Assessment summary

Information in this section provides a summary of the relevant fisheries statistics and stock assessment outcomes to inform determining the biological stock status of Yellowtail Scad (*Trachurus novaezelandiae*) against criteria for the 'Status of Australian fish stocks' (SAFS) and a total allowable commercial catch (TACC) in New South Wales (NSW) waters. Where data are unavailable or insufficient to reliably inform a criterion, the heading has been retained and the lack of information or alternative proxy indicated in the summary. This format has been maintained to transparently represent the available data and highlight areas where alternate data sources or analyses probably are required to improve status determination in the future.

Stock structure

Yellowtail scad have an Australian distribution from southern Queensland to northern Western Australia (Stewart and Ferrell, 2001), and also occur off New Zealand (Horn, 1993). Their biological stock structure remains unknown; but in NSW there is evidence of spatial differences in growth rates which might be indicative of subpopulations (Stewart and Ferrell, 2001). Similar population variability has been observed for Yellowtail Scad in New Zealand (Horn, 1993).

Here, assessment of stock structure is presented at the biological stock level for eastern Australia. The Western Australian stock status remains jurisdictional.

Biology

Very few Australian studies have assessed population parameters for Yellowtail Scad, and all work is limited to the eastern Australian stock (Stewart and Ferrell, 2001; Neira, 2009; Neira et al., 2015). Annual spawning is assumed to occur along continental shelf waters off NSW and QLD (across an area of at least 24 000 km^2) during early spring (October), and potentially in response to discrete water masses with specific temperatures (e.g. ~21.5 °C; Neira, 2009; Neira et al., 2015). Eggs have been recorded along all NSW shelf waters to 200 m depth, but are more prevalent north of 32°S and up to 26°S (Neira, 2009; Neira et al., 2015). Based on various broad assumptions, including batch fecundity and spawning fractions derived from congenerics (the Atlantic Horse Mackerel, *T. trachurus* and Pacific Jack Mackerel, *T. symmetricus*), Neira (2009) proposed a spawning biomass of Yellowtail Scad at <10,000 t in 2002. But, owing to the above uncertainties among others (e.g. no understanding of total spawning areas or times), Neira (2009) highlighted the biomass estimate should be used with caution. No work has assessed subsequent dispersal patterns, although Smith (2003) identified larvae off Sydney (within 3 km and down to 50 m).

Juveniles typically recruit to inshore marine areas, including the lower reaches of estuaries, across shallow, soft substrate, and often remain close to permanent structures (e.g. wharves), where they grow quite quickly (Stewart and Ferrell, 2001). There are no formal published estimates of 50% size at maturity, but using unpublished data, Kailola et al. (1993) proposed sizes of ~20 and 22 cm fork length (FL) for males and females, which are comparable to data collected from NSW specimens. According to Stewart and Ferrell (2001), such sizes correspond to 2–3 year-old fish; depending on latitudinal variation. Specifically, size-at-age data derived from otoliths suggest Yellowtail Scad grow more slowly off southern than northern NSW, with mean sizes of 19 and 20 cm FL at 2 years, respectively (Stewart and Ferrell, 2001).

Irrespective of latitudinal differences in growth, adults remain distributed across coastal areas, and often are associated with rocky reefs. Estimated L-infinities are between 24 and 31 cm FL (0.20 and 0.42 kg) and with a maximum reported age of 28 years (Stewart and Ferrell, 2001).

Stock status and rationale

Yellowtail Scad's distributions cross jurisdictional boundaries into Queensland, Victoria and Western Australia, but only small catches and low effort are reported from these other states, and for eastern Australia are unlikely to impact on the overall biological stock. There is a substantial Commonwealth component to the fishery, but these catches mostly are captured within NSW reporting (see below). The species is not expensive; with the average inflation-adjusted price fluctuating between ~$1.7 and $3.2 per kg for consistent sizes over the past 18 years.

Using all of the available data, the species has been intermittently assessed for stock status over the past 14 years within the NSW 'RAW' framework and always designated 'fully fished' (below). More recently, using nine years of size-at-age data (from otoliths) interspersed among 20 years of catch-and-effort data, Broadhurst et al. (2018) modelled the stock to produce estimates of natural and fishing mortalities, along with their size selection and catchability by the most common fishing gear (purse seines used in the NSW ocean-haul fishery). The most appropriate model suggested that fishing mortality was low. However, the estimates around the low fishing mortality were imprecise, precluding predicting biomass or recruitment in the absence of greater continuity in size-at-age data. Nevertheless, because catchability was very small, Broadhurst et al. (2018) postulated that it would require a five-fold increase in existing fishing effort (~4600 boat days) for fishing mortality to approach the estimated natural mortality. These results imply an underutilised resource.

