

**Biology, stock status and  
management summaries for  
selected fish species in  
south-western Australia**

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**Fish illustrations**

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**We dedicate this guide to the memory of our  
friend and colleague, Ben Chuwen**

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## **Introduction**

### **Objective**

Many people are interested in fishes, but often it can be difficult to access reliable information on the biology, status and management of a particular fish species. Although there is a long history of world class fisheries research and management in Australia, the full details are generally only available in a fragmented manner in various scientific journals, books and reports. In some cases, these sources of information can be difficult to find and, even for fisheries researchers and managers, who usually have access to scientific journals, certain types of information such as unpublished reports or student theses, can be hard to acquire. The first objective in developing this guide was thus to collate a range of important details relating to current biological understanding, stock status and management for 30 of Western Australia's most important and/or well known, temperate marine fish species. The second objective was to provide a comprehensive list of publications relevant to each species, to enable easier access to more detailed information on those species.

### **Features of the content and layout**

Given the large number of species of fish in temperate Western Australia (Wakefield *et al.*, in press), it is impossible to incorporate all of the recreationally and/or commercially important temperate fishes within this guide. With input from researchers and managers (Department of Fisheries, Murdoch University and Edith Cowan University) and other fishing industry stakeholders (Recfishwest and WAFIC) during a workshop held in June 2011, 30 of the most commonly-targeted and/or widely recognised temperate fish species in Western Australia were identified for inclusion in the guide. These include species caught by both the recreational and commercial sectors, and which, collectively, are found in estuaries and temperate marine ecosystems, *i.e.* in nearshore and offshore coastal waters, in the water column (pelagic) or near the sea-floor (demersal).

The fish species have been ordered according to taxonomic family and a bibliography has been provided at the end of each species report, for easy identification of information relevant to that species. Where available, estimates for each criterion considered in this guide are reported for one stock in south-western Australia. If multiple estimates are available, the reader is referred to relevant literature containing those other estimates. If information is unavailable for Western Australia, but is available elsewhere, then this is included for at least one location.

The information contained within this guide has been presented in as concise a manner as possible. This has meant, for example, that only point estimates for the various biological and stock assessment parameters considered have been provided, *i.e.*, no standard errors or confidence limits, noting that if this extra information is required, it can usually be found in the cited literature. Furthermore, as there is an abundance of information in the popular literature on how to catch different fish species throughout Western Australia, this aspect has not been covered.

As a “scientific document”, the use of some complex terminology, as employed by researchers and managers on a daily basis, could not be avoided without reducing the relevance of this document. In the next section (Criteria Evaluated), explanations have thus been provided for various key terms used throughout the document, as well as for common abbreviations and equation/model parameters.

Where information is lacking the words “not reported” have been used to indicate a probable gap in current knowledge, thereby identifying where future research may be required (noting, of course, that a reference containing the relevant details may exist but which we failed to locate during our literature search). As this guide has succinctly summarised available biological and stock status data and management information for each fish species, a reader wanting for extensive information about a species will also need to refer to the cited literature. In the context of management for a species, this is likely to include, in particular, various editions of the Annual State of the Fisheries and Aquatic Resources Report, produced by the Western Australian Department of Fisheries (DoF) (Fletcher and Santoro, 2012). Whilst every effort has been made to ensure the accuracy of the information contained within this guide, we strongly encourage readers to refer to the original sources of information.

As new research and management information are constantly becoming available, unavoidably, this book might already be out of date to a certain extent by the time of publication. Despite this, we hope this guide will act as a useful reference for years to come.

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## Criteria evaluated

**Scientific name:** Genus and species name (scientific family name; common family name)

**Common names:** The first common name given is that listed in the Codes of Australian Aquatic Biota (Rees *et al.*, 2012), followed by other well-known common names.

**Key identifying features:** General description of key identifying features. See commonly cited references such as Hutchins and Swainston (1986), Yearsley *et al.* (2001) or Allen (2009) for diagrams and definitions associated with these key features.

### Distribution

**Worldwide:** A global description of the distribution of this species is provided if appropriate, otherwise it is indicated to be endemic to Western Australia.

**Western Australia:** A description of the distribution of this species within Western Australian waters.

**Maximum length, weight and age:** The maximum total body length (in mm) and whole wet body weight (in kg) are provided using the largest recorded individual caught by a recreational fisher in Western Australia or during a particular study. The maximum age is reported as the oldest specimen aged in a particular study.

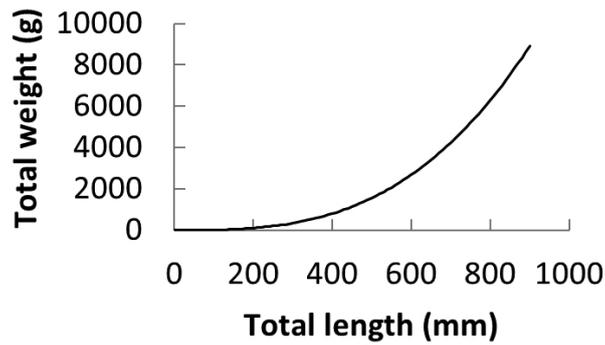
**Weight-length relationship:** Where possible, an equation is presented for combined sexes (unless otherwise indicated) which relates fish total wet body weight in g ( $W$ ) to total body length ( $TL$ ), fork length ( $FL$ ) or standard length ( $SL$ ). Total length is the length of the fish from the tip of the snout to the end of the tip of the caudal fin when it is placed in a “natural” position. Fork length is the horizontal distance from the tip of the snout to the posterior edge of the fork of the caudal fin. Standard length is the horizontal distance from the edge of the snout to the end of the caudal peduncle.

Weight-length relationships may be used for a wide variety of purposes, such as to produce estimates for the weights of fish collected from anglers or fish processors after filleting, which thereby enables further analyses requiring information on weight, or parameter estimates (such as in various stock assessment models). Weight-length relationships for fish species are typically expressed as either a power relationship or as a (linear) log-log relationship.

A power relationship, is represented as

$$W = aL^b, \quad (1)$$

where  $L$  is either total, fork or standard length, and  $a$  and  $b$  are constants, noting that  $b$  is usually close to 3, due to the way in which body mass typically scales in proportion to body length. An example of this type of relationship is shown using tailor (*Pomatomus saltatrix*)  $W = 0.000015L^{2.97}$  (Gaughan *et al.*, 2006) (Figure 1).

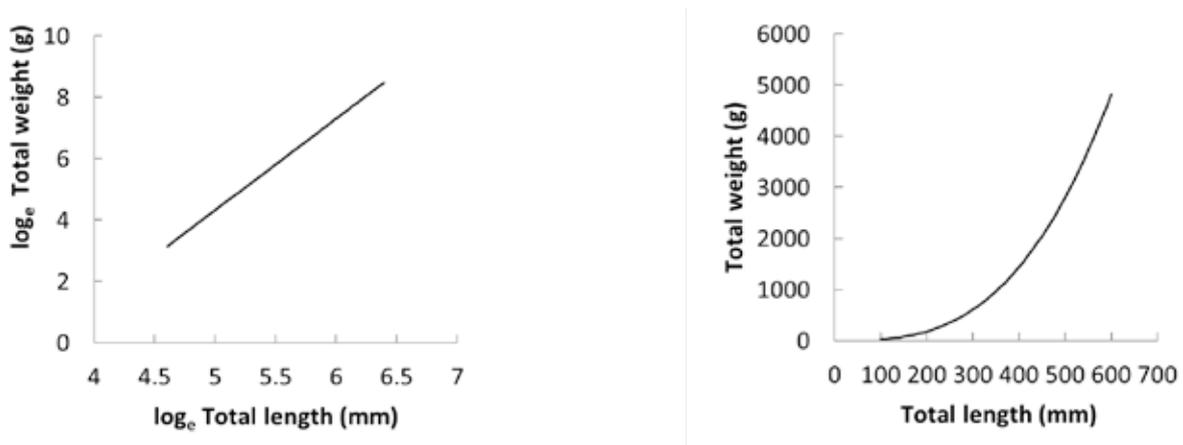


**Figure 1** Power relationship, predicting total body weight (g) from total body length, for tailor (*Pomatomus saltatrix*).

A (linear) log-log relationship is represented as

$$\log_e W = \log_e a + b \log_e L. \quad (2)$$

An example of this type of relationship is shown using baldchin groper (*Choerodon rubescens*)  $\log_e W = -8.486 + 3.237 \log_e L$  (Fairclough, 2005) (Figure 2).



**Figure 2** (a) Linear relationship relating the natural logarithms of total body weight to those for total body length for baldchin groper (*Choerodon rubescens*) and (b) the corresponding power relationship for this species.

When using a log-log relationship, predicted values for the natural logarithms of weight are back log-transformed to derive an estimate for the actual weight for a fish, given its length. Such back log-transformation results in a biased estimate for weight, which may be corrected using an equation such as that of Beauchamp and Olson (2013)

$$E_{corr} = E_{uncorr} e^{ms/2}, \quad (3)$$

where  $E_{corr}$  represents the bias-corrected estimate for weight,  $E_{uncorr}$  is the back-transformed estimate for weight prior to bias-correction,  $e$  is Euler's number (2.71828) and  $ms$  is the mean of the squared residuals, calculated when fitting the linear equation. When available, values for  $ms$  are reported. Unless otherwise specified, a single weight-length equation is reported for each species, calculated using combined weight-length data for the two sexes. To assist the reader in interpreting the relationships, tables are provided for each species providing estimates of weight for specified values of length.

**Length relationship:** Where available, the relationships between variables for length, such as between total length ( $TL$ ) and, fork length ( $FL$ ) or standard length ( $SL$ ), are given. Note that, for a number of species, the relationship between total length and fork length (or *vice versa*) is not reported in the literature because the tail is not forked.

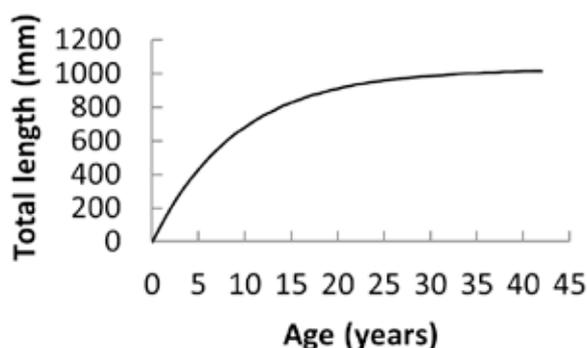
**Growth:** Fish growth is typically modelled using the von Bertalanffy growth equation (von Bertalanffy, 1938), which relates the (mean) lengths of fish at different ages on their date of capture. The von Bertalanffy growth equation is

$$L_t = L_\infty(1 - e^{-k(t-t_0)}) , \quad (4)$$

where  $L_t$  is the estimated length (mm) at age  $t$  (years),  $L_\infty$  is the “asymptotic” length, describing average maximum size (mm) of individuals in the population,  $k$  is the growth coefficient ( $\text{year}^{-1}$ ) describing the rate at which the asymptotic length is reached and  $t_0$  is the hypothetical age (years) at which fish have zero length. The value for  $L_\infty$  determines the height of the curve whereas the value for  $k$ , which typically ranges upwards to about one, determines the steepness of the early part of the curve.  $t_0$  is a nuisance parameter (*i.e.*, one that is needed, but does not tell us much apart from providing an indication as to the quality of the length and age data used to construct the growth curve) which should approximate zero but may be substantially negative if there are few small fish in the sample data to which the curve is being fitted (*i.e.* which would otherwise act to “tie down” the early part of the growth curve).

Tables are provided for each species providing estimates of total length (mm) for specified values of age (years). Occasionally, various other growth equations (with different shapes) such as the more flexible Schnute growth curve (Schnute, 1981) are used if the von Bertalanffy is shown to provide a poor fit to the data. An example of a von Bertalanffy growth curve is provided for male West Australian dhufish (*Glaucosoma hebraicum*)

$L_t = 1025(1 - e^{-0.11(t-0.052)})$  (Hesp *et al.*, 2002) (Figure 3).



**Figure 3** A von Bertalanffy growth curve for male West Australian dhufish (*Glaucosoma hebraicum*).

**Length and age at maturity:** The relationship between the probability of individuals being mature (during the spawning period) and their total lengths (mm) or ages (years) is typically described using a logistic equation such as either of the following forms. In the first equation, the probability of a fish being mature given its length,  $P_L$  is

$$P_L = 1/e^{(a+bL)} , \quad (5)$$

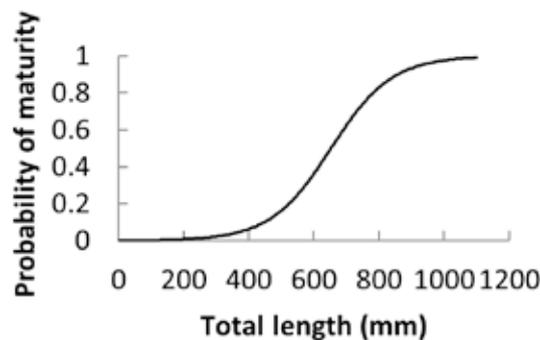
where  $a$  and  $b$  are constants and  $L$  is the length of the individual. Using this equation,  $L_{50}$ , the length at which the probability of a fish being mature is 0.5, may be determined as

$$L_{50} = a/b, \quad (6)$$

Similarly,  $P_L$  may be described by the functionally equivalent equation as

$$P_L = 1 / (1 + e^{(-\log_e(19)(L - L_{50}) / (L_{95} - L_{50}))}) , \quad (7)$$

where  $L_{50}$  and  $L_{95}$  are the lengths at which the probability of a fish being mature is 0.5 and 0.95, respectively. The ages at which the probability of maturity are 0.5 and 0.95 may be estimated using this same equation, substituting ages for lengths. An example of a logistic curve is provided in Figure 4 for the female western blue grouper (*Achoerodus gouldii*)  $P_L = 1 / (1 + e^{(-\log_e(19)(L - 653) / (927 - 653))})$  (Coulson *et al.*, 2009). This graph shows that, at a length of 653 mm, the probability of any fish in the population being mature is (on average) 0.5, compared with 0.95 at 927 mm.



**Figure 4** Logistic curve describing the relationship between the probability of maturity of individuals with respect to total length for female western blue grouper (*Achoerodus gouldii*).

**Reproductive style:** A species is described as either gonochoristic (individuals remain as one of two distinct sexes throughout life) or hermaphroditic (at least some individuals of a species change sex at some point during life). The following types of hermaphroditism are considered in the guide; protogynous hermaphroditism (sex change from a mature female to a male), protandrous hermaphroditism (sex change from a mature male to a female) and rudimentary hermaphroditism (where individuals develop from an early bisexual juvenile stage into either mature females or males and remain that sex for the rest of their life). Understanding the “reproductive style” of a species is important for assessing potential impacts of fishing pressure on that species, as hermaphroditic species can be more susceptible to overfishing.

This section also indicates if a species has been recorded as a “multiple” or “batch” spawner, where individual females release several batches of eggs (*i.e.* at different times) during the species’ spawning period (= most species). In contrast, a species may also be considered to be a “total spawner” or a single-spawning species. Biologists also sometimes use the terms “synchronous spawner” or “asynchronous spawner”, referring to whether all of the eggs in an ovary develop and are then released at the same time. Multiple spawners typically produce more eggs than total spawners (and may thus be more resilient to fishing pressure).

**Adult sex ratio:** An estimate of the ratio of the numbers of adult females to adult males in the population. This ratio is usually calculated from the numbers of females and males collected from sampling throughout the year that are above the  $L_{50}$  at maturity (see above) for the respective sexes, or the numbers of females and males collected during the spawning season belonging to length classes in which 50% or more of individuals are mature. The sex ratio for adults has been presented rather than the overall sex ratio for the population because different sampling gears and sampling intensities are often employed to collect juveniles *vs* adults. Thus

estimates of the overall population sex ratio are not likely to be accurate and a knowledge of the ratio of the adult sex ratio is likely to be most informative for better understanding the reproductive biology of a species (*i.e.*, as only adults spawn). Note that one needs to be cautious in drawing conclusions relating to this statistic as fish may have been caught using multiple fishing gears (each with a different size-based selectivity), or there may be differences in the selectivity of a fishing gear for different sexes. Note also there is no “standard” sex ratio for a fish species, *i.e.* whereas the ratio of adult females to adult males is approximately equal in many species, it differs markedly in others, such as for many hermaphroditic species.

**Length and age at sex change:** The relationship between the probability of individuals of hermaphroditic species having changed from the initial sex to the other (terminal) sex with respect to length or age. These relationships are typically described using the same logistic equations used to calculate length at maturity. The parameters  $L_{50}$  and  $L_{95}$  are used to describe the lengths at which the probability of a fish having changed sex is 0.5 and 0.95, respectively, as may be estimated using Equation 7 (see above, under Length and age at maturity). It should also be noted that not all fish species change sex (*i.e.*, are gonochoristic).

**Spawning season:** Describes the period during the year when the majority of spawning activity takes place. Fish biologists sometimes also refer to the main period of spawning for a species which may be defined, for example, as those months during the year when more than 50% of the females possess ovaries that are either fully mature (*e.g.*, ovaries containing mainly yolked oocytes) or are in spawning condition (*i.e.*, possess migratory nucleus stage oocytes, hydrated oocytes and/or post-ovulatory follicles). An oocyte is defined as an immature female reproductive cell prior to fertilization.

**Spawning location and habitat:** The location and/or habitat in which spawning occurs. For example, certain species may only spawn over reefs in coastal waters, or exclusively in estuaries.

**Fecundity:** Fecundity is a measure of the number of eggs produced by individual female fish during a specified time period, *e.g.*, a year or day. Batch fecundity is the number of eggs released by an individual female during a spawning event (*i.e.*, on a given day), whereas annual fecundity is the number of eggs released by a female during a spawning season. Batch fecundity is typically estimated by counting hydrated oocytes in samples of ovarian tissue of reproductively active females just prior to spawning (and extrapolating from the average number of oocytes per gram of ovarian tissue for a fish up to the total weight of its ovaries). Species may have either determinate or indeterminate fecundity. Species with determinate fecundity are those for which the number of eggs that will be released by a female during a spawning season is “fixed” prior to the commencement of that season. In such species, annual fecundity can be determined from counts of yolked oocytes in ovaries of fish just prior to the commencement of the spawning period. In contrast, species with indeterminate fecundity are those for which the number of eggs that will be released by a female during a spawning season is not fixed prior to its commencement. For this latter group of species, annual fecundity must be determined using a combination of data on batch fecundity, spawning period duration and spawning frequency (see below). Relationships between batch fecundity ( $BF$ ) or annual fecundity ( $F$ ) with fish length are often described using a power relationship (Equation 1). To assist the reader in interpreting these relationships, tables are provided with estimates of  $BF$  or  $F$  for specified fish lengths.

**Spawning frequency:** Describes the frequency with which actively spawning females release batches of eggs during the spawning season, *e.g.*, on average, individual fish spawn every 2 days. Data on spawning frequency are most often collected for species with indeterminate

fecundity. The method by which spawning frequency has been estimated, *i.e.*, the hydrated oocyte or post-ovulatory follicle method (Hunter and Goldberg, 1980; Hunter *et al.*, 1985) is listed if specified in the literature.

### **Development and habitat use**

**Eggs:** A brief description of the type and location of eggs of this species. Eggs (and larvae) are often described as neustonic (living at the surface of the water column), pelagic (free in the water column) or benthic (living on or near the bottom).

**Larvae:** A brief description of the larval stages and habitat preferences of the larvae of the species.

**Juveniles:** A brief description of the development and habitat preferences of the juveniles of the species.

**Adults:** A brief description of the development and habitat preferences of the adults of the species.

**Migration:** A description of known fish migration patterns. The term “fish migration” typically refers to predictable, active (and often cyclical) movements between habitats by large numbers of individuals in a population. For example, the adults of certain fish species undertake migrate seasonally to spawning areas.

**Stock delineation:** A brief description of the genetic stock structure of the species in temperate Western Australia, if known. Stock structure may vary from being panmictic (random mating within a breeding population) to populations which are genetically distinct between localized areas.

**Diet:** A brief description of the dietary composition of the species.

### **Fishery**

**Recreational:** An indication of the importance of the species to the recreational sector and the methods by which it is caught.

**Commercial:** An indication of the importance of the species to the commercial sector, the fisheries in which it is caught, and by what method.

**Age at full recruitment into the fishery:** The age at which fish are assumed to be fully vulnerable to the fishing gear used by the fishery targeting the species. This parameter is often determined from age composition data and taken as the age corresponding to one year above that at which the numbers of fish in the sample is greatest.

**Gear selectivity parameters:** Gear type and specifications (*e.g.*, gillnet, mesh size) are provided along with the relationship describing the size- or age-related vulnerability of capture (*i.e.*, probability) of individuals to the gear. This relationship is typically expressed as a logistic relationship (Equations 5 and 7), where  $L_{50}$  and  $L_{95}$  refer to the respective lengths at which the relative vulnerabilities to the fishing gear are 0.5 and 0.95.

### **Management parameters**

Managing Western Australia’s finfish resources represents a huge challenge, as more than 3,000 finfish species (including target and non-target species) exist over the more than 12,800 km of coastline (Wakefield *et al.*, in press). To address this issue, DoF has identified key “indicator” species in each of the four marine “bioregions” in the state (*i.e.*, the North Coast, Gascoyne Coast, West Coast and South Coast bioregions ) (DoF, 2011). Assessment and monitoring is focused towards these indicator species, which are representative of different “suites” of

species located in various broad ecological areas. These areas include estuaries, nearshore marine waters (<20 m depth), the marine inshore demersal zone (20 – 250 m depth), the marine offshore demersal zone (250 m depth to the edge of the exclusive economic zone (200 nm offshore) and the marine pelagic zone.

The indicator species, *i.e.*, those fish species for which, collectively, assessments of their stock status are considered to be indicative of the status of an entire suite of species, have been selected according to various biological attributes (*e.g.*, longevity, reproductive characteristics, recruitment patterns, stock structure and post catch and release survival, noting that species at the more vulnerable end of the spectrum (in terms of impacts of fishing) are chosen to ensure conservative (precautionary) management. A detailed description of the approach adopted by DoF for monitoring, assessing and managing finfish resources in Western Australia, including a full list of species used as indicators for each suite, is provided in DoF (2011). Whilst a number of the species included represent indicator species of different suites within the West Coast or South Coast bioregions, some do not, or have only recently been proposed as indicator species for future monitoring and assessment. It should therefore be recognized that, although stock assessment information may be very limited for some species, the status of those species is monitored and assessed indirectly through assessments of other (indicator) species. Note also that DoF adopts a risk-based Ecosystem Based Fisheries Management (EBFM) approach (Fletcher and Santoro, 2012).

**Total mortality:** Available estimates for the instantaneous rate of total mortality ( $Z$ , year<sup>-1</sup>) are provided along with the area for which the study was completed, and the method of estimation, (*e.g.*, catch curve analysis). Total mortality refers to the rate of death of individuals in a population due to natural causes (*e.g.*, predation, disease, senescence) and fishing (also including effects of post-release mortality due to hooking injuries and/or barotrauma, and high-grading).

**Natural mortality:** Available estimates for the instantaneous rate of natural mortality ( $M$ , year<sup>-1</sup>) area provided along with the area for which the study was completed and the method of estimation (*e.g.*, Hoenig's (1983) empirical equation for fish, which relates to mortality rates of 84 lightly-fished stocks to their maximum ages, and is often used if the maximum age of the species is known). Natural mortality is that which occurs as the result of natural causes (*i.e.*, predation, disease, senescence) and not fishing.

**Fishing mortality:** Available estimates for the instantaneous rate of fishing mortality ( $F$ , year<sup>-1</sup>) are provided along with the area for which the study was completed. Can be calculated as  $F = Z - M$ .

**Biological reference points:** Where available, estimates are provided for various biological reference points against which estimates of the level of fishing mortality or spawning biomass for a fish stock may be compared to gain an indication of stock status (*e.g.*,  $F=2/3M$ ,  $F=M$ ,  $F_{MSY}$ ,  $F_{0.1}$ ,  $F_{Max}$ ,  $SPR$ ,  $SSB/R$ ,  $YPR$ ,  $EPR$ ).  $F_{MSY}$  for example, is the value of  $F$  at which the maximum sustainable yield is achieved, whereas  $F_{0.1}$  is a more conservative level of  $F$  than  $F_{MSY}$ .  $SPR$  (spawning potential ratio) is a measure of the level to which a stock's reproductive capacity has declined from the original, unfished (virgin) level.  $SSB/R$  (spawning stock biomass per recruit) is the expected lifetime reproduction potential of individual fish, measured in terms of biomass.  $YPR$  (yield per recruit) is the expected biomass that individual fish, recruited into the fishery at a specific age, contribute to catches over their lifetime.  $EPR$  (eggs per recruit) is the estimate of the average expected lifetime reproductive potential of individual fish, measured in terms of egg production, and provides a measure of the impact that fishing has had on the potential productivity of the stock.

A biological reference point may be used as a target reference point (to indicate the level where fishing mortality or biomass should be), a threshold reference point (a level at which there is sufficient concern to trigger management and/or research actions) or a limit reference point (where fishing should be restricted or ceased in order to allow stock recovery). Depending on the species' biological attributes and thus, in turn, its vulnerability to exploitation, different values of fishing mortality and spawning biomass are used to correspond to the target, threshold and limit reference points. As is best practice in fisheries management around the world [e.g., Caddy and Mahon (1998); (2006)], DoF assess the stock status of finfish species against clearly-defined reference points for those species (see Wise *et al.*, 2007 for more detailed information).

An example of fishing mortality-based reference points were those employed by DoF for the West Australian dhufish (*Glaucosoma hebraicum*), where the target reference point is  $F=2/3M$ , the threshold reference point is  $F=M$  and the limit reference point is  $F=3/2M$ . An estimate of natural mortality ( $M$ ) for West Australian dhufish is  $M=0.11 \text{ year}^{-1}$  (Hesp *et al.*, 2002; Wise *et al.*, 2007). An estimate of  $F$  for this species, based on recreational catch samples taken from the waters off Perth is  $0.14 \text{ year}^{-1}$  (Wise *et al.*, 2007). In this instance, the estimate for  $F$  is greater than that for  $M$  and is thus between the threshold and limit reference points for this species. Note that a range of information, including estimates of current  $F$  or biomass in relation to defined reference points, but also other information (e.g. characteristics influencing the inherent vulnerability of a species to fishing or other factors) is used as advice for informing the management of a fish stock using what, DoF terms, a "weight-of-evidence" framework. For more information on this aspect, see DoF (2011).

**Current status:** Current status of the species based on the best available, and reported, information obtained mainly from DoF, in the State of the Fisheries and Aquatic Resources Report (Fletcher and Santoro, 2012), the Resource Assessment Framework (Fletcher *et al.*, 2005; DoF, 2011) and International Union for Conservation of Nature (IUCN) Redlist ([www.iucnredlist.org](http://www.iucnredlist.org)).

### Catch trends

**Recreational:** A brief description of catch trends in terms of fish caught by recreational fishers from boats and the shore, and the area to which they pertain, are provided. **Commercial:** A brief description of catch trends in terms of this species caught by commercial fishers, and the area to which they pertain, are provided.

### Management regulations

**Recreational:** Current management regulations (at 1 February 2013) in terms of the bag limit and Minimum Legal Limit (MLL) for capture and retention, also known as minimum size limit, for recreational catch of this species are provided (DoF, 2013). Historical changes are also listed by year, indicating the time when the change in regulations was implemented. Note that recreational fishing regulations were first introduced in Western Australia in 1913. If a species was not specifically listed for a recorded management change, then the earliest information will be for 1991, when a 'low risk' or 'bread and butter' category was introduced and encapsulated most species not listed elsewhere, excluding some species of baitfish (*i.e.*, pilchards, scaly mackerel) and feral freshwater species, which have no catch limit.

**Commercial:** A general summary of current management regulations for commercial fisheries in which this species is caught. The reader is referred to the State of the Fisheries and Aquatic Resources Report (Fletcher and Santoro, 2012) for further details.

**Current research:** A brief description of current research underway which relates to this species.

**Comments/other published information:** Additional references relating to this species which has not been provided elsewhere in the document.

**References:** References are cited in the text and presented in alphabetical order at the end of each species report.

## References

- Allen, G. R., 2009. Field guide to marine fishes of tropical Australia and south-east Asia, 4th edn. Western Australian Museum, Perth, Western Australia.
- Caddy, J. F., Mahon, R., 1998. A short review of precautionary reference points and some proposals for their use in data-poor situations. FAO. Rome, Italy. FAO Technical Paper 379.
- Coulson, P. G., Hesp, S. A., Hall, N. G., Potter, I. C., 2009. The western blue groper (*Achoerodus gouldii*), a protogynous hermaphroditic labrid with exceptional longevity, late maturity, slow growth, and both late maturation and sex change. *Fishery Bulletin* 107, 57-75.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairclough, D., 2005. The biology of four tuskfish species (*Choerodon*: Labridae) in Western Australia, PhD thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 204.
- Fletcher, W. J., Chesson, J., Sainsbury, K. J., Hundloe, T. J., Fisher, M., 2005. A flexible and practical framework for reporting on ecologically sustainable development for wild capture fisheries. *Fisheries Research* 71, 175-183.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gaughan, D. J., Ayvazian, S., Nowara, G., Craine, M., Brown, J., 2006. The development of a rigorous sampling program for a long term annual index of recruitment for finfish species from south-western Australia. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 1999/153, Fisheries Research Report No. 154. pp. 135.
- Hesp, S. A., Potter, I. C., Hall, N. G., 2002. Age and size composition, growth rate, reproductive biology, and habitats of the West Australian dhufish (*Glaucosoma hebraicum*) and their relevance to the management of this species. *Fishery Bulletin* 100, 214-227.
- Hoenig, J., 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82, 898-903.
- Hunter, J. R., Goldberg, S. R., 1980. Spawning incidence and batch fecundity in northern anchovy, *Engraulis mordax*. *Fishery Bulletin* 77, 641-652.
- Hunter, J. R., Lo, N. C. H., Leong, R. J. H., 1985. Batch fecundity in multiple spawning fishes, In An egg production method for estimating spawning biomass of pelagic fishes: application to the northern anchovy (*Engraulis mordax*). Lasker, R. (ed), pp. 67-77.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Lembo, G. (ed) 2006. Selected papers presented at the workshop on biological reference points: Rome, 20-21 April 2004. FAO, Rome, Italy.
- Rees, A. J. J., Yearsley, G. K., Gowlett-Holmes, K., Pogonoski, J., 2012. Codes for Australian Aquatic Biota (on-line version). CSIRO Marine and Atmospheric Research. Available: <http://www.cmar.csiro.au/caab/>
- Schnute, J., 1981. A versatile growth model with statistically stable parameters. *Canadian Journal of Fisheries and Aquatic Sciences* 38.
- von Bertalanffy, L., 1938. A quantitative theory of organic growth (Inquiries on growth laws II). *Human Biology* 10, 181-213.

- Wakefield, C. B., Newman, S. J., Boddington, D. K., in press. Exceptional longevity, slow growth and late maturation infer high vulnerability to exploitation for bass groper *Polyprion americanus* (Teleostei: Polyprionidae). *Aquatic Biology* xx, xx-xx.
- Wise, B. S., St John, J., Lenanton, R., 2007. Spatial scales of exploitation among populations of demersal scalefish: implications for management. Part 1: Stock status of the key indicator species for the demersal scalefish fisheries in the West Coast Bioregion. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2003/052. Fisheries Research Report No. 163. pp. 130.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

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## Abbreviations

Term	Definition
DGDLF	A collective name for two fisheries (the WCDSGLF and JASDGDLF, see below) which target sharks and rays but also retain demersal scalefish. The Demersal Gillnet and Demersal Longline Fishery extends over the continental shelf waters along the south and lower west coasts.
DoF	Department of Fisheries, Western Australia
GABTS	Great Australian Bight Trawl Sector
GDSF	Gascoyne Demersal Scalefish Managed Fishery
JASDGDLF	Joint Authority Southern Demersal Gillnet and Demersal Longline Managed Fishery.
NDSF	Northern Demersal Scalefish Fishery
PDSF	Pilbara Demersal Scalefish Fishery
SBBSMNMF	Shark Bay Beach Seine and Mesh Net Managed Fishery
SCEMF	South Coast Estuarine Managed Fishery
UWA	University of Western Australia
WCDGDLF	West Coast Demersal Gillnet and Demersal Longline (Interim) Managed Fishery.
WCDSIMF	West Coast Demersal Scalefish (Interim) Managed Fishery is a handline and dropline fishery, and is the main commercial fishery targeting demersal species in the West Coast bioregion. This fishery encompasses the waters of the Indian Ocean just south of Shark Bay to just east of Augusta and extends seaward to the 200 nm boundary of the Australian Fishing Zone (~200 nm).
WBTF	The Western Billfish and Tuna Fishery is a Commonwealth fishery which operates along the coast of Western Australia using predominately pelagic longlines.
WCEF	West Coast Estuarine (Interim) Managed Fishery

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## Fish species reports

### Cobbler (*Cnidoglanis macrocephalus*)

Reviewed by Kim Smith (DoF)



**Scientific name:** *Cnidoglanis macrocephalus* (Plotosidae; Eeltail catfish)

**Common names:** Estuary cobbler *also* estuarine catfish, cobbler

**Key identifying features:** Upper lip ends in prominent tentacle, colour varies from blackish-grey to mottled pattern of pale and dark blotches, rear margin of caudal fin less rounded than similar catfish species (Hutchins and Thompson, 1983).

#### Distribution of species

**Worldwide:** Endemic to southern Australian waters from Queensland to Western Australia (McGrouther, 2005).

**Western Australia:** Southern Western Australian border to Abrolhos Islands (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 910mm, 2.6 kg (Hutchins and Swainston, 1986), 13 years (Kailola *et al.*, 1993).

**Length/weight relationship:** [Swan River] Females  $\log W = -2.76 + 3.35 \cdot \log SL$  ( $R^2 = 0.99$ ,  $n = 84$ ); Males  $\log W = -2.61 + 3.26 \cdot \log SL$  ( $R^2 = 0.99$ ,  $n = 155$ ) (Morrison, 1988).

SL (cm)	30	40	50	
Weight (g)	Females	154	404	854
	Males	160	410	848

**Length relationship:** Not reported.

**Growth:** [Swan River, Schnute growth curve] Females  $y_1 = 225$  mm,  $y_2 = 537$  mm,  $a = 0.25$ ,  $b = 0.90$ ,  $\tau_1 = 1$  year,  $\tau_2 = 4$  years ( $n = 517$ ,  $R^2 = 0.91$ ); Males  $y_1 = 239$  mm,  $y_2 = 525$  mm,  $a = 0.02$ ,  $b = 1.75$ ,  $\tau_1 = 1$  year,  $\tau_2 = 4$  years ( $n = 447$ ,  $R^2 = 0.85$ ) (Laurenson *et al.*, 1994). See also Nel *et al.* (1985) and Chuwen *et al.* (2011).

Age (years)	2	6	10
Females, TL (mm)	325	652	767
Males, TL (mm)	356	655	859

**Length and age at maturity:** [Swan River] 22% of 1+ males and 14% of 1+ females mature. All 2+ and older fish mature. Typical size at maturity is 385 mm for males and 405 mm for females (Nel *et al.*, 1985). See also Laurenson *et al.* (1993a) for Wilson Inlet. In that estuary, the size and age at maturity has declined, possibly due to fishing-induced evolutionary changes (Chuwen *et al.*, 2011).

**Reproductive style:** Gonochoristic. Single spawner which generally mates in pairs (Nel *et al.*, 1985; Laurenson *et al.*, 1993a; Neira *et al.*, 1998; Harrison, 2001; Smith, 2006).

**Adult sex ratio:** [Wilson Inlet, gill nets] F1.5:M1 (Laurenson *et al.*, 1993a).

**Length and age at sex change:** Not applicable.

**Spawning season:** [Swan River] October to December (Nel *et al.*, 1985); [Wilson Inlet] October to January (Laurenson *et al.*, 1993a). Differences in spawning times between estuaries may be related to water temperature (Laurenson *et al.*, 1993a).

**Spawning habitat and location:** [Swan River] Shallow coastal waters and lower parts of estuaries (Gomon *et al.*, 2008), subject to availability of suitable structural habitat for nesting (Laurenson *et al.*, 1993a).

Fecundity: Annual fecundity;  $\log F = -3.6992 + 2.5404 * \log TL$  ( $n=44$ ,  $R^2=0.80$ ) (Nel *et al.*, 1985).

TL (mm)	300	500	700
Fecundity (eggs)	392	1,436	3,377

**Spawning frequency:** Once per year (Laurenson *et al.*, 1993b).

### Development and habitat use

**Eggs:** Males brood eggs in burrows with eggs resting on substrate, or in between pelvic fins (Nel *et al.*, 1985; Laurenson *et al.*, 1993a; Neira *et al.*, 1998; Harrison, 2001).

**Larvae:** Males guard larvae in burrow (Laurenson *et al.*, 1993a).

**Juveniles:** Typically associated with marine vegetation including detached beds of seagrass or macrophytes in surf zones off sandy beaches, or in sheltered marine environments or estuaries (Lenanton *et al.*, 1982; Lenanton and Caputi, 1989; Hyndes *et al.*, 1999; Crawley *et al.*, 2006).

**Adults:** Estuaries and nearshore coastal waters over seagrass beds and reef habitats, also in shallow bays and sandy inlets near river mouths (Potter *et al.*, 1983; Loneragan *et al.*, 1987; Valesini *et al.*, 2004). Often concealed beneath rocky ledges during daylight hours (Gomon *et al.*, 2008).

**Migration:** Seasonal, localised migrations occur in winter with individuals of this species moving to accumulations of detached macrophytes (Lenanton *et al.*, 1982; Hyndes *et al.*, 1999). Juveniles also aggregate at night in small drift macrophytes in the surf zone to feed and escape predation (Lenanton *et al.*, 1982; Lenanton and Caputi, 1989).

**Stock delineation:** Genetic divergence between populations indicates that little interbreeding occurs between estuarine populations (Ayvazian *et al.*, 1994).

**Diet:** Feeding occurs at night and diet changes markedly with increasing body size (Nel *et al.*, 1985). Cobblers feed primarily on bivalves (and other molluscs), detritus, organic material, crustaceans, worms and algae (Thomson, 1957; Lenanton *et al.*, 1982; Lenanton and Caputi, 1989; Platell and Hall, 2006; Platell *et al.*, 2006). Juveniles in surf zones of sandy beaches consume more amphipods than larger fish (Lenanton and Caputi, 1989; Crawley *et al.*, 2006).

### Fishery

**Recreational:** Occasionally taken by recreational fishers (Loneragan *et al.*, 1989; Malseed and Sumner, 2001), in both the West Coast and South Coast bioregions. Recreational fishing for this species was banned in the Swan-Canning River in 2007 (Smith *et al.*, 2012b).

**Commercial:** Frequently caught in the estuarine and nearshore finfish fisheries of the West

Coast and South Coast bioregions as part of the West Coast Estuarine (Interim) Managed Fishery (WCEF) and South Coast Estuarine Managed Fishery (SCEMF), respectively (Lenanton and Potter, 1987; Smith, 2006; Smith *et al.*, 2012a; Smith *et al.*, 2012b). A ban on this species in the Swan-Canning River was introduced in 2007 (Smith *et al.*, 2012b). Targeted at night with gillnets, haul nets and beach seines (Smith *et al.*, 2012a; Smith *et al.*, 2012b). Also occasionally caught as by-catch in the temperate demersal gillnet and longline fishery (McAuley and Simpfendorfer, 2003).

**Age at full recruitment:** Not reported.

**Gear selectivity parameters:**  $\theta_1=6.1$ ;  $\theta_2=6802$  [parameters of method of Kirkwood and Walker (1986) and Chuwen *et al.* (2011)]. See Laurenson *et al.* (1993a) and Chuwen *et al.* (2011) for description of lengths of fish caught by different gillnet mesh sizes.

### Management parameters

**Total mortality:** [Wilson Inlet] 1.82 year<sup>-1</sup> (Chuwen *et al.*, 2011). Estimates using a form of catch curve analysis involving Poisson regression, taking into account recruitment variability and gear selectivity.

**Natural mortality estimates:** [Wilson Inlet, Hoenig's (1983) equation for fish] 0.35 year<sup>-1</sup> (Chuwen *et al.*, 2011).

**Fishing mortality estimates:** [Wilson Inlet] 1.47 year<sup>-1</sup> (Chuwen *et al.*, 2011). See Chuwen *et al.* (2011) for comparison with estimates for earlier years.

**Biological reference points:** F-based target reference points of Gabriel and Mace (1999) considered by Chuwen *et al.* (2011) in the context of their estimates.

**Current status:** Stock level acceptable in the Peel-Harvey Estuary (Smith *et al.*, 2012b), and adequate in Wilson Inlet and Oyster Harbour (Smith *et al.*, 2012a). This species has been protected in the Swan-Canning River since 2007 (Smith *et al.*, 2012b). Species has not been assessed in other estuaries of the West Coast or South Coast bioregions. An indicator species for the estuarine suite in the West Coast and South Coast bioregions (DoF, 2011). Overall risk to sustainability for this suite is moderate in the West Coast and South Coast bioregions (DoF, 2011). Inherent vulnerability for this species is extreme, current risk to wild stock is minimal (South Coast estuaries except Wilson Inlet which is moderate) or extreme (West Coast estuaries) (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

**Recreational:** Small recreational catches of this species have been recorded during surveys of estuaries in the West Coast (Malseed and Sumner, 2001) and South Coast bioregions (Smallwood and Sumner, 2007). Note that targeted spearing (gidgy) of this species occurs at night and is unlikely to have been picked up in recreational surveys.

**Commercial:** Since 2000, 95% of the commercial catch was taken in estuaries of the South Coast bioregion, with the remaining 5% from the West Coast bioregion (predominantly the Peel-Harvey Estuary) (Smith *et al.*, 2012b). A complete catch trend graph is shown for the Peel-Harvey Estuary in the 2010/11 State of the Fisheries and Aquatic Resources Report (Smith *et al.*, 2012b). Total annual landings in the West Coast bioregion from 2001 – 2010 varied between <1 t to 9 t, with historical catches much higher (up to 298 t in the Peel-Harvey Estuary in 1961) (Smith *et al.*, 2012b). Landings of this species in the Swan-Canning Estuary declined from >20 t in the 1970s to <1 t in 1997, leading to the current closure of the fishery (Smith *et al.*, 2012b). The total catch of cobbler in the South Coast

Estuarine Managed fishery in 2011 was 65 t, of which 78% was caught in Wilson Inlet (Smith *et al.*, 2012a). The historic peak of 79 t was achieved in 1985 and again in 2003 (Smith *et al.*, 2012a).

## Management regulations

*Recreational*: Currently listed in the “nearshore/estuarine finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1975)	-	230	
Statewide (1991)	20	230	
Statewide (1995)	8	430	
West Coast (2003)	4	430	
South Coast (2005)	4	430	
West Coast (2008)	4	430	Spatial closure = Swan-Canning River
Statewide (2013)	8	430	Spatial closure = Swan-Canning River

*Commercial*: Nearshore and estuarine finfish fisheries in the West Coast and South Coast bioregions are regulated primarily using input controls (such as limited entry and gear restrictions) as well as seasonal and temporal closures, and size limits (Smith *et al.*, 2012a; Smith *et al.*, 2012b).

