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Gascoyne Demersal Scalefish Resource

2024 Assessment

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Resource Assessment Report No. 3

Gascoyne Demersal Scalefish Resource

2024 Assessment

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Important disclaimer

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Executive Summary

The Gascoyne Demersal Scalefish Resource (GDSR) comprises over 80 species inhabiting inshore (20-250 m deep) and offshore (>250 m deep) waters in the Gascoyne Coast Bioregion (GCB; south of Onslow to north of Kalbarri). The GDSR is primarily targeted by commercial, charter and recreational boat-based line fishers. Snapper and Goldband Snapper are the indicator species selected for monitoring and assessing the status of the inshore suite of the GDSR, while Ruby Snapper and Greybanded Grouper are the indicators for the offshore suite.

Periodic assessments of GDSR indicator species demonstrated that historical fishing of Snapper led to stocks being below the limit reference level between 2010 and 2020. A formal harvest strategy was introduced in 2017 for the GDSR followed by a recovery plan for oceanic Snapper in 2018. The recovery plan is designed to limit total removals (including retained catches and estimated post-release mortality) of Snapper by all sectors to no more than 100 t and recover stocks to the threshold level by 2027 and the target level by 2037. The main commercial fishery targeting the GDSR, the Gascoyne Demersal Scalefish Managed Fishery (GDSMF), holds a Wildlife Trade Organisation accreditation (valid until January 2028; Department of Climate Change, Energy, the Environment and Water 2025).

This 2024 GDSR assessment is focused on the two main indicators (Snapper and Goldband Snapper) that collectively make up are a large proportion of the total catches retained by all fishing sectors. The assessment includes available catch and effort information and biological data (sizes and ages) for Snapper up to 2023 (inclusive) and for Goldband Snapper up to 2020 (inclusive).

Snapper

The 2024 integrated (Level 5) model assessment of the oceanic Snapper stock in the GCB, which incorporated catch, commercial catch rate and age composition data up to 2023, indicates a steadily increasing relative female spawning biomass (B_{rel}) in recent years, accompanying marked reductions in fishing mortality (F, associated with a decrease in catch to low levels) and several recent years of above-average recruitment into the fishery (2016-2018 cohorts). The point estimate of B_{rel} in 2023 was at 0.33 of the unfished level (60% CI = 0.27-0.39, corresponding to a 0.7 probability of being above the threshold level of 0.3). The estimate of F in 2023 was estimated as 0.07 year^{-1}, below the target reference level of 0.09 year^{-1} corresponding to 2/3 of the estimated rate of natural mortality (M) for this stock. The risk to oceanic Snapper in the GCB is assessed as **Medium** and the stock is classified as **Sustainable – Recovering**.

Model projections for different future catch scenarios of 75-150 t annually in 2025, 2026, and 2027 (i.e., until the next full assessment of the GDSR is due), and assuming constant average recruitment over this period, suggest that an increase in annual total removals to 150 t per year would not markedly impact on the estimated probability (>90%) of meeting the next (2027) recovery milestone for the stock of B_{rel} being above the threshold reference level. Note that as Snapper exhibits interannual variation in recruitment, the trajectory could differ.

Goldband Snapper

The 2022 catch curve and equilibrium biomass analysis (Level 3) assessment of Goldband Snapper in the GCB, based on age composition data from 2018-20, estimated that the average long-term F of 0.07 $year^{-1}$ has remained below the target level of 0.11 $year^{-1}$ (2/3M) for this stock. This likely reflects a period of low catches relative to the TACC for this species. The female B_{rel} in 2018-20 was estimated as 0.66 (95% CI = 0.59-0.72), well above the threshold reference level of 0.3 (proxy for B_{MSY}). The risk to Goldband Snapper in the GCB is assessed as **Low** and the stock is classified as **Sustainable – Adequate**.

Ecological Components

In addition to Snapper and Goldband Snapper, GDSR catches comprise a range of other demersal species, including tropical snappers, emperors and groupers. Commercial catches of those species have declined with recent reductions in effort, following the marked reduction in Snapper TACC in 2018 to recover this stock. Catches of other demersal species have remained steady in surveys of boat-based private recreational fishers from 2013-14 to 2020-21 and reported by charter fishers from 2014-15 to 2023-24. The risk to stocks of those species is assessed as **Low**.

Line fishing is highly selective and both bycatch and interactions with threatened and endangered species are low. There is also little impact with benthic habitats. The risk to these ecological components is assessed as **Negligible**.

As the quota system for commercial fishing and recreational fishing regulations restrict catches to a relatively small percentage of the total biomass available (e.g., retained Snapper catches are limited to fish above the minimum legal length), there is limited effect on the food chain. Therefore, the risk to the ecosystem is assessed as **Low**.

Assessment Overview

Target Stocks

Species/Stock	Risk	Fishing Mortality (*F*)	Relative Biomass (*B*)	Status
Snapper	Medium	*F* < Target	*B* ≈ Threshold	Sustainable – Recovering
Goldband Snapper	Low	*F* < Target	*B* > Target	Sustainable – Adequate

As the 2023 estimate of biomass of Snapper is around the Threshold level (60% CI = 0.27-0.39), and with the estimated fishing mortality well below F_{MSY}, Milestone 2 of the oceanic Snapper recovery plan (to rebuild biomass above Threshold with >0.8 probability) is likely to be met by 2027. Under all model projection scenarios (future annual catches of 75-150 t), Milestone 2 is estimated to have been met in 2024, and the stock is predicted to continue rebuilding to the target (Milestone 3). Note that as Snapper exhibits interannual variation in recruitment, the trajectory could differ.

Ecological Components

Feature	Risk	Comments
Other Retained Species	Low	Lower fishing effort and catches since management measures implemented to recover Snapper stock
Bycatch Species	Negligible	Highly selective fishing methods
ETP Species	Negligible	Highly selective fishing methods
Habitats	Negligible	Little direct impact on benthic habitats
Ecosystem	Low	Limited effect on food chain and management limits proportion of stocks exploited

Risks to ecological components affected by fishing activities targeting the GDSR are assessed as Acceptable (Medium risk or lower). In line with the harvest strategy, management should continue to focus on meeting objectives relating to ecological, economic and social objectives.

Socio-Economic Components and External Drivers

Feature	Risk	Comments
Economic	Medium	Level 2: GVP $1-5 million
Social	Medium	Level 4: Provides employment, recreational fishing and associated tourism
External Drivers (Climate)	Medium sensitivity	Medium sensitivity for Snapper and low for Goldband Snapper. Highest level reported.
External Drivers (Other)	Low	Commonwealth trawl fishing rarely occurs.

1 Background

1.1 Resource Overview

The Gascoyne Demersal Scalefish Resource (GDSR) comprises over 80 demersal species inhabiting inshore (20-250 m deep) and offshore (>250 m deep) waters in the Gascoyne Coast Bioregion (GCB; south of Onslow to north of Kalbarri). The GDSR is primarily targeted by commercial, charter and recreational boat-based line fishers. Indicator species selected for monitoring and assessing the status of the inshore suite of the GDSR include the oceanic stock of Snapper and Goldband Snapper, while indicators for the offshore suite include Greybanded Grouper and Ruby Snapper.

The main commercial fishery targeting the GDSR, the Gascoyne Demersal Scalefish Managed Fishery (GDSMF), use mechanised handlines to target primarily Snapper and Goldband Snapper. Other demersal species caught include tropical snappers, emperors, and groupers. Licensed charter vessels and private recreational vessels targeting the GDSR out of Denham, Carnarvon and the Ningaloo-Exmouth area catch a similar range of demersal species (Jackson et al. 2020).

The GDSR has been managed under a formal harvest strategy since 2017 (DPIRD 2017). Stock assessments of key indicator species are undertaken periodically to determine stock status and set the total allowable commercial catch (TACC) for Snapper and other mixed demersal species, and to manage recreational fishing. A recovery plan was implemented for the oceanic Snapper stock in 2018 (DPIRD 2020), following an assessment demonstrating that historical overfishing had led to this stock being reduced below the limit level (Jackson et al. 2020). Management measures introduced in 2018 to recover the stock included a substantial reduction of the Snapper TACC and a closure of an area at the northern end of Bernier Island to fishing for Snapper from 1 June to 31 August to protect key spawning aggregations of this species.

1.2 Assessment Approach

The methods used by the Department to assess the status of aquatic resources in WA have been categorised into five broad levels, ranging from relatively simple analysis of catch and effort information, through to the application of more sophisticated analyses and models that incorporate biological data (e.g., Braccini et al. 2021; Newman et al. 2024). The relevance and applicability of each assessment level varies among stocks and is determined based on the level of ecological risk, the biology and population dynamics of the relevant species, the characteristics of the fisheries exploiting the species, and types, quantity and quality of available data.

Irrespective of the types of assessment methods used, all stock assessments undertaken by the Department apply a risk-based, weight-of-evidence approach. This requires the consideration of each available line of evidence, including outputs from quantitative (empirical and/or model-based) analyses, and qualitative lines of evidence such as biological and fishery information that describe the inherent vulnerability of the species to fishing. For each stock, all the lines of evidence are considered within the Department's ISO 31000 based risk assessment framework to derive an overall risk status from the combinations of consequence and likelihood scores (Fletcher 2015).

1.3 Scope

This report provides an assessment of the GDSR, following the principles of ecosystem-based fisheries management (EBFM; Fletcher 2015). The document provides information relevant to monitoring of the broader resource (Section 2), as well as more detailed stock assessment outputs for key target species (Section 3). Additional information relevant to assessing the risk of fishing to other ecological components targeting the GDSR is presented in Section 4.

As outlined in the GDSR harvest strategy, the resource is monitored primarily through annual reviews of available catch information, as well as periodic model-based assessments of stock status for indicator species (DPIRD 2017). Since the implementation of the recovery plan for oceanic Snapper, the annual review process considers estimates of the total removals from this stock, including retained catches and estimates of post-release mortality (PRM) of Snapper for each fishing sector, to ensure these are maintained below a recovery benchmark aimed to recover the stock to the threshold level within one generation time (i.e. by 2027) and to the target level by 2037.

Stock assessments are conducted periodically for the GDSR indicator species (Snapper and Goldband Snapper), in addition to other important inshore or offshore species when data are available. These assessments (see Appendix 1 for more detail) provide estimates of relative female spawning stock biomass (B_{rel}) and fishing mortality (F). These estimates are compared to internationally recognised biological reference points to assess status and risk to stocks (Department of Fisheries 2015), and to help ensure the rate of recovery of oceanic Snapper is sufficient to rebuild the stock within the recovery timeframe.

This 2024 assessment provides the most recent integrated (Level 5) model estimates of B_{rel} and F for Snapper based on data up to 2023 (inclusive), along with the results of the 2022 catch curve and per-recruit (Level 3) assessment of Goldband Snapper.

2 Resource Assessment

2.1 Catch

The GDSR comprise over 80 demersal species landed by commercial, charter and recreational fishers in inshore and offshore waters of the GCB. Inshore demersal species occurring in waters 20-250 m deep typically contribute more than 95% to catches of commercial (GDSMF), charter and recreational fishers. Catches of inshore demersal species in the GDSR are dominated by seven species across those fisheries, including Snapper and Goldband Snapper (Table 2.1). Catches of offshore species contribute < 5% to commercial, charter and recreational catches, dominated by Ruby Snapper (Table 2.1).

Although commercial catches in the GCB have historically been dominated by Snapper, the magnitude and composition of GDSMF catches changed markedly after management measures were introduced in 2018 to recover the oceanic stock of this species. Snapper now comprises a much lower proportion of the catch. In 2022-23, total retained catches of demersal species by the GDSMF were 142 t, lower than in recent fishing seasons (range 158-195 t between 2019-20 and 2021-22). Only five species each contributed more than 2% to catches and seven species comprised 82% of the total (Table 2.1). Retained catches of demersal species by the GDSMF in 2022-23 were below the combined TACC of 278 t (51 t Snapper and 227 t of other species) and are considered acceptable.

Charter fishers in the GCB land a wide range of fish species, with the seven dominant demersal species listed in Table 2.1 collectively comprising 60% of overall retained catches in numbers in 2022-23. A total of 51 t demersal catch (currently reported for the top 10 species) was retained by charter fishers in the GCB in 2022-23, which was at a similar level to catches retained in 2021-22 (47 t) and 2020-21 (52 t). Most of these catches (36 t) were landed in the Carnarvon-Shark Bay area (including 5 t in the inner gulfs), with 15 t caught in the Ningaloo-Exmouth area. The retained charter catch of Snapper in 2022-23 was 18 t (Table 2.1), of which 14 t were taken from the oceanic stock.

Catches of the top 15 demersal species retained by boat-based private recreational fishers in the GCB in 2020-21 was 93 t (95% CI = 74-112 t), with 90% of those catches represented by the seven dominant species (Table 2.1; Ryan et al., 2022). The 2020-21 recreational catches in the GCB were higher than those in 2017-18 (86 t) but at a similar level to those in 2015-16 (100 t) and 2013-14 (94 t). Snapper catches by recreational fishers in 2020-21 were 16 t (Table 2.1), of which the majority are caught within the inner gulfs of Shark Bay. An estimated 2 t of oceanic Snapper were landed by recreational fishers in 2020-21, based on an estimated proportion of recreational Snapper catches in the GCB taken in oceanic waters (~ 15% based on GCB catches of 21 t in 2017-18 and inner gulf catches in 2018-19 of 18 t, see Taylor et al. 2019).

In 2022-23, the total removal of oceanic Snapper by all fishing sectors was estimated as 69 t, well below the overall recovery benchmark of 100 t. The total removal by the commercial GDSMF was 51 t (48 t retained and 3 t estimated PRM). Total removals of oceanic Snapper by charter and private recreational fishers were estimated as 16 t (14 t retained and 2 t PRM in 2022-23) and 3 t (2 t retained and 1 t PRM in 2020-21), respectively.

Table 2.1. Retained catches (tonnes, t) of dominant inshore and offshore species of demersal scalefish landed by commercial, charter and recreational fishers in the GCB in 2022-23 (commercial and charter) and 2020-21 (recreational; see Ryan et al. 2022). Species listed represent ~ 80% of retained estimated catches of demersal species by weight since 2011. Note that catches have been rounded to the nearest 1 t.

Species	Commercial	Charter	Recreational
Inshore demersal species			
Goldband Snapper	61	13	9
Snapper	48	18	16
Rankin Cod	3	4	10
Red Emperor	3	5	11
Redthroat Emperor	2	3	8
Grass Emperor	<1	1	18
Spangled Emperor	<1	5	12
Offshore demersal species			
Ruby Snapper	5	<1	5
Greybanded Grouper	3	<1	<1

2.2 Effort

Since 2008, the number of active vessels in the GDSMF has decreased from ~ 20 to an average of 10 vessels fishing following substantial reductions in Snapper TACC in 2018 (Table 2.2). In the 2022-23 fishing season, 8 GDSMF vessels fished for a total of 424 days. Many of the GDSMF fishers also hold licences in other commercial fisheries and only operate seasonally in this fishery.

The number of charter operators fishing in the GCB has remained relatively stable over the last two decades, mostly fluctuating around 30-40 vessels annually. In 2022-23, 36 charter vessels conducted a total of 1,607 fishing trips in the GCB (Table 2.2). Most of the charter fishing effort is focused in the Ningaloo-Exmouth region (27 vessels, 970 trips), compared to 18 vessels (637 trips) reported in the Carnarvon-Shark Bay area.

The Statewide recreational fishing surveys undertaken since 2011-12 show estimated number of boat days, fishing trips and hours fished by boat-based recreational fishers in the GCB declined between 2011-12 and 2013-14 but have since exhibited a steady increase back to their 2011-12 levels (Fisher and Fairclough 2024). Private recreational vessels are estimated to have fished 313,873 days (95% CL = 276,096-351,650 days) in 2021-22 (Ryan et al. 2022).

Table 2.2. Performance statistics relating to fishing effort (fishing days/trips, number of active vessels) of the key fishing sectors targeting the WCDSR.

Sector	Previous season	Current season	Further description
Commercial (GDSMF)	2021-22: 358 days (10 active vessels)	2022-23: 307 days (8 active vessels)	
Charter	GCB, 2021-22: 1,019 trips (28 vessels)	GCB, 2022-23: 1,216 trips (35 vessels)	Trips recording demersal catches, includes inner gulfs of Shark Bay
Recreational	GCB, 2017-18: 42,367 days	GCB, 2020-21: 55,327 days	Boat-fishing days in GCB (Ryan et al. 2022)

2.3 Social and Economic

The GDSR provides high social and/or economic amenity through employment in fishing and fish processing, but also through recreational fishing and fishing-related tourism. The commercial fishery provides fish supply to consumers via markets and restaurants both locally and in Perth. The estimated gross value of product (GVP) for the GDSR in 2022-23 was $1-5 million (Table 2.3). The value of recreational fishing in WA was estimated at $1.1 billion annually, with around 13% of the total recreational boat-based fishing effort being in the GCB (Ryan et al. 2022; Moore et al. 2023).

The GDSR harvest strategy defines the social and economic performance of each sector against social and economic objectives (DPIRD 2017). These are applied within the constraints of meeting objectives for ecological sustainability, and while having regard to the objectives of other sectors. Performance against socio-economic objectives is currently measured for the commercial sector based on gross value of product levels, and for charter and boat-based recreational fishers as participation relative to historical levels (Table 2.3).

Following management actions taken in 2018 to recover the oceanic Snapper stock, there is a medium level of risk to both social value and economic returns relating to the GDSR.

Table 2.3. Performance statistics (GVP, participation) relating to the current socio-economic objectives for the GDSR.

Sector	Previous season	Current season	Further description
Commercial (GDSMF)	2021-22: $1-5 million	2022-23: $1-5 million	Below threshold ($3 million) due to reduced Snapper TACC implemented in 2018 as part of the Snapper Recovery Plan
Charter	GCB, 2021-22: 11,008 client days	GCB, 2022-23: 10,850 client days	Between between target and upper threshold (10,176 and 12,211 client days, respectively)
Recreational	GCB, 2017-18: 178,633 hours fished	GCB, 2020-21: 220,919 hours fished	Between lower threshold and target (203,144 and 253,930 hours, respectively)

3 Species Assessment

3.1 Snapper

3.1.1 Catch

Most Snapper catches in oceanic waters of the GCB have historically been retained by the commercial sector (Figure 3.1). Snapper fishing in this region dates back to the early 1900s, with annual catches in the 1960s, 1980s and 1990s often exceeding 500 t (Figure 3.1). Catches of Snapper peaked at around 1,300 t in 1985, triggering the fishery transitioning to a limited-entry commercial fishery. A Total Allowable Commercial Catch (TACC) for Snapper of 564 t was first introduced in 2001.

Since the former Shark Bay Snapper Managed Fishery became the GDSMF in 2008, daily logbook data show that commercial Snapper catches remained steady around 230-240 t until 2014, after which they declined to 133 t in 2017 (Figure 3.1). During this period, Snapper still comprised most of the demersal catch in the GDSMF (Figure 3.2). Following the 2017 stock assessment, which indicated that spawning biomass of the stock had declined to around the limit level, the TACC for this species was substantially reduced to 51 t. Since 2018, a much lower proportion of the total annual GDSMF catch has comprised Snapper (Figure 3.2).

Most of the GDSMF Snapper catch is taken during winter (June-August) when this species aggregate to spawn over inshore reefs to the north and west of islands that bound Shark Bay (Figure 3.2, Figure 3.3). Spatial analysis of daily logbook data since 2008 provides no evidence of marked expansion/contraction in areas fished in recent years, except that catches in several key (10×10 nm) fishery blocks have reduced markedly since the introduction of the North Bernier Island spawning closure in 2018 (Figure 3.3).

In 2022-23, around 75% of the total catch of Snapper in oceanic waters of the GCB was taken by the commercial GDSMF (48 t). The most recent estimate of recreational boat-based catch of Snapper in the GCB (including the inner gulfs of Shark Bay) was 16 t in 2020-21 (Ryan et al. 2022), of which ~ 2 t are taken from oceanic waters. The charter catch reported in 2022-23 was 18 t in the GCB, of which 14 t was taken from the oceanic stock. Charter vessels operate in some of the areas where the commercial fleet operates, whereas most recreational fishing tends to occur further inshore, closer to Carnarvon and Denham.