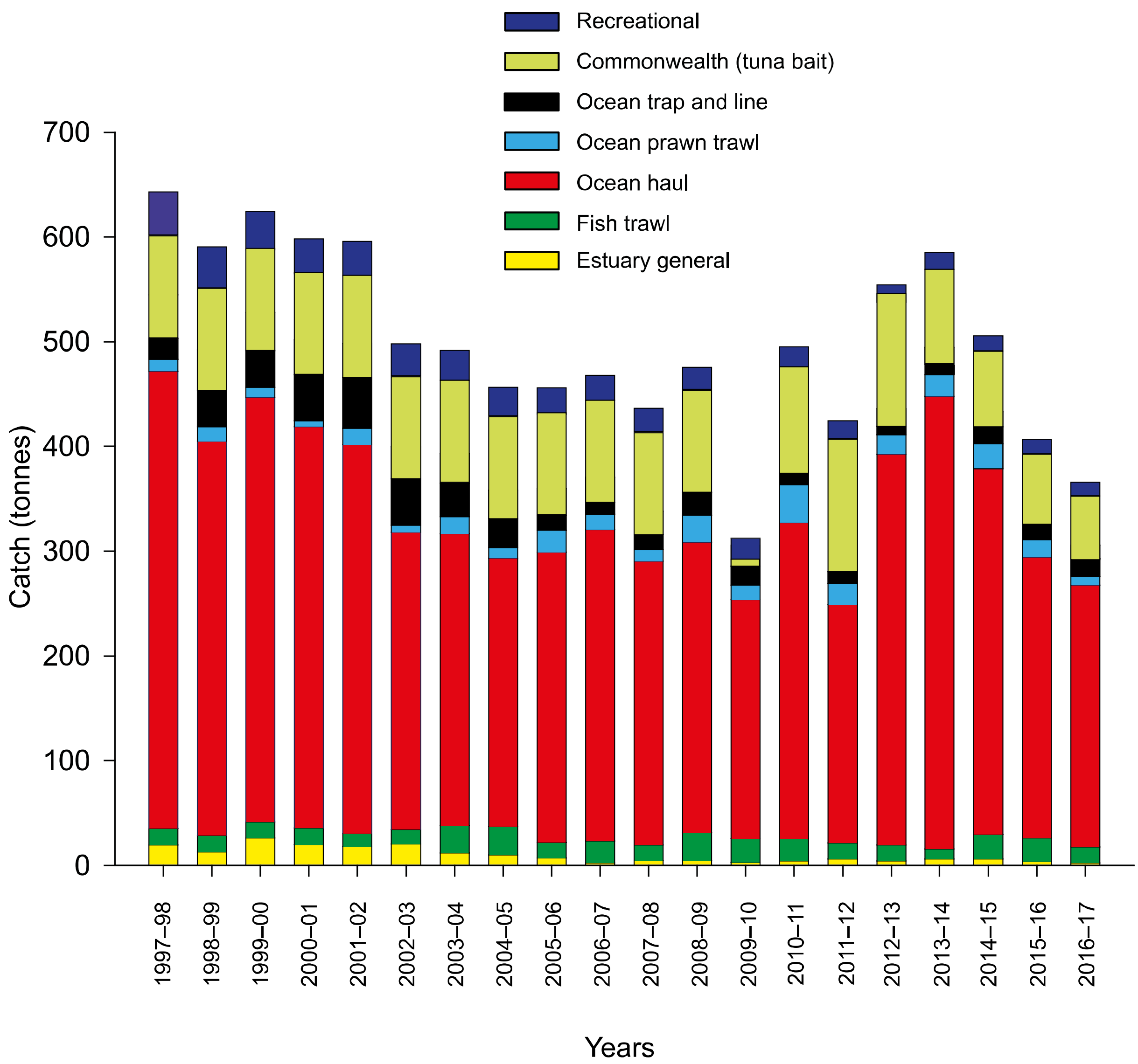
Notwithstanding few attempts at formal stock modelling, Yellowtail Scad has most recently been included in the SAFS framework and assessed according to the outlined criteria. The current assessment is based on data collected off NSW waters, where the bulk of the commercial and, relatively lower, recreational catches are taken. The weight of evidence presented in this assessment summary and in the most recent NSW stock-assessment overview, suggests that the biomass is unlikely to be recruitment overfished, and the current level of fishing pressure is unlikely to cause the stock to become recruitment overfished.

On the basis of this evidence the eastern Australian biological stock of Yellowtail Scad is classified as sustainable in NSW waters.

Fisheries statistics

Catch information

During the past two decades, the reported total annual retained catch ('harvest') of Yellowtail Scad in NSW has varied between ~327 and 650 t for a mean (± SD) of 506 ± 97 t. This catch is harvested in up to nine designated fisheries, encompassed within those classified as commercial, charter boat, recreational and Aboriginal.



Commercial

Partitioned annual reported commercial catches of Yellowtail Scad in NSW are available from 1997–98 to present, and encompass six fisheries, each with key fishing gears: estuary general (beach seines); fish trawl (high-opening, single rigged otter trawls); ocean haul (purse seines); ocean prawn trawl (low-opening, triple-rigged otter trawls); ocean trap and line (hook-and-line); and Commonwealth tuna bait (purse seines and submersible lift nets) (Fig. 1). Total

Catch information

reported commercial catches have ranged from 307 (2009–10) to 608 t (1997–98), but mostly have remained fairly stable at 450–520 t (mean of 482 ± 85 t; Fig. 1).

Typically around 80–90% of all landed Yellowtail Scad are purse seined by vessels working in the NSW ocean-haul fishery or caught using submersible lift nets and/or purse seines in the Commonwealth tuna-bait fishery (the latter under a 'Section 37' permit in NSW). Within these two fisheries, NSW ocean-haul purse seiners land at least 60% of the total catch for a mean of 314 ± 62 t p.a. Commonwealth vessels land 90 ± 40 t p.a.; although data are unavailable prior to 2008–09, and have been populated in Figure 1 based on the average of recent reported fiscal years.

Reported fish- and ocean prawn-trawl catches have remained fairly consistent among years at means of 18 ± 5 and 16 ± 7 t p.a. By comparison, estuary general and ocean trap-and-line catches peaked at 21 and 49 t p.a. respectively before 2006–07, and then stabilised at 4 ± 1 and 14 ± 4 t p.a. over the subsequent decade (Fig. 1).

Charter boats

Yellowtail Scad are also caught from charter boats (hook-and-line) in NSW (Gray and Kennelly, 2017; 2018), but catches have not been separated from Jack Mackerel (*Trachurus declivis*) and therefore are excluded in Figure 1. In any case, the total annual combined catches of both species over the past decade have only been reported at between 1500 and 9500 fish p.a. Even if all individuals were Yellowtail Scad then using a mean weight — most recently estimated in recreational catches (0.24 kg; West et al., 2015) —the harvested numbers still only equate to ~0.4–2.2 t p.a.

Recreational

Estimates of the recreational harvest (hook-and-line) of Yellowtail Scad are available from the National Recreational and Indigenous Fishing Survey in 2000–01 (Henry and Lyle, 2003) and a NSW state-wide survey in 2013–14 (West et al., 2015). These two studies provided a broad overview of recreational catches, which have been interpolated here among preceding, intervening and subsequent years (Fig. 1). Both surveys estimated catches in terms of numbers, which have been crudely transformed to weights using mean sizes. Specifically, in 2000–01, the estimated harvest was ~152 000 fish weighing 33 t, while in 2013–14, 90 000 fish or 16 t was retained.

