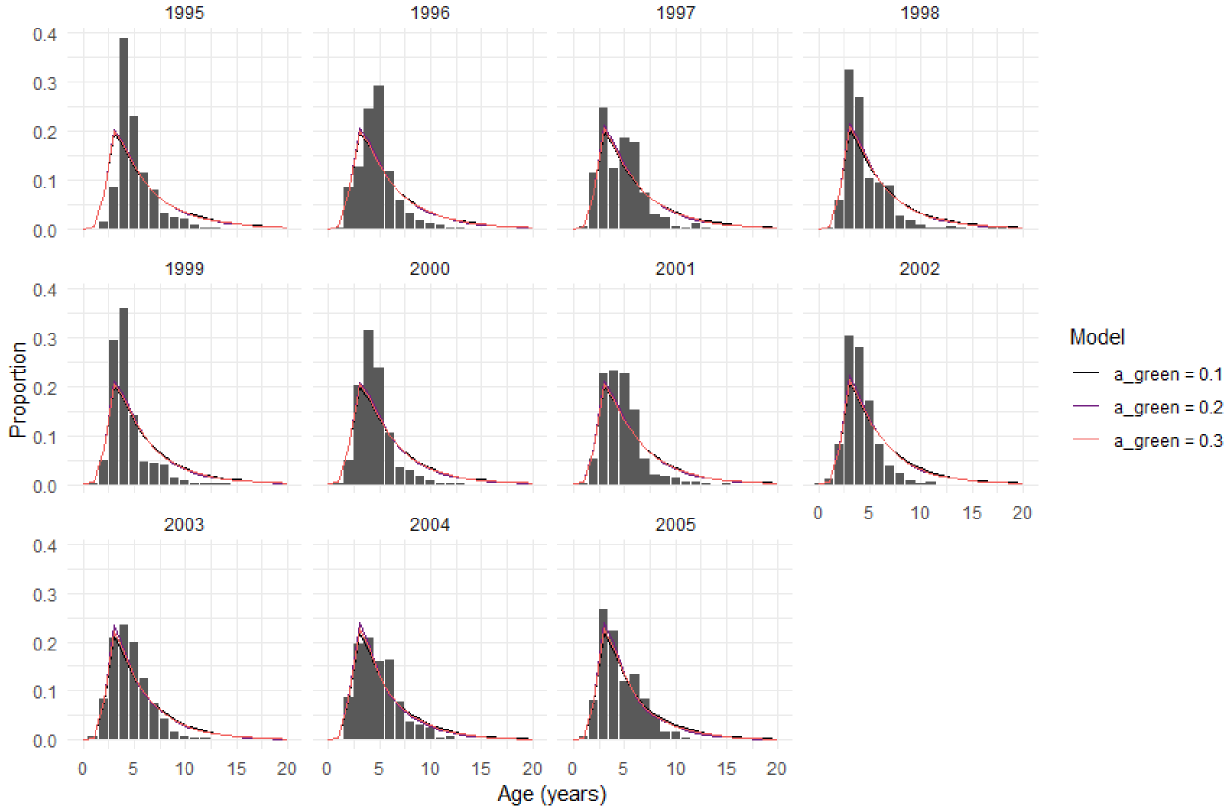

Figure 17.– Stock model predictions of common coral trout ages in the Conway strata. Bars represent the measured values, while the coloured lines represents the model fit with different different values of assumed fishing in green zones (a_green). The frequency of each observation is recorded as a proportion.

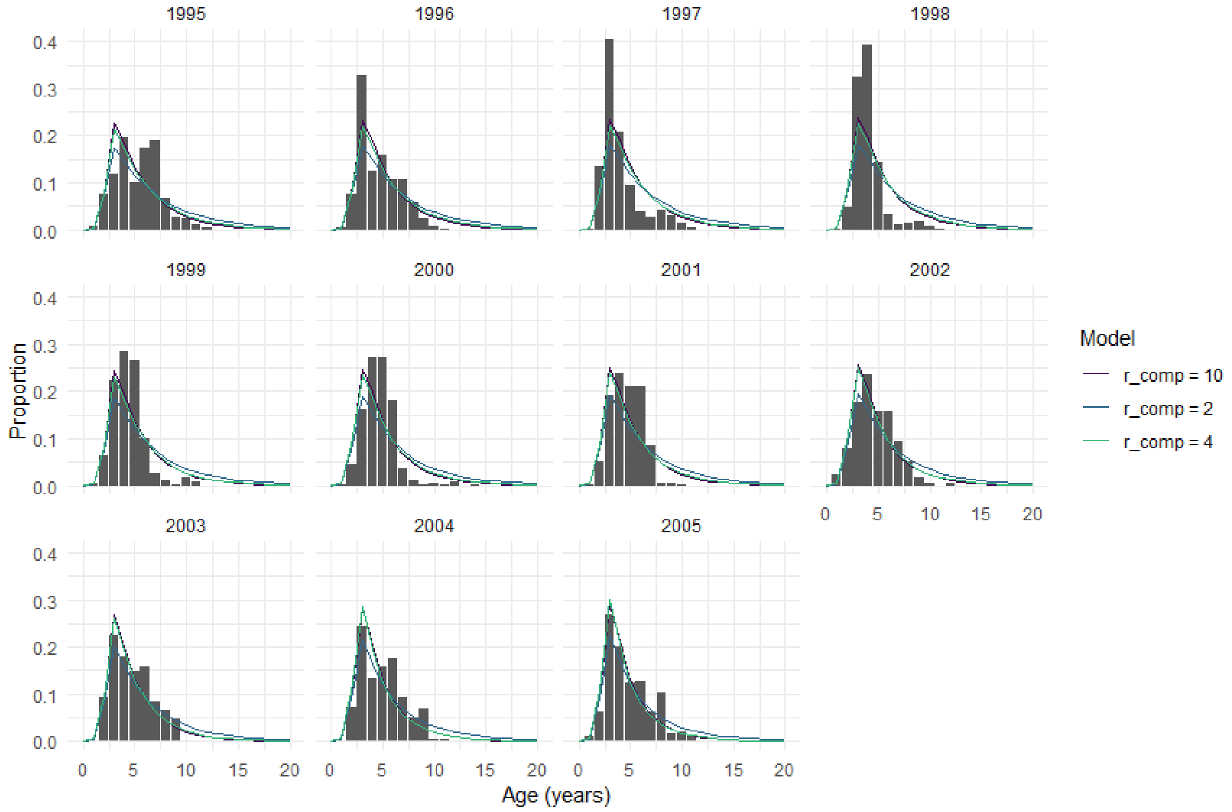

Figure 18 – Stock model predictions of common coral trout ages in the Kurrimine River strata. Bars represent the measured values, while the coloured lines represents the model fit with different recruitment compensation (r_comp) values. The frequency of each observation is recorded as a proportion.

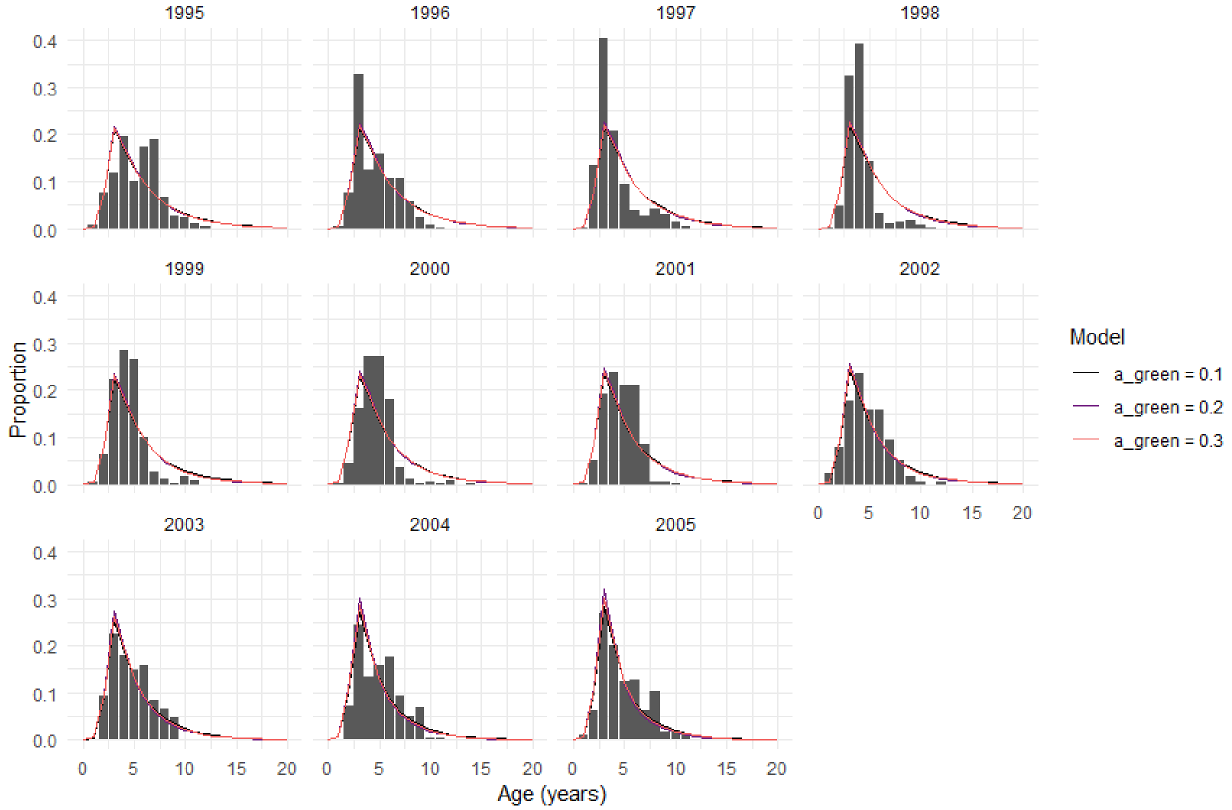

Figure 19 – Stock model predictions of common coral trout ages in the Kurrimine River strata. Bars represent the measured values, while the coloured lines represents the model fit with different different values of assumed fishing in green zones (a_green). The frequency of each observation is recorded as a proportion.

6.3 Abundance indicies

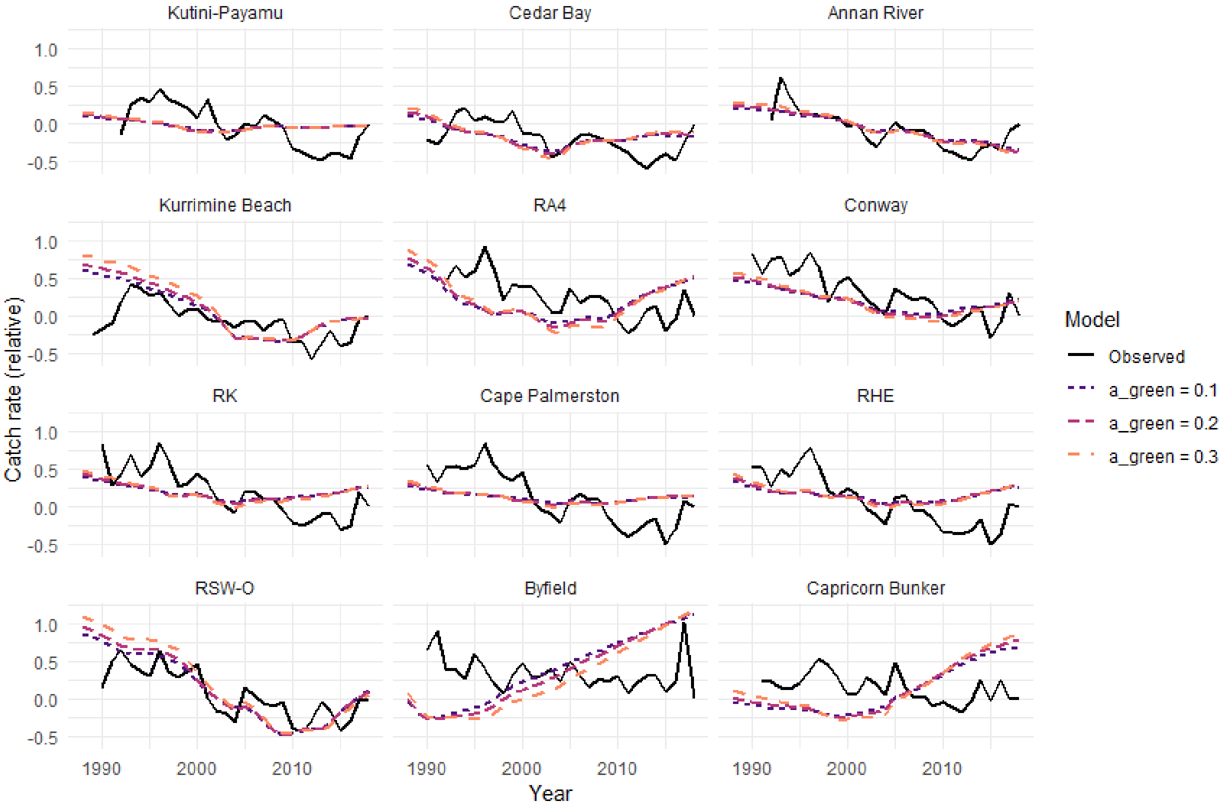

Figure 20 – Stock model fitted values to the standardised commercial catch rates (observed) for each of the model scenarios with different values of assumed fishing in green zones (a_green) for each of the 12 strata.