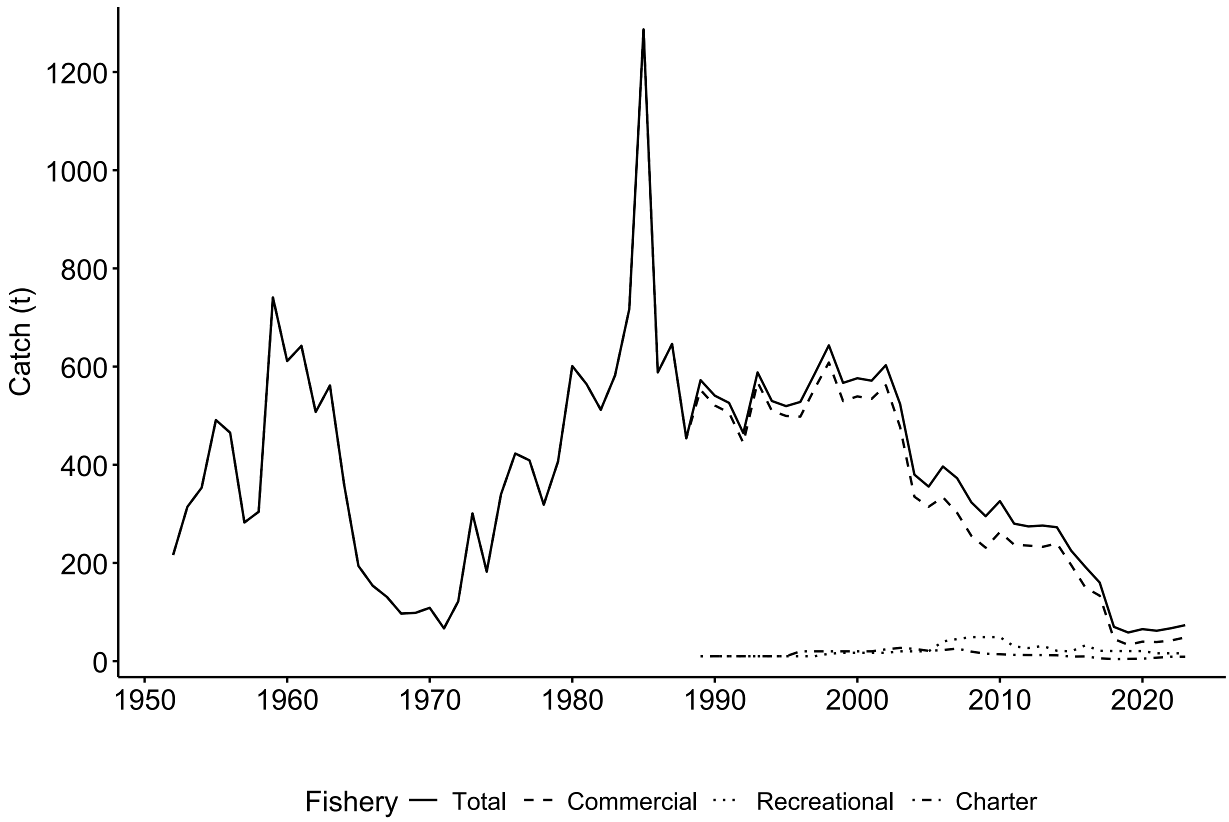

Figure 3.1. Annual catches (in tonnes, t) of Snapper collectively retained by commercial, charter and recreational fishers in oceanic waters of the GCB since 1951.

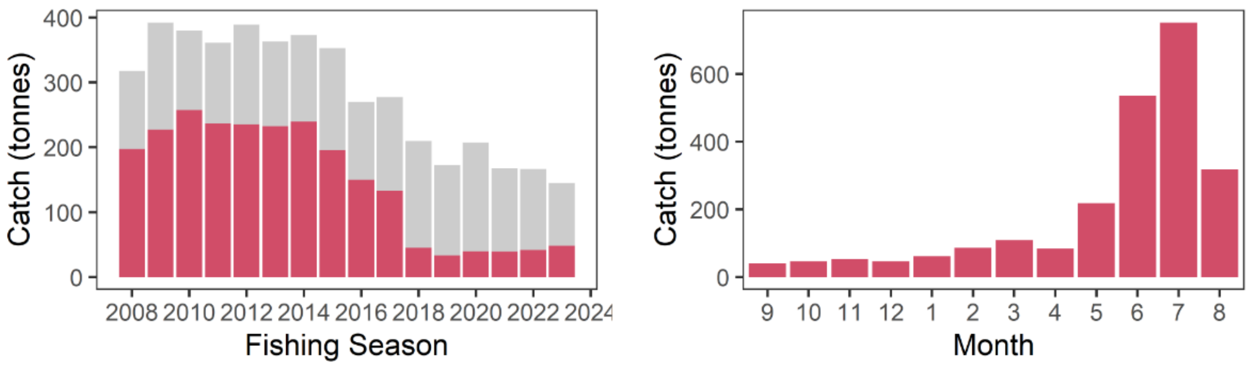

Figure 3.2. Annual (left) and monthly (right) retained catches of Snapper (in red) and other demersal species (in grey) recorded in daily logbooks from the GDSMF since 2007-08. Note that each fishing season extends from 1 Sep to 31 Aug.

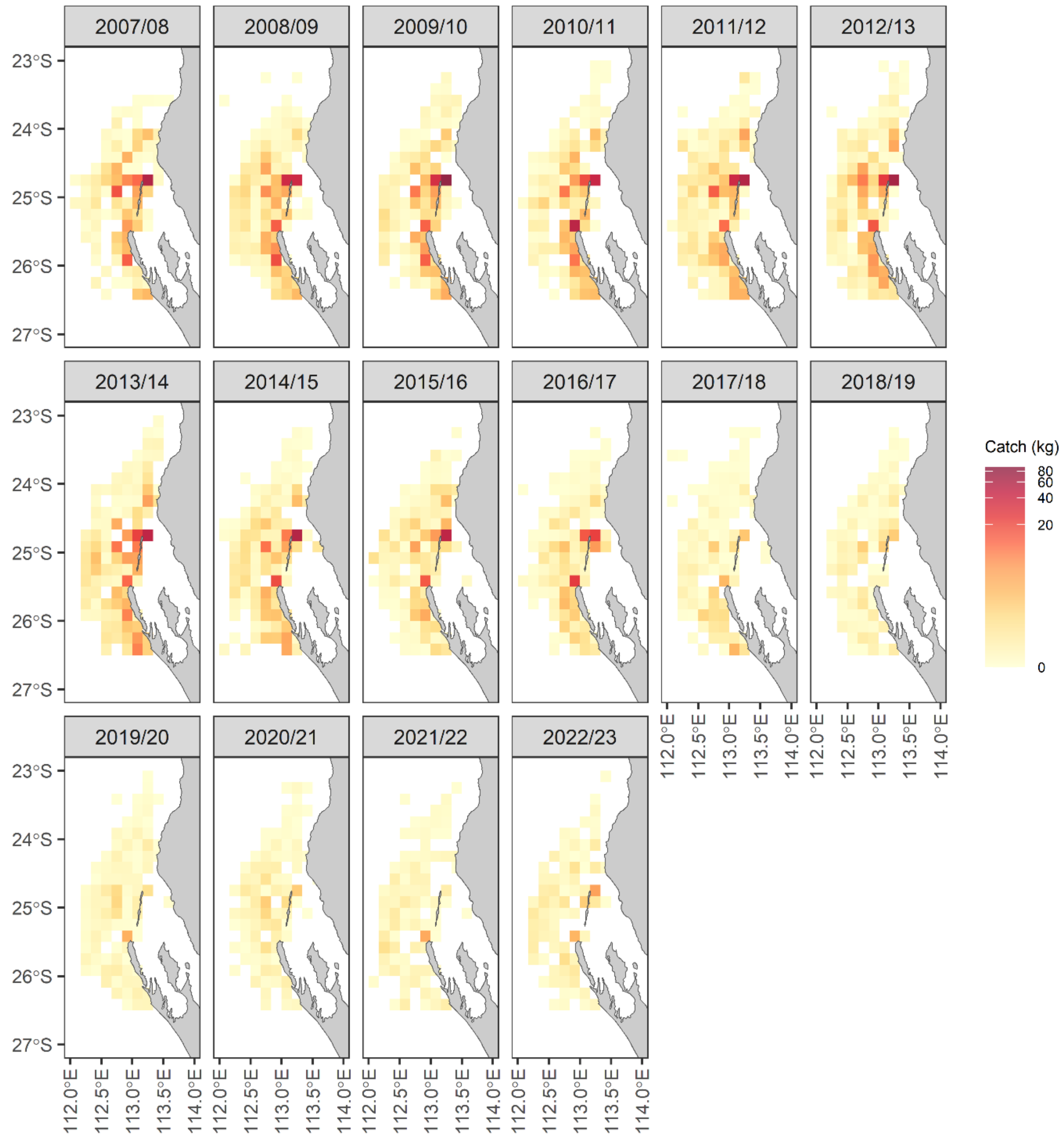

Figure 3.3. Spatial distribution of annual Snapper catches by 10 nm reporting blocks in the GDSMF since 2007-08. Note that data are grouped by fishing season (1 Sep – 31 Aug).

3.1.2 Catch Per Unit Effort

Standardised commercial catch per unit effort (CPUE) time series for Gascoyne oceanic Snapper are calculated separately from monthly logbook data (1977-1989 and 1990-2007) and daily logbook data (2008-2017 and 2018-2023). The split in the monthly logbook CPUE time series corresponds to the introduction of finer-scale fishery-specific reporting blocks within Shark Bay, whereas the split in daily logbook CPUE coincides with a substantial management change resulting in a marked reduction in Snapper TACC. Each time series has been adjusted for assumed changes in fishing efficiency over time (see Appendix 1 for more detail on CPUE analyses).

The standardised time series of Snapper CPUE from monthly returns remained relatively stable over the 1977-1989 period and showed a progressive decline from 1990 to 2007 (Figure 3.4). The standardised CPUE based on daily logbook information increased between 2008 and 2014 before declining to a markedly lower level in 2015-2017 (Figure 3.5). The relatively high CPUE observed in 2013 and 2014 is consistent with the Snapper CPUE trend in the northern parts of the West Coast Bioregion and was likely driven by a pulse of good recruitment prior to the significant decline in CPUE in 2015. Following the substantial reduction in TACC to recover the stock, the Snapper CPUE remained relatively stable between 2018 and 2022 (Figure 3.5).

There was a notable increase in the standardised CPUE in the 2023 fishing season, almost doubling from the 2022 index (Figure 3.5). This increase was supported by inspection of spatial patterns in CPUE for several commercial operators who, in recent years, operated in the same general areas of the fishery. Overall, this increasing trend in Snapper CPUE is indicative of stock rebuilding.

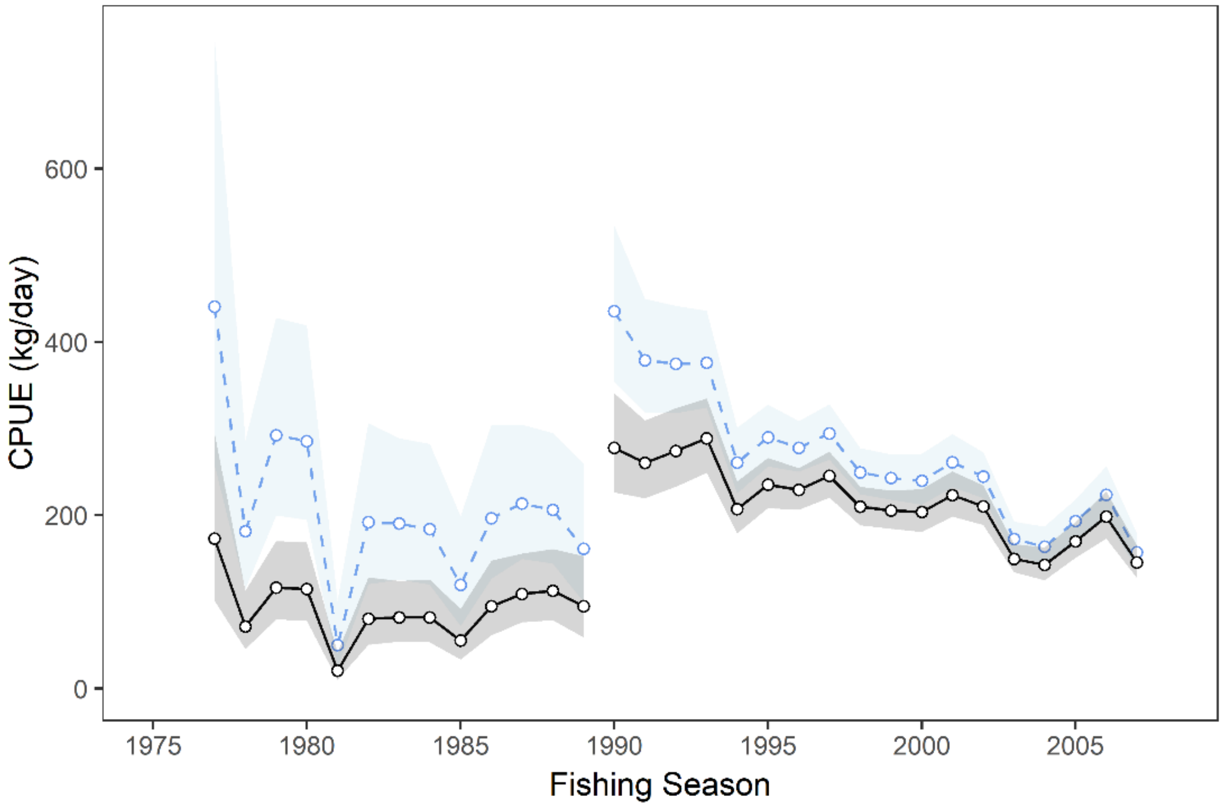

Figure 3.4. Standardised commercial CPUE (kg/day) for oceanic Snapper from monthly logbook data for the two periods: 1977-1989 and 1990-2007. Note that the two periods indicate separate analyses and therefore must be treated as separate indices. The blue lines indicate the standardised CPUE adjusted for fishing efficiency (as per Marriott et al. 2011, as calculated for the nearby West Coast Demersal Scalefish (Interim) Managed Fishery).

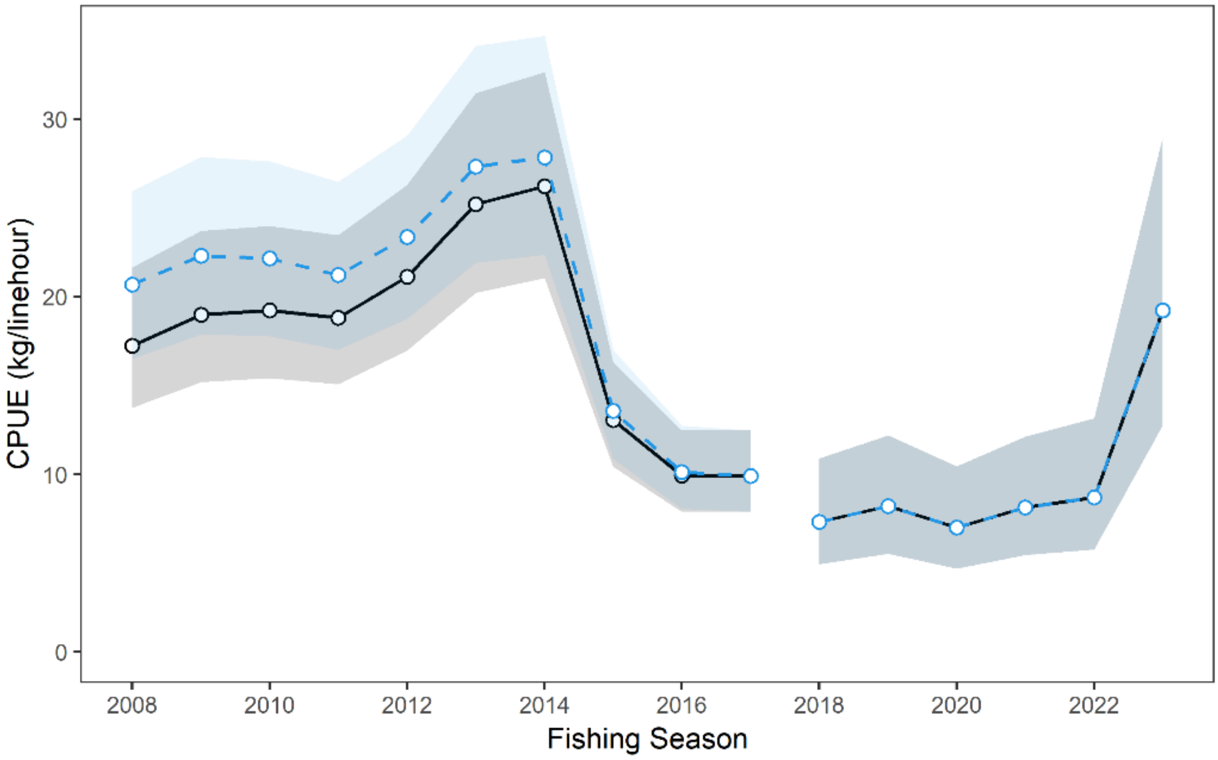

Figure 3.5. Standardised commercial CPUE (kg/line hour) for oceanic Snapper from daily logbook returns for the two periods: 2008-2017 and 2018-2023. Note that the two periods indicate separate analyses and therefore must be treated as separate indices. The blue lines indicate the standardised CPUE adjusted for assumed changes in fishing efficiency (2% per year in first period, 0% in second period) relative to the reference year for each period (i.e., 2017 and 2023, respectively).

3.1.3 Length and Age Compositions

Biological data for Gascoyne oceanic Snapper have been collected from commercial line catches since the 1980s, with age data available from the early 1990s. Most biological samples were obtained from commercial catches in the vicinity of the main spawning grounds between June and August. Since 2018, when the commercial TACC was reduced to a historically low level and a closure was implemented to protect the key spawning aggregations north of Bernier Island during the key spawning period (June-August inclusive), fishery-independent research surveys have been undertaken annually to provide samples for assessments. Although fish were sampled using the same line fishing methods as used by commercial fishers, the research surveys were limited to three trips per season and conducted in a relatively small area (primarily inside the spawning closure) compared to the full spatial extent of the commercial fishery where commercial fishers operate.

Fishery-dependent data

The majority of fish sampled from commercial Snapper catches since the 1990s range between 400 mm and 750 mm in total length (TL), with the lower end of the length compositions sometimes close to ‘knife-edged’, associated with the effect of the minimum legal length (MLL) in place for this species, but with these compositions also being affected by variations in annual recruitment strength (Figure 3.6). The mean length of (aged) fish increased from 504 mm TL in 2004 to 643 mm TL in 2017 before decreasing to 517 mm in 2021. The lower average mean lengths in 2020 and 2021 are likely due to the

MLL reduction in 2018 from 410 to 380 mm, and likely also affected by a relatively strong recent recruitment.

Age composition samples from commercial catches have primarily comprised relatively young fish between 5-10 years of age, with the mode varying between years (Figure 3.7). This variation is likely due, at least in part, to variability in recruitment, combined with impacts of fishing and/or differences in sampling. Although a few fish older than 20 years were present in samples collected in most years since the early 1990s, they were absent in 2013-14, and since 2017 (Figure 3.7). The limited number of older fish in recent samples indicates that the population has experienced high levels of exploitation, also consistent with the limited numbers of fish >15 years in survey samples. As only limited commercial fishing has been undertaken since management changes were introduced in 2018, commercial sample sizes in 2020 and 2021 were much lower than earlier samples.

Fishery-independent data

The size and age data collected annually during fishery-independent research surveys in the north Bernier Island spawning closure since 2018 indicate that Snapper are first selected by the line fishing gear at around 300 mm TL and 2-3 years of age (Figure 3.8). In contrast to data sampled from commercial catches, impacted by the MLL, the survey data provide an earlier signal of variations in annual recruitment to this stock. In particular, the composition of ages at length data from the fishery-independent surveys show the 2016 cohort recruiting as 2-year old fish to catches in 2018, which together with subsequent 2017 and 2018 cohorts (mostly recruiting as 3-year-olds fish in 2020 and 2021, respectively) comprise the majority of recent catches (Figure 3.8).

In contrast to survey data collected between 2018 and 2021, which include several cohorts spawned prior to 2015, the two most recent years of age sample data were dominated by recruitment from 2016-2018 (Figure 3.8). Given the very low annual catches harvested from the stock since 2018, this lack of older fish is unlikely to reflect removals due to fishing mortality, but rather indicates that the recent survey data may not be fully representative of the overall stock. Anecdotal reports from key fishers suggest that larger fish have been caught on reefs inshore of the survey area, and when fishing during the night (with survey fishing predominantly conducted during daylight hours), suggesting any diel changes in fish behaviour may influence catchability and thus the lengths of fish in samples.