Aboriginal

There is no information available on Aboriginal catches of Yellowtail Scad in NSW waters, but this is likely to be marginal.

Discards

Like all fishing gears (e.g. MacLennan, 1992), none of those used to catch Yellowtail Scad in NSW are completely selective for the targeted sizes, which vary according to fisher-specific requirements and market-driven factors. For purse seines targeting fish for human consumption, a minimum commercial size (MCS) of ~15 cm fork length (FL) appears relevant

Catch information

(Stewart and Ferrell, 2001), but Graham et al. (2009) observed fish trawlers retain individuals as small as 10 cm FL. It is likely that other commercial fishers targeting Yellowtail Scad for bait retain all sizes caught.

While formal manipulative experiments are required to assess purse-seine selectivity (and escape mortality), Broadhurst et al. (2018) estimated a fleet-wide 50% retention among fish aged 5 years (or ~20 cm FL), and with ~7–36% of 2–4 year-old fish (~15–18 cm FL) escaping. Based on the MCS of 15 cm FL above, such selectivity would imply minimal discarding, but the actual quantities remain unknown. Because Yellowtail Scad are targeted as bait by Commonwealth vessels, discarding might not be widespread.

Despite having large mesh sizes (≥90 mm between the knots), fish trawlers in NSW are able to catch quite small Yellowtail Scad by using very low (and variable) hanging ratios in their codends (Graham et al., 2009). During a three-year observer study of NSW fish trawlers (mostly using large hanging ratios) in the early 1990s, Liggins (1996) did not note Yellowtail Scad as being abundant in catches, but more recently during a short-term manipulative experiment, Graham et al. (2009) observed a mean catch of ~150 individuals <10 cm FL discarded per 90-min deployment off Sydney (when nocturnally targeting School Whiting (*Sillago flindersi*)).

Nocturnally fished, triple-rigged penaeid trawls (mostly north of 33°S) also discard some Yellowtail Scad (based on MCS), but owing to their low headline heights and the apparent vertical movement of fish off the bottom at night, catches typically are limited to dusk and dawn deployments. Certainly, Kennelly et al. (1998) failed to record any notable catches of Yellowtail Scad during a three-year observer-based study of penaeid trawlers working 28–33°S. By comparison, nocturnally deployed, single-rigged penaeid trawls in Botany Bay and Port Jackson, Sydney historically caught substantial quantities of juvenile Yellowtail Scad (e.g. means of >100 and 10 individuals —<10 cm FL—per 30–90 deployment), but these fisheries have been closed since 2001 (Liggins and Kennelly, 1996). Current discarding of Yellowtail Scad by the remaining estuarine diurnal penaeid trawlers (currently~115 vessels in the Hawkesbury, Hunter and Clarence rivers) is marginal.

Beach seiners in NSW discard Yellowtail Scad, with Gray et al. (2001) and Gray and Kennelly (2003) estimating annual rates of up to 66 and 82% of the total catches for two estuaries, but the absolute quantities were low (e.g. 0.7–0.4 t per estuary p.a.). Further, based on work done by Broadhurst et al. (2007) a decade ago, estuarine beach seiners were recently granted a permit to increase mesh size to reduce bycatches of small Sand Whiting (*Sillago cilliata*); modifications that will have concomitant benefits for the selection of Yellowtail Scad.

No formal data are available describing discarding by ocean trap-and-line fishers, but assuming most Yellowtail Scad caught in this fishery are hooked, discarding rates should not exceed those by anglers. Despite no legal size and an individual bag limit of up to 50 fish per day, recreational fishers annually discard a considerable component of their angled Yellowtail Scad catches. Henry and Lyle (2003) estimated ~50%, for a total weight of ~33 t, while West et al. (2105) suggested a discard rate of 37% or ~9 t p.a.

Considering the above, and using broad ratios of retained-to-discarded catches among fisheries, scaled-up total discards of Yellowtail Scad in NSW are likely to be in the vicinity of

Catch information
~30 and 65 t p.a (or less than ~10% of the retained catch). No data are available on the fate of these discards, but studies on other small pelagics gears imply a bias towards mortality when discarded from active commercial fishing gears (Broadhurst et al., 2006; Uhlmann and Broadhurst, 2015). But, assuming fishing depths are shallow and hook ingestion is minimal, then based on other pelagics, the survival of discarded angled Yellowtail Scad should be >60–70% (Butcher et al., 2010; Broadhurst et al., 2012). Considering recreational fishing is likely to be the main contributor towards the total amount of discards, many Yellowtail Scad should survive, but clearly studies are required to estimate unaccounted fishing mortality.
Illegal, unregulated and unreported Given there is no minimum legal size for Yellowtail Scad and a very large recreational bag limit, their reported recreational catches might be fairly representable for that sector. By comparison, commercial logbook reporting might be prone to some misreporting, particularly among fishers targeting Yellowtail Scad for bait (i.e. which are never landed). However, there is no formal evidence to negate the existing catch and effort data.
Other jurisdictions The quantities of Yellowtail Scad taken by fisheries in other jurisdictions are small. Reported Western Australian catches are limited to bycatch by some purse seiners. Commonwealth catches are also low, and typically <0.6 t p.a, while ~15 t p.a. is landed in Queensland by otter trawlers.

Effort information

Commercial

Historical effort data describing the targeting of Yellowtail Scad are only available for vessels in the NSW ocean-haul and Commonwealth tuna-bait fisheries, and the latter only date to 2009–10. Further, prior to 2009, logbook effort data in the NSW ocean-haul fishery were calculated on monthly rather than daily returns, and so to standardize comparisons, all post-2009 effort data have been adjusted accordingly.

New South Wales (ocean haul) purse-seine effort peaked at over 2000 days in 1999–00, fell sharply the following year to 1 300 days, and then steadily declined within a range of 950–680 days over the subsequent 15 years following reductions in vessel numbers. By comparison, Commonwealth tuna-bait effort peaked in 2011–12 before remaining fairly steady for three years, after which it fell to only 236 days last year.