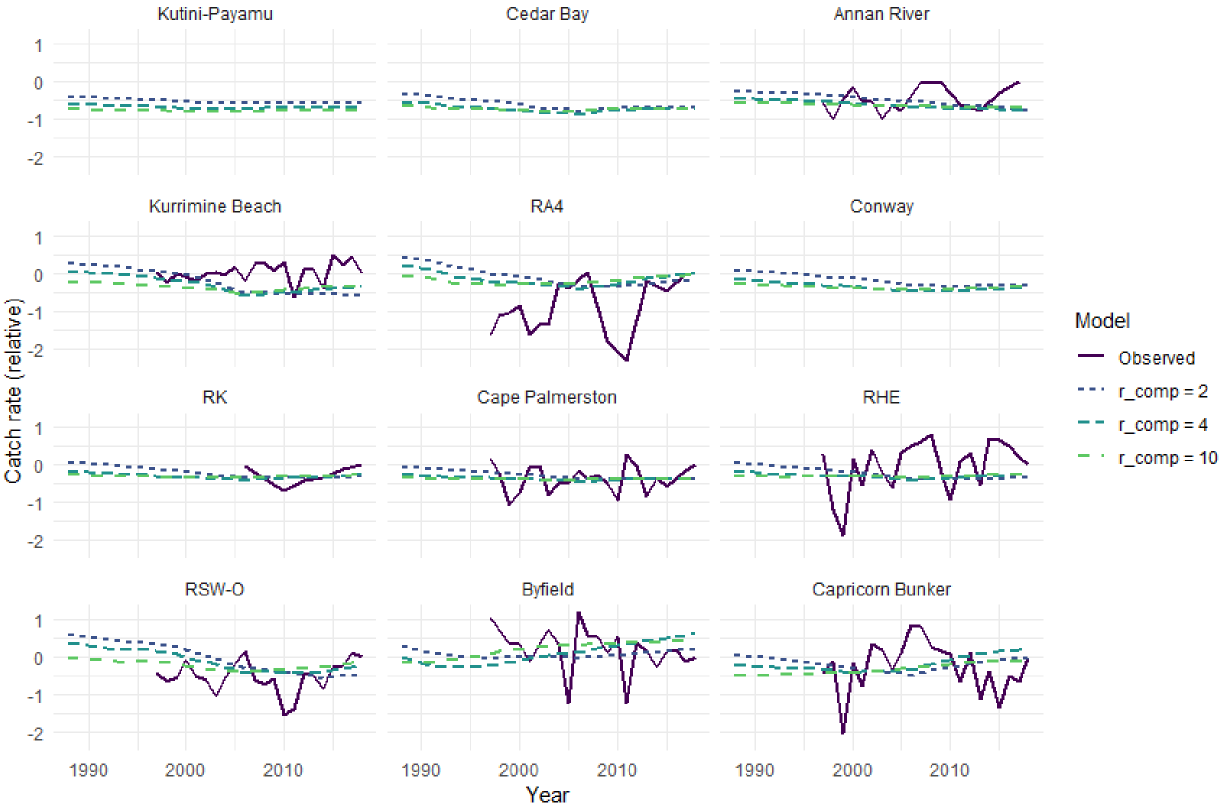

Figure 21 – Stock model fitted values to underwater visual survey estimates (observed) in areas open to fishing for each of the model scenarios with different recruitment compensation (r_comp) values for each of the 12 strata.

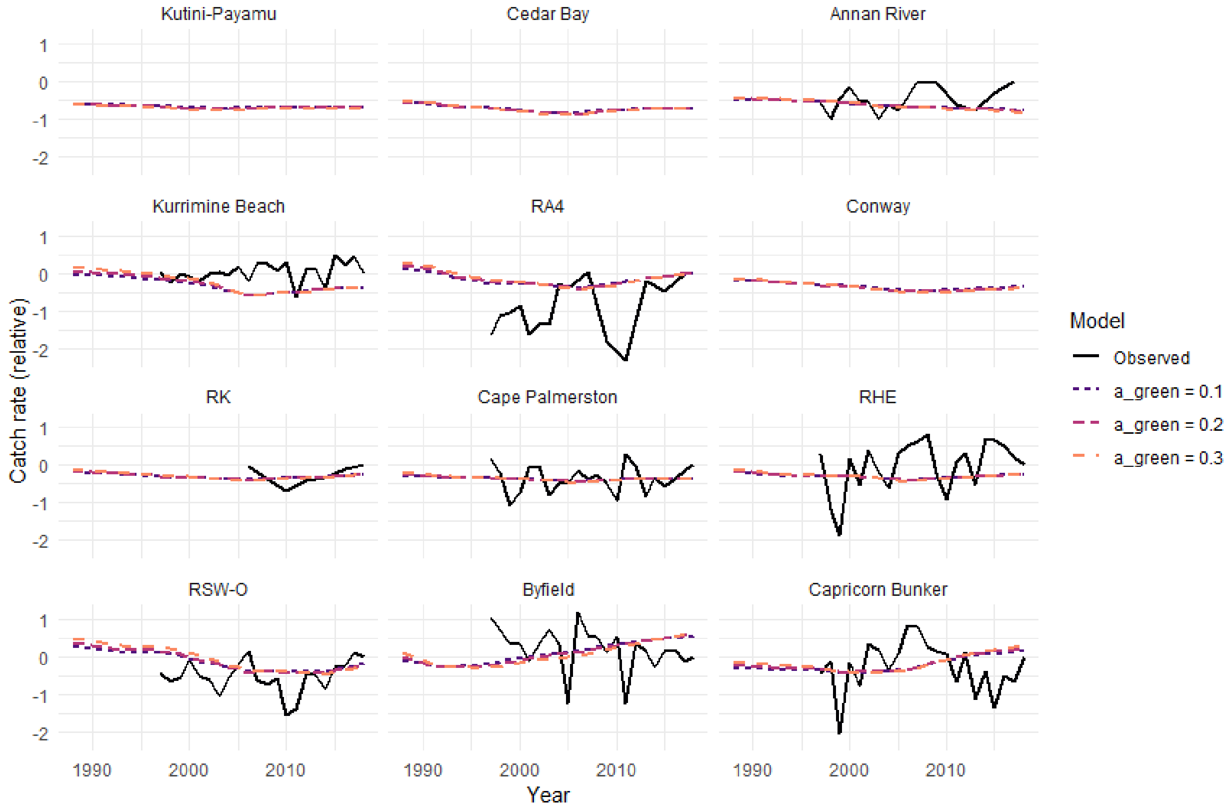

Figure 22 –Stock model fitted values to underwater visual survey estimates (observed) in areas open to fishing for each of the model scenarios with different values of assumed fishing in green zones (a_green) for each of the 12 strata.

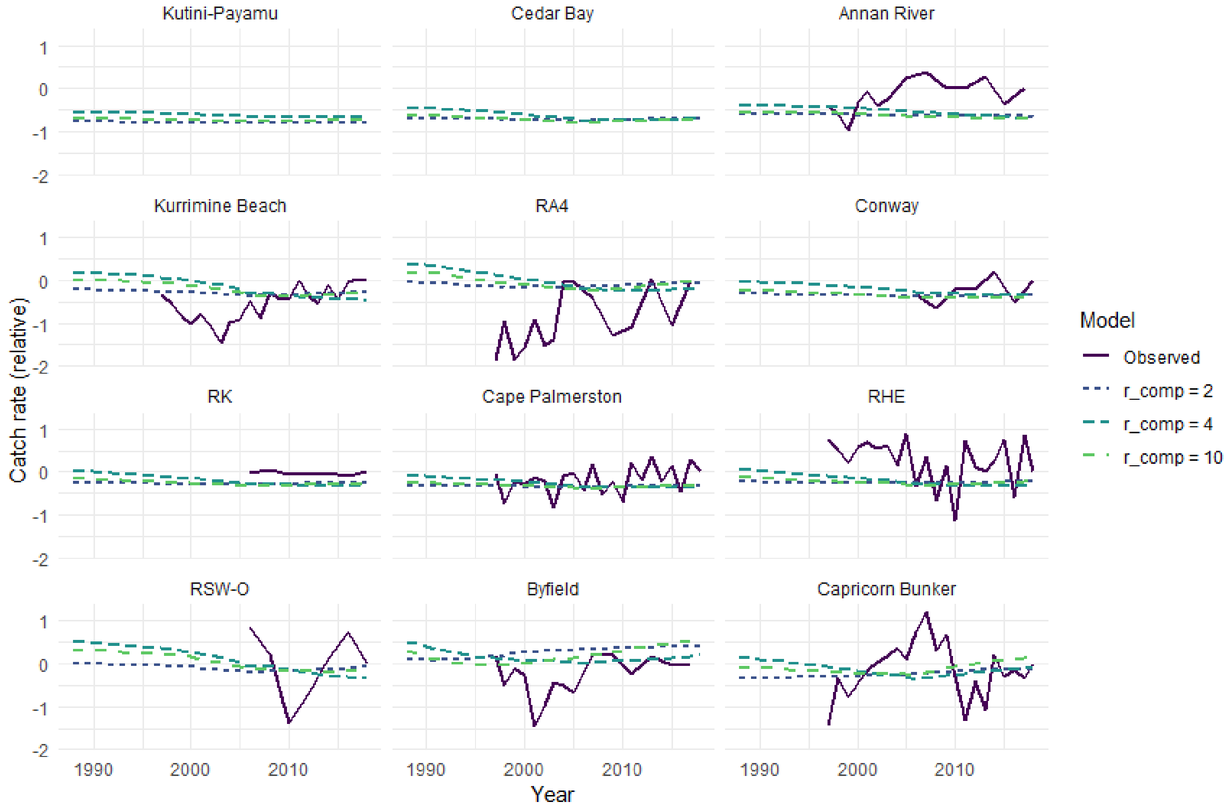

Figure 23 – Stock model fitted values to underwater visual survey estimates (observed) in areas closed to fishing for each of the model scenarios with different recruitment compensation (r_comp) values for each of the 12 strata.

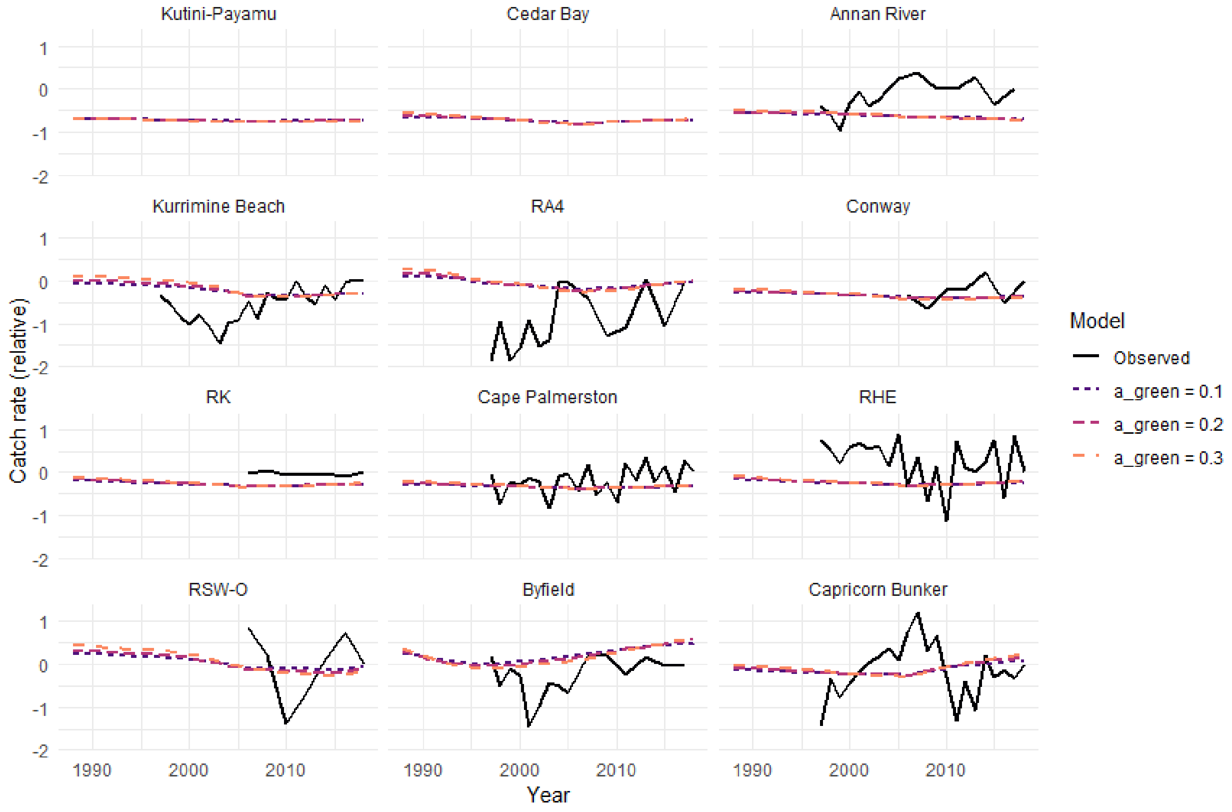

Figure 24 – Stock model fitted values to underwater visual survey estimates (observed) in areas closed to fishing for each of the model scenarios with different values of assumed fishing in green zones (a_green) for each of the 12 strata.