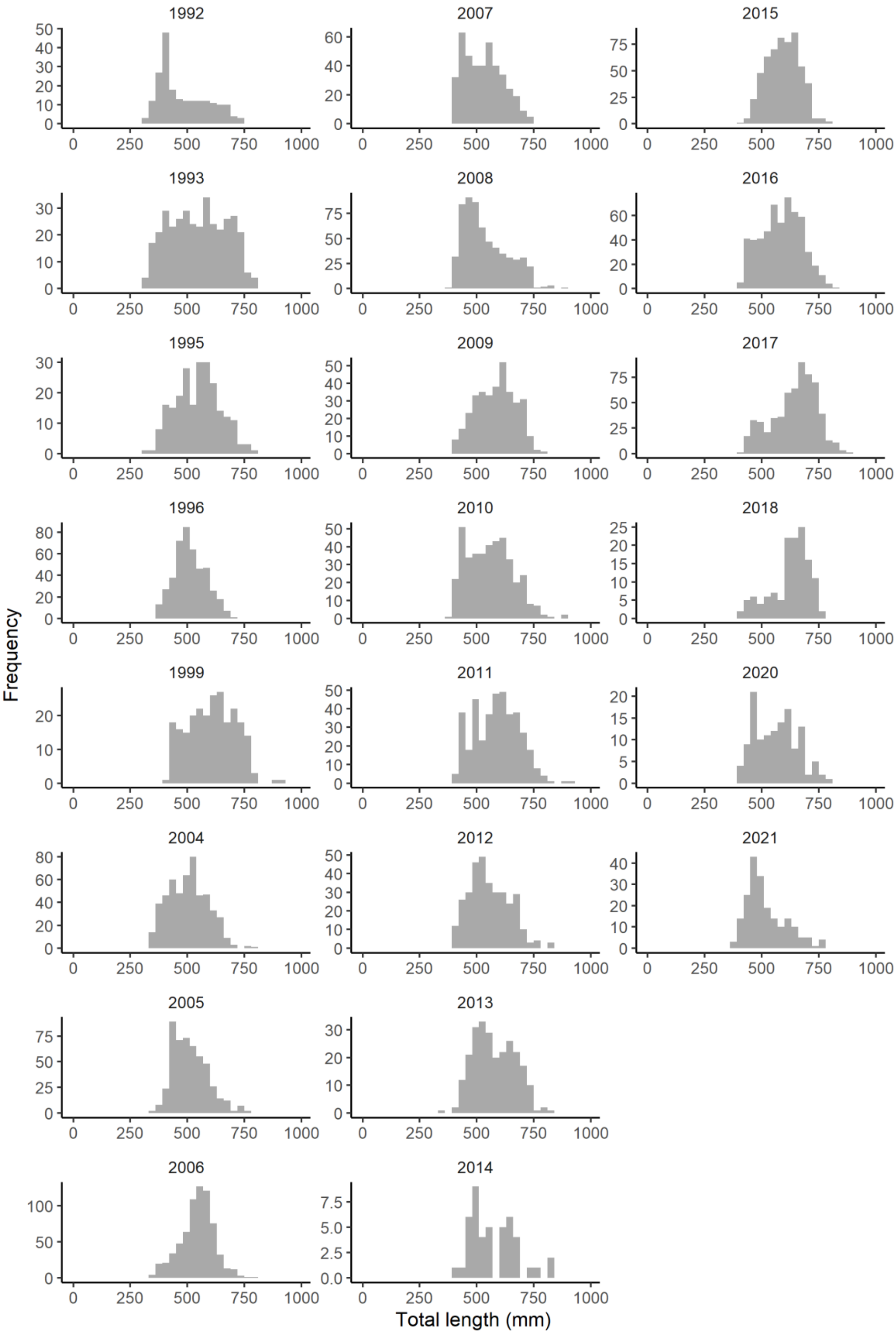

Figure 3.6. Length-frequency distributions for Gascoyne oceanic Snapper sampled from commercial line catches since 1992 (note these include aged fish only).

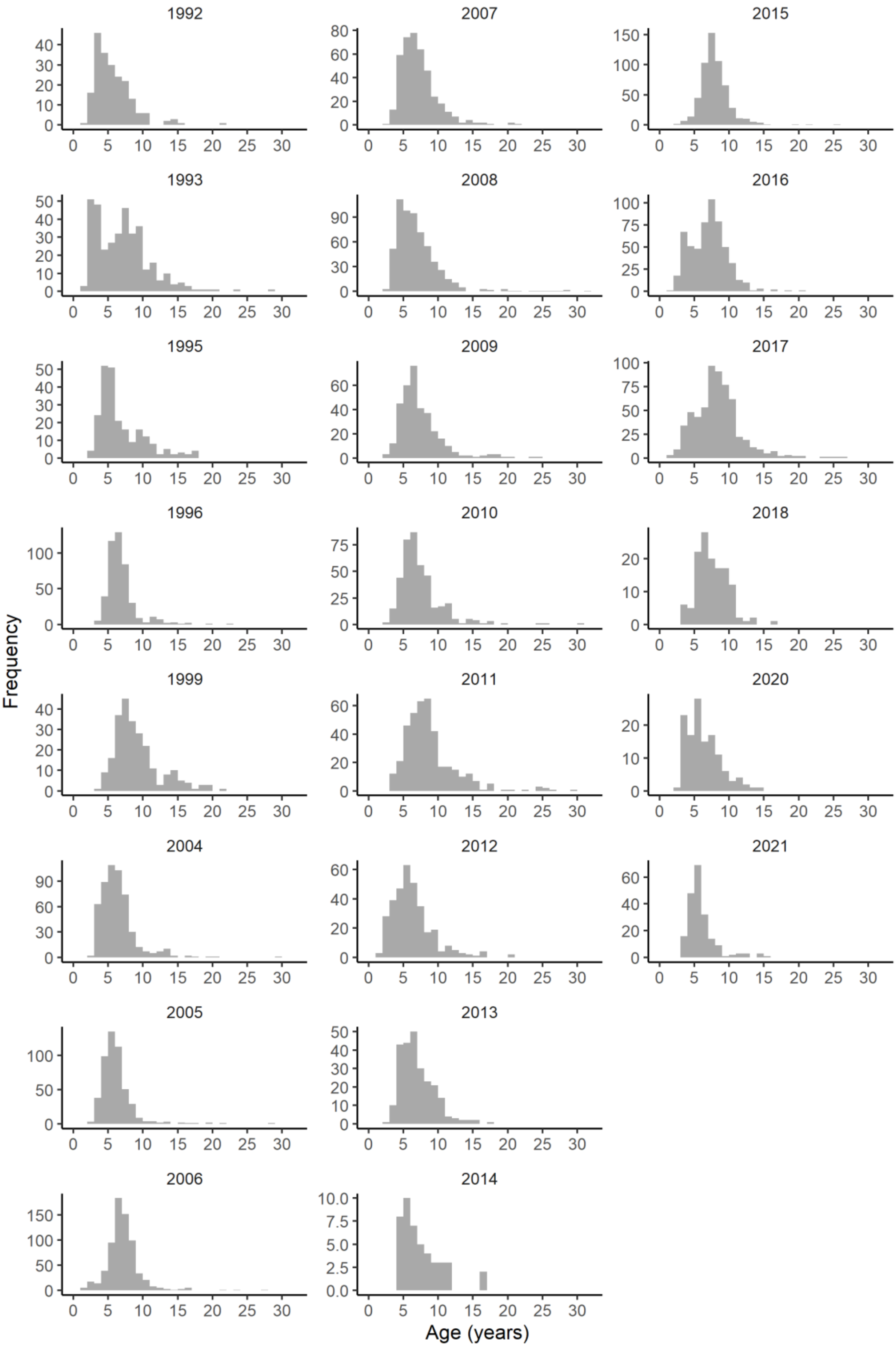

Figure 3.7. Age-frequency distributions for Gascoyne oceanic Snapper sampled from commercial line catches since 1992.

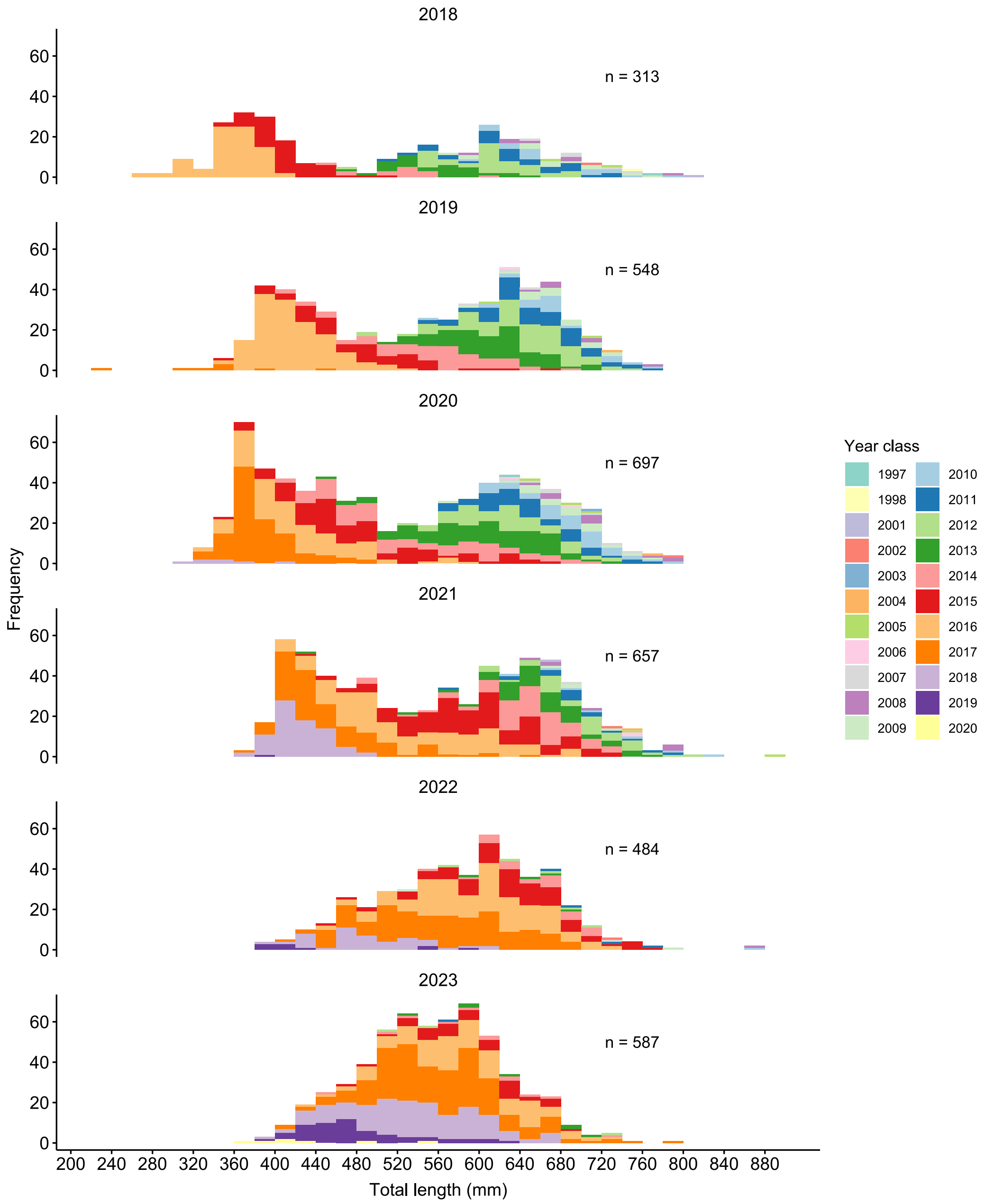

Figure 3.8. Composition of ages at length for Gascoyne oceanic Snapper sampled by fishery-independent line fishing surveys undertaken between 2018 and 2023. Note that the different colours correspond to individual year classes (cohorts) within each 20 mm length class.

3.1.4 Environmental Impacts

Climate projections for WA (Pilbara to Albany) include increases in sea surface temperature, number of marine heatwave days, sea level increases, ocean acidification, intense and variable storms and rainfall decreases (Chandrapavan and Jackson 2024). Recruitment success of demersal species varies between years, influenced in part by environmental factors. Spawning of Snapper is closely linked to temperature (peaking during winter in the GCB when water temperatures are ~ 19-21°C (Wakefield et al., 2015). Warming waters and more frequent marine heatwaves may result in water temperatures not falling to those levels in winter or a change in the time of year when those temperatures occur. This could affect the timing of the spawning period and/or recruitment success of this species. Projections of a weaker Leeuwin Current and increased El Niño events may affect dispersal of eggs and larvae during spawning. The overall impact of these on the broader stock is unclear at this stage. Reduced rainfall may negatively influence primary productivity and larval prey in nearshore nursery areas. A recruitment index for oceanic Snapper is being developed with more work required to better understand relationships between annual abundance of the earliest age classes and key environmental drivers (wind, sea surface temperature, chlorophyll, sea level, and Leeuwin Current strength; Jackson et al. 2023).

Snapper is a temperate species and based on its abundance, distribution and phenological characteristics in the GCB stock, it has been assessed as having medium sensitivity to the effects of climate change (Jackson et al. 2024). A risk assessment will be completed to evaluate the potential for negative effects on Snapper of future predicted environmental characteristics, such as temperature and productivity.

3.1.5 Model Assessment

3.1.5.1 Level 5 Assessment

Over the history of the fishery, the estimated relative female spawning biomass (B_{rel}) (i.e. current estimated stock level relative to that expected for an unfished stock) of Snapper in oceanic waters of the GCB declined from ~ 0.8 in 1952 (assuming a relatively low initial fishing mortality, F, of 0.03 year^{-1} in earlier years) to ~ 0.5 in the mid-1960s, before rebuilding over the next decade as annual catches reduced back to ~ 200 t (Figure 3.9a). As annual catches increased to a peak close to 1,300 t in 1985, and continued fluctuating around 500 t until TACC reductions were first implemented in the mid-2000s (Figure 3.9c), the estimated B_{rel} shows a gradual decline to below the threshold level of 0.3. The estimated annual F peaked at more than double the value of natural mortality (M) around 2010, with B_{rel} falling below the limit level of 0.2 around that same time (Figure 3.9a, b).

Following a gradual decline in standardised catch per unit effort (CPUE) from 1990 to 2007, the CPUE briefly stabilised and then slightly increased in 2013-14 before decreasing markedly to a low level in 2015 (Figure 3.9d). Since 2018, when substantial management measures were introduced to facilitate stock recovery, annual catches have been maintained at ~ 75 t. In response to the large decrease in the estimated annual F over these years associated with this reduced catch, the estimated B_{rel} shows a rapid increase to just above the threshold level in 2023, as is also indicated by a substantial increase in CPUE observed from 2022 to 2023 (Figure 3.9d). The described trends in B_{rel} and F over time are summarised in the Kobe plot shown in Figure 3.9e.

In 2023, female B_{rel} was estimated at 0.33 (60% CI = 0.27-0.39, corresponding to a 0.7 probability of being above the threshold level of 0.3). The estimated F in 2023 was 0.07 year^{-1} (60% CI = 0.05-0.08 year^{-1}), i.e., below the target level (the level most suitable for a stock at or above B_{MSY}) corresponding to 2/3M (0.09 year^{-1}). Note that for an overfished stock, however, an even lower level of F, as can be determined from model projection analyses, may be required to rebuild the stock to an acceptable level in a desired timeframe. In addition to the current low TACC (well below the estimated MSY, Figure 3.9c), the recent increase in stock levels has been supported by above-average recruitment to the stock driven by relatively strong cohorts spawned in 2016-2018 (Figure 3.9f-h). This recent recruitment pulse follows an extended period of below-average annual recruitment to the stock estimated since the late 1990s, when spawning stock levels declined below the target level. The trend for estimated annual recruitment levels does not indicate any years of complete recruitment failure, despite female B_{rel} breaching the limit reference level of 0.2 between 2010 and 2020.

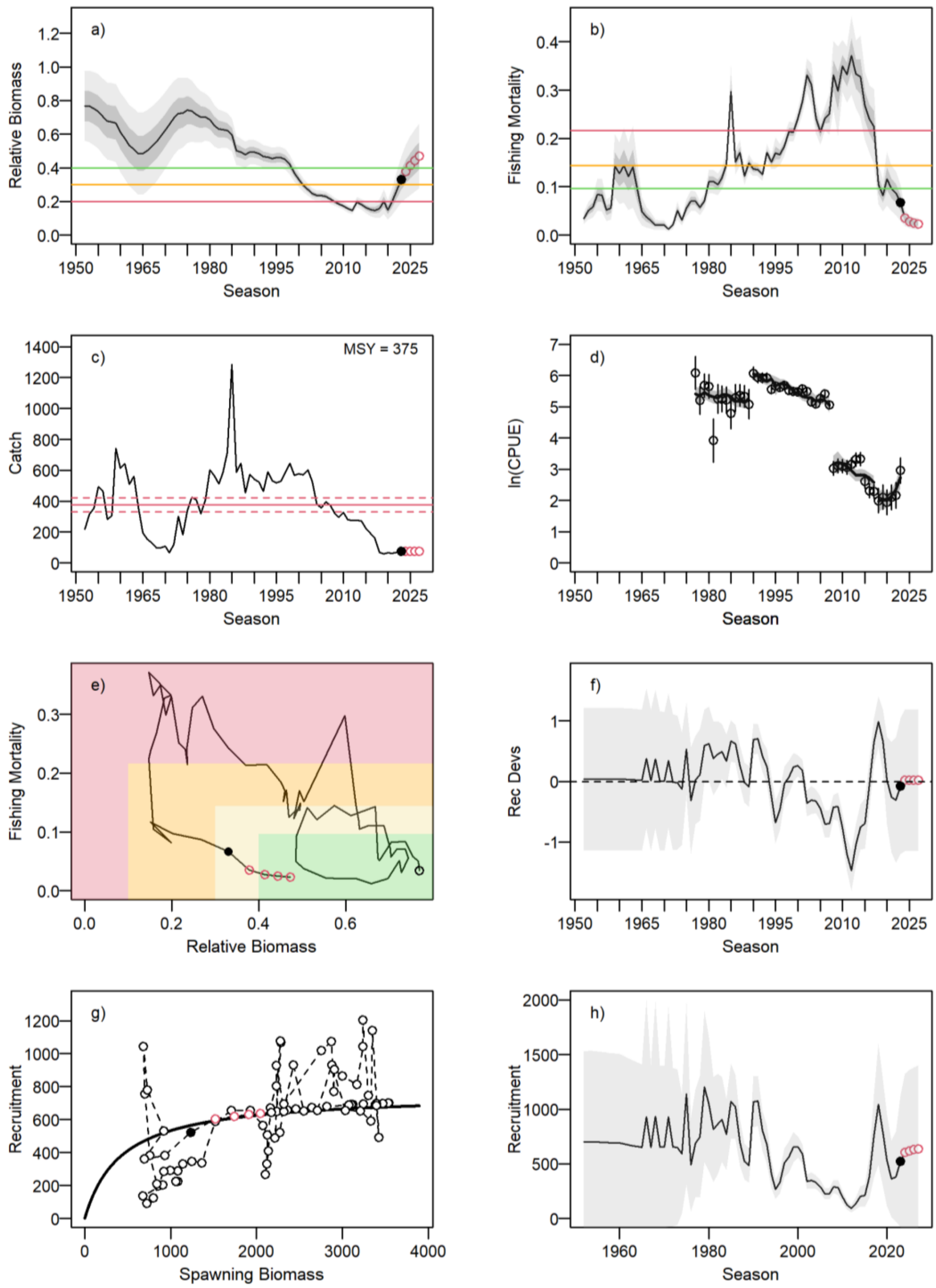

Figure 3.9. Outputs from the bespoke integrated model, including estimated a) relative female spawning biomass B_{rel}, b) fishing mortality (F, y^{-1}), c) retained catches (tonnes; black line) and maximum sustainable yield (MSY ±95% CI; red lines), d) commercial CPUE in log space (dotted lines and shading, with observed values shown as circles), e) Kobe plot showing the trajectory of B_{rel} and F over time, f) annual recruitment deviations in log space, g) stock-recruitment relationship with annual recruitment and B_{rel}, and *h*) annual recruitment levels. Values are estimated for 1952-2023 and projected for 2024-2027 (red open circles) with specified constant catch (75 t). Dark grey and light grey shaded areas represent 60% and 95% CIs, respectively. Horizontal lines in plots a and b denote the target (green), threshold (yellow) and limit (red) reference levels for B_{rel} (i.e., 0.4, 0.3 and 0.2, respectively) and F (relative to natural mortality M, i.e., 2/3M, M and 1.5M, respectively), which are also represented as the coloured areas in the Kobe plot (e).

Model projections

Model projections for different future catch scenarios of 75, 100, 125 and 150 t annually in 2025, 2026, and 2027 (i.e., until the next full assessment of the GDSR is due), and assuming constant average recruitment over this period, suggest that an increase in annual total removals to 150 t per year would not markedly impact on the estimated probability (>90%) of meeting the next (2027) recovery milestone for the stock of B_{rel} being above the threshold reference level (Figure 3.10; Table 3.1). For all the future catch scenarios, *F* is highly likely to remain below the limit and threshold reference levels (Table 3.1). It is important to note, however, that recruitment can be highly variable in this species, this adds considerable uncertainty regarding the stock recovery trajectory. A level of 'precaution' is therefore suggested for future assessments, to incorporate below-average recruitment scenarios.