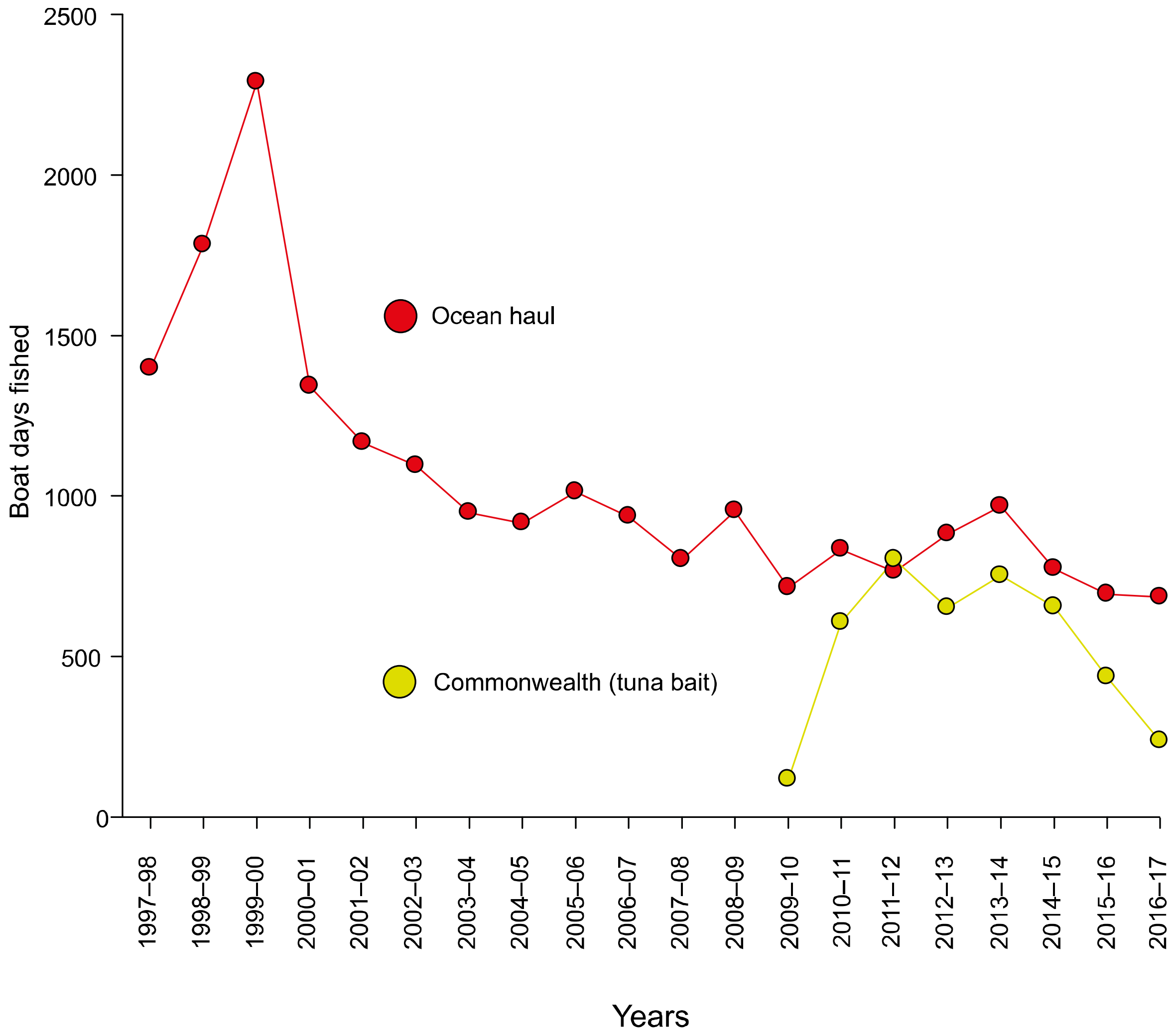


Figure 1 **Purse-seine effort (days fished) for New South Wales ocean-haul (red) and purse-seine/lift-net effort for Commonwealth tuna-bait (green) fishers that reported targeting Yellowtail Scad.**

Charter boats

There are no effort data for charter boats catching only Yellowtail Scad. Data have been combined with Jack Mackerel. Nevertheless, the effort directed against these two species is summarized in Figure 3. While virtually negligible (compared to commercial effort), the boat-hours fished was greatest in 2003–04, and then declined in 2007–08 before a second peak in 2014–15.