7. Appendix B - Estimates of Habitat Area by Year and Stratum

7.1 Blue Zones

Table 8 – Blue-zone habitat area (hectares) by Year and Stratum.

Year	Annan River	Byfield	Cape Palmerston	Capricorn Bunker	Cedar Bay	Conway	Kurrimine Beach	Kutini-Payamu	RA4	RHE	RK	RSW-O
1951	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1952	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1953	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1954	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1955	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1956	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1957	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1958	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1959	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1960	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1961	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1962	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1963	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1964	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1965	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1966	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1967	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1968	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1969	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1970	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1971	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1972	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1973	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1974	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1975	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1976	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1977	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1978	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1979	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1980	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1981	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1982	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0

Year	Annan River	Byfield	Cape Palmerston	Capricorn Bunker	Cedar Bay	Conway	Kurrimine Beach	Kutini-Payamu	RA4	RHE	RK	RSW-O
1983	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1984	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1985	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1986	39192.0	14322.0	24909.00	10237.00	16017.00	100288.0	60786.0	161985.0	8290.0	10269.00	23757.00	5258.0
1987	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
1988	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
1989	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
1990	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
1991	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
1992	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
1993	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
1994	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
1995	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
1996	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
1997	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
1998	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
1999	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
2000	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
2001	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
2002	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
2003	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
2004	37232.4	13605.9	23663.55	9725.15	15216.15	95273.6	57746.7	132827.7	7875.5	9755.55	22569.15	4995.1
2005	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0
2006	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0
2007	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0
2008	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0
2009	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0
2010	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0
2011	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0
2012	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0
2013	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0
2014	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0
2015	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0
2016	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0
2017	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0
2018	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0

Year	Annan River	Byfield	Cape Palmerston	Capricorn Bunker	Cedar Bay	Conway	Kurrimine Beach	Kutini-Payamu	RA4	RHE	RK	RSW-O
2019	28497.0	11250.0	16839.00	6108.00	8699.00	76130.0	41913.0	100684.0	6004.0	7282.00	18877.00	3229.0

7.2 Green Zones

Table 9 – Green-zone habitat area (hectares) by Year and Stratum.

Year	Annan River	Byfield	Cape Palmerston	Capricorn Bunker	Cedar Bay	Conway	Kurrimine Beach	Kutini-Payamu	RA4	RHE	RK	RSW-O
1951	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1952	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1953	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1954	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1955	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1956	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1957	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1958	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1959	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1960	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1961	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1962	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1963	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1964	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1965	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1966	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1967	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1968	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1969	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1970	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1971	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1972	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1973	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1974	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1975	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1976	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1977	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1978	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1979	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0

Year	Annan River	Byfield	Cape Palmerston	Capricorn Bunker	Cedar Bay	Conway	Kurrimine Beach	Kutini-Payamu	RA4	RHE	RK	RSW-O
1980	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1981	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1982	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1983	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1984	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1985	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1986	1.0	1.0	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.0
1987	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
1988	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
1989	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
1990	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
1991	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
1992	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
1993	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
1994	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
1995	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
1996	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
1997	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
1998	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
1999	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
2000	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
2001	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
2002	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
2003	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
2004	1959.6	716.1	1245.45	511.85	800.85	5014.4	3039.3	29157.3	414.5	513.45	1187.85	262.9
2005	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0
2006	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0
2007	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0
2008	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0
2009	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0
2010	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0
2011	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0
2012	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0
2013	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0
2014	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0
2015	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0

Year	Annan River	Byfield	Cape Palmerston	Capricorn Bunker	Cedar Bay	Conway	Kurrimine Beach	Kutini-Payamu	RA4	RHE	RK	RSW-O
2016	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0
2017	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0
2018	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0
2019	10695.0	3072.0	8070.00	4129.00	7318.00	24158.0	18873.0	61301.0	2286.0	2987.00	4880.00	2029.0