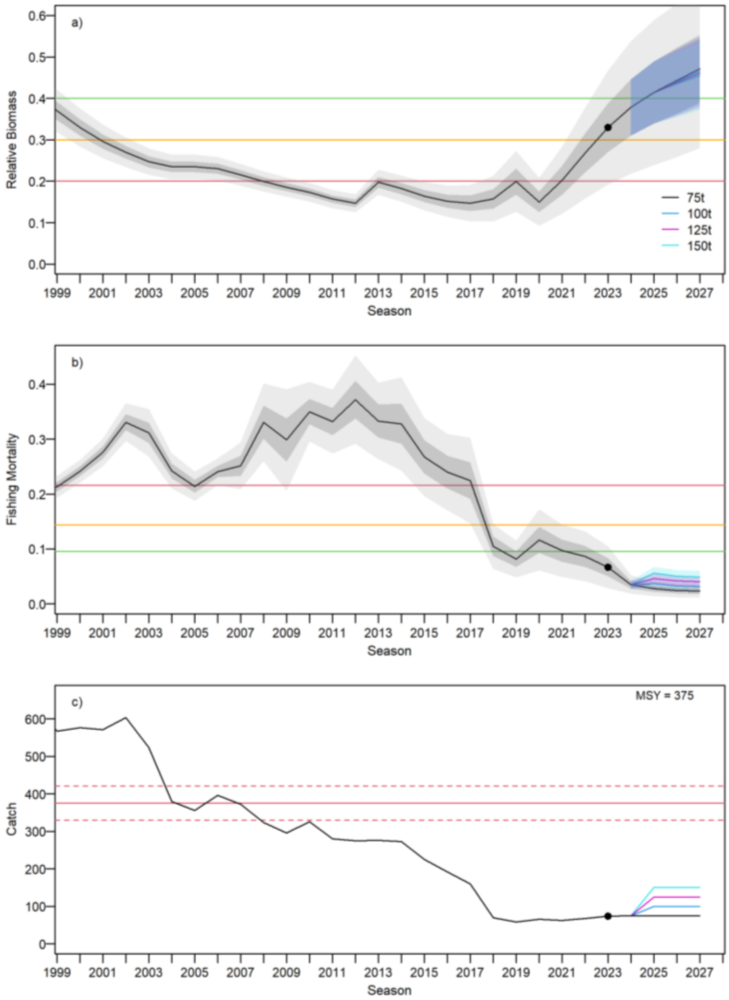

Figure 3.10. Estimated annual a) relative female spawning biomass, B_{rel}; b) fishing mortality, *F* (y^{-1}); and c) the estimated Maximum Sustainable Yield, MSY (±95% CI; solid and dashed red lines) plotted over annual retained catches (t). B_{rel} and *F* are estimated for 1952-2023 (plotted from 1999 onwards) and projected for 2024-2027 based on four future catch scenarios of 75 t (black), 100 t (dark blue), 125 t (purple), and 150 t (light blue). Note that the projected catch for 2024 is 75 t in all scenarios. Dark grey and light grey shaded areas in B_{rel} and *F* plots represent 60% and 95% confidence intervals, respectively. Horizontal lines in the top two plots denote the target (green), threshold (yellow) and limit (red) reference levels for B_{rel} (i.e., B_{rel} = 0.4, 0.3 and 0.2, respectively) and *F* (i.e. 2/3*M*, *M* and 1.5*M*, respectively).

Table 3.1. Integrated model estimates of relative female spawning biomass (B_{rel}) and fishing mortality (F; year^{-1}), and associated 60% CIs, for oceanic Snapper based on 4-year projections with catches set to 75 t, 100 t, 125 t and 150 t (note the projected catch for 2024 is 75 t in all scenarios). The probabilities (P), in each year, of the stock being above the B_{rel}-based limit (0.2) and threshold (0.3), and below the F-based limit (1.5M) and threshold (F=M) are also presented.

	Season	Relative spawning biomass (B_{rel})				Fishing mortality (F)			
		Estimate	60% CI	*P* > Limit	*P* > Threshold	Estimate	60% CI	*P* < Limit	*P* < Threshold
Last year of data	2023	0.33	(0.27-0.39)	0.97	0.66	0.07	(0.05-0.08)	1.00	1.00
Projection 75 t catch	2024	0.38	(0.31-0.45)	0.99	0.83	0.04	(0.03-0.04)	1.00	1.00
	2025	0.41	(0.34-0.49)	0.99	0.90	0.03	(0.02-0.03)	1.00	1.00
	2026	0.44	(0.36-0.52)	1.00	0.94	0.02	(0.02-0.03)	1.00	1.00
	2027	0.47	(0.39-0.55)	1.00	0.96	0.02	(0.02-0.03)	1.00	1.00
Projection 100 t catch	2024	0.38	(0.31-0.45)	0.99	0.83	0.04	(0.03-0.04)	1.00	1.00
	2025	0.41	(0.34-0.49)	0.99	0.90	0.04	(0.03-0.04)	1.00	1.00
	2026	0.44	(0.36-0.52)	0.99	0.93	0.03	(0.03-0.04)	1.00	1.00
	2027	0.47	(0.38-0.55)	1.00	0.96	0.03	(0.02-0.04)	1.00	1.00
Projection 125 t catch	2024	0.38	(0.31-0.45)	0.99	0.83	0.04	(0.03-0.04)	1.00	1.00
	2025	0.41	(0.34-0.49)	0.99	0.90	0.05	(0.04-0.06)	1.00	1.00
	2026	0.44	(0.36-0.52)	0.99	0.93	0.04	(0.03-0.05)	1.00	1.00
	2027	0.46	(0.38-0.54)	1.00	0.95	0.04	(0.03-0.05)	1.00	1.00
Projection 150 t catch	2024	0.38	(0.31-0.45)	0.99	0.83	0.04	(0.03-0.04)	1.00	1.00
	2025	0.41	(0.34-0.49)	0.99	0.90	0.06	(0.04-0.07)	1.00	1.00
	2026	0.43	(0.36-0.51)	0.99	0.92	0.05	(0.04-0.06)	1.00	1.00
	2027	0.45	(0.37-0.54)	1.00	0.94	0.05	(0.04-0.06)	1.00	1.00

3.1.6 Risk-based Weight of Evidence Assessment

Category	Line of Evidence
Catch	The Total Allowable Commercial Catch (TACC) for this species was reduced to 51 t in 2018 as a part of the Snapper Recovery Plan. In recent years, ~ 75% of the total catch of Snapper in oceanic waters of the GCB has been taken by the commercial Gascoyne Demersal Scalefish Managed Fishery, with catches maintained below the TACC since 2018 (GDSMF; 48 t in 2022-23). The most recent estimate of recreational boat-based catch of Snapper in the GCB (including the inner gulfs of Shark Bay) was 16 t in 2020-21 (Ryan et al. 2022), of which ~ 2 t are taken from oceanic waters. The charter catch reported in 2022-23 was 18 t in the GCB, of which 14 t was taken from the oceanic stock. Most commercial Snapper catches in the GCB have been taken from key spawning aggregations targeted by fishers during the winter months (June – August). Since 2018, when a Snapper spawning closure was introduced in waters north of Bernier Island and the TACC for this stock was markedly reduced, the spatial distribution of Snapper catches has changed markedly, with low catches being taken across a greater area of the GDSMF. Snapper is now primarily retained while fishers target Goldband Snapper and other demersal species in more offshore waters.
Level 1 Assessment Since the introduction of the Snapper Recovery Plan in 2018, recent low catch levels and wide spatial distribution of catches indicate that the stock is currently unlikely to be experiencing overfishing.	
Catch Per Unit Effort	Changes in reporting (monthly to daily-trip logbooks) and management have resulted in breaks in the series of CPUE. The annual standardised CPUE for oceanic Snapper, adjusted to account for assumed changes in fishing efficiency over time, was relatively stable between 1977 and 1989, before showing a gradual decline from 1990 to 2007. More recently, the standardised CPUE time series based on daily logbook data shows an increase in 2013 and 2014 before declining markedly to a lower level in 2015-2017. Since 2018, when the TACC was substantially reduced to recover the stock, the standardised CPUE initially remained stable before almost doubling from 2022 to 2023.
Level 2 Assessment Prior to the commencement of the 2018 recovery plan for Snapper, CPUE declined over an extended period from 1990. Following instigation of the recovery plan, recent increases in daily logbook CPUE indicate that the oceanic stock of Snapper is likely to be rebuilding.	
Size Composition	Most fish sampled from commercial Snapper catches since the 1990s range between 400 mm and 750 mm in total length, with the lower end of the length compositions generally truncated by the MLL in place for

	this species. The mean length of aged fish increased from 504 mm in 2004 to 643 mm in 2017 before decreasing to 517 mm in 2021. The lower average mean lengths in 2020 and 2021 are likely due to the reduction in the MLL from 410 to 380 mm in 2018 and may also reflect relatively strong recent recruitment. The survey length data provides evidence of inter-annual variability in recruitment to this stock in recent years, with likely strong year classes recently joining the stock.
Age Composition	Commercial age composition data from the early 1990s have primarily comprised young Snapper of 5-10 years of age, with the mode varying between years likely reflecting a combination of recruitment variability and changing levels of fishing mortality. The limited number of older fish sampled since the early 1990s indicates that the population has experienced high levels of exploitation since this time. Age composition samples collected by fishery-independent line fishing surveys since 2018 provide evidence of strong recruitment from cohorts spawned in 2016-2018, which dominate recent survey catches. As the age structure has not changed markedly in the last few years, despite the likely high survival of older cohorts due to the very low TACC since 2018, this raises some concern about whether the age samples from the restricted survey area are fully representative of the overall stock.

Level 3 Assessment

The trends in length and age compositions of oceanic Snapper are indicative of variable recruitment. The trends in length distributions are influenced by this recruitment over time and thus alone may not indicate changes in stock status of Snapper. However, recent age distributions demonstrate a reduction in the proportion of older fish in the stock, consistent with the stock having been overfished prior to commencement of the Snapper Recovery plan. Recent strong year classes recruiting to the stock may reflect commencement of recovery and increasing B_{rel}.

Integrated Model	Outputs from the bespoke integrated assessment model indicate a steadily increasing level of B_{rel} in recent years, following marked reductions in *F* (associated with a decrease in catch to low levels) and several recent years of above-average recruitment into the fishery (2016-2018 cohorts). The point estimate of B_{rel} in 2023 was at 0.33 of the unfished level (60% CI = 0.27-0.39, corresponding to a 0.7 probability of being above the threshold level of 0.3). The *F* estimate in 2023 was 0.07 year^{-1} (60% CI = 0.05-0.08 year^{-1}), below the target reference level corresponding to 2/3*M* (0.09 year^{-1}). Projections by the model to 2027 (when the next assessment is due), under different scenarios of future catches and assuming constant average recruitment over this period, indicate that an increase in total removals from the current recovery benchmark (100 t) to 150 t would still result in a high probability (>0.9) of meeting the next stock recovery milestone, i.e., to rebuild the stock above the threshold level by 2027 and maintain *F* well below the threshold level of *M* in those years.
Level 5 Assessment Integrated model outputs demonstrate that overfishing is not occurring, allowing the stock to rebuild at an acceptable rate.	
Environmental Impact	Snapper in oceanic waters of the GCB have been assessed as having medium sensitivity to the effects of climate change, based on their abundance, distribution and phenology. However, exposure to climate change will be considered as part of future risk assessment. Risk levels may be influenced by the GCB being towards the northern limit of the distribution of this temperate species.
Risk Assessment C1 Minor (Above Target): The likelihood of minor depletion is assessed as unlikely (5-<20% probability of estimated B_{rel} in the integrated model being above the target). C2 Moderate (Above Threshold, below Target): The likelihood of moderate depletion is assessed as likely, with an estimated probability of estimated B_{rel} in the integrated model being between the target and threshold of > 50%. C3 High (Above Limit, below Threshold): The likelihood of high depletion is assessed as unlikely, with an estimated probability of B_{rel} being between the threshold and limit of 15%. While the 95% confidence interval around the estimated B_{rel} suggests a likelihood of around 30% that the stock in 2023 was between the Limit and Threshold levels of 0.2 and 0.3, respectively, this likelihood is reduced to 15% (i.e., unlikely) in the projection for 2024 based on the continued low TACC in the most recent fishing season (2023-24). C4 Major (Below Limit): The likelihood of major depletion is assessed as remote, with an estimated probability of < 5% that B_{rel} was below the limit reference level of 0.2 in 2023. Based on the risk matrix below, the overall risk to the oceanic Snapper stock in the GCB in 2023 is assessed as **Medium** (C2 × L4). On the basis of this evidence, the stock is classified as **Sustainable – Recovering**.	

Consequence (Stock level)	Likelihood			
	1 Remote (<5%)	2 Unlikely (5-<20%)	3 Possible (20-50%)	4 Likely (>50%)
1 Minor (above Target)		X		
2 Moderate (between Target and Threshold)				Medium
3 High (between Threshold and Limit)		X		
4 Major (below Limit)	X			

3.1.7 Assessment Advice

This 2024 assessment update for the oceanic Snapper stock in the GCB indicates that Milestone 2 of the Recovery Plan, aiming to rebuild B_{rel} to above threshold level of 0.3 by 2027, has likely already been achieved (estimated B_{rel} of 0.33, with a 0.7 probability of being above the threshold level of 0.3 in 2023). Model projections, while based on the assumption of constant future average recruitment, suggest that an increase in the current recovery limit for total removals to 150 t total (across all sectors) over the next 3 years (2025-2027) is unlikely to markedly impact the estimated probability of the stock being above the threshold level in 2027 (> 0.9).

3.2 Goldband Snapper

3.2.1 Catch

The majority of Goldband Snapper in the GCB has been landed by commercial line fishers (primarily operating in waters south of Point Maud, Coral Bay), with only a small amount landed by trap and trawl fishing (primarily in the waters north of Tantabiddi, Ningaloo) during the mid-1980s to mid-1990s. Commercial line catches of Goldband Snapper reported through the 1980s and 1990s were low (< 20 t) and mostly incidental as line-fishing vessels mainly targeted Snapper and other inshore demersal species in waters 30-80 m deep. Goldband Snapper catches increased rapidly in the late 1990s as vessels moved offshore to fish deeper waters (100–250 m), peaking at 283 t in 2002-03 (Figure 3.11). Management measures introduced in the mid-2000s to reduce commercial effort in deeper, offshore waters resulted in a reduction in Goldband Snapper catch to ~ 50-100 t. In 2022-23, 61 t Goldband Snapper were retained by the GDSMF.

Historical charter and recreational catches of Goldband Snapper are unknown but are unlikely to have been substantial as this species is found in deeper offshore waters that were not routinely accessed by recreational vessels in the past. Since the introduction of mandatory charter logbooks in 2002, Goldband Snapper catches by charter fishers in the GCB show a gradual increase to ~ 10 t in 2008, peaking at 19 t in 2021 before reducing to 13-14 t over the next two years (Figure 3.11). Catches of Goldband Snapper by private recreational fishers in the GCB, estimated from periodic boat-based fishing surveys, remained relatively steady at ~ 5-10 t between 2011-12 and 2020-21 (Ryan et al. 2022).

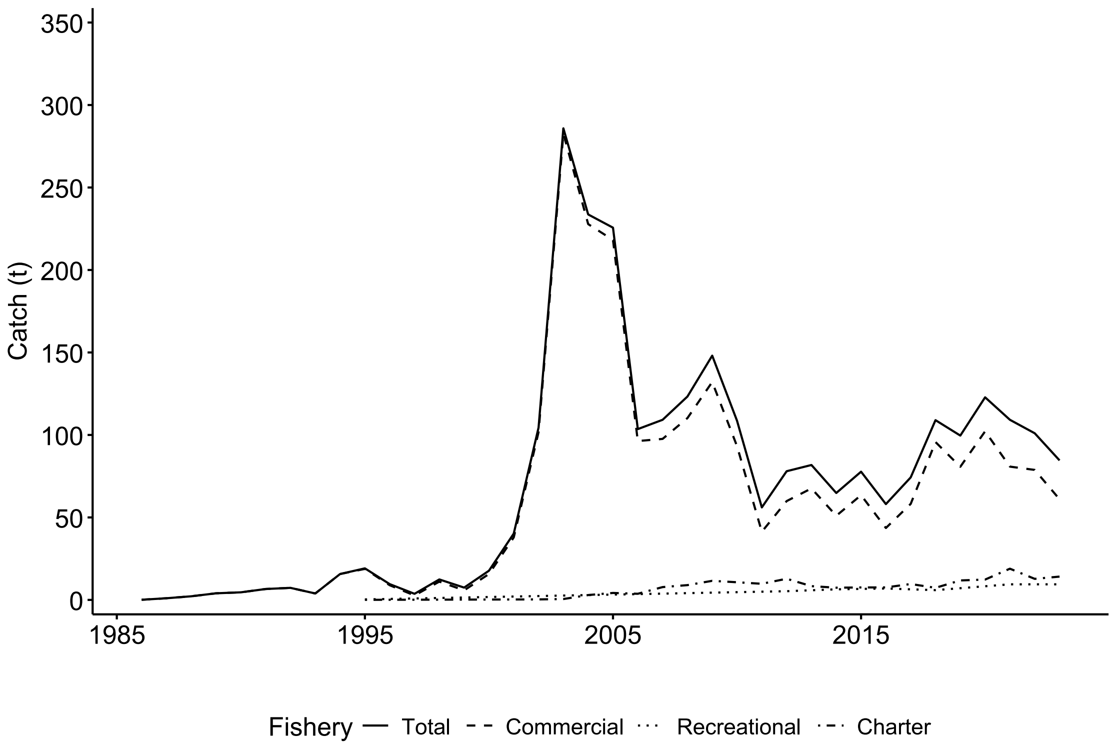

Figure 3.11. Annual catches (in tonnes, t) of Goldband Snapper collectively retained by commercial, charter and recreational fishers in oceanic waters of the GCB since 1986.

The spatial distribution of commercial Goldband Snapper catches, plotted by 60×60 nm reporting blocks in the GCB, has changed throughout the development of the fishery, from relatively lightly fished blocks in the 1990s to more heavily fished blocks in the early-mid 2000s (Figure 3.12). Plotting catches by the finer-scale 10×10 nm blocks used for logbook reporting from 2008 onwards shows that GDSMF catches of this species are confined to a relatively small number of blocks (Figure 3.13). This reflects the association of Goldband Snapper with limited areas of suitable habitat type, i.e. hard structure with vertical relief in waters of ~ 80-150 m depth.

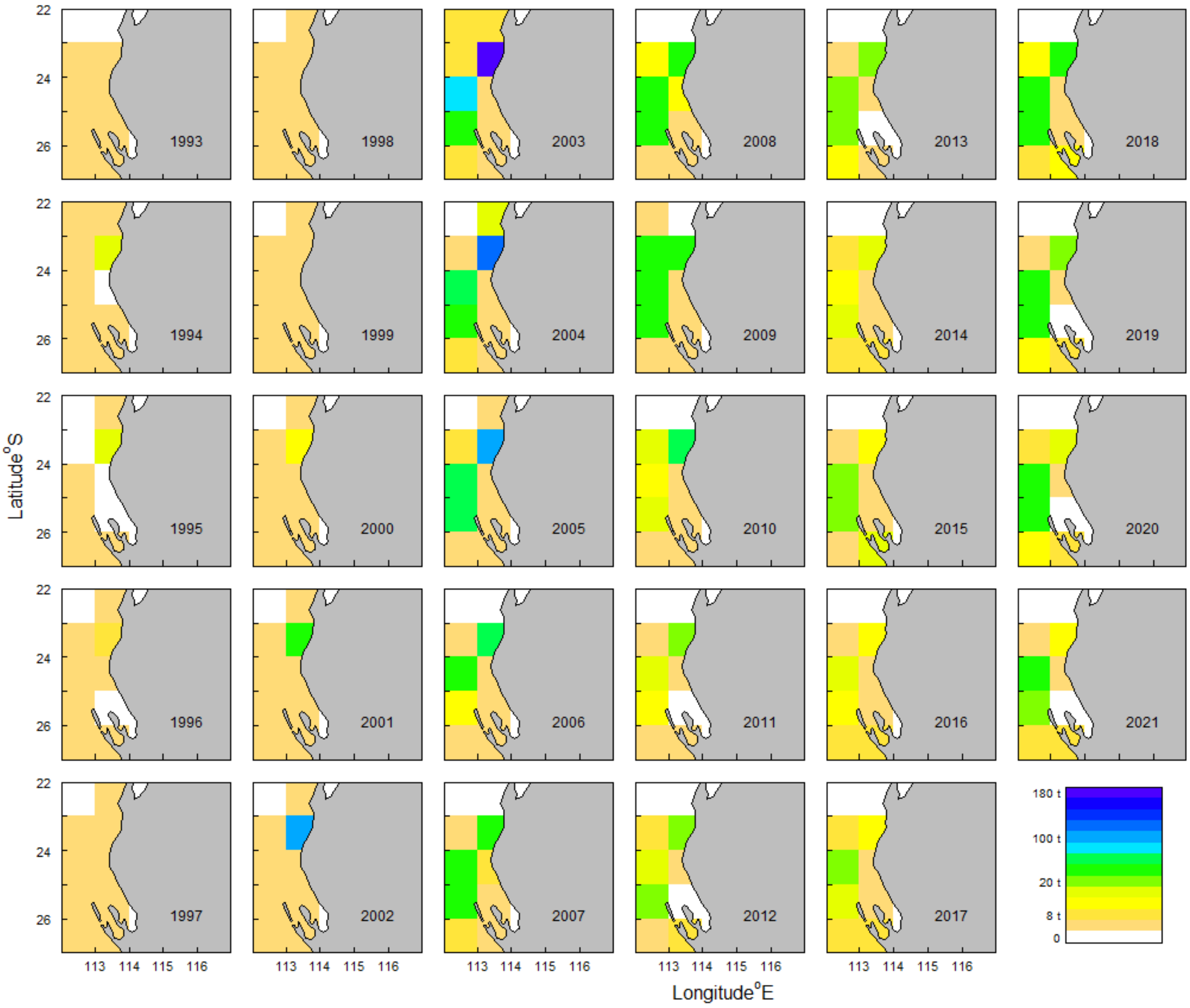

Figure 3.12. Spatial distribution of annual Goldband Snapper catches by commercial fishers in 60 nm reporting blocks in the GCB from 1992-93 to 2016-17. Note that 1993 label denotes the 1992-93 fishing season (1 Sep – 31 Aug).