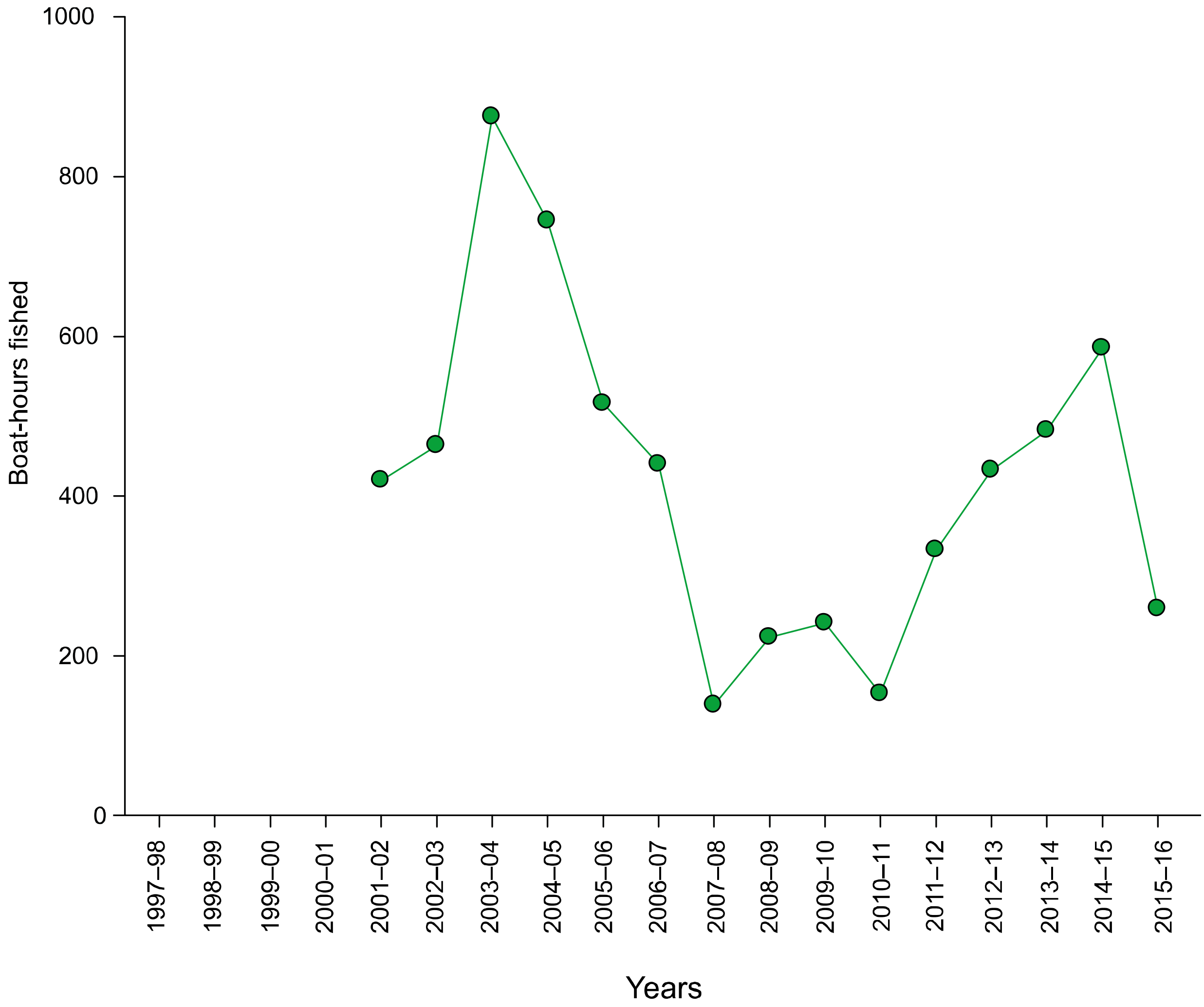


Figure 2 **Hook-and-line effort (boat-hours fished) for New South Wales charter boats that reported targeting Yellowtail Scad and Jack Mackerel combined between 2001–02 and 2015–16.**

Recreational

Along with catches, state-wide estimates of recreational fishing effort are limited to two time points: 2000–01 and 2013–14. Further, these effort estimates are not species-specific, but rather encompass broad spatial (e.g. coastal region, fresh vs. saltwater, boat- vs. shore-based, etc.) and technical categories (gear type).

Nevertheless, for saltwater fishing there was a 37% decadal decrease in effort from ~4 000 000 fisher days to 2 500 000 fisher days (Fig. 4). In terms of spatially separated effort, there were 32, 53, and 29% declines in offshore, inshore and estuarine fishing, respectively (Fig. 4). Of note, West et al. (2015) estimated the absolute recreational effort at 758 716 fishers and 320 818 boats.