8. Appendix C - Catch Reconstruction Code

```
# this chunk reconstructs the catch history
#     minor alterations to code by George Leigh from previous coral trout assessment

# Rfish

l1 = Rfish1$Species.ID == "CORAL TROUT - UNSPEC"
l2 = Rfish2$SpeciesName  per centin per cent c("Barcheek Coral Trout",
 "Bluespotted Coral Trout", "Coral trout unspecified")
df1a = Rfish1[l1,] # 1495 x 52
df2a = Rfish2[l2,] # 570 x 43

# Location / FishingLocation refers to locations reported by fishers
#   this will need to be grouped into regions
df1a$Location = factor(levels(df1a$Location)[df1a$Location])
df2a$FishingLocation =
 factor(levels(df2a$FishingLocation)[df2a$FishingLocation])

m1 = match(df1a$Location, Rfish1.Loc$Location)
m2 = match(df2a$FishingLocation, Rfish2.Loc$Location)
l1 = !is.na(m1) & (Rfish1.Loc$NearestTown[m1] != "" |
 (Rfish1.Loc$Location[m1] == "" & Rfish1.Loc$NearestTown[m1] == ""))
m1[l1] = match(paste(df1a$Location, df1a$Nearest.Town),
 paste(Rfish1.Loc$Location, Rfish1.Loc$NearestTown))[l1]
l2 = !is.na(m2) & Rfish2.Loc$NearestTown[m2] != ""
m2[l2] = match(paste(df2a$FishingLocation, df2a$NearestTown),
 paste(Rfish2.Loc$Location, Rfish2.Loc$NearestTown))[l2]

# remove lines with missing values
df1b = df1a[!is.na(m1),]
df2b = df2a[!is.na(m2),]
m1 = m1[!is.na(m1)]
m2 = m2[!is.na(m2)]

# Add extra fields. Shelf refers to inshore/offshore
df1b$Subregion = Rfish1.Loc$Subregion[m1]
df2b$Subregion = Rfish2.Loc$Subregion[m2]
df1b$Shelf = Rfish1.Loc$Shelf[m1]
df2b$Shelf = Rfish2.Loc$Shelf[m2]

# A few changes for readability
SubregionListGBR = c("Cape York", "Lockhart River", "Princess Charlotte Bay",
 "Cooktown", "Cairns", "Townsville", "Mackay", "Swains", "Capricorn-Bunker")

SubregionListNonGBR = c("South of GBR", "Gulf of Carpentaria",
 "Torres Strait", "WA")

# We don't care about shelf position when not on the GBR.
df1b$Shelf[!(df1b$Subregion  per centin per cent SubregionListGBR)] = "Inshore"
df2b$Shelf[!(df2b$Subregion  per centin per cent SubregionListGBR)] = "Inshore"
SubregionShelfList = c(paste(rep(SubregionListGBR, each = 2),
 c("Inshore", "Offshore")), paste(SubregionListNonGBR, "Inshore"))
df1b$SubregionShelf = factor(paste(df1b$Subregion, df1b$Shelf),
 levels = SubregionShelfList)
df2b$SubregionShelf = factor(paste(df2b$Subregion, df2b$Shelf),
 levels = SubregionShelfList)

# Results
#   w_kept & WeightedKept are values specific for each record that have
#     upweighted the numbers of reported fish caught to a number caught
#     over the year for the representative component of the fishing population.
#     The result is numbers caught for each subregion & shelf.
x = cbind(tapply(df1b$w_kept, list(df1b$SubregionShelf, df1b$Year), sum),
 tapply(df2b$WeightedKept, df2b$SubregionShelf, sum))
dimnames(x)[[2]][4] = "2005"
x[is.na(x)] = 0
Rfish <- x

RfishAlex <- Rfish[c(3:14,16:18),]

Rfish  <- Rfish[c(1:14,16:18),] # get reigons
Rfish  <- t(Rfish)
Rfish  <- as.data.frame(Rfish)
```

```
rec <- data.frame(Year=as.numeric(colnames(RfishAlex)[1]), OG=word(row.names(RfishAlex)[1],1,-2), Shelf=word(row.
names(RfishAlex)[1],-1), Catch=RfishAlex[1,1], Survey='RFish')

i <- 1

for (j in 2:ncol(RfishAlex))
  rec <- rbind(rec,data.frame(Year=as.numeric(colnames(RfishAlex)[j]), OG=word(row.names(RfishAlex)[i],1,-2), Shelf
=word(row.names(RfishAlex)[i],-1), Catch=RfishAlex[i,j], Survey='RFish'))

for (i in 2:nrow(RfishAlex)) {
  for (j in 1:ncol(RfishAlex)) {
    rec <- rbind(rec,data.frame(Year=as.numeric(colnames(RfishAlex)[j]), OG=word(row.names(RfishAlex)[i],1,-2), Shel
f=word(row.names(RfishAlex)[i],-1), Catch=RfishAlex[i,j], Survey='RFish'))
  }
}

# NRIFS (Aust)

NRIFS$HHDefFactor  <- factor(NRIFS$HouseholdID)

NRIFS <- subset(NRIFS, !is.na(Fishingregioncode) & Commonname=='Coral trout - unspecified')

# create defined regions
NRIFS$RegionDef <- with(NRIFS,paste(Fishingregioncode,subregionGrouping))

NRIFS$RegionDef[NRIFS$Fishingregioncode  per centin per cent c(1, 2, 18)] = "South of GBR"
NRIFS$RegionDef[NRIFS$Fishingregioncode == 8] = "Torres Strait"
NRIFS$RegionDef[NRIFS$Fishingregioncode  per centin per cent c(9, 10, 11)] = "Gulf of Carpentaria"
NRIFS$RegionDef[NRIFS$Fishingregioncode  per centin per cent c(12:17, 19)] = "Inland"

NRIFS$RegionDefFactor <- factor(NRIFS$RegionDef)

# Estimated statewide catch size
#   final result still in numbers - PersonDiaryWeight refers to a multiplier
#   used to upweight the recorded numbers caught to a number caught over the
#   year for the representative component of the fishing population.
SumKept = with(NRIFS,tapply(PersonDiaryWeight * Numkept.person, RegionDefFactor, FUN=sum))
FinalSubregionList = c("Cape York O", "Lockhart River O",
 "Princess Charlotte Bay O", "Cooktown I", "Cooktown O", "Cairns I",
 "Cairns O", "Townsville I", "Townsville O", "Mackay I", "Mackay O", "Swains",
 "Capricorn-Bunker I", "Capricorn-Bunker O")
FinalKept = rep(0, length(FinalSubregionList))
names(FinalKept) = FinalSubregionList
FinalReleased = rep(0, length(FinalSubregionList))
names(FinalReleased) = FinalSubregionList
FinalCatch = rep(0, length(FinalSubregionList))
names(FinalCatch) = FinalSubregionList
FinalKeptInterstate = FinalKept
FinalReleasedInterstate = FinalReleased
FinalCatchInterstate = FinalCatch

# proportion of region code 3 going to cap-bunker inshore, offshore & swains
Prop3 = c(0.20, 0.33, 0.47)
Prop3Interstate = Prop3
# proportion of region code 4 going to mackay inshore & offshore
Prop4 = c(0.72, 0.28)
Prop4Interstate = Prop4
# proportion of region code 5 going to townsville inshore & offshore
Prop5 = c(0.25, 0.75)
# proportion of region code 6 going to cairns inshore & offshore
Prop6 = c(0.14, 0.86)
# proportion of region code 7 going to cooktown inshore & offshore
Prop7 = c(0.17, 0.83)

FinalKept["Capricorn-Bunker I"] = FinalKept["Capricorn-Bunker I"] +
 Prop3[1] * sum(SumKept[c("3 Inshore", "3 Offshore")])
FinalKept["Capricorn-Bunker O"] = FinalKept["Capricorn-Bunker O"] +
 Prop3[2] * sum(SumKept[c("3 Inshore", "3 Offshore")])
FinalKept["Swains"] = FinalKept["Swains"] +
 Prop3[3] * sum(SumKept[c("3 Inshore", "3 Offshore")])

FinalKept["Mackay I"] = FinalKept["Mackay I"] +
 Prop4[1] * sum(SumKept[c("4 Inshore", "4 Offshore")])
FinalKept["Mackay O"] = FinalKept["Mackay O"] +
 Prop4[2] * sum(SumKept[c("4 Inshore", "4 Offshore")])
```

```
FinalKept["Townsville I"] = FinalKept["Townsville I"] +
 Prop5[1] * sum(SumKept[c("5 Inshore", "5 Offshore")])
FinalKept["Townsville O"] = FinalKept["Townsville O"] +
 Prop5[2] * sum(SumKept[c("5 Inshore", "5 Offshore")])

FinalKept["Cairns I"] = FinalKept["Cairns I"] +
 Prop6[1] * sum(SumKept[c("6 Inshore", "6 Offshore")])
FinalKept["Cairns O"] = FinalKept["Cairns O"] +
 Prop6[2] * sum(SumKept[c("6 Inshore", "6 Offshore")])

FinalKept["Cooktown I"] = FinalKept["Cooktown I"] +
 Prop7[1] * sum(SumKept[c("7 Inshore", "7 Offshore")])
FinalKept["Cooktown O"] = FinalKept["Cooktown O"] +
 Prop7[2] * sum(SumKept[c("7 Inshore", "7 Offshore")])

FinalNrifsAust  <- FinalKept

# NRIFS (Qld)

NRIFS <- subset(NRIFS, !is.na(Fishingregioncode) &
                       Commonname=='Coral trout - unspecified' & StateofResidence=="03.QLD")

# create defined regions
NRIFS$RegionDef <- with(NRIFS,paste(Fishingregioncode,subregionGrouping))

NRIFS$RegionDef[NRIFS$Fishingregioncode  per centin per cent c(1, 2, 18)] = "South of GBR"
NRIFS$RegionDef[NRIFS$Fishingregioncode == 8] = "Torres Strait"
NRIFS$RegionDef[NRIFS$Fishingregioncode  per centin per cent c(9, 10, 11)] = "Gulf of Carpentaria"
NRIFS$RegionDef[NRIFS$Fishingregioncode  per centin per cent c(12:17, 19)] = "Inland"

NRIFS$RegionDefFactor <- factor(NRIFS$RegionDef)

# Estimated statewide catch size
SumKept = with(NRIFS,tapply(PersonDiaryWeight * Numkept.person, RegionDefFactor, FUN=sum))
FinalSubregionList = c("Cape York O", "Lockhart River O",
 "Princess Charlotte Bay O", "Cooktown I", "Cooktown O", "Cairns I",
 "Cairns O", "Townsville I", "Townsville O", "Mackay I", "Mackay O", "Swains",
 "Capricorn-Bunker I", "Capricorn-Bunker O")
FinalKept = rep(0, length(FinalSubregionList))
names(FinalKept) = FinalSubregionList
FinalReleased = rep(0, length(FinalSubregionList))
names(FinalReleased) = FinalSubregionList
FinalCatch = rep(0, length(FinalSubregionList))
names(FinalCatch) = FinalSubregionList
FinalKeptInterstate = FinalKept
FinalReleasedInterstate = FinalReleased
FinalCatchInterstate = FinalCatch

FinalKept["Capricorn-Bunker I"] = FinalKept["Capricorn-Bunker I"] +
 Prop3[1] * sum(SumKept[c("3 Inshore", "3 Offshore")])
FinalKept["Capricorn-Bunker O"] = FinalKept["Capricorn-Bunker O"] +
 Prop3[2] * sum(SumKept[c("3 Inshore", "3 Offshore")])
FinalKept["Swains"] = FinalKept["Swains"] +
 Prop3[3] * sum(SumKept[c("3 Inshore", "3 Offshore")])

FinalKept["Mackay I"] = FinalKept["Mackay I"] +
 Prop4[1] * sum(SumKept[c("4 Inshore", "4 Offshore")])
FinalKept["Mackay O"] = FinalKept["Mackay O"] +
 Prop4[2] * sum(SumKept[c("4 Inshore", "4 Offshore")])

FinalKept["Townsville I"] = FinalKept["Townsville I"] +
 Prop5[1] * sum(SumKept[c("5 Inshore", "5 Offshore")])
FinalKept["Townsville O"] = FinalKept["Townsville O"] +
 Prop5[2] * sum(SumKept[c("5 Inshore", "5 Offshore")])

FinalKept["Cairns I"] = FinalKept["Cairns I"] +
 Prop6[1] * sum(SumKept[c("6 Inshore", "6 Offshore")])
FinalKept["Cairns O"] = FinalKept["Cairns O"] +
 Prop6[2] * sum(SumKept[c("6 Inshore", "6 Offshore")])

FinalKept["Cooktown I"] = FinalKept["Cooktown I"] +
 Prop7[1] * sum(SumKept[c("7 Inshore", "7 Offshore")])
FinalKept["Cooktown O"] = FinalKept["Cooktown O"] +
 Prop7[2] * sum(SumKept[c("7 Inshore", "7 Offshore")])
```

```
FinalNrifsQld  <- FinalKept

# SWIRFS 2011

SWIRFS10$ShelfPos <- ifelse(SWIRFS10$Bioregion  per centin per cent c('RE1 North','RE1 Central','RE1 South', 'RD
South','RE2', 'RF1 North','RE3 North', 'RF1 South','RE3 South', 'RF2', 'RHC North','RE4', 'RE5', 'RE6', 'RE
7', 'RHC South','RE8'),'inshore','offshore')

SWIRFS10$ShelfPos[SWIRFS10$Bioregion  per centin per cent c('South of GBR', 'Gulf of Carpentaria')]  <- ''

SWIRFS10$HHDef  <- substring(SWIRFS10$PersonID, 1, 6)

SWIRFS10$HHDefFactor <- factor(SWIRFS10$HHDef)

SWIRFS10$RegionDef <- with(SWIRFS10,paste(GeorgeSubregion,ShelfPos))

SWIRFS10$RegionDefFactor <- factor(SWIRFS10$RegionDef,levels=c('Cape York offshore', 'Lockhart River inshore','Loc
khart River offshore', 'Princess Charlotte Bay offshore','Cooktown inshore', 'Cooktown offshore', 'Cairn
s inshore', 'Cairns offshore','Townsville inshore', 'Townsville offshore', 'Mackay inshore', 'Mackay off
shore', 'Swains offshore', 'Capricorn-Bunker inshore','Capricorn-Bunker offshore', 'South of GBR ', 'Gul
f of Carpentaria '))

SWIRFS10 <- subset(SWIRFS10,ScientificName=='Serranidae')

# Find total catch and total number of diary pages for each
#   household-region combination.
NKeptMat <- with(SWIRFS10, tapply(NKept,list(HHDefFactor,RegionDefFactor),FUN=sum))
NPageMat <- with(SWIRFS10, tapply(NKept,list(HHDefFactor,RegionDefFactor),FUN=length))

dim <- with(SWIRFS10,c(nlevels(HHDefFactor),nlevels(RegionDefFactor)))

HHMat <- with(SWIRFS10,array(rep(levels(HHDefFactor),times=nlevels(RegionDefFactor)),dim=dim))

RegionMat <- with(SWIRFS10,array(rep(levels(RegionDefFactor),each=nlevels(HHDefFactor)),dim=dim))

Rfish.Weights  <- subset(Rfish.Weights, HouseholdID  per centin per cent levels(SWIRFS10$HHDefFactor))

wMat <- array(rep(Rfish.Weights$weight_calib_NICLW, times  = nlevels(SWIRFS10$RegionDefFactor)),dim=dim)

id <- !is.na(NPageMat)

dfSum = data.frame(HH  = HHMat[id],Region  = RegionMat[id], NKept  = NKeptMat[id], NPage  = NPageMat[id], w  = wMat[id])

lf = glm(NKept ~ Region, family  = quasipoisson(link  = log), offset  = log(NPage), data=dfSum)

# Assume that expected total catch by a
#   household is proportional to the number of diary pages returned by
#   that household, and depends on the region.  Other than that, it
#   does not depend on the home address of the household.  Obviously,
#   fishers who live close to the fishing ground will go fishing there
#   more often.  This analysis takes that into account, but assumes
#   that fishers from all over Queensland have, on average, the same
#   skill level.
# Get the estimated dispersion parameter from the GLM.  I prefer to
#   estimate it from the mean deviance.  R, for some reason, prefers
#   to estimate it from the Pearson residuals.

x = anova(lf)