**Current research**: Juvenile recruitment is monitored annually by DoF, along with the age, length and sex structures in commercial catches and trends in catch per unit effort. DoF commenced a 3-year tagging study in 2012, run in collaboration with commercial fishers from the South Coast Estuarine Managed Fishery. Ongoing data collection occurs through commercial logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

## References

- Ayvazian, S. G., Johnson, M. S., McGlashan, D. J., 1994. High levels of genetic subdivision of marine and estuarine populations of the estuarine catfish *Cnidoglanis macrocephalus* (Plotosidae) in southwestern Australia. *Marine Biology* 118, 25-31.
- Chuwen, B. M., Potter, I. C., Hall, N. G., Hoeksema, S. D., Laurenson, L. J. B., 2011. Changes in catch rates and length and age at maturity, but not growth, of an estuarine plotosid (*Cnidoglanis macrocephalus*) after heavy fishing. *Fishery Bulletin* 109, 247-260.
- Crawley, K. R., Hyndes, G. A., Ayvazian, S. G., 2006. Influence of different volumes and types of detached macrophytes on fish community structure in surf zones of sandy beaches. *Marine Ecology Progress Series* 307, 233-246.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Gabriel, W. L., Mace, P. M., 1999. A review of biological reference points in the context of the precautionary approach, *In* Fifth National NMFS Stock Assessment Workshop. Restrepo, V. R. (ed), NOAA Tech. Memo. NMFS-F/SPO-40. pp. 24-45.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.

- Harrison, N., 2001. A five-year management strategy for recreational fishing on the West Coast of Western Australia. Final Report. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Management Paper No. 153. pp. 114.
- Hoenig, J., 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82, 898-903.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Hutchins, B., Thompson, M., 1983. The marine and estuarine fishes of south-western Australia: a field guide for anglers and divers. Western Australian Museum, Perth, Western Australia.
- Hyndes, G. A., Platell, M. E., Potter, I. C., Lenanton, R. C. J., 1999. Does the composition of the demersal fish assemblages in temperate coastal waters change with depth and undergo consistent seasonal changes. *Marine Biology* 134, 335-352.
- Kailola, P. J., Williams, M. J., Stewart, P. C., Reichelt, R. E., McNee, A., Grieve, C., 1993. Australian Fisheries Resources. Bureau of Resource Sciences and the Fisheries Research and Development Corporation. Canberra, Australia. pp. 422.
- Kirkwood, G., Walker, T., 1986. Gill net mesh selectivities for gummy shark, *Mustelus antarcticus* Gunther, taken in south-eastern Australian Waters. *Marine and Freshwater Research* 37, 689-697.
- Laurenson, L. J. B., Neira, F. J., Potter, I. C., 1993a. Reproductive biology and larval morphology of the marine plotosid *Cnidoglanis macrocephalus* (Teleostei) in a seasonally-closed Australian estuary. *Hydrobiologica* 268, 179-192.
- Laurenson, L. J. B., Potter, I. C., Hall, N. G., 1994. Comparisons between generalized growth curves for two estuarine populations of the eel tailed catfish *Cnidoglanis macrocephalus*. *Fishery Bulletin* 92, 880-889.
- Laurenson, L. J. B., Potter, I. C., Lenanton, R. C. J., Hall, N. G., 1993b. The significance of size at sexual maturity, mesh size and closed fishing waters to the commercial fishery for the catfish *Cnidoglanis macrocephalus* in Australian estuaries. *Journal of Applied Ichthyology* 9, 210-221.
- Lenanton, R. C. J., Caputi, N., 1989. The roles of food supply and shelter in the relationship between fishes, in particular *Cnidoglanis macrocephalus* (Valenciennes) and detached macrophytes in the surf zone of sandy beaches. *Journal of Experimental Marine Biology and Ecology* 128, 165-176.
- Lenanton, R. C. J., Potter, I. C., 1987. Contribution of estuaries to commercial fisheries in temperate Western Australia and the concept of estuarine dependence. *Estuaries* 10, 28-35.
- Lenanton, R. C. J., Robertson, A. I., Hansen, J. A., 1982. Nearshore accumulations of detached macrophytes as nursery areas for fish. *Marine Ecology Progress Series* 9, 51-57.
- Loneragan, N. R., Potter, I. C., Lenanton, R. C. J., 1989. Influence of site, season and year on contributions made by marine, estuarine, diadromous and freshwater species to the fish fauna of a temperate Australian estuary. *Marine Biology* 103, 461-479.
- Loneragan, N. R., Potter, I. C., Lenanton, R. C. J., Caputi, N., 1987. Influence of environmental variables on the fish fauna of the deeper waters of a large Australian estuary. *Marine Biology* 94, 631-641.
- Malseed, B. E., Sumner, N. R., 2001. A 12-month survey of recreational fishing in the Peel-Harvey Estuary of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 127. pp. 48.
- McAuley, R., Simpfendorfer, C., 2003. Catch composition of the Western Australian temperate demersal gillnet and demersal longline fisheries, 1994 to 1999. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 146. pp. 78.
- McGrouther, M., 2005. Estuary Catfish. Australian Museum. Available: [www.austmus.gov.au/fishes/fishfacts/fish/cmaceph](http://www.austmus.gov.au/fishes/fishfacts/fish/cmaceph) (Accessed 12 November 2012).
- Morrison, P. F., 1988. Reproductive biology of two species of plotosid catfish, *Tandanus bostocki* and *Cnidoglanis macrocephalus*, from south-western Australia, PhD thesis, University of Western Australia, Perth, Western Australia. pp. 187.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.

- Nel, S. A., Potter, I. C., Loneragan, N. R., 1985. The biology of the catfish *Cnidoglanis macrocephalus* (Plotosidae) in an Australian estuary. *Estuarine, Coastal and Shelf Science* 21, 895-909.
- Platell, M. E., Hall, N. G., 2006. Synthesis and gap assessment of fish dietary data required for modelling ecosystems in south-western Australia. Perth, Western Australia. FRDC Project No. 2002/016. pp. 126.
- Platell, M. E., Orr, P. A., Potter, I. C., 2006. Inter- and intraspecific partitioning of food resources by six large and abundant fish species in a seasonally open estuary. *Journal of Fish Biology* 69, 243-262.
- Potter, I. C., Loneragan, N. R., Lenanton, R. C. J., Chrystal, P. J., Grant, C. J., 1983. Abundance, distribution and age structure of fish populations in a Western Australian estuary. *Journal of Zoology, London* 200, 21-50.
- Smallwood, C. B., Sumner, N. R., 2007. A 12-month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002/03. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 159. pp. 56.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012a. South Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Smith, K., Brown, J., Howard, A., Walshe, K., Fissioli, J., 2012b. West Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 80-97.
- Smith, K. A., 2006. Review of fishery resources and status of key fishery stocks in the Swan-Canning Estuary. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 156. pp. 84.
- Thomson, J. M., 1957. The food of Western Australian estuarine fishes. *Western Australian Fisheries and Fauna Department Bulletin* 7, 1-13.
- Valesini, F. J., Potter, I. C., Wildsmith, M. D., Hourston, M., Platell, M. E., Coen, N. J., Schafer, L. N., Seidel, S. T., Whitehead, A. L., 2004. The importance to fish species of the various habitats in nearshore marine waters of south-western Australia. Murdoch University. Perth, Western Australia. FRDC Project No. 2000/159. pp. 452.

## Southern garfish (*Hyporhamphus melanochir*)

Reviewed by Kim Smith (DoF)



**Scientific name:** *Hyporhamphus melanochir* (Hemiramphidae; Halfbeaks)

**Common names:** Southern garfish *also* southern sea garfish, gardie

**Key identifying features:** Lower jaw extended into a bill, no dark mark on side below dorsal fin, silver strip along midline, t-shaped small sensory pore before eye (Yearsley *et al.*, 2001).

### Distribution

**Worldwide:** Endemic to southern Australia (Collette, 1974).

**Western Australia:** Southern Western Australian border to Lancelin (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 500 mm (including beak), 0.6 kg (Gomon *et al.*, 2008), 10 years (Jones *et al.*, 2002).

**Length/weight relationship:** [West Coast and South Coast bioregions]  $W=5.627*10^{-6}SL^{3.029}$  ( $n=1,345$ ,  $R^2=0.895$ ) (Jones *et al.*, 2002).

TL (mm)	200	300	400
Weight (g)	49	168	401

**Length relationship:** [South Australia]  $TL=1.1423*SL+0.7732$  ( $n=388$ ,  $R^2=0.995$ ) (Jones *et al.*, 2002).

**Growth:** [West Coast and South Coast] Females  $L_{\infty}=330$  mm,  $k=0.05$  year<sup>-1</sup>,  $t_0=-4.6$  years ( $n=302$ ); Males  $L_{\infty}=303$  mm,  $k=0.05$  year<sup>-1</sup>,  $t_0=-4.1$  years ( $n=150$ ) (Jones *et al.*, 2002).

Age (years)	2	5	8
Females, SL (mm)	93	126	154
Males, SL (mm)	80	111	138

**Length and age maturity:** [West Coast and South Coast, SL]  $L_{50}=228$  mm,  $A_{50}=1.6$  years (Jones *et al.*, 2002). See also Thomson (1957a).

**Reproductive style:** [South Australia] Gonochoristic. Serial batch spawner with asynchronous spawning (Jones *et al.*, 2002).

**Sex ratio:** [West Coast and South Coast] F1:M1 (Jones *et al.*, 2002).

**Length and age at sex change:** Not applicable.

**Spawning season:** [West Coast and South Coast] September – April (Jones *et al.*, 2002). See also Thomson (1957b) and Smith *et al.* (2008).

**Spawning location and habitat:** Spawning occurs throughout species range and in coastal waters, near vegetation (Jordan *et al.*, 1998; Jones *et al.*, 2002). Some anecdotal evidence of spawning in Wilson Inlet (Neira and Potter, 1992). The species is structured into multiple breeding sub-populations across its range (Steer *et al.*, 2009a).

**Fecundity:** [West Coast and South Coast] Batch fecundity;  $BF=102.3*SL-1773$  ( $n=52$ ,  $R^2=0.29$ ) (Jones *et al.*, 2002). See also Thomson (1957a).

TL (mm)	200	300	400
Fecundity (eggs)	273	1,296	2,319

**Spawning frequency:** Not reported.

### Development and habitat use

**Eggs:** Pelagic but with adhesive filaments that may attach to aquatic vegetation (*i.e.*, seagrass or drift algae) (Collette, 1974; Noell, 2005).

**Larvae:** Larvae hatch at advanced development stage (post-flexion) and are neustonic.

Limited larval dispersal from spawning sites and post-flexion larvae can maintain their position in the water column where they tend to aggregate around floating seaweed (Jordan *et al.*, 1998; Noell, 2002; 2005).

**Juveniles:** Estuarine waters and shallow inshore waters (Lenanton, 1982).

**Adults:** Seagrass beds in shallow inshore waters (Jones *et al.*, 2002).

**Migration:** [South Australia] Believed to exhibit (possibly offshore) movements associated with spawning, although spawning grounds currently unknown (Fowler *et al.*, 2008).

**Stock delineation:** Four genetically separate populations identified in Australia located in; Western Australia (samples from Cockburn Sound and Oyster Harbour), western South Australia, South Australian gulfs/Victorian bays and Tasmania (Donnellan *et al.*, 2002). South Australia has several semi-discrete populations (Steer *et al.*, 2009b; Steer *et al.*, 2010).

**Diet:** Herbivorous, feeds predominantly on seagrass, filamentous green algae, diatoms, chironomid algae and polychaetes (Thomson, 1957b). *H.melanochir* are also predated by *A. georgianus* (Thomson, 1957a) and *A. truttaceus*. In South Australia, *H. melanochir* have been observed feeding on vegetation at the bottom of the water column during the day while rising to the surface to feed on invertebrates at night (Robertson and Klumpp, 1983).

### Fishery

**Recreational:** Caught by shore and boat-based recreational line fishers in nearshore and estuarine environments of the West Coast and South Coast bioregions (Jones *et al.*, 2002; Smallwood and Sumner, 2007; Sumner *et al.*, 2008; Smallwood *et al.*, 2012).

**Commercial:** Frequently caught in the estuarine and nearshore finfish fisheries of the West Coast and South Coast bioregions (Jones *et al.*, 2002; Smith *et al.*, 2012a; Smith *et al.*, 2012b). This species is caught using a variety of methods although the greatest catch is obtained from beach seine and haul nets and gill netting (Jones *et al.*, 2002).. This species is often caught opportunistically, rather than being targeted.

**Age at full recruitment:** [South and West Coast, commercial, TL] Overall mean length = 288 mm, mean age = 2.2 years. These differ seasonally, and between bioregions (Jones *et al.*, 2002).

**Gear selectivity parameters:** [South Australia] For haul net mesh selectivity see Steer *et al.* (2011).

### Management parameters

**Total mortality:** [West Coast and South Coast]  $0.98 \text{ year}^{-1}$  ( $n=1,413$ ) (Jones *et al.*, 2002).

**Natural mortality:** Not reported.

**Fishing mortality:** [South Australia] High mortality rate. Recent estimate of annual harvest fraction of legal-sized garfish is 69% (McGarvey *et al.*, 2009).

**Biological reference points:** Not reported.

**Current status:** Current stock levels listed as acceptable for the West Coast bioregion (Smith *et al.*, 2012b). An indicator species for the nearshore suite in the West Coast bioregion (Smith *et al.*, 2012b). Overall risk to sustainability for this suite is moderate in the West Coast and South Coast bioregions (DoF, 2011). Inherent vulnerability is moderate, current risk to wild stock is minimal (South Coast) or moderate (West Coast) (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

**Recreational:** Total estimated recreational boat-based catch in the West Coast bioregion was 2 t for 1996/97 and 7 t in 2005/06 (Sumner *et al.*, 2008). Total estimated recreational catch in the West Coast bioregion was 35 t in 2000/01 (Henry and Lyle, 2003). An estimated 0.2 t was retained within estuaries of the South Coast bioregion in 2002/03 (Smallwood and Sumner, 2007). See also Harvey (2004), Smallwood *et al.* (2006) and Smallwood *et al.* (2012).

**Commercial:** Up to five species of garfish are landed in Western Australian waters, although southern garfish is the dominant species. Since 2000, about 54% of commercial catch has been in the West Coast bioregion, 31% from the South Coast, 13% from the Gascoyne Coast and 1% from the North Coast (Smith *et al.*, 2012b). Although highly variable, commercial catches in the nearshore and estuarine fisheries of the West Coast have increased from 11.5 t in 2007 to 19.2 t in 2011 (from a peak of 44 t in 1999), with a large proportion of this from Cockburn Sound (Smith *et al.*, 2012b). Commercial catches in the nearshore and estuarine fisheries of the South Coast have decreased from 18 t in 2007 to 10.8 t in 2011, with a low of 7.6 t in 2009 (Smith *et al.*, 2012a). See also Jones *et al.* (2002).

### Management regulations

**Recreational:** Currently included in the “all other species of finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1958)	-	230	
Statewide (1991)	40	-	
West Coast (2009)	30	-	
Statewide (2013)	30	-	

**Commercial:** South Coast and West Coast nearshore and estuarine fisheries are managed primarily through input controls (limited entry, gear restrictions, spatial and temporal closures) (Smith *et al.*, 2012a; Smith *et al.*, 2012b). Size limit for commercial fishers ended in 2011. See also Jones *et al.* (2002).

**Current research:** Intermittent sampling of age, length and sex of fishery landings in Cockburn sound conducted by DoF. Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Diet* [Victoria] (Klumpp and Nichols, 1983); *Reproduction* [Tasmania] (Jordan *et al.*, 1998); *Parasites* [South Australia] (Hutson *et al.*, 2011); *Commercial fisheries* [South Australia] (Steer *et al.*, 2009b; Steer *et al.*, 2011).

## References

- Collette, B. B., 1974. The garfishes (Hemiramphidae) of Australia and New Zealand. *Records of the Australian Museum* 29, 11-105.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Donnellan, S., Haigh, L. J., Elphinstone, M., McGlennon, D., Ye, Q., 2002. Genetic discrimination between southern sea garfish (*Hyporhamphus melanochir*) stocks of Western Australia, South Australia, Victoria and Tasmania, In Fisheries biology and habitat ecology of southern sea garfish *Hyporhamphus melanochir* in Southern Australia. Jones, G. K., Ye, Q., Ayvazian, S., Coutin, P. (eds), FRDC Project No. 1997/133, pp. 9-112.
- Fowler, A. J., Steer, M. A., Jackson, W. B., Lloyd, M. T., 2008. Population characteristics of southern sea garfish (*Hyporhamphus melanochir*, Hemiramphidae) in South Australia. *Marine and Freshwater Research* 59, 429-443.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Harvey, M. J., 2004. An evaluation of Western Australian recreational fishing regulations with a case study from a metropolitan boat ramp, Honours thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 97.
- Henry, G. W., Lyle, J. M. (eds) 2003. The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forest, Canberra, Australia.
- Hutson, K. S., Brock, E. L., Steer, M. A., 2011. Spatial variation in parasite abundance: evidence of geographical population structuring in southern garfish *Hyporhamphus melanochir*. *Journal of Fish Biology* 78, 166-182.
- Jones, G. K., Ye, Q., Ayvazian, S., Coutin, P., 2002. Fisheries biology and habitat ecology of southern sea garfish (*Hyporhamphus melanochir*) in southern Australian waters. SARDI. FRDC Project No. 1997/133. pp. 328.
- Jordan, A., Mills, D., Ewing, G., Lyle, J. M., 1998. Assessment of inshore habitats around Tasmania for life history stages of commercial finfish species. Tasmanian Aquaculture and Fisheries Institute Marine Research Laboratories. Tasmania, Australia. FRDC Project No 94/037.
- Klumpp, D. W., Nichols, P. D., 1983. Nutrition of the southern sea garfish *Hyporhamphus melanochir*: gut passage rate and daily consumption of two food types and assimilation of seagrass components. *Marine Ecology Progress Series* 12, 207-216.
- Lenanton, R. C. J., 1982. Alternative non-estuarine nursery habitats for some commercially and recreationally important fish species of south-western Australia. *Australian Journal of Marine and Freshwater Research* 33, 881-900.
- McGarvey, R., Fowler, A. J., Feenstra, J. E., Burch, P., Jackson, W. B., 2009. Southern Garfish (*Hyporhamphus melanochir*) Fishery. SARDI (Aquatic Sciences). Adelaide, South Australia. SARDI Report No. 397. pp. 82.
- Neira, F. J., Potter, I. C., 1992. The ichthyoplankton of a seasonally closed estuary in temperate Australia. Does an extended period of opening influence species composition? *Journal of Fish Biology* 41, 935-953.
- Noell, C. J., 2002. Larval development of the southern sea garfish (*Hyporhamphus melanochir*) and the river garfish (*H. regularis*) (Beloniformes: Hemiramphidae) from South Australian waters. *Fishery Bulletin* 101, 368-367.

- Noell, C. J., 2005. Early life stages of the southern sea garfish, *Hyporhamphus melanochir* (Valenciennes 1846), and their association with seagrass beds, PhD thesis, School of Earth and Environmental Sciences. University of Adelaide, Adelaide, South Australia. pp. 137.
- Robertson, A. I., Klumpp, D. W., 1983. Feeding habits of the southern Australian garfish *Hyporhamphus melanochir*: a diurnal herbivore and nocturnal carnivore. *Marine Ecology Progress Series* 10, 197-201.
- Smallwood, C. B., Beckley, L. E., Sumner, N. R., 2006. Shore-based recreational angling in the Rottne Island Reserve, Western Australia: spatial and temporal distribution of catch and fishing effort. *Pacific Conservation Biology* 12, 238-51.
- Smallwood, C. B., Pollock, K. H., Wise, B. S., Hall, N. G., Gaughan, D. J., 2012. Expanding roving-aerial surveys to include counts of recreational shore fishers from remotely-operated cameras: benefits, limitations and cost-effectiveness. *North American Journal of Fisheries Management* 32, 1265-1276.
- Smallwood, C. B., Sumner, N. R., 2007. A 12-month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002/03. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 159. pp. 56.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012a. South Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Smith, K., Brown, J., Howard, A., Walshe, K., Fissioli, J., 2012b. West Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 80-97.
- Smith, K. A., Brown, J., Hammond, M., Nardi, A., 2008. Development of cost-effective indices to monitor the nearshore fish communities of the Swan Region. Western Australian Department of Fisheries. Perth, Western Australia. Final report to the Swan Catchment Council. pp. 121.
- Steer, M. A., Fowler, A. J., Gillanders, B. M., 2009a. Spatial management of southern garfish (*Hyporhamphus melanochir*) in South Australia: stock structure and adult movement. SARDI. Adelaide, South Australia. SARDI Research Report Series No. 333, FRDC Project No. 2007/029. pp. 97.
- Steer, M. A., Fowler, A. J., Gillanders, B. M., 2009b. Age-related movement patterns and population structuring in southern garfish, *Hyporhamphus melanochir*; inferred from otolith chemistry. *Fisheries Management and Ecology* 16, 265-278.
- Steer, M. A., Halverson, G. P., Fowler, A. J., Gillanders, B. M., 2010. Stock discrimination of Southern Garfish (*Hyporhamphus melanochir*) by stable isotope ratio analysis of otolith aragonite. *Environmental Biology of Fishes* 89, 369-381.
- Steer, M. A., McGarvey, R., Fowler, A. J., Jackson, W. B., Lloyd, M. T., 2011. Promoting stock recovery through the standardisation of fishing gear: streamlining the haul net sector of South Australia's Garfish Fishery. SARDI. Adelaide, South Australia. SARDI Research Report Series No. 578. pp. 55.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Thomson, J. M., 1957a. The size at maturity and spawning times of some Western Australian estuarine fishes. Western Australian Department of Fisheries. Perth, Western Australia. Fishery Bulletin of Western Australia No. 8. pp. 8.
- Thomson, J. M., 1957b. The food of Western Australian estuarine fishes. *Western Australian Fisheries and Fauna Department Bulletin* 7, 1-13.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## Bight redfish (*Centroberyx gerrardi*)

Reviewed by David Fairclough (DoF)



**Scientific name:** *Centroberyx gerrardi* (Berycidae; Alfonsinos)

**Common names:** Bight redfish *also* red snapper, nannygai

**Key identifying features:** White stripe along lateral line, widely separated nostrils, dorsal fin with 6 spines, enlarged teeth at jaw tips (Yearsley *et al.*, 2001).

### Distribution

**Worldwide:** Endemic to southern Australia.

**Western Australia:** Southern Western Australian border to Lancelin (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 660 mm, 4.6 kg (Hutchins and Swainston, 1986), 71 years (Stokie and Krusic-Golub, 2005).

**Length/weight relationship:** [Cape Naturaliste]  $W=0.0001*FL^{2.758}$  (Mackie *et al.*, 2009). See also Knuckey *et al.* (2006) and Graham (1999).

FL (mm)	300	400	500
Weight (g)	679	1,501	2,778

**Length relationship:** Not reported.

**Growth:** [Great Australian Bight, *FL*] Females  $L_{\infty}=481$  mm,  $k=0.023$  year<sup>-1</sup>,  $t_0=30.9$  years

Males  $L_{\infty}=420$  mm,  $k=0.034$  year<sup>-1</sup>,  $t_0=27.6$  years (Stokie, 2004). See also Brown and Sivakumaran (2007).

Age (years)	20	40	60
Females, TL (mm)	332	387	422
Males, TL (mm)	337	378	399

**Length and age maturity:** [Great Australian Bight, *FL*]  $L_{50}=250$  mm,  $A_{50}=9$  years (Brown and Sivakumaran, 2007).

**Reproductive style:** [Cape Naturaliste] Gonochoristic. Multiple batch spawners who form spawning aggregations (Mackie *et al.*, 2009).

**Adult sex ratio:** [GABTS, trawl] F1:M1 ( $n = 866$ ) (Brown and Sivakumaran, 2007).

**Length and age at sex change:** Not applicable

**Spawning season:** [Cape Naturaliste] February – April (Brown and Sivakumaran, 2007; Mackie *et al.*, 2009).

**Spawning location and habitat:** [Cape Naturaliste] Aggregate above “lumps” on the seabed during spawning period (Mackie *et al.*, 2009).

**Fecundity:** Indeterminate (Brown and Sivakumaran, 2007); batch fecundity is probably low (Mackie *et al.*, 2009).

**Spawning frequency:** Not reported.

### **Development and habitat use**

**Eggs:** [Berycidae] Pelagic (Leis and Carson-Ewart, 2000).

**Larvae:** [Berycidae] Pelagic (Leis and Carson-Ewart, 2000).

**Juveniles:** Not reported.

**Adults:** Can be solitary or form aggregations and inhabit deep reefs along the edge of the continental shelf, within caves and beneath ledges. (Harvey *et al.*, 2004; Gomon *et al.*, 2008; Mackie *et al.*, 2009). Higher abundance in cooler waters (Langlois *et al.*, 2012).

**Migration:** Not reported.

**Stock delineation:** Not reported.

**Diet:** [*Centroberyx affinis*] Omnivorous. Feeds predominantly on benthic-pelagic fish and pelagic crustaceans (Coleman and Mobley, 1984; Bulman *et al.*, 2001).

### **Fishery**

**Recreational:** With the aid of improved technology, this species is increasingly being targeted by recreational boat-based rod and line fishers and spear fishers in the West Coast and South Coast bioregions (Mackie *et al.*, 2009). This species is also caught by charter boats in these bioregions (Telfer, 2010).

**Commercial:** A commercially important species caught predominantly in several fisheries including: the Great Australian Bight Trawl Sector (GABTS) of the Southern and Eastern Scalefish and Shark Fishery, by open access wetline fishers in the South Coast bioregion, line fishers in the south-west management area of the West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF) and by temperate Demersal Gillnet and Demersal Longline Fisheries (DGDLF) operating in the West and South Coast bioregions. Taken mainly at depths  $\leq 200$  m in the West Coast bioregion and the GABTS (Klaer, 2012). See also McAuley and Simpfendorfer (2003).

**Age at full recruitment into the fishery:** [Great Australian Bight] Females=17 years ( $n=287$ ), Males=15 years ( $n=314$ ) (Stokie, 2004).

**Gear selectivity parameters:** Not reported.

### **Management parameters**

**Total mortality:** Not reported but estimated in stock assessment models for South Australian stocks (Klaer, 2012).

**Natural mortality:** [Great Australian Bight, Pauly (1980) equation]  $0.1 \text{ year}^{-1}$  (Klaer, 2012). See also Brown and Sivakumaran (2007) for other estimates.

**Fishing mortality:** Not reported but estimated in stock assessment models for South Australian stocks (Klaer, 2012).

**Biological reference points:** Increase in fishing effort (2002 data) resulted in a 66% reduction in the production of eggs per-recruit according to the model (assuming  $M=0.13 \text{ year}^{-1}$ ) (Brown and Sivakumaran, 2007). Spawning stock biomass is estimated to be 90% of unexploited stock level ( $SSB_0$ ) in the Great Australian Bight (Klaer, 2012).

**Current status:** A proposed indicator species for the inshore demersal suite in the South Coast bioregion (DoF, 2011). Overall risk to sustainability for this suite is medium to high in the West Coast and South Coast bioregions (DoF, 2011). Inherent vulnerability for the species is high while current risk to wild stock is high (West Coast) or moderate (South Coast) (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

**Recreational:** Total estimated recreational boat-based catch in the West Coast bioregion increased from 1 t in 1996/97 to 5 t in 2005/06 (Sumner *et al.*, 2008). An estimated 26,722 individuals of this species were caught by recreational anglers in Western Australia in 2000/01 (Henry and Lyle, 2003). This species is the most frequently caught (in number) by charter fishers in the South Coast bioregion (Telfer, 2010).

**Commercial:** The total statewide commercial catch of *Centroberyx gerrardi* in 2010/11 was 40 t (Fletcher and Santoro, 2012). Commercial catches in 2011 included 29 t caught in the WCDSIMF (Fairclough *et al.*, 2012). The DGDLF recorded 6.2 t of *Centroberyx* spp. caught in the South Coast bioregion in 2011, and a further 0.2 t in the West Coast bioregion. Commercial catches of *Centroberyx* spp. in the South Coast Demersal Line Fishery have decreased from 37 t in 2007 to 23.9 t in 2011, with a high of 47.2 t in 2008 (Molony *et al.*, 2012). Note: this species is often grouped under *Centroberyx* spp. (McAuley and Rowland, 2012). See also Klaer (2012).

### Management regulations

**Recreational:** Currently listed in the “demersal finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1988)	-	230	
Statewide (1991)	8	230	
Statewide (1992/93)	20	230	
West Coast (2003)	4	230	
West Coast (2005)	4	300	
South Coast (2005)	8	300	
West Coast (2009)	2	300	Closed season (15 Oct – 15 Dec) Compulsory possession of release weight

**Commercial:** The WCDSIMF is regulated using various input controls (restricted entry, total fishing time allocations, maximum number of lines and hooks) (Fairclough *et al.*, 2012). The DGDLF is regulated using various input controls (transferable time/gear effort, mesh and hook sizes, maximum net length), output controls as well as temporal (16 Aug – 15 Oct) and spatial closures (McAuley and Rowland, 2012). The South Coast Demersal Line Fishery is currently ‘open access’ for the holder of a valid Fishing Boat Licence (for the boat) and a Commercial Fishing Licence (for the fisher) (Molony *et al.*, 2012).

**Current research:** Another assessment of indicator species for the south-west management area of the West Coast bioregion will be conducted in 2012/13. Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based

fishing in 2011/12 may also provide additional catch information. A collaborative NRM-funded research project between Murdoch University and DoF recently commenced which will describe the key biological characteristics of this species in Western Australia.

**Comments/other published information:** *Passive acoustic monitoring* (Mackie *et al.*, 2009); *Age structure modeling* (Wise and Tilzey, 2000).

## References

- Brown, L. P., Sivakumaran, K. P., 2007. Spawning and reproductive characteristics of bight redfish and deepwater flathead in the Great Australian Bight trawl fishery. Primary Industries Queensland, Victoria. FRDC Project No. 2003/003. pp. 49.
- Bulman, C., Althaus, F., He, X., Bax, N. J., Williams, A., 2001. Diets and trophic guilds of demersal fishes of the south-eastern Australian shelf. *Marine and Freshwater Research* 52, 537-548.
- Coleman, N., Mobley, M., 1984. Diets of commercially exploited fish from Bass Strait and adjacent Victorian waters, south-eastern Australia. *Australian Journal of Marine and Freshwater Research* 35, 549-560.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Graham, K. J., 1999. Trawl fish length-weight relationships from data collected during FRV Kapala surveys. New South Wales Fisheries. New South Wales, Australia. Fisheries Research Report Series: 2.
- Harvey, E., Cappo, M., Kendrick, G., 2004. Fishes of the Recherche Archipelago, In Characterising fish habitats of the Recherche Archipelago. Kendrick, G., Harvey, E., McDonald, J., Pattiaratchi, C., Cappo, M., Fromont, J., Shortis, M., Grove, S., Bickers, A., Baxter, K., Goldberg, N., Kletczkowski, M., Butler, J. (eds), University of Western Australia, Perth, Western Australia.
- Henry, G. W., Lyle, J. M. (eds) 2003. The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forest, Canberra, Australia.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Klaer, N., 2012. Bight redfish (*Centroberyx gerrardi*) stock assessment based on data up to 2010/11, In Stock assessment for the Southern and Eastern Scalefish and Shark Fishery: 2011, vol. 1. Tuck, G. N. (ed), Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart, Tasmania, pp. 346-376.
- Knuckey, I., Koopman, M., Gason, A., Hudson, R., 2006. Resource survey of the Great Australian Bight Trawl Fishery 2005. Australian Fisheries Management Authority. Canberra, ACT. Project R04/1102. pp. 40.
- Langlois, T. J., Radford, B. T., Van Niel, K. P., Meeuwig, J. J., Pearce, A. F., Rousseaux, C. S. G., Kendrick, G. A., Harvey, E. S., 2012. Consistent abundance distributions of marine fishes in an old, climatically buffered, infertile seascape. *Global Ecology and Biogeography* 21, 886-897.
- Leis, J. M., Carson-Ewart, B. M., 2000. The larvae of Indo-pacific coastal fishes: a guide to identification (Fauna Malesiana Handbook 2). Brill: Leiden.
- Mackie, M. C., McCauley, R. D., Gill, H. S., Gaughan, D. J., 2009. Management and monitoring of fish spawning aggregations within the West Coast bioregion of Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2004/051, Fisheries Research Report No. 187. pp. 244.

- McAuley, R., Rowland, F., 2012. Temperate demersal gillnet and demersal longline fisheries status report, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 282-294.
- McAuley, R., Simpfendorfer, C., 2003. Catch composition of the Western Australian temperate demersal gillnet and demersal longline fisheries, 1994 to 1999. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 146. pp. 78.
- Molony, B., Lai, E., Holtz, M., 2012. South Coast demersal scalefish resource report: statistics only, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 295-297.
- Pauly, D., 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *Journal du Conseil International pour l'Exploration de la Mer* 39, 175-192.
- Stokie, T. K., 2004. Age estimation of bight redfish (*Centroberyx gerrardi*). Marine and Freshwater Resources Institute. Queenscliff, Victoria. Project Number R03/1723. pp. 16.
- Stokie, T. K., Krusic-Golub, K., 2005. Age estimation of bight redfish and deepwater flathead in the Great Australian Bight Trawl Fisher, 2004/05. Primary Industries Research. Queenscliff, Victoria. Project No. R04/1098. pp. 28.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Telfer, C., 2010. The Western Australian charter boat industry: working towards long-term sustainability, MSc thesis, School of Natural Sciences. Edith Cowan University, Perth, Western Australia. pp. 153.
- Wise, B., Tilzey, R., 2000. Age structured modelling of deepwater flathead (*Neoplatycephalus conatus*) and bight redfish (*Centroberyx gerrardi*) in the Great Australian Bight Trawl Fishery (GABTF). Bureau of Rural Sciences. Canberra, Australia. AFMA Project R99/0180.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## Southern blue spotted flathead (*Platycephalus speculator*)

Reviewed by Peter Coulson (Murdoch University)



**Scientific name:** *Platycephalus speculator* (Platycephalidae; Flatheads)

**Common names:** Southern blue spotted flathead *also* blue-spotted flathead, southern flathead

**Key identifying features:** Caudal fin margin with 3 – 5 large black spots, no greatly enlarged teeth at tip of upper jaw, one pair of bony ridges behind the eye and no large dark blotch inside operculum (Yearsley *et al.*, 2001).

### Distribution of species

**Worldwide:** Endemic to southern Australia (Gomon *et al.*, 2008).

**Western Australia:** Southern Western Australian border to Carnarvon (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 900 mm, 8 kg (Gomon *et al.*, 2008), 12 years (Hyndes *et al.*, 1992a).

**Length/weight relationship:** [West Coast bioregion]  $W=4.35*10^{-6}TL^{3.05}$  [unpublished DoF data, cited in Sumner (2008)].

TL (mm)	300	400	500
Weight (g)	1,562	3,756	7,419

**Length relationship:** Not applicable for *FL* vs *TL*.

**Growth:** [Wilson Inlet] Females  $L_{\infty}=482$  mm,  $k=0.593$  year<sup>-1</sup>,  $t_0=-0.056$  years ( $n=711$ )

Males  $L_{\infty}=429$  mm,  $k=0.573$  year<sup>-1</sup>,  $t_0=-0.134$  years ( $n=630$ ) (Hyndes *et al.*, 1992a).

Age (years)	2	6	10
Females, TL (mm)	340	469	481
Males, TL (mm)	303	416	428

**Length and age at maturity:** [Wilson Inlet] Females  $L_{50}=250$  mm, Males  $L_{50}=325$  mm. Most females and males attain maturity at 2 and ~ 1 years old, respectively, and at 250 – 400 mm and 190 – 310 mm, respectively (Hyndes *et al.*, 1992a; Hyndes *et al.*, 1992b).

**Reproductive style:** Gonochoristic. Multiple spawner (Hyndes *et al.*, 1992b).

Adult sex ratio: [Wilson Inlet, beach seines, gillnets and otter trawls] F1.14:M1 (Hyndes *et al.*, 1992b).

**Length and age at sex change:** Not applicable.

**Spawning season:** [Wilson Inlet] December to April (Hyndes *et al.*, 1992b).

**Spawning location and habitat:** Spawn in open and closed estuaries on the south coast and adjacent marine waters, but not in estuaries on the lower west coast of Western Australia (Hyndes *et al.*, 1992b; Potter and Hyndes, 1999).

**Fecundity:** Not reported.

**Spawning frequency:** Not reported.

### **Development and habitat use**

**Eggs:** Pelagic; estuaries and coastal waters (Hyndes *et al.*, 1992b; Potter and Hyndes, 1999).

**Larvae:** Description of pelagic larval stages (Neira *et al.*, 1998); estuaries and coastal waters (Hyndes *et al.*, 1992b; Neira and Potter, 1992; Breheny *et al.*, 2012).

**Juveniles:** Estuaries (Hyndes *et al.*, 1992b).

**Adults:** Sand and sparsely vegetated weed or seagrass areas in sheltered marine embayments and estuaries as well as surf zones and nearshore reef habitats (Ayvazian and Hyndes, 1995; Chatfield *et al.*, 2010). Most abundant in areas  $\leq 30$  m depth (Chatfield *et al.*, 2010).

**Migration:** Life cycle can be completed within south coast estuaries, but species is a marine-estuarine opportunist on the lower west coast (Potter and Hyndes, 1999).

**Stock delineation:** Not reported.

**Diet:** Ambush predator which feeds predominantly on crustaceans, teleosts (both benthic and mid-water species) and gastropods. Diet in Wilson Inlet found to overlap considerably with the diets of two small cormorant species (Humphries *et al.*, 1992).

### **Fishery**

**Recreational:** Species of Platycephalidae, including the blue spotted flathead, are caught by recreational fishers from boats and from the shore using lines and nets in the Gascoyne Coast, West Coast and South Coast bioregions (Hyndes *et al.*, 1992b; Sumner *et al.*, 2002; Smallwood and Sumner, 2007).

**Commercial:** Species of Platycephalidae, including the blue spotted flathead, are targeted using gill and haul nets in the South Coast Estuarine Managed Fishery (SCEMF) as well as beach-based nearshore commercial fisheries (Lenanton and Potter, 1987; Smith *et al.*, 2012).

**Age at full recruitment:** Not reported.

**Gear selectivity parameters:** Not reported.

### **Management parameters**

**Total mortality:** Not reported.

**Natural mortality:** Not reported.

**Fishing mortality:** Not reported.

**Biological reference points:** Not reported.

**Current status:** Overall risk to sustainability for the nearshore suite of species is moderate in the South Coast bioregion (DoF, 2011). Inherent vulnerability for the species and current risk to wild stock is minimal (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

## Catch trends

**Recreational:** Total recreational catch of Platycephalidae from boat-based fishing was estimated to be 5.4 t in the West Coast bioregion in 1996/97 (Sumner and Williamson, 1999) and 2.6 t in estuaries of the South Coast bioregion in 2002/03 (Smallwood and Sumner, 2007). See also Sumner *et al.* (2002) and Harvey (2004).

**Commercial:** Total commercial catch of Platycephalidae in Western Australia was 3 t in 2010/11 (Fletcher and Santoro, 2012). Catches in the SCMF and beach-based nearshore commercial fisheries decreased from 9.1 t in 2007 to 3.6 t in 2011, with a low of 3 t in 2010 (Smith *et al.*, 2012).

## Management regulations

**Recreational:** Currently listed in the “nearshore/estuarine finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1986)	-	300	
Statewide (2001)	20	300	
West Coast (2003)	8	300	
Gascoyne Coast (2004)	8	300	
South Coast (2005)	8	300	
Statewide (2013)	8	300	

**Commercial:** The South Coast nearshore and estuarine fisheries are managed primarily through input controls (limited entry, gear restrictions, spatial and temporal closures, and size limits) (Smith *et al.*, 2012).

**Current research:** Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

## References

- Ayvazian, S. G., Hyndes, G. A., 1995. Surf-zone fish assemblages in south-western Australia: do adjacent nearshore habitats and the warm Leeuwin Current influence the characteristics of the fish fauna? *Marine Biology* 122, 527-536.
- Breheny, N. B., Beckley, L. E., Wakefield, C. B., 2012. Ichthyoplankton assemblages associated with pink snapper (*Pagrus auratus*) spawning aggregations in coastal embayments of southwestern Australia. *Journal of the Royal Society of Western Australia* 95, 103-114.
- Chatfield, B. S., Van Niel, K. P., Kendrick, G. A., Harvey, E. S., 2010. Combining environmental gradients to explain and predict the structure of demersal fish distributions. *Journal of Biogeography* 37, 593-605.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Harvey, M. J., 2004. An evaluation of Western Australian recreational fishing regulations with a case study from a metropolitan boat ramp, Honours thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 97.

- Humphries, P., Hyndes, G. A., Potter, I. C., 1992. Comparisons between the diets of distant taxa (Teleost and Cormorant) in an Australian estuary. *Estuaries* 15, 327-334.
- Hyndes, G. A., Loneragan, N. R., Potter, I. C., 1992a. Influence of sectioning otoliths on marginal increment trends and age and growth estimates for the flathead *Platycephalus speculator*. *Fishery Bulletin* 90, 276-284.
- Hyndes, G. A., Neira, F. J., Potter, I. C., 1992b. Reproductive biology and early life history of the marine teleost *Platycephalus speculator* Klunzinger (Platycephalidae) in a temperate Australian estuary. *Journal of Fish Biology* 40, 859-874.
- Lenanton, R. C. J., Potter, I. C., 1987. Contribution of estuaries to commercial fisheries in temperate Western Australia and the concept of estuarine dependence. *Estuaries* 10, 28-35.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Neira, F. J., Potter, I. C., 1992. The ichthyoplankton of a seasonally closed estuary in temperate Australia. Does an extended period of opening influence species composition? *Journal of Fish Biology* 41, 935-953.
- Potter, I. C., Hyndes, G. A., 1999. Characteristics of the ichthyofaunas of southwestern Australian estuaries, including comparisons with holarctic estuaries and estuaries elsewhere in temperate Australia: a review. *Australian Journal of Ecology* 24, 395-421.
- Smallwood, C. B., Sumner, N. R., 2007. A 12-month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002/03. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 159. pp. 56.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012. South Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Sumner, N. R., 2008. An assessment of the finfish catch by recreational fishers, tour operators, commercial lobster fishers and commercial wetline fishers from the Houtman Abrolhos Islands during 2006. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 175. pp. 32.
- Sumner, N. R., Williamson, P. C., 1999. A 12-month survey of coastal recreational boat fishing between Augusta and Kalbarri on the west coast of Western Australia during 1996-97. Western Australian Department of Fisheries. Fisheries Research Report No. 117. pp. 52.
- Sumner, N. R., Williamson, P. C., Malseed, B. E., 2002. A 12-month survey of recreational fishing in the Gascoyne bioregion of Western Australia during 1998-99. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 53.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## Breaksea cod (*Epinephelides armatus*)

Reviewed by David Fairclough (DoF)



**Scientific name:** *Epinephelides armatus* (Serranidae; Groupers)

**Common names:** Breaksea cod *also* blackarse snapper, blackarse cod, blackarse, tiger cod

**Key identifying features:** Black blotch surrounds anus, often has a pale stripe on tip of snout (Hutchins and Thompson, 1983).

### Distribution of species

*Worldwide:* Endemic to Western Australia.

*Western Australia:* Recherché Archipelago to Carnarvon (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 550 mm (Hutchins and Thompson, 1983), 3 kg (AAA, 2011), 19 years (Moore *et al.*, 2007).

**Length/weight relationships:** [Lower west coast]  $\ln W = 3.118 * \ln TL - 11.672$  ( $n=217$ ,  $R^2=0.996$ ) (Moore, 2005). See also Eastman (2001).

TL (mm)	200	300	400
Weight (g)	127	451	1,107

**Length relationship:** Not applicable for *FL* vs *TL*.

**Growth:** [Lower west coast] Females  $L_{\infty}=561$  mm,  $k=0.14$  year<sup>-1</sup>,  $t_0=0.24$  years ( $n=335$ ,  $R^2=0.794$ ); Males  $L_{\infty}=588$  mm,  $k=0.17$  year<sup>-1</sup>,  $t_0=0.04$  years ( $n=283$ ,  $R^2=0.789$ ) (Moore *et al.*, 2007).