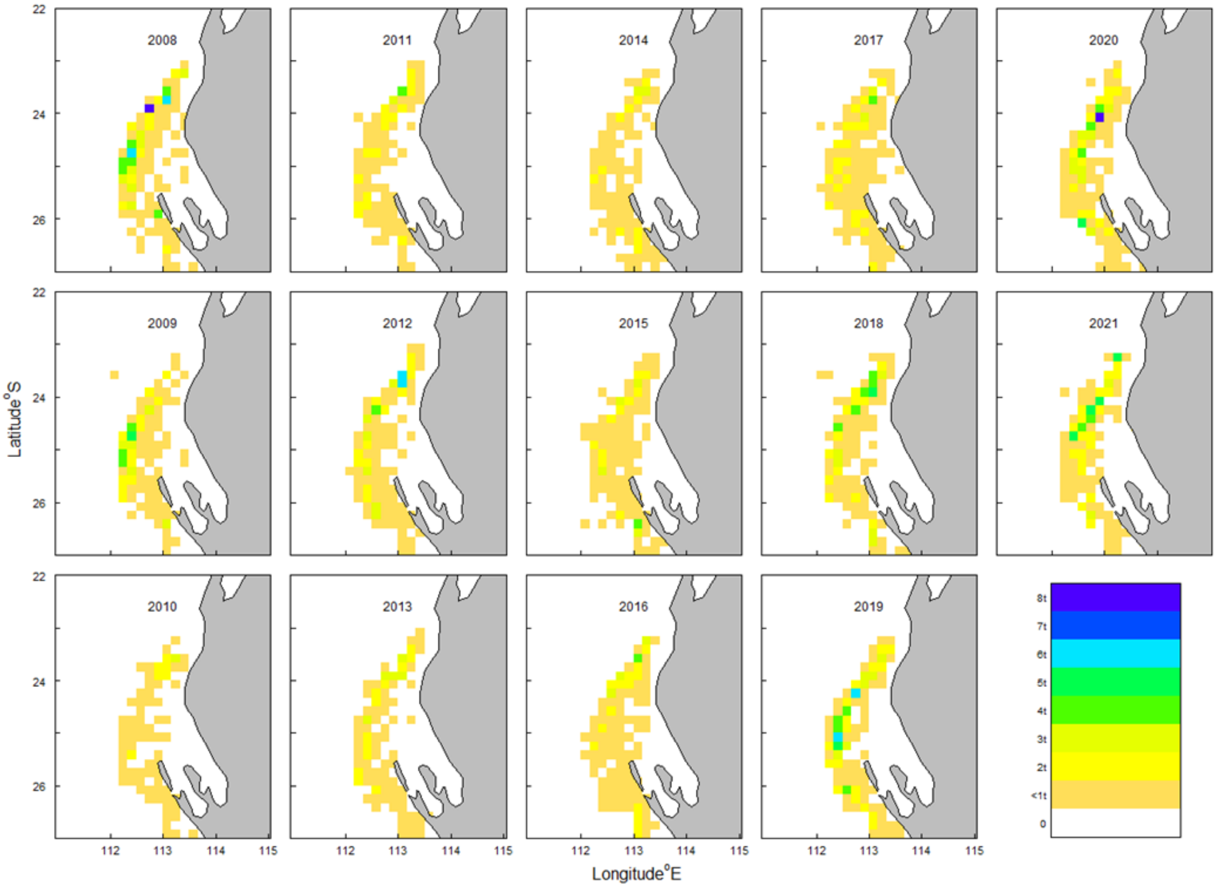

Figure 3.13. Spatial distribution of annual Goldband Snapper catches reported by commercial fishers in 10 nm blocks in the GCB since 2007-08. Note that 2008 label denotes the 2007-08 fishing season (1 Sep – 31 Aug).

3.2.2 Catch Per Unit Effort

Due to the uncertainty about the reporting of Goldband Snapper catches in the earlier years of the fishery (often grouped as Jobfishes, see Appendix 1), CPUE information presented for this species in this report is focused on those based on daily logbook data since 2008. The annual time series of nominal commercial CPUE for Goldband Snapper in the GDSMF broadly fluctuated between 2.5 and 5 kg/line hour between 2008 and 2017, before increasing to around 7.5-10 kg/line hour (Figure **3**3.14). This change coincided with a substantial reduction in the TACC for Snapper in 2018, when changes in targeting led to an increased proportion of Goldband Snapper in the total GSDMF catch (Figure **3**3.14). These recent changes suggest two separate, relatively short time series (pre- and post-2018) of data, resulting in limited signal in the two indices.

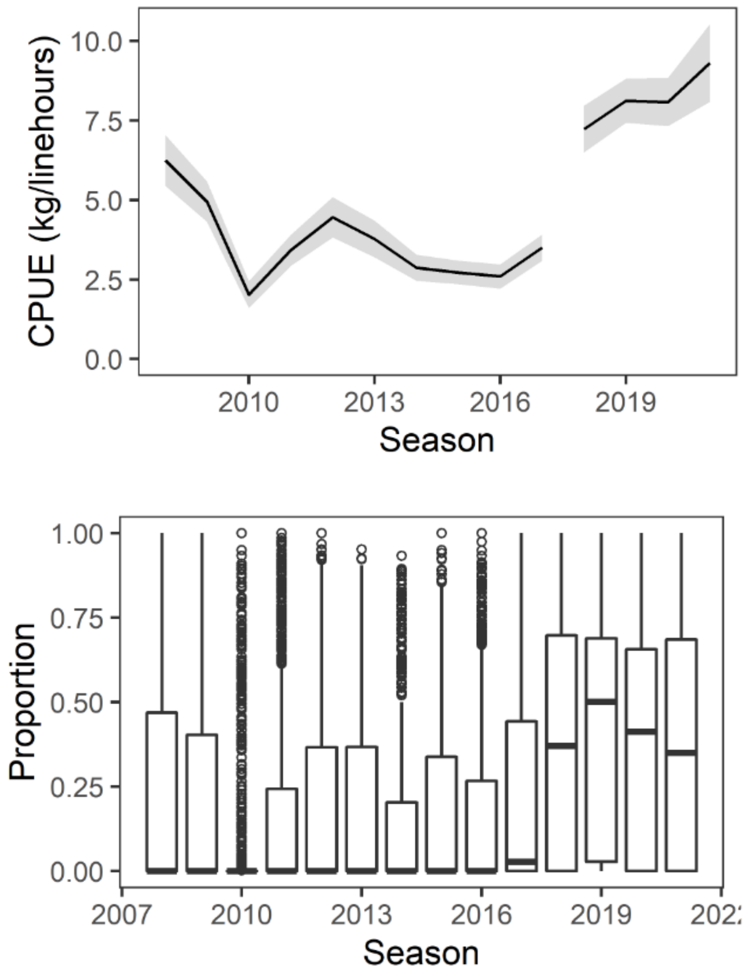

Figure 3.14. Annual (top) nominal catch per unit effort (CPUE) of Goldband Snapper in the GDSMF, and (bottom) proportion of Goldband Snapper in the total GDSMF catch, based on daily logbook data between 2008 and 2021.

3.2.3 Length Composition

Goldband Snapper are sampled periodically from waters of the GCB. The most recent sampling between 2018 and 2020 collected a total of 990 Goldband Snapper caught collectively by drop lining and long lining, where 502 fish were sampled from research surveys and 488 fish sampled from commercial catches. Total lengths of Goldband Snapper sampled between 2018 and 2020 ranged from 305 to 841 mm (Figure 3.15). Most samples comprised mature fish, with a very small proportion (< 2%) of individuals below 420 mm, the approximate the size at which 50% of females are estimated to mature. While the length composition sample collected from research surveys in 2018 and 2019 primarily comprised individuals of 600-800 mm, the commercial sample from 2020 was clearly bimodal and included a second mode of smaller fish around 500 mm (Figure 3.15). This may be due to a younger cohort recruiting into the fishery in the most recent sampling year or could be a result of sampling differences between the survey and commercial catches.

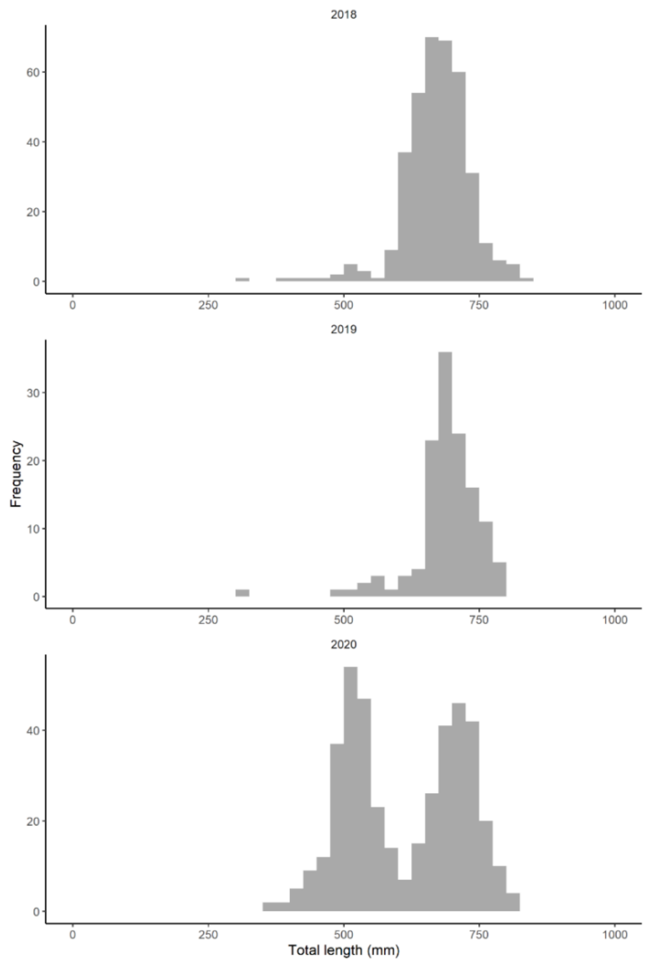

Figure 3.15. Length-frequency distributions for Goldband Snapper in the GCB sampled by research surveys in 2018 and 2019 and from commercial catches in 2020, using droplines and longlines.

3.2.4 Age Composition

The ages of Goldband Snapper sampled in the GCB between 2018 and 2020 were similar to those of fish collected between 2010 and 2013, with individuals from the two sampling periods ranging from 2-28 years and 2-32 years, respectively (Figure 3.16, see Jackson et al. 2020 for earlier data). In the most recent sampling period, 10% of fish were > 15 years of age, and two sampled individuals (31 and 32 years of age) were older than the previously recorded maximum age of 28 years for this species in the Gascoyne (and WA).

In contrast to the substantial differences observed between length compositions from the survey and commercial data, the age compositions were, to some extent, more similar between years (Figure 3.16). Samples collected by research surveys in 2018 and 2019 were similar, with the frequency of fish in both peaking at age 4 years. Both distributions included substantial numbers of fish between 10-15 years, although the numbers of fish of these ages relative to other ages was greater for 2019. In contrast to 2018 and 2019 research samples, the 2020 commercial sample had relatively few fish at these ages. (Figure 3.16). Thus, there remains some uncertainty around the observed differences in the research and commercial samples, and how representative and comparable data from the two sources are.

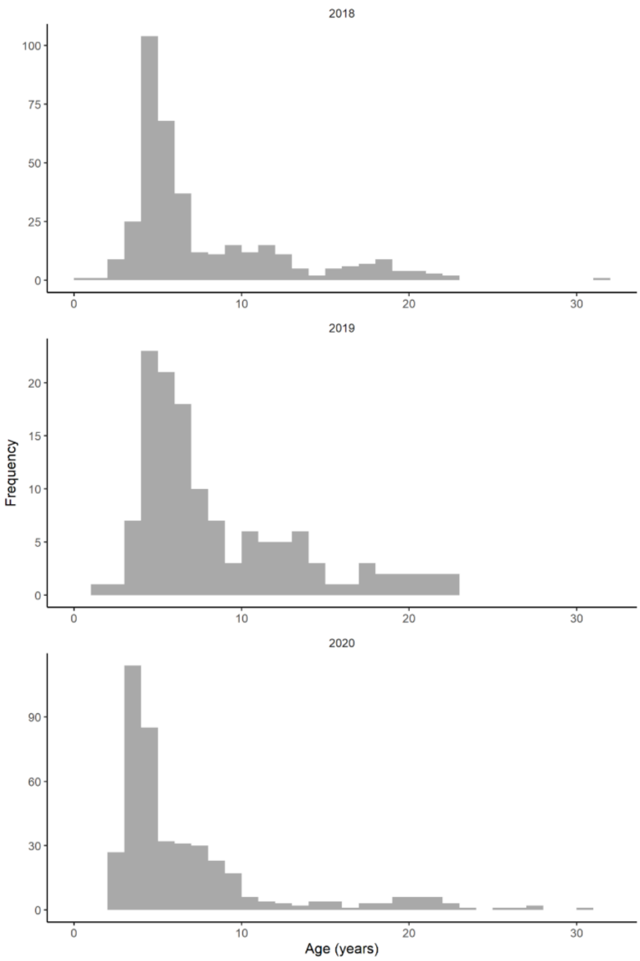

Figure 3.16. Age-frequency distributions for Goldband Snapper in the GCB sampled in 2018 and 2019 by research surveys and in 2020 from commercial catches, using droplines and longlines.

3.2.5 Environmental Impacts

Climate projections for WA (Pilbara to Albany) include increases in sea surface temperature, number of marine heatwave days, sea level increases, ocean acidification, intense and variable storms and rainfall decreases (Chandrapavan and Jackson 2024). Goldband Snapper is a tropical species and based on its abundance, distribution and phenological characteristics in the GCB stock, it has been assessed as having low sensitivity to the effects of climate change (Jackson et al. 2024). A risk assessment will be conducted in future to evaluate how projected changes in environmental variables may affect stocks.

3.2.6 Model Assessment

3.2.6.1 Level 3 Assessment

The estimated long-term average *F* for fully-selected Goldband Snapper in the GCB, derived by fitting an age-based catch curve model that accounts for recruitment variability to age composition data collected between 2018 and 2020 (see Appendix 2 for model fit), has remained relatively low (Table 3.2). The estimate of *F* derived from all available data was slightly higher than the estimate based only on data collected during the research surveys in 2018 and 2019 (0.07 and 0.05 year^{-1}, respectively). Both estimates were slightly higher than that estimated by the same method in the previous assessment of the stock in 2010-2013 (0.02 year^{-1}), however, they were still well below the target reference level of 0.11 year^{-1} corresponding to 2/3 of the estimated *M* for this stock (Table 3.2). Estimates of the logistic selectivity parameter showed that 50% of Goldband Snapper are selected by line fishing gear in the Gascoyne by 4 years of age, with 95% of individuals selected by around 5-6 years of age (Table 3.2).

Fitting a Chapman & Robson catch curve separately to survey (2018 and 2019) and commercial (2020) age composition data yielded very similar estimates of *F* to those generated by the multi-year catch curve (0.07 and 0.09 year^{-1}, respectively). This provides some confidence that age composition data from these two sources generate similar assessment outputs.

Estimates of female B_{rel} for Goldband Snapper in the Gascoyne, derived from an equilibrium biomass model (i.e., a per-recruit analysis that accounts for potential effects of fishing on recruitment by incorporating a stock-recruitment relationship, assuming a steepness of 0.75), were 0.66 (95% CI = 0.59-0.72) based on all data from 2018-20 (Figure 3.16), and 0.75 (95% CI = 0.66-0.87) based only on research survey data (from 2018-19). Both estimates (and lower 95% CLs) were well above the threshold reference level of 0.3 (Figure 3.17), noting that the estimated value of B_{rel} corresponding to B_{MSY} was very close to this (0.28).

Table 3.2. Catch curve estimates of long-term average F (y^{-1}, ±95% CI) and age-based logistic selectivity parameters (A_{50} and A_{95}; ±95% CI) for Goldband Snapper based on age composition data collected from research surveys and commercial catches in the GCB in 2018-2020. Point estimates of F were compared to reference levels, where green denotes F < target level of 2/3M.

Area	All data (2018-2020)	Research data only (2018-2019)
F	0.07 (0.05-0.09)	0.05 (0.02-0.07)
A_{50} selectivity	4.2 (4.0-4.4)	4.6 (4.2-5.0)
A_{95} selectivity	5.3 (4.9-5.6)	6.1 (5.4-6.8)

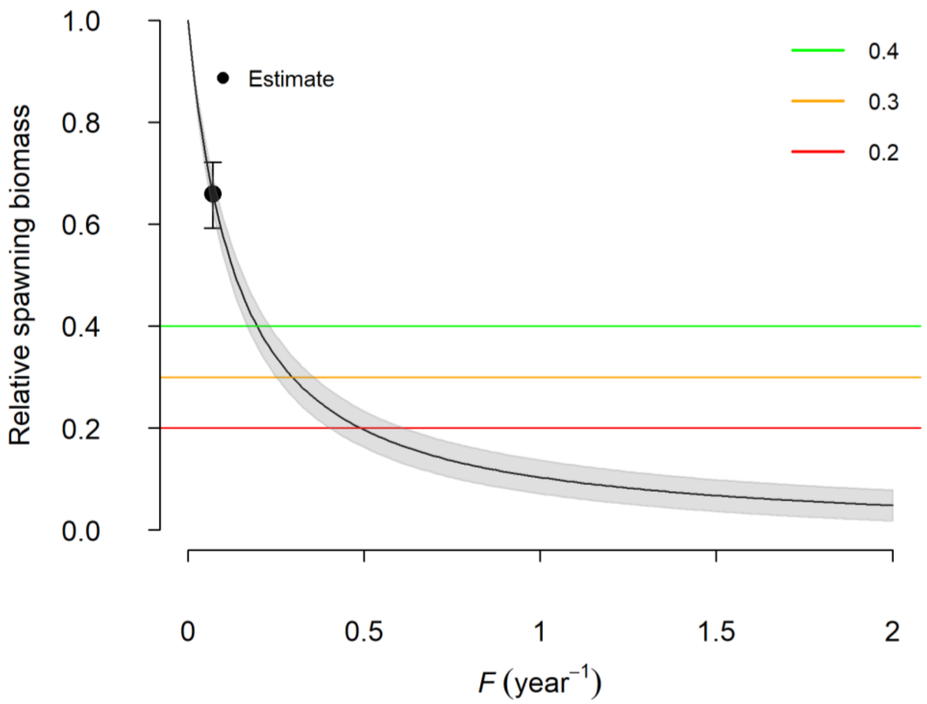

Figure 3.17. Relationship between female relative spawning biomass (±95% CI in grey, accounting for uncertainty in M and h) for Goldband Snapper in the GCB and fishing mortality (F, $year^{-1}$). The black circle and arrow bars denote the point estimate for relative spawning biomass (B_{rel}; ±95%, accounting for uncertainty in M, h and F), where the estimate for F is that derived from catch curve analysis using age data from 2018-2020. The target, threshold and limit reference levels are shown as the green, yellow and red horizontal lines, respectively, where the threshold level represents a proxy for B_{MSY}.

3.2.7 Risk-based Weight of Evidence Assessment

Category	Line of Evidence
Catch	Management measures introduced to reduce effort in offshore waters resulted in a decrease of Goldband Snapper catches to ~ 50-100 t from earlier higher levels. In 2022-23, 61 t Goldband Snapper were retained by the GDSMF. Catches of this species by charter and private recreational fishers in the GCB were 13 t and 10 t, respectively, in that same year. The spatial distribution of commercial Goldband Snapper catches has been stable since the mid-2000s, with most of the catch coming from specific areas where this species is closely associated with hard structure in waters of ~ 80-150 m depth.
Level 1 Assessment The recent relatively low levels of catch of Goldband Snapper being maintained below the TACC and lack of evidence of any spatial shifts in catches in the GCB do not provide any evidence that the stock is experiencing overfishing.	
Catch Per Unit Effort	The annual nominal CPUE for Goldband Snapper in the GDSMF, based on daily logbook data since 2008, has broadly fluctuated between 2.5 and 5 kg/line/hour until 2017, before increasing to a higher level. After a substantial reduction in the TACC for Snapper in 2018, leading to an increased proportion of Goldband Snapper in the total GSDF catch, the annual CPUE of this species increased to around 7.5-10 kg/line/hour. These recent changes in fish targeting suggest that the two separate time series (pre- and post-2018) of CPUE are not directly comparable. There is uncertainty as to whether these two relatively short CPUE series provide reliable abundance indices for Goldband Snapper.
Level 2 Assessment Due to uncertainty around the Goldband annual commercial CPUE as a reliable index of abundance, it is considered that these data should not currently be used for informing estimates of stock status.	
Length Composition	The total lengths of Goldband Snapper from commercial catches and research surveys in the Gascoyne, sampled by line fishing between 2018 and 2020, ranged from around 300 to 840 mm. Less than 2% of the sampled fish were below the approximate size at which 50% of females are estimated to have attained maturity (420 mm). Therefore, most individuals would have the opportunity to spawn before being selected by fishing gear. While the length composition of fish collected from the research surveys in 2018 and 2019 primarily comprised individuals of 600-800 mm, the commercial sample from 2020 was clearly bimodal and included a second mode of fish around 500 mm. This may indicate a younger cohort recruiting into the fishery in the most recent sampling year or could be a result of sampling differences between the survey and commercial catches.