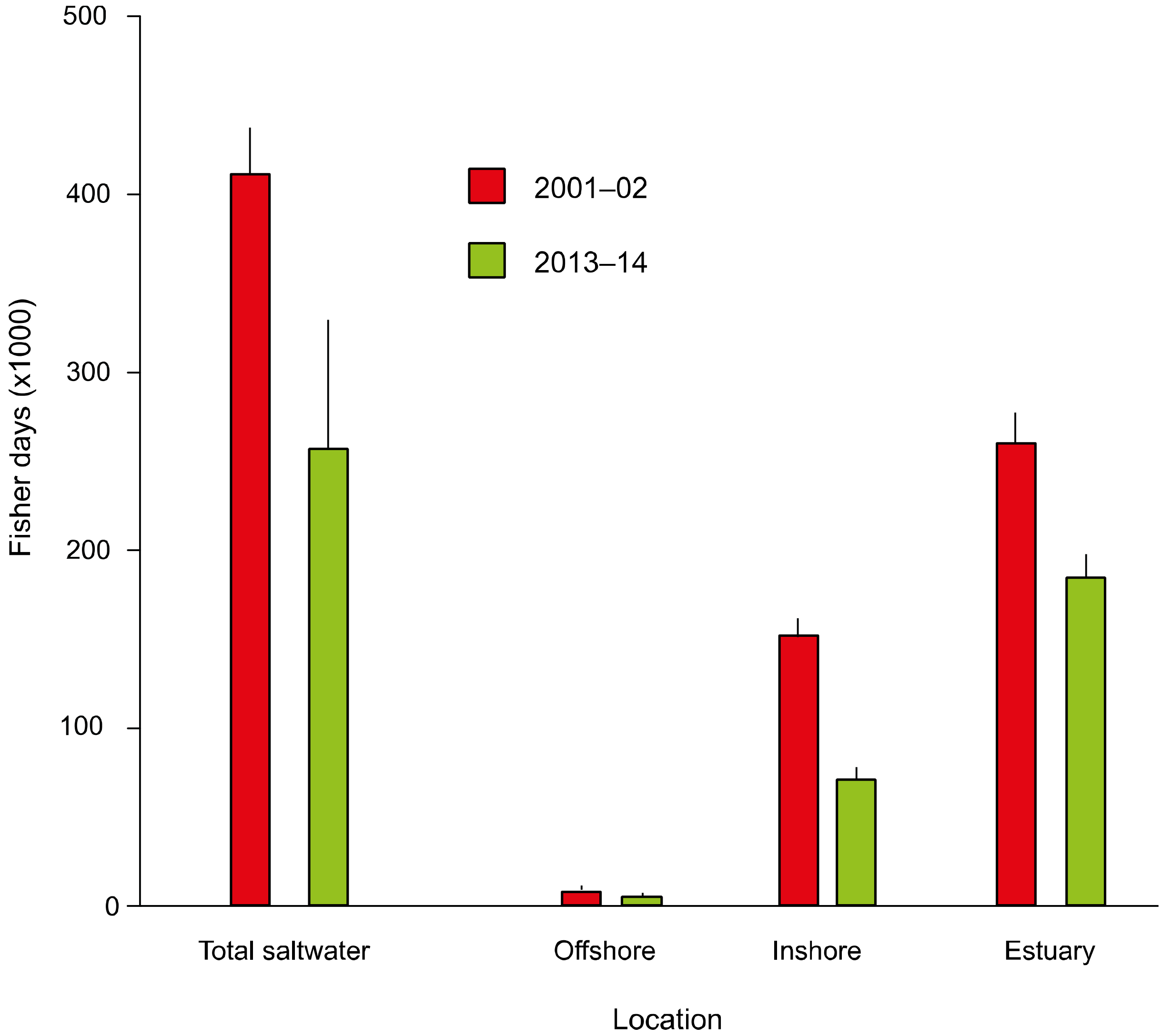


Figure 3 **Mean (+SE) New South Wales recreational fishing effort (fisher days: mostly hook-and-line) as a total, and partitioned by locations during 2000–01 and 2013–14.**

Aboriginal

There are no formal data available describing partitioned aboriginal catches of Yellowtail Scad in NSW waters, although these are likely to be marginal.

Catch-rate information

The units used to describe catch rates (or catch-per-unit-of-effort; CPUE) vary according to the fishery and associated data-reporting nuances. Nevertheless, all catch rates involve some form of days fished, and are standardised here for the time-series presented.

Commercial

Since 1999, the purse-seined catch rate (kg per boat-day fished) of Yellowtail Scad in the NSW ocean-haul fishery steadily increased to 2011–12, but more recently remained at 380–450 kg per boat day (Fig. 5). Broadhurst et al. (2018) attempted to model this change in fishing effort through 2 and 4% increases in fishing power, but inclusion did not improve model fits for estimating natural and fishing mortalities, or fleet selectivity.

The reported catch rates of fishers in the Commonwealth tuna-bait fishery are only available post 2008–09. While catch rates also increased until 2011–12, there was a subsequent reduction that appeared slightly (and negatively) correlated to the catch rate by purse seiners in the NSW ocean-haul fishery (Fig. 5).

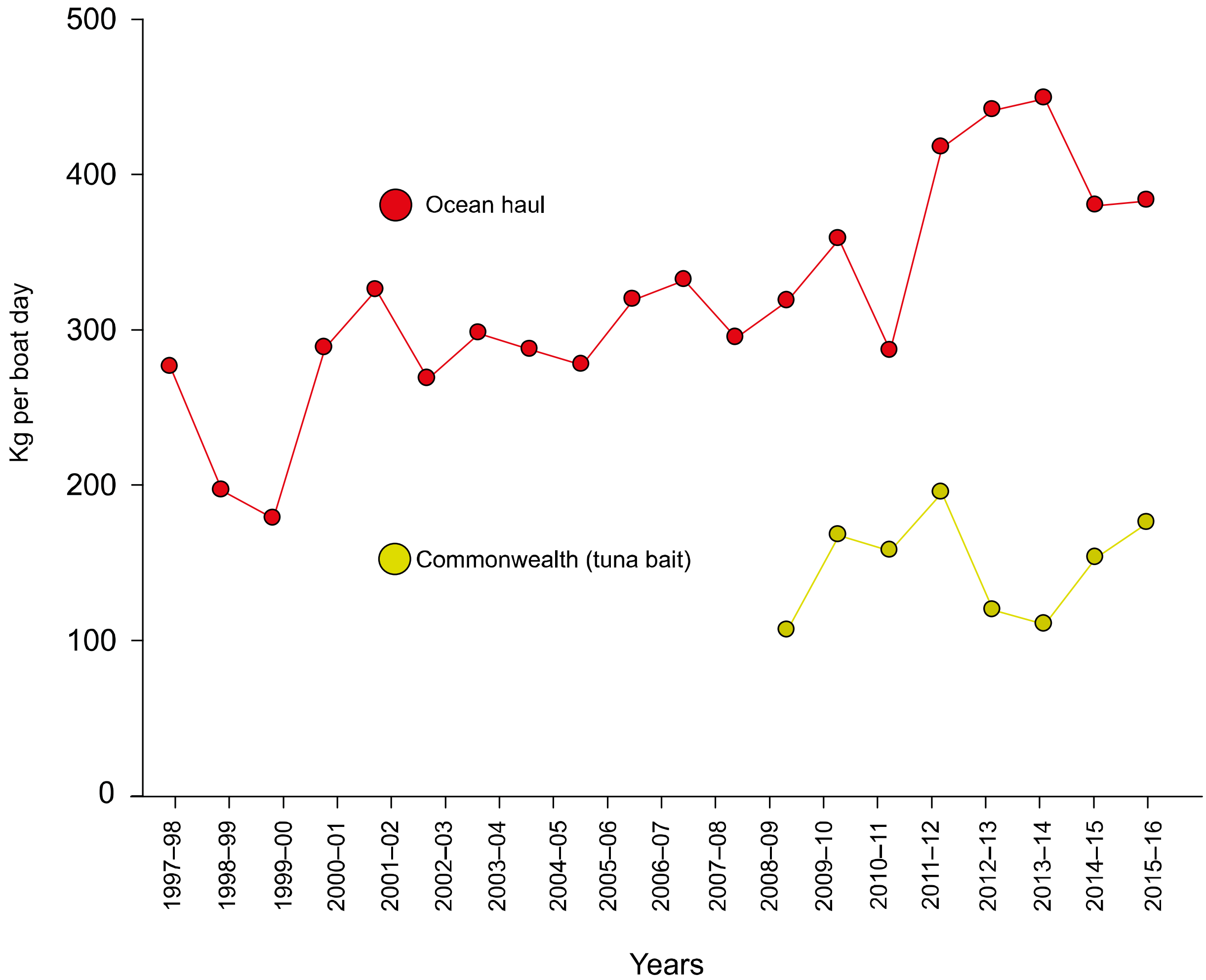


Figure 4 Standardized commercial catch rates (kg per boat day) of Yellowtail Scad purse seined in the New South Wales ocean-haul fishery and caught in the Commonwealth tuna-bait fishery.