n = dim(x)[1] # Final row
# Dispersion parameter for unweighted data
Disp = x[n, "Resid. Dev"] / x[n, "Resid. Df"]
# Estimated statewide catch size
SumKept = with(dfSum,tapply(w * NKept, Region, FUN=sum))
# Apply formula for variance of a compound Poisson distribution.
#   Denote the quasi-Poisson distribution by Q(mu, sigma), where mu is
#   the mean and sigma is the dispersion parameter, which has the same
#   dimensions as mu.  If N_i ~ P(lambda_i), X_ij ~ Q(mu_i, sigma_i)
#   i.i.d. and Y = sum_i=1^n sum_j=1^{N_i} X_ij, then E(Y) = sum_i=1^n
#   lambda_i mu_i and V(Y) = sum_i=1^n lambda_i mu_i (sigma_i + mu_i).
#   Here we estimate mu_i by the weighted-up observed catch by a
#   particular household in a particular region, and lambda_i by 1.
SeKept = with(dfSum,sqrt(tapply(w^2 * NKept * (Disp + NKept), Region, FUN=sum)))
```

```
FinalSwirfsQld = SumKept

FinalNrifsAust  <- FinalNrifsAust[2:14]
FinalNrifsQld  <- FinalNrifsQld[2:14]

FinalSwirfsQld <- FinalSwirfsQld[c(8,11,5,6,1,2,14,15,9,10,13,3,4)]

FinalSwirfsDiff = (FinalNrifsAust - FinalNrifsQld)*(FinalSwirfsQld / FinalNrifsQld)
FinalSwirfsDiff[is.na(FinalSwirfsDiff)] <- 0
FinalSwirfsAust = FinalSwirfsQld + FinalSwirfsDiff

attr(FinalNrifsAust,'name')[11] <- 'Swains O'

for (i in 1:length(FinalNrifsAust))
  rec <- rbind(rec, data.frame(Year=2000, OG=word(attr(FinalNrifsAust,'name')[i],1,-2), Shelf=ifelse(word(attr(Fina
lNrifsAust,'name')[i],-1)=='O','Offshore','Inshore'), Catch=FinalNrifsAust[i], Survey='NRIFS'))


for (i in 1:length(FinalSwirfsAust))
  rec <- rbind(rec, data.frame(Year=2010, OG=word(attr(FinalSwirfsAust,'name')[i],1,-2), Shelf=ifelse(word(attr(Fin
alSwirfsAust,'name')[i],-1)=='offshore','Offshore','Inshore'), Catch=FinalSwirfsAust[i], Survey='SWIRFS-2010'))

row.names(rec) <- NULL

## Swirfs 2014

SWIRFS14$ShelfPos <- ifelse(SWIRFS14$BioregionRaw  per centin per cent c('RE1 North','RE1 Central','RE1 South', 'R
D South','RE2', 'RF1 North','RE3 North', 'RF1 South','RE3 South', 'RF2', 'RHC North','RE4', 'RE5', 'RE6', '
RE7', 'RHC South','RE8'),'inshore','offshore')

SWIRFS14$ShelfPos[SWIRFS14$BioregionRaw  per centin per cent c('South of GBR', 'Gulf of Carpentaria')]  <- ''

SWIRFS14$HHDef  <- substring(SWIRFS14$PersonID, 1, 6)

SWIRFS14$HHDefFactor <- factor(SWIRFS14$HHDef)

SWIRFS14$RegionDef <- with(SWIRFS14,paste(GeorgeSubregion,ShelfPos))

SWIRFS14$RegionDefFactor <- factor(SWIRFS14$RegionDef,levels=c('Cape York offshore', 'Lockhart River inshore','Loc
khart River offshore', 'Princess Charlotte Bay offshore','Cooktown inshore', 'Cooktown offshore', 'Cairn
s inshore', 'Cairns offshore','Townsville inshore', 'Townsville offshore', 'Mackay inshore', 'Mackay off
shore', 'Swains offshore', 'Capricorn-Bunker inshore','Capricorn-Bunker offshore', 'South of GBR ', 'Gul
f of Carpentaria '))

# Find total catch and total number of diary pages for each household-region combination.
NKeptMat <- with(SWIRFS14, tapply(NKept,list(HHDefFactor,RegionDefFactor),FUN=sum))
NPageMat <- with(SWIRFS14, tapply(NKept,list(HHDefFactor,RegionDefFactor),FUN=length))

dim <- with(SWIRFS14,c(nlevels(HHDefFactor),nlevels(RegionDefFactor)))

HHMat <- with(SWIRFS14,array(rep(levels(HHDefFactor),times=nlevels(RegionDefFactor)),dim=dim))

RegionMat <- with(SWIRFS14,array(rep(levels(RegionDefFactor),each=nlevels(HHDefFactor)),dim=dim))

Rfish.Weights  <- subset(Rfish.Weights, HouseholdID  per centin per cent levels(SWIRFS14$HHDefFactor))

wMat <- array(rep(Rfish.Weights$weight_calib_NICLW, times = nlevels(SWIRFS14$RegionDefFactor)),dim=dim)

id <- !is.na(NPageMat)

dfSum = data.frame(HH = HHMat[id],Region = RegionMat[id], NKept = NKeptMat[id], NPage = NPageMat[id], w = wMat[id])

lf = glm(NKept ~ Region, family = quasipoisson(link = log), offset = log(NPage), data=dfSum)

# Assume that expected total catch by a
#   household is proportional to the number of diary pages returned by
#   that household, and depends on the region.  Other than that, it
#   does not depend on the home address of the household.  Obviously,
#   fishers who live close to the fishing ground will go fishing there
#   more often.  This analysis takes that into account, but assumes
#   that fishers from all over Queensland have, on average, the same
#   skill level.
```

```r
# Get the estimated dispersion parameter from the GLM.  I prefer to
#   estimate it from the mean deviance.  R, for some reason, prefers
#   to estimate it from the Pearson residuals.

x = anova(lf)
n = dim(x)[1] # Final row
# Dispersion parameter for unweighted data
Disp = x[n, "Resid. Dev"] / x[n, "Resid. Df"]
SumKept = with(dfSum,tapply(w * NKept, Region, FUN=sum)) # Estimated statewide catch size
# Apply formula for variance of a compound Poisson distribution.
#   Denote the quasi-Poisson distribution by Q(mu, sigma), where mu is
#   the mean and sigma is the dispersion parameter, which has the same
#   dimensions as mu.  If N_i ~ P(lambda_i), X_ij ~ Q(mu_i, sigma_i)
#   i.i.d. and Y = sum_i=1^n sum_j=1^{N_i} X_ij, then E(Y) = sum_i=1^n
#   lambda_i mu_i and V(Y) = sum_i=1^n lambda_i mu_i (sigma_i + mu_i).
#   Here we estimate mu_i by the weighted-up observed catch by a
#   particular household in a particular region, and lambda_i by 1.
SeKept = with(dfSum,sqrt(tapply(w^2 * NKept * (Disp + NKept), Region, FUN=sum)))

FinalSwirfs14Qld <- SumKept

FinalSwirfs14Qld <- FinalSwirfs14Qld[c(1:7,9:11)]

idx <- c(6,12,13,3,4,9,10,11,7,8)

FinalSwirfs14Diff <- (FinalNrifsAust[idx] - FinalNrifsQld[idx])*(FinalSwirfs14Qld / FinalNrifsQld[idx])

FinalSwirfs14Aust <- FinalSwirfs14Qld + FinalSwirfs14Diff

for (i in 1:length(FinalSwirfs14Aust))
  rec <- rbind(rec, data.frame(Year=2014, OG=word(attr(FinalSwirfs14Aust,'name')[i],1,-2), Shelf=ifelse(word(attr(FinalSwirfs14Aust,'name')[i],-1)=='offshore','Offshore','Inshore'), Catch=FinalSwirfs14Aust[i], Survey='SWIRFS-2014'))

row.names(rec) <- NULL


rec$OGShelf <- paste(rec$OG,rec$Shelf)

ogshelfs <- c('Cairns Inshore','Cairns Offshore','Capricorn-Bunker Inshore','Capricorn-Bunker Offshore','Cooktown Inshore','Cooktown Offshore','Lockhart River Inshore','Lockhart River Offshore','Mackay Inshore','Mackay Offshore','Princess Charlotte Bay Inshore','Princess Charlotte Bay Offshore','Swains Offshore','Townsville Inshore','Townsville Offshore')

sgs <- c(7,3,9,6,2,2,1,1,8,4,1,1,5,7,3)

ogsg <- data.frame(OGShelf=ogshelfs,SG=sgs)

rec <- merge(rec,ogsg)

recyrs <- c(1997,1999,2000,2002,2005,2010,2014)

recmat <- matrix(0, nrow=length(recyrs), ncol=9)

for (i in 1:length(recyrs))
  for (sg in 1:9)
    recmat[i,sg] <- sum(rec$Catch[which(rec$Year==recyrs[i] & rec$SG==sg)])

recmat <- as.data.frame(recmat)

RegionNameString <- c('SG 1','SG 2','SG 3','SG 4','SG 5','SG 6','SG 7','SG 8','SG 9')

names(recmat) <- RegionNameString

row.names(recmat) <- recyrs

## Commercial reconstruction..

StYr <- 1951
EndYr <- params$end_year

Years <- StYr:EndYr
nYear <- length(Years)
```

```
nRegion <- length(RegionNameString)
nPops <- length(unique(Data$Strata))

CatchMatOut <- array(0, dim = c(nYear, nPops))
dimnames(CatchMatOut) <- list(Years, unique(Data$Strata))

CatchMatOut.Comm <- CatchMatOut # commercial
CatchMatOut.Recr <- CatchMatOut # recreational

# Cape Palmerston

p_capbunk <- (Rfish[1,16]/(Rfish[1,16]+Rfish[1,17]))

p_mackay <- (Rfish[1,13]/(Rfish[1,13]+Rfish[1,14]))

p_swains <- 0.2

CatchMatOut.Comm[which(Years  per centin per cent 1962:1981),'Cape Palmerston'] <- (1-p_swains)*FB[1:20,6] # 1962:1981
CatchMatOut.Comm[which(Years  per centin per cent 1962:1981),'RSW-O'] <- p_swains*FB[1:20,6] # 1962:1981

# Mackay: RA4, Conway, RK, RHE, Inshore.. (Byfield)

Mackay.Comm.Inshore <- p_mackay * FB[1:20,5]  # comm inshore 62:81
Mackay.Comm.Inshore[8:20] <- min(Mackay.Comm.Inshore[8:20],Mackay.Comm.Inshore[7]) # ?

CatchMatOut.Comm[which(Years  per centin per cent 1962:1981),'Byfield'] <- Mackay.Comm.Inshore + p_capbunk * FB[1:20,7]

CatchMatOut.Comm[which(Years  per centin per cent 1962:1981),'RK'] <- .5*(FB[1:20,5] - Mackay.Comm.Inshore)
CatchMatOut.Comm[which(Years  per centin per cent 1962:1981),'Conway'] <- .5*(FB[1:20,5] - Mackay.Comm.Inshore)

# Cairns-Townsville: Lucinda (Kurrimine Beach)

CatchMatOut.Comm[which(Years  per centin per cent 1962:1981),'Kurrimine Beach'] <- (Rfish[1,12]/(Rfish[1,11]+Rfish[1,12])) * FB[1:20,4] + (Rfish[1,10]/(Rfish[1,9]+Rfish[1,10])) * FB[1:20,3]

# Cooktown: SG 2

p <- (with(subset(Data, Year==1990 & Group==2), sum(Weight))  / with(subset(Data, Year==1990 & Group  per centin per cent 1:2), sum(Weight)) )
p2 <- (Rfish[1,8]/(Rfish[1,7]+Rfish[1,8]))
CatchMatOut.Comm[which(Years  per centin per cent 1962:1981),'Annan River'] <- 0.8*p*p2*FB[1:20,2]
CatchMatOut.Comm[which(Years  per centin per cent 1962:1981),'Cedar Bay'] <- 0.2*p*p2*FB[1:20,2]

# PCB, LR, CY: Kutini-Payamu

p <- (with(subset(Data, Year==1990 & Group==1), sum(Weight))  / with(subset(Data, Year==1990 & Group  per centin per cent 1:2), sum(Weight)) )
CatchMatOut.Comm[which(Years  per centin per cent 1962:1981),'Kutini-Payamu'] <- p*p2*FB[1:20,2]

# Cap Bunker: Cap Bunker

# use average again
CatchMatOut.Comm[which(Years  per centin per cent 1962:1981),'Capricorn Bunker'] <- (1-p_capbunk) * FB[1:20,7]

# 1982:1988

# Cape Palmerston. & RSW-O
CatchMatOut.Comm[which(Years  per centin per cent 1982:1988),'Cape Palmerston'] <- (with(subset(Data, Year==1990 & Strata=='Cape Palmerston'), sum(Weight)) / CatchMatOut.Comm[which(Years==1981),'Cape Palmerston'])^((1982:1988-1981)/(1989-1981))*CatchMatOut.Comm[which(Years==1981),'Cape Palmerston']

CatchMatOut.Comm[which(Years  per centin per cent 1982:1988),'RSW-O'] <- (with(subset(Data, Year==1990 & Strata=='RSW-O'), sum(Weight)) / CatchMatOut.Comm[which(Years==1981),'RSW-O'])^((1982:1988-1981)/(1989-1981))*CatchMatOut.Comm[which(Years==1981),'RSW-O']

# Mackay:  RA4, Conway, RK, RHE, Inshore.. (Byfield)
CatchMatOut.Comm[which(Years  per centin per cent 1982:1988),'Conway'] <- (with(subset(Data, Year==1990 & Strata=='Conway'), sum(Weight))/CatchMatOut.Comm[which(Years==1981),'Conway'])^((1982:1988-1981)/(1989-1981))*CatchMatOut.Comm[which(Years==1981),'Conway']

CatchMatOut.Comm[which(Years  per centin per cent 1982:1988),'RK'] <- (with(subset(Data, Year==1990 & Strata=='RK')
```

```
, sum(Weight))/CatchMatOut.Comm[which(Years==1981),'RK'])^((1982:1988-1981)/(1989-1981))*CatchMatOut.Comm[which(Years==
1981),'RK']

CatchMatOut.Comm[which(Years  per centin per cent 1982:1988),'Byfield'] <- (with(subset(Data, Year==1990 & Strata==
'Byfield'), sum(Weight))/CatchMatOut.Comm[which(Years==1981),'Byfield'])^((1982:1988-1981)/(1989-1981))*CatchMatOut.C
omm[which(Years==1981),'Byfield']

EndBegin <- 1988
nExtrapYear <- EndBegin - StYr + 1

ExtrapPar <- 0.1 # Catch grows 10 per cent per year
ExtrapMult <- exp(-ExtrapPar * (nExtrapYear + 1 - (1:nExtrapYear)))

CatchMatOut.Comm[which(Years  per centin per cent StYr:EndBegin),'RHE'] <- ExtrapMult * with(subset(Data,Year==1990 & S
trata == 'RHE'), sum(Weight))

CatchMatOut.Comm[which(Years  per centin per cent StYr:EndBegin),'RA4'] <- ExtrapMult * with(subset(Data,Year==1990 & S
trata == 'RA4'), sum(Weight))

# Townsville and Cairns. Lucinda (Kurrimine Beach)
CatchMatOut.Comm[which(Years  per centin per cent 1982:1988),'Kurrimine Beach'] <- (with(subset(Data, Year==1990
& Strata=='Kurrimine Beach'), sum(Weight))/CatchMatOut.Comm[which(Years==1981),'Kurrimine Beach'])^((1982:1988-198
1)/(1989-1981))*CatchMatOut.Comm[which(Years==1981),'Kurrimine Beach']

# Cooktown: Cedar Bay and Annan River

CatchMatOut.Comm[which(Years  per centin per cent 1982:1988),'Cedar Bay'] <- (with(subset(Data, Year==1990 & Strata
=='Cedar Bay'), sum(Weight))/CatchMatOut.Comm[which(Years==1981),'Cedar Bay'])^((1982:1988-1981)/(1989-1981))*Catch
MatOut.Comm[which(Years==1981),'Cedar Bay']

CatchMatOut.Comm[which(Years  per centin per cent 1982:1988),'Annan River'] <- (with(subset(Data, Year==1990 & Str
ata=='Annan River'), sum(Weight))/CatchMatOut.Comm[which(Years==1981),'Annan River'])^((1982:1988-1981)/(1989-1981
))*CatchMatOut.Comm[which(Years==1981),'Annan River']

#PCB, Cape York, LR: Kutini-Payamu