Age (years)	3	5	10
Females, TL (mm)	200	292	427
Males, TL (mm)	237	338	481

**Length and age at maturity:** [Lower west coast] Females  $L_{50}=306$  mm,  $L_{95}=357$  mm; Males  $L_{50}=256$  mm,  $L_{95}=317$  mm. All females and males < 5 and 3 years, respectively, are immature. The majority of females and males are mature by 7 and 5 years, respectively (Moore *et al.*, 2007).

**Reproductive style:** Gonochoristic. This is the first confirmed gonochorist of the sub-family Anthiinae, with all other species being protogynous hermaphrodites. Multiple spawner (Moore *et al.*, 2007).

**Adult sex ratio:** [Lower west coast, rod and line] F1:M1.22 (Moore *et al.*, 2007).

**Length and age at sex change:** Not applicable.

**Spawning season:** October - April (Moore *et al.*, 2007).

**Spawning locality:** Over reefs in coastal waters (Moore *et al.*, 2007).

**Fecundity:** Indeterminate (Moore *et al.*, 2007).

**Spawning frequency:** Not reported.

### **Development and habitat use**

**Eggs:** [Family Serranidae] Pelagic (Neira *et al.*, 1998).

**Larvae:** [Family Serranidae] Pelagic. Ephinephaline larvae have elongate dorsal and pelvic fin spines (Leis and Carson-Ewart, 2000).

**Juveniles:** Limestone and coral reefs (Moore, 2005).

**Adults:** Continental shelf waters over prominent limestone and coral reefs. Relatively common in coastal waters <100 m deep (Hutchins and Swainston, 1986; Lenanton *et al.*, 2009).

**Migration:** No evidence of migratory behavior (Moore, 2005).

**Stock delineation:** Not reported.

**Diet:** A carnivorous species which feeds by “ram-feeding” and preys predominantly on teleosts, decapods and crustaceans (Platell *et al.*, 2010).

### **Fishery**

**Recreational:** An important recreational species caught by boat-based line fishers (Wise *et al.*, 2007; Sumner *et al.*, 2008) and charter boats (Telfer, 2010).

**Commercial:** Not targeted by commercial fishers but caught as by-product by the West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF) (Fairclough *et al.*, 2012) and in rock lobster pots (De Lestang *et al.*, 2012).

**Age at full recruitment:** [Lower west coast, recreational and research line fishing data] ~ 5 years, *i.e.*, 1 year after peak in age compositions shown in Moore *et al.* (2007).

**Gear selectivity parameters:** Not reported.

### **Management parameters**

**Total mortality:** [Catch curve analysis] ~0.60 year<sup>-1</sup> in waters > 40 m near Two Rocks, 1.34 year<sup>-1</sup> in waters <40 m near Rottnest Island (Moore, 2005).

**Natural mortality:** [Pauly's (1980) equation] Females 0.46 year<sup>-1</sup>; Males 0.45 year<sup>-1</sup> (Moore, 2005; Moore *et al.*, 2007).

**Fishing mortality:** 0.14 year<sup>-1</sup> (*i.e.*,  $F=Z-M$ ). Mortality estimates require updating with more recent data and consideration of representativeness of age composition in samples (Moore *et al.*, 2007).

**Biological reference points:** Not reported.

**Current status:** Overall risk to sustainability for the nearshore demersal suite is medium high in the West Coast and South Coast bioregions (DoF, 2011). Inherent vulnerability for the species is moderate and current risk to wild stock is moderate (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

## Catch trends:

**Recreational:** Total estimated recreational boat-based catch in the West Coast bioregion was 17 t for 1996/97 and 16 t in 2005/06 (Sumner *et al.*, 2008). This species is the most frequently caught (in number) by charter fishers in the West Coast and South Coast bioregions (Telfer, 2010).

**Commercial:** The total landed weight of this species was 5 t in 2010/11 (Fletcher and Santoro, 2012). By-catch in rock lobster pots in 2010/11 was 126 kg (De Lestang *et al.*, 2012).

## Management regulations

**Recreational:** Currently listed in the “demersal finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1991)	4	-	
West Coast (2003)	4	300	
South Coast (2003)	4	300	
West Coast (2009)	2	300	Closed season: 15 Oct – 15 Dec Compulsory possession of release weight
Statewide (except West Coast) (2013)	3	300	

**Commercial:** The WCDSIMF, in which breaksea cod is a by-product species, is regulated using various input controls (restricted entry, total fishing time allocations, maximum number of lines and hooks) (Fairclough *et al.*, 2012).

**Current research:** Research is being undertaken by DoF to obtain more robust (and current) estimates of mortality. Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published research:** *Intestinal worms* (Aken’Ova *et al.*, 2003); *Distribution linked to water temperature* (Langlois *et al.*, 2012b); *Length frequency using stereo-video techniques* (Langlois *et al.*, 2012a); *Barotrauma* (Lenanton *et al.*, 2009).

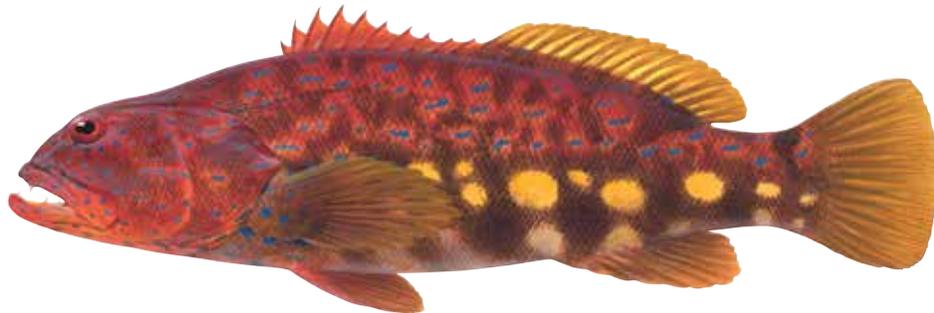
## References

- AAA, 2011. Western Australia state record fish captures up to 25 August 2011. Australian Anglers Association (WA Division). Available: <http://www.aaawa.iinet.net.au/StateFishingRecords.html> (Accessed 24 November 2012).
- Aken’Ova, T. O. L., Cribb, T. H., Bray, R. A., 2003. A new species of *Dactylostomum* Woolcock, 1935 (Digenea: Opecoelidae) from the goatfish *Openeichthys lineatus* (Bloch & Schneider) (Mullidae) in Western Australian waters. *Systematic Parasitology* 56, 63-68.
- De Lestang, S., Thomson, A., Rossbach, M., Kennedy, J., Baudains, G., Steele, A., 2012. West Coast rock lobster fishery status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 37-47.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Eastman, A., 2001. Age, growth and reproductive biology of the breaksea cod, *Epinephelides armatus*, BSc (Honours) thesis, Curtin University of Technology, Perth, Western Australia. pp. 67.

- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Hutchins, B., Thompson, M., 1983. The marine and estuarine fishes of south-western Australia: a field guide for anglers and divers. Western Australian Museum, Perth, Western Australia.
- Langlois, T. J., Fitzpatrick, B. R., Fairclough, D. V., Wakefield, C., Hesp, A., McLean, D., Harvey, E. S., Meeuwig, J. J., 2012a. Similarities between line fishing and baited stereo-video estimations of length-frequency: novel application of kernel density estimates. *PLoS One* 7, (e45973).
- Langlois, T. J., Radford, B. T., Van Niel, K. P., Meeuwig, J. J., Pearce, A. F., Rousseaux, C. S. G., Kendrick, G. A., Harvey, E. S., 2012b. Consistent abundance distributions of marine fishes in an old, climatically buffered, infertile seascape. *Global Ecology and Biogeography* 21, 886-897.
- Leis, J. M., Carson-Ewart, B. M., 2000. The larvae of Indo-pacific coastal fishes: a guide to identification (Fauna Malesiana Handbook 2). Brill: Leiden.
- Lenanton, R., St John, J., Wise, B., Keay, I., Gaughan, D. J., 2009. Maximising survival of released undersize west coast reef fish. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2000/194, Fisheries Research Report No. 191. pp. 130.
- Moore, S., 2005. The biology of the breaksea cod *Epinephelides armatus* in coastal marine waters of south-western Australia, BSc (Honours) thesis, Murdoch University, Perth, Western Australia. pp. 101.
- Moore, S. E., Hesp, S. A., Hall, N. G., Potter, I. C., 2007. Age and size compositions, growth and reproductive biology of the breaksea cod *Epinephelides armatus*, a gonochoristic serranid. *Journal of Fish Biology* 71, 1407-1429.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Pauly, D., 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *Journal du Conseil International pour l'Exploration de la Mer* 39, 175-192.
- Platell, M. E., Hesp, S. A., Cossington, S. M., Lek, E., Moore, S. E., Potter, I. C., 2010. Influence of selected factors on the dietary compositions of three targeted and co-occurring temperate species of reef fishes: implications for food partitioning. *Journal of Fish Biology* 76, 1255-1276.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Telfer, C., 2010. The Western Australian charter boat industry: working towards long-term sustainability, MSc thesis, School of Natural Sciences. Edith Cowan University, Perth, Western Australia. pp. 153.
- Wise, B. S., St John, J., Lenanton, R., 2007. Spatial scales of exploitation among populations of demersal scalefish: implications for management. Part 1: Stock status of the key indicator species for the demersal scalefish fisheries in the West Coast Bioregion. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2003/052. Fisheries Research Report No. 163. pp. 130.

## Harlequin fish (*Othos dentex*)

Reviewed by Ben French (Murdoch University)



**Scientific name:** *Othos dentex* (Serranidae; Groupers)

**Common names:** Harlequin fish *also* chinese lantern, tiger cod

**Key identifying features:** Bright blue spots and yellow blotches on dark brown to yellow sides, 10 dorsal fin spines (Hutchins and Thompson, 1983).

### Distribution of species

**Worldwide:** Endemic to southern Australian waters (Gomon *et al.*, 2008).

**Australia:** Southern Western Australian border to Jurien Bay (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 760 mm, 4.25 kg (Hutchins and Swainston, 1986), [South Australia] 42 years (Saunders *et al.*, 2010).

**Length/weight relationship:**  $W=0.000005059*TL^{3.1667}$  ( $n=249$ ,  $R^2=0.98$ ) (B. French, unpublished data, Murdoch University).

TL (mm)	300	400	500
Weight (g)	353	879	1,782

**Length relationship:** Not reported.

**Growth:** [South Australia, sexes combined]  $L_{\infty}=565$  mm,  $k=0.17$  year<sup>-1</sup>,  $t_0=-0.32$  years ( $n=26$ ) (Saunders *et al.*, 2010).

Age (years)	10	20	30
TL (mm)	567	547	562

**Length and age at maturity:** Not reported.

**Reproductive style:** [South Australia] Possibly gonochoristic (overlapping size ranges) (Saunders *et al.*, 2010).

**Adult sex ratio:** Not reported.

**Length and age at sex change:** Not reported.

**Spawning season:** Not reported.

**Spawning location and habitat:** Not reported.

**Fecundity:** Not reported.

**Spawning frequency:** Not reported.

## **Development and habitat use**

**Eggs:** [Serranidae] Pelagic (Leis and Carson-Ewart, 2000).

**Larvae:** [Serranidae] Pelagic (Leis and Carson-Ewart, 2000).

**Juveniles:** Not reported.

**Adults:** [South Australia] Shallow reefs and caves with drop offs (from about 4 m to 60 m deep) (Gomon *et al.*, 2008; Baker *et al.*, 2009).

**Migration:** None.

**Stock delineation:** Not reported.

**Diet:** [South Australia] A predator that feeds on abalone (Shepherd, 1973) and small fish species (Scott *et al.*, 1974).

## **Fishery**

**Recreational:** Targeted by recreational boat-based line fishers (Sumner *et al.*, 2008) as well as spear fishers (Smith, 2000). This species is also caught by fishers on charter boats (Telfer, 2010).

**Commercial:** Not targeted by commercial fishers but taken as by-catch in the temperate Demersal Gillnet and Demersal Longline Fisheries (DGDLF) in the West Coast and South Coast bioregions (McAuley and Simpfendorfer, 2003). This species is also taken as by-product in the West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF) (D. Fairclough, DoF, *pers. comm.* 2012) and in rock lobster pots (Baker, 2009).

**Age at full recruitment:** Not reported.

**Gear selectivity parameters:** Not reported.

## **Management parameters**

**Total mortality:** Not reported.

**Natural mortality:** Not reported.

**Fishing mortality:** Not reported.

**Biological reference points:** Not reported.

**Current status:** Overall risk to sustainability for the nearshore demersal suite of species is medium to high in the West Coast and South Coast bioregions (DoF, 2011). Inherent vulnerability for the species is moderate and current risk to wild stock is moderate (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

## **Catch trends**

**Recreational:** The total estimated retained catch of this species by recreational boat-based fishers in the West Coast bioregion was 1,256 fish in 1996/97 and 1,989 fish in 2005/06 (Sumner *et al.*, 2008). It was also estimated that 4,697 fish of this species were kept by recreational anglers in Western Australia in 2000/01 (Henry and Lyle, 2003). See also (Telfer, 2010) for information on catch of this species from charter boats.

**Commercial:** Occasionally obtained as a by-catch of the DGDLF in the West Coast and South Coast bioregions, but no catch information reported (McAuley and Simpfendorfer, 2003).

## Management regulations

**Recreational:** Currently listed in the “demersal finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1991)	4	-	
West Coast (2009)	2		Closed season: 15 Oct – 15 Dec Compulsory possession of release weight
Statewide (except West Coast) (2013)	3		

**Commercial:** The DGDLF is regulated using various input controls (transferable time/gear effort, mesh and hook sizes, maximum net length), output controls as well as temporal (16 Aug – 15 Oct) and spatial closures (McAuley and Rowland, 2012). The WCDSIMF is regulated using various input controls (restricted entry, total fishing time allocations, maximum number of lines and hooks) (Fairclough *et al.*, 2012).

**Current research:** Biological studies being undertaken as part of a PhD at Murdoch University. Ongoing data collection occurs through commercial logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

## References

- Baker, J. L., 2009. Marine Species of Conservation Concern in South Australia: Volume 1 - Bony and Cartilaginous Fishes. Report for the South Australian Working Group for Marine Species of Conservation Concern. Science and Conservation Division, and Coast and Marine Conservation branches of S.A. Department for Environment and Heritage (DEH); Marine and Coastal Community Network of S.A. (MCCN), and Threatened Species Network (TSN). Web version published by Reef Watch, South Australia.
- Baker, J. L., Shepherd, S. A., Crawford, H., Brown, A., Smith, K., Lewis, J., Hall, C., 2009. Surveys of uncommon/rare and cryptic reef fishes in South Australia. Report to Commonwealth Department of the Environment, Water, Heritage and the Arts. Adelaide, South Australia. EnviroFund Project 63120. pp. 37.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Henry, G. W., Lyle, J. M. (eds) 2003. The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forest, Canberra, Australia.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Hutchins, B., Thompson, M., 1983. The marine and estuarine fishes of south-western Australia: a field guide for anglers and divers. Western Australian Museum, Perth, Western Australia.
- Leis, J. M., Carson-Ewart, B. M., 2000. The larvae of Indo-pacific coastal fishes: a guide to identification (Fauna Malesiana Handbook 2). Brill: Leiden.
- McAuley, R., Rowland, F., 2012. Temperate demersal gillnet and demersal longline fisheries status report, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 282-294.

- McAuley, R., Simpfendorfer, C., 2003. Catch composition of the Western Australian temperate demersal gillnet and demersal longline fisheries, 1994 to 1999. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 146. pp. 78.
- Saunders, R. J., Bryars, S. R., Fowler, A. J., 2010. Preliminary consideration of the biology of several of South Australia's marine fish species that have conservation or management interest. SARDI. Adelaide, South Australia. SARDI Publication No. F2009/000693-1. Sardi Research Report Series No. 426. pp. 41.
- Scott, T. D., Glover, C. J. M., Southcott, R. B., 1974. The marine and freshwater fishes of South Australia, 2nd edn. Government Publishing Service, Adelaide, South Australia.
- Shepherd, S. A., 1973. Studies on southern Australian abalone (genus *Haliotis*). 1: Ecology of five sympatric species. *Australian Journal of Marine and Freshwater Research* 24, 217-257.
- Smith, A. K., 2000. Underwater fishing in Australia and New Zealand. Mountain Ocean and Travel Publications, Victoria, Australia.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Telfer, C., 2010. The Western Australian charter boat industry: working towards long-term sustainability, MSc thesis, School of Natural Sciences. Edith Cowan University, Perth, Western Australia. pp. 153.

## Eightbar grouper (*Hyporthodus octofasciatus*)

Reviewed by Stephen Newman (DoF)



**Scientific name:** *Hyporthodus octofasciatus* (Serranidae; Groupers) (often confused with *Hyporthodus septemfasciatus*)

**Common names:** Eightbar grouper *also* grey-banded rockcod, bar cod

**Key identifying features:** Eight dark vertical bands on side of body, a dark blotch on upper portion of caudal peduncle, blackish brown dorsal, anal and pelvic fins; faint brown band from eye to the operculum (Heemstra and Randall, 1993; Rome and Newman, 2010). It differs from *Ephinephelus septemfasciatus* by having a different configuration of dark bars on the side of the body.

### Distribution

**Worldwide:** Indo-West Pacific from South Africa to Japan, Australia and New Zealand. Most distribution records for *H. septemfasciatus* outside of Japan, China and Korea are probably for *H. octofasciatus* (Heemstra and Randall, 1993).

**Western Australia:** Entire Western Australian coastline (Rome and Newman, 2010).

**Maximum length, weight and age:** 1,000 mm (Rome and Newman, 2010), 12 kg (Heemstra and Randall, 1993), 47 years (Wakefield *et al.*, 2013).

**Length/weight relationship:**  $W=0.00001356*L^{3.03}$  ( $n=156$ ,  $R^2=0.99$ ) (Wakefield *et al.*, 2013).

TL (mm)	400	600	800
Weight (g)	1,039	3,549	8,484

**Length relationship:** Not applicable.

**Growth:** [Western Australia, sexes combined]  $L_{\infty}=1,100$  mm,  $k=0.11$  year<sup>-1</sup>,  $t_0=-0.41$  years ( $n=26$ ) (Wakefield *et al.*, 2013). Differences in growth between temperate and tropical waters (Wakefield *et al.*, 2013).

Age (years)	10	20	30
TL (mm)	750	983	1,061

**Length and age at maturity:** [Western Australia, tropical waters] Females  $L_{50}=560$  mm,  $A_{50}=6.1$  years,  $L_{95}=900$  mm,  $A_{95}=16.4$  years (Wakefield *et al.*, 2013). No mature females were recorded in temperate waters (Wakefield *et al.*, 2013).

**Reproductive style:** Monandric protogynous hermaphrodite (Wakefield *et al.*, 2013).

**Adult sex ratio:** Not reported.

**Length and age at sex change:** [Western Australia, tropical waters]  $L_{50}=1,022$  mm (Wakefield *et al.*, 2013).

**Spawning season:** Late spring to summer (October – February) (Wakefield *et al.*, 2013).

**Spawning location and habitat:** No evidence of reproduction south of ~30°S latitude (Wakefield *et al.*, 2013).

**Fecundity:** Not reported.

**Spawning frequency:** Not reported.

#### **Development and habitat use**

**Eggs:** [Serranidae] Pelagic (Leis and Carson-Ewart, 2000).

**Larvae:** [Serranidae] Pelagic (Leis and Carson-Ewart, 2000).

**Juveniles:** Not reported.

**Adults:** Offshore reefs at depths of 150 – 300 m (Heemstra and Randall, 1993; Rome and Newman, 2010).

**Migration:** Not reported.

**Stock delineation:** Not reported.

**Diet:** Not reported.

#### **Fishery**

**Recreational:** Caught using hook and line in deep waters by recreational boat-based fishers (To and Pollard, 2008).

**Commercial:** Caught using various wetline methods (*i.e.*, handlines and droplines) by offshore demersal fisheries throughout Western Australia, including the West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF), South Coast Demersal Line Fishery, Gascoyne Demersal Scalefish Fishery (GDSF), Pilbara Demersal Scalefish Fishery (PDSF) and the Northern Demersal Scalefish Fishery (NDSF) (DoF, 2011; Fairclough *et al.*, 2012; Molony *et al.*, 2012).

**Age at full recruitment into the fishery:** Not reported.

**Gear selectivity parameters:** Not reported.

#### **Management parameters**

**Total mortality:** Not reported.

**Natural mortality:** 0.09 year<sup>-1</sup> (Wakefield *et al.*, 2013).

**Fishing mortality:** Not reported.

**Biological reference points:** Not reported.

**Current status:** A proposed indicator species for the offshore demersal zone in the West Coast and a current indicator species in the South Coast bioregion (DoF, 2011). Overall risk to sustainability for this offshore demersal suite is medium high in all four bioregions (DoF, 2011). Inherent vulnerability for the species is high and current risk to wild stock is moderate (DoF, 2011). See DoF (2011) for more detailed risk assessment data. Assessed in IUCN Red List in 2008 as data deficient (To and Pollard, 2008).

## Catch trends

**Recreational:** Not reported. Catches of this species are likely to have been incorporated into a general “cod” category (Sumner *et al.*, 2008).

**Commercial:** The total catch of this species for 2010/11 in Western Australia was 23 t, of which <4 t was caught by the WCDSIMF (Fairclough *et al.*, 2012). Commercial catches of this species in the South Coast Demersal Line Fishery have dropped from 2.5 t in 2007 to 1.4 t in 2011, with a low of 0.5 t in 2010 (Molony *et al.*, 2012).

## Management regulations

**Recreational:** Currently listed in the “demersal finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1991)	4	-	
West Coast (2009)	2	-	Closed season (15 Oct – 15 Dec) Compulsory possession of release weight
Statewide (except West Coast) (2013)	3	-	

**Commercial:** The WCDSIMF is regulated using various input controls (restricted entry, total fishing time allocations, maximum number of lines and hooks) (Fairclough *et al.*, 2012). The South Coast Demersal Line Fishery is currently ‘open access’ for the holder of a valid Fishing Boat Licence (for the boat) and a Commercial Fishing Licence (for the fisher) (Molony *et al.*, 2012).

**Current research:** Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

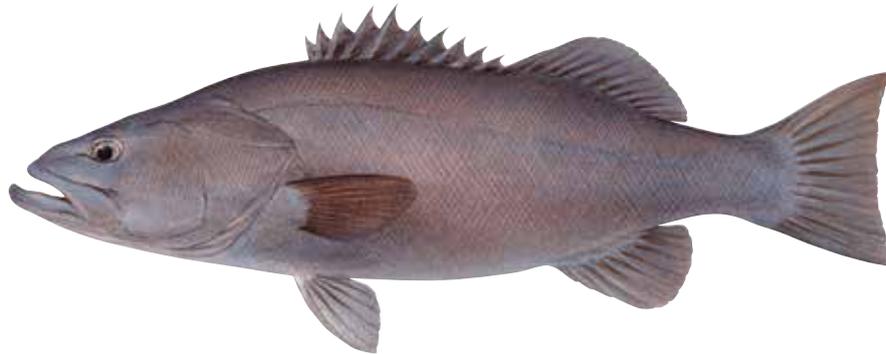
## References

- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Heemstra, P. C., Randall, J. E., 1993. Volume 16. Groupers of the World. Food and Agriculture Organization of the United Nations. Rome, Italy. FAO Fisheries Synopsis No. 125, Volume 14. pp. 382.
- Leis, J. M., Carson-Ewart, B. M., 2000. The larvae of Indo-pacific coastal fishes: a guide to identification (Fauna Malesiana Handbook 2). Brill: Leiden.
- Molony, B., Lai, E., Holtz, M., 2012. South Coast demersal scalefish resource report: statistics only, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 295-297.
- Rome, B., Newman, S. J., 2010. North Coast Fish Identification Guide. Western Australian Department of Fisheries. Perth, Western Australia. pp. 1-79.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.

- To, A. W. L., Pollard, D., 2008. *Hyporthodus octofasciatus*. 2012 IUCN Red List of Threatened Species. Available: <http://www.iucnredlist.org/> (Accessed August 2012).
- Wakefield, C. B., Newman, S. J., Marriott, R. J., Boddington, D. K., Fairclough, D. V., 2013. Contrasting life history characteristics of the eightbar grouper *Hyporthodus octofasciatus* (Pisces: Epinephelidae) over a large latitudinal range reveals spawning omission at higher latitudes. *ICES Journal of Marine Science: Journal du Conseil*.

## Hapuku (*Polyprion oxygeneios*)

Reviewed by Corey Wakefield (DoF)



**Scientific name:** *Polyprion oxygeneios* (Polyprionidae; Wreckfishes)

**Common names:** Hapuku also hapuka, New Zealand groper

**Key identifying features:** Uniformly grey on back, operculum broadly angular with obvious ridge ending in a strong spine, dorsal fin continuous with distinct spinous part, large mouth and head (Yearsley *et al.*, 2001). Similar to *P.americanus*, which has a parallel distribution in southern Australia, the two species are differentiated by *P.oxygeneios* having a body length <30% standard length (versus >35% standard length), a pectoral fin length 35 – 44% of head length (versus 44 – 50 head length), side of body distinctly dark above and pale below in adults (versus side of body uniformly pigmented in adults) and pelagic juveniles with oblique bands (versus mottled colouring) (Gomon *et al.*, 2008).

### Distribution

**Worldwide:** Global distribution in temperate and sub-tropical waters, except South Africa (Gomon *et al.*, 2008).

**Western Australia:** Southern Western Australia to Rottnest Island (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 1,800 mm, 70 kg (Yearsley *et al.*, 2001), 35 years for females and 52 years for males (Wakefield *et al.*, 2010).

**Length/weight relationship:**  $W=0.000002582*TL^{3.24337}$  ( $n=98$ ) (C. Wakefield, DoF, unpublished data).

Length (mm)	400	800	1,200
Weight (g)	710	6,725	25,054

**Length relationship:** Not applicable.

**Growth:** [South Coast] Females  $L_{\infty}=905$  mm,  $k=0.23$  year<sup>-1</sup>,  $t_0=0.20$  years ( $n=361$ )  
Males  $L_{\infty}=877$  mm,  $k=0.22$  year<sup>-1</sup>,  $t_0=0.47$  years ( $n=399$ ) (Wakefield *et al.*, 2010).

Age (years)	10	20	30
Females, TL (mm)	818	896	904
Males, TL (mm)	789	867	876

**Length and age at maturity:** [South Coast] Females  $L_{50}=760$  mm,  $A_{50}=7.1$  years; Males  $L_{50}=702$ mm,  $A_{50}=6.8$  years (Wakefield *et al.*, 2010).

**Reproductive style:** Gonochoristic (Roberts, 1989; Wakefield *et al.*, 2010),

**Adult sex ratio:** [South Coast, commercial hook and line] F1:M1.2 (Wakefield *et al.*, 2010),

**Length and age at sex change:** Not applicable.

**Spawning season:** [South Coast] May – September (Wakefield *et al.*, 2010), similar to New Zealand (Beentjes and Francis, 1999).

**Spawning location and habitat:** Not reported, but possibly forms spawning aggregations (Beentjes and Francis, 1999; Wakefield *et al.*, 2010).

**Fecundity:** Not reported.

**Spawning frequency:** Not reported.

### **Development and habitat use**

**Eggs:** [New Zealand] Likely to drift upwards in the water column after spawning to become pelagic (Anderson *et al.*, 2012).

**Larvae:** [New Zealand] Pelagic (Anderson *et al.*, 2012); [USA] Description of larval stages (Richards, 2006).

**Juveniles:** [New Zealand] Until about 50 cm in length, juveniles are pelagic and predominantly found in surface waters in association with flotsam (Roberts, 1996).

**Adults:** Deep offshore waters of the continental slope between 100 – 500 m depth, predominantly over reef and rough ground (Wakefield *et al.*, 2010). Maximum recorded depth is 854 m (Barreiros *et al.*, 2004).

**Migration:** [New Zealand] Not reported but tagging has shown that some individuals of this species have strong site associations, while others migrate large distances (Beentjes and Francis, 1999).

**Stock delineation:** Mixing between populations throughout southern hemisphere likely (Wakefield *et al.*, 2010) due to its long pelagic juvenile phase (Francis *et al.*, 1999). Evidence of pan-oceanic mixing in *Polyprion* species (Sedberry *et al.*, 1996; Ball *et al.*, 2000).

**Diet:** [Western Australia] Squid and teleosts (C. Wakefield, DoF, *pers. comm.* 2012). [South Australia] Various bottom-dwelling and pelagic fish species, as well as benthic invertebrates (Baker, 2009).

### **Fishery**

**Recreational:** Targeted by recreational fishers in New Zealand and South Australia (Francis *et al.*, 1999; Baker, 2009), and beginning to appear in catches in Western Australia (C. Wakefield, DoF, *pers. comm.*, 2012)

**Commercial:** Caught by commercial fishers using handlines and droplines in Western Australian waters in the West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF) and the South Coast Demersal Line Fishery (Fairclough *et al.*, 2012; Molony *et al.*, 2012). Also caught in Commonwealth waters in the Western Deepwater Trawl Fishery (Emery *et al.*, 2009)

**Age at full recruitment into the fishery:** [South Coast] ~5 years, 1 year following peak in age composition (Wakefield *et al.*, 2010).

**Gear selectivity parameters:** Not reported.

## Management parameters

**Total mortality:** [Derived from age composition data] 0.10-0.14 year<sup>-1</sup> (Wakefield *et al.*, 2010).

**Natural mortality:** [Hoenig's (1983) equation for fish] 0.09 year<sup>-1</sup> (Wakefield *et al.*, 2010).

**Fishing mortality:** 0.01-0.05 year<sup>-1</sup> (Wakefield *et al.*, 2010).

**Biological reference points:**  $F_{\text{target}}=0.06$  year<sup>-1</sup> (*i.e.*, 2/3M) (Wakefield *et al.*, 2010).

**Current status:** Uncertain (Wakefield *et al.*, 2010). A proposed indicator species for the offshore demersal zone in the West Coast and South Coast bioregions (DoF, 2011). Overall risk to sustainability for the offshore demersal suite in the West Coast and South Coast bioregions is medium to high (DoF, 2011). Inherent vulnerability of the species is high and current risk to wild stock is moderate (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

## Catch trends

**Recreational:** No recreational catch information available for Western Australia.

**Commercial:** Total commercial catch in Western Australia in 2010/11 was 13 t (Fletcher and Santoro, 2012). The majority of this catch was taken by the South Coast Demersal Line Fishery, with 14.8 t caught in 2011, a decrease from the peak of 18.5 t caught in 2009 (Molony *et al.*, 2012). Only 1 t was recorded in WCDSIMF for 2011 (Fairclough *et al.*, 2012). The Western Deepwater Trawl Fishery took small, intermittent catches of this species with <0.3 t from 2000 – 2003 (Emery *et al.*, 2009).

## Management regulations

**Recreational:** Currently listed in the “demersal finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1991)	40	-	
South Coast (2005)	2	-	
West Coast (2005)	2	-	
West Coast (2009)	2	-	Closed season (15 Oct – 15 Dec) Compulsory possession of release weight
Statewide (except West Coast) (2013)	3	-	

**Commercial:** Management of this species in the WCDSIMF involves a variety of input controls (restricted entry, total fishing time allocations, maximum number of lines and hooks) (Fairclough *et al.*, 2012). The South Coast Demersal Line Fishery is currently ‘open access’ for the holder of a valid Fishing Boat Licence (for the boat) and a Commercial Fishing Licence (for the fisher) (Molony *et al.*, 2012). The Western Deepwater Trawl Fishery is managed using a number of arrangements including limited entry and species specific limits (Emery *et al.*, 2009).

**Current research:** Genetic studies are underway, firstly to confirm the taxonomy of *Polyprion* species in Western Australia and secondly, examine connectivity between Australia (east and west coast) and New Zealand. Additional studies are underway investigating age-based demography and reproduction from the lower west coast and fish ecology of upper slope in Western Australia with respect to latitude and depth (C. Wakefield, DoF, *pers. comm.*, 2012). Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Heavy metals and poisons* [New Zealand] (Solly and Harrison, 1972; Brooks and Rumsey, 1974; Van den Broek *et al.*, 1981); *Lipid and fatty acids* [New Zealand] (Vlieg and Body, 1988); *Predation* [New Zealand] (Jaquet *et al.*, 2000; Lussesau and Wing, 2006); *Liver oil* [New Zealand] (Shorland, 1953).

## References

- Anderson, S. A., Salinas, I., Walker, S. P., Gublin, Y., Pether, S., Kohn, Y. Y., Symonds, J. E., 2012. Early development of New Zealand hapuku *Polyprion oxygeneios* eggs and larvae. *Journal of Fish Biology* 80, 555-571.
- Baker, J. L., 2009. Marine Species of Conservation Concern in South Australia: Volume 1 - Bony and Cartilaginous Fishes. Report for the South Australian Working Group for Marine Species of Conservation Concern. Science and Conservation Division, and Coast and Marine Conservation branches of S.A. Department for Environment and Heritage (DEH); Marine and Coastal Community Network of S.A. (MCCN), and Threatened Species Network (TSN). Web version published by Reef Watch, South Australia.
- Ball, A. O., Sedberry, G. R., Zatzoff, M. S., Chapman, R. W., Carlin, J. L., 2000. Population structure of the wreckfish *Polyprion americanus* determined with microsatellite genetic markers. *Marine Biology* 137, 1077-1090.
- Barreiros, J. P., Machado, L., Hostim-Silva, M., Sazima, I., Heemstra, P. C., 2004. First record of *Polyprion oxygeneios* (Perciformes: Polyprionidae) for the south-west Atlantic and a northernmost range extension. *Journal of Fish Biology* 64, 1439-1441.
- Beentjes, M. P., Francis, M. P., 1999. Movement of hapuku (*Polyprion oxygeneios*) determined from tagging studies. *New Zealand Journal of Marine and Freshwater Research* 33, 1-12.
- Brooks, R. R., Rumsey, D., 1974. Heavy metals in some New Zealand commercial sea fishes. *New Zealand Journal of Marine and Freshwater Research* 8, 155-166.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Emery, T., Brown, M., Auld, S., 2009. Western Deepwater Trawl Fishery data summary 2008. Australian Fisheries Management Authority. Canberra, Australia. pp. 23.
- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Francis, M. P., Mulligan, K. P., Davies, N. M., Beentjes, M.P., 1999. Age and growth estimates for New Zealand hapuku, *Polyprion oxygeneios*. *Fishery Bulletin* 97, 227-242.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Hoening, J., 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82, 898-903.
- Jaquet, N., Dawson, S., Slooten, E., 2000. Seasonal distribution and diving behaviour of male sperm whales off Kaikoura: foraging implications. *Canadian Journal of Zoology* 78, 407-419.
- Lussesau, S. M., Wing, S. R., 2006. Importance of local production versus pelagic subsidies in the diet of an isolated population of bottlenose dolphins *Tursiops* sp. *Marine Ecology Progress Series* 321, 283-293.

- Molony, B., Lai, E., Holtz, M., 2012. South Coast demersal scalefish resource report: statistics only, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 295-297.
- Richards, W. D. (ed) 2006. Early stages of Atlantic fishes - an identification guide for the Western Central North Atlantic, Volume 1. CRC Press.
- Roberts, C. D., 1989. Reproductive mode in the percomorph fish genus *Polyprion* Oken. *Journal of Fish Biology* 34, 1-9.
- Roberts, C. D., 1996. Hapuku and bass: the mystery of the missing juveniles. *Seafood New Zealand* 4, 17-21.
- Sedberry, G. R., Carlin, J. L., Chapman, R. W., Eleby, B., 1996. Population structure in the pan-oceanic wreckfish, *Polyprion americanus* (Teleostei: Polyprionidae), as indicated by mtDNA variation. *Journal of Fish Biology* 49, 318-329.
- Shorland, F. B., 1953. New Zealand fish oils. 6. Seasonal variations in the composition of New Zealand groper (*Polyprion oxygeneios*) liver oil. *Biochemistry Journal* 54, 673-677.
- Solly, S. R. B., Harrison, D. L., 1972. DDT in some New Zealand marine and freshwater fauna. *New Zealand Journal of Marine and Freshwater Research* 6, 456-462.
- Van den Broek, W. L. F., Tracey, D. M., Solly, S. R. B., Avrahami, M., 1981. Mercury levels in some New Zealand sea fishes. *New Zealand Journal of Marine and Freshwater Research* 15, 137-146.
- Vlieg, P., Body, D. R., 1988. Lipid contents and fatty acid composition of some New Zealand freshwater finfish and marine finfish, shellfish, and roes. *New Zealand Journal of Marine and Freshwater Research* 22, 151-162.
- Wakefield, C. B., Newman, S. J., Molony, B. W., 2010. Age-based demography and reproduction of hapuku, *Polyprion oxygeneios*, from the south coast of Western Australia: implications for management. *ICES Journal of Marine Science* 67, 1164-1174.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## West Australian dhufish (*Glaucosoma hebraicum*)

Reviewed by David Fairclough (DoF)



**Scientific name:** *Glaucosoma hebraicum* (Glaucosomatidae; Pearl Perches)

**Common name:** West Australian Dhufish *also* dhufish, dhuie

**Key identifying features:** No shield-like bone at top of operculum, dark curved bar through eye, pale gill rakers and body cavity membrane (Yearsley *et al.*, 2001).

### Distribution of species

**Worldwide:** Endemic to Western Australia (Hutchins and Swainston, 1986).

**Australia:** Recherché Archipelago to Shark Bay (Hutchins and Swainston, 1986).

**Maximum length and age:** 1,219 mm, 25.8 kg (Hutchins & Thomson, 1995), 41 years (Hesp *et al.*, 2002a).

**Length/weight relationship:** [West Coast bioregion] Females  $\log W = \log 0.0000417 + 2.859 * \log TL$  ( $n=486$ ,  $R^2=0.995$ ); Males  $\log W = \log 0.0000322 + 2.898 * \log TL$  ( $n=486$ ,  $R^2=0.995$ ) (Hesp *et al.*, 2002a).

TL (mm)	300	500	700
Weight – Females (g)	500	2,170	5,680
Weight – Male (g)	485	2,130	5,660

**Length relationship:** Not applicable.

**Growth curve:** [West Coast bioregion] Females  $L_{\infty}=929$  mm,  $k=0.11$  year<sup>-1</sup>,  $t_0=0.141$  years ( $n=675$ ,  $R^2=0.83$ ); Males  $L_{\infty}=1025$  mm,  $k=0.11$  year<sup>-1</sup>,  $t_0=0.052$  years ( $n=799$ ,  $R^2=0.90$ ) (Hesp *et al.*, 2002a). See also Lenanton *et al.* (2009a).

Age (years)	5	15	30
Females, TL (mm)	285	748	894
Males, TL (mm)	430	827	987

**Length and age at maturity:** Females  $L_{50}=301$  mm; Males  $L_{50}=320$  mm (Hesp *et al.*, 2002a)

**Reproductive style:** Gonochoristic. Multiple spawner (Hesp *et al.*, 2002a). Reproductive strategy involves complex social system, spawning in pairs or small groups (Lenanton *et al.*, 2009a; Mackie *et al.*, 2009).

**Adult sex ratio:** [West Coast bioregion, Metropolitan Zone, commercial, recreational and research sampling using lines and gillnets] F1:M1.1 (Lenanton *et al.*, 2009a). See also Marr (1980) and Hesp (1997).

**Length and age at sex change:** Not applicable.

**Spawning season:** November to April, with increased activity from December to March (Hesp *et al.*, 2002a). See also Marr (1980), Abordi (1986) and May (1986).

**Spawning location and habitat:** Over reefs (Hesp *et al.*, 2002a; Mackie *et al.*, 2009).

**Fecundity:** Batch fecundity;  $BF=(0.0841TL - 10.432)^3$  (Wise *et al.*, 2007; Lenanton *et al.*, 2009a).

TL (mm)	300	500	700
Fecundity (eggs)	3,240	31,608	113,647

**Spawning frequency:** ~1.7 days (hydrated oocyte method) to 2 days (post-ovulatory follicle method) (McKeever, 2011).

### Development and habitat use

**Eggs:** Pelagic (Neira *et al.*, 1998).

**Larvae:** Description of larval stages (Neira *et al.*, 1998). Pelagic (Jones, 1986; Cleary and Jenkins, 2003) but settle to a benthic habitat once eyes have adapted to low light (Pironet and Neira, 1998; Shand, 2001). Based on laboratory studies, settlement occurs at ~ 45 days, when the larvae are ~ 8 mm long (Pironet and Neira, 1998; Cleary and Jenkins, 2003). Has been speculated that the strength of the northwards-flowing Capes current may play a role in distributing larvae northwards (Lenanton *et al.*, 2009a). Particle modelling by Berry *et al.* (2012) indicates that, overall, the strength of ocean currents is unlikely to profoundly impact recruitment strength (but may impact localised recruitment to some areas).

**Juveniles:** Small juveniles (<150 mm) found predominantly over sandy areas of sand-inundated low profile reef (with mixed macroalgae, sponge and seagrass) and in small isolated patches of low or medium profile reef surrounded by sandy areas or seagrass beds in coastal inshore waters between 2 – 48 m depth (Wakefield *et al.*, 2013). Larger juveniles (150 – 300 mm) are found over low-lying reefs, *i.e.*, rock ledges < 30 cm high (Hesp *et al.*, 2002a; Mitsopoulos and Molony, 2010).

**Adults:** Fish > 300 mm are found over prominent reefs (Hesp *et al.*, 2002a).

**Migration:** Tagging and otolith microchemistry studies indicate restricted movement and limited mixing of adults latitudinally along the west coast, respectively (Lenanton *et al.*, 2009a; Mackie *et al.*, 2009; Fairclough *et al.*, 2013) except during spawning where individuals may move into shallower waters, especially in the southern West Coast bioregion (Mackie *et al.*, 2009). Individuals are more active at night (Mackie *et al.*, 2009).

**Stock delineation:** Microsatellite DNA studies indicate a single genetic stock (Berry *et al.*, 2012). Otolith microchemistry studies indicate geographic residency of adults along the West Coast bioregion and that by the early juvenile phase, individuals will have settled adjacent to their adult location (Lenanton *et al.*, 2009a; Fairclough *et al.*, 2013).

**Diet:** Predominantly crustaceans, teleosts and molluscs. Diet undergoes pronounced changes with increasing body size (Lek, 2004). See also Marr (1980), Robinson (1987) and Platell *et al.* (2010).

### Fishery

**Recreational:** One of the most important species for boat-based recreational line fishers, including charter operators, especially in the West Coast bioregion (Wise *et al.*, 2007; Telfer, 2010; Fairclough *et al.*, 2012).

**Commercial:** A commercially important species caught in the West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF) and Demersal Gillnet and Demersal Longline Fisheries (DGDLF) (Fairclough *et al.*, 2012; McAuley and Rowland, 2012). Small numbers of this species are also caught as by-catch in rock lobster pots (De Lestang *et al.*, 2012).

**Age at full recruitment:** 9 years (Hesp *et al.*, 2002).

**Gear selectivity parameters:** Females  $L_{50}=503$  mm; Males  $L_{95}=658$  mm (Hesp *et al.*, 2010).

### Management parameters

**Total mortality:** [West Coast bioregion,  $Z=M+F$  using  $M=0.11$  year<sup>-1</sup>] 0.17 – 0.37 year<sup>-1</sup> (Wise *et al.*, 2007).

**Natural mortality:** A range of estimates available for the West Coast bioregion including; 0.12 – 0.21 year<sup>-1</sup> calculated using Hoenig's (1983) regression method (Hesp *et al.*, 2002a; Wise *et al.*, 2007) and 0.11 – 0.21 year<sup>-1</sup> calculated using the maximum age method (Hesp *et al.*, 2002b; Wise *et al.*, 2007).