Catch-rate information

Charter boats

Charter-boat catch rates (kg per boat-hour fished) are available from 2001–02 but, as stated, are aggregated for both Yellowtail Scad and Jack Mackerel, and with unknown proportions (although the rate is minimal with only 1–3 fish per boat hour). There was little change among catch rates to 2006–07, after which there was a reduction followed by an increase in the last reported year.

Yellowtail Scad and Jack Mackerel will be separated in future reporting, which will better facilitate discerning trends in charter-boat catch rates, although it is unlikely that charter-boat customers would request directed effort at such a low-priced species in lieu of more favoured species (e.g. Flatheads, *Platycephalus* spp. and Pink Snapper, *Pagrus auratus*) (Gray and Kennelly, 2017).

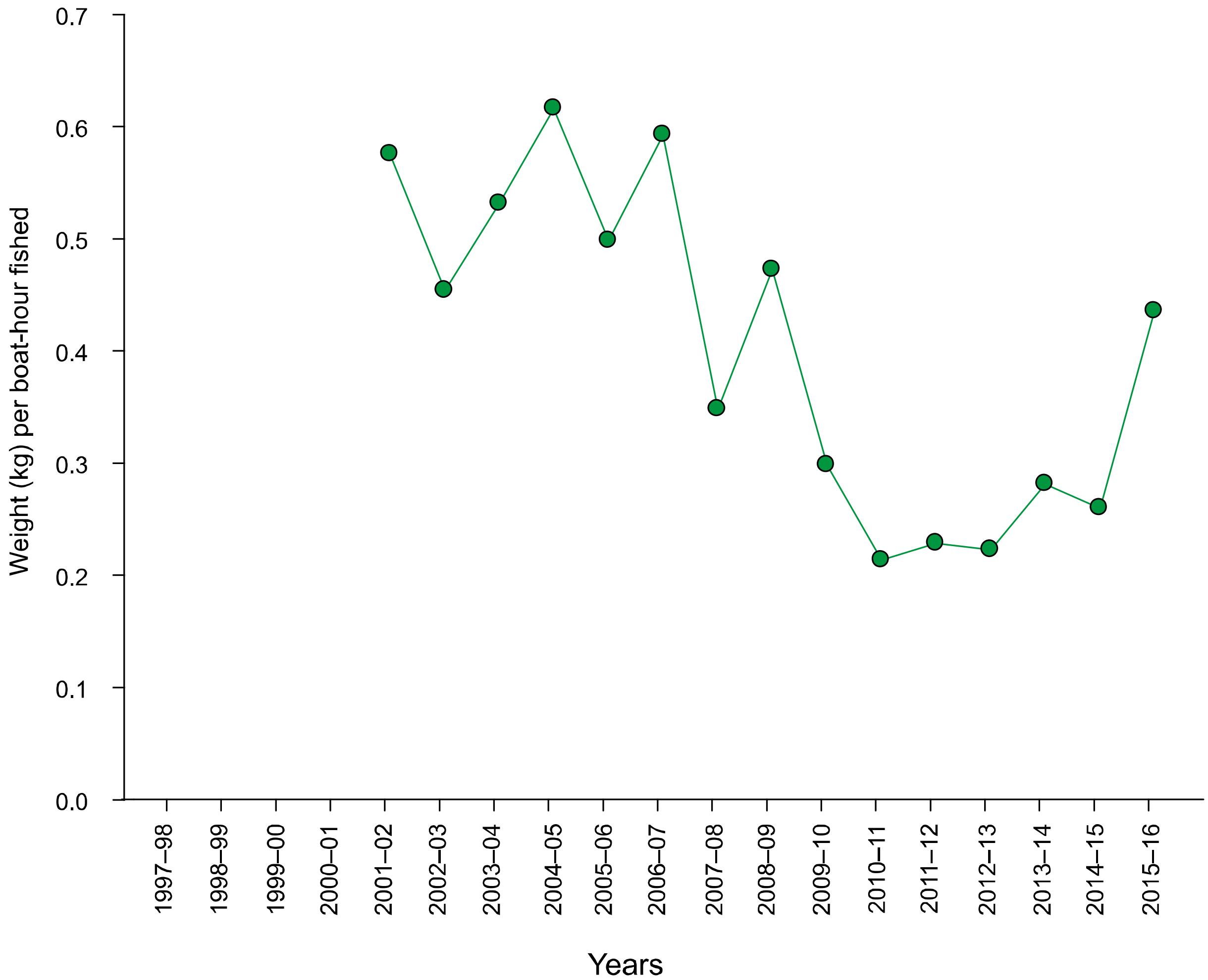


Figure 5 **Standardized catch rates (kg per boat-hour fished) of aggregated Yellowtail Scad and Jack Mackerel hooked by anglers onboard charter boats in New South Wales.**

Catch-rate information

Recreational

Notwithstanding some confounding between survey methodologies (discussed by West et al., 2015) for the two available time points, and a lack of partitioned effort among species, the coarse overall angled catch rate (kg per fisher day) of Yellowtail Scad in NSW has remained consistent.

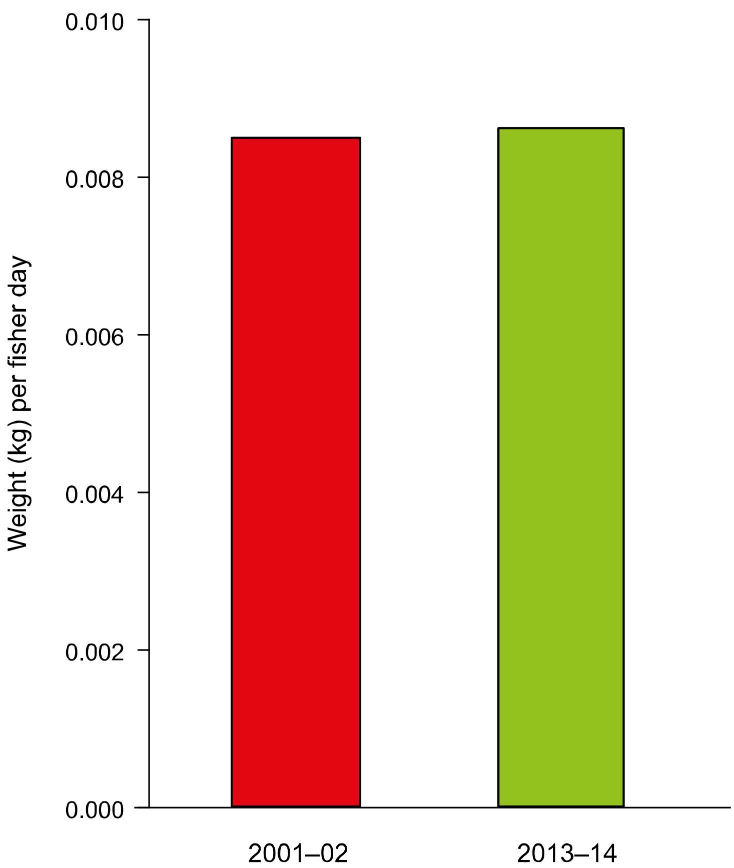


Figure 6 **Estimated weight (kg) of Yellowtail Scad angled per fisher day in New South Wales during 2000–01 and 2013–14.**

Aboriginal

Owing to a lack of partitioned catches or effort by Aboriginal fishers in NSW, there are no available temporal descriptions of catch rates.

Stock assessment summary

Stock-assessment methodology	
Year of most recent assessment	2018
Assessment method	Published stock assessment, weight of evidence, and interpolation.
Main data inputs	Commercial fishing catches: reported annual catches for all sectors by fiscal years (1997–98 to 2016–17); Recreational fishing catches: interpolated annual catches preceding, intervening and subsequent to two survey points (national recreational and indigenous fishing survey in 2000–01 and a NSW state-wide recreational fishing survey in 2013–14); Charter-boat fishery catches: reported annual catches by fiscal year (2000–2017; above); Size-at-age data comprising 2 347 otoliths of fish ages 0+ to -18 years; Estimated discards: all fisheries and based on published single time point observer-based accounts extrapolated among years using ratios to retained catches (above); Commercial catch rates: reported annual catch-and-effort data for purse seiners (responsible for 80–90% of the total catch; Length compositions: port monitoring (2000–2015; and Growth: estimated from otoliths and sizes.
Main data inputs (rank)*	Size at age: high; Commercial fishing catches: high; Recreational fishing catches: medium Estimated discards and rates: low Commercial fishing catch rates: high Length compositions: high
Key model structure and assumptions	The published stock assessment involved hazard functions applied to two decades of data to enable survival analyses. Key assumptions are that:

Stock-assessment methodology	
	1. Annual intervals among collected size-at-age data did not affect modelling outputs (not evident based on model convergence and fits); 2. Purse-seine selectivity is defined by a logistic regression (needs to be formally assessed); 3. Fishing mortality was not overly affected by variable fishing power.
Sources of uncertainty evaluated	The models were successfully converged, and not affected by variable inputs within the above assumptions.

*1 – High quality: data have been subjected to documented quality assurance and peer-review processes, are considered representative and robust and provide a high level of confidence to support fisheries-management decisions.

2 – Medium quality: data have been subjected to some internal quality assurance processes, have some documented limitations, but are still considered sufficiently accurate and informative to be useful to inform fisheries-management decisions with some caveats.

3 – Low quality: data have been subjected to limited, or no quality assurance processes, may be compromised by unknown or documented limitations that have not been fully explored, but are considered the best available information and require a high level of precaution to be exercised when interpreted to inform fisheries-management decisions.

Status indicators and limits - reference levels	
Biomass indicator or proxy:	Formal stock assessment indicated very low catchability and that fishing mortality was substantially lower than natural mortality (0.22 p.a.). These are the proxies for biomass. A predicted five-fold increase in effort would be required to inflict a fishing mortality approaching the estimated natural mortality.
Biomass limit reference level:	None specified in a formal harvest strategy, but natural mortality ≤ fishing mortality.
Fishing mortality indicator or proxy:	Fishing mortality compared to natural mortality.
Fishing mortality limit reference level:	The estimated natural mortality of 0.22 p.a and this would be the limit for fishing mortality.

Stock assessment results	
Biomass status in relation to limit:	Results of the stock assessment indicate that natural mortality comprises much of the total mortality, and so the biomass apparently is close to virgin state.
Fishing mortality in relation to limit:	Negligible.
Previous SAFS stock status:	Yellowtail Scad will be assessed under the SAFS framework for the first time in 2018. For the past 15 years, the species has been assessed as 'fully fished' under the NSW RAW framework.
Current SAFS stock status:	Defined as sustainable on the basis of the stock assessment.

Fishery interactions

Several fishing gears used to catch Yellowtail Scad within the designated fisheries (Fig. 1) are known to interact with listed or protected species of concern, and are summarized in Table 1 (Kennelly, 2018).

Table 1 Summary of fisheries catching Yellowtail Scad, with documented incidentally caught threatened, endangered or protected (TEP) species.

Name of fishery	TEP species
Ocean trap and line	Black Rock Cod, Eastern Blue Devil, Green Turtle, Greynurse Shark, Great Hammerhead, Humpback Whale, Scalloped Hammerhead, Short-tail Shearwater, Southern Dogfish, and White Shark
Fish trawl	Great Hammerhead, Green Turtle, Loggerhead Turtle, seals and Scalloped Hammerhead
Ocean prawn trawl	Green Turtle and Greynurse Shark
Estuary general	Green Turtle

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