CatchMatOut.Comm[which(Years  per centin per cent 1982:1988),'Kutini-Payamu'] <- (with(subset(Data, Year==1990 &
Strata=='Kutini-Payamu'), sum(Weight))/CatchMatOut.Comm[which(Years==1981),'Kutini-Payamu'])^((1982:1988-1981)/(19
89-1981))*CatchMatOut.Comm[which(Years==1981),'Kutini-Payamu']

# Cap bunker: Capricorn Bunker

CatchMatOut.Comm[which(Years  per centin per cent 1982:1988),'Capricorn Bunker'] <- (with(subset(Data, Year==1990
& Strata=='Capricorn Bunker'), sum(Weight))/CatchMatOut.Comm[which(Years==1981),'Capricorn Bunker'])^((1982:1988-1
981)/(1989-1981))*CatchMatOut.Comm[which(Years==1981),'Capricorn Bunker']

# shouldn't these all be Year==1989? (above)

# Commercial 1989:EndYear

yrs <- 1989:EndYr
for (i in 1:length(yrs))
  for (pop in unique(Data$Strata))
    CatchMatOut.Comm[which(Years==yrs[i]),pop] <- with(subset(Data,Year==yrs[i] & Strata == pop), sum(Weight))

EndBegin <- 1961
nExtrapYear <- EndBegin - StYr + 1

ExtrapPar <- 0.1 # Catch grows 10 per cent per year
ExtrapMult <- exp(-ExtrapPar * (nExtrapYear + 1 - (1:nExtrapYear)))

CatchMatOut.Comm[which(Years  per centin per cent StYr:EndBegin),] <- cbind(ExtrapMult)  per cent* per cent rbind(Cat
chMatOut.Comm[which(Years==(EndBegin+1)),])

## Recreational reconstruction ..

# Rec 1962:1980
RecreationalMultipliers <- c(5.3,5.3,5.35,4.4,5.45,5.45)

# Cape Palmerston
CatchMatOut.Recr[which(Years  per centin per cent 1962:1980),'Cape Palmerston'] <- RecreationalMultipliers[5] * CatchM
atOut.Comm[which(Years  per centin per cent 1962:1980),'Cape Palmerston']
```

```
CatchMatOut.Recr[which(Years  per centin per cent 1962:1980),'RSW-O'] <- RecreationalMultipliers[5] * CatchMatOut.Comm[w
hich(Years  per centin per cent 1962:1980),'RSW-O']

# Mackay. SG 4 and 8


CatchMatOut.Recr[which(Years  per centin per cent 1962:1980),'Byfield'] <- RecreationalMultipliers[4] * p_mackay * FB[1
:19,5] + RecreationalMultipliers[4] * p_capbunk * FB[1:19,7]

CatchMatOut.Recr[which(Years  per centin per cent 1962:1980),'RA4'] <- .1* RecreationalMultipliers[4] * (1-p_mackay) *
FB[1:19,5]

CatchMatOut.Recr[which(Years  per centin per cent 1962:1980),'RK'] <- .3* RecreationalMultipliers[4] * (1-p_mackay) * FB
[1:19,5]

CatchMatOut.Recr[which(Years  per centin per cent 1962:1980),'RHE'] <- .2* RecreationalMultipliers[4] * (1-p_mackay) *
FB[1:19,5]

CatchMatOut.Recr[which(Years  per centin per cent 1962:1980),'Conway'] <- .4* RecreationalMultipliers[4] * (1-p_mackay)
* FB[1:19,5]


# Townsville & Cairns. SG 7 and 3

CatchMatOut.Recr[which(Years  per centin per cent 1962:1980),'Kurrimine Beach'] <- CatchMatOut.Comm[which(Years  per
centin per cent 1962:1980),'Kurrimine Beach'] * RecreationalMultipliers[2]

# Cooktown. SG 2

CatchMatOut.Recr[which(Years  per centin per cent 1962:1980),'Cedar Bay'] <- CatchMatOut.Comm[which(Years  per centi
n per cent 1962:1980),'Cedar Bay'] * RecreationalMultipliers[1]

CatchMatOut.Recr[which(Years  per centin per cent 1962:1980),'Annan River'] <- CatchMatOut.Comm[which(Years  per cen
tin per cent 1962:1980),'Annan River'] * RecreationalMultipliers[1]

# Cape york to pcb are 0 here

# CB. SG 6 and 9

CatchMatOut.Recr[which(Years  per centin per cent 1962:1980),'Capricorn Bunker'] <- 5*(CatchMatOut.Comm[which(Years
per centin per cent 1962:1980),'Capricorn Bunker'] + (1-p_capbunk) * FB[1:19,7]) * RecreationalMultipliers[1]

# Cape Palmerston 1981..1989 .. 1996

PropFall1990 <- 0.2145
AvgFishWeight <- 1.576 # weight multiplier to convert fish numbers to kilograms

p <- .8

CatchMatOut.Recr[which(Years  per centin per cent 1981:1989),'Cape Palmerston'] <- ((p*AvgFishWeight*FinalNrifsAust[1
1]/CatchMatOut.Recr[which(Years==1980),'Cape Palmerston'])/(1-2*PropFall1990))^((1981:1989-1980)/(2000-1980))*CatchM
atOut.Recr[which(Years==1980),'Cape Palmerston']

CatchMatOut.Recr[which(Years==1990),'Cape Palmerston'] <- ((p*AvgFishWeight*FinalNrifsAust[11]/CatchMatOut.Recr[which(Years
==1980),'Cape Palmerston'])/(1-2*PropFall1990))^((1990-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Cape
Palmerston']*(1-PropFall1990)

CatchMatOut.Recr[which(Years  per centin per cent 1991:1996),'Cape Palmerston'] <- ((p*AvgFishWeight*FinalNrifsAust[1
1]/CatchMatOut.Recr[which(Years==1980),'Cape Palmerston'])/(1-2*PropFall1990))^((1991:1996-1980)/(2000-1980))*CatchM
atOut.Recr[which(Years==1980),'Cape Palmerston']*(1-2*PropFall1990)


CatchMatOut.Recr[which(Years  per centin per cent 1981:1989),'RSW-O'] <- (((1-p)*AvgFishWeight*FinalNrifsAust[11]/CatchM
atOut.Recr[which(Years==1980),'RSW-O'])/(1-2*PropFall1990))^((1981:1989-1980)/(2000-1980))*CatchMatOut.Recr[which(Year
s==1980),'RSW-O']

CatchMatOut.Recr[which(Years==1990),'RSW-O'] <- (((1-p)*AvgFishWeight*FinalNrifsAust[11]/CatchMatOut.Recr[which(Years==1980)
,'RSW-O'])/(1-2*PropFall1990))^((1990-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RSW-O']*(1-PropFall1990)

CatchMatOut.Recr[which(Years  per centin per cent 1991:1996),'RSW-O'] <- (((1-p)*AvgFishWeight*FinalNrifsAust[11]/CatchM
atOut.Recr[which(Years==1980),'RSW-O'])/(1-2*PropFall1990))^((1991:1996-1980)/(2000-1980))*CatchMatOut.Recr[which(Year
s==1980),'RSW-O']*(1-2*PropFall1990)
```

```
# Mackay 1981..1989 .. 1996. SG 4 and 8

p <- 0.25

CatchMatOut.Recr[which(Years  per centin per cent 1981:1989),'RA4'] <- ((p*AvgFishWeight*FinalNrifsAust[10]/CatchMatOut.Recr[which(Years==1980),'RA4'])/(1-2*PropFall1990))^((1981:1989-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RA4']

CatchMatOut.Recr[which(Years==1990),'RA4'] <- ((p*AvgFishWeight*FinalNrifsAust[10]/CatchMatOut.Recr[which(Years==1980),'RA4'])/(1-2*PropFall1990))^((1990-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RA4']*(1-PropFall1990)

CatchMatOut.Recr[which(Years  per centin per cent 1991:1996),'RA4'] <- ((p*AvgFishWeight*FinalNrifsAust[10]/CatchMatOut.Recr[which(Years==1980),'RA4'])/(1-2*PropFall1990))^((1991:1996-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RA4']*(1-2*PropFall1990)


CatchMatOut.Recr[which(Years  per centin per cent 1981:1989),'RK'] <- ((p*AvgFishWeight*FinalNrifsAust[10]/CatchMatOut.Recr[which(Years==1980),'RK'])/(1-2*PropFall1990))^((1981:1989-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RK']

CatchMatOut.Recr[which(Years==1990),'RK'] <- ((p*AvgFishWeight*FinalNrifsAust[10]/CatchMatOut.Recr[which(Years==1980),'RK'])/(1-2*PropFall1990))^((1990-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RK']*(1-PropFall1990)

CatchMatOut.Recr[which(Years  per centin per cent 1991:1996),'RK'] <- ((p*AvgFishWeight*FinalNrifsAust[10]/CatchMatOut.Recr[which(Years==1980),'RK'])/(1-2*PropFall1990))^((1991:1996-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RK']*(1-2*PropFall1990)


CatchMatOut.Recr[which(Years  per centin per cent 1981:1989),'RHE'] <- ((p*AvgFishWeight*FinalNrifsAust[10]/CatchMatOut.Recr[which(Years==1980),'RHE'])/(1-2*PropFall1990))^((1981:1989-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RHE']

CatchMatOut.Recr[which(Years==1990),'RHE'] <- ((p*AvgFishWeight*FinalNrifsAust[10]/CatchMatOut.Recr[which(Years==1980),'RHE'])/(1-2*PropFall1990))^((1990-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RHE']*(1-PropFall1990)

CatchMatOut.Recr[which(Years  per centin per cent 1991:1996),'RHE'] <- ((p*AvgFishWeight*FinalNrifsAust[10]/CatchMatOut.Recr[which(Years==1980),'RHE'])/(1-2*PropFall1990))^((1991:1996-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RHE']*(1-2*PropFall1990)



CatchMatOut.Recr[which(Years  per centin per cent 1981:1989),'Conway'] <- ((p*AvgFishWeight*FinalNrifsAust[10]/CatchMatOut.Recr[which(Years==1980),'Conway'])/(1-2*PropFall1990))^((1981:1989-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Conway']

CatchMatOut.Recr[which(Years==1990),'Conway'] <- ((p*AvgFishWeight*FinalNrifsAust[10]/CatchMatOut.Recr[which(Years==1980),'Conway'])/(1-2*PropFall1990))^((1990-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Conway']*(1-PropFall1990)

CatchMatOut.Recr[which(Years  per centin per cent 1991:1996),'Conway'] <- ((p*AvgFishWeight*FinalNrifsAust[10]/CatchMatOut.Recr[which(Years==1980),'Conway'])/(1-2*PropFall1990))^((1991:1996-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Conway']*(1-2*PropFall1990)


# inshore..
CatchMatOut.Recr[which(Years  per centin per cent 1981:1989),'Byfield'] <- ((AvgFishWeight*(FinalNrifsAust[9]+FinalNrifsAust[12])/CatchMatOut.Recr[which(Years==1980),'Byfield'])/(1-2*PropFall1990))^((1981:1989-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Byfield']

CatchMatOut.Recr[which(Years==1990),'Byfield'] <- ((AvgFishWeight*(FinalNrifsAust[9]+FinalNrifsAust[12])/CatchMatOut.Recr[which(Years==1980),'Byfield'])/(1-2*PropFall1990))^((1990-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Byfield']*(1-PropFall1990)

CatchMatOut.Recr[which(Years  per centin per cent 1991:1996),'Byfield'] <- ((AvgFishWeight*(FinalNrifsAust[9]+FinalNrifsAust[12])/CatchMatOut.Recr[which(Years==1980),'Byfield'])/(1-2*PropFall1990))^((1991:1996-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Byfield']*(1-2*PropFall1990)


# Cairns-Townsville 1981..1989 .. 1996. SG 3 and 7

CatchMatOut.Recr[which(Years  per centin per cent 1981:1989),'Kurrimine Beach'] <- ((AvgFishWeight*sum(FinalNrifsAust
```

```
[5:8])/CatchMatOut.Recr[which(Years==1980),'Kurrimine Beach'])/(1-2*PropFall1990))^((1981:1989-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Kurrimine Beach']

CatchMatOut.Recr[which(Years==1990),'Kurrimine Beach'] <- ((AvgFishWeight*sum(FinalNrifsAust[5:8])/CatchMatOut.Recr[which(Years==1980),'Kurrimine Beach'])/(1-2*PropFall1990))^((1990-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Kurrimine Beach']*(1-PropFall1990)

CatchMatOut.Recr[which(Years per centin per cent 1991:1996),'Kurrimine Beach'] <- ((AvgFishWeight*sum(FinalNrifsAust[5:8])/CatchMatOut.Recr[which(Years==1980),'Kurrimine Beach'])/(1-2*PropFall1990))^((1991:1996-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Kurrimine Beach']*(1-2*PropFall1990)

# Cooktown 1981..1989 .. 1996. SG 2

p_cedar <- .4

CatchMatOut.Recr[which(Years per centin per cent 1981:1989),'Annan River'] <- ((p_cedar*AvgFishWeight*(FinalNrifsAust[4])/CatchMatOut.Recr[which(Years==1980),'Annan River'])/(1-2*PropFall1990))^((1981:1989-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Annan River']

CatchMatOut.Recr[which(Years==1990),'Annan River'] <- ((p_cedar*AvgFishWeight * FinalNrifsAust[4]/CatchMatOut.Recr[which(Years==1980),'Annan River'])/(1-2*PropFall1990))^((1990-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Annan River']*(1-PropFall1990)

CatchMatOut.Recr[which(Years per centin per cent 1991:1996),'Annan River'] <- ((p_cedar*AvgFishWeight*FinalNrifsAust[4]/CatchMatOut.Recr[which(Years==1980),'Annan River'])/(1-2*PropFall1990))^((1991:1996-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Annan River']*(1-2*PropFall1990)


CatchMatOut.Recr[which(Years per centin per cent 1981:1989),'Cedar Bay'] <- ((AvgFishWeight*(((1-p_cedar)*FinalNrifsAust[4])+FinalNrifsAust[3])/CatchMatOut.Recr[which(Years==1980),'Cedar Bay'])/(1-2*PropFall1990))^((1981:1989-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Cedar Bay']

CatchMatOut.Recr[which(Years==1990),'Cedar Bay'] <- ((AvgFishWeight *(((1-p_cedar)*FinalNrifsAust[4])+FinalNrifsAust[3])/CatchMatOut.Recr[which(Years==1980),'Cedar Bay'])/(1-2*PropFall1990))^((1990-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Cedar Bay']*(1-PropFall1990)

CatchMatOut.Recr[which(Years per centin per cent 1991:1996),'Cedar Bay'] <- ((AvgFishWeight*(((1-p_cedar)*FinalNrifsAust[4])+FinalNrifsAust[3])/CatchMatOut.Recr[which(Years==1980),'Cedar Bay'])/(1-2*PropFall1990))^((1991:1996-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Cedar Bay']*(1-2*PropFall1990)

# CB. SG 6 and 9

CatchMatOut.Recr[which(Years per centin per cent 1981:1989),'Capricorn Bunker'] <- ((AvgFishWeight*(FinalNrifsAust[13])/CatchMatOut.Recr[which(Years==1980),'Capricorn Bunker'])/(1-2*PropFall1990))^((1981:1989-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Capricorn Bunker']

CatchMatOut.Recr[which(Years==1990),'Capricorn Bunker'] <- ((AvgFishWeight*(FinalNrifsAust[13])/CatchMatOut.Recr[which(Years==1980),'Capricorn Bunker'])/(1-2*PropFall1990))^((1990-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Capricorn Bunker']*(1-PropFall1990)