**Fishing mortality:** [West Coast bioregion] 0.06 – 0.26 year<sup>-1</sup> (Wise *et al.*, 2007).

**Biological reference points:**  $F_{\text{limit}} \sim 0.11$  year<sup>-1</sup> (*i.e.*,  $F=3/2M$ ).

$YPR_{\text{max}}$  at  $\sim F=0.16$  year<sup>-1</sup>

$E/R$ ,  $SPR=20\%$  at  $\sim F=0.08$  year<sup>-1</sup>,  $SPR 40\%$  at  $\sim F=0.2$  year<sup>-1</sup> (Wise *et al.*, 2007).

**Current status:** Breeding stock levels assessed as recovering in the West Coast bioregion (Fairclough *et al.*, 2012). An indicator species in the inshore demersal ecosystem (DoF, 2011a). Overall risk to sustainability for the inshore demersal suite in the West Coast bioregion is medium to high (DoF, 2011a). Inherent vulnerability for the species is high and current risk to wild stock is high (DoF, 2011a). See DoF (2011a) for more detailed risk assessment data.

### Catch trends

**Recreational:** The recreational catch of this species in the West Coast bioregion has decreased from 181 t in 2005/06 to 85 t in 2009/10, while the charter sector retained 12 t in 2010/11 (Fairclough *et al.*, 2012). This species is one of the most frequently caught (in number) by charter fishers in the West Coast and South Coast bioregion (Telfer, 2010). See also Sumner and Williamson (1999), Harvey (2004), Wise *et al.* (2007) and Sumner *et al.* (2008) for more catch information.

**Commercial:** Total commercial catch in Western Australian waters in 2010/11 was 75 t (live weight) (Fletcher and Santoro, 2012). Commercial catch of this species peaked at 254 t in 2002/03, of which 72% was taken by the wetline fishery (Wise *et al.*, 2007). In 2011, the WCDSIMF retained 67 t, an increase from 54 t in 2010 (Fairclough *et al.*, 2012). The DGDLF retained 13 t in 2010/11, an increase from 16 t in 2009/10 (McAuley and Rowland, 2012). A complete catch trend graph is shown in the 2010/11 State of the Fisheries and Aquatic Resources Report. In 2009/10, 11.8 t was retained in the South Coast bioregion (DoF, 2011b). In the West Coast bioregion, 0.2 t of this species was caught in rock lobster pots during 2010/11 (De Lestang *et al.*, 2012).

### Management regulations

**Recreational:** Currently listed in the “demersal finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1958)	-	330	
Statewide (1975)	3	500	
Statewide (1977)	10	500	
Statewide (1985)	5	500	
Statewide (1991)	4	500	
West Coast (2003)	2	500	
Gascoyne Coast (2005)	2	500	
South Coast (2007)	2	500	
West Coast (2009)	1	500	Closed season (15 Oct – 15 Dec) Compulsory possession of release weight
Statewide (except West Coast) (2013)	1	500	

**Commercial:** The WCDSIMF is regulated using various input controls (restricted entry, total fishing time allocations, maximum number of lines and hooks) (Fairclough *et al.*, 2012). The DGDLF is regulated using various input controls (transferable time/gear effort, mesh and hook sizes, maximum net length), output controls as well as temporal (16 Aug – 15 Oct) and spatial closures (McAuley and Rowland, 2012). The South Coast Demersal Line Fishery is currently ‘open access’ for the holder of a valid Fishing Boat Licence (for the boat) and a Commercial Fishing Licence (for the fisher) (Molony *et al.*, 2012).

**Current research:** DoF is undertaking collaborative research with Curtin University, to explore the use of passive acoustic methods for monitoring relative abundances of demersal species (including dhufish), and a project with CSIRO using DNA techniques for identifying dhufish larvae (DoF, 2012). Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Retinal development* (Shand, 2001); *Aquaculture* (Stephens *et al.*, 2001; 2002a; b; 2003); *Parasitism* (Hesp *et al.*, 2002b); *Age and mortality estimation* (Craine *et al.*, 2009); *Acoustic tracking* (Mackie *et al.*, 2009); *Effects of sanctuary zones* (Kleczkowski *et al.*, 2008); *Identification of microsatellite markers* (BurrIDGE and England, 2009); *Simulation modeling for exploring implications of alternative management, catch and behavioural characteristics* (Burch, 2009; Hesp *et al.*, 2010; Fisher *et al.*, 2011); *Barotrauma* (Lenanton *et al.*, 2009b).

## References

- Abordi, J., 1986. The reproductive biology of the Westralian jewfish, *Glaucosoma hebraicum* (Pisces: Glaucosomidae), Part 1, Gonad morphology, Biology Project 301/302 thesis, School of Biology, Curtin University, Perth, Western Australia. pp. 66.
- Berry, O., England, P. R., Fairclough, D., Jackson, G., Greenwood, J., 2012. Microsatellite DNA analysis and hydrodynamic modeling reveal the extent of larval transport and gene flow between management zones in an exploited marine fish (*Glaucosoma hebraicum*). *Fisheries Oceanography* 21, 243-254.
- Burch, R., 2009. Description and parameterisation of an agent-based model to explore the effects of recruitment variability on populations of *Glaucosoma hebraicum* in a recreational fishery, Honours thesis, Murdoch University, Perth, Western Australia. pp. 139.
- BurrIDGE, C. P., England, P. R., 2009. Tri- and tetranucleotide microsatellites in dhufish *Glaucosoma hebraicum* (Perciformes). *Permanent Genetic Resources Note* 9, 948-951.

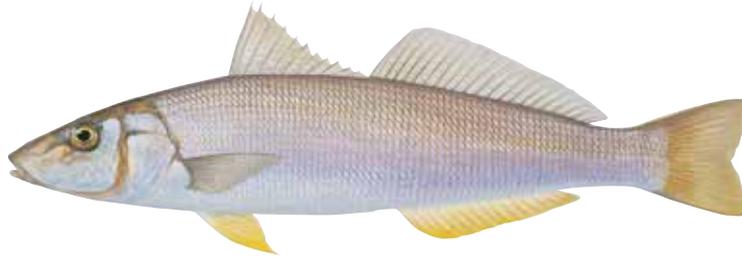
- Cleary, J. J., Jenkins, G. I., 2003. Further development of aquaculture techniques for the production of WA dhufish (*Glaucosoma hebraicum*): FRDC Project 1999/322 incorporating development of aquaculture techniques for the production of WA dhufish (*Glaucosoma hebraicum*). Challenger TAFE. Perth, Western Australia. FRDC Project No. 1999/322. pp. 179.
- Craine, M., Rome, B., Stephenson, P., Wise, B., Gaughan, D. J., Lenanton, R., Steckis, R., 2009. Determination of a cost effective methodology for ongoing age monitoring needed for the management of scalefish fisheries in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2004/042, Fisheries Research Report No. 192. pp. 110.
- De Lestang, S., Thomson, A., Rossbach, M., Kennedy, J., Baudains, G., Steele, A., 2012. West Coast rock lobster fishery status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 37-47.
- DoF, 2011a. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2011b. State of the fisheries and aquatic resources report 2010/2011, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, p. 359.
- DoF, 2012. Research, monitoring, assessment and development plan 2011-2012. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 106. pp. 152.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Fairclough, D. V., Edmonds, J. S., Jackson, G., Lenanton, R. C. J., Kemp, J., Molony, B. W., Keay, I., Crisafulli, B. M., Wakefield, C. B., 2013. A comparison of the stock structures of two exploited demersal teleosts, employing complementary methods of otolith element analysis. *Journal of Experimental Marine Biology and Ecology* 439, 181-195.
- Fisher, E. A., Hesp, S. A., Hall, N. G., 2011. Exploration of the effectiveness of alternative management responses to variable recruitment. Murdoch University. Perth, Western Australia. FRDC Project No. 2008/06. pp. 167.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Harvey, M. J., 2004. An evaluation of Western Australian recreational fishing regulations with a case study from a metropolitan boat ramp, Honours thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 97.
- Hesp, S. A., 1997. The biology of the dhufish, *Glaucosoma hebraicum*, in offshore waters on the lower west coast of Australia, BSc (Honours) thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 63.
- Hesp, S. A., Burch, R. J., Tink, C. J., Hall, N. G., 2010. Development of an agent-based model to communicate implications of recruitment variability of finfish to recreational fishers. Murdoch University. Perth, Western Australia. FRDC Project No. 2008/033. pp. 81.
- Hesp, S. A., Potter, I. C., Hall, N. G., 2002a. Age and size composition, growth rate, reproductive biology, and habitats of the West Australian dhufish (*Glaucosoma hebraicum*) and their relevance to the management of this species. *Fishery Bulletin* 100, 214-227.
- Hesp, S. A., Hobbs, R. P., Potter, I. C., 2002b. Infection of the gonads of *Glaucosoma hebraicum* by the nematode *Philometra lateolabracis*: occurrence and host response. *Journal of Fish Biology* 60, 663-673.
- Hoening, J., 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82, 898-903.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Jones, H. E., 1986. Marine resources map of Western Australia, Part 1. The Resources. *Fisheries Department of Western Australia Report* 74, 30-31.

- Kleczkowski, M., Babcock, R. C., Clapin, G., 2008. Density and size of reef fishes in and around a temperate marine reserve. *Marine and Freshwater Research* 59, 165-176.
- Lek, E., 2004. Diets of three carnivorous fish species in marine waters of the west coast of Australia, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 99.
- Lenanton, R., St John, J., Keay, I., Wakefield, C., Jackson, G., Wise, B., Gaughan, D. J., 2009a. Spatial scales of exploitation among populations of demersal scalefish: implications for management. Part 2: stock structure and biology of two indicator species, West Australian dhufish (*Glaucosoma hebraicum*) and pink snapper (*Pagrus auratus*) in the West Coast Bioregion. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2003/052. Fisheries Research Report No. 174. pp. 187.
- Lenanton, R., St John, J., Wise, B., Keay, I., Gaughan, D. J., 2009b. Maximising survival of released undersize west coast reef fish. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2000/194, Fisheries Research Report No. 191. pp. 130.
- Mackie, M. C., McCauley, R. D., Gill, H. S., Gaughan, D. J., 2009. Management and monitoring of fish spawning aggregations within the West Coast bioregion of Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2004/051, Fisheries Research Report No. 187. pp. 244.
- Marr, F., 1980. Growth, reproduction and dietary preference of the Jewfish, *Glaucosoma hebraicum*. School of Biology, Western Australian Institute of Technology. Perth, Western Australia. Biology Project 301/201. pp. 41.
- McAuley, R., Rowland, F., 2012. Temperate demersal gillnet and demersal longline fisheries status report, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 282-294.
- McKeever, L., 2011. Aspects of spawning in West Australian Dhufish (*Glaucosoma hebraicum*), Independent Study Contract Report. School of Biological Sciences. Murdoch University, Perth, Western Australia.
- Mitsopoulos, G., Molony, B., 2010. Protecting inshore and demersal scalefish-identification of critical habitats for juvenile dhufish. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 210. pp. 36.
- Molony, B., Lai, E., Holtz, M., 2012. South Coast demersal scalefish resource report: statistics only, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 295-297.
- Moy, I., 1986. The reproductive biology of the Western Jewfish, *Glaucosoma hebraicum* (Pisces: Glaucosomatidae), Part II, Gonadal Analysis, School of Biology. Curtin University, Perth, Western Australia. pp. 66.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Pironet, F. N., Neira, F. J., 1998. Hormone-induced spawning and development of artificially reared larvae of the West Australian dhufish, *Glaucosoma hebraicum* (Glaucosomatidae). *Marine and Freshwater Research* 49, 133-142.
- Platell, M. E., Hesp, S. A., Cossington, S. M., Lek, E., Moore, S. E., Potter, I. C., 2010. Influence of selected factors on the dietary compositions of three targeted and co-occurring temperate species of reef fishes: implications for food partitioning. *Journal of Fish Biology* 76, 1255-1276.
- Robinson, R. G., 1987. The morphology and histology of the alimentary tract: the dietary preference of the Western Australian Jewfish: *Glaucosoma hebraicum*, BSc thesis, School of Biology. Curtin University of Technology, Perth, Western Australia. pp. 46.
- Shand, J., 2001. Visual development of the West Australian Dhufish (*Glaucosoma hebraicum*). University of Western Australia. Perth, Western Australia. FRDC Project No. 1998/329. pp. 24.
- Stephens, F. J., Cleary, J. J., Jenkins, G., Jones, B., Raidal, S. R., Thomas, J. B., 2001. Pathogenesis and epidemiology of spontaneous exophthalmos in the West Australian dhufish *Glaucosoma hebraicum* Richardson. *Journal of Fish Diseases* 24, 515-522.
- Stephens, F. J., Cleary, J. J., Jenkins, G., Jones, B., Raidal, S. R., Thomas, J. B., 2002a. The effect of CO<sub>2</sub>-rich ground water on the West Australian dhufish (*Glaucosoma hebraicum*). *Aquaculture* 208, 169-176.

- Stephens, F. J., Cleary, J. J., Jenkins, G., Jones, B., Raidal, S. R., Thomas, J. B., 2002b. Health problems of the Western Australian dhufish. Perth, Western Australia. FRDC Project 98/328. pp. 101
- Stephens, F. J., Cleary, J. J., Jenkins, G., Jones, B., Raidal, S. R., Thomas, J. B., 2003. Treatments to control *Haliotrema abaddon* in the West Australian dhufish, *Glaucosoma hebraicum*. *Aquaculture* 215, 1-10.
- Sumner, N. R., Williamson, P. C., 1999. A 12-month survey of coastal recreational boat fishing between Augusta and Kalbarri on the west coast of Western Australia during 1996-97. Western Australian Department of Fisheries. Fisheries Research Report No. 117. pp. 52.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Telfer, C., 2010. The Western Australian charter boat industry: working towards long-term sustainability, MSc thesis, School of Natural Sciences. Edith Cowan University, Perth, Western Australia. pp. 153.
- Wakefield, C. B., Newman, S. J., Marriott, R. J., Boddington, D. K., Fairclough, D. V., 2013. Contrasting life history characteristics of the eightbar grouper *Hyporthodus octofasciatus* (Pisces: Epinephelidae) over a large latitudinal range reveals spawning omission at higher latitudes. *ICES Journal of Marine Science: Journal du Conseil*.
- Wise, B. S., St John, J., Lenanton, R., 2007. Spatial scales of exploitation among populations of demersal scalefish: implications for management. Part 1: Stock status of the key indicator species for the demersal scalefish fisheries in the West Coast Bioregion. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2003/052. Fisheries Research Report No. 163. pp. 130.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## Yellowfin whiting (*Sillago schomburgkii*)

Reviewed by Joshua Brown (DoF)



**Scientific name:** *Sillago schomburgkii* (Sillaginidae; Whiting)

**Common name:** Yellowfin whiting

**Key identifying features:** Elongate body with pointed snout, bright yellow pelvic and anal fins, no spots, blotches or stripes along the upper sides of body of adults. Juveniles have dark blotches along upper side of body (Yearsley *et al.*, 2001; Gomon *et al.*, 2008).

### Distribution

**Worldwide:** Endemic to Australia (McKay, 1992).

**Western Australia:** Southern Western Australian border to Exmouth Gulf (Gomon *et al.*, 2008). Most abundant between Augusta and Shark Bay (J.Brown, *pers. comm.*, DoF).

**Maximum length, weight and age:** 414 mm, 0.68 kg (Hutchins and Swainston, 1986), 12 years (Hyndes and Potter, 1997).

**Length/weight relationships:** [West Coast bioregion]  $W=2.02*10^{-6}TL^{3.24}$  ( $n=934$ ) (Gaughan *et al.*, 2006). See also Coulson (2003) for Shark Bay estimates.

TL (mm)	200	300	400
Weight (g)	58	214	544

**Length relationship:** Not reported.

**Growth:** [West Coast bioregion] Females  $L_{\infty}=333$  mm,  $k=0.53$  year<sup>-1</sup>,  $t_0=-0.16$  years ( $n=662$ ,  $R^2=0.95$ ); Males  $L_{\infty}=325$  mm,  $k=0.49$  year<sup>-1</sup>,  $t_0=-0.22$  years ( $n=554$ ,  $R^2=0.93$ ) (Hyndes and Potter, 1997). See also Gaughan *et al.* (2006) for South Coast bioregion estimates and Hyndes *et al.* (1997).

Age (years)	1	3	5
Females, TL (mm)	153	271	312
Males, TL (mm)	123	232	282

**Length and age at maturity:** [West Coast bioregion]  $L_{50}=199$  mm (Gaughan *et al.*, 2006). In comparison, virtually all females and about half of males recorded by Hyndes and Potter (1997) were mature by 200 mm. Most females and males mature by 2 years (Hyndes and Potter, 1997).

**Reproductive style:** Gonochoristic. Multiple spawner (Hyndes and Potter, 1997).

**Adult sex ratio:** [West Coast bioregion, seine net] F1.8:M1 (Hyndes and Potter, 1997).

**Length and age at sex change:** Not applicable.

**Spawning season:** [West Coast bioregion] December to February (Hyndes and Potter, 1997).

Spawning season earlier and longer in Shark Bay (August to December), presumably due to differences in water temperature (Coulson *et al.*, 2005). See also Lenanton (1969).

**Spawning location and habitat:** Shallow, nearshore waters (Hyndes and Potter, 1997).

**Fecundity:** Indeterminate (Coulson, 2003).

**Spawning frequency:** Not reported.

### **Development and habitat use**

**Eggs:** [*Sillago* species] Pelagic (Neira *et al.*, 1998).

**Larvae:** Description of larval stages (Neira *et al.*, 1998). Coastal waters (Bruce, 1995).

**Juveniles:** Shallow waters in sheltered, marine nearshore environments and estuaries over bare sand (Lenanton, 1982; Hyndes *et al.*, 1996; Hyndes *et al.*, 1997; Hyndes and Potter, 1997).

**Adults:** Deeper waters in sheltered, marine nearshore environments and estuaries over bare sand (Lenanton, 1982; Hyndes *et al.*, 1996; Hyndes *et al.*, 1997; Hyndes and Potter, 1997).

**Migration:** Moves away from shore during the day and back towards shore at night (Hyndes *et al.*, 1996). Adult fish tend to move closer to shore during the spawning season, which increases their catchability (J. Brown, *pers. comm.*, DoF).

**Stock delineation:** [New South Wales] Not reported (Dixon *et al.*, 1987).

**Diet:** Predominantly crustaceans and polychaetes (Hyndes *et al.*, 1997; Platell and Potter, 2001).

### **Fishery**

**Recreational:** *Sillago* species (including *S. schomburgkii*) are commonly targeted largely by shore-based rod and line anglers, and some boat-based fishers, in coastal and estuarine waters of the South Coast, West Coast and Gascoyne Coast (Shark Bay) bioregions (Lenanton, 1969).

**Commercial:** Targeted by a variety of commercial seine net fisheries including the West Coast Beach Bait Managed Fishery, South West Beach Seine Fishery in the West Coast bioregion (Smith *et al.*, 2012a), the Shark Bay Beach Seine and Mesh Net Managed Fishery (SBBSMNF) in the Gascoyne Coast bioregion (Jackson *et al.*, 2012a), and estuarine and beach-based nearshore commercial fisheries in the South Coast bioregion (Lenanton, 1969; Smith *et al.*, 2012b).

**Age at full recruitment:** 2 – 3 years (Coulson, 2003).

**Gear selectivity parameters:** Not reported.

### **Management parameters**

**Total mortality:** [Shark Bay, catch curve analysis] 0.81 year<sup>-1</sup> (Coulson, 2003).

**Natural mortality:** [Shark Bay, obtained by re-fitting Hoenig's (1983) equation for estimating mortality using the data provided in Hoenig (1982) and assuming a common maximum age for both sexes] 0.68 year<sup>-1</sup> (reported as Z) (Coulson, 2003). Note: the estimate is higher than would be obtained by using Hoenig's (1983) original equation.

**Fishing mortality:** [Shark Bay] 0.13 year<sup>-1</sup> (*i.e.*,  $F=Z-M$ ).

**Biological reference:** Not reported.

**Current status:** Stock levels of *Sillago* species not assessed in the West Coast bioregion (Smith *et al.*, 2012a) and adequate in Shark Bay (Jackson *et al.*, 2012a). *Sillago* species are proposed indicator species for the nearshore ecosystem in the West Coast, Gascoyne Coast and South Coast bioregions (DoF, 2011). Overall risk to sustainability for the nearshore suite is moderate in the South Coast and Gascoyne Coast bioregions and medium to high in the West Coast bioregion (DoF, 2011). Inherent vulnerability and current risk to wild stock for the species is minimal in the Gascoyne Coast and West Coast bioregions (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

Due to the difficulties in distinguishing the various *Sillago* species, they are often grouped together for analysis of recreational and commercial catches.

**Recreational:** The total estimated recreational boat-based catch of *Sillago* species in the West Coast bioregion was 58 t for 1996/97 and 46 t in 2005/06 (Sumner *et al.*, 2008). The total recreational catch of *Sillago* species was estimated as 154 t in the West Coast bioregion and 11 t in the South Coast bioregion in 2000/01 (Henry and Lyle, 2003). Yellowfin whiting was the dominant species caught by recreational anglers in the Blackwood Estuary during two previous creel surveys (Caputi, 1976; Prior and Beckley, 2007). See also Malseed *et al.* (2000), Malseed and Sumner (2001a; b), Harvey (2004), Smallwood *et al.* (2006), Smallwood and Sumner (2007) and Smallwood *et al.* (2012).

**Commercial:** A total of 119 t of yellowfin whiting was reportedly caught by commercial fishers in Western Australia in 2010/11 (Fletcher and Santoro, 2012). The majority of the commercial catch of *Sillago* species from 2000 – 2011 was taken in the Gascoyne Coast bioregion (67%) with the remainder from the West Coast (23%), South Coast (7%) and North Coast (3%) bioregions (Smith *et al.*, 2012a). The majority (86%) of the catch in the West Coast bioregion was reported to be yellowfin whiting (Smith *et al.*, 2012a). This species was considered overfished in the Shark Bay region in the 1960s, prior to a marked reduction in the number of fishing units in the SBBSMNMF (Shaw, 2000).

### Management regulations

**Recreational:** Currently included in the “all other species of finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1913)	-	230	
Statewide (1958)	-	220	
Statewide (1991)	40	-	
West Coast (2003)	16	-	
West Coast (2005)	40	-	
West Coast (2007)	16	-	
Gascoyne Coast (2008)	16	-	
South Coast (2008)	16	-	
West Coast (2009)	12	-	
Statewide (2013)	30	-	

**Commercial:** This species is caught in multiple commercial fisheries including the SBBSMNMF, West Coast Beach Bait Managed Fishery and South West Beach Seine Fishery. These operate under a variety of input control systems including limits on numbers of boats, gear sizes and fishing areas (*i.e.*, to protect nursery areas) (Shaw, 2000; Jackson *et al.*, 2012b). A legal minimum size limit of 220 mm existed for commercial fishers until March 2011.

**Current research:** A NRM funded project is currently being run by DoF to assess the stock status of several *Sillago* species in the West Coast and South Coast bioregions as well as to ascertain the composition of *Sillago* species in recreational and commercial catches. Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Review of studies* [South Australia] (Jones, 1981).

## References

- Bruce, A. D., 1995. Larval development of King George whiting, *Sillaginodes punctatus*, school whiting, *Sillago bassensis*, and yellow-fin whiting, *Sillago schomburgkii* (Percoidei: Sillaginidae), from South Australian waters. *Fishery Bulletin* 93, 27-43.
- Caputi, N., 1976. Creel census of amateur line fishermen in the Blackwood River estuary, Western Australia, during 1974-75. *Marine and Freshwater Research* 27, 583-593.
- Coulson, P. G., 2003. Comparisons between the biology of two species of whiting (Sillaginidae) in Shark Bay, Western Australia, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 76.
- Coulson, P. G., Hesp, S. A., Potter, I. C., Hall, N. G., 2005. Comparisons between the biology of two co-occurring species of whiting (Sillaginidae) in a large marine embayment. *Environmental Biology of Fishes* 73, 125-139.
- Dixon, P., Crozier, R. H., Black, M., Church, A., 1987. Stock identification and discrimination of commercially important whittings in Australian waters using genetic criteria. Centre for Marine Science, University of New South Wales. New South Wales, Australia. FIRTA Project 83/16. pp. 69.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gaughan, D. J., Ayvazian, S., Nowara, G., Craine, M., Brown, J., 2006. The development of a rigorous sampling program for a long term annual index of recruitment for finfish species from south-western Australia. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 1999/153, Fisheries Research Report No. 154. pp. 135.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Harvey, M. J., 2004. An evaluation of Western Australian recreational fishing regulations with a case study from a metropolitan boat ramp, Honours thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 97.
- Henry, G. W., Lyle, J. M. (eds) 2003. The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forest, Canberra, Australia.
- Hoening, J., 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82, 898-903.
- Hoening, J. M., 1982. A compilation of mortality and longevity estimates for fish, molluscs, and cetaceans, with a bibliography of comparative life history studies. GSO Technical Report Reference No. 82-2.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Hyndes, G. A., Platell, M. E., Potter, I. C., 1997. Relationships between diet and body size, mouth morphology, habitat and movements of six sillaginid species in coastal waters: implications for resource partitioning. *Marine Biology* 128, 585-598.
- Hyndes, G. A., Potter, I. C., 1997. Age, growth and reproduction of *Sillago schomburgkii* in south-western Australian, nearshore waters and comparisons of life history styles of a suite of *Sillago* species. *Environmental Biology of Fishes* 49, 435-447.

- Hyndes, G. A., Potter, I. C., Lenanton, R. C., 1996. Habitat partitioning by whiting species (Sillaginidae) in coastal waters. *Environmental Biology of Fishes* 45, 21-40.
- Jackson, G., Norriss, J., Lunow, C., 2012a. Inner Shark Bay scalefish fishery status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 154-160.
- Jackson, G., Marriott, R., Lai, E., Lunow, C., 2012b. Gascoyne Demersal scalefish fishery status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 146-153.
- Jones, G. K., 1981. Yellowfin whiting (*Sillago schomburgkii*) studies in South Australian waters. *SAFIC* 5, 20-23.
- Lenanton, R. C. J., 1969. Whiting fishery - Shark Bay. *Western Australian Department of Fisheries and Wildlife* 2, 4-11.
- Lenanton, R. C. J., 1982. Alternative non-estuarine nursery habitats for some commercially and recreationally important fish species of south-western Australia. *Australian Journal of Marine and Freshwater Research* 33, 881-900.
- Malseed, B. E., Sumner, N. R., 2001a. A 12-month survey of recreational fishing in the Swan-Canning Estuary basin of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 126. pp. 44.
- Malseed, B. E., Sumner, N. R., 2001b. A 12-month survey of recreational fishing in the Peel-Harvey Estuary of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 127. pp. 48.
- Malseed, B. E., Sumner, N. R., Williamson, P. C., 2000. A 12-month survey of recreational fishing in the Leschenault Estuary of Western Australia during 1998. Western Australian Department of Fisheries. Perth, Western Australia. pp. 36.
- McKay, R. J., 1992. Volume 14. Sillaginid fishes of the world. Food and Agriculture Organization of the United Nations. Rome, Italy. FAO Fisheries Synopsis No. 125, Volume 14. pp. 87.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Platell, M. E., Potter, I. C., 2001. Partitioning of food resources amongst 18 abundant benthic carnivorous fish species in marine waters on the lower west coast of Australia. *Journal of Experimental Marine Biology and Ecology* 261, 31-54.
- Prior, S. P., Beckley, L. E., 2007. Characteristics of recreational anglers in the Blackwood Estuary, a popular tourist destination in southwestern Australia. *Tourism in Marine Environments* 4, 15-28.
- Shaw, J., 2000. Fisheries Environmental Management Review Gascoyne Region. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Environmental Management Review No. 1.
- Smallwood, C. B., Beckley, L. E., Sumner, N. R., 2006. Shore-based recreational angling in the Rottneest Island Reserve, Western Australia: spatial and temporal distribution of catch and fishing effort. *Pacific Conservation Biology* 12, 238-51.
- Smallwood, C. B., Pollock, K. H., Wise, B. S., Hall, N. G., Gaughan, D. J., 2012. Expanding roving-aerial surveys to include counts of recreational shore fishers from remotely-operated cameras: benefits, limitations and cost-effectiveness. *North American Journal of Fisheries Management* 32, 1265-1276.
- Smallwood, C. B., Sumner, N. R., 2007. A 12-month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002/03. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 159. pp. 56.
- Smith, K., Brown, J., Howard, A., Walshe, K., Fissioli, J., 2012a. West Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 80-97.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012b. South Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## King George whiting (*Sillaginodes punctata*)

Reviewed by Glenn Hyndes (Edith Cowan University)



**Scientific name:** *Sillaginodes punctata* (Sillaginidae; Whiting)

**Common names:** King George whiting *also* spotted whiting

**Key identifying features:** Elongate body with pointed snout, numerous small dark spots on sides, small scales, and two dorsal fins which are often slightly separated (Yearsley *et al.*, 2001).

### Distribution of species

**Worldwide:** Endemic to southern Australia.

**Western Australia:** Southern Western Australian border to Jurien Bay (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 720 mm, 4.8 kg (Gomon *et al.*, 2008), 14 years (Hyndes *et al.*, 1998). [SA] maximum age = 17 years (Fowler *et al.*, 1999; 2000).

**Length/weight relationship:**  $W=1.10*10^{-6}TL^{3.29}$  ( $n=1,099$ ) (Gaughan *et al.*, 2006).

TL (mm)	300	400	500
Weight (g)	155	400	834

**Length relationship:** Not reported.

**Growth:** [West Coast bioregion] Females  $L_{\infty}=532$  mm,  $k=0.47$  year<sup>-1</sup>,  $t_0=0.13$  years ( $n=194$ ); Males  $L_{\infty}=500$  mm,  $k=0.53$  year<sup>-1</sup>,  $t_0=0.16$  years ( $n=124$ ) (Hyndes *et al.*, 1998). Size-at-age declines with increasing latitude (and decreasing water temperature) (Sulin, 2012). See also Orr (2000), Gaughan *et al.* (2006), Potter *et al.* (2011) and Sulin (2012). Growth highly seasonal in South Australia, but not in Western Australia (Hyndes *et al.*, 1998; McGarvey and Fowler, 2002; Sulin, 2012).

Age (years)	2	6	10
Females, TL (mm)	311	498	527
Males, TL (mm)	311	477	497

**Length and age at maturity:** [West Coast bioregion] Females,  $L_{50}=410$  mm,  $L_{95} \sim 450$  mm (Hyndes *et al.*, 1998). Majority of females mature by 4 years, all mature by 5 years. Data for males not provided. See also Gaughan *et al.* (2006).

**Reproductive style:** Gonochoristic. Multiple spawner (Hyndes *et al.*, 1998).

**Adult sex ratio:** Not reported.

**Length and age at sex change:** Not applicable.

**Spawning season:** [West Coast bioregion] June to September (Hyndes *et al.*, 1998). [South Australia] Spawn from April to July (Fowler *et al.*, 1999; 2000).

**Spawning locality:** [West Coast bioregion] Around reefs in waters between 6 – 50m deep

(Hyndes *et al.*, 1998). There is anecdotal evidence of spawning aggregation behaviour from fishers. Additional information: [South Australia, Victoria] Spawn in deeper waters, with medium-high wave energy, while hydrodynamic modeling suggests post-larvae originate from spawning grounds in South Australia or western Victoria (Fowler *et al.*, 2000; Hamer *et al.*, 2004).

**Fecundity:** [South Australia] Indeterminate (Fowler *et al.*, 1999); Batch fecundity:  $BF=461.16*TL-143772.8$  ( $n=29$ ,  $R^2=0.4567$ ) (Fowler *et al.*, 1999).

TL (mm)	400	450	500
Fecundity (eggs)	40,000	64,000	87,000

**Spawning frequency:** [SA] Once every 2 days (Fowler *et al.*, 1999).

## Development and habitat use

**Eggs:** Pelagic (Bruce, 1995; Neira *et al.*, 1998).

**Larvae:** [South Australia] Passively transported to shallow, nearshore marine waters (Bruce, 1995; Fowler *et al.*, 2000). Pre-settlement duration ~ 80-130 days (Fowler and Short, 1996). [Victoria] Weak swimming ability of larvae consistent with passive dispersal (Jenkins and Welsford, 2002). Larval period 3 – 5 months (Jenkins and May, 1994; Jenkins, 2005). Description of pelagic larval stages (Neira *et al.*, 1998).

**Juveniles:** Sandy areas in sheltered shallow, nearshore marine waters as well as in estuaries (Hyndes *et al.*, 1998). [South Australia] Settle over seagrass meadows or bare sand areas in sheltered embayments (Jenkins and May, 1994).

**Adults:** Around reefs on weedy or sandy bottoms in waters between 6 – 50m depth (Hyndes *et al.*, 1998). Adults do not spawn in estuaries (Potter *et al.*, 2011).

**Migration:** Exhibits pronounced size-related offshore movements between habitats at different life stages (Hyndes *et al.*, 1996; Hyndes *et al.*, 1998; Fowler and March, 1999; Fowler *et al.*, 2002; Sulin, 2012). In the nearshore habitat, early juveniles undertake movements away from shore during the day and towards shore at night (Hyndes *et al.*, 1996).

**Stock delineation:** Parasitological and allozyme studies indicate sub-structuring of the stock along the southern coast (Sandars, 1945; Dixon *et al.*, 1987). Conversely, a more recent genetic study provided no evidence of long-standing population structure/contemporary population differentiation (Fowler and McGarvey, 2000). It has been hypothesised that assemblages in estuaries on the south coast of Western Australia are derived from relatively discrete, nearby spawning assemblages (Potter *et al.*, 2011).

**Diet:** Predominantly crustaceans and polychaetes. Small juveniles consume large amounts of copepods. The diet in larger individuals changes to increasing consumption of polychaetes, penaeids and carids (Hyndes *et al.*, 1997; Orr, 2000; Whitehead, 2000).

## Fishery

**Recreational:** Caught by boat and shore-based recreational anglers, including charter boats, using lines in coastal and estuarine waters of the South Coast and West Coast bioregions (Smallwood and Sumner, 2007; Sumner *et al.*, 2008; Telfer, 2010).

**Commercial:** One of the most frequently caught species in nearshore and estuarine finfish commercial gillnet, haul net and beach seine fisheries in the South Coast and West Coast bioregions (Smith *et al.*, 2012a; Smith *et al.*, 2012b). This species is also taken in the temperate Demersal Gillnet and Demersal Longline Fishery (DGDLF) and the West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF) (DoF, 2011).

**Age at full recruitment:** Not reported.

**Gear selectivity parameters:** Not reported.

### Management parameters

**Total mortality:** Not reported.

**Natural mortality:** [South Australia] Value fixed at 0.4 year<sup>-1</sup> in stock assessments (but also with sensitivity tests for different values of *M*) (McGarvey and Feenstra, 2011).

**Fishing mortality:** [South Australia] See McGarvey *et al.* (2005), Fowler *et al.* (2008) and McGarvey and Feenstra (2011).

**Biological reference points:** [South Australia] Biological performance indicators/ stock assessment modeling provided by Fowler and McGarvey (2000), McGarvey *et al.* (2005), Fowler *et al.* (2008) and McGarvey and Feenstra (2011).

**Current status:** Overall risk to sustainability is moderate for the West Coast and South Coast bioregions (DoF, 2011). Overall risk to sustainability for the inshore demersal suite is medium to high in the South Coast and West Coast bioregion (DoF, 2011). Inherent vulnerability and current risk to wild stock for this species is moderate in the West Coast and South Coast bioregions (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

**Recreational:** The total estimated recreational boat-based catch was 28 t in 1996/97, 19 t in 2005/06 in the West Coast bioregion (Sumner *et al.*, 2008) and 40 t in 2000/01 in the South Coast bioregion (Henry and Lyle, 2003). An estimated 10.9 t of this species was retained in estuaries of Western Australia in 2002/03 (Smallwood and Sumner, 2007). Catches in the West Coast bioregion from charter boats have been stable from 2003/04 onwards, but in the South Coast bioregion, they increased in 2006/07 and 2007/08 (Telfer, 2010). See also Harvey (2004), Smallwood *et al.* (2006) and Smallwood *et al.* (2011).

**Commercial:** A total of 15 t of this species was taken by commercial fishers in Western Australia in 2010/11 (Fletcher and Santoro, 2012). The total catch of this species in the West Coast bioregion has varied from 0.9 t in 2007 to 4.4 t in 2011, with a high of 5.9 t in 2010 (Smith *et al.*, 2012b). In the South Coast bioregion, the total catch of this species has remained relatively static between 2007 (8.0 t) to 2011 (7.8 t), from a peak of 9.1 t in 2008 (Smith *et al.*, 2012a). See also Gaughan *et al.* (2006). See also (Kemp *et al.*, 2012).

### Management regulations

**Recreational:** Currently listed in the “nearshore/estuarine finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1913)	-	250	
Statewide (1986)	30	250	
Statewide (1991)	20	-	
West Coast (2003)	8	280	
South Coast (2003)	20	280	
South Coast (2005)	12	280	
Statewide (2013)	12	280	

**Commercial:** South Coast and West Coast nearshore and estuarine fisheries are managed primarily through input controls (limited entry, gear restrictions, spatial and temporal closures, and size limits) (Smith *et al.*, 2012a; Smith *et al.*, 2012b).

**Current research:** Collaborative stock assessment studies are being undertaken by DoF and Murdoch University (FRDC 2010/001). Ongoing data collection is occurring from commercial and charter fishing logbooks. Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published research:** *Planktonic transport of larvae* [Victoria] (Moran *et al.*, 2004); *Factors affecting shallow/deep hooking rates* [Victoria] (Grixiti *et al.*, 2010); *Growth* (Barber and Jenkins, 2001); *Age validation* [South Australia] (Fowler and Short, 1998); *Movement* [South Australia] (McGarvey and Feenstra, 2002); *Per-recruit analysis* [South Australia] (Sluczanowski *et al.*, 1990); *Diet* [South Australia] (Jenkins *et al.*, 2011); *Hydrodynamic modeling exploring larval movement* [South Australia] (Fowler and McGarvey, 2000; Hamer *et al.*, 2004).

## References

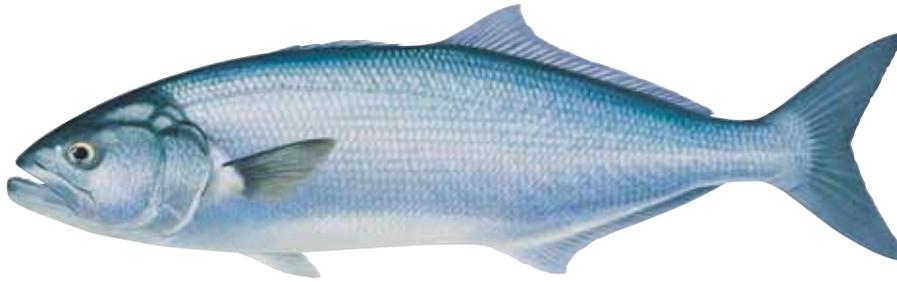
- Barber, M. C., Jenkins, G. P., 2001. Differential effects of food and temperature lead to decoupling of short-term otolith and somatic growth rates in juvenile King George whiting. *Journal of Fish Biology* 58, 1320-1330.
- Bruce, A. D., 1995. Larval development of King George whiting, *Sillaginodes punctatus*, school whiting, *Sillago bassensis*, and yellow-fin whiting, *Sillago schomburghii* (Percoidei: Sillaginidae), from South Australian waters. *Fishery Bulletin* 93, 27-43.
- Dixon, P., Crozier, R. H., Black, M., Church, A., 1987. Stock identification and discrimination of commercially important whittings in Australian waters using genetic criteria. Centre for Marine Science, University of New South Wales. New South Wales, Australia. FIRTA Project 83/16. pp. 69.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Fowler, A. J., Jones, G. K., McGarvey, R., 2002. Characteristics and consequences of movement patterns of King George whiting (Perciformes: *Sillaginodes punctata*) in South Australia. *Marine and Freshwater Research* 53, 1055-1069.
- Fowler, A. J., March, W. A., 1999. Characteristics of movement of adult King George whiting (Percoidei: Sillaginidae) in South Australia waters, *In Australian Society for Fish Biology*. Hancock, D. A., Smith, D. C., Koehn, J. D. (eds), Australian Society for Fish Biology, Victoria, Australia. pp. 136-143.
- Fowler, A. J., McGarvey, R., 2000. Development of an integrated fisheries management model for King George Whiting (*Sillaginodes punctata*) in South Australia. SARDI. Adelaide, South Australia. FRDC Project No. 95/008. pp. 232.
- Fowler, A. J., McGarvey, R., Feenstra, J. E., 2008. King George whiting (*Sillaginodes punctata*) fishery. SARDI. South Australia. SARDI Research Report Series No. 296. pp. 77.
- Fowler, A. J., McLeay, L. J., Short, D. A., 1999. Reproductive mode and spawning information based on gonad analysis for the King George whiting (Percoidei: Sillaginidae) from South Australia. *Marine and Freshwater Research* 50, 1-14.
- Fowler, A. J., McLeay, L. J., Short, D. A., 2000. Spatial variation in size and age structures and reproductive characteristics of the King George whiting (Percoidei: Sillaginidae) in South Australian waters. *Marine and Freshwater Research* 51.
- Fowler, A. J., Short, D. A., 1996. Temporal variation in the early life-history characteristics of the King George Whiting (*Sillaginodes punctata*) from analysis of otolith microstructure. *Marine and Freshwater Research* 47, 809-818.

- Fowler, A. J., Short, D. A., 1998. Validation of age determination from otoliths of the King George whiting *Sillaginodes punctata* (Perciformes). *Marine Biology* 130, 577-587.
- Gaughan, D. J., Ayvazian, S., Nowara, G., Craine, M., Brown, J., 2006. The development of a rigorous sampling program for a long term annual index of recruitment for finfish species from south-western Australia. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 1999/153, Fisheries Research Report No. 154. pp. 135.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Grixiti, D., Conron, S. D., Ryan, K., Versace, V. L., 2010. Circle versus longshank hooks: comparing hooking locations and recreational catch for juvenile snapper *Pagrus auratus* and King George whiting *Sillaginodes punctata*. *Fisheries Research* 106, 27-31.
- Hamer, P. A., Jenkins, G., Sivakumaran, K. P., 2004. Identifying the spawning locations of a recreational fishing based study. Department of Primary Industries. Victoria. Fisheries Victoria Assessment Report Series No. 21.
- Harvey, M. J., 2004. An evaluation of Western Australian recreational fishing regulations with a case study from a metropolitan boat ramp, Honours thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 97.
- Henry, G. W., Lyle, J. M. (eds) 2003. The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forest, Canberra, Australia.
- Hyndes, G. A., Platell, M. E., Potter, I. C., 1997. Relationships between diet and body size, mouth morphology, habitat and movements of six sillaginid species in coastal waters: implications for resource partitioning. *Marine Biology* 128, 585-598.
- Hyndes, G. A., Platell, M. E., Potter, I. C., Lenanton, R. C. J., 1998. Age composition growth, reproductive biology and recruitment of King George whiting, *Sillaginodes punctata*, in coastal waters of southwestern Australia. *Fishery Bulletin* 96, 258-270.
- Hyndes, G. A., Potter, I. C., Lenanton, R. C., 1996. Habitat partitioning by whiting species (Sillaginidae) in coastal waters. *Environmental Biology of Fishes* 45, 21-40.
- Jenkins, G. P., 2005. Influence of climate on the fishery recruitment of a temperate, seagrass-associated fish, the King George whiting *Sillaginodes punctata*. *Marine Ecology Progress Series* 288, 263-271.
- Jenkins, G. P., May, H. M. A., 1994. Variation in settlement and larval duration of King George whiting, *Sillaginodes punctatus* (Sillaginidae), in Swan Bay, Victoria, Australia. *Bulletin of Marine Science* 54, 281-296.
- Jenkins, G. P., Syme, A., Macreadie, P. I., 2011. Feeding ecology of King George whiting *Sillaginodes punctatus* (Perciformes) recruits in seagrass and unvegetated habitats. Does diet reflect habitat utilization? *Journal of Fish Biology* 78, 1561-1573.
- Jenkins, G. P., Welsford, D. C., 2002. The swimming abilities of recently settled post-larvae of *Sillaginodes punctata*. *Journal of Fish Biology* 60, 1043-1050.
- Kemp, J., Fowler, A., Smith, K., 2012. King George Whiting *Sillaginodes punctata*, In Status of key Australian fish stocks reports 2012. Flood, M., Stobutzki, I., Andrews, J., Begg, G., Fletcher, W., Gardner, C., Kemp, J., Moore, A., O'Brien, A., Quinn, R., Roach, J., Rowling, K., Sainsbury, K., Saunders, T., Ward, T., Winning, M. (eds), Fisheries Research and Development Corporation, Canberra, Australia, pp. 380-385.
- McGarvey, R., Feenstra, J. E., 2002. Estimating rates of fish movement from tag recoveries: conditioning by recapture. *Canadian Journal of Fisheries and Aquatic Sciences* 59, 1054-1064.
- McGarvey, R., Feenstra, J. E., 2011. Stock assessment models with graphical user interfaces for key South Australian marine finfish stocks. SARDI. South Australia. FRDC Project No. 1999/145. pp. 177.
- McGarvey, R., Fowler, A. J., 2002. Seasonal growth of King George Whiting (*Sillaginodes punctata*) estimated from length-at-age samples of the legal sized harvest. *Fish Bulletin* 100, 545-558.
- McGarvey, R., Fowler, A. J., Feenstra, J. E., Jackson, W. B., Jennings, P. R., 2005. King George Whiting (*Sillaginodes punctata*) fishery. Fishery assessment report to PIRSA for the Marine Scalefish Fishery Management Committee. SARDA. South Australia. SARDI Research Report Series No. 91. pp. 88.