Age Composition	The ages of Goldband Snapper sampled in the GCB between 2018 and 2020 were similar to those previously collected in 2010-2013, comprising 10% of individuals > 15 years of age. In the most recent sampling period, two sampled fish (31 and 32 years of age) were older than the previously recorded maximum age (28 years) of this species in the Gascoyne (and WA). While the distribution of ages in these samples is broadly indicative of inter-annual variability in recruitment of this species, there remains some uncertainty around the inconsistencies in data observed between the research and commercial samples, and how representative or comparable data from the two sources are.
Equilibrium Biomass Model	Catch curve estimates of *F* for Goldband Snapper in the Gascoyne, derived from a multi-year catch curve method that accounts for inter-annual variability in recruitment indicates that the 'long-term' average *F* of fully selected individuals has remained low. The 2018-2020 estimate of *F* at the stock (bioregion) level of 0.07 $year^{-1}$ (95% CI = 0.05-0.09 $year^{-1}$) was below the target reference level of 0.11 $year^{-1}$. The estimated B_{rel} at the bioregion level, derived from a per-recruit analysis that accounts for the potential effect of fishing on recruitment (assuming a stock-recruitment relationship with a steepness of 0.75), was 0.66 (95% CI = 0.59-0.72) in 2018-2020. This estimate (and lower 95% CI) is above the target reference level of 0.4.
Level 3 Assessment Consistent with the presence of old fish in recent age compositions and catches remaining at low levels relative to the TACC, equilibrium model estimates of *F* and B_{rel} suggest that overfishing has not been occurring, and the stock is not depleted. However, these results should be interpreted with caution, due to a greater understanding of the representativeness of age samples being required and the equilibrium assumptions of the models used.	
Environmental Impact	Goldband Snapper have been assessed as having low sensitivity to climate change effects based on its abundance, distribution and phenology. A risk assessment will be conducted in future to evaluate how projected changes in environmental variables may affect stocks.

Risk Assessment

C1 Minor (Above Target): Based on estimated B_{rel} from equilibrium models, the likelihood of minor depletion is assessed as likely (>50%).

C2 Moderate (Above Threshold, below Target): Based on estimated B_{rel} from equilibrium models, the likelihood of moderate depletion is assessed as unlikely (5 - <20%).

C3 High (Above Limit, below Threshold): Based on estimated B_{rel} from equilibrium models, the likelihood of high depletion is assessed as Remote (< 5%).

C4 Major (Below Limit): Based on estimated B_{rel} from equilibrium models, the likelihood of major depletion is assessed as Remote (< 5%).

Based on the risk matrix below, the overall risk to the Goldband Snapper stock in the GCB in 2022 is assessed as **Low** (C2 × L2). On the basis of this evidence, the stock is classified as **Sustainable – Adequate**.

	Likelihood			
Consequence (Stock level)	1 Remote (<5%)	2 Unlikely (5-20%)	3 Possible (20-50%)	4 Likely (>50%)
1 Minor (above Target)				X
2 Moderate (between Target and Threshold)		LOW		
3 High (between Threshold and Limit)	X			
4 Major (below Limit)	X			

3.2.8 Assessment Advice

The 2022 assessment of Goldband Snapper in the GCB suggests that it is likely that B_{rel} is above the target reference level of 0.4. The estimated 'long-term' average *F* is below the target level, reflecting the recent level of fishing remaining at low levels relative to the TACC. Results should be treated with some caution due to the strong equilibrium assumptions of the Level 3 assessment methods, and concerns regarding the representativeness of age samples.

4 Ecological Assessment

An Ecological Risk Assessment (ERA) for the Gascoyne Demersal Scalefish Resource was undertaken in 2016. The current risk to ecological components other than the target stocks of this resource are reviewed annually as part of the Department's annual Status Reports of the Fisheries and Aquatic Resources of Western Australia (State of the Fisheries; e.g., Newman et al. 2024).

4.1 Other Retained Species

Line fishing for demersal species using baited hooks is highly selective for fishes and catches a range of other demersal species in the GDSR, including tropical snappers, emperors and groupers. Commercial catches of those species have declined with reductions in effort overall, following the introduction of a lower TACC for Snapper since 2018 as part of the Snapper Recovery Plan. Catches of other demersal species have remained steady in surveys of private boat-based recreational fishers from 2013-14 to 2020-21 and reported catches of charter fishers from 2014-15 to 2023-24. The risk to these other retained species is assessed as **Low**.

4.2 Bycatch Species

Line fishing is highly selective. The GDSR comprises a large number of demersal species of medium to high market value, with very few species captured that are not retained. Therefore, bycatch is low. The risk to bycatch species is assessed as **Negligible**.

4.3 ETP Species

Mandatory reporting by commercial and charter fishers of interactions with listed endangered, threatened and protected (ETP) species suggests line fishing interactions in the GCB are low. A 2016 Ecological Risk Assessment assessed the impact of GDSMF on a range of ETPs, including sea snakes, elasmobranchs, whales and dolphins, marine turtles, dugongs (*Dugong dugon*), seabirds, and potato cod (*Epinephelus tukula*, which is protected in WA) (Department of Climate Change, Energy, the Environment and Water 2025). Line fishing gears used in the fishery are highly selective for fishes and there is a low likelihood of vessel strikes (for cetaceans, dugongs and marine turtles). Five interactions with ETPs have been reported in logbooks since 2019. These included one interaction with a grey nurse shark (*Carcharias taurus*), which was released alive, and four interactions with unidentified sharks. Three of these sharks were released alive, and one was dead. As reported in the 2016 Ecological Risk Assessment, and noting the reduced fishing effort since the start of the Snapper Recovery Plan, the risk to ETP species is assessed as **Negligible**.

4.4 Habitats

Line fishing is the main method used in by commercial and recreational fishers to target the GDSR. This fishing method has limited physical impact on the benthic environment. The risk to benthic habitats is considered **Negligible**.

4.5 Ecosystem

As the commercial quota management system and recreational fishing regulations limit catches to a relatively small percentage of the total available biomass, there is limited effect on the food chain. The risk to the ecosystem is considered **Low**.

4.6 Assessment Advice

In line with the harvest strategy and Snapper Recovery Plan (with Snapper currently at Medium risk), management should continue to focus on meeting objectives relating to the sustainability of target stocks.

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Appendix 1: Assessment Description

Level 1 Assessment

Trends in catch over time provide important inputs to the assessment of each key demersal species in the GCB and can be important for understanding changes in fishery dynamics and recruitment of key stocks. Analyses of commercial and charter catch information also consider the spatial extent of catches (by reporting blocks) and how these change over time.

The reporting of Goldband Snapper catches in WA has been inconsistent throughout time. Historically, commercial fishers were recording catches of this species within the grouped Jobfishes category, comprising Goldband Snapper, Sharptooth Snapper and Rosy Snapper. For assessments of this species, available fishery-independent survey data on species compositions from the North Coast Bioregion (showing that 91% of total Jobfsh catches comprise Goldband Snapper) have been used to separate early combined Jobfish catches to individual species. There is greater confidence in the accuracy of reporting of Goldband Snapper in the Gascoyne since the GDSMF was formed in 2008.

Demersal scalefish catches by commercial fishers are reported in weight (kg), while recreational and charter catches are reported in numbers. To monitor the overall demersal scalefish catch in the GCB, annual retained catches of key species, or groups of species, by charter and recreational fishers are converted to weight using available length and weight information. Weight-length relationships for the key species (e.g., Smallwood et al. 2018) are applied to calculate average weights from the lengths of retained fish derived from charter logbooks and recreational boat-ramp surveys. Annual catches of each key species are then calculated from the number of retained fish in each year and the estimated average weights of those fish. Where the annual average weight is based on less than 100 fish, the long-term average weight is applied using all available data for the species. As long-term average weights are updated when new data become available, annual charter and recreational catches can vary slightly between reporting years.

As required for assessments of key demersal species in the GCB, available data on charter catches since 2002 and periodic survey estimates of boat-based recreational catches since 2011-12 have been used to derive time series of retained catches going back to 1975. For example, boat-based private recreational catches have been linearly interpolated between survey years, with catches in years since the last survey assumed to have remained the same. Recreational and charter catches of Snapper and Goldband Snapper in the GCB are assumed to have been low prior to the late 1980s and mid-1990s, respectively.

Level 2 Assessment

Annual time series of commercial catch per unit effort (CPUE) for Gascoyne oceanic Snapper are calculated from catch and effort logbook data. Due to differences in reporting, CPUE time series are calculated separately based on data from monthly logbooks (1977-2008) and daily logbooks (2008-2023). The fishing (quota) season runs from 1 September to 31 August, with most of the catch landed during the winter months, coinciding with the spawning period. The 2023 fishing season (i.e., 2022-23) therefore refers to catches from 1 September 2022 to 31 August 2023.

Monthly Logbook CPUE

In previous assessments of Gascoyne oceanic Snapper, commercial CPUE from monthly returns were calculated from 1990, which coincided with the introduction of fishery-specific spatial blocks throughout WA and thus finer-scale fishery-specific blocks within Shark Bay. Additional monthly data are also available from 1977, but with spatial resolution only available on a 60×60 nm basis. During this period, data for both the Gascoyne oceanic and Gascoyne inshore fisheries were combined over multiple blocks, and so there is some uncertainty regarding data within these blocks, and their use in subsequent CPUE analyses specific to the Gascoyne oceanic Snapper fishery. For this assessment, catch returns that could be readily assigned to the Gascoyne oceanic fishery have been used to derive an annual CPUE index for the period 1977-1989. From 1990, identified spatial blocks are all specific to the Gascoyne oceanic fishery and so there is less uncertainty associated with these data. An annual CPUE index for the period 1990-2008 was derived from data available for these oceanic-specific blocks.

For monthly logbook data, a Generalised Linear Modelling (GLM) framework is used to derive standardised annual time series of CPUE for Snapper caught by handlining methods for each reporting period (1977-1989 and 1990-2007). Targeting of species is considered using a year-specific qualification level calculated as the minimum proportion of that species in an individual fishing event to explain a proportion (90%) of the cumulative catch in that year. 'Main' vessels were also considered which were identified as those vessels operating in the fishery for at least five years. Additional analyses of skipper and vessel combinations were not explored due to limited resolution of the monthly CPUE data. Prior to use in stock assessment models, the standardised annual time series of CPUE calculated from monthly returns were adjusted to account for assumed increases in fishing efficiency resulting from the adoption of new technologies, including mechanised hand lines, colour sounders and GPS (Marriott et al. 2011).

Daily Logbook CPUE

In 2008, the fishery transitioned to the collection of daily catch and effort data, which were reported on a finer spatial scale (10 nm x 10nm blocks) than the monthly returns. In recent assessments of Gascoyne oceanic Snapper, CPUE data from the daily logbooks have been calculated as two separate time series from 2008-2017 and 2018 onwards, with the split corresponding to substantial management changes and reduction in Snapper TACC. The split in time series is also supported by the distinct reduction in the observed proportion of Snapper in the daily catch records.

A subset of the daily logbook records of catch and effort data were identified using a method by Stephens and MacCall (2004) for use in estimating CPUE. This method uses the species composition of catches taken during individual fishing sessions to infer if the fishing effort occurred in a habitat where the species of interest is likely to occur. A critical value of probability that best predicts the presence and absence of target species in individual catch records forms an objective basis for sub-setting the trip records. The set of catch and effort records for CPUE analysis was further restricted to the main months of fishing (March-August) and to records from the main fishers, which were identified as those who had fished for at least four seasons, with an annual average catch of Snapper of at least 1000 kg and an average number of fishing sessions per year of at least 10. For the period 2018-2023, the minimum number of reported fishing seasons was reduced to three.

For daily logbook data, a Generalised Additive Modelling (GAM) framework is used to derive standardised annual time series of CPUE of Snapper caught by handlining methods for the two identified periods (2008-2017 and 2018-2023). The CPUE time series was standardised using a GAM for year (fixed effect), month (fixed effect), spatial location (longitude x latitude smoother) and fisher (random effect smoother). Prior to use in assessment models, the standardised CPUE time series for the 2008-2017 period was adjusted to account for an assumed 2% annual increase in fishing efficiency. No change in fishing efficiency was assumed for the most recent time period (2018-2023) due to the very low TACC in place for Snapper.

A discrete, state-space version of the Schaefer biomass dynamics model with an annual time step, developed for the study of Marks et al. (2021) has been fitted to catch data and standardised (adjusted) CPUE time series for Snapper in the 2022 assessment (DPIRD unpublished report). Due to lack of sufficient information to inform the model, results were highly uncertain and considered not currently useful for assessing this species. This analysis was not repeated for this (2024) Snapper assessment, with emphasis placed on the Level 5 model informed by biological data.

Level 3 Assessment

Catch Curve Analyses

For Goldband Snapper, the instantaneous rate of total mortality (Z, year^{-1}) was estimated from age composition data using catch curve analysis. Fishing mortality (F, year^{-1}) was calculated as $F = Z - M$, where M is the assumed value of natural mortality for this species in the GCB (0.16 year^{-1}, calculated from the mortality equation by Quinn and Deriso (1999) assuming 1% of fish survive to the previously recorded maximum age of 28 years in WA). Given the equilibrium assumptions common to catch curve models, it is important to emphasise that these F estimates represent the long-term, average F experienced by fully selected fish in the population. For a long-lived species, if exploitation in recent years has increased, this may not be reflected in the estimates of F from catch curve analysis (i.e. values may represent under-estimates of recent F).

Multiple catch curve models, differing in complexity and inherent assumptions, have been previously fitted to available data to explore the extent to which model uncertainty impacts on the assessment results. Due to the annual variability in recruitment of Goldband Snapper in the GCB, the method considered most appropriate for the assessment of this stock is a multi-year catch curve model assuming age-based, logistic selectivity and that accounts for variable inter-annual recruitment. A full mathematical description of this catch curve model was provided by Fairclough et al. (2014).

The catch curve model was simultaneously fitted to age composition data from the three most recent consecutive years of sampling, noting the first two years of data were from fishery-dependent surveys, and the latter from fishery dependent sampling. These samples were collected by line fishing (drop lining and long lining) between 2018 and 2020, where data are grouped by the biological year of Goldband Snapper (1 January – 31 December) to distinguish each cohort based on the spawning period in which the individuals of that year class were spawned (e.g. Fairclough et al. 2014). The catch curve model was fitted in AD Model Builder (Fournier et al. 2012), with outputs analysed and plotted using the software R (R Core Team 2023; see Appendix 2 for model fits). Estimates of F and age-based selectivity parameters were then used as input for the equilibrium biomass model used to estimate the relative spawning potential of the stock (see below).

To explore the sensitivity of model outputs to the source of age composition data used in catch curve analyses (i.e. collected by research surveys and commercial catches), the multi-year catch curve was fitted to all available data for the recent sampling period (2018-2020), as well as to only those data collected by research surveys undertaken in 2018 and 2019. As commercial samples were only available for a single year (2020), a Chapman and Robson catch curve (see Fairclough et al. 2014) was applied to these data, as well as to the pooled survey data from 2018-19 to compare results.

Equilibrium Biomass Model

Estimates of female relative spawning biomass (B_{rel}) for Goldband Snapper were derived were derived from an age-based equilibrium biomass model. This is essentially a per-recruit model that incorporates a Beverton and Holt stock-recruitment relationship (with the steepness parameter *h* set to 0.75, as recommended by Francis 1992) to account for expected impacts of fishing on recruitment. While analyses are subject to several of the (equilibrium) assumptions that also apply to catch curve analyses, these analyses incorporate additional knowledge of key biological characteristics of a fish stock, such as growth, maturity and selectivity (Table A1.1).

The equilibrium biomass model analyses were undertaken in R (R Core Team 2023) using the L3Assess package (Hesp 2023, see vignette for full model description). The model was specified to use an annual timestep and incorporated catch curve estimates of *F* and age-based selectivity (retention) parameters, as well as biological parameters provided in Table A1.1. The analyses assumed deterministic growth of fish, a sex ratio at birth of 1:1, constant *M* across all ages, and constant *F* for individuals fully vulnerable to capture and retention by the fishery.

Uncertainty around *F*, *M* and *h* were considered by re-sampling 500 normally distributed values of each parameter based on the estimated or specified mean and associated standard deviation, where the latter ranged between 0.025 and 0.1.

Table A1.1. Biological parameter inputs to the equilibrium biomass model analyses for Goldband Snapper in the GCB.

Parameters	Value	Additional information
Growth (von Bertalanffy)		$L_t = L_\infty(1 - \exp(-k\,(t - t_0)))$
L_∞ (mm FL)	632	Updated 2022
k (year^{-1})	0.34	Updated 2022
t_0 (years)	0.03	Updated 2022
Weight-length (g, mm TL)		$W = a\,L^b$
a	2.47×10^{-5}	Wakefield, unpublished data
b	2.95	Wakefield, unpublished data
Maturity (logistic)		$P = 1/(1 + \exp\,(-log_e\,(19)(A - A_{50}^{\text{mat}})/(A_{95}^{\text{mat}} - A_{50}^{\text{mat}})))$
A_{50}^{mat} (years)	3.3	Updated 2022
A_{95}^{mat} (years)	6.4	Updated 2022
Natural mortality		
M (year^{-1})	0.16 (sd 0.01)	$-\ln(0.01)/A_{\max}$, where $A_{\max} = 28$ years
Steepness		
h	0.75 (sd 0.025)	

Level 5 Assessment

Bespoke Integrated Model

A bespoke age-structured dynamic population model was used to provide estimated annual time series of female B_{rel} and F for the oceanic Snapper stock in the GCB. The model was fitted using annual time series of observed catches (all sectors, since 1952), standardised commercial CPUE indices (1977 to 2023, adjusted for changes in fishing efficiency) and age composition data sampled from commercial catches (since 1992) and recent fishery-independent surveys (2018 to 2023). The biological parameters specified as model inputs are provided in Table A1.2 (see also Appendix 3 for biological data analyses undertaken prior to the 2024 assessment to inform these updated parameters).

The model uses a 20-year ‘burn-in period’ to set up the initial state of the modelled population, assuming there was already some depletion of the stock prior to the first year of data (1952). A description of the age-based integrated model applied in previous assessments, which is broadly similar to the current bespoke model, is provided by Jackson et al. (2020). The following key changes were made to the model and input data for the current assessment:

- Inclusion of commercial CPUE from 1977-1989, previously not used in assessments. The standardised commercial CPUE data were split into four separate time series, based on (1) monthly returns from 1977-1989, (2) monthly returns from 1990-2007, (3) daily logbook data from 2008-2017 and (4) daily logbook data from 2018-2023.

Consequently, four catchability coefficients are estimated in the model, one for each time series.

- The current model included three separate growth periods estimated using available data (as opposed to two periods in the 2022 assessment): an initial growth period up to 2013 (estimated from 2008-2011 data), a second growth period from 2013-2018 (estimated from 2016-2018 data, given evidence that growth had been increasing in the years leading up to 2013), and a third growth period from 2019 to the end of model forecast period (using growth parameters from the earlier period, given evidence of recent decline in growth).
- Logistic age-based relationships were still used to model gear selectivity and retention, however, for this assessment, age-based retention parameters were specified (rather than estimated) at values corresponding to the minimum legal length (accounting for a change from 410 to 380 mm in 2020, converted to age using the estimated growth parameters from the relevant growth period). Age-based, logistic gear selectivity curves were estimated (rather than specified) separately for the commercial fishery (for several time blocks to allow for time-varying selectivity for this fleet), and the fishery-independent surveys undertaken since 2018 (assumed to not be time-varying).

The model was projected for 4 years from the last year of available data until the year of the next Snapper assessment (i.e., 2027), assuming average recruitment for this period, as determined from the Beverton-Holt stock recruitment relationship. Several modelling scenarios were run to explore the influence of different future catch levels on the projected recovery trajectories. For all scenarios, catches in 2024 were specified as 75 t (i.e., corresponding to the current level), with annual catches in 2025-2027 specified as 75 t, 100 t, 125 t and 150 t.