CatchMatOut.Recr[which(Years per centin per cent 1991:1996),'Capricorn Bunker'] <- ((AvgFishWeight*(FinalNrifsAust[13])/CatchMatOut.Recr[which(Years==1980),'Capricorn Bunker'])/(1-2*PropFall1990))^((1991:1996-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Capricorn Bunker']*(1-2*PropFall1990)

# SG 1

EndBegin <- 1999
nExtrapYear <- EndBegin - StYr + 1

ExtrapPar <- 0.1 # Catch grows 10 per cent per year
ExtrapMult <- exp(-ExtrapPar * (nExtrapYear + 1 - (1:nExtrapYear)))

CatchMatOut.Recr[which(Years per centin per cent StYr:EndBegin),'Kutini-Payamu'] <- ExtrapMult * sum(Rfish[1,1:6])

# 1997 : 2013

# Cape Palmerston

CatchMatOut.Recr[which(Years==1999),'Cape Palmerston'] <- ((AvgFishWeight*FinalNrifsAust[11]/CatchMatOut.Recr[which(Years==1980),'Cape Palmerston'])/(1-2*PropFall1990))^((1999-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Cape Palmerston']*(1-2*PropFall1990)

CatchMatOut.Recr[which(Years==2000),'Cape Palmerston'] <- AvgFishWeight*p_swains*FinalNrifsAust[11]
```

```
CatchMatOut.Recr[which(Years==1997),'Cape Palmerston']  <- p_swains*(Rfish[1,15]/Rfish[2,15]) * CatchMatOut.Recr[which(Years==1999),'Cape Palmerston']

CatchMatOut.Recr[which(Years==1998),'Cape Palmerston'] <- CatchMatOut.Recr[which(Years==1997),'Cape Palmerston'] * ( CatchMatOut.Recr[which(Years==2000),'Cape Palmerston'] / CatchMatOut.Recr[which(Years==1999),'Cape Palmerston'] )

CatchMatOut.Recr[which(Years  per centin per cent 2001:2002),'Cape Palmerston'] <- CatchMatOut.Recr[which(Years==2000),'Cape Palmerston']

CatchMatOut.Recr[which(Years==2011),'Cape Palmerston'] <- p_swains*AvgFishWeight * FinalSwirfsAust[11]

CatchMatOut.Recr[which(Years  per centin per cent 2003:2010),'Cape Palmerston']  <- (CatchMatOut.Recr[which(Years==2011),'Cape Palmerston']/CatchMatOut.Recr[which(Years==2002),'Cape Palmerston']) ^ ((1:8)/(2011-2002)) * CatchMatOut.Recr[which(Years==2002),'Cape Palmerston']

CatchMatOut.Recr[which(Years  per centin per cent 2012:min(2013,EndYr)),'Cape Palmerston'] <- CatchMatOut.Recr[which(Years==2011),'Cape Palmerston']


CatchMatOut.Recr[which(Years==1999),'RSW-O'] <- ((AvgFishWeight*FinalNrifsAust[11]/CatchMatOut.Recr[which(Years==1980),'RSW-O'])/(1-2*PropFall1990))^((1999-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RSW-O']*(1-2*PropFall1990)

CatchMatOut.Recr[which(Years==2000),'RSW-O'] <- AvgFishWeight*(1-p_swains)*FinalNrifsAust[11]

CatchMatOut.Recr[which(Years==1997),'RSW-O']  <- (1-p_swains)*(Rfish[1,15]/Rfish[2,15]) * CatchMatOut.Recr[which(Years==1999),'RSW-O']

CatchMatOut.Recr[which(Years==1998),'RSW-O'] <- CatchMatOut.Recr[which(Years==1997),'RSW-O'] * ( CatchMatOut.Recr[which(Years==2000),'RSW-O'] / CatchMatOut.Recr[which(Years==1999),'RSW-O'] )

CatchMatOut.Recr[which(Years  per centin per cent 2001:2002),'RSW-O'] <- CatchMatOut.Recr[which(Years==2000),'RSW-O']

CatchMatOut.Recr[which(Years==2011),'RSW-O'] <- (1-p_swains)*AvgFishWeight * FinalSwirfsAust[11]

CatchMatOut.Recr[which(Years  per centin per cent 2003:2010),'RSW-O']  <- (CatchMatOut.Recr[which(Years==2011),'RSW-O']/CatchMatOut.Recr[which(Years==2002),'RSW-O']) ^ ((1:8)/(2011-2002)) * CatchMatOut.Recr[which(Years==2002),'RSW-O']

CatchMatOut.Recr[which(Years  per centin per cent 2012:min(2013,EndYr)),'RSW-O'] <- CatchMatOut.Recr[which(Years==2011),'RSW-O']

# Mackay. SG 4 and 8

p <- 0.25

CatchMatOut.Recr[which(Years==2000),'RA4'] <- p*AvgFishWeight*FinalNrifsAust[10]

CatchMatOut.Recr[which(Years==1999),'RA4'] <- ((CatchMatOut.Recr[which(Years==2000),'RA4']/CatchMatOut.Recr[which(Years==1980),'RA4'])/(1-2*PropFall1990))^((1999-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RA4']*(1-2*PropFall1990)

CatchMatOut.Recr[which(Years==1997),'RA4'] <- ((Rfish[1,14]) / (Rfish[2,14])) * CatchMatOut.Recr[which(Years==1999),'RA4']

CatchMatOut.Recr[which(Years==1998),'RA4'] <- CatchMatOut.Recr[which(Years==1997),'RA4'] * ( CatchMatOut.Recr[which(Years==2000),'RA4'] / CatchMatOut.Recr[which(Years==1999),'RA4'] )

CatchMatOut.Recr[which(Years  per centin per cent 2001:2002),'RA4'] <- CatchMatOut.Recr[which(Years==2000),'RA4']

CatchMatOut.Recr[which(Years==2011),'RA4'] <- p * AvgFishWeight * FinalSwirfsAust[10]

CatchMatOut.Recr[which(Years  per centin per cent 2003:2010),'RA4']  <- (CatchMatOut.Recr[which(Years==2011),'RA4']/CatchMatOut.Recr[which(Years==2002),'RA4']) ^ ((1:8)/(2011-2002)) * CatchMatOut.Recr[which(Years==2002),'RA4']

CatchMatOut.Recr[which(Years  per centin per cent 2012:min(2013,EndYr)),'RA4'] <- CatchMatOut.Recr[which(Years==2011),'RA4']



CatchMatOut.Recr[which(Years==2000),'RK'] <- p * AvgFishWeight*FinalNrifsAust[10]
```

```
CatchMatOut.Recr[which(Years==1999),'RK'] <- ((CatchMatOut.Recr[which(Years==2000),'RK']/CatchMatOut.Recr[which(Years==1980),'RK'])/(1-2*PropFall1990))^((1999-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RK']*(1-2*PropFall1990)

CatchMatOut.Recr[which(Years==1997),'RK'] <- ((Rfish[1,14]) / (Rfish[2,14])) * CatchMatOut.Recr[which(Years==1999),'RK']

CatchMatOut.Recr[which(Years==1998),'RK'] <- CatchMatOut.Recr[which(Years==1997),'RK'] * ( CatchMatOut.Recr[which(Years==2000),'RK'] / CatchMatOut.Recr[which(Years==1999),'RK'] )

CatchMatOut.Recr[which(Years  per centin per cent 2001:2002),'RK'] <- CatchMatOut.Recr[which(Years==2000),'RK']

CatchMatOut.Recr[which(Years==2011),'RK'] <- p * AvgFishWeight * FinalSwirfsAust[10]

CatchMatOut.Recr[which(Years  per centin per cent 2003:2010),'RK']  <- (CatchMatOut.Recr[which(Years==2011),'RK']/CatchMatOut.Recr[which(Years==2002),'RK']) ^ ((1:8)/(2011-2002)) * CatchMatOut.Recr[which(Years==2002),'RK']

CatchMatOut.Recr[which(Years  per centin per cent 2012:min(2013,EndYr)),'RK'] <- CatchMatOut.Recr[which(Years==2011),'RK']



CatchMatOut.Recr[which(Years==2000),'RHE'] <- p * AvgFishWeight*FinalNrifsAust[10]

CatchMatOut.Recr[which(Years==1999),'RHE'] <- ((CatchMatOut.Recr[which(Years==2000),'RHE']/CatchMatOut.Recr[which(Years==1980),'RHE'])/(1-2*PropFall1990))^((1999-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'RHE']*(1-2*PropFall1990)

CatchMatOut.Recr[which(Years==1997),'RHE'] <- ((Rfish[1,14]) / (Rfish[2,14])) * CatchMatOut.Recr[which(Years==1999),'RHE']

CatchMatOut.Recr[which(Years==1998),'RHE'] <- CatchMatOut.Recr[which(Years==1997),'RHE'] * ( CatchMatOut.Recr[which(Years==2000),'RHE'] / CatchMatOut.Recr[which(Years==1999),'RHE'] )

CatchMatOut.Recr[which(Years  per centin per cent 2001:2002),'RHE'] <- CatchMatOut.Recr[which(Years==2000),'RHE']

CatchMatOut.Recr[which(Years==2011),'RHE'] <- p *AvgFishWeight * FinalSwirfsAust[10]

CatchMatOut.Recr[which(Years  per centin per cent 2003:2010),'RHE']  <- (CatchMatOut.Recr[which(Years==2011),'RHE']/CatchMatOut.Recr[which(Years==2002),'RHE']) ^ ((1:8)/(2011-2002)) * CatchMatOut.Recr[which(Years==2002),'RHE']

CatchMatOut.Recr[which(Years  per centin per cent 2012:min(2013,EndYr)),'RHE'] <- CatchMatOut.Recr[which(Years==2011),'RHE']



CatchMatOut.Recr[which(Years==2000),'Conway'] <- p * AvgFishWeight*FinalNrifsAust[10]

CatchMatOut.Recr[which(Years==1999),'Conway'] <- ((CatchMatOut.Recr[which(Years==2000),'Conway']/CatchMatOut.Recr[which(Years==1980),'Conway'])/(1-2*PropFall1990))^((1999-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Conway']*(1-2*PropFall1990)

CatchMatOut.Recr[which(Years==1997),'Conway'] <- ((Rfish[1,14]) / (Rfish[2,14])) * CatchMatOut.Recr[which(Years==1999),'Conway']

CatchMatOut.Recr[which(Years==1998),'Conway'] <- CatchMatOut.Recr[which(Years==1997),'Conway'] * ( CatchMatOut.Recr[which(Years==2000),'Conway'] / CatchMatOut.Recr[which(Years==1999),'Conway'] )

CatchMatOut.Recr[which(Years  per centin per cent 2001:2002),'Conway'] <- CatchMatOut.Recr[which(Years==2000),'Conway']

CatchMatOut.Recr[which(Years==2011),'Conway'] <- p * AvgFishWeight * FinalSwirfsAust[10]

CatchMatOut.Recr[which(Years  per centin per cent 2003:2010),'Conway']  <- (CatchMatOut.Recr[which(Years==2011),'Conway']/CatchMatOut.Recr[which(Years==2002),'Conway']) ^ ((1:8)/(2011-2002)) * CatchMatOut.Recr[which(Years==2002),'Conway']

CatchMatOut.Recr[which(Years  per centin per cent 2012:min(2013,EndYr)),'Conway'] <- CatchMatOut.Recr[which(Years==2011),'Conway']



CatchMatOut.Recr[which(Years==2000),'Byfield'] <- AvgFishWeight*(FinalNrifsAust[9] + FinalNrifsAust[12])

CatchMatOut.Recr[which(Years==1999),'Byfield'] <- ((CatchMatOut.Recr[which(Years==2000),'Byfield']/CatchMatOut.Recr[which
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```
(Years==1980),'Byfield'])/(1-2*PropFall1990))^((1999-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Byfield']*(1-2*PropFall1990)

CatchMatOut.Recr[which(Years==1997),'Byfield'] <- (sum(Rfish[1,c(13,16)]) / sum(Rfish[2,c(13,16)])) * CatchMatOut.Recr[which(Years==1999),'Byfield']

CatchMatOut.Recr[which(Years==1998),'Byfield'] <- CatchMatOut.Recr[which(Years==1997),'Byfield'] * ( CatchMatOut.Recr[which(Years==2000),'Byfield'] / CatchMatOut.Recr[which(Years==1999),'Byfield'] )

CatchMatOut.Recr[which(Years  per centin per cent 2001:2002),'Byfield'] <- CatchMatOut.Recr[which(Years==2000),'Byfield']

CatchMatOut.Recr[which(Years==2011),'Byfield'] <-  AvgFishWeight * sum(FinalSwirfsAust[c(9,12)])

CatchMatOut.Recr[which(Years  per centin per cent 2003:2010),'Byfield']  <- (CatchMatOut.Recr[which(Years==2011),'Byfield']/CatchMatOut.Recr[which(Years==2002),'Byfield']) ^ ((1:8)/(2011-2002)) * CatchMatOut.Recr[which(Years==2002),'Byfield']

CatchMatOut.Recr[which(Years  per centin per cent 2012:min(2013,EndYr)),'Byfield'] <- CatchMatOut.Recr[which(Years==2011),'Byfield']


# Cairns-Townsville. SG 3 and 7

CatchMatOut.Recr[which(Years==2000),'Kurrimine Beach'] <- AvgFishWeight*sum(FinalNrifsAust[5:8])

CatchMatOut.Recr[which(Years==1999),'Kurrimine Beach'] <- ((CatchMatOut.Recr[which(Years==2000),'Kurrimine Beach']/CatchMatOut.Recr[which(Years==1980),'Kurrimine Beach'])/(1-2*PropFall1990))^((1999-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Kurrimine Beach']*(1-2*PropFall1990)

CatchMatOut.Recr[which(Years==1997),'Kurrimine Beach'] <- (sum(Rfish[1,9:12]) / sum(Rfish[2,9:12])) * CatchMatOut.Recr[which(Years==1999),'Kurrimine Beach']

CatchMatOut.Recr[which(Years==1998),'Kurrimine Beach'] <- CatchMatOut.Recr[which(Years==1997),'Kurrimine Beach'] * ( CatchMatOut.Recr[which(Years==2000),'Kurrimine Beach'] / CatchMatOut.Recr[which(Years==1999),'Kurrimine Beach'] )

CatchMatOut.Recr[which(Years  per centin per cent 2001:2002),'Kurrimine Beach'] <- CatchMatOut.Recr[which(Years==2000),'Kurrimine Beach']

CatchMatOut.Recr[which(Years==2011),'Kurrimine Beach'] <- AvgFishWeight * sum(FinalSwirfsAust[5:8])

CatchMatOut.Recr[which(Years  per centin per cent 2003:2010),'Kurrimine Beach']  <- (CatchMatOut.Recr[which(Years==2011),'Kurrimine Beach']/CatchMatOut.Recr[which(Years==2002),'Kurrimine Beach']) ^ ((1:8)/(2011-2002)) * CatchMatOut.Recr[which(Years==2002),'Kurrimine Beach']

CatchMatOut.Recr[which(Years  per centin per cent 2012:min(2013,EndYr)),'Kurrimine Beach'] <- CatchMatOut.Recr[which(Years==2011),'Kurrimine Beach']


# Cooktown

p_cedar <- .4

CatchMatOut.Recr[which(Years==2000),'Cedar Bay'] <- p_cedar * AvgFishWeight*(FinalNrifsAust[3] + FinalNrifsAust[4])

CatchMatOut.Recr[which(Years==1999),'Cedar Bay'] <- ((CatchMatOut.Recr[which(Years==2000),'Cedar Bay']/CatchMatOut.Recr[which(Years==1980),'Cedar Bay'])/(1-2*PropFall1990))^((1999-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Cedar Bay']*(1-2*PropFall1990)

CatchMatOut.Recr[which(Years==1997),'Cedar Bay'] <-  ((Rfish[1,7]+Rfish[1,8]) / (Rfish[2,7]+Rfish[2,8])) * CatchMatOut.Recr[which(Years==1999),'Cedar Bay']

CatchMatOut.Recr[which(Years==1998),'Cedar Bay'] <- CatchMatOut.Recr[which(Years==1997),'Cedar Bay'] * ( CatchMatOut.Recr[which(Years==2000),'Cedar Bay'] / CatchMatOut.Recr[which(Years==1999),'Cedar Bay'] )

CatchMatOut.Recr[which(Years  per centin per cent 2001:2002),'Cedar Bay'] <- CatchMatOut.Recr[which(Years==2000),'Cedar Bay']

CatchMatOut.Recr[which(Years==2011),'Cedar Bay'] <- p_cedar * AvgFishWeight * (FinalSwirfsAust[3] + FinalSwirfsAust[4])

CatchMatOut.Recr[which(Years  per centin per cent 2003:2010),'Cedar Bay']  <- (CatchMatOut.Recr[which(Years==2011),'Cedar Bay']/CatchMatOut.Recr[which(Years==2002),'Cedar Bay']) ^ ((1:8)/(2011-2002)) * CatchMatOut.Recr[which(Years==2
```