- Moran, S. M., Jenkins, G. P., Keough, M. J., Hindell, J. S., 2004. Evidence for secondary planktonic transport of post-larvae of seagrass-associated King George whiting. *Journal of Fish Biology* 64, 1226-1241.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Orr, P., 2000. The biology of four commercial fish species in a seasonally closed estuary, PhD thesis, Murdoch University, Perth, Western Australia. pp. 275.
- Potter, I. C., Chuwen, B. M., Hesp, S. A., Hall, N. G., Hoeksema, S. D., Fairclough, D. V., Rodwell, T. M., 2011. Implications of the divergent use of a suite of estuaries by two exploited marine fish species. *Journal of Fish Biology* 79, 662-691.
- Sandars, D. F., 1945. Five new microcotylids from fish from Western Australian waters. *Journal and Proceedings of the Royal Society of Western Australia* 29, 107-137.
- Sluczanowski, P. W. R., Jones, G. K., Forbes, S., Baker, J., Lewis, R. K., Wright, G., 1990. Examining the “per recruit” effects of size limits using the PRAna software package, *In Australian Society for Fish Biology*. Hancock, D. A. (ed), Australian Society for Fish Biology, Victoria, Australia. pp. 57-64.
- Smallwood, C. B., Beckley, L. E., Sumner, N. R., 2006. Shore-based recreational angling in the Rottne Island Reserve, Western Australia: spatial and temporal distribution of catch and fishing effort. *Pacific Conservation Biology* 12, 238-51.
- Smallwood, C. B., Pollock, K. H., Wise, B. S., Hall, N. G., Gaughan, D. J., 2011. Quantifying recreational fishing catch and effort: a pilot study of shore-based fishers in the Perth Metropolitan area. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 216. pp. 60.
- Smallwood, C. B., Sumner, N. R., 2007. A 12-month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002/03. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 159. pp. 56.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012a. South Coast nearshore and estuarine finfish resources status report, *In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries*. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Smith, K., Brown, J., Howard, A., Walshe, K., Fissioli, J., 2012b. West Coast nearshore and estuarine finfish resources status report, *In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries*. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 80-97.
- Sulin, E., 2012. Size and age compositions and growth of King George Whiting (*Sillaginodes punctata*) in south-western Australia, MSc thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Telfer, C., 2010. The Western Australian charter boat industry: working towards long-term sustainability, MSc thesis, School of Natural Sciences. Edith Cowan University, Perth, Western Australia. pp. 153.
- Whitehead, A., 2000. Variations in abundance, feeding patterns and prey availability of post-settlement King George Whiting, *Sillaginodes punctata*, in nearshore marine waters, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 55.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## Tailor (*Pomatomus saltatrix*)

Reviewed by Paul Lewis (DoF)



**Scientific name:** *Pomatomus saltatrix* (Pomatomidae; Bluefish)

**Common names:** Tailor, small fish < 35cm often called choppers.

**Key identifying features:** Silvery body, 7 – 8 short dorsal fin spines depressed into a groove and connected to each other via a membrane, oblique mouth with a prominent lower jaw (Yearsley *et al.*, 2001).

### Distribution

**Worldwide:** Coastal temperate and subtropical waters of all ocean basins, except the eastern Pacific (Goodbred and Graves, 1996).

**Western Australia:** Southern Western Australian border to Onslow (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 1,200 mm, 14.4 kg (Gomon *et al.*, 2008), 10 years (Smith *et al.*, in press)

**Length/weight relationship:** [West Coast bioregion]  $W=0.7*10^{-5}TL^{3.0415}$  ( $R^2=0.996$ ,  $n=1692$ ) (Smith *et al.*, in press). See also Smith *et al.* (in press) for fork length to weight relationship and Gaughan *et al.* (2006) for another West Coast bioregion relationship.

TL (mm)	300	600	900
Weight (g)	239	1,971	6,767

**Length relationship:** [West Coast bioregion]  $TL=1.1288*FL-0.4264$  ( $R^2=0.999$ ,  $n=3497$ ).

**Growth curves:** [West Coast bioregion] Females  $L_{\infty}=546$  mm,  $k=0.57$  year<sup>-1</sup>,  $t_0=-0.04$  years ( $n=300$ ); Males  $L_{\infty}=660$  mm,  $k=0.37$  year<sup>-1</sup>,  $t_0=-0.13$  years ( $n=300$ ) (Smith *et al.*, in press). See also Gaughan *et al.* (2006) and Young *et al.* (1999).

Age (years)	2	4	6
Females, TL (mm)	375	491	529
Males, TL (mm)	360	517	592

**Length and age at maturity:** [West Coast bioregion]  $L_{50}=330$  mm,  $L_{95}=451$  mm ( $n=1632$ ) (Smith *et al.*, in press).

**Reproductive style:** Gonochoristic. Fractional, broadcast spawner (Smith *et al.*, in press).

**Adult sex ratio:** [West Coast bioregion, recreational and commercial] F1.5: M1 ( $n=2,859$ ). Ratio consistent across years, size classes and sectors (Smith *et al.*, in press).

**Length and age at sex change:** Not applicable.

**Spawning season:** Spring and autumn in the West Coast bioregion and, winter and spring in the Gascoyne Coast bioregion (Lenanton *et al.*, 1996; Smith *et al.*, in press).

**Spawning location and habitat:** Probably in inner-shelf waters between summer and autumn (Lenanton *et al.*, 1996; Chisholm).

**Fecundity:** [West Coast bioregion] Indeterminate fecundity; [Eastern USA] Batch fecundity;  $BF=6.036.6e^{0.0053TL}$  (Robillard *et al.*, 2008). See also Robillard *et al.* (2008) for batch fecundity versus somatic weight relationship.

TL (mm)	300	600	900
Fecundity (eggs)	29,602	145,160	711,831

**Spawning frequency:** Not reported.

### Development and habitat use

**Eggs:** Small buoyant pelagic eggs which hatch at 46 – 48 hours. Eggs are likely to be transported southwards by the Leeuwin current in winter-spring and northwards by the Capes Current in summer-autumn. Positioning of eggs also affected strongly by wind driven surface water currents (Juanes *et al.*, 1996; Lenanton *et al.*, 1996; Neira *et al.*, 1998; Pearce and Pattiaratchi, 1999).

**Larvae:** Larvae generally collected between coastal areas and the edge of the continental shelf where water temperatures are between 18 – 25°C (Lenanton *et al.*, 1996; Chisholm, 2004). A larval duration of 18 – 25 days has been identified in Eastern USA (Hare and Cowen, 1993). Description of larval stages (Neira *et al.*, 1998).

**Juveniles:** Sheltered estuarine and shallow coastal areas of the lower west coast of Western Australia, mainly between Cervantes and Bunbury, are important nursery habitats (Lenanton *et al.*, 1996; Young *et al.*, 1999).

**Adults:** Once tailor attain maturity, they move northwards and offshore to pelagic waters, and also move inshore in search of food (Gomon *et al.*, 2008).

**Migration:** Adults migrate to spawning grounds (Lenanton, 1974; Juanes *et al.*, 1996; Young *et al.*, 1999). In southern Africa, divergent migratory patterns were found, including a northern stock that is migratory and a southern stock showing combinations of seasonally transient and resident behaviour (Hedger *et al.*, 2010).

**Stock delineation:** A stable isotope study indicated that tailor in Shark Bay constitute a single stock and that fish throughout south-western Australia and in Shark Bay may also be regarded as a single, although not homogenous, stock (Edmonds *et al.*, 1999). Tailor from the east coast and west coasts of Australian are genetically distinct, and are considered as separate stocks (Nurthen *et al.*, 1992). A genetic study across several countries has provided evidence that tailor in eastern and western Australia are closely related, as are those from U.S.A., Portugal and South Africa, while tailor from Brazil are distantly related to other groups (Goodbred and Graves, 1996).

**Diet:** [Eastern Australia] Juveniles feed on small crustaceans, cephalopods and fish and adults prey mainly on small schooling fish (Bade, 1977; Gomon *et al.*, 2008).

### Fishery

**Recreational:** Listed as the tenth most commonly retained species in Western Australia in a survey undertaken in 2001/02, with the majority caught by shore-based recreational fishers

in the West Coast bioregion (Henry and Lyle, 2003). Recreational fishing effort is focused in shallow, nearshore waters during summer and autumn when this species is mainly caught at dawn and dusk with bait or lures cast from beaches and rock platforms (Cribb, 1994; Lenanton *et al.*, 1996; Young *et al.*, 1999).

**Commercial:** The majority of commercial catches for this species are taken in the Gascoyne Coast bioregion using beach seince and haul nets in the Shark Bay Beach Seine and Mesh Net Managed Fishery (SBBSMNMF) (Smith *et al.*, 2012b). This species is also fished in the West Coast Estuarine Managed Fishery (WCEF), and in estuarine and beach-based nearshore commercial fisheries in the South Coast bioregion (Smith, 2006; Smith *et al.*, 2012a).

**Age at full recruitment:** Not reported.

**Gear selectivity:** Not reported.

### Management parameters

**Total mortality:** Not reported.

**Natural mortality:** [West Coast bioregion] 0.42 year<sup>-1</sup> (Smith *et al.*, in press).

**Fishing mortality:** Assuming 100% reporting of tags, fish < 250 mm (the minimum legal limit for tailor at time of study) was 0.058 year<sup>-1</sup> (SE = 0.013 year<sup>-1</sup>), while for fish > 250 mm it was 0.081 year<sup>-1</sup> (SE = 0.029 year<sup>-1</sup>) (Young *et al.*, 1999).

**Biological reference points:** Not reported.

**Current status:** Stock level acceptable in West Coast bioregion (Smith *et al.*, 2012a), adequate in Gascoyne Coast bioregion (Jackson *et al.*, 2012). An indicator species for the nearshore suite in the West Coast bioregion, and a proposed indicator for the Gascoyne Coast bioregion (DoF, 2011). Overall risk to sustainability for the nearshore suite is moderate (South Coast and Gascoyne Coast bioregions) or medium to high (West Coast bioregion) (DoF, 2011). Inherent vulnerability of this species is moderate while current risk to wild stock is minimal in the Gascoyne Coast and moderate in the West Coast bioregion (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

**Recreational:** The estimated total catch from recreational fishers in Western Australia was 187 t in 2000/01 (Henry and Lyle, 2003). The total estimated recreational boat-based catch in the West Coast bioregion was 14 t for 1996/97 and 3 t in 2005/06 (Sumner *et al.*, 2008). The catch in the Gascoyne Coast bioregion was estimated at 5 t in 1998/99 (Sumner *et al.*, 2002). See also Malseed *et al.* (2000), Malseed and Sumner (2001a; b), Harvey (2004), Smallwood *et al.* (2006), Smith (2006), Smith *et al.* (2008) and Smallwood *et al.* (2011).

**Commercial:** A total of 24 t of this species was taken by commercial fishers in Western Australia in 2010/11, down from a peak of 90 t in 1965 (Smith *et al.*, 2012a). Since 2001, 84% of tailor has been caught in the Gascoyne Coast bioregion, 15% in the West Coast bioregion and 1% in the South Coast bioregion (Smith *et al.*, 2012a). A complete catch trend graph is shown in the 2010/11 State of the Fisheries and Aquatic Resources Report. In 2011, the catch in the Gascoyne Coast bioregion was 18 t, almost all of which was taken in Shark Bay (Smith *et al.*, 2012a). See also Smith (2006).

### Management regulations

**Recreational:** Currently listed in the “nearshore/estuarine finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1913)	-	200	
Statewide (1937)	-	225	
Statewide (1975)	-	250	
Statewide (1990)	20	250	
Statewide (1995)	8	250	
West Coast (2003)	8	300	Two fish only > 600mm
South Coast (2003)	8	300	
Gascoyne Coast (2003)	8	300	
South Coast (2005)	8	300	Two fish only > 600mm
West Coast (2009)	8	300	Two fish only > 500mm

**Commercial:** The South Coast nearshore and estuarine fisheries, WCEF and SBBSMNMF are managed primarily through input controls such as limited entry, gear restrictions (*i.e.*, net length and mesh size), spatial and temporal closures and size limits (Jackson *et al.*, 2012; Smith *et al.*, 2012b). Minimum legal size for commercial fishers is 300 mm (increased from 250 mm in October 2003).

**Current research:** NRM-funded project being run by DoF to provide more rigorous monitoring and assessment of this species as well as identify sources of recruitment to the Perth Metropolitan fishery (Smith *et al.*, 2012b). Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Age validation and growth* [Eastern USA] (Robillard *et al.*, 2009); *Stock assessment* [Queensland, New South Wales] (Leigh and O'Neill, 2004); *Biology* [South Africa] (Van der Elst, 1976); *Early life history* [South Africa] (Beckley and Connell, 1996).

## References

- Bade, T. M., 1977. The biology of tailor (*Pomatomus saltatrix* Linn.) from the east coast of Australia, MSc thesis, University of Queensland, Queensland, Australia. pp. 116.
- Beckley, L. E., Connell, A. D., 1996. Early life history of *Pomatomus saltatrix* off the east coast of South Africa. *Marine and Freshwater Research* 47, 319-322.
- Chisholm, W., 2004. Larval distribution of tailor (*Pomatomus saltatrix*: Pisces) off Western Australia, Honours thesis, School of Environmental Science, Murdoch University, Perth, Western Australia. pp. 75.
- Cribb, A., 1994. The hole in Perth's tailor fishery, In *Western Fisheries*. pp. 28-36.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Edmonds, J. S., Steckis, R. A., Moran, M. J., Caputi, N., Morita, M., 1999. Stock delineation of pink snapper and tailor from Western Australia by analysis of stable isotope and strontium/calcium ratios in otolith carbonate. *Journal of Fish Biology* 53, 243-259.
- Gaughan, D. J., Ayvazian, S., Nowara, G., Craine, M., Brown, J., 2006. The development of a rigorous sampling program for a long term annual index of recruitment for finfish species from south-western Australia. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 1999/153, Fisheries Research Report No. 154. pp. 135.

- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Goodbred, C. O., Graves, J. E., 1996. Genetic relationships among geographically isolated populations of Bluefish (*Pomatomus saltatrix*). *Marine and Freshwater Research* 47, 347-355.
- Hare, J. A., Cowen, R. K., 1993. Ecological and evolutionary implications of the larval transport and reproductive strategy of blue fish *Pomatomus saltatrix*. *Marine Ecology Progress Series* 98, 1-16.
- Harvey, M. J., 2004. An evaluation of Western Australian recreational fishing regulations with a case study from a metropolitan boat ramp, Honours thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 97.
- Hedger, R. D., Næsje, T. F., Cowley, P. D., Thorstad, E. B., Attwood, C., Økland, F., Wilke, C. G., Kerwath, S., 2010. Residency and migratory behaviour by adult *Pomatomus saltatrix* in a South African coastal embayment. *Estuarine, Coastal and Shelf Science* 89, 12-20.
- Henry, G. W., Lyle, J. M. (eds) 2003. The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forest, Canberra, Australia.
- Jackson, G., Norriss, J., Lunow, C., 2012. Inner Shark Bay scalefish fishery status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 154-160.
- Juanes, F., Hare, J., Miskiewicz, A. G., 1996. Comparing early life history strategies of *Pomatomus saltatrix*: a global approach. *Marine and Freshwater Research* 47, 365-379.
- Leigh, G. M., O'Neill, M. F., 2004. Stock assessment of the Queensland - New South Wales Tailor Fishery (*Pomatomus saltatrix*). Southern Fisheries Centre, Department of Primary Industries and Fisheries. Queensland. pp. 98.
- Lenanton, R. C. J., 1974. Fish and crustacea of the Western Australian south coast rivers and estuaries. Western Australian Department of Fisheries. Perth Western Australia. Fisheries Research Bulletin of Western Australia No. 13. pp. 1-17.
- Lenanton, R. C. J., Ayvazian, S. G., Pearce, A. F., Steckis, R. A., Young, G. C., 1996. Tailor (*Pomatomus saltatrix*) off Western Australia: where does it spawn and how are the larvae distributed? *Marine and Freshwater Research* 47, 337-347.
- Malseed, B. E., Sumner, N. R., 2001a. A 12-month survey of recreational fishing in the Swan-Canning Estuary basin of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 126. pp. 44.
- Malseed, B. E., Sumner, N. R., 2001b. A 12-month survey of recreational fishing in the Peel-Harvey Estuary of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 127. pp. 48.
- Malseed, B. E., Sumner, N. R., Williamson, P. C., 2000. A 12-month survey of recreational fishing in the Leschenault Estuary of Western Australia during 1998. Western Australian Department of Fisheries. Perth, Western Australia. pp. 36.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Nurthen, R. K., Cameron, R., Briscoe, D. A., 1992. Population genetics of Tailor, *Pomatomus saltatrix* (Linnaeus) (Pisces: Pomatomidae), in Australia. *Australian Journal of Marine and Freshwater Research* 43, 1481-1486.
- Pearce, A., Pattiaratchi, C. B., 1999. The Capes Current: a summer countercurrent flowing past Cape Leeuwin and Cape Naturaliste, Western Australia. *Continental Shelf Research* 19, 401-420.
- Robillard, E., Reiss, C. S., Jones, C. M., 2008. Reproductive biology of bluefish (*Pomatomus saltatrix*) along the East Coast of the United States. *Fisheries Research* 90, 198-208.
- Robillard, E., Reiss, C. S., Jones, C. M., 2009. Age validation and growth of bluefish (*Pomatomus saltatrix*) along the east coast of the United States. *Fisheries Research* 95, 65-75.

- Smallwood, C. B., Beckley, L. E., Sumner, N. R., 2006. Shore-based recreational angling in the Rottne Island Reserve, Western Australia: spatial and temporal distribution of catch and fishing effort. *Pacific Conservation Biology* 12, 238-51.
- Smallwood, C. B., Pollock, K. H., Wise, B. S., Hall, N. G., Gaughan, D. J., 2011. Quantifying recreational fishing catch and effort: a pilot study of shore-based fishers in the Perth Metropolitan area. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 216. pp. 60.
- Smith, K., Brown, J., Howard, A., Walshe, K., Fissioli, J., 2012a. West Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 80-97.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012b. South Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Smith, K. A., 2006. Review of fishery resources and status of key fishery stocks in the Swan-Canning Estuary. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 156. pp. 84.
- Smith, K. A., Brown, J., Hammond, M., Nardi, A., 2008. Development of cost-effective indices to monitor the nearshore fish communities of the Swan Region. Western Australian Department of Fisheries. Perth, Western Australia. Final report to the Swan Catchment Council. pp. 121.
- Smith, K. A., Brown, J., Lewis, P., Dowling, C., Howard, A., Lenanton, R., in press. Status of nearshore finfish stocks in south-western Western Australia: Australian herring and tailor. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. xx. pp. xx.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Sumner, N. R., Williamson, P. C., Malseed, B. E., 2002. A 12-month survey of recreational fishing in the Gascoyne bioregion of Western Australia during 1998-99. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 53.
- Van der Elst, R., 1976. Game fish of the east coast of southern Africa. I. The biology of elf, *Pomatomus saltatrix* (Linnaeus), in the coastal waters of Natal. Oceanographic Research Institute. Durban, South Africa. Report No. 44. pp. 59.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.
- Young, G. C., Wise, B. S., Ayzavian, S. G., 1999. A tagging study on tailor (*Pomatomus saltatrix*) in Western Australian waters: their movement, exploitation, growth and mortality. *Marine and Freshwater Research* 50, 633-642.

## Silver trevally (*Pseudocaranx georgianus*)

Reviewed by Emily Fisher (Murdoch University)



**Scientific name:** *Pseudocaranx georgianus* (formerly *Pseudocaranx dentex*) (Carangidae; Trevallies)

**Common names:** Silver trevally *also* silvery trevally, skipjack trevally, white trevally, skippy

**Key identifying features:** Posterior margin of upper jaw nearly vertical, no scales on lachrymal bone, below and in front of eye, and usually has a large and diffuse dark spot on opercle (Gomon *et al.*, 2008).

### Distribution

**Worldwide:** New Zealand and southern Australia, but not fully understood because of previous taxonomic confusion with other species. Until recently regarded as part of the widely-distributed, anti-tropical *P. dentex* (Gomon *et al.*, 2008).

**Western Australia:** Southern Western Australian border to Lancelin, including Rottneest Island. Note: a similar species, *P. dinjerra*, extends from the Abrolhos Islands to North-West Cape (Smith-Vaniz and Jelks, 2006). A recent detailed morphological and genetic study of “silver trevally” collected as far north as Port Gregory (and from the Abrolhos Islands) were all *P. georgianus* (*i.e.*, not *P. dinjerra*) (Robert, 2012).

**Maximum length, weight and age:** 938 mm, 10 kg (Hutchins and Swainston, 1986), 18 years (Farmer *et al.*, 2005).

**Length/weight relationship:** [Lower west coast, inshore]  $\ln W = 2.992 * \ln TL - 11.331$  ( $n=1424$ ,  $R^2=0.996$ ) (French, 2003; Farmer *et al.*, 2005).

TL (mm)	200	400	600
Weight (g)	92	732	2,462

**Length relationship:**  $TL = 1.203 * FL - 0.6185$  (French, 2003).

**Growth:** [Lower west coast, inshore] Females  $L_{\infty} = 477$  mm,  $k = 0.24$  year<sup>-1</sup>,  $t_0 = 0.37$  years ( $n=434$ ,  $R^2=0.819$ ); Males  $L_{\infty} = 459$  mm,  $k = 0.27$  year<sup>-1</sup>,  $t_0 = 0.22$  years ( $n=337$ ,  $R^2=0.568$ ) (Farmer *et al.*, 2005). These growth parameters were estimated by fitting a growth curve to lengths at age for fish in inshore waters (<60 m deep). See Farmer *et al.* (2005) for estimates from other areas of the West Coast bioregion where geographical differences in growth rates have been identified.

Age (years)	4	8	12
Females, TL (mm)	310	413	452
Males, TL (mm)	312	409	442

**Length and age at maturity:** [Lower west coast, inshore] Females  $L_{50}=310$  mm,  $L_{95}=378$  mm, 54% mature by 3 years; Males  $L_{50}=310$  mm,  $L_{95}=378$  mm, 50% mature by 3 years (Farmer *et al.*, 2005). See Farmer *et al.* (2005) for estimates from other areas of the West Coast bioregion.

**Reproductive style:** Gonochoristic. Broadcast, multiple spawner (Farmer *et al.*, 2005).

**Adult sex ratio:** [Lower west coast, inshore, rod and line fishing] F1.12:M1 (Farmer *et al.*, 2005).

**Length and age at sex change:** Not applicable.

**Spawning season:** [Lower west coast, inshore] August to December, beginning in July in the upper West Coast bioregion (Farmer *et al.*, 2005).

**Spawning location and habitat:** Marine waters, near reefs (Farmer *et al.*, 2005).

**Fecundity:** Indeterminate (Farmer *et al.*, 2005). [New South Wales] Estimated fecundity 30,000 – 220,000 eggs for fish between 230 – 370mm (Rowling and Raines, 2000).

**Spawning frequency:** Not reported.

### **Development and habitat use**

**Eggs:** Pelagic (Neira *et al.*, 1998).

**Larvae:** [New South Wales] Evident in greater numbers in deeper waters, up to 100 m (Gray *et al.*, 1992; Gray, 1993; Syahailatua *et al.*, 2011). Additional information on *P. dentex* from Japan, where Phototaxis demonstrated 3 days after hatching (Masuda and Tsukamoto, 1999) while the larval stages have also been described (Neira *et al.*, 1998). Larvae of *Pseudocaranx* spp. have been recorded in sampling in Western Australia (Muhling, 2006; Holliday, 2009; Breheny *et al.*, 2012).

**Juveniles:** Found predominantly in inshore waters < 20 m deep over bare sand and around structures (*i.e.*, jetties, bridges, harbours) as well as in estuaries, bays and other shallow shelf waters (Lenanton and Potter, 1987; Potter and Hyndes, 1994; Farmer *et al.*, 2005). [Japan, *P. dentex*] Small juveniles have strong association with drift objects. At ~ 40 mm total length the lateral line is fully developed, enabling tight schooling (as opposed to drift object association), at which stage fish migrate to inshore nursery grounds (Masuda and Tsukamoto, 1999).

**Adults:** Adults found in schools over a variety of reef habitats and other structures on the continental shelf (Harvey *et al.*, 2004; Farmer *et al.*, 2005). Also found over seagrass, macroalgal beds and in surf zones (Ayvazian and Hyndes, 1995; Harvey *et al.*, 2004). The largest and oldest individuals are caught in water depths > 60 m (Harvey *et al.*, 2004; Farmer *et al.*, 2005).

**Migration:** Evidence of offshore movement with increasing size and age (Farmer *et al.*, 2005).

**Stock delineation:** Recent work has resulted in the description of a new species, *P. dinjerra*, which has a more northern distribution (Abrolhos Islands to North-West Cape) than *P. georgianus* (formally *P. dentex*), which was previously thought to extend over the entire distribution range in Western Australia (Smith-Vaniz and Jelks, 2006). *P. georgianus* is clearly genetically different from *P. wright* (Smith-Vaniz and Jelks, 2006) and there is no evidence that *P. georgianus* in inshore and offshore waters are genetically distinct (Bearham, 2004).

**Diet:** Opportunistic feeders. Depending on its position in the water column this species feeds on small teleosts, crabs, littorinids, amphipods, echinoderms, isopods and small bivalves (Thomson, 1957; French *et al.*, 2012). Diet varies with region (French *et al.*, 2012). [Victoria] planktonic crustaceans (Hindell *et al.*, 2000).

## Fishery

**Recreational:** A popular recreational species targeted by shore and boat-based recreational fishers using rod and line in coastal waters of the West Coast and South Coast bioregions (Sumner and Williamson, 1999; Smallwood and Sumner, 2007; Sumner *et al.*, 2008).

**Commercial:** An important commercial species in southern Australian waters, although caught in greater numbers off New South Wales and Victoria (Rowling and Raines, 2000). A minor species caught in the estuarine and nearshore finfish commercial fisheries, including beach-based fisheries which operate in the South Coast and West Coast bioregions (Smith *et al.*, 2012a; Smith *et al.*, 2012b).

**Age at full recruitment:** [Lower west coast, inshore] 5 years (Farmer *et al.*, 2005).

**Gear selectivity parameters:** Not reported.

## Management parameters

**Total mortality:** [Lower west coast, inshore, catch curve analysis] 0.57 year<sup>-1</sup> (Farmer *et al.*, 2005). See also Farmer *et al.* (2005) for estimates obtained from other methods and for the upper West Coast bioregion. As at least some individuals apparently migrate to offshore waters, these mortality estimates are not representative of the entire stock and also ignore impacts of offshore migration on the age composition of the inshore component of the stock.

**Natural mortality:** [Lower west coast, inshore, Bayesian method of Hall *et al.* (2004)] 0.38 year<sup>-1</sup> (Farmer *et al.*, 2005). See also Farmer *et al.* (2005) for estimates obtained from other methods and for the upper West Coast bioregion.

**Fishing mortality:** [Lower west coast, inshore] 0.11 year<sup>-1</sup> (Farmer *et al.*, 2005)

**Biological reference points:** [Lower west coast, inshore]

$YPR_{\text{current}} = 0.02 \text{ kg year}^{-1}$

$F_{0.1} = 0.69 \text{ kg year}^{-1}$

$SSB/R_{\text{current}} = 0.35 \text{ kg year}^{-1}$

$SPR_{\text{current}} = 0.81$  (Farmer *et al.*, 2005). See also Farmer *et al.* (2005) for estimates for the upper West Coast bioregion.

**Current status:** Overall risk to sustainability for the nearshore suite is moderate in the South Coast and Gascoyne Coast bioregions and medium to high in the West Coast bioregion (DoF, 2011). Inherent vulnerability for the species is moderate and current risk to wild stock is minimal in the Gascoyne Coast and moderate in the West Coast bioregion (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

## Catch trends

**Recreational:** The total estimated recreational boat-based catch of *Pseudocaranx* spp. in the West Coast bioregion was 38 t for 1996/97 and 34 t in 2005/06 (Sumner *et al.*, 2008). The total estimated recreational catch in 2000/01 was 42 t in the West Coast bioregion and 93 t in the South Coast bioregion (Henry and Lyle, 2003). An estimated 6.1 t was retained from South Coast estuaries in 2002/03 (Smallwood and Sumner, 2007). See also Caputi (1976), Harvey (2004), Smallwood *et al.* (2006), Prior and Beckley (2007) and Smallwood *et al.* (2011).

**Commercial:** A total of 10 t of *P. dentex* was taken by commercial fishers in Western Australia in 2010/11 (Fletcher and Santoro, 2012). The total catch of Carangidae in the West Coast bioregion in the nearshore and estuarine fishery has remained relatively static, with 2 t

taken in 2007 and 2.1 t in 2011, with a high of 3.5 t in 2010 (Smith *et al.*, 2012b). In the South Coast bioregion the total catch of Carangidae has declined from 3.1 t in 2007 to 2.0 t in 2011 (Smith *et al.*, 2012a). Small amounts of this species was caught in rock lobster pots during 2010/11 (De Lestang *et al.*, 2012).

## Management regulations

**Recreational:** Currently listed in the “nearshore/estuarine finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1958)	-	200	
Statewide (1991)	20	200	
South Coast (2003)	20	250	
West Coast (2003)	8	250	
Gascoyne Coast (2003)	8	250	
South Coast (2005)	12	250	
Statewide (2013)	8	250	

**Commercial:** The South Coast and West Coast nearshore and estuarine fisheries are managed primarily through input controls (limited entry, gear restrictions, spatial and temporal closures, and size limits) (Smith *et al.*, 2012a; Smith *et al.*, 2012b).

**Current research:** A collaborative Murdoch University and DoF study is developing a stock assessment model to simultaneously estimate fishing mortality in inshore and offshore waters, employing length-at-age data (FRDC 2010/001). Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Disease* (Mori *et al.*, 1992); *Commercial fishing*: [New Zealand] (Langley, 2004; Walsh *et al.*, 2010); *Behaviour towards SCUBA divers* (Watson and Harvey, 2007); *Response to baited video* (Birt *et al.*, 2012); *Diet* [eastern Australia] (Coleman and Mobley, 1984; Bulman *et al.*, 2001).

## References

- Ayvazian, S. G., Hyndes, G. A., 1995. Surf-zone fish assemblages in south-western Australia: do adjacent nearshore habitats and the warm Leeuwin Current influence the characteristics of the fish fauna? *Marine Biology* 122, 527-536.
- Bearham, D., 2004. A mtDNA study of the population structure of silver trevally *Pseudocaranx dentex* and the relationship between silver and sand trevally *Pseudocaranx wrighti* in Western Australian waters, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 112.
- Birt, M. J., Harvey, E. S., Langlois, T. J., 2012. Within and between day variability in temperate reef fish assemblages: learned response to baited video. *Journal of Experimental Marine Biology and Ecology* 416-417, 92-100.
- Breheny, N. B., Beckley, L. E., Wakefield, C. B., 2012. Ichthyoplankton assemblages associated with pink snapper (*Pagrus auratus*) spawning aggregations in coastal embayments of southwestern Australia. *Journal of the Royal Society of Western Australia* 95, 103-114.
- Bulman, C., Althaus, F., He, X., Bax, N. J., Williams, A., 2001. Diets and trophic guilds of demersal fishes of the south-eastern Australian shelf. *Marine and Freshwater Research* 52, 537-548.
- Caputi, N., 1976. Creel census of amateur line fishermen in the Blackwood River estuary, Western Australia, during 1974-75. *Marine and Freshwater Research* 27, 583-593.
- Coleman, N., Mobley, M., 1984. Diets of commercially exploited fish from Bass Strait and adjacent Victorian waters, south-eastern Australia. *Australian Journal of Marine and Freshwater Research* 35, 549-560.

- De Lestang, S., Thomson, A., Rossbach, M., Kennedy, J., Baudains, G., Steele, A., 2012. West Coast rock lobster fishery status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 37-47.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Farmer, B. M., French, D. J. W., Potter, I. C., Hesp, S. A., Hall, N. G., 2005. Determination of biological parameters for managing the fisheries for mulloway and silver trevally in Western Australia. Murdoch University. Perth, Western Australia. FRDC Project No. 2002/004. pp. 149.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- French, B., Platell, M. E., Clarke, K. R., Potter, I. C., 2012. Ranking of length-class, seasonal and regional effects on dietary compositions of the co-occurring *Pagrus auratus* (Sparidae) and *Pseudocaranx georgianus* (Carangidae). *Estuarine, Coastal and Shelf Science* 115, 309-325.
- French, D. J. W., 2003. The biology of the silver trevally *Pseudocaranx dentex* on the lower west coast of Australia, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 74.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Gray, C. A., 1993. Horizontal and vertical trends in the distributions of larval fishes in coastal waters off central New South Wales, Australia. *Marine Biology* 116, 649-666.
- Gray, C. A., Otway, N. M., Laurenson, F. A., Miskiewicz, A. G., Pethebridge, R. L., 1992. Distribution and abundance of marine fish larvae in relation to effluent plumes from sewage outfalls and depth of water. *Marine Biology* 113, 549-559.
- Hall, N. G., Hesp, S. A., Potter, I. C., 2004. A bayesian approach for overcoming inconsistencies in mortality estimates using, as an example, data for *Acanthopagrus latus*. *Canadian Journal of Fisheries and Aquatic Sciences* 61, 1202-1211.
- Harvey, E., Cappo, M., Kendrick, G., 2004. Fishes of the Recherche Archipelago, In Characterising fish habitats of the Recherche Archipelago. Kendrick, G., Harvey, E., McDonald, J., Pattiaratchi, C., Cappo, M., Fromont, J., Shortis, M., Grove, S., Bickers, A., Baxter, K., Goldberg, N., Kletczkowski, M., Butler, J. (eds), University of Western Australia, Perth, Western Australia.
- Harvey, M. J., 2004. An evaluation of Western Australian recreational fishing regulations with a case study from a metropolitan boat ramp, Honours thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 97.
- Henry, G. W., Lyle, J. M. (eds) 2003. The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forest, Canberra, Australia.
- Hindell, J. S., Jenkins, G. P., Keough, M. J., 2000. Variability in abundances of fishes associated with seagrass habitats in relation to diets of predatory fishes. *Marine Biology* 136, 725-737.
- Holliday, D., 2009. Incorporation of larval fishes into a developing anti-cyclonic eddy of the Leeuwin Current: timing, sources and pathways, PhD thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 251.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Langley, A. D., 2004. Length and age composition of trevally (*Pseudocaranx dentex*) in commercial landings from the TRE 1 purse-seine fishery, 2002-03. New Zealand Fisheries Assessment Report 2004/39. pp. 17.
- Lenanton, R. C. J., Potter, I. C., 1987. Contribution of estuaries to commercial fisheries in temperate Western Australia and the concept of estuarine dependence. *Estuaries* 10, 28-35.
- Masuda, R., Tsukamoto, K., 1999. School formation and concurrent developmental changes in carangid fish with reference to dietary conditions. *Environmental Biology of Fishes* 56, 243-252.

- Mori, K., Nakai, T., Muroga, K., Arimoto, M., Mushiake, K., Furusawa, I., 1992. Properties of a new virus belonging to Nodaviridae found in larval striped jack (*Pseudocaranx dentex*) with nervous necrosis. *Virology* 187, 368-371.
- Muhling, B. A., 2006. Larval fish assemblages in coastal, shelf and offshore waters of south-western Australia, PhD thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 226.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Potter, I. C., Hyndes, G. A., 1994. Composition of the fish fauna of a permanently open estuary on the southern coast of Australia, and comparisons with a nearby seasonally closed estuary. *Marine Biology* 121, 199-209.
- Prior, S. P., Beckley, L. E., 2007. Characteristics of recreational anglers in the Blackwood Estuary, a popular tourist destination in southwestern Australia. *Tourism in Marine Environments* 4, 15-28.
- Robert, M. A., 2012. A morphological and molecular approach to species question about *Pseudocaranx* in Western Australian waters, Honours thesis, School of Environmental Science. Murdoch University. pp. 110.
- Rowling, K. R., Raines, L. P., 2000. Description of the biology and an assessment of the fishery of silver trevally (*Pseudocaranx dentex*) off New South Wales. Cronulla, New South Wales, Australia. NSW Fisheries Final Report Series No. 24, FRDC Project No. 97/125.
- Smallwood, C. B., Beckley, L. E., Sumner, N. R., 2006. Shore-based recreational angling in the Rottne Island Reserve, Western Australia: spatial and temporal distribution of catch and fishing effort. *Pacific Conservation Biology* 12, 238-51.
- Smallwood, C. B., Pollock, K. H., Wise, B. S., Hall, N. G., Gaughan, D. J., 2011. Quantifying recreational fishing catch and effort: a pilot study of shore-based fishers in the Perth Metropolitan area. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 216. pp. 60.
- Smallwood, C. B., Sumner, N. R., 2007. A 12-month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002/03. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 159. pp. 56.
- Smith-Vaniz, W. F., Jelks, H. L., 2006. Australian trevallies of the genus *Pseudocaranx* (Teleostei: Carangidae), with description of a new species from Western Australia. *Memoirs of Museum Victoria* 63, 97-106.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012a. South Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Smith, K., Brown, J., Howard, A., Walshe, K., Fissioli, J., 2012b. West Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 80-97.
- Sumner, N. R., Williamson, P. C., 1999. A 12-month survey of coastal recreational boat fishing between Augusta and Kalbarri on the west coast of Western Australia during 1996-97. Western Australian Department of Fisheries. Fisheries Research Report No. 117. pp. 52.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Syahailatua, A., Taylor, M. D., Suthers, I. M., 2011. Growth variability and stable isotope composition of two larval carangid fishes in the East Australian Current: the role of upwelling in the separation zone. *Deep-Sea Research II* 58, 691-698.
- Thomson, J. M., 1957. The food of Western Australian estuarine fishes. *Western Australian Fisheries and Fauna Department Bulletin* 7, 1-13.
- Walsh, C., McKenzie, J. M., Maolagain, O., Buckthought, D., Blackwell, R., James, G. D., 2010. Length and age composition of commercial trevally landings in TRE1 and TRE 7, 2007-2008. New Zealand. New Zealand Fisheries Assessment Report 2010/22. pp. 57.
- Watson, D. L., Harvey, E. S., 2007. Behaviour of temperate and sub-tropical reef fishes towards a stationary SCUBA diver. *Marine and Freshwater Behaviour and Physiology* 40, 85-103.

## Samson fish (*Seriola hippos*)

Reviewed by Andrew Roland (Recfishwest)



**Scientific name:** *Seriola hippos* (Carangidae; Trevallies)

**Common names:** Samson fish *also* sea kingfish

**Key identifying features:** Greyish back with yellowish stripe through midline, dorsal fin with 6 – 8 spines and 22 – 23 soft rays, short pectoral fins (Yearsley *et al.*, 2001).

### Distribution

**Worldwide:** Southern Australia, New Zealand and Norfolk Island.

**Western Australia:** Southern Western Australian border to Shark Bay (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 1,800 mm, 55 kg (Gomon *et al.*, 2008), 29 years (Rowland, 2009).

**Length/weight relationship:** [West Coast bioregion]  $W=1.497*10^{-4}FL^{2.982}$  ( $n=264$ ,  $R^2=0.99$ ) (Rowland, 2009).

FL (mm)	800	1,200	1,600
Weight (kg)	4.6	16.2	39.6

**Length relationship:** [West Coast bioregion]  $TL=1.09*FL+17.84$  ( $n=443$ ,  $R^2=0.998$ ) (Rowland, 2009).

**Growth:** [West Coast bioregion, Schnute growth curve] Females  $y_1=435.3$  mm,  $y_2=1,089.1$  mm,  $a=0.044$ ,  $b=2.748$ ,  $\tau_1=1$  year,  $\tau_2=10$  years ( $n=207$ ,  $R^2=0.929$ ); Males  $y_1=400.3$ mm,  $y_2=1,034.5$ mm,  $a=0.13634$ . 50ast bioregionporate new management regulations. Minor changes made to commercial heading,  $b=1.971$ ,  $\tau_1=1$  year,  $\tau_2=10$  years ( $n=167$ ,  $R^2=0.943$ ) (Rowland, 2009).

Age (years)	5	15	25
Females, TL (mm)	608	924	1,089
Males, TL (mm)	568	891	1,034

**Length and age maturity:** Females  $L_{50}=831$  mm,  $L_{95}=942$  mm,  $A_{50}\sim 4$  years (Rowland, 2009).

**Reproductive style:** Gonochoristic. Serial spawner (Rowland, 2009).

**Sex ratio:** [West Coast bioregion] F1.36:M1 ( $n=552$ ) (Rowland, 2009).

**Length and age at sex change:** Not applicable.

**Spawning season:** [West Coast bioregion] October – February (Rowland, 2009).

**Spawning location and habitat:** [West Coast bioregion] Aggregate to the west of Rottnest Island, (Rowland, 2009).

**Fecundity:** [West Coast bioregion] Indeterminate. Batch fecundity;  $BF=5,021*FL-4,698,076$  ( $n=6$ ,  $R^2=0.815$ ) (Rowland, 2009).

TL (mm)	1000	1200	1600
Fecundity (eggs)	322,924	1,327,124	3,335,524

**Spawning frequency:** Not reported.

### Development and habitat use

**Eggs:** [*Seriola* spp.] Pelagic (Neira *et al.*, 1998; Rowland, 2009).

**Larvae:** Pelagic (Rowland, 2009). Description of larval stages (Neira *et al.*, 1998).

**Juveniles:** Surface waters underneath jellyfish or drifting, detached seagrass. Found in waters up to 150 m deep (Rowland, 2009).

**Adults:** Found on inshore and offshore reefs, seagrass beds and around jetties/piles and channel markers and around artificial reef structures such as shipwrecks (Harvey *et al.*, 2004; Rowland, 2009). Occasionally observed or caught in the lower reaches of estuaries (Lenanton and Potter, 1987; Malseed and Sumner, 2001; Smith, 2006).

**Stock delineation:** Likely to be a single population along the Western Australian coast (Rowland, 2009).

**Migration:** Migrates long distances (*i.e.*, from the South Coast) to spawning aggregation areas along the lower west coast including off Rottnest Island (Rowland, 2009).