Additional sensitivity analyses were conducted to examine model outputs with varying model assumptions and data inputs, including key changes since the last assessment and applying alternative (lower and higher) specified values for steepness; *h* (0.65, 0.85), natural mortality; *M* (0.13, 0.15 year^{1}), and initial fishing mortality; *F* (0, 0.06 year^{1}).

The integrated stock assessment model was run using the software package ADMB (Fournier et al. 2012), with annual point estimates and associated 60% and 95% confidence intervals (CI) reported for female B_{rel}, *F* and recruitment. The estimated B_{rel} and *F* (and associated 60% CI) in 2023 and at the end of the projection period (2027) were compared to harvest strategy reference levels to evaluate current status and predicted rates of recovery.

Evaluation of conversion of the age-based (bespoke) integrated model used to assess the oceanic Snapper stock in the Gascoyne into the Stock Synthesis (SS) modelling framework (Methot and Wetzel 2013) is currently underway, and additional models in SS are being explored to incorporate additional data (e.g. marginal length and conditional age-at-length data) to better inform the stock assessment model, and thus its estimates of stock status and exploitation.

Table A1.2. Biological parameters employed for the integrated model analyses of the oceanic Snapper stock in the GCB.

Parameter	Value	Additional information
Growth parameters		$L_t = L_\infty(1 - \exp(-k\ t))$ Estimated for two periods using age- and length-based catch curve model in L3Assess (Hesp 2023). See Appendix 3 for analysis and results.
L_∞ (mm TL)	777 (1952-2012, 2019-2027) 738 (2013-2018)	Updated in 2024
k (year^{-1})	0.18 (1952-2012, 2019-2027) 0.28 (2013-2018)	Updated in 2024
Total-fork length parameters		FL (mm) $= a_L\ TL$ (mm) $+ b_L$
a_L	0.897	Wakefield (2006)
b_L	23.058	Wakefield (2006)
Length-weight parameters		W(g) $= a_W\ TL$ (mm) ^{bw}
a_W	5.61×10^{-5}	Wakefield et al. (2017)
b_W	2.827	Wakefield et al. (2017)
Maturity parameters		Logistic, age-based
A_{50}^{mat} (years)	4.0 (1952-2017) 3.1 (2018-2027)	Updated in 2024
A_{95}^{mat} (years)	6.0 (1952-2017) 6.74 (2018-2027)	Updated in 2024
Steepness (h)	0.75	Beverton & Holt stock recruitment relationship
Recruitment variability	0.6	Standard deviation for recruitment deviations in log space
Natural mortality, M (year^{-1})	0.14	Estimated using the method described by Quinn and Deriso (1999), assuming 1% survival to the maximum age of 32 years in the Gascoyne
Initial fishing mortality, F (year^{-1})	0.03	

Appendix 2: Model Diagnostics

Snapper

Model fits

As described in Section 3.1.2, the individual time CPUE time series for oceanic Snapper in the Gascoyne are each relatively short with no overlap. In general (after adjusting for assumed changes in fishing efficiency), the observed and estimated annual CPUE from the monthly catch and effort data since 1977 were initially stable before declining gradually from around 1990 to 2007 (Figure A2.1). The integrated assessment model generally provides relatively good fits to these two CPUE time series, except for in the first few years (1977-1981), when observed values fluctuated widely and were more uncertain.

Since the CPUE have been calculated based on data from more detailed daily logbooks introduced in 2008, annual CPUE values were broadly stable until 2012, when observed values increase until 2014 (Figure A2.1). The assessment model underestimates the CPUE values for these three years, despite the increase being consistent with CPUE trends for Snapper in the northern West Coast Bioregion, driven by a strong recruitment pulse (Fairclough et al. 2021). Conversely, the model slightly overestimates the CPUE in 2015-17, when observed values suggest a large and rapid decrease in stock levels. Despite a larger uncertainty in CPUE values since 2018, due to the currently low number of catch and effort records, the model provides a good visual fit to the most recent CPUE time series and honours the large increase in observed CPUE from 2022 to 2023 (Figure A2.1).

Visual fits of the integrated model to annual age composition data collated from commercial catches since the 1990s are relatively good, with time-varying gear selectivity allowing the mode of the estimated age frequencies to fluctuate between years (Figure A2.2, Figure A2.3). For the fishery-independent survey undertaken since 2018, it was assumed that selectivity should not vary over time (i.e. due to broadly standardised fishing gear and handlining methods). Although the model does not fit well to the first two years of survey age samples, when the strong cohorts from 2016-2018 were first represented in data, the model fits improved from 2020 onwards (Figure A2.2).

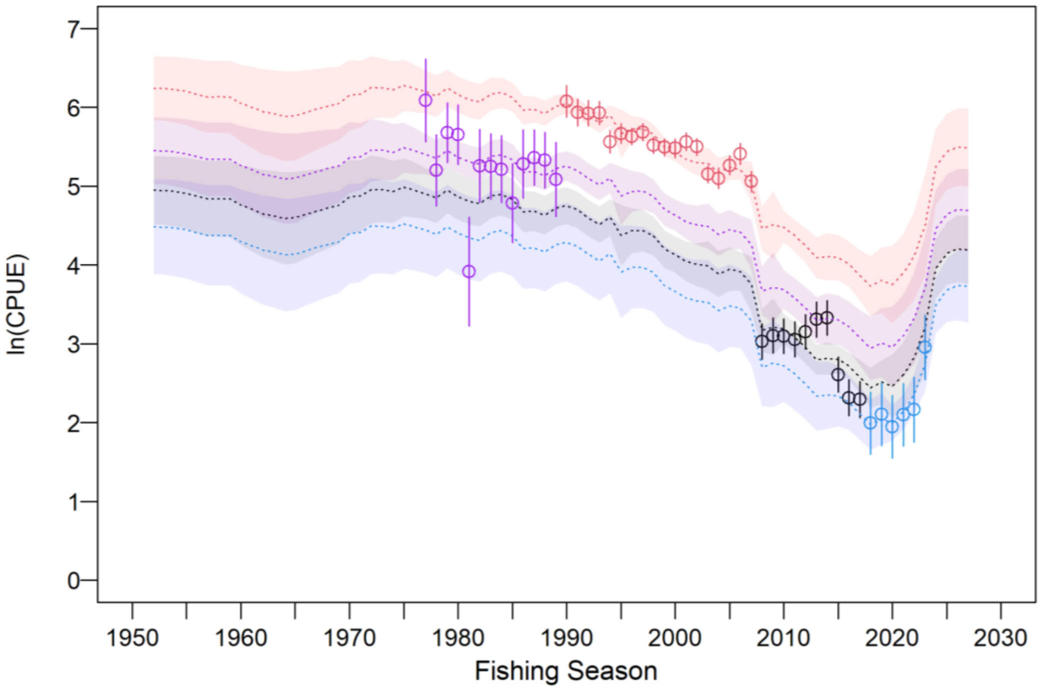

Figure A2.1. Expected (dotted lines and shading) and observed (open circles and error bars) standardised commercial catch per unit effort (CPUE) for Gascoyne oceanic Snapper, associated with monthly catch and effort return (CAES) data collected from 1977-1989 (purple), 1991-2008 (red), and daily logbook data collected in 2009-2017 (black) and in 2018-2023 (blue).

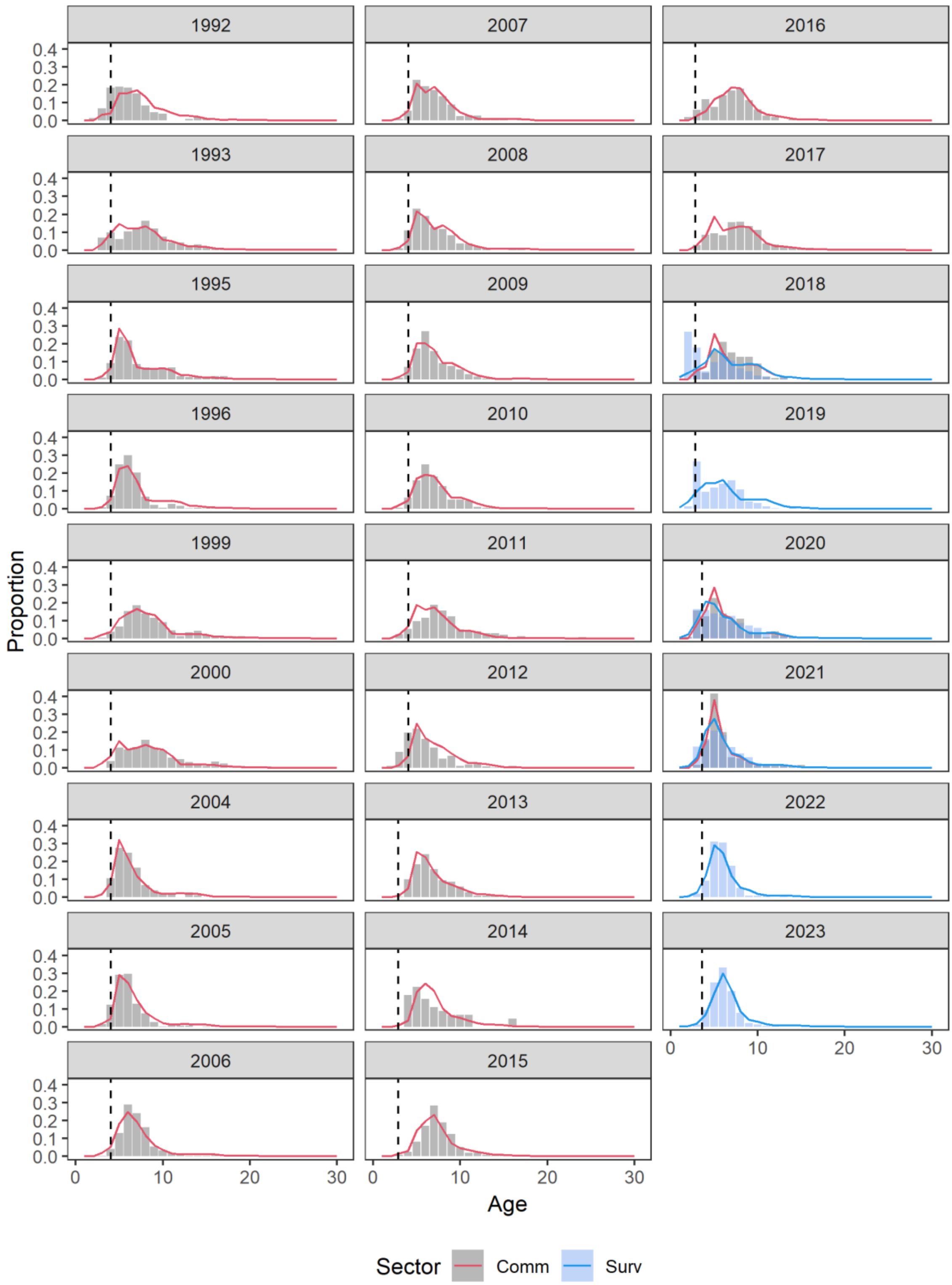

Figure A2.2. Fits of the age-based integrated assessment model to annual age composition data sampled from commercial catches (in red) and from fishery-independent research surveys (in blue) for Gascoyne oceanic Snapper.

Age at selection

With the A_{50} for retention specified at values corresponding to the MLL for Snapper in Gascoyne oceanic waters (fluctuating around 3-4 years, depending on variations in growth over time), annual trends in the estimated mean age at which fish become selected by the gear selectivity (i.e. A_{50} estimated from commercial age composition data) indicate substantial temporal variation (Figure A2.3). These variations reflect, at least in part, variations in abundance of fish at age due to recruitment variation. The estimated gear selectivity A_{50} has gradually increased since the 1990s, potentially influenced by the extended period of estimated below-average recruitment to the stock prior to the strong recent recruitment pulse from 2016-2018 (Figure A2.3). In contrast, the age-based gear selectivity estimated from data collected during fishery-independent research surveys, assumed to be time-varying, was lower (just below 5 years) (Figure A2.3).

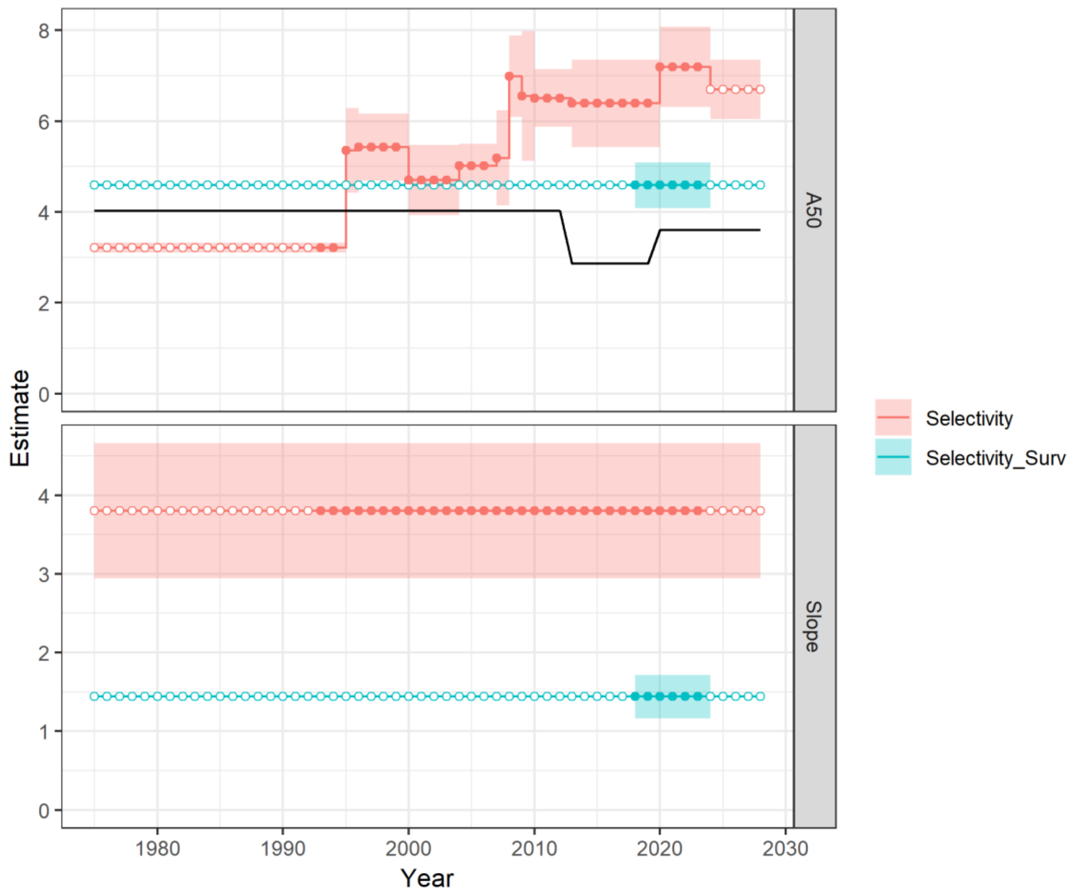

Figure A2.3. Estimates of selectivity parameters associated with the age-based integrated model fit to commercial (red) and survey (blue) data for the Gascoyne oceanic Snapper. The black line denotes the age at retention given the estimated changes in growth (in 2013 and 2020) and change in minimum legal length MLL (from 410 to 380 mm in 2020). Filled circles are values estimated by the model, whereas white circles denote the years before available data (early) or projection (late) periods.

Sensitivity analyses

Estimates of B_{rel} follow a similar trend across all model scenarios of alternate steepness (*h*), natural mortality (*M*), and initial *F*, with estimates of B_{rel} in the first year (1933) varying considerably between models with alternative specified values for initial *F* (Figure A2.4). Across all other model scenarios, estimates of initial B_{rel} were around 0.75. Estimates of B_{rel} across all models decline around 1965 before increasing in 1975 and following similar trajectories in recent years. Where h = 0.65 (scenario 2), estimates of B_{rel} in recent years were lower than with other models (Figure A2.4). General trends in *F* are similar across all models, except for scenario 2 between 2013-2017, where h = 0.65. In this model, the *F* declines sharply in 2013 and remains around 0.25 before declining sharply again in 2018 (Figure A2.4). Generally, estimates of uncertainty for B_{rel} and *F* overlapped in all model scenarios (Table A2.1). When decreasing *h* to 0.65, the estimated B_{rel} was lower (0.16; 60% CI = 0.10-0.21), but the *F* remained similar (0.07; 60% CI = 0.05-0.09), to the 'base case' scenario with a steepness of 0.75. As expected, when increasing *h*, the estimates of B_{rel} and *F* were higher and lower, respectively, than those from the base model.

Table A2.1. Summary of model sensitivity analyses relative to outputs from the base case model.

Model	Relative spawning biomass (B_{rel})		Fishing mortality (*F*)	
	Estimate	60% CI	Estimate	60% CI
Current (base case; h = 0.75, M = 0.14 y^{-1}, initial F = 0.03 y^{-1})	0.33	(0.27-0.39)	0.07	(0.05-0.08)
h = 0.65	0.16	(0.10-0.21)	0.07	(0.05-0.09)
h = 0.85	0.39	(0.33-0.46)	0.06	(0.05-0.08)
M = 0.13 y^{-1}	0.28	(0.23-0.33)	0.07	(0.05-0.09)
M = 0.15 y^{-1}	0.35	(0.29-0.42)	0.06	(0.05-0.08)
Initial F = 0 y^{-1}	0.33	(0.27-0.39)	0.07	(0.05-0.08)
Initial F = 0.06 y^{-1}	0.33	(0.27-0.39)	0.07	(0.05-0.08)

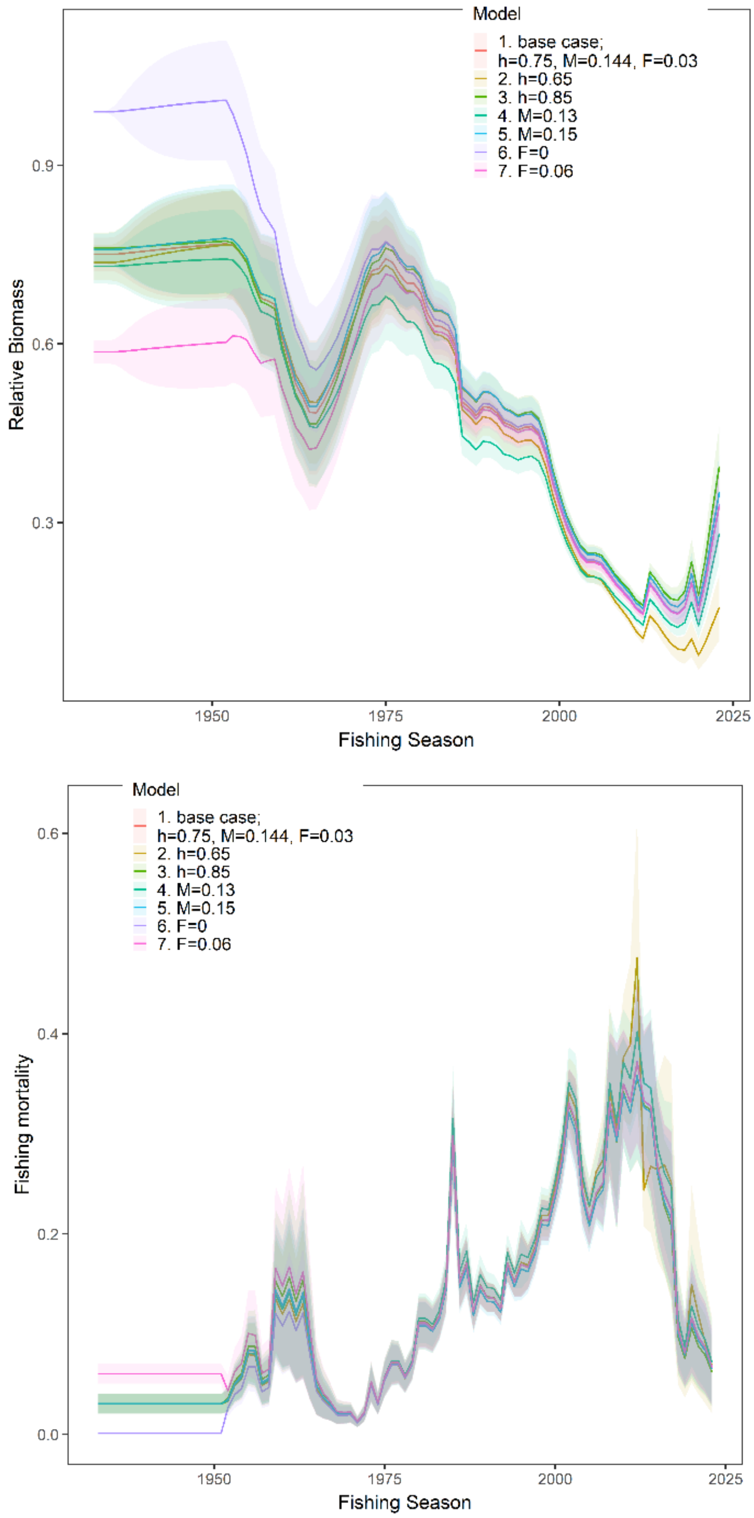

Figure A2.4. Model estimates (±95% CI) of relative spawning biomass (B_{rel}; left) and fishing mortality (*F*; right), across all model scenarios with alternative values of steepness (*h*), natural mortality (*M*) and initial *F*.