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002),'Cedar Bay']

CatchMatOut.Recr[which(Years  per centin per cent 2012:min(2013,EndYr)),'Cedar Bay'] <- CatchMatOut.Recr[which(Years==2011),'Cedar Bay']



CatchMatOut.Recr[which(Years==2000),'Annan River'] <- (1-p_cedar) * AvgFishWeight*(FinalNrifsAust[3] + FinalNrifsAust[4])

CatchMatOut.Recr[which(Years==1999),'Annan River'] <- ((CatchMatOut.Recr[which(Years==2000),'Annan River']/CatchMatOut.Recr[which(Years==1980),'Annan River'])/(1-2*PropFall1990))^((1999-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Annan River']*(1-2*PropFall1990)

CatchMatOut.Recr[which(Years==1997),'Annan River'] <-  ((Rfish[1,7]+Rfish[1,8]) / (Rfish[2,7]+Rfish[2,8])) * CatchMatOut.Recr[which(Years==1999),'Annan River']

CatchMatOut.Recr[which(Years==1998),'Annan River'] <- CatchMatOut.Recr[which(Years==1997),'Annan River'] * ( CatchMatOut.Recr[which(Years==2000),'Annan River'] / CatchMatOut.Recr[which(Years==1999),'Annan River'] )

CatchMatOut.Recr[which(Years  per centin per cent 2001:2002),'Annan River'] <- CatchMatOut.Recr[which(Years==2000),'Annan River']

CatchMatOut.Recr[which(Years==2011),'Annan River'] <- (1-p_cedar) * AvgFishWeight * (FinalSwirfsAust[3] + FinalSwirfsAust[4])

CatchMatOut.Recr[which(Years  per centin per cent 2003:2010),'Annan River']  <- (CatchMatOut.Recr[which(Years==2011),'Annan River']/CatchMatOut.Recr[which(Years==2002),'Annan River']) ^ ((1:8)/(2011-2002)) * CatchMatOut.Recr[which(Years==2002),'Annan River']

CatchMatOut.Recr[which(Years  per centin per cent 2012:min(2013,EndYr)),'Annan River'] <- CatchMatOut.Recr[which(Years==2011),'Annan River']


# PCB and LR

CatchMatOut.Recr[which(Years  per centin per cent 2000:min(2013,EndYr)),'Kutini-Payamu'] <- AvgFishWeight * (FinalSwirfsAust[1] + FinalSwirfsAust[2])

# CB.

CatchMatOut.Recr[which(Years==2000),'Capricorn Bunker'] <- AvgFishWeight*FinalNrifsAust[13]

CatchMatOut.Recr[which(Years==1999),'Capricorn Bunker'] <- ((CatchMatOut.Recr[which(Years==2000),'Capricorn Bunker']/CatchMatOut.Recr[which(Years==1980),'Capricorn Bunker'])/(1-2*PropFall1990))^((1999-1980)/(2000-1980))*CatchMatOut.Recr[which(Years==1980),'Capricorn Bunker']*(1-2*PropFall1990)

CatchMatOut.Recr[which(Years==1997),'Capricorn Bunker'] <- ((Rfish[1,17]) / (Rfish[2,17])) * CatchMatOut.Recr[which(Years==1999),'Capricorn Bunker']

CatchMatOut.Recr[which(Years==1998),'Capricorn Bunker'] <- CatchMatOut.Recr[which(Years==1997),'Capricorn Bunker'] * ( CatchMatOut.Recr[which(Years==2000),'Capricorn Bunker'] / CatchMatOut.Recr[which(Years==1999),'Capricorn Bunker'] )

CatchMatOut.Recr[which(Years  per centin per cent 2001:2002),'Capricorn Bunker'] <- CatchMatOut.Recr[which(Years==2000),'Capricorn Bunker']

CatchMatOut.Recr[which(Years==2011),'Capricorn Bunker'] <- AvgFishWeight * FinalSwirfsAust[13]

CatchMatOut.Recr[which(Years  per centin per cent 2003:2010),'Capricorn Bunker']  <- (CatchMatOut.Recr[which(Years==2011),'Capricorn Bunker']/CatchMatOut.Recr[which(Years==2002),'Capricorn Bunker']) ^ ((1:8)/(2011-2002)) * CatchMatOut.Recr[which(Years==2002),'Capricorn Bunker']

CatchMatOut.Recr[which(Years  per centin per cent 2012:min(2013,EndYr)),'Capricorn Bunker'] <- CatchMatOut.Recr[which(Years==2011),'Capricorn Bunker']


# Recreational 2014:2018

CatchMatOut.Recr[which(Years  per centin per cent 2014:EndYr),'Kutini-Payamu']  <- CatchMatOut.Recr[which(Years==2013),'Kutini-Payamu']
CatchMatOut.Recr[which(Years  per centin per cent 2014:EndYr),'Cedar Bay'] <- p_cedar * FinalSwirfs14Aust[5]
CatchMatOut.Recr[which(Years  per centin per cent 2014:EndYr),'Annan River'] <- (1-p_cedar) * FinalSwirfs14Aust[5] + FinalNrifsAust[4]
CatchMatOut.Recr[which(Years  per centin per cent 2014:EndYr),'Kurrimine Beach'] <- FinalSwirfs14Aust[1] + FinalSwirfs1
```

```
4Aust[9] + FinalSwirfs14Aust[10]
p <- 0.25
CatchMatOut.Recr[which(Years  per centin per cent 2014:EndYr),'RA4'] <- p*FinalSwirfs14Aust[7]
CatchMatOut.Recr[which(Years  per centin per cent 2014:EndYr),'RK'] <- p*FinalSwirfs14Aust[7]
CatchMatOut.Recr[which(Years  per centin per cent 2014:EndYr),'RHE'] <- p*FinalSwirfs14Aust[7]
CatchMatOut.Recr[which(Years  per centin per cent 2014:EndYr),'Conway'] <- p*FinalSwirfs14Aust[7]

CatchMatOut.Recr[which(Years  per centin per cent 2014:EndYr),'Cape Palmerston'] <- (1-p_swains) * FinalSwirfs14Aust[8
]
CatchMatOut.Recr[which(Years  per centin per cent 2014:EndYr),'RSW-O'] <- p_swains * FinalSwirfs14Aust[8]

CatchMatOut.Recr[which(Years  per centin per cent 2014:EndYr),'Capricorn Bunker'] <- FinalSwirfs14Aust[3]
CatchMatOut.Recr[which(Years  per centin per cent 2014:EndYr),'Byfield'] <- FinalSwirfs14Aust[2] + FinalSwirfs14Aust[6]

EndBegin <- 1961

nExtrapYear <- EndBegin - StYr + 1
ExtrapPar <- 0.2 # Catch grows 20 per cent per year
ExtrapMult <- exp(-ExtrapPar * (nExtrapYear + 1 - (1:nExtrapYear)))

CatchMatOut.Recr[which(Years  per centin per cent StYr:EndBegin),] <- cbind(ExtrapMult)  per cent* per cent rbind(Cat
chMatOut.Recr[which(Years==(EndBegin+1)),])

# adjustment for non-CCT observations
names(uvs)[names(uvs)=='GENUS_SPECIES'] <- 'Species'

uvs$Species[uvs$Species=='Plectropomus leopardus'] <- 'CCT'
uvs$Species[!uvs$Species=='CCT'] <- 'Other'

uvs$ID <- 1:nrow(uvs)

uvs <- st_as_sf(uvs, coords = c('SITE_LONG','SITE_LAT'), crs=st_crs(bio)) # make spatial

uvs$idx <- st_nearest_feature(uvs, strata) # get spatial index

uvs$Strata <- strata$Strata[uvs$idx] # assign population

step_one <- uvs  per cent> per cent group_by(Strata,Species)  per cent> per cent summarise(ab = mean(ABUNDANCE))
step_two <- step_one  per cent> per cent group_by(Strata)  per cent> per cent summarise(ab = sum(ab))
step_three <- step_one  per cent> per cent filter(Species=='CCT')
step_four <- step_three$ab / step_two$ab

CatchMatOut.Recr[,'Annan River'] <- step_four[1] * CatchMatOut.Recr[,'Annan River']
CatchMatOut.Recr[,'Byfield'] <- step_four[2] * CatchMatOut.Recr[,'Byfield']
CatchMatOut.Recr[,'Cape Palmerston'] <- step_four[3] * CatchMatOut.Recr[,'Cape Palmerston']
CatchMatOut.Recr[,'Capricorn Bunker'] <- step_four[4] * CatchMatOut.Recr[,'Capricorn Bunker']
CatchMatOut.Recr[,'Cedar Bay'] <- step_four[5] * CatchMatOut.Recr[,'Cedar Bay']
CatchMatOut.Recr[,'Conway'] <- step_four[6] * CatchMatOut.Recr[,'Conway']
CatchMatOut.Recr[,'Kurrimine Beach'] <- step_four[7] * CatchMatOut.Recr[,'Kurrimine Beach']
CatchMatOut.Recr[,'RA4'] <- step_four[8] * CatchMatOut.Recr[,'RA4']
CatchMatOut.Recr[,'RHE'] <- step_four[9] * CatchMatOut.Recr[,'RHE']
CatchMatOut.Recr[,'RK'] <- step_four[10] * CatchMatOut.Recr[,'RK']
CatchMatOut.Recr[,'RSW-O'] <- step_four[11] * CatchMatOut.Recr[,'RSW-O']

CatchMatOut.Recr[,'Kutini-Payamu'] <- step_four[1] * CatchMatOut.Recr[,'Kutini-Payamu'] # using annan river

CatchMatOut <- CatchMatOut.Comm + CatchMatOut.Recr

cdf1 <- as.data.frame(CatchMatOut.Comm)
cdf1$Year <- row.names(cdf1)
cdf1$Sector <- 'Commercial'

cdf2 <- as.data.frame(CatchMatOut.Recr)
cdf2$Year <- row.names(cdf2)
cdf2$Sector <- 'Recreational'

Combined <- rbind(cdf1,cdf2)
```