**Diet:** Teleost fishes, predominantly pilchards and cephalopod species (Rowland, 2009).

### Fishery

**Recreational:** A common by-catch or by-product species for boat-based recreational line fishers targeting other demersal species (*e.g.*, West Australian dhufish, Spanish Mackerel) in the West and South Coast bioregions. However, this species is targeted by charter operators and during sportfishing competitions involving rod and line fishing and spearfishing (Rowland, 2009; Telfer, 2010).

**Commercial:** Not of major commercial interest but is caught as byproduct in temperate Demersal Gillnet and Demersal Longline Fisheries (DGDLF) of the West and South Coast bioregions (McAuley and Rowland, 2012). Samson fish is one of the top six fish species (by weight) caught by the West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF) (Fairclough *et al.*, 2012).

**Age at full recruitment:** 7 years (Rowland, 2009).

**Gear selectivity parameters:** Not reported.

### Management parameters

**Total mortality:** [West Coast bioregion, catch curve analysis] 0.21 year<sup>-1</sup>. Several estimates, based on different methods of calculation available (Rowland, 2009).

**Natural mortality:** [West Coast bioregion, Hoenig's (1983) equation for fish] 0.20 year<sup>-1</sup>. Several estimates, based on different methods of calculation available (Rowland, 2009).

**Fishing mortality:** [West Coast bioregion] 0.04 year<sup>-1</sup> (Rowland, 2009).

**Biological reference points:** Not reported.

**Current status:** Probably lightly to moderately exploited based on the estimates of fishing mortality provided by Rowland (2009). An indicator species for the pelagic zone in the West Coast and South Coast bioregions (DoF, 2011). Overall risk to sustainability for the pelagic suite is low (DoF, 2011). Inherent vulnerability for the species is moderate and current risk to wild stock is minimal (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

**Recreational:** The total estimated recreational boat-based catch in the West Coast bioregion was 35 t for 1996/97 and 24 t in 2005/06 (Sumner *et al.*, 2008). The recreational catch at the Abrolhos Islands was estimated to be 8.5 t in 2006 (Sumner, 2008). See also Harvey (2004) and (Telfer, 2010).

**Commercial:** A total of 34 t (live weight) of this species was taken by commercial fishers in Western Australia in 2010/11 (Fletcher and Santoro, 2012). In 2011, the total catch of this species in the WCDSIMF was 16 t (Fairclough *et al.*, 2012). Total catch from the DGDLF in 2010/11 was 3.5 t in the South Coast bioregion and 3.3 t in the West Coast bioregion (McAuley and Rowland, 2012).

### Management regulations

**Recreational:** Currently listed in the “large pelagic finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1958)	-	381	
Statewide (1973/74)	-	600	
Statewide (1977)	10	600	
Statewide (1991)	4	600	
West Coast (2003)	2	600	
Gascoyne Coast (2004)	2	600	
South Coast (2005)	2	600	
West Coast (2008)	2	600	Abrolhos FHPA: Protected in anchorage areas of inhabited areas
Statewide (2013)	3	600	

**Commercial:** The WCDSIMF is regulated using various input controls (restricted entry, total fishing time allocations, maximum number of lines and hooks) (Fairclough *et al.*, 2012). The DGDLF is regulated using various input controls (transferable time/gear effort, mesh and hook sizes, maximum net length), output controls as well as temporal (16 Aug – 15 Oct) and spatial closures (McAuley and Rowland, 2012).

**Current research:** Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Acoustic data* (Parsons *et al.*, 2006); *Parasites* (Hutson *et al.*, 2011); *Tagging studies* [South Australia] (Hutson *et al.*, 2007).

### References

DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.

- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Harvey, E., Cappo, M., Kendrick, G., 2004. Fishes of the Recherche Archipelago, In Characterising fish habitats of the Recherche Archipelago. Kendrick, G., Harvey, E., McDonald, J., Pattiaratchi, C., Cappo, M., Fromont, J., Shortis, M., Grove, S., Bickers, A., Baxter, K., Goldberg, N., Kletczkowski, M., Butler, J. (eds), University of Western Australia, Perth, Western Australia.
- Harvey, M. J., 2004. An evaluation of Western Australian recreational fishing regulations with a case study from a metropolitan boat ramp, Honours thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 97.
- Hoenig, J., 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82, 898-903.
- Hutson, K. S., Catalano, S. R., Whittington, I. D., 2011. Metazoan parasite survey of selected macro-inshore fish of southeastern Australia, including species of commercial importance. James Cook University. Townsville, Queensland. FRDC Project No. 2007/225. pp. 259.
- Hutson, K. S., Smith, B. P., Godfrey, R. T., Whittington, I. D., Chambers, C. B., Ernst, I., Gillanders, B. M., 2007. A tagging study on yellowtail kingfish (*Seriola lalandi*) and Samson fish (*S. hippos*) in South Australian waters. *Transactions of the Royal Society of South Australia* 131, 128-134.
- Lenanton, R. C. J., Potter, I. C., 1987. Contribution of estuaries to commercial fisheries in temperate Western Australia and the concept of estuarine dependence. *Estuaries* 10, 28-35.
- Malseed, B. E., Sumner, N. R., 2001. A 12-month survey of recreational fishing in the Peel-Harvey Estuary of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 127. pp. 48.
- McAuley, R., Rowland, F., 2012. Temperate demersal gillnet and demersal longline fisheries status report, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 282-294.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Parsons, M. J., McCauley, R. D., Mackie, M. C., Siwabessy, P. J. W., 2006. Evaluation of acoustic backscatter data collected from Samson fish (*Seriola hippos*) spawning aggregations in Western Australia, In Eighth European Conference on Underwater Acoustics. Jesus, S. M., Rodriguez, O. C. (eds), Caroeira, Portugal.
- Rowland, A. J., 2009. The biology of samson fish *Seriola hippos* with emphasis on the sportfishery in Western Australia, PhD thesis, Murdoch University, Perth, Western Australia. pp. 209.
- Smith, K. A., 2006. Review of fishery resources and status of key fishery stocks in the Swan-Canning Estuary. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 156. pp. 84.
- Sumner, N. R., 2008. An assessment of the finfish catch by recreational fishers, tour operators, commercial lobster fishers and commercial wetline fishers from the Houtman Abrolhos Islands during 2006. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 175. pp. 32.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Telfer, C., 2010. The Western Australian charter boat industry: working towards long-term sustainability, MSc thesis, School of Natural Sciences. Edith Cowan University, Perth, Western Australia. pp. 153.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## Mahi mahi (*Coryphaena hippurus*)

Reviewed by Stephen Newman (DoF)



**Scientific name:** *Coryphaena hippurus* (Coryphaenidae; Dolphinfishes)

**Common names:** Mahi mahi *also* dolphinfish, dorado

**Key identifying features:** Distinctive hump-head with dorsal fin that extends from the head almost to the caudal fin, an anal fin that extends from about the midpoint of the body of the caudal fin, no sharp spines in the caudal and anal fins, short pectoral fins and, brightly coloured turquoise, yellow and silver body with black spots (Collette, 1999; Yearsley *et al.*, 2001). Co-occurs with *C.equiselis* which is frequently misidentified as juvenile or female *C.hippurus* (Collette, 1999).

### Distribution

**Worldwide:** Distributed widely in all oceanic tropical and subtropical waters, close to offshore islands and further offshore from continental masses, beyond the area of influence of water runoff (FAO, 1994). Also known to approach the coast (Collette, 1999).

**Western Australia:** Entire Western Australian coastline (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 1,620 mm, 22.4 kg (Hutchins and Swainston, 1986), [Florida] 4 years (Beardsley, 1967).

**Length/weight relationship:** [North Atlantic]  $\ln W = 2.71 \ln FL - 10.42$  ( $n=32,215$ ,  $R^2=0.97$ ) (Thompson, 1999). See also [Florida] Beardsley (1967), [Canary Islands] (Castro *et al.*, 1999) and [Puerto Rico] (Rivera and Appeldoorn, 2000).

FL (cm)	50	100	150
Weight (kg)	1.2	7.8	23.5

**Length relationship:** [Pacific Coast, Panama and Columbia]  $FL = 0.8278 TL$  ( $n=522$ ,  $r=0.979$ ) (Lasso and Zapata, 1999). See also Rivera and Appeldoorn (2000).

**Growth:** [North Carolina, FL] Females  $L_{\infty} = 1,250$  mm,  $k = 1.24$  year<sup>-1</sup>,  $t_0 = -0.059$  years ( $n=146$ )  
Males  $L_{\infty} = 1,286$  mm,  $k = 1.33$  year<sup>-1</sup>,  $t_0 = -0.016$  years ( $n=189$ ) (Schwenke and Buckle, 2008).  
For a comprehensive review of growth parameters see Chang and Maunder (2012).

Age (years)	1	2	3
Females, TL (mm)	914	1,153	1,222
Males, TL (mm)	953	1,198	1,263

**Length and age at maturity:** [North Carolina, FL] Females  $L_{50} = 457$  mm; Males  $L_{50} = 476$  mm (Schwenke and Buckle, 2008). See also Beardsley (1967), Massuti and Morales-Nin (1997), Oxenford (1999), Wu *et al.* (2001) and, Schwenke and Buckle (2008).

**Reproductive style:** [Mexico] Gonochoristic, multiple spawner which forms aggregations (Alejo-Plata *et al.*, 2011). See also Massuti and Morales-Nin (1997), Oxenford (1999) and Arocha *et al.* (1999).

**Adult sex ratio:** [Mexico, commercial] Sex ratio varies seasonally and with length (Alejo-Plata *et al.*, 2011).

**Length and age at sex change:** Not applicable.

**Spawning season:** [New South Wales] October – January (Dempster, 2004). [Mexico] Spawning period 90 days (Alejo-Plata *et al.*, 2011). See also Potoschi *et al.* (1999).

**Spawning location and habitat:** [New South Wales] Offshore waters of Queensland and New South Wales (Kingsford and Defries, 1999; Dempster, 2004).

**Fecundity:** [Puerto Rico] Indeterminate. Batch fecundity  $BF=6.03*10^{-6}FL^{3.67}$  (Perez and Sadvoy, 1991). For a comprehensive review of reproductive characteristics see Nel (1995), Oxenford (1999) and Alejo-Plata *et al.* (2011).

FL (mm)	500	1000	1500
Fecundity (eggs)	48,477	617,046	2,723,576

**Spawning frequency:** [Western Australia, aquaculture] Every 2 days (Nel, 1995); [Mexico] Every 2 days (Alejo-Plata *et al.*, 2011).

### Development and habitat use

**Eggs:** Pelagic (Richards, 2006).

**Larvae:** [North-west shelf] Oceanic and slope tropical waters (Young *et al.*, 1986).

[New South Wales] Offshore surface waters, with the East Australian Current a likely mechanism for southward dispersal (Kingsford and Defries, 1999). [USA] Description of larval stages (Richards, 2006).

**Juveniles:** [New South Wales] Attracted to fish aggregation devices and other floating debris (Dempster, 2004).

**Adults:** [New South Wales] Wide ranging pelagic species. Most abundant in warm tropical currents and around fish aggregation devices (Dempster, 2004).

**Migration:** [New South Wales] Tagged fish moved up to 20 km per day (Kingsford and Defries, 1999). [Atlantic, Pacific and Mediterranean] Pre-spawning migration is likely (Massuti and Morales-Nin, 1995; Oxenford, 1999; Wu *et al.*, 2001; Schwenke and Buckle, 2008).

**Stock delineation:** [New South Wales] Tagging studies indicate it is strongly site-associated (Kingsford and Defries, 1999). In Mexico and California, however, individuals have been shown to disperse widely. Large-scale migrations have resulted in high genetic variation and gene flow (Tripp-Valdez *et al.*, 2010; Alejo-Plata *et al.*, 2011). Populations probably panmictic throughout the Western Mediterranean and Eastern Atlantic (Pla and Pujolar, 1999).

**Diet:** [New South Wales] Mainly piscivorous but also consume invertebrate species, including those associated with floating debris (Dempster, 2004). [Atlantic, Eastern Caribbean] Forages on a range of small oceanic pelagic fish species (e.g. flying fish), juveniles of larger oceanic fish species (including tuna), pelagic fish larvae and invertebrate species (Oxenford, 1999; Oxenford and Hunte, 1999).

## Fishery

**Recreational:** [New South Wales] Caught by trolling using baits or lures, especially in offshore waters around floating debris and fish aggregation devices (Kingsford and Defries, 1999; Dempster, 2004).

**Commercial:** Trolled or baited lines, and as by-catch of international long-lining vessels in offshore waters (Kingsford and Defries, 1999). Targeted to a small extent by the Christmas Island Line Fishery (Newman *et al.*, 2012). A by-product species in the Commonwealth Western Tuna and Billfish Fishery (WTBF) (Patternson *et al.*, 2011).

**Age at full recruitment into the fishery:** [New South Wales] 44% of fish caught were 360-420mm FL (Dempster, 2004).

**Gear selectivity parameters:** Not reported.

## Management parameters

**Total mortality:** [Barbados, Hoenig's (1983) equation for fish] 4.22 year<sup>-1</sup> (Oxenford, 1985). For a comprehensive review of mortality estimates see also Oxenford (1999).

**Natural mortality:** [Barbados, Pauly's (1980) equation] 2.56 year<sup>-1</sup> (Oxenford, 1985). See also Oxenford (1999).

**Fishing mortality:** Not reported in cited literature.

**Biological reference points:** Not reported.

**Current status:** Assessed in IUCN Red List in 2011 as a species of Least Concern (Collette *et al.*, 2011).

## Catch trends

**Recreational:** [New South Wales] Recreational catch may exceed commercial catch in some areas (Steffe *et al.*, 1996).

**Commercial:** A total of 11 t of this species was caught as by-product in the WBTF from 2005-2011 (Patternson *et al.*, 2011).

## Management regulations

**Recreational:** Currently listed in the "large pelagic finfish" category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1988)	3	-	
Statewide (1991)	4	-	
West Coast (2003)	2	-	
Gascoyne Coast (2005)	4	500	
South Coast (2005)	2	500	
West Coast (2006)	2	500	
Statewide (2013)	3	500	

**Commercial:** The Christmas Island Line Fishery, in which this species is infrequently targeted, is managed primarily through input controls (*i.e.*, limited entry and gear restrictions) (Newman *et al.*, 2012). Management arrangements for the WBTF include input controls such as limited entry, gear and area controls as well as output controls such as by-catch restrictions and total allocated catches (Patternson *et al.*, 2011).

**Current research:** Ongoing data collection occurs through charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Aquaculture* (Hassler and Hogarth, 1977; Hagood *et al.*, 1981; Ostrowski and Divakaran, 1990; Kraul *et al.*, 1992; Kraul, 1993; Nel, 1995); *Biogenic amines* (Staruszkiewicz *et al.*, 2004); *Precautionary management* (Mahon and Oxenford, 1999); *Economics* (Cannizzaro *et al.*, 1999); *Parasitism* (Carbonell *et al.*, 1999); *Morphometrics* (Castro *et al.*, 1999); *Range shifts associated with water currents and ocean temperatures* (Norton, 1999).

## References

- Alejo-Plata, C., Díaz-Jaimes, P., Salgado-Ugarte, I. H., 2011. Sex ratios, size at sexual maturity, and spawning seasonality of dolphinfish (*Coryphaena hippurus*) captured in the Gulf of Tehuantepec, Mexico. *Fisheries Research* 110, 207-216.
- Arocha, F., Marcano, L. A., Larez, A., Altuve, D., Alio, J., 1999. The fishery, demographic size structure and oocyte development of dolphinfish, *Coryphaena hippurus*, in Venezuela and adjacent waters. *Scientia Marina* 63, 401-409.
- Beardsley, G. L., Jr., 1967. Age, Growth, and Reproduction of the Dolphin, *Coryphaena hippurus*, in the Straits of Florida. *Copeia* 1967, 441-451.
- Cannizzaro, L., D'Andrea, F., Potoschi, A., Scalisi, M., 1999. Economic aspects of fishing of dolphinfish in Sicily. *Scientia Marina* 63, 459-464.
- Carbonell, E., Massuti, E., Castro, J. J., Garcia, R. M., 1999. Parasitism of dolphinfishes, *Coryphaena hippurus* and *Coryphaena equiselis*, in the western Mediterranean (Balearic Islands) and central-eastern Atlantic (Canary Islands). *Scientia Marina* 63, 343-354.
- Castro, J. J., Santiago, J. A., Hernandez-Garcia, V., Pla, C., 1999. Growth and reproduction of the dolphinfish (*Coryphaena equiselis* and *Coryphaena hippurus*) in the Canary Islands, Central-East Atlantic *Scientia Marina* 63, 317-325.
- Chang, S.-K., Maunder, M. N., 2012. Aging material matters in the estimation of von Bertalanffy growth parameters for dolphinfish (*Coryphaena hippurus*). *Fisheries Research* 119–120, 147-153.
- Collette, B. B., 1999. Coryphaenidae, Dolphinfishes (“dolphins”), In FAO species identification guide for fishery purposes. The living marine resources of the western central Pacific. Volume 4. Bony fishes Part 2 (Mugilidae to Carangidae). Carpenter, K. E., Niem, V. H. (eds), FAO, Rome, Italy, pp. 2656-2658.
- Collette, B. B., Acero, A., Amorim, A. F., BOustany, A., Canales Ramirez, C., Cardenas, G., Carpender, K. E., de Oliveira Leite, N., Di Natale, A., Fox, W., Fredau, F. L., Graves, J., Viera Hazin, F. H., Juan Jorda, M., Mine Vera, C., Miyabe, N., Montano Cruz, R., Nelson, R., Oxenford, H. A., Schaefer, K., Serra, R., Sun, C., Teixeira Lessa, R. P., Pires Ferreira Travossos, P. E., Uozumi, Y., Yanez, E., 2011. *Coryphaena hippurus*. 2012 IUCN Red List of Threatened Species. Available: <http://www.iucnredlist.org/> (Accessed August 2012).
- Dempster, T., 2004. Biology of fish associated with moored fish aggregation devices (FADs): implications for the development of a FAD fishery in New South Wales, Australia. *Fisheries Research* 68, 189-201.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- FAO, 1994. World review of highly migratory species and straddling stocks. Food and Agriculture Organisation. Rome, Italy. FAO Fisheries Technical Paper No. 337. pp. 70.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Hagood, R. W., Rothwelly, G. N., Swafford, M., Tosaki, M., 1981. Preliminary report on the aquaculture development of the dolphin fish, *Coryphaena hippurus* (Linnaeus). *Journal of the World Mariculture Society* 12, 135-139.

- Hassler, W. W., Hogarth, W. T., 1977. The growth and culture of dolphin, *Coryphaena hippurus*, in North Carolina. *Aquaculture* 12, 115-122.
- Hoenig, J., 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82, 898-903.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Kingsford, M. J., Defries, A., 1999. The ecology of and fishery for *Coryphaena* spp. in the waters around Australia and New Zealand. *Scientia Marina* 63, 267-275.
- Kraul, S., 1993. Larviculture of the Mahimahi *Coryphaena hippurus* in Hawaii, USA. *Journal of the World Aquaculture Society* 24, 410-421.
- Kraul, S., Nelson, A., Brittain, K., Ako, H., Ogasawara, A., 1992. Evaluation of live feeds for larval and postlarval Mahi mahi *Coryphaena hippurus*. *Journal of the World Aquaculture Society* 23, 299-306.
- Lasso, J., Zapata, L., 1999. Fisheries and biology of *Coryphaena hippurus* (Pisces: Coryphaenidae) in the Pacific coast of Columbia and Panama. *Scientia Marina* 63, 387-399.
- Mahon, R., Oxenford, H. A., 1999. Precautionary assessment and management of dolphinfish in the Caribbean. *Scientia Marina* 63, 429-438.
- Massuti, E., Morales-Nin, B., 1995. Seasonality and reproduction of dolphin-fish (*Coryphaena hippurus*) in the Western Mediterranean. *Scientia Marina* 59, 357-364.
- Massutí, E., Morales-Nin, B., 1997. Reproductive biology of dolphin-fish (*Coryphaena hippurus* L.) off the island of Majorca (western Mediterranean). *Fisheries Research* 30, 57-65.
- Nel, S. A., 1995. Commercialisation of the mahi mahi. *Australasia Aquaculture* 9, 51-53.
- Newman, S. J., Bellchambers, L., Skepper, C., Pember, M., Evans, S., Rome, B., Green, R., 2012. Indian Ocean Territories Fishery Status Report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 348-353.
- Norton, J. G., 1999. Apparent habitat extensions of dolphinfish (*Coryphaena hippurus*) in response to climate transients in the California Current. *Scientia Marina* 63, 239-260.
- Ostrowski, A. C., Divakaran, S., 1990. Survival and bioconversion of n-3 fatty acids during early development of dolphin (*Coryphaena hippurus*) larvae fed oil-enriched rotifers. *Aquaculture* 89, 273-285.
- Oxenford, H. A., 1985. Biology of the dolphin *Coryphaena hippurus* and its implications for the Barbadian fishery, PhD thesis, University of the West Indies, Cave Hill, Barbados. pp. 366.
- Oxenford, H. A., 1999. Biology of the dolphinfish (*Coryphaena hippurus*) in the western central Atlantic: a review. *Scientia Marina* 63, 277-301.
- Oxenford, H. A., Hunte, W., 1999. Feeding habitats of the dolphinfish (*Coryphaena hippurus*) in the eastern Caribbean. *Scientia Marina* 63, 303-315.
- Patternson, H., Larcombe, J., Hormis, M., 2011. Western Tuna and Billfish Fishery, In Fisheries status reports 2010: status of fish stocks and fisheries managed by the Australian Government. Woodhams, J., Stobutzki, I., Vieira, S., Currotti, R., Begg, G. (eds), Bureau of Rural Sciences & Australian Bureau of Agricultural and Resource Economics, Canberra, Australia, pp. 368-385.
- Pauly, D., 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *Journal du Conseil International pour l'Exploration de la Mer* 39, 175-192.
- Perez, R. N., Sadovy, Y., 1991. Preliminary data on landings records and reproductive biology of *Coryphaena hippurus* L. in Puerto Rico, In Proceedings of the 44th Gulf and Caribbean Fisheries Institute. pp. 636-650.
- Pla, C., Pujolar, J. M., 1999. Genetic homogeneity of dolphinfish (*Coryphaena hippurus*) in the western Mediterranean and the eastern Atlantic. *Scientia Marina* 63, 337-341.
- Potoschi, A., Renones, O., Cannizzaro, L., 1999. Sexual development, maturity and reproduction of dolphinfish (*Coryphaena hippurus*) in the western and central Mediterranean. *Scientia Marina* 63, 367-372.
- Richards, W. D. (ed) 2006. Early stages of Atlantic fishes - an identification guide for the Western Central North Atlantic, Volume 1. CRC Press.

- Rivera, G. A., Appeldoorn, R. S., 2000. Age and growth of dolphinfish, *Coryphaena hippurus*, off Puerto Rico. *Fishery Bulletin* 98, 345-352.
- Schwenke, K. I., Buckle, J. A., 2008. Age, growth and reproduction of dolphinfish (*Coryphaena hippurus*) caught off the coast of North Carolina. *Fishery Bulletin* 106, 82-92.
- Staruszkiewicz, W. F., Barnett, J. D., Rogers, P. L., Benner Jr, R. A., Wong, L. L., Cook, J., 2004. Effects of on-board and dockside handling on the formation of biogenic amines in mahi mahi (*Coryphaena hippurus*), skipjack tuna (*Katsuwonus pelamis*), and yellowfin tuna (*Thunnus albacares*). *Journal of Food Protection* 67, 134-141.
- Steffe, A. S., Murphy, J. J., Chapman, D. J., Tarlinton, G. N. G., Gordon, T. N. T., Grinberg, A., 1996. An assessment of the impact of offshore recreational fishing in New South Wales waters on the management of commercial fisheries. New South Wales. FRDC Project No 94/053. pp. 140.
- Thompson, N. B., 1999. Characterization of the dolphinfish (Corypaenidae) fishery of the United States western north Atlantic Ocean. *Scientia Marina* 63, 421-427.
- Tripp-Valdez, M. A., García de León, F. J., Ortega-García, S., Lluch-Cota, D., López-Martínez, J., Cruz, P., 2010. Population genetic structure of dolphinfish (*Coryphaena hippurus*) in the Gulf of California, using microsatellite loci. *Fisheries Research* 105, 172-177.
- Wu, C. C., Su, W. C., Kawasaki, T., 2001. Reproductive biology of the dolphin fish *Coryphaena hippurus* on the east coast of Taiwan. *Journal of Taiwanese Fisheries Science* 67, 784-793.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.
- Young, G. C., Leis, J. M., Hausfeld, H. F., 1986. Seasonal and spatial distribution of fish larvae in waters over the North West continental shelf of Western Australia. *Marine Ecology Progress Series* 31, 209-222.

## Western Australian salmon (*Arripis truttaceus*)

Reviewed by Kim Smith (DoF)



**Scientific name:** *Arripis truttaceus* (Arripidae; Australian salmon)

**Common names:** Western Australian Salmon (juveniles often referred to as salmon trout)

**Key identifying features:** Single continuous dorsal fin with a notch after the last fin spine, no black tips on caudal fin lobes, yellowish pectoral fin with black blotch at base, smooth scales (Yearsley *et al.*, 2001).

### Distribution

**Worldwide:** Western and southern coastline of Australia, rarely in Victoria and Tasmania (Paulin, 1993).

**Western Australia:** Kalbarri southwards to southern Western Australian border (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 961 mm, 9.4 kg (Hutchins and Swainston, 1986), 9 years (Cappo, 1987).

**Length/weight relationship:** [Lower west coast and south coast]  $W=1.3*10^{-6}L^{3.36}$  ( $n = 196$ ) (Gaughan *et al.*, 2006).

TL (mm)	200	500	800
Weight (g)	70	1522	7385

**Length relationship:** [cm]  $FL=-0.104+1.47*TL$  (Nicholls, 1973).

**Growth:** [Lower west coast] Female  $L_{\infty}=1,012$  mm,  $k=0.210$  year<sup>-1</sup>,  $t_0$ =fixed at zero years ( $n=30$ ) Male  $L_{\infty}=881$  mm,  $k=0.269$  year<sup>-1</sup>,  $t_0$ =fixed at zero years ( $n=35$ ) (Gaughan *et al.*, 2006). See also (Gaughan *et al.*, 2006) for South Coast bioregion estimates and Nicholls (1973).

Age (years)	2	4	6
Females, TL (mm)	347	575	725
Males, TL (mm)	367	581	706

**Length and age at maturity:** 60 – 65 cm, 3 – 5 years (Nicholls, 1973; Cappo, 1987).

**Reproductive style:** Gonochoristic. Serial batch spawner (Stanley, 1980).

**Adult sex ratio:** [Lower west coast, commercial] F1:M1 (Gaughan *et al.*, 2006).

**Length and age at sex change:** Not applicable.

**Spawning season:** February to June, mainly April to May, coinciding with strongest flows of the Leeuwin Current (Malcolm, 1960).

**Spawning location and habitat:** Southern part of west coast, southwards from Perth, but largely between Cape Leeuwin and Busselton (Walker, 1982).

**Fecundity:** Not reported.

**Spawning frequency:** Not reported.

### **Habitat**

**Eggs:** [*Arripis*] Pelagic. Spherical with a single oil globule (Neira *et al.*, 1998).

**Larvae:** Larval description (Neira *et al.*, 1998). Neustonic (K. Smith, DoF, unpublished data).

**Juveniles:** Soft substrates in shallow, sheltered bays and coastal waters (Cappo *et al.*, 2000) (Malcolm, 1960; Lenanton, 1982).

**Adults:** Form schools in exposed coastal waters near reefs and the surge zone (Cappo *et al.*, 2000), with some movement into oceanic waters (Malcolm, 1960).

**Migration:** Maturing juveniles from south-eastern Australian waters migrate westwards just prior to their first spawning to join local pre-spawning adults in southern Western Australian grounds (as far north as Rottnest Island) in mid-late summer (Malcolm, 1959; 1966; Stanley, 1980; Walker, 1982; Cappo, 1987; Lenanton *et al.*, 1991).

**Stock delineation:** Single stock over full range of species distribution (Ayvazian *et al.*, 2004; Moore, 2011). Western Australian Salmon was previously thought to be a subspecies of *Arripis trutta esper* (Fairbridge, 1951; Malcolm, 1959; 1960; Roberston, 1982; Paulin, 1993).

**Diet:** Mainly piscivorous. Stomach contents include small fish, benthic crustaceans and seagrass (Thomson, 1957; Roberston, 1982). Feeding success is increased by forming small schools (Foster *et al.*, 2001).

### **Fishery**

**Recreational:** A popular recreational species targeted predominantly by shore-based rod and line fishers (Ayvazian *et al.*, 1997; Henry and Lyle, 2003). Fishing effort along the south west coast of Western Australia is concentrated on spawning migrations which form in late summer/early autumn (Walker, 1982).

**Commercial:** A key commercial nearshore species commonly targeted using beach seines during pre- and post-spawning migrations as part of the South Coast Salmon Managed Fishery and South West Coast Salmon Managed Fishery (Malcolm, 1960; Walker, 1982; Smith *et al.*, 2012a; Smith *et al.*, 2012b). Due to low market demand, commercial fishers have not targeted this species in recent years.

**Age at full recruitment:** Fishery based on fish of ages 3+ to 8+ years, with most of the catch between 4+ to 6+ years (Malcolm, 1960; Stanley, 1980).

**Gear selectivity parameters:** Not reported.

### **Management parameters**

**Total mortality:** Not reported.

**Natural mortality:** Not reported.

**Fishing mortality:** Not reported.

**Biological reference points:** Not reported.

**Current status:** Stock level is adequate in the West Coast bioregion (Smith *et al.*, 2012b). An indicator species for the nearshore zone in the South Coast bioregion (DoF, 2011). Overall risk to sustainability for the nearshore suite is low (DoF, 2011). Inherent vulnerability of the species is minimal and current risk to wild stock is moderate (DoF, 2011). See DoF (2011) for more detailed risk assessment data. A national assessment by (Stewart *et al.*, 2012) lists the biological stock of this species in Western Australia as sustainable.

### Catch trends

**Recreational:** In 1994/96, the highest catches of this species were obtained in autumn, coinciding with the commercial fishing season (Ayvazian *et al.*, 1997). The total estimated recreational boat-based catch in the West Coast bioregion was 12 t for 1996/97 and 17 t in 2005/06 (Sumner *et al.*, 2008). See also Harvey (2004), Smallwood *et al.* (2006), Prior and Beckley (2007) and Smallwood *et al.* (2012) for additional catch information.

**Commercial:** Total commercial landings in Western Australia have been declining since 1995 when a peak of 4,046 t was reported. Since 2000, 58% of total commercial landings has been taken in the South Coast bioregion, with the remaining 32% from the West Coast bioregion (Smith *et al.*, 2012a). The declining trend is driven by catches in the South Coast bioregion (where the majority of commercial landings are taken), where the annual catch steadily declined from an historical peak of 2,728 t in 1995 to 291 t in 2010 (Smith *et al.*, 2012a). This decline was largely caused by decreased fishing effort, which is attributed to weak market demand. By contrast, the catch trend in the West Coast bioregion was non-directional over the long term, although annual landings have varied widely from <1 t (in 2000) to 1,364 t (in 1968) (Smith *et al.*, 2012b). West Coast bioregion landings of 1,291 t in 1995 and 1,194 t in 2006 were close to the historical peak reached in 1968. A complete catch trend graph is shown in the 2010/11 State of the Fisheries and Aquatic Resources Report. See also (Stewart *et al.*, 2012).

### Management regulations

**Recreational:** Currently listed in the “nearshore/estuarine finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1913)	-	250	
Statewide (1958)	-	240	
Statewide (1975)	-	300	
Statewide (1979)	5	300	
Statewide (1991)	4	300	

**Commercial:** South Coast and West Coast nearshore and estuarine fisheries are managed primarily through input controls (limited entry, spatial and gear restrictions) (Smith *et al.*, 2012a; Smith *et al.*, 2012b). Minimum legal size is 300 mm. Area restrictions are also used by the South Coast Salmon Managed Fishery and South West Coast Salmon Managed Fishery (Smith *et al.*, 2012a; Smith *et al.*, 2012b).

**Current research:** DoF has monitored recruitment (annual fishery-independent index of recruitment) since 1996 and intermittently surveys the age composition of commercial landings. Ongoing data collection occurs through commercial logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Genetic analysis of evolutionary history* (Moore, 2011); *Parasites* (Bolton *et al.*, 2006; Catalano *et al.*, 2011; Hutson *et al.*, 2011); *Biology of Eastern Australian Salmon* (Neira *et al.*, 1998; Stevens and Kalish, 1998; Stewart *et al.*, 2011).

## References

- Ayvazian, S., Lenanton, R., Wise, B., Steckis, R., Nowara, G., 1997. Western Australian Salmon and Australian herring creel survey. Fisheries Western Australia. Perth, Western Australia. FRDC Project No. 93/79. pp. 93.
- Ayvazian, S. G., Bastow, T. P., Edmonds, J. S., How, J., Nowara, G. B., 2004. Stock structure of Australian herring (*Arripis georgiana*) in southwestern Australia. *Fisheries Research* 67, 39-53.
- Bolton, T. F., Hayward, C. J., Turner, A. J., 2006. The Piscicolid leech *Austrobdella translucens*, Badham, 1916: a new host record from Australian salmon, *Arripis trutta* (forster, 1801), and a new locality record for Yellowfin whiting, *Sillago schomburgkii*, Peters 1864, in South Australia. *Australian Zoologist* 33, 385-387.
- Cappo, M. C., 1987. The biology and exploitation of Australian salmon in South Australia. *SAFISH* 12, 4-14.
- Cappo, M. C., Walters, C. J., Lenanton, R. C. J., 2000. Estimation of rates of migration, exploitation and survival using tag recovery data for western Australian “salmon” (*Arripis truttaceus*: Arripidae: Percoidae). *Fisheries Research* 44, 207-214.
- Catalano, S. R., Hutson, K. S., Ratcliff, R. M., Whittington, I. D., 2011. The value of host and parasite identification for arripid fish. *Marine and Freshwater Research* 62, 72-82.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairbridge, W. A., 1951. Some populations of the Australian “salmon” *Arripis trutta*, In Proceedings of the 2nd Indo-Pacific Fish Conference. pp. 80-4.
- Foster, E. G., Ritz, D. A., Osborn, J. E., Swadling, K. M., 2001. Schooling affects the feeding success of Australian salmon (*Arripis trutta*) when preying on mysid swarms (*Paramesopodopsis rufa*). *Journal of Experimental Marine Biology and Ecology* 261, 93-106.
- Gaughan, D. J., Ayvazian, S., Nowara, G., Craine, M., Brown, J., 2006. The development of a rigorous sampling program for a long term annual index of recruitment for finfish species from south-western Australia. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 1999/153, Fisheries Research Report No. 154. pp. 135.
- Gomon, M. F., Bray, C. D., Kuiter, R. H. (eds) 2008. Fishes of Australia’s southern coast. Reed New Holland, Sydney, Australia.
- Harvey, M. J., 2004. An evaluation of Western Australian recreational fishing regulations with a case study from a metropolitan boat ramp, Honours thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 97.
- Henry, G. W., Lyle, J. M. (eds) 2003. The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forest, Canberra, Australia.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Hutson, K. S., Catalano, S. R., Whittington, I. D., 2011. Metazoan parasite survey of selected macro-inshore fish of southeastern Australia, including species of commercial importance. James Cook University. Townsville, Queensland. FRDC Project No. 2007/225. pp. 259.
- Lenanton, R. C., Joll, L., Penn, J. W., Jones, G. K., 1991. The influence of the Leeuwin current on coastal fisheries of Western Australia. *Journal of the Royal Society of Western Australia* 74, 101-114.
- Lenanton, R. C. J., 1982. Alternative non-estuarine nursery habitats for some commercially and recreationally important fish species of south-western Australia. *Australian Journal of Marine and Freshwater Research* 33, 881-900.
- Malcolm, W. B., 1959. The populations of Australian “salmon”, *Arripis trutta* (Bloch & Schneider), in Western Australia. *Australian Journal of Marine and Freshwater Research* 10, 22-29.
- Malcolm, W. B., 1960. Area of distribution, and movement of the western subspecies of the Australian “salmon”, *Arripis trutta esper* Whitley. *Australian Journal of Marine and Freshwater Research* 11, 282-325.

- Malcolm, W. B., 1966. Synopsis for FAO species and stocks thesaurus of data on *Arripis trutta* (Bloch & Schneider), In Commonwealth-states fisheries conference, Southern Pelagic Project Committee technical session. CSIRO, New South Wales, Australia.
- Moore, G., 2011. Aspects of the evolutionary history of a pair of fish species (Arripidae: Arripis) on either side of a biogeographic barrier in southern Australian seas, PhD thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 229.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Nicholls, A. G., 1973. Growth in Australian "salmon" *Arripis trutta* (Bloch & Schneider). *Australian Journal of Marine and Freshwater Research* 24, 159-176.
- Paulin, C., 1993. Review of the Australasian fish family Arripidae (Percomorpha), with the description of a new species. *Australian Journal of Marine and Freshwater Research* 44, 459-471.
- Prior, S. P., Beckley, L. E., 2007. Characteristics of recreational anglers in the Blackwood Estuary, a popular tourist destination in southwestern Australia. *Tourism in Marine Environments* 4, 15-28.
- Roberston, A. I., 1982. Population dynamics and feeding ecology of juvenile Australian salmon (*Arripis trutta*) in Western Port, Victoria. *Australian Journal of Marine and Freshwater Research* 33, 369-375.
- Smallwood, C. B., Beckley, L. E., Sumner, N. R., 2006. Shore-based recreational angling in the Rottneest Island Reserve, Western Australia: spatial and temporal distribution of catch and fishing effort. *Pacific Conservation Biology* 12, 238-51.
- Smallwood, C. B., Pollock, K. H., Wise, B. S., Hall, N. G., Gaughan, D. J., 2012. Expanding roving-aerial surveys to include counts of recreational shore fishers from remotely-operated cameras: benefits, limitations and cost-effectiveness. *North American Journal of Fisheries Management* 32, 1265-1276.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012a. South Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Smith, K., Brown, J., Howard, A., Walshe, K., Fissioli, J., 2012b. West Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 80-97.
- Stanley, C. A., 1980. Lee's phenomenon in the Western subspecies of the Australian salmon *Arripis trutta esper*. *Australian Journal of Marine and Freshwater Research* 31, 13-19.
- Stevens, D. W., Kalish, J. M., 1998. Validated age and growth of kahawai (*Arripis trutta*) in the Bay of Plenty and Tasman Bay. New Zealand. NIWA Technical Report No. 11. pp. 33.
- Stewart, J., Fowler, A., Kemp, J., Lyle, J., Rowling, K., Smith, K., 2012. Australian salmon *Arripis trutta*, *A. truttaceus*, In Status of key Australian fish stocks reports 2012. Flood, M., Stobutzki, I., Andrews, J., Begg, G., Fletcher, W., Gardner, C., Kemp, J., Moore, A., O'Brien, A., Quinn, R., Roach, J., Rowling, K., Sainsbury, K., Saunders, T., Ward, T., Winning, M. (eds), Fisheries Research and Development Corporation, Canberra, Australia, pp. 246-253.
- Stewart, J., Hughes, J., McAllister, J., Lyle, J. M., MacDonald, M., 2011. Australian salmon (*Arripis trutta*): population structure, reproduction, diet and composition of commercial and recreational catches. Cronulla Fisheries Research Centre. New South Wales. Fisheries Final Report Series No. 129, FRDC Project No 2006/18 and 2008/056. pp. 257.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Thomson, J. M., 1957. The food of Western Australian estuarine fishes. *Western Australian Fisheries and Fauna Department Bulletin* 7, 1-13.
- Walker, M. H., 1982. The present state of the Western Australian fishery for Australian salmon. Department of Fisheries and Wildlife. Perth, Western Australia. Department of Fisheries and Wildlife Report 52.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## Australian herring (*Arripis georgianus*)

Reviewed by Joshua Brown (DoF)



**Scientific name:** *Arripis georgianus* (Arripidae; Australian salmon)

**Common names:** Australian herring *also* herring, tommy rough, ruff

**Key identifying features:** Prominent black tips on caudal fin, vertical rows of golden spots on upper surface, scales rough to touch, single continuous dorsal fin with a notch after the last fin spine (Yearsley *et al.*, 2001).

### Distribution of species

**Worldwide:** Southern Australian waters, from Shark Bay to Victoria.

**Western Australia:** Southern Western Australian border to Shark Bay (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 411 mm (Hutchins and Swainston, 1986), 0.876 kg, 12 years (Smith *et al.*, in press).

**Length/weight relationship:** [Lower west coast and south coast]  $W=1.44*10^{-5}TL^{2.94}$  ( $n=2,963$ ) (Gaughan *et al.*, 2006). See also Ayvazian *et al.* (2000).

TL (mm)	100	200	300
Weight (g)	11	84	276

**Length relationship:** [Western Australia]  $TL=1.174*FL - 3.365$  (Ayvazian *et al.*, 2000).

**Growth:** [West Coast bioregion] Females  $L_{\infty}=271.5$  mm,  $k=0.57$  year<sup>-1</sup>,  $t_0=-0.30$  years ( $n=4,565$ ); Males  $L_{\infty}=236.7$  mm,  $k=0.86$  year<sup>-1</sup>,  $t_0=-0.08$  years ( $n=2,731$ ) (Smith *et al.*, in press).

Age (years)	2	6	10
Females, TL (mm)	198	264	271
Males, TL (mm)	197	235	237

See also Fairclough *et al.* (2000a), Orr (2000), Gaughan *et al.* (2006) and Potter *et al.* (2011).

**Length and age at maturity:** [West Coast bioregion] Females  $L_{50}=194.1$  mm,  $A_{50}=2.2$  years; Males  $L_{50}=174.4$  mm,  $A_{50}=1.8$  years (Smith *et al.*, in press). See also Fairclough *et al.* (2000b) and Orr (2000).

**Reproductive style:** [Western Australia/South Australia] Gonochoristic. Multiple spawner (Fairclough *et al.*, 2000b).

**Adult sex ratio:** [West Coast bioregion] commercial F59.8:M40.2 ( $n=5,197$ ); recreational F68.4:M31.6 ( $n=6,685$ ) (Smith *et al.*, in press).

**Length and age at sex change:** Not applicable.

**Spawning season:** [Western Australia/South Australia] Late May to early June (Lenanton, 1978; Fairclough *et al.*, 2000b; Gaughan *et al.*, 2006; Smith *et al.*, in press).

**Spawning location and habitat:** South-western Australia (Fairclough *et al.*, 2000b; Ayvazian *et al.*, 2004). Does not spawn in estuaries (Potter *et al.*, 2011).

**Fecundity:** [Western Australia/South Australia] Determinate. Annual fecundity  $F=4619.3 \cdot e^{0.0114TL}$  ( $n=37$ ,  $R^2=0.84$ ) (Fairclough *et al.*, 2000b). See also Lenanton (1978).

TL (mm)	200	250	300
Fecundity (eggs)	45,200	79,900	141,200

**Spawning frequency:** Not reported.

### Development and habitat use

**Eggs:** Pelagic (Neira *et al.*, 1998).

**Larvae:** Sheltered nearshore waters (Ayvazian *et al.*, 2004).

**Juveniles:** Sheltered nearshore waters, estuaries and bays (Lenanton, 1982; Valesini *et al.*, 1997; Fairclough *et al.*, 2000b; Ayvazian *et al.*, 2004; Smith *et al.*, in press).

**Adults:** Pelagic, in nearshore coastal marine waters, estuaries and bays (Lenanton, 1982; Hutchins and Swainston, 1986; Valesini *et al.*, 1997).

**Migration:** Eggs and larvae are transported from spawning areas in south-western Australia to nursery areas in estuaries and shallow, coastal marine waters off southern Australia by the Leeuwin Current (Fairclough *et al.*, 2000b; Ayvazian *et al.*, 2004).. Migrate along the south coast of Australia to spawning areas in south-western Australia at about 2 years of age (Fairclough *et al.*, 2000b; Ayvazian *et al.*, 2004).

**Distribution of stock:** Single stock over full range of species distribution (Ayvazian *et al.*, 2000; Ayvazian *et al.*, 2004; Moore, 2011).

**Diet:** Opportunistic carnivore which predominantly feeds on crustaceans and teleosts with some polychaetes, molluscs and macro-algae (Orr, 2000). See also Thomson (1957), Wallace (1976) and Lenanton (1982).

### Fishery

**Recreational:** One of the most popular recreational fish species. Targeted predominantly by shore-based anglers in coastal and estuarine waters, especially during the spawning period from April – June (Lenanton and Hall, 1976; Sumner and Williamson, 1999; Henry and Lyle, 2003; Ayvazian *et al.*, 2004; Smallwood and Sumner, 2007; Smallwood *et al.*, 2012).

**Commercial:** One of the most frequently caught species in the nearshore and estuarine finfish commercial gill net, haul net, beach seine and trap net fisheries which operate in the South Coast and West Coast bioregions (Smith *et al.*, 2012a; Smith *et al.*, 2012b). This species is also caught by commercial fishers in South Australia, with negligible catch taken in Victoria (Smith *et al.*, 2012b). See also Walker and Clarke (1987), Ayvazian *et al.* (2000), Gaughan *et al.* (2006) and Smith *et al.* (in press).

**Age at full recruitment:** Not specified.

**Gear selectivity parameters:** [WA, recreational] Females  $L_{50}=215.6$  mm,  $L_{95}=278.8$  mm; Males,  $L_{50}=216.1$  mm,  $L_{95}=269.4$  mm. [WA], commercial, haul net] Females,  $L_{50}=197.0$  mm,  $L_{95}=254.9$  mm; Males,  $L_{50}=216.5$  mm,  $L_{95}=255.7$  mm (Wise and Hall, 2000).

## Management parameters

**Total mortality:** Not reported.

**Natural mortality:** [Maximum age] 0.4 year<sup>-1</sup> (Ayvazian *et al.*, 2000).

**Fishing mortality:** Not reported but included in Smith *et al.* (in press).

**Biological reference points:** A preliminary population dynamics model was developed for this species but the results were inconclusive (further data required) (Wise and Hall, 2000).

**Current status:** Stock level is uncertain in the West Coast and South Coast bioregions (Smith *et al.*, 2012a; Smith *et al.*, 2012b). An indicator species for the nearshore zone in the West Coast and South Coast bioregions (DoF, 2011). Overall risk to sustainability for the nearshore suite is low in the South Coast bioregion and medium to high in the West Coast bioregion (DoF, 2011). Inherent vulnerability of the species is minimal and current risk to wild stock is high in the West Coast bioregion and moderate in the South Coast bioregion (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

## Catch trends

**Recreational:** The total estimated recreational boat-based catch in the West Coast bioregion was 46 t for 1996/97 and 40 t in 2005/06 (Sumner *et al.*, 2008). The total estimated recreational catch from boat and shore-based fishers in Western Australia in 2000/01 was estimated to be 523 t (Henry and Lyle, 2003). An estimated 4.1 t was retained within South Coast estuaries in 2002/03 (Smallwood and Sumner, 2007). See also Lenanton and Hall (1976), Ayvazian *et al.* (1997), Harvey (2004), Smallwood *et al.* (2006) and Smallwood *et al.* (2012).

**Commercial:** The total catch of this species by commercial fishers in Western Australia has declined from a peak catch of 1,537 t in 1991, to a historic low of 147 t in 2011 (Smith *et al.*, 2012b). Since 2000, 83% of catch was taken in the South Coast bioregion with the remaining 17% in the West Coast bioregion (Smith *et al.*, 2012b). A complete catch trend graph is shown in the 2010/11 State of the Fisheries and Aquatic Resources Report. From 2008 to 2011, landings of this species in South Australia have comprised 43% of the national catch (Smith *et al.*, 2012b). Large fluctuations in the commercial catch probably reflect levels of targeting by commercial fishers, and annual recruitment variability (influenced by the strength of the Leeuwin current) (Jones and Nowara, 2000; Smith *et al.*, in press). See also Gaughan *et al.* (2006).

## Management regulations

**Recreational:** Currently included in the “all other species of finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1913)	-	152	
Statewide (1937)	-	178	
Statewide (1991)	40	-	
West Coast (2009)	30	-	

**Commercial:** South Coast and West Coast nearshore and estuarine fisheries are managed primarily through input controls (limited entry, gear restrictions, spatial and temporal closures) (Smith *et al.*, 2012a; Smith *et al.*, 2012b). A minimum legal size limit of 180 mm was removed in 2011. See also Ayvazian *et al.* (2000) and Smith *et al.* (in press).

**Current research:** Stock assessment (Fletcher and Santoro, 2012). Ongoing data collection occurs through commercial logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

## References

- Ayvazian, S., Lenanton, R., Wise, B., Steckis, R., Nowara, G., 1997. Western Australian Salmon and Australian herring creel survey. Fisheries Western Australia. Perth, Western Australia. FRDC Project No. 93/79. pp. 93.
- Ayvazian, S. G., Bastow, T. P., Edmonds, J. S., How, J., Nowara, G. B., 2004. Stock structure of Australian herring (*Arripis georgiana*) in southwestern Australia. *Fisheries Research* 67, 39-53.
- Ayvazian, S. G., Jones, G. K., Fairclough, D., Potter, I. C., Wise, B. S., Dimmlich, W. F., 2000. Stock assessment of Australian herring. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 96/105. pp. 225.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairclough, D. V., Dimmlich, W. F., Potter, I. C., 2000a. Length and age comparisons and growth rates of the Australian herring *Arripis georgiana* in different regions. *Marine and Freshwater Research* 51, 631-640.
- Fairclough, D. V., Dimmlich, W. F., Potter, I. C., 2000b. Reproductive biology of the Australian herring *Arripis georgiana*. *Marine and Freshwater Research* 51, 619-630.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gaughan, D. J., Ayvazian, S., Nowara, G., Craine, M., Brown, J., 2006. The development of a rigorous sampling program for a long term annual index of recruitment for finfish species from south-western Australia. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 1999/153, Fisheries Research Report No. 154. pp. 135.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Harvey, M. J., 2004. An evaluation of Western Australian recreational fishing regulations with a case study from a metropolitan boat ramp, Honours thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 97.
- Henry, G. W., Lyle, J. M. (eds) 2003. The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forest, Canberra, Australia.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Jones, G. K., Nowara, G. B., 2000. Fishery-dependent and independent factors affecting commercial catches of Australian herring (*Arripis georgiana*) in southern Australian waters, In Stock assessment of Australian herring. Ayvazian, S. G., Jones, G. K., Fairclough, D., Potter, I. C., Wise, B. S., Dimmlich, W. F. (eds), Western Australian Department of Fisheries, FRDC Project No. 96/105, Perth, Western Australia, pp. 151-163.
- Lenanton, R. C. J., 1978. Age, spawning time and fecundity of Australian herring (*Arripis georgianus* C. & V.) (Pisces: Arripidae) from the waters around Rottnest Island, Western Australia. *Australian Journal of Marine and Freshwater Research* 29, 599-612.
- Lenanton, R. C. J., 1982. Alternative non-estuarine nursery habitats for some commercially and recreationally important fish species of south-western Australia. *Australian Journal of Marine and Freshwater Research* 33, 881-900.
- Lenanton, R. C. J., Hall, N. G., 1976. The Western Australian amateur fishery for Australian herring (*Arripis georgianus*): results of the 1973 creel census. Western Australian Department of Fisheries. Perth. Fisheries Report No. 25. pp. 59.
- Lenanton, R. C. J., Robertson, A. I., Hansen, J. A., 1982. Nearshore accumulations of detached macrophytes as nursery areas for fish. *Marine Ecology Progress Series* 9, 51-57.
- Moore, G., 2011. Aspects of the evolutionary history of a pair of fish species (Arripidae: Arripis) on either side of a biogeographic barrier in southern Australian seas, PhD thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 229.

- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Orr, P., 2000. The biology of four commercial fish species in a seasonally closed estuary, PhD thesis, Murdoch University, Perth, Western Australia. pp. 275.
- Potter, I. C., Chuwen, B. M., Hesp, S. A., Hall, N. G., Hoeksema, S. D., Fairclough, D. V., Rodwell, T. M., 2011. Implications of the divergent use of a suite of estuaries by two exploited marine fish species. *Journal of Fish Biology* 79, 662-691.
- Smallwood, C. B., Beckley, L. E., Sumner, N. R., 2006. Shore-based recreational angling in the Rottne Island Reserve, Western Australia: spatial and temporal distribution of catch and fishing effort. *Pacific Conservation Biology* 12, 238-51.
- Smallwood, C. B., Pollock, K. H., Wise, B. S., Hall, N. G., Gaughan, D. J., 2012. Expanding roving-aerial surveys to include counts of recreational shore fishers from remotely-operated cameras: benefits, limitations and cost-effectiveness. *North American Journal of Fisheries Management* 32, 1265-1276.
- Smallwood, C. B., Sumner, N. R., 2007. A 12-month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002/03. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 159. pp. 56.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012a. South Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Smith, K., Brown, J., Howard, A., Walshe, K., Fissioli, J., 2012b. West Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 80-97.
- Smith, K. A., Brown, J., Lewis, P., Dowling, C., Howard, A., Lenanton, R., in press. Status of nearshore finfish stocks in south-western Western Australia: Australian herring and tailor. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. xx. pp. xx.
- Sumner, N. R., Williamson, P. C., 1999. A 12-month survey of coastal recreational boat fishing between Augusta and Kalbarri on the west coast of Western Australia during 1996-97. Western Australian Department of Fisheries. Fisheries Research Report No. 117. pp. 52.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Thomson, J. M., 1957. The food of Western Australian estuarine fishes. *Western Australian Fisheries and Fauna Department Bulletin* 7, 1-13.
- Valesini, F. J., Potter, I. C., Platell, M. E., Hyndes, G. A., 1997. Ichthyofaunas of a temperate estuary and adjacent marine embayment: implications regarding choice of nursery area and influence of environmental changes. *Marine Biology* 128, 318-328.
- Walker, M. H., Clarke, D. P., 1987. The Australian herring fishery in Western Australia, 1973-1985. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Wallace, J. H., 1976. The food of the fish in the Blackwood River estuary. Environmental Protection Authority. Perth, Western Australia. Environmental Protection Authority Technical Report No. 5. pp. 8.
- Wise, B. S., Hall, N. G., 2000. Stock assessment of Australian herring (*Arripis georgiana*), In Stock assessment of Australian herring. Ayvazian, S. G., Jones, G. K., Fairclough, D., Potter, I. C., Wise, B. S., Dimmlich, W. F. (eds), Western Australian Department of Fisheries, FRDC Project No. 96/105, Perth, Western Australia, pp. 165-201.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## **Black bream (*Acanthopagrus butcheri*)**

Reviewed by Ben Chuwen (Institute for Marine and Antarctic Studies)



**Scientific name:** *Acanthopagrus butcheri* (Sparidae; Sea breams)

**Common names:** Black bream

**Key identifying features:** Upper body often has a blackish hue, anal and pelvic fins are grey-brown, and a small black spot is present at base of pectoral fin (Yearsley *et al.*, 2001).

### **Distribution of species**

**Worldwide:** Endemic to southern Australia.

**Western Australia:** Southern Western Australian border to Shark Bay (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 530 mm, 3.45 kg (Hutchins and Thompson, 1983), 31 years (Jenkins *et al.*, 2006; Potter *et al.*, 2008).

**Length/weight relationships:** [Swan River]  $\log_{10} W = -5.07 + 3.14 * \log_{10} TL$  ( $n=1,790$ ,  $R^2=0.99$ ) (Sarre and Potter, 2000). For other relationships, see Sarre and Potter (2000).

TL (mm)	200	300	400
Weight (g)	143	511	1,260

**Length relationship:** Not reported.

**Growth:** [Swan River] Females  $L_{\infty}=438$  mm,  $k=0.30$  year<sup>-1</sup>,  $t_0=0.13$  years ( $n=733$ ,  $R^2=0.94$ )  
Males  $L_{\infty}=419$  mm,  $k=0.31$  year<sup>-1</sup>,  $t_0=0.15$  years ( $n=894$ ,  $R^2=0.94$ ) (Sarre and Potter, 2000).

Age (years)	2	6	10
Females, TL (mm)	207	368	417
Males, TL (mm)	204	357	401

Growth is highly variable between estuaries and can change markedly in the same estuary (Morrison *et al.*, 1998; Sarre and Potter, 2000; Cottingham, 2008). Growth not strongly influenced by genetics (Partridge *et al.*, 2004), but is apparently influenced strongly by density-dependent factors (Cottingham, 2008; Gardner *et al.*, 2010; Gardner *et al.*, in press). See also Sarre and Potter (2000), Hoeksema *et al.* (2006a) and Chuwen (2009) for growth parameters in other Western Australian estuaries.

**Reproductive style:** Rudimentary hermaphrodite, multiple spawner (Sarre and Potter, 1999). Individuals of this species in New South Wales were reported to exhibit different forms of hermaphroditism, including protogyny, depending on environmental conditions (Rowland and Snape, 1994).

**Length and age at maturity:** [Swan River] Females  $L_{50} = 217.8$  mm,  $A_{50} = 2.2$  years; Males  $L_{50} = 211.9$  mm,  $A_{50} = 2.1$  years (Sarre and Potter, 1999). See also Thomson (1957) and Chuwen (2009).

**Adult sex ratio:** [Swan River, seine net] F1.25:M1 (Sarre and Potter, 1999; 2000).

**Length and age at sex change:** Not applicable.

**Spawning season:** [Swan River] Spring to early summer, in widely ranging salinities of ~0 to 45 (Sarre and Potter, 1999). See also Sarre and Potter (1999) and Chuwen (2009).

**Spawning location and habitat:** Typically in upper reaches of estuaries (Sarre and Potter, 1999).

**Fecundity:** [Swan River] Determinate. Annual fecundity estimates;  $\log_{10} F = -4.65 + 4.25 * \log_{10} TL$  ( $n=25$ ,  $R^2=0.87$ ) (Sarre and Potter, 1999). See also Thomson (1959) and Holt (1978).

TL (mm)	200	300	400
Fecundity (eggs)	134,703	754,684	2,563,038

**Spawning frequency:** Not reported.

### Development and habitat use

**Eggs:** Pelagic, upper reaches of rivers and estuaries (Lenanton, 1977; Neira *et al.*, 1998).

**Larvae:** Coastal lakes, rivers and estuaries (Noriss *et al.*, 2002). Description of larval stages (Neira *et al.*, 1998).

**Juveniles:** Coastal lakes, rivers, estuaries (shallower regions of upper or middle reaches) and occasionally coastal marine waters (Noriss *et al.*, 2002; Smith, 2006).

**Adults:** Coastal lakes, rivers, estuaries and occasionally coastal marine waters. An estuarine species, *i.e.* it typically completes its life cycle in estuaries (Potter and Hyndes, 1999; Smith, 2006).

**Migrations:** Moves upstream into rivers to breed during summer (Sarre and Potter, 1999), although there is evidence of residency by some adult fish (Smith, 2006). Evidence of movement of individuals into nearshore waters at night (Young *et al.*, 1997) and away from highly saline areas (Young and Potter, 2002). [Victoria] Frequently undertakes movements  $>30$  km day<sup>-1</sup> (Hindell *et al.*, 2008); [South Australia] Individuals within a population often exhibit different migratory behaviours (Elsdon and Gillanders, 2005); [Tasmania] Prefer brackish waters (Sakabe and Lyle, 2010).

**Stock delineation:** Local populations in eastern and western Australia are genetically distinct (Farrington *et al.*, 2000), while those in individual estuaries in Western Australia are also genetically distinct (Chaplin *et al.*, 1998). [Eastern Australia] Genetic divergence positively correlated with distance (Burrige and Versace, 2007). Hybridisation between *A. butcheri* and *A. australis* is common in some estuaries (Rowland, 1984; Roberts *et al.*, 2008).

**Diet:** Opportunistic carnivore which feeds on shellfish, worms, crustaceans, small fish and algae (Wallace, 1976; Holt, 1978; Sarre *et al.*, 2000a; Chuwen *et al.*, 2007).

### Fishery

**Recreational:** Targeted by shore and boat-based rod and line fishers in rivers and estuaries in the West Coast and South Coast bioregions (Malseed *et al.*, 2000; Malseed and Sumner, 2001b; a; Smallwood and Sumner, 2007). It is the most commonly-retained fish species in the Swan-Canning Estuary (Smith, 2006). Some recreational netting was also undertaken in these areas (Heald, 1984).

**Commercial:** Important commercial species in Western Australia (Lenanton and Potter, 1987;

Smith, 2006). Frequently caught in the West Coast and South Coast estuarine finfish fisheries, including the South Coast Managed Fishery, using gill nets and haul nets (Smith *et al.*, 2012a; Smith *et al.*, 2012b). The number of commercial fishers catching black bream has declined markedly in many estuaries. For example, in the Swan-Canning Estuary, up to 130 fishers were engaged in commercial fishing in 1919. The number of registered vessels declined from ~ 30 vessels in the 1960s-70s to 4 vessels in 2000-2004 (Lenanton, 1978; Lenanton *et al.*, 1984; Smith, 2006) and commercial activity is now negligible (Smith *et al.*, 2012b).

**Age at full recruitment:** Not reported.

**Gear selectivity parameters:** [South Coast estuaries]. Gillnet selectivity parameters for the method of Kirkwood and Walker (1984) were  $\theta_1=3.10$ ,  $\theta_2=1506.30$ . Total length ranges for which relative selectivity was  $> 0.2$  were 80-189 mm (35 mm mesh), 100 – 239 mm (51 mm mesh), 130 – 269 mm (63 mm mesh), 170 – 309 mm (76 mm mesh), 210 – 349 mm (89 mm mesh), 250 – 279 mm (102 mm mesh) and 290 – 409 mm (115 mm mesh) (Chuwen, 2009).

### Management parameters

**Total mortality:** [Wellstead Estuary, Poisson regression] 0.25 year<sup>-1</sup> (Chuwen, 2009). See also Chuwen (2009) for estimates at other locations.

**Natural mortality:** [Hoenig's (1983) equation for fish] 0.134 year<sup>-1</sup> (Chuwen, 2009).

**Fishing mortality:** 0.116 year<sup>-1</sup> (*i.e.*,  $F=Z-M$ ).

**Biological reference points:**  $F_{0.1}=0.173$  year<sup>-1</sup> (Penn, 2000).

**Current status:** Stock status listed as acceptable in most estuaries of the West Coast and South Coast bioregion, where assessed (Smith *et al.*, 2012a; Smith *et al.*, 2012b). Evidence of increased abundance in shallow nearshore waters and reduced abundance in deeper, offshore waters in the Swan River since 1990 (Smith, 2006; Cottingham, 2008). Recent estimates of  $Z$  by Chuwen (2009) were highest for south coast estuaries where commercial fishing was greatest (Wilson Inlet and Oyster Harbour), and least for an estuary that has been closed to commercial fishing for more than 20 years (Wellstead Estuary). An indicator species for the estuarine suite in the West Coast and South Coast bioregions (DoF, 2011). Overall risk to sustainability for the estuarine suite is moderate in the South Coast and West Coast bioregion (DoF, 2011). Inherent vulnerability of the species and current risk to wild stock is moderate (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

**Recreational:** The total catch from recreational fishers in the West Coast bioregion was estimated to be 24 t in 2000/01 (Henry and Lyle, 2003). Several studies also estimated the recreational catch of this species in specific estuaries, including 0.53 t in the Peel-Harvey Estuary in 1998/99, (Malseed and Sumner, 2001a), and 0.31 t in the Swan-Canning Estuary in 1998/99 (Malseed and Sumner, 2001b). The total estimated recreational catch from estuaries in the South Coast bioregion was 28 t in 2000/01 (Henry and Lyle, 2003) and 23.3 t in 2002/03 (Smallwood and Sumner, 2007). It is the most commonly retained fish species by recreational fishers in Swan-Canning Estuary (Smith, 2006).

**Commercial:** A total of 53 t of this species was taken by commercial fishers in Western Australia in 2010/11 (Fletcher and Santoro, 2012). From 2001 to 2010, 93% was caught in the South Coast bioregion (mostly at Beaufort Inlet, Stokes Inlet, Wilson Inlet and Oyster Harbour) with the remaining 7% in the West Coast bioregion (mostly in the Swan Canning Estuary) (Smith *et al.*, 2012b). Total catch of this species from estuarine fisheries in the West

Coast bioregion has remained relatively static with 0.9 t in 2007 and 0.7 t in 2011, with a high of 2.6 t in 2010 (Smith *et al.*, 2012b). A complete catch trend graph is shown in the 2010/11 State of the Fisheries and Aquatic Resources Report. In 2011, a total of 44 t was taken from the South Coast bioregion, with a low of 30 t in 2000 and a peak of 70 t in 1993 (Smith *et al.*, 2012a). Considered heavily depleted in 1990s in the Blackwood River Estuary (Lenanton, 1977; Valesini *et al.*, 1997; Lenanton *et al.*, 1999) prior to restocking in 2002/03 (Potter *et al.*, 2008).

## Management regulations

**Recreational:** Currently listed in the “nearshore/estuarine finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1913)	-	200	
Statewide (1937)	-	240	
Statewide (1975)	-	250	
Statewide (1986)	30	250	
Statewide (1991)	20	250	
Statewide (2000)	20	250	Swan-Canning bag limit = 8 fish
West Coast (2003)	4	250	Swan-Canning = only 2 fish >400 mm
South Coast (2005)	8	250	
Statewide (2013)	6	250	Swan-Canning = only 2 fish >400 mm

**Commercial:** West Coast and South Coast estuarine finfish fisheries are regulated using various input controls (such as limited entry and gear restrictions) as well as seasonal and temporal closures, and size limits (Smith *et al.*, 2012a; Smith *et al.*, 2012b).

**Current research:** Temporal changes in growth and productivity (Alan Cottingham, PhD, Murdoch University) and restocking (Murdoch University/Challenger Institute of Technology). Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/ other published information:** *Aquaculture* (Haddy and Pankhurst, 2000; Sarre *et al.*, 2000b; Doupe *et al.*, 2003; Sarre *et al.*, 2003; Doupe and Lymbery, 2005a; b; Gardner, 2008); *Restocking/stock enhancement* (Dibden *et al.*, 2000; Jenkins *et al.*, 2006; Gardner, 2008; Gardner *et al.*, 2010; Gardner *et al.*, in press); *Eye development* (Shand *et al.*, 1999); *Otolith vs somatic growth* (Chuwen, 2009); *Otolith chemistry* (Elsdon and Gillanders, 2004; 2005; 2006); *Genetic primers* (Yap *et al.*, 2000); *Reproductive biology* (Haddy and Pankhurst, 1998); *Age determination* (Morrison *et al.*, 1998). *Habitat re-establishment* (Hindell, 2007); *Genetics of feed conversion efficiency* (Doupe and Lymbery, 2004); *Salinity tolerance/mass mortalities* (Hoeksema *et al.*, 2006a; Hoeksema *et al.*, 2006b); *Trophic interactions* (Linke, 2011).

## References

- Burridge, C. P., Versace, V. L., 2007. Population genetic structuring in *Acanthopagrus butcheri* (Pisces: Sparidae): does low gene flow among estuaries apply to both sexes? *Marine Biotechnology* 9, 33-44.
- Chaplin, J. A., Baudains, G. A., Gill, H. S., McCulloch, R., Potter, I. C., 1998. Are assemblages of black bream (*Acanthopagrus butcheri*) in different estuaries genetically distinct? *International Journal of Salt Lake Research* 6, 303-321.
- Chuwen, B., Platell, M., Potter, I., 2007. Dietary compositions of the sparid *Acanthopagrus butcheri* in three normally closed and variably hypersaline estuaries differ markedly. *Environmental Biology of Fishes* 80, 363-376.

- Chuwen, B. M., 2009. Characteristics of the ichthyofaunas of offshore waters in different types of estuary in Western Australia, including the biology of black bream *Acanthopagrus butcheri*, PhD thesis, School of Biological Sciences, Murdoch University. Murdoch University, Perth, Western Australia. pp. 213.
- Chuwen, B. M., Hoeksema, S. D., Potter, I. C., 2009. Factors influencing the characteristics of the fish faunas in offshore, deeper waters of permanently-open, seasonally-open and normally closed estuaries. *Estuarine, Coastal and Shelf Science* 81, 279-295.
- Cottingham, A., 2008. The current state of the stock of black bream *Acanthopagrus butcheri* in the Swan-Canning Estuary, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 89.
- Dibden, C. J., Jenkins, G., Sarre, G. A., R. C. J., L., Ayvazian, S. G., 2000. The evaluation of a recreational fishing stock enhancement trial of black bream (*Acanthopagrus butcheri*) in the Swan River, Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 124. pp. 23.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Doupe, R. G., Lymbery, A. J., 2004. Indicators of genetic variation for feed conversion efficiency in black bream. *Aquaculture Research* 35, 1305-1309.
- Doupe, R. G., Lymbery, A. J., 2005a. Additive genetic and other sources of variation in growth traits of juvenile black bream *Acanthopagrus butcheri*. *Aquaculture Research* 36, 621-626.
- Doupe, R. G., Lymbery, A. J., 2005b. Genetic co-variation in production traits of sub-adult black bream *Acanthopagrus butcheri* after grow out. *Aquaculture Research* 36, 1128-1132.
- Doupe, R. G., Lymbery, A. J., Greeff, J., 2003. Genetic variation in the growth traits of straight-bred and cross bred black bream (*Acanthopagrus butcheri* Munro) at 90 days of age. *Aquaculture Research* 34, 1297-1301.
- Elsdon, T. S., Gillanders, B. M., 2004. Fish otolith chemistry influenced by exposure to multiple environmental variables. *Journal of Experimental Marine Biology and Ecology* 313, 269-284.
- Elsdon, T. S., Gillanders, B. M., 2005. Alternative life-history patterns of estuarine fish: barium in otoliths elucidates freshwater residency. *Canadian Journal of Fisheries and Aquatic Sciences* 52, 1143-1152.
- Elsdon, T. S., Gillanders, B. M., 2006. Identifying migratory contingents of fish by combining otolith Sr:Ca with temporal collections of ambient Sr:Ca concentrations. *Journal of Fish Biology* 69, 643-657.
- Farrington, L. W., Austin, C. M., Coutin, P. C., 2000. Allozyme variation and stock structure in the black bream, *Acanthopagrus butcheri* (Munro) (Sparidae) in southern Australia: implications for fisheries management, aquaculture and taxonomic relationship with *Acanthopagrus australis* (Gunther). *Fisheries Management and Ecology* 7, 265-279.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gardner, M. J., 2008. Comparison of the genetics and biology of restocked vs wild black bream, *Acanthopagrus butcheri*, in the Blackwood Estuary, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 139.
- Gardner, M. J., Cottingham, A., Hesp, S. A., Chaplin, J. A., Jenkins, G. I., Phillips, N. M., Potter, I. C., in press. Biological and genetic characteristics of restocked and wild *Acanthopagrus butcheri* (Sparidae) in a south-western Australian estuary. *Reviews in Fisheries Science* xx, xx-xx.
- Gardner, M. J., Cottingham, A., Phillips, N. M., Hesp, S. A., Chaplin, J. A., Jenkins, G. I., 2010. Biological performance and genetics of restocked and wild black bream in the Blackwood River estuary. Murdoch University & Challenger TAFE. Perth, Western Australia. Report to the West Australian Fish Foundation and Western Australian Department of Fisheries. pp. 60.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.

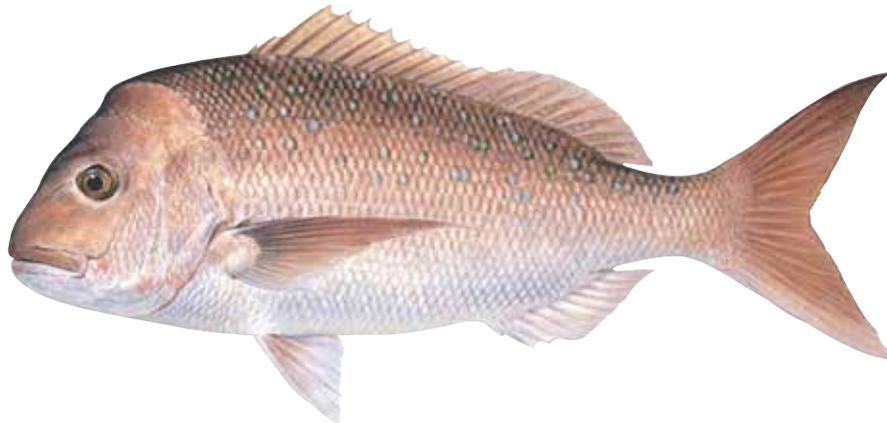
- Haddy, J. A., Pankhurst, N. W., 1998. Annual change in reproductive condition and plasma concentrations of sex steroids in black bream, *Acanthopagrus butcheri* (Munro) (Sparidae). *Marine and Freshwater Research* 49, 389-397.
- Haddy, J. A., Pankhurst, N. W., 2000. The effects of salinity on reproductive development, plasma steroid levels, fertilisation and egg survival in black bream *Acanthopagrus butcheri*. *Aquaculture* 188, 115-131.
- Heald, D. I., 1984. Amateur net fishing survey of two Western Australian south coast estuaries in January 1981. Western Australian Department of Fisheries. Perth, Western Australia. Report No. 60. pp. 63.
- Henry, G. W., Lyle, J. M. (eds) 2003. The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forest, Canberra, Australia.
- Hindell, J. S., 2007. Determining patterns of use by black bream *Acanthopagrus butcheri* (Munro, 1949) of re-established habitat in a south-eastern Australian estuary. *Journal of Fish Biology* 71, 1331-1346.
- Hindell, J. S., Jenkins, G. P., Womersley, B., 2008. Habitat utilisation and movement of black bream *Acanthopagrus butcheri* (Sparidae) in an Australian estuary. *Marine Ecology Progress Series* 366, 219-229.
- Hoeksema, S. D., Chuwen, B. M., Hesp, S. A., Hall, N. G., Potter, I. C., 2006a. Impact of environmental changes on the fish faunas of Western Australian south-coast estuaries. Murdoch University. Perth, Western Australia. FRDC Project No. 2002/017.
- Hoeksema, S. D., Chuwen, B. M., Potter, I. C., 2006b. Massive mortalities of the black bream *Acanthopagrus butcheri* (Sparidae) in two normally-closed estuaries, following extreme increases in salinity. *Journal of the Marine Biological Association of the United Kingdom* 86, 893-897.
- Hoenig, J., 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82, 898-903.
- Holt, C. P., 1978. The biology of three teleost species in the Swan Rivery Estuary, Honours thesis, Murdoch University, Perth, Western Australia. pp. 50.
- Hutchins, B., Thompson, M., 1983. The marine and estuarine fishes of south-western Australia: a field guide for anglers and divers. Western Australian Museum, Perth, Western Australia.
- Jenkins, G. I., French, D. J. W., Potter, I. C., de Lestang, S., Hall, N. G., Partridge, G. J., Hesp, S. A., Sarre, G. A., 2006. Restocking the Blackwood River Estuary with the black bream *Acanthopagrus butcheri*. Aquaculture Development Unit, Challenger TAFE and Murdoch University. Perth, Western Australia. FRDC Project No. 2000/180. pp. 84.
- Kirkwood, G. P., Walker, M. H., 1984. A new method for estimating tag shedding rates, with application to data for Australian salmon, *Arripis trutta esper* Whitley. *Australian Journal of Marine and Freshwater Research* 35, 601-606.
- Lenanton, R. C., Ayzavian, S. G., Dibden, C. J., Jenkins, G., Jenkins, J., Sarre, G. A., 1999. The use of stock enhancement to improve the catch rates of black bream, *Acanthopagrus butcheri* (Munro) for Western Australian recreational fishers, In Stock enhancement and sea ranching. Howell, B. R., Moksness, E., Syasand, T. (eds), Fishing News Books, London, UK, pp. 219-230.
- Lenanton, R. C. J., 1977. Aspects of the ecology of fish and commercial crustaceans of the Blackwood River estuary Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Bulletin of Western Australia No. 19. pp. 72.
- Lenanton, R. C. J., 1978. Fish and exploited crustaceans of the Swan-Canning estuary. Western Australian Department of Fisheries and Wildlife. Perth, Western Australia. Western Australian Department of Fisheries and Wildlife Report No. 35. pp. 36.
- Lenanton, R. C. J., Potter, I. C., 1987. Contribution of estuaries to commercial fisheries in temperate Western Australia and the concept of estuarine dependence. *Estuaries* 10, 28-35.
- Lenanton, R. C. J., Potter, I. C., Loneragan, N. R., Chrystal, P. J., 1984. Age structure and changes in abundance of three important species of teleost in a eutrophic estuary (Pisces: Teleostei). *Journal of Zoology, London* 203, 311-327.
- Linke, T. E., 2011. Trophic interactions among abundant members of the fish fauna in a permanently-open and a seasonally-open estuary in south-western Australia, PhD thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 241.

- Malseed, B. E., Sumner, N. R., 2001a. A 12-month survey of recreational fishing in the Peel-Harvey Estuary of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 127. pp. 48.
- Malseed, B. E., Sumner, N. R., 2001b. A 12-month survey of recreational fishing in the Swan-Canning Estuary basin of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 126. pp. 44.
- Malseed, B. E., Sumner, N. R., Williamson, P. C., 2000. A 12-month survey of recreational fishing in the Leschenault Estuary of Western Australia during 1998. Western Australian Department of Fisheries. Perth, Western Australia. pp. 36.
- Morrison, A. K., Coutin, P. C., Robertson, S. G., 1998. Age determination of black bream, *Acanthopagrus butcheri* (Sparidae), from the Gippsland Lakes of south-eastern Australia indicates slow growth and episodic recruitment. *Marine and Freshwater Research* 49, 491-498.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Noriss, J. V., Tregonning, J. E., Lenanton, R. C. J., Sarre, G. A., 2002. Biological synopsis of the black bream *Acanthopagrus butcheri* (Munro) (Teleostei: Sparidae) in Western Australia with reference to information from other southern states. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 93. pp. 48.
- Partridge, G. J., Sarre, G. A., Hall, N. G., Jenkins, G. I., Chaplin, J. A., Potter, I. C., 2004. Comparisons between the growth of *Acanthopagrus butcheri* cultured from broodstock from two isolated estuarine populations that are reproductively isolated and differ markedly in growth rate. *Aquaculture* 231, 51-58.
- Penn, J. W. (ed) 2000. State of the Fisheries Report 1999/2000, Perth, Western Australia.
- Potter, I. C., French, D. J. W., Jenkins, J. I., Hesp, S. A., Hall, N. G., de Lestang, S., 2008. Comparisons of the growth and gonadal development of otolith-stained, cultured black bream, *Acanthopagrus butcheri*, in an estuary with those of its wild stock. *Reviews in Fisheries Science* 16, 303-315.
- Potter, I. C., Hyndes, G. A., 1999. Characteristics of the ichthyofaunas of southwestern Australian estuaries, including comparisons with holarctic estuaries and estuaries elsewhere in temperate Australia: a review. *Australian Journal of Ecology* 24, 395-421.
- Roberts, D. G., Gray, C. A., West, R. J., Ayre, D. J., 2008. Evolutional impacts of hybridization and interspecific gene flow in an obligately estuarine fish. *Journal of Evolutionary Biology* 22, 27-35.
- Rowland, S. J., 1984. Hybridization between the estuarine fishes yellowfin bream, *Acanthopagrus australis* (Günther), and black bream, *A. butcheri* (Munro) (Pisces: Sparidae). *Australian Journal of Marine and Freshwater Research* 35, 427-440.
- Rowland, S. J., Snape, R., 1994. Labile protogynous hermaphroditism in the black bream *Acanthopagrus butcheri* (Munro) (Sparidae). *Proceedings of the Linnean Society of New South Wales* 114, 225-232.
- Sakabe, R., Lyle, J. M., 2010. The influence of tidal cycles and freshwater inflow on the distribution and movement of an estuarine resident fish *Acanthopagrus butcheri*. *Journal of Fish Biology* 77, 643-660.
- Sarre, G. A., Partridge, G. J., Jenkins, G. I., Potter, I. C., Tiiväl, D. J., 2003. Factors required for the successful aquaculture of black bream (*Acanthopagrus butcheri*) in inland water bodies. Perth, Western Australia. FRDC Project No. 1999/320.
- Sarre, G. A., Platell, M. E., Potter, I. C., 2000a. Do the dietary compositions of *Acanthopagrus butcheri* in four estuaries and a coastal lake vary with body size and season within and amongst these water bodies? *Journal of Fish Biology* 56, 103-122.
- Sarre, G. A., Partridge, G. J., Lenanton, R. C. J., Jenkins, G. I., Potter, I. C., 2000b. Elucidation of the characteristics of inland fresh and saline water bodies that influence growth and survival of black bream. Perth, Western Australia. FRDC Project No. 97/309.
- Sarre, G. A., Potter, I. C., 1999. Comparisons between the reproductive biology of black bream *Acanthopagrus butcheri* (Teleostei: Sparidae) in four estuaries with widely differing characteristics. *International Journal of Salt Lake Research* 8, 179-210.

- Sarre, G. A., Potter, I. C., 2000. Variation in age compositions and growth rates of *Acanthopagrus butcheri* (Sparidae) among estuaries: some possible contributing factors. *Fishery Bulletin* 98, 785-799.
- Shand, J., Archer, M. A., Collin, S. P., 1999. Ontogenetic changes in the retinal photoreceptor mosaic in a fish, the Black Bream, *Acanthopagrus butcheri*. *The Journal of Comparative Neurology* 412, 203-217.
- Smallwood, C. B., Sumner, N. R., 2007. A 12-month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002/03. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 159. pp. 56.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012a. South Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Smith, K., Brown, J., Howard, A., Walshe, K., Fissioli, J., 2012b. West Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 80-97.
- Smith, K. A., 2006. Review of fishery resources and status of key fishery stocks in the Swan-Canning Estuary. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 156. pp. 84.
- Thomson, J., 1959. Some aspects of the ecology of Lake Macquarie, N.S.W., with regard to an alleged depletion of fish. XII. Summery Review. *Marine and Freshwater Research* 10, 399-408.
- Thomson, J. M., 1957. The size at maturity and spawning times of some Western Australian estuarine fishes. Western Australian Department of Fisheries. Perth, Western Australia. Fishery Bulletin of Western Australia No. 8. pp. 8.
- Valesini, F. J., Potter, I. C., Platell, M. E., Hyndes, G. A., 1997. Ichthyofaunas of a temperate estuary and adjacent marine embayment: implications regarding choice of nursery area and influence of environmental changes. *Marine Biology* 128, 318-328.
- Wallace, J. H., 1976. The food of the fish in the Blackwood River estuary. Environmental Protection Authority. Perth, Western Australia. Environmental Protection Authority Technical Report No. 5. pp. 8.
- Yap, E. S., Spencer, P. B. S., Chaplin, J. A., Potter, I. C., 2000. The estuarine teleost, *Acanthopagrus butcheri* (Sparidae), shows low levels of polymorphism at five microsatellite loci. *Molecular Ecology* 9, 2224-2225.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.
- Young, G. C., Potter, I. C., 2002. Influence of exceptionally high salinities, marked variations in freshwater discharge and opening of estuary mouth on the characteristics of the ichthyofauna of a normally-closed estuary. *Estuarine, Coastal and Shelf Science* 55, 223-246.
- Young, G. C., Potter, I. C., Hyndes, G. A., de Lestang, S., 1997. The ichthyofauna of an intermittently open estuary: implications of bar breaching and low salinities on faunal composition. *Estuarine, Coastal and Shelf Science* 45, 53-68.

## Pink snapper (*Pagrus auratus*)

Reviewed by Gary Jackson and Corey Wakefield (DoF)



**Scientific name:** *Pagrus auratus* (Sparidae; Sea breams). Note: same scientific name is used for the species in Queensland, New South Wales and New Zealand while confusingly, *Chrysophrys auratus*, is used in Victoria and South Australia (SA) (Gomon *et al.*, 2008).

**Common names:** Pink snapper *also* pinkie and snapper (elsewhere in Australia).

**Key identifying species:** Upper body is pale pink to dark red often with turquoise-blue spots (can be particularly pronounced in juveniles). Adult males may have prominent lump on forehead (Moran *et al.*, 1998), enlarged canine teeth at front (Yearsley *et al.*, 2001).

### Distribution of species

**Worldwide:** Widely distributed throughout the western Indo-Pacific, from around southern Australia and northern New Zealand to China and Japan (Paulin, 1990).

**Western Australia:** Southern Western Australian border to Onslow (Gomon *et al.*, 2008).

**Maximum length, weight and age:** [Australia] 1,300 mm, 20 kg (Gomon *et al.*, 2008), 41 years (Norriss and Crisafulli, 2010); [New Zealand] 55 – 60 years (Horn, 1986; Francis *et al.*, 1992a).

**Length/weight relationship:** [West Coast and South Coast bioregion]  $W=0.0000561 * FL^{2.827}$  (Wakefield, 2006). See also Moran and Burton (1990) and Jackson *et al.* (2010).

FL (mm)	400	600	800
Weight (g)	1,273	4,007	9,038

**Length relationship:** [West Coast and South Coast bioregion] Females  $FL=0.897*TL-23.058$  ( $n=1,385$ ,  $R^2=0.996$ ); Male  $FL=0.892*TL-23.797$  ( $n=1236$ ,  $R^2=0.995$ ) (Wakefield, 2006).

Sexes combined:  $TL=1.133*FL+13.198$  (Wise *et al.*, 2007). See also Moran and Burton (1990).

**Growth:** [Perth] Females  $L_{\infty}=1,150$  mm,  $k=0.12$  year<sup>-1</sup>,  $t_0=0.41$  years ( $n=872$ ,  $R^2=0.89$ );

Males  $L_{\infty}=1,127$  mm,  $k=0.12$  year<sup>-1</sup>,  $t_0=0.46$  years ( $n=793$ ,  $R^2=0.88$ ) (Wakefield, 2006). See also Tapp (2003), Wakefield (2006), St John *et al.* (2007), Jackson (2007), Jackson *et al.* (2010) and [New Zealand] Sim-Smith *et al.* (2011). Juvenile growth varies seasonally, related to temperature (Lenanton, 1974).

Age (years)	5	10	15
Females, TL (mm)	549	820	969
Males, TL (mm)	542	806	951

**Reproductive style:** [New Zealand] Functional gonochorist (Francis and Pankhurst, 1988). Serial batch spawner (Crossland, 1977a; Saunders *et al.*, 2012).

**Adult sex ratio:** [Perth, commercial and recreational line fishers] F1:M1 (Wakefield, 2006). See also Jackson *et al.* (2011).

**Length and age at sex change:** Not applicable.

**Spawning season:** Season varies with geographic location: late-autumn through to early spring in Shark Bay region (Moran *et al.*, 2003; Wakefield, 2006; Jackson *et al.*, 2010; Wakefield *et al.*, in prep), spring and summer on west coast, and summer on south coast (Wakefield, 2006; 2010; Wakefield *et al.*, in prep). Spawning strongly associated with water temperature, mostly occurring between 19 – 21°C (Wakefield, 2010; Wakefield *et al.*, in prep). In Cockburn Sound, spawning occurs at night during the 3 hours after the high tide, peaking around the new and full moons (Wakefield, 2010). In Shark Bay, spawning mostly in early afternoon to late evening (Jackson and Cheng, 2001). Evidence of localized spawning omission in New Zealand (Sim-Smith *et al.*, 2011).

**Spawning location and habitat:** Spawning aggregations occur in Western Australian marine embayments and coastal areas such as Shark Bay, and in Perth Metropolitan waters, in Cockburn Sound, Owen Anchorage and Warnbro Sound (Jackson and Cheng, 2001; Moran *et al.*, 2003; Wakefield, 2006; 2010). Significant spawning along the west coast also occurs in offshore locations outside these marine embayments. Spawning aggregations also observed in Victoria (Jenkins, 1986; Coutin *et al.*, 2003; Hamer *et al.*, 2011).

**Fecundity:** [New Zealand, South Australia] Indeterminate (Scott and Pankhurst, 1992; Zeldis, 1993; Saunders *et al.*, 2012). A positive relationship exists between batch fecundity and fish size (Crossland, 1977a; Jackson, 2007). In Western Australia, batch fecundity between 2,000 – 660,000 was found for inner Shark Bay females between 172 – 725 mm FL (Mackie *et al.*, 2009). Estimates also available for South Australia (Saunders, 2009) and New Zealand (Crossland, 1977a).

**Spawning frequency:** Spawning fraction data available for inner Shark Bay (Jackson *et al.*, 2011) and Perth Metropolitan waters (Wakefield, 2006; 2010). Variation in spawning frequency found within, and between, seasons in the northern Spencer Gulf (Saunders *et al.*, 2012).

### Development and habitat use

**Eggs:** Pelagic. Eggs can be retained by eddies within embayment spawning areas (Neira *et al.*, 1998; Nahas *et al.*, 2003; Wakefield, 2010) but are transported by ocean currents in more open waters along west coast. See also [Western Australia] (Jackson and Cheng, 2001; Wakefield, 2010; Breheny *et al.*, 2012); [New Zealand] (Crossland, 1980; Zeldis, 1993; Zeldis and Francis, 1998).

**Larvae:** Often retained within spawning areas in marine embayments (Neira and Potter, 1992; Nahas *et al.*, 2003; Breheny *et al.*, 2012). Initially pelagic (Francis, 1994a; Fowler and Jennings, 2003), then settle over soft muddy bottoms at ~ 9-12 mm in length (Kingsford and Atkinson, 1994; Trnski, 2002; Breheny *et al.*, 2012). Larvae capable of diel vertical migrations for feeding (Murphy *et al.*, 2011). Use of olfactory cues (smell) to find settlement habitats shown in New Zealand (Radford *et al.*, 2012). Description of larval stages (Neira *et al.*, 1998).

**Juveniles:** Estuaries, coastal embayments and sheltered marine waters (Lenanton, 1974; Paul and Tarring, 1980; Gillanders, 2002; Wakefield, 2006; St John *et al.*, 2007; Wakefield *et al.*, 2013). In some locations (Cockburn Sound, Shark Bay) spawning areas constitute nursery areas for early juveniles. See also [Victoria] (Francis, 1995; Hamer and Jenkins, 2004; Fowler *et al.*, 2005; Hamer *et al.*, 2005; Hamer *et al.*, 2011). [New Zealand] (Francis, 1993; Thrush *et al.*, 2002; Ross *et al.*, 2007).

**Adults:** Continental shelf waters out to 300-400 m, sheltered marine embayments and coastal rocky reefs (Kailola *et al.*, 1993; Wakefield, 2006).

**Migration:** In shelf waters off the west coast, inshore-offshore migration for spawning (Moran *et al.*, 2003; Wakefield, 2006; Wise *et al.*, 2007; Wakefield *et al.*, 2011). Individual movement patterns vary with fish moving up to 33 km west off Cockburn Sound and up to 92 km north and 134 km south (Wakefield *et al.*, 2011). Distances travelled increase with increasing fish size (Wakefield *et al.*, 2011). Most fish tagged off Shark Bay were recaptured with 20 km of release with few fish moving 200-400 km (Moran *et al.*, 2003). Very limited movement inside Shark Bay (Moran and Kangas, 2003; Norriss *et al.*, 2012) and in Queensland (Moran and Kangas, 2003; Sumpton *et al.*, 2003) but up to 2,000 km in southern and eastern Australia (Sanders, 1974; Fowler *et al.*, 2005).

**Stock delineation:** [West Coast bioregion] Single genetic stock in West Coast bioregion with genetic isolation by distance (Gardner, 2011). Some mixing of juveniles, relatively limited mixing of adults (Lenanton *et al.*, 2009a; Fairclough *et al.*, 2013). In Shark Bay, there are three separate stocks within the two gulfs which are distinct from the stock in adjacent oceanic waters (Johnson *et al.*, 1986; Edmonds *et al.*, 1989; Moran *et al.*, 1998; Edmonds *et al.*, 1999; Bastow *et al.*, 2002; Moran *et al.*, 2003). Stock structure is highly complex across Australian distribution (Jackson *et al.* 2012a).

**Diet:** Ontogenetic differences in diet between juveniles and adults. Identified as feeding on crustaceans, teleosts, echinoderms and molluscs (Ang, 2003; French *et al.*, 2012). See also [New Zealand] (Coleman, 1972; Russell, 1983), [Victoria] (Winstanley, 1983), [South Australia] (Saunders, 2009).

## Fishery

**Recreational:** A highly sought after species targeted predominantly by boat-based fishers (including charter operators) in the West Coast and Gascoyne Coast bioregions, especially Shark Bay (Telfer, 2010; Fairclough *et al.*, 2012; Wise *et al.*, 2012).

**Commercial:** Species has a very long history of exploitation, particularly in Shark Bay (Marriott *et al.*, 2012). One of the key demersal target species in the West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF) (Fairclough *et al.*, 2012), the Gascoyne Demersal Scalefish Managed Fishery (GDSF) (Jackson *et al.*, 2012b). Also taken in the temperate Demersal Gillnet and Demersal Longline Fishery (DGDLF) (Fairclough *et al.*, 2012).

**Age at full recruitment:** Variable temporally and spatially (due to variability in annual recruitment, individual growth and other factors) (Lenanton *et al.*, 2009a).

**Gear selectivity parameters:** Not reported.

**Length and age at maturity:** [Perth metropolitan zone] Females  $L_{50}=585$  mm,  $L_{95}=752$  mm; Males  $L_{50}=566$  mm,  $L_{95}=730$  mm (Wakefield, 2006). See also Wakefield (2006), Lenanton *et al.* (2009b) and Jackson *et al.* (2010).

## Management parameters

**Total mortality:** 0.72 – 0.76 year<sup>-1</sup> (*i.e.*,  $Z=F+M$ )

**Natural mortality:** [Hoenig's (1983) equation for fish] 0.12 year<sup>-1</sup> (Wise *et al.*, 2007). See also Wakefield *et al.* (2007).

**Fishing mortality estimates:** [Perth metropolitan zone, recreational] 0.60 – 0.76 year<sup>-1</sup> (Wise *et al.*, 2007). See also Wise *et al.* (2007) for other site, management area and sector-specific estimates.

**Biological reference points:** [Perth Metropolitan zone]

$F_{\text{limit}} \sim 0.18 \text{ year}^{-1}$  (*i.e.*,  $F=3/2M$ )

$\text{YPR}_{\text{max}}$  at  $\sim F=0.15 \text{ year}^{-1}$

E/R, SPR=20% at  $\sim F=0.17 \text{ year}^{-1}$ , SPR 40% at  $\sim F=0.1 \text{ year}^{-1}$  (Wise *et al.*, 2007).

Mature or spawning biomass estimates available for Shark Bay stocks based on mark-recapture (Jackson *et al.*, 2005), daily egg production method (Jackson and Cheng, 2001; Jackson *et al.*, 2011) and modeling (Moran, 1992; Jackson and Cheng, 2001; Jackson *et al.*, 2005; Jackson, 2007).

**Current status:**  $F_{\text{limit}}$  exceeded in all management zones (Wise *et al.*, 2007), *i.e.* prior to management changes for offshore demersal scalefish species. Stocks now treated as recovering after the introduction of a range of management measures for the WCDSIMF during 2007- 2009 (Fairclough *et al.*, 2012). In the Gascoyne Coast bioregion, snapper stocks are either recovering or recovered following management intervention (Jackson *et al.*, 2012b; Jackson *et al.*, 2012c). An indicator species for the inshore demersal suite in the Gascoyne Coast and West Coast bioregions, and a proposed indicator species in the South Coast bioregion (DoF, 2011). Overall risk to sustainability for the inshore demersal suite is medium to high in the Gascoyne Coast, West Coast and South Coast bioregions (DoF, 2011). Inherent vulnerability of the species is moderate (West Coast, South Coast) and high (Gascoyne Coast) while the current risk to wild stock is moderate (Gascoyne Coast) and high (West Coast, South Coast) (DoF, 2011). See DoF (2011) for more detailed risk assessment data. Further detailed information on stock status for Western Australian stocks in (Jackson *et al.*, 2012a).

## Catch trends

**Recreational:** The total estimated recreational boat-based catch in the West Coast bioregion increased from 25 t in 1996/97 to 40 t in 2005/06 (Sumner *et al.*, 2008). Following the introduction of a range of management measures during 2007-2009, estimated recreational boat-based catch decreased to 24 t in 2009/10 (Fairclough *et al.*, 2012). Catch taken by charter vessels in 2010/11 was 8 t (Fairclough *et al.*, 2012). The total estimated recreational boat-based catch in the Gascoyne Coast bioregion was 30 t in 2007/08 (Jackson *et al.*, 2012b). Catch taken by charter vessels in 2010/11 was 12 t (Jackson *et al.*, 2012b).

Relatively small catches taken from the three separate stocks in the inner gulfs of Shark Bay (Jackson *et al.*, 2012c). See also (Telfer, 2010).

**Commercial:** In 2010/11, approximately 190 t of this species was taken in the West Coast bioregion, 263 t in the Gascoyne Coast Bioregion (Fairclough *et al.*, 2012; Jackson *et al.*, 2012b) and a further 40 t in the South Coast Bioregion (Molony *et al.*, 2012). A complete catch trend graph can be found in the 2010/11 State of the Fisheries and Aquatic Resources Report. See also (Jackson *et al.*, 2012a).

## Management regulations

**Recreational:** Currently listed in the “demersal finfish” category (DoF, 2013). A wide variety of recreational rules has been introduced for pink snapper (including spatial and temporal closures, maximum size limits, slot limit). Only bag limits and MLL are shown in the following table.

Bioregion (Year)	Bag limit	MLL
Statewide (1913)	-	279
Statewide (1977)	10	380
Statewide (1978)	10	380 <sup>SB</sup> , 280 <sup>SC</sup>
Statewide (1985)	10	380 <sup>WC</sup> , 280 <sup>SC</sup>
Statewide (1988)	10	410 <sup>WC</sup> , 280 <sup>SC</sup>
Statewide (1991)	8	410
Statewide (1997)	8 except where 2 <sup>EG</sup> , 4 <sup>WG</sup>	410 except where 500 <sup>EG</sup> , 450 <sup>WG</sup>
Statewide (2001)	8 except where 2 <sup>EG</sup> , 4 <sup>WG</sup>	410 except where 500 <sup>EG</sup> , 450 <sup>WG</sup> , 280 <sup>WI</sup>
West Coast (2003)	4	410
Gascoyne Coast (2004)	6 except where 1 <sup>SB</sup>	410 except where 500 <sup>SB</sup>
Gascoyne Coast (2005)	4 except where 1 <sup>SB</sup>	410 except where 500 <sup>SB</sup>
South Coast (2005)	4	410 except where 280 <sup>WI</sup>
South Coast (2007)	4	410
West Coast (2008)	2	410 except where 450 <sup>South 31S</sup>
West Coast (2009)	2	410 except where 500 <sup>South 31S</sup>
Statewide (except West Coast) (2013)	3 except where 2 <sup>SB</sup>	500

EG = Eastern Gulf of Shark Bay, WG = Western Gulf of Shark Bay, SB = Shark Bay (all gulfs), WI = Wilson Inlet, WC = West Coast, SC = South Coast, South 31S = south of 31°S latitude.

**Commercial:** Demersal scalefish fisheries (*i.e.* WCDSIMF, GDSF) in the Gascoyne Coast, West Coast and South Coast Bioregions are regulated using a range of input (restricted entry, total fishing time allocations, maximum number of lines and hooks), output controls (total allowable catch and individual quotas) and biological controls (minimum legal lengths) (Fairclough *et al.*, 2012; Jackson *et al.*, 2012b).

**Current research:** Ongoing stock status monitoring and research is being undertaken by DoF. Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published works:** *Sexual dimorphism* (Moran *et al.*, 1998); *Depletion rates from trawling* (Wakefield *et al.*, 2007); *Reproductive biology* (Mackie *et al.*, 2009), [Victoria] (Macdonald, 1982), [New Zealand] (Crossland, 1977a; b); *Biomass* [New Zealand] (Crossland, 1980; Zeldis, 1993; Zeldis and Francis, 1998); *Age and growth* [New Zealand] (Francis *et al.*, 1992a; Francis *et al.*, 1992b; Francis, 1994b), [New South Wales] (Fielder *et al.*, 2005) (Bell *et al.*, 1991; Pankhurst *et al.*, 1991; Battaglione and Talbot, 1992; Fielder *et al.*, 2005), [Global] (Kingsford and Atkinson, 1994); *Stock structure* [Victoria] (Sanders, 1974); *Stock assessment* [Queensland] (Ferrell and Sumpton, 1998), [Victoria] (Coutin *et al.*, 2003); *Survival after tagging* [New South Wales] (Quartararo and Kearney, 1996), [Queensland] (Sumpton *et al.*, 2003); *Larval distributions* [New South Wales] (Smith, 2003); *Identification of juvenile habitats from otolith isotopes* [New South Wales] (Gillanders and Kingsford, 2003); *Pagrus*

*major* [Japan] (Paulin, 1990; Tabata and Taniguchi, 2000); *Barotrauma* (Lenanton *et al.*, 2009b); *Length frequency using stereo-video techniques* (Langlois *et al.*, 2012).

## References

- Ang, H. P., 2003. Comparisons of the diets of four species of sparid on the central and lower west coast of Australia, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 59.
- Bastow, T. P., Jackson, G., Edmonds, J. S., 2002. Elevated salinity and isotopic composition of fish otolith carbonate: stock delineation of pink snapper, *Pagrus auratus*, in Shark Bay, Western Australia. *Marine Biology* 141, 801-806.
- Battaglione, S. C., Talbot, R. B., 1992. Induced spawning and larval rearing of snapper, *Pagrus auratus* (Pisces: Sparidae), from Australian waters. *New Zealand Journal of Marine and Freshwater Research* 26, 179-185.
- Bell, J. D., Quartararo, N., Henry, G. W., 1991. Growth of snapper, *Pagrus auratus*, from south-eastern Australia in captivity. *New Zealand Journal of Marine and Freshwater Research* 25, 117-121.
- Breheny, N. B., Beckley, L. E., Wakefield, C. B., 2012. Ichthyoplankton assemblages associated with pink snapper (*Pagrus auratus*) spawning aggregations in coastal embayments of southwestern Australia. *Journal of the Royal Society of Western Australia* 95, 103-114.
- Coleman, J. A., 1972. Food of snapper, *Chrysophrys auratus* (Forster), in the Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 6, 221-239.
- Coutin, P., Cashmore, S., Sivakumuran, K. P., 2003. Assessment of the snapper fishery in Victoria. Marine and Freshwater Resources Institute Melbourne, Victoria. FRDC Project No. 97/127. pp. 207.
- Crossland, J., 1977a. Seasonal reproductive cycle of snapper *Chrysophrys auratus* (Foster) in the Hauraki Gulf. *New Zealand Journal of Marine and Freshwater Research* 11, 37-60.
- Crossland, J., 1977b. Fecundity of the snapper *Chrysophrys auratus* (Pisces: Sparidae) from the Hauraki Gulf. *New Zealand Journal of Marine and Freshwater Research* 11, 767-775.
- Crossland, J., 1980. The number of snapper, *Chrysophrys auratus* (Forster), in the Hauraki Gulf, New Zealand, based on egg surveys in 1974-75 and 1975-1976. *New Zealand Research Bulletin* No. 22.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Edmonds, J. S., Moran, M. J., Caputi, N., Morita, M., 1989. Trace element analysis of fish sagittae as an aid to stock identification: pink snapper (*Chrysophrys auratus*) in Western Australian waters. *Canadian Journal of Fisheries and Aquatic Sciences* 46, 50-54.
- Edmonds, J. S., Steckis, R. A., Moran, M. J., Caputi, N., Morita, M., 1999. Stock delineation of pink snapper and tailor from Western Australia by analysis of stable isotope and strontium/calcium ratios in otolith carbonate. *Journal of Fish Biology* 53, 243-259.
- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Fairclough, D. V., Edmonds, J. S., Jackson, G., Lenanton, R. C. J., Kemp, J., Molony, B. W., Keay, I., Crisafulli, B. M., Wakefield, C. B., 2013. A comparison of the stock structures of two exploited demersal teleosts, employing complementary methods of otolith element analysis. *Journal of Experimental Marine Biology and Ecology* 439, 181-195.
- Ferrell, D. J., Sumpton, W. D., 1998. Assessment of the fishery for snapper (*Pagrus auratus*) in Queensland and New South Wales. Queensland Department of Primary Industries and New South Wales Fisheries Research Institute. pp. 143.
- Fielder, D. S., Bardsley, W. J., Allan, G. L., Pankhurst, P. M., 2005. The effects of salinity and temperature on growth and survival of Australian snapper, *Pagrus auratus* larvae. *Aquaculture* 250, 201-214.

- Fowler, A. J., Gillanders, B. M., Hall, K. C., 2005. Relationship between elemental concentration and age from otoliths of adult snapper (*Pagrus auratus*, Sparidae): implications for movement and stock structure. *Marine and Freshwater Research* 56, 661-676.
- Fowler, A. J., Jennings, P. R., 2003. Dynamics in 0+ recruitment and early life history for snapper (*Pagrus auratus*, Sparidae) in South Australia. *Marine and Freshwater Research* 54, 941-956.
- Francis, M., Williams, M., Pryce, A., Pollard, S., Scott, S., 1992b. Daily increments in otoliths of juvenile Snapper, *Pagrus auratus* (Sparidae). *Marine and Freshwater Research* 43, 1015-1032.
- Francis, M. P., 1993. Does water temperature determine year class strength in New Zealand snapper (*Pagrus auratus*, Sparidae)? *Fisheries Oceanography* 2, 65-72.
- Francis, M. P., 1994a. Duration of larval and spawning periods in *Pagrus auratus*; (Sparidae) determined from otolith daily increments. *Environmental Biology of Fishes* 39, 137-152.
- Francis, M. P., 1994b. Growth of juvenile snapper, *Pagrus auratus*. *New Zealand Journal of Marine and Freshwater Research* 28, 201-218.
- Francis, M. P., 1995. Spatial and seasonal variation in the abundance of juvenile snapper (*Pagrus auratus*) in the north-western Hauraki Gulf. *New Zealand Journal of Marine and Freshwater Research* 29, 565-579.
- Francis, M. P., Pankhurst, N. W., 1988. Juvenile sex inversion in the New Zealand snapper *Chrysophrys auratus* (Block and Schneider, 1801) (Sparidae). *Australian Journal of Marine and Freshwater Research* 39, 625-631.
- Francis, R., Paul, L., Mulligan, K., 1992a. Ageing of adult snapper (*Pagrus auratus*) from otolith annual ring counts: validation by tagging and oxytetracycline injection. *Marine and Freshwater Research* 43, 1069-1089.
- French, B., Platell, M. E., Clarke, K. R., Potter, I. C., 2012. Ranking of length-class, seasonal and regional effects on dietary compositions of the co-occurring *Pagrus auratus* (Sparidae) and *Pseudocaranx georgianus* (Carangidae). *Estuarine, Coastal and Shelf Science* 115, 309-325.
- Gardner, M. J., 2011. Genetic determination of the stock structures of pink snapper (*Pagrus auratus*) and baldchin groper (*Choerodon rubescens*) in Western Australian waters. Perth, Western Australia. WAMSI Final Report September 2011. pp. 17.
- Gillanders, B. M., 2002. Connectivity between juvenile and adult fish populations: do adults remain near their recruitment estuaries. *Marine Ecology Progress Series* 240, 115-223.
- Gillanders, B. M., Kingsford, M. J., 2003. Spatial variation in elemental composition of otoliths of three species of fish (family Sparidae). *Estuarine, Coastal and Shelf Science* 57, 1049-1064.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Hamer, P. A., Acevedo, S., Jenkins, G. P., Newman, A., 2011. Connectivity of a large embayment and coastal fishery: spawning aggregations in one bay source local and broad-scale fishery replenishment. *Journal of Fish Biology* 78, 1090-1109.
- Hamer, P. A., Jenkins, G. P., 2004. High levels of spatial and temporal recruitment variability in the temperate sparid *Pagrus auratus*. *Marine and Freshwater Research* 55, 663-673.
- Hamer, P. A., Jenkins, G. P., Gillanders, B. M., 2005. Chemical tags in otoliths indicate the importance of local and distant settlement areas to populations of a temperate sparid, *Pagrus auratus*. *Canadian Journal of Fisheries and Aquatic Sciences* 62, 623-630.
- Hoening, J., 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82, 898-903.
- Horn, P. L., 1986. Distribution and growth of snapper *Chrysophrys auratus* in the North Taranaki Bight, and management implications of these data. *New Zealand Journal of Marine and Freshwater Research* 20, 419-430.
- Jackson, G., 2007. Fisheries biology and management of pink snapper, *Pagrus auratus*, in the inner gulfs of Shark Bay, Western Australia, PhD thesis, Murdoch University, Perth, Western Australia. pp. 254.
- Jackson, G., Cheng, Y. W., 2001. Parameter estimation with egg production surveys to estimate snapper, *Pagrus auratus*, biomass in Shark Bay, Western Australia. *Journal of Agricultural, Biological and Environmental Statistics* 6, 243-257.

- Jackson, G., Cheng, Y. W., Wakefield, C. B., 2011. An evaluation of the daily egg production method to estimate spawning biomass of snapper (*Pagrus auratus*) stocks in inner Shark Bay, Western Australia, following more than a decade of surveys 1997-2007. *Fisheries Research* 117-118, 22-34.
- Jackson, G., Fowler, A., Holmes, B., Kemp, J., Stewart, J., 2012a. Snapper *Pagrus auratus*, In Status of key Australian fish stocks reports 2012. Flood, M., Stobutzki, I., Andrews, J., Begg, G., Fletcher, W., Gardner, C., Kemp, J., Moore, A., O'Brien, A., Quinn, R., Roach, J., Rowling, K., Sainsbury, K., Saunders, T., Ward, T., Winning, M. (eds), Fisheries Research and Development Corporation, Canberra, Australia, pp. 344-354.
- Jackson, G., Marriott, R., Lai, E., Lunow, C., 2012b. Gascoyne Demersal scalefish fishery status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 146-153.
- Jackson, G., Norriss, J., Lunow, C., 2012c. Inner Shark Bay scalefish fishery status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 154-160.
- Jackson, G., Norriss, J. V., Mackie, M. C., Hall, N. G., 2010. Spatial variation in life history characteristics of snapper (*Pagrus auratus*) within Shark Bay, Western Australia. *New Zealand Journal of Marine and Freshwater Research* 44, 1-15.
- Jackson, G., Sumner, N. R., Cribb, A., Norriss, J., 2005. Comparing conventional 'social-based' and alternative output-based management models for recreational finfish fisheries using Shark Bay pink snapper as a case study. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2003/066. pp. 80.
- Jenkins, G., 1986. Composition, seasonality and distribution of ichthyoplankton in Port Phillip Bay, Victoria. *Marine and Freshwater Research* 37, 507-520.
- Johnson, M. S., Creagh, S., Moraon, M., 1986. Genetic subdivision of stocks of snapper *Chrysophrys unicolor*, in Shark Bay, Western Australia. *Australian Journal of Marine and Freshwater Research* 37, 337-345.
- Kailola, P. J., Williams, M. J., Stewart, P. C., Reichelt, R. E., McNee, A., Grieve, C., 1993. Australian Fisheries Resources. Bureau of Resource Sciences and the Fisheries Research and Development Corporation. Canberra, Australia. pp. 422.
- Kingsford, M., Atkinson, M., 1994. Increments in otoliths and scales: How they relate to the age and early development of reared and wild larval and juvenile *Pagrus auratus* (Sparidae). *Marine and Freshwater Research* 45, 1007-1021.
- Langlois, T. J., Fitzpatrick, B. R., Fairclough, D. V., Wakefield, C., Hesp, A., McLean, D., Harvey, E. S., Meeuwig, J. J., 2012. Similarities between line fishing and baited stereo-video estimations of length-frequency: novel application of kernel density estimates. *PLoS One* 7, (e45973).
- Lenanton, R., St John, J., Keay, I., Wakefield, C., Jackson, G., Wise, B., Gaughan, D. J., 2009a. Spatial scales of exploitation among populations of demersal scalefish: implications for management. Part 2: stock structure and biology of two indicator species, West Australian dhufish (*Glaucosoma hebraicum*) and pink snapper (*Pagrus auratus*) in the West Coast Bioregion. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2003/052. Fisheries Research Report No. 174. pp. 187.
- Lenanton, R., St John, J., Wise, B., Keay, I., Gaughan, D. J., 2009b. Maximising survival of released undersize west coast reef fish. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2000/194, Fisheries Research Report No. 191. pp. 130.
- Lenanton, R. C. J., 1974. The abundance and size composition of trawled juvenile snapper *Chrysophrys unicolor* (Quoy and Gaimard) from Cockburn Sound, Western Australia. *Australian Journal of Marine and Freshwater Research* 25, 281-285.
- Macdonald, C. M., 1982. Life-history characteristics of snapper *Chrysophrys auratus* (Block and Schneider, 1801) in Australian waters. Ministry for Conservation, Fisheries and Wildlife. Victoria, Australia.
- Mackie, M. C., Jackson, G., Tapp, N. E., Norriss, J. V., Thomson, A., 2009. Macroscopic and microscopic description of pink snapper (*Pagrus auratus*) gonads from Shark Bay, Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 184. pp. 32.

- Marriott, R. J., Jackson, G., Lenanton, R., Stephenson, P., Lai, E., Telfer, C., Bruce, C., Wise, B. S., Adams, D. J., Norriss, J., Molony, B., 2012. Biology and stock status of key demersal species in the Gascoyne Coast bioregion. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 228. pp. 221.
- Molony, B., Lai, E., Holtz, M., 2012. South Coast demersal scalefish resource report: statistics only, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 295-297.
- Moran, M., Kangas, M., 2003. The effects of the trawl fishery on the stock of pink snapper, *Pagrus auratus*, in Denham Sound, Shark Bay. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Bulletin No. 31. pp. 52.
- Moran, M. J., 1992. Yield and egg-per-recruit models of Shark Bay snapper: a case study in justification and implementation of an increase in minimum legal length, *In* Legal sizes and their use in fisheries management. Hancock, D. A. (ed), Australian Government Publishing Service, Canberra, Australia. pp. 89-97.
- Moran, M. J., Burton, C., 1990. Relationships among partial and whole lengths and weights for Western Australian pink snapper *Chrysophrys auratus* (Sparidae). Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 89. pp. 13.
- Moran, M. J., Burton, C., Caputi, N., 1998. Sexual and location variation in head morphology of snapper, *Pagrus auratus*, Sparidae, in the Shark Bay region of Western Australia. *Marine and Freshwater Research* 50, 27-34.
- Moran, M. J., Burton, C., Jenke, J., 2003. Long-term movement patterns of continental shelf and inner gulf snapper (*Pagrus auratus*, Sparidae) from tagging in the Shark Bay region of Western Australia. *Marine and Freshwater Research* 54, 913-922.
- Murphy, H. A., Jenkins, G., Hamer, P. A., Swearer, S. E., 2011. Diel vertical migration related to foraging success in snapper *Chrysophrys auratus*. *Marine Ecology Progress Series* 433, 185-194.
- Nahas, E. L., Jackson, G., Pattiaratchi, C. B., Ivey, G. N., 2003. Hydrodynamic modelling of snapper *Pagrus auratus* egg and larval dispersal in Shark Bay, Western Australia: reproductive isolation at a fine spatial scale. *Marine Ecology Progress Series* 265, 213-226.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Neira, F. J., Potter, I. C., 1992. The ichthyoplankton of a seasonally closed estuary in temperate Australia. Does an extended period of opening influence species composition? *Journal of Fish Biology* 41, 935-953.
- Norriss, J., Crisafulli, B., 2010. Longevity in Australian snapper *Pagrus auratus* (Sparidae). *Journal of the Royal Society of Western Australia* 93, 129-132.
- Norriss, J., Moran, M., Jackson, G., 2012. Tagging studies reveal restricted movement of snapper (*Pagrus auratus*) within Shark Bay, supporting fine scale fisheries management. *Marine and Freshwater Research* 63, 1191-1199.
- Pankhurst, P., Montgomery, J., Pankhurst, N., 1991. Growth, development and behaviour of artificially reared larval *Pagrus auratus* (Bloch & Schneider, 1801) (Sparidae). *Marine and Freshwater Research* 42, 391-398.
- Paul, L. J., Tarring, S. C., 1980. Growth rate and population structure of snapper, *Chrysophrys auratus*, in the East Cape region, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 14, 237-247.
- Paulin, C. D., 1990. *Pagrus auratus*, a new combination for the species known as "snapper" in Australasian waters (Pisces: Sparidae). *New Zealand Journal of Marine and Freshwater Research* 24, 259-265.
- Quartararo, N., Kearney, R. E., 1996. Effects of dart tags on the growth and survival of captive snapper, *Pagrus auratus* (Sparidae). *Fisheries Research* 25, 231-238.
- Radford, C. A., Sim-Smith, C. J., Jeffs, A. G., 2012. Can larval snapper, *Pagrus auratus*, smell their new home? *Marine and Freshwater Research* 63, 898-904.
- Ross, P. M., Thrush, S. F., Montgomery, J. C., Walker, J. W., Parsons, D. M., 2007. Habitat complexity and predation risk determine juvenile snapper (*Pagrus auratus*) and goatfish (*Upeneichthys lineatus*) behaviour and distribution. *Marine and Freshwater Research* 58, 1144-1151.
- Russell, B. C., 1983. The food and feeding habits of rocky reef fish of north-eastern New Zealand. *New Zealand Journal of Marine and Freshwater Research* 17, 121-145.

- Sanders, M. J., 1974. Tagging indicates at least two stocks of snapper *Chrysophrys auratus* in south-east Australian waters. *New Zealand Journal of Marine and Freshwater Research* 8, 371-374.
- Saunders, R. J., 2009. The reproductive biology and recruitment dynamics of snapper, *Chrysophrys auratus*, PhD thesis, School of Earth and Environmental Sciences. University of Adelaide, Adelaide, South Australia. pp. 154.
- Saunders, R. J., Fowler, A. J., Gillanders, B. M., 2012. The spawning dynamics of snapper (*Chrysophrys auratus*) in northern Spencer Gulf, South Australia. *New Zealand Journal of Marine and Freshwater Research* 46, 491-510.
- Scott, S. G., Pankhurst, N. W., 1992. Interannual variation in the reproductive cycle of the New Zealand snapper *Pagrus auratus* (Bloch & Schneider) (Sparidae). *Journal of Fish Biology* 41, 685-696.
- Sim-Smith, C. J., Jeffs, A. G., Radford, C. A., 2011. Localised spawning omission in snapper, *Chrysophrys auratus* (Sparidae). *Marine and Freshwater Research* 63, 150-159.
- Smith, K. A., 2003. Larval distributions of some commercially valuable fish species over the Sydney continental shelf. *Proceedings of the Linnean Society of New South Wales* 124, 1-11.
- St John, J., Keay, I. S., Wise, B. S., Gaughan, D. J., Lenanton, R. C., 2007. Spatial scales of exploitation among populations of demersal scalefish: implications for management. Part 2: stock structure and biology of two key demersal fishes, Western Australian dhufish (*Glaucosoma hebraicum*) and snapper (*Pagrus auratus*), on the lower west coast of Australia. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2003/052, Fisheries Research Report No. 174. pp. 181.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Sumpton, W. D., Sawynok, B., Carstens, N., 2003. Localised movement of snapper (*Pagrus auratus*, Sparidae) in a large subtropical marine embayment. *Marine and Freshwater Research* 54, 923-930.
- Tabata, K., Taniguchi, N., 2000. Differences between *Pagrus major* and *Pagrus auratus* through mainly mtDNA control region analysis. *Fisheries Science* 66, 9-18.
- Tapp, N., 2003. Do size differences of juvenile snapper (*Pagrus auratus*) in two regions of Shark Bay, Western Australia, reflect different environmental conditions, MSc thesis, Edith Cowan University, Perth, Western Australia. pp. 87.
- Telfer, C., 2010. The Western Australian charter boat industry: working towards long-term sustainability, MSc thesis, School of Natural Sciences. Edith Cowan University, Perth, Western Australia. pp. 153.
- Thrush, S. F., Schultz, D., Hewitt, J. E., Talley, D., 2002. Habitat structure in soft-sediment environments and abundance of juvenile snapper *Pagrus auratus*. *Marine Ecology Progress Series* 245, 273-280.
- Trnski, T., 2002. Behaviour of settlement-stage larvae of fishes with an estuarine juvenile phase: *in situ* observation sin a warm-temperate estuary. *Marine Ecology Progress Series* 242, 205-214.
- Wakefield, C., Potter, I. C., Hall, N. G., Lenanton, R. C. J., in prep. Reproduction of *Pagrus auratus* (Teleostei: Sparidae) varies markedly with latitude and in association with water temperature: implications for management and global climate change.
- Wakefield, C. B., 2006. Latitudinal and temporal comparisons of the reproductive biology and growth of snapper *Pagrus auratus* (Sparidae), in Western Australia, PhD thesis, Murdoch University, Perth, Western Australia. pp. 162.
- Wakefield, C. B., 2010. Annual, lunar and diel reproductive periodicity of a spawning aggregation of snapper *Pagrus auratus* (Sparidae) in a marine embayment on the lower west coast of Australia. *Journal of Fish Biology* 77, 1359-1378.
- Wakefield, C. B., Fairclough, D. V., Lenanton, R. C. J., Potter, I. C., 2011. Spawning and nursery habitat partitioning and movement patterns of *Pagrus auratus* (Sparidae) on the lower west coast of Australia. *Fisheries Research* 109, 243-251.

- Wakefield, C. B., Lewis, P. D., Coutts, T. B., Fairclough, D. V., Langlois, T. J., 2013. Fish assemblages associated with natural and anthropogenically-modified habitats in a marine embayment: comparison of baited videos and opera-house traps. *PLoS One* 8.
- Wakefield, C. B., Moran, M. J., Tapp, N. E., Jackson, G., 2007. Catchability and selectivity of juvenile snapper (*Pagrus auratus*, Sparidae) and western butterflyfish (*Pentapodus vitta*, Nemipteridae) from prawn trawling in a large marine embayment in Western Australia. *Fisheries Research* 85, 37-48.
- Winstanley, R., 1983. The food of snapper *Chrysophrys auratus* in Port Phillip Bay, Victoria. Fisheries and Wildlife Division, Victoria. Commercial Fisheries Report No. 10.
- Wise, B. S., St John, J., Lenanton, R., 2007. Spatial scales of exploitation among populations of demersal scalefish: implications for management. Part 1: Stock status of the key indicator species for the demersal scalefish fisheries in the West Coast Bioregion. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2003/052. Fisheries Research Report No. 163. pp. 130.
- Wise, B. S., Telfer, C. F., Lai, E. K. M., Hall, N. G., Jackson, G., 2012. Long-term monitoring of boat-based recreational fishing in Shark Bay, Western Australia: providing scientific advice for sustainable management in a World Heritage Area. *Marine and Freshwater Research* 63, 1129-1141.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.
- Zeldis, J. R., 1993. Applicability of egg surveys for spawning-stock biomass estimation of snapper, orange roughy and hoki in New Zealand. *Bulletin of Marine Science* 53, 864-890.
- Zeldis, J. R., Francis, R. I. C. C., 1998. A daily egg production method estimate of snapper biomass in Hauraki Gulf, New Zealand. *ICES Journal of Marine Science* 55, 522-534.

## Tarwhine (*Rhabdosargus sarba*)

Reviewed by Kim Smith (DoF)



**Scientific name:** *Rhabdosargus sarba* (Sparidae; Seabreams)

**Common names:** Tarwhine *also* silver bream, golden-lined seabream

**Key identifying features:** Deep body, upper profile convex, rounded head and thin wavy yellow lines along silvery sides, no black spot at base of pectoral fin, second and third anal fin spines similarly enlarged, 6 or 7 scale rows between lateral line and fourth dorsal spine (Yearsley *et al.*, 2001).

### Distribution of species

**Worldwide:** Widely distributed throughout the Indo-Pacific (Kuitert, 1993).

**Western Australia:** Albany to Coral Bay (Hutchins and Swainston, 1986).

**Maximum length, weight and age:** 500 mm, 2.5 kg (Hutchins and Swainston, 1986), 13 years (Hesp, 2003; Hesp *et al.*, 2004a). See also Munro (1949).

**Length/weight relationship:** [Perth coastal waters]  $W=2.846244*TL-3.8822$  (Fisher *et al.*, 2011).

TL (mm)	200	300	400
Weight (g)	565	850	1,135

**Length relationship:** Not reported.

**Growth:** [Perth coastal waters]  $L_{\infty}=289.9$  mm,  $k=0.59$  year<sup>-1</sup>,  $t_0=0.12$  years ( $n=1,487$ ) (Hesp *et al.*, 2004a). Parameters derived by fitting a modified form of von Bertalanffy growth function which takes into account size-related movements between habitats. See also Hesp *et al.* (2004a) for additional information for the Swan River Estuary and Shark Bay.

Age (years)	2	6	10
TL (mm)	194	281	289

**Length and age at maturity:** [Perth coastal waters] Females  $L_{50}=218$  mm; Males  $L_{50}=206$  mm (Hesp and Potter, 2003).

**Reproductive style:** Rudimentary hermaphrodite, multiple spawner (Hesp and Potter, 2003; Hughes *et al.*, 2008). See also [Arabian Gulf] (El-Agamy, 1989), [Hong Kong] Clearly protandrous in that region (Yeung and Chan, 1987), [South Africa] Considered protandrous (Garratt, 1993).

**Adult sex ratio:** [Perth coastal waters, seine net] Close to parity in adults (Hesp and Potter, 2003).

**Length and age at sex change:** Not applicable for Western Australia.

**Spawning season:** [Perth coastal waters] Early winter and spring (Hesp and Potter, 2003). See Hesp *et al.* (2004b) for the lower Swan River Estuary and Shark Bay.

**Spawning location and habitat:** Typically found in marine waters over reefs, but also in the lower reaches of estuaries. Spawning occurs in the lower Swan River Estuary at night at the commencement of ebb tide (Hesp and Potter, 2003; Hesp *et al.*, 2004b).

**Fecundity:** [Swan River] Indeterminate. Batch fecundity  $\ln BF = 5.0025 * \ln TL - 17.557$  ( $n=30$ ,  $R^2=0.52$ ) (Hesp and Potter, 2003; Hesp *et al.*, 2004b).

TL (mm)	180	220	260
Fecundity (eggs)	7,691	58,464	346,545

**Spawning frequency:** [Swan River] Spawn ~45 times during a single spawning season, and, on average, every 2.7 days. Prevalence of spawning in the lower Swan River Estuary is greatest on days of highest tidal amplitude (Hesp *et al.*, 2004b).

### Development and habitat use

**Eggs:** [Japan] Pelagic (Neira *et al.*, 1998)

**Larvae:** Unvegetated, sheltered nearshore marine waters or in estuaries (Neira and Potter, 1992; Neira *et al.*, 1998; Hesp and Potter, 2003). [Japan] Best hatching rates of larvae in aquaculture at 18.5 – 22°C, and salinities of 20 – 32 (Mihelakakis and Kitajima, 1994). [New South Wales] Larvae typically swim near the surface and settle at ~ 8 – 12 mm, often over seagrass (Trnski, 2002). Description of larval stages (Neira *et al.*, 1998).

**Juveniles:** Seagrass, sheltered nearshore reefs, exposed sandy beaches and estuaries (Hesp *et al.*, 2004a; Hesp *et al.*, 2004b). See also [Eastern Australia] (McNeill *et al.*, 1992; Gray *et al.*, 1996; Smith and Suthers, 2000)

**Adults:** Often form schools in estuaries, coastal lakes, bays or exposed reefs (Munro, 1949; Hesp *et al.*, 2004a).

**Migration:** [Perth coastal waters] Migrate from sheltered nearshore waters, to exposed nearshore waters and then to reefs (Hesp *et al.*, 2004a).

**Stock delineation:** Populations around the world may actually be different species (Hesp *et al.*, 2004a). Individuals in Western Australia are likely to comprise a single stock (Smith, 2006)

**Diet:** Predominantly crustaceans, molluscs, macrophytes and sediment. Becomes herbivorous with increasing size (Ang, 2003). See also [South Africa] (Blaber, 1984), [Eastern Australia] Thomson (1959), [India] (Patnaik, 1973).

### Fishery

**Recreational:** Commonly taken as by-catch by boat and shore-based line fishers in coastal and estuarine systems within the West Coast and South Coast bioregions (Malseed and Sumner, 2001; Cusack and Roennfeldt, 2002). Occasionally targeted by fishers in some locations such as the lower Swan River Estuary and in Cockburn Sound (Hesp, 2003).

**Commercial:** Species of minor importance in the South Coast bioregion in nearshore estuarine gill net and haul net finfish fisheries (Smith *et al.*, 2012).

**Age at full recruitment:** Not reported.

**Gear selectivity parameters:** Not reported.

## Management parameters

**Total mortality:** Not reported.

**Natural mortality:** Not reported.

**Fishing mortality:** Not reported.

**Biological reference points:** Not reported.

**Current status:** Overall risk to sustainability for the nearshore suite is medium to high in the West Coast bioregion and low in the South Coast bioregion (DoF, 2011). Inherent vulnerability of the species and current risk to wild stock is minimal in the West Coast bioregion (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

## Catch trends

**Recreational:** Boat-based catch of this species was recorded during surveys in the West Coast bioregion in 1996/97 (5,337 retained fish) and 2005/06 (1,732 retained fish) (Sumner *et al.*, 2008). It was estimated that <1 t was caught in the Swan River and Canning estuaries in 2000/01 (Henry and Lyle, 2003). The total catch from recreational fishers in estuaries within the South Coast bioregion was estimated to be 0.5 t in 2002/03 (Smallwood and Sumner, 2007). 1,093 fish were estimated to be retained in the Gascoyne Coast bioregion in 1998/99 (Sumner *et al.*, 2002). See also Malseed and Sumner (2001), Smallwood *et al.*, (2006) and Smallwood *et al.* (2011).

**Commercial:** A total of 5 t of this species was taken by commercial fishers in Western Australia in 2010/11 (Fletcher and Santoro, 2012). The total catch of this species in the South Coast bioregion in the nearshore and estuarine fishery increased from 3.1 t in 2007 to 6.1 t in 2011, with a low of 2.7 t in 2009 (Smith *et al.*, 2012).

## Management regulations

**Recreational:** Currently listed in the “nearshore/estuarine finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1913)	-	200	
Statewide (1973/74)	-	230	
Statewide (1991)	20	230	
West Coast (2003)	16	230	
Gascoyne Coast (2005)	16	250	
West Coast (2005)	16	250	
South Coast (2005)	8	250	
Statewide (2013)	6	250	

**Commercial:** South Coast nearshore and estuarine finfish fisheries are regulated using various input controls (such as limited entry and gear restrictions) as well as seasonal and temporal closures, and size limits (Smith *et al.*, 2012).

**Current research:** Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Reproductive biology* [Eastern Australia] (Hughes *et al.*, 2008); *Identification of juvenile habitats from otolith isotopes* [New South Wales] (Gillanders and Kingsford, 2003); *Aquaculture* [Taiwan] (1994); *Age and growth* [South Africa] (