Goldband Snapper

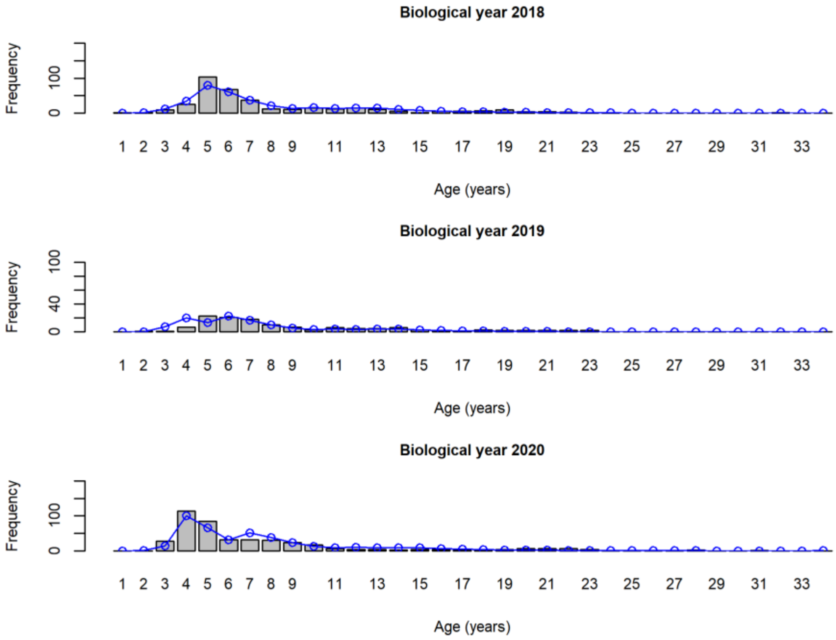

Figure A2.5. Catch curve fitted to age composition data for Goldband Snapper collected by research surveys and commercial catches between 2018 and 2020.

Appendix 3: Snapper Growth Analyses

The biological parameters used in the previous (2022) assessment of Gascoyne oceanic Snapper were estimated using length-at-age samples collected from waters off Carnarvon in the early 2000s (Wakefield et al. 2015; 2017) and from recent research surveys undertaken annually since 2018, which provided evidence of recent changes in growth and maturity (Jackson et al. 2023). Estimates of von Bertalanffy growth parameters used in the 2022 Snapper assessment were based on data collected for two sampling periods that comprised some smaller fish, required to inform the lower end of the growth curves (i.e., early 2000s and 2018-2021).

For this assessment, available length-at-age data were further analysed for temporal changes in growth using a form of catch curve model, implemented in the R package 'L3Assess' (Hesp 2023). This method, which is fitted to marginal length and conditional age-at-length data, simultaneously estimates parameters to describe growth, length-based selectivity and fishing mortality. Accounting for impacts of selectivity and fishing mortality when estimating growth is expected to reduce bias in estimated growth parameters.

Current growth analyses for Snapper were based on data from two alternate time periods (2008-2011 and 2016-2018). As samples from both these periods contained some older fish (> 15 years), it was considered feasible to estimate both the growth coefficient (k) and asymptotic length (L_∞) from these data (note a value for t_0 is not estimated by this method, i.e., it is assumed that fish at age zero have zero length).

Consistent with earlier growth analyses, the revised analyses indicate that meansize at age has changed over time, associated with higher estimated k values for the more recent period, but lower estimates of L_∞ (Table A3.1). Catch curve model fits and diagnostics are shown in Figure A3.1 - Figure A3.3). The respective estimates of mean length were substantially greater for the early than late period at age 3 years (419 vs 324 mm), age 5 years (461 vs 556 mm) and age 8 years (660 vs 593 mm).

Further exploration of commercial mean length-at-age data for fish in individual age classes (from 4+ to 8+ years) provided evidence for a generally increasing trend in size at age between the early 2000s and late 2010s, and some indication of declining growth since 2019 (Figure A3.4), possibly associated with density-dependent factors (i.e., increase in recent abundance). For the current assessment model, it was therefore deemed appropriate to consider three separate growth periods:

- 1st growth period extending up to 2013 (estimated from 2008-2011 data, i.e. first period of data with sufficient information to estimate all growth parameters),
- 2nd growth period from 2013-2018 (estimated from 2016-2018 data, given evidence that growth had been increasing in the years leading up to 2013),
- 3rd growth period from 2019 to end of model forecast period (using growth parameters from the earlier period, given evidence of recent decline in growth).

Note that use of this approach represents an approximation to growth changes over time, which are cumulative and gradual, rather than being abrupt. Future assessments could be improved by using a more sophisticated approach for modelling time-varying growth, e.g. as used in the bespoke ADMB assessment model for WA dhufish for the west coast bioregion (Fisher et al., 2025), but which is more easily implementable in Stock Synthesis.

Table A3.1. Estimates (±95% confidence intervals) of sex-specific von Bertalanffy growth parameters ($\boldsymbol{L_\infty}$, $\boldsymbol{k}$), as well as length-based selectivity ($\boldsymbol{L_{50}^{sel}}$) and fishing mortality ($\boldsymbol{F}$) (combined for females and males) for Gascoyne oceanic Snapper using the catch curve method described by Hesp (2023), based on data from 2008-2011 and 2016-2018. *n* = number of fish. Note that *F* corresponds to the long-term equilibrium *F*, as opposed to reflecting *F* in recent years only.

	2008-2011	2016-2018
Females	(*n* = 864)	(*n* = 811)
L_∞ (mm)	777.4 (740.4-816.3)	738.2 (731.2-745.3)
k (year^{-1})	0.18 (0.17-0.20)	0.28 (0.27-0.28)
Males	(*n* = 895)	(*n* = 714)
L_∞ (mm)	734.2 (704.1-765.6)	688.8 (675.7-702.0)
k (year^{-1})	0.21 (0.19-0.22)	0.32 (0.30-0.34)
Sexes combined		
L_{50}^{sel} (years)	416.6 (410.1-423.2)	537.5 (530.4-544.8)
F (year^{-1})	0.18 (0.16-0.2)	0.23 (0.21-0.26)
CV	0.11 (0.11-0.12)	0.08 (0.08-0.09)

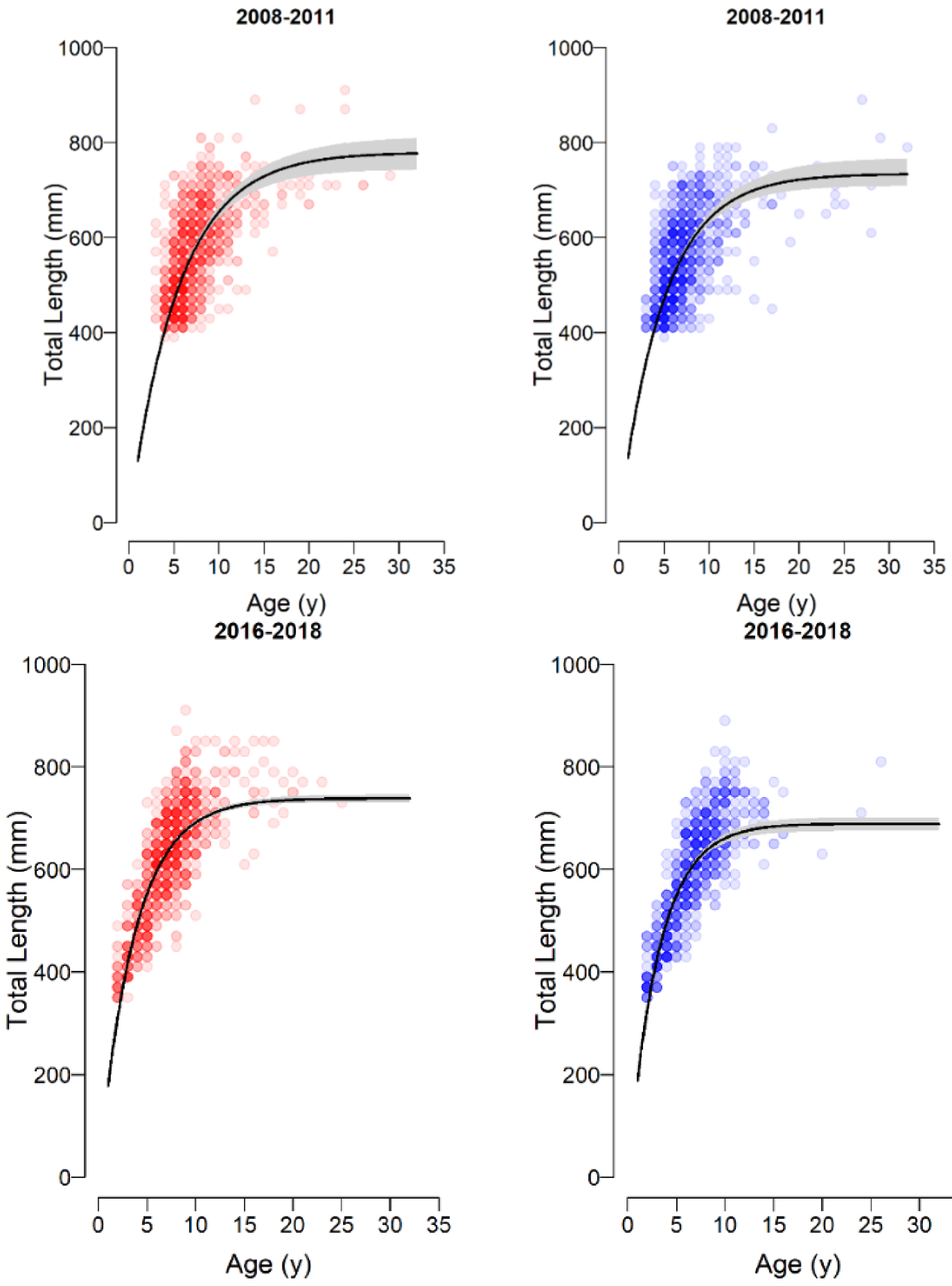

Figure A3.1. Growth curves for female (left) and male (right) Snapper sampled from oceanic waters in the Gascoyne, estimated from a length- and age-based catch curve model fitted to conditional age-at-length and marginal length data from commercial samples from 2008-2011 (top) and 2016-2018 (bottom).

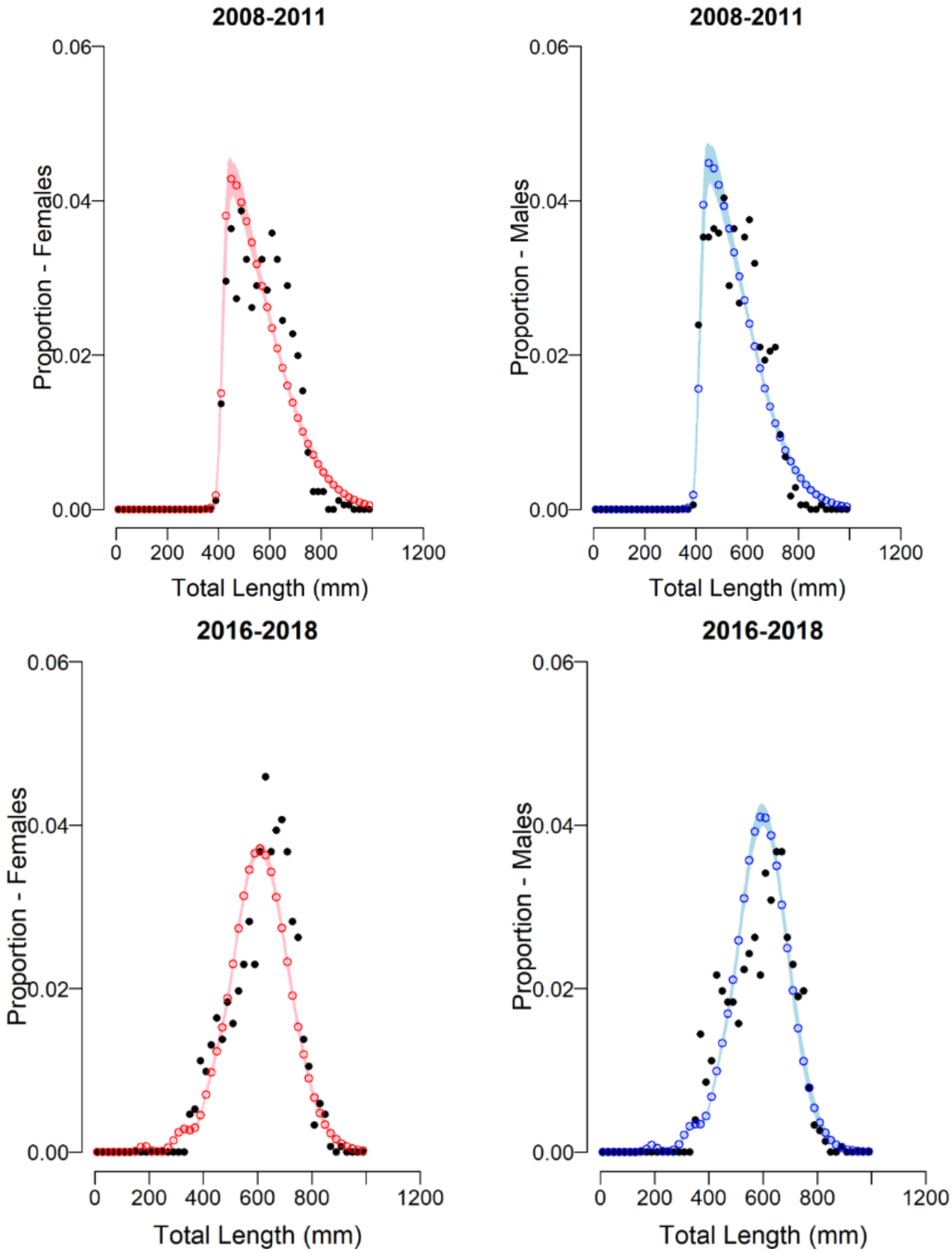

Figure A3.2. Fits of the age and length-based catch curve model to marginal length composition data for female (left) and male (right) Snapper samples in 2008-2011 (top) and 2016-2018 (bottom).

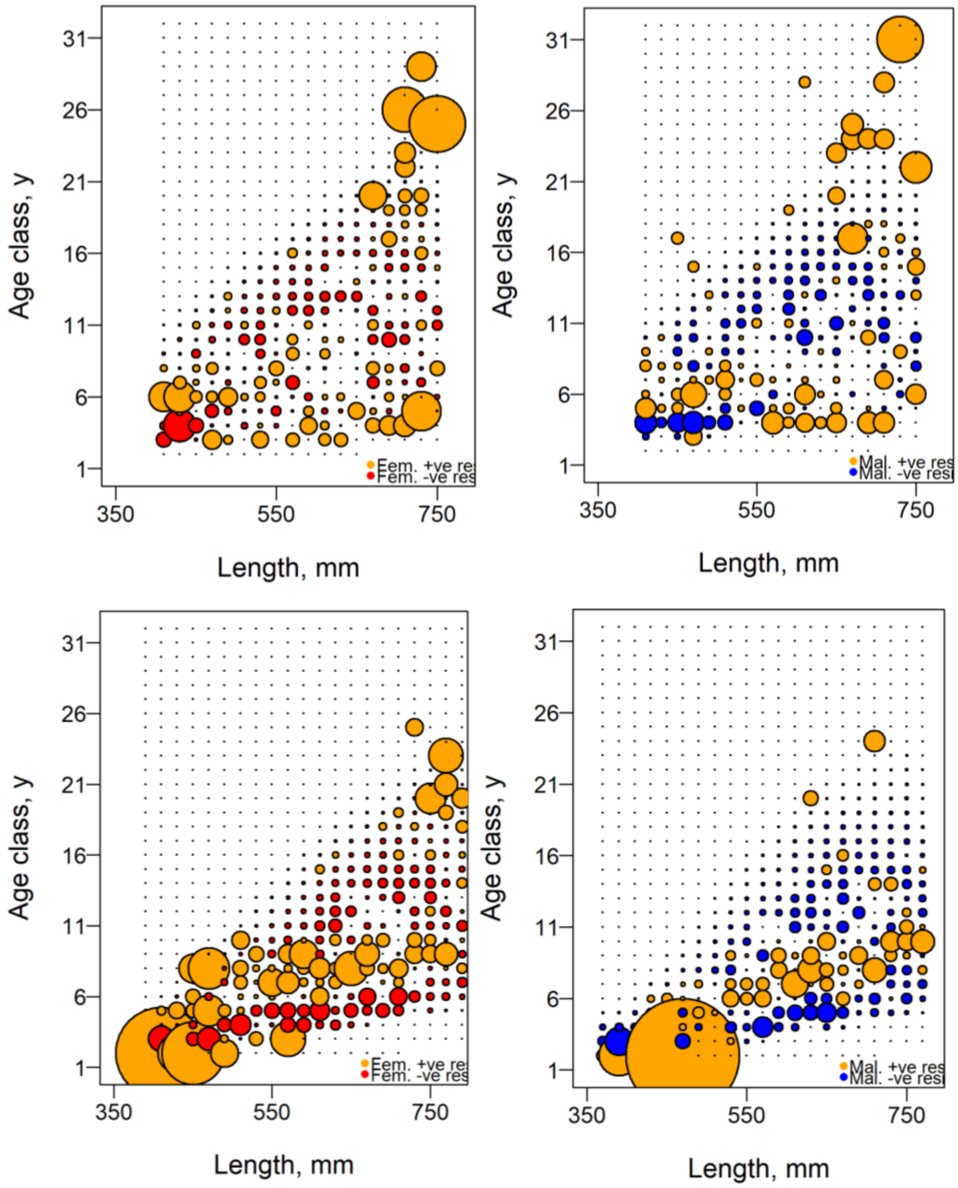

Figure A3.3. Pearson residuals for observed and expected proportions at age in each length class derived from the age and length-based catch curve model fitted to conditional age-at-length and marginal length data for female (left) and male (right) Snapper samples in 2008-2011 (top) and 2016-2018 (bottom). Note, large circles tend to correspond to length classes with small sample sizes.

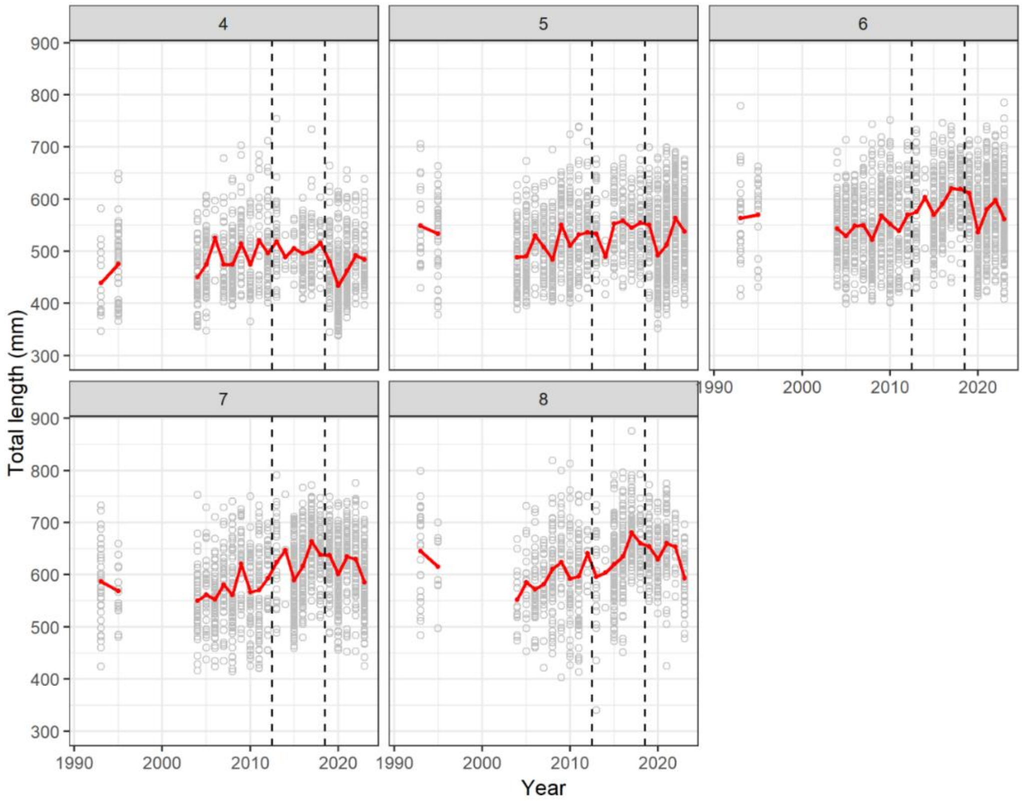

Figure A3.4. Total lengths (mm) of 4 to 8-year-old Snapper sampled from commercial catches in the Gascoyne between 1993 and 2023 (note that no data are available from 1994 and 1996-2003). The red line denotes mean length-at-age in each year at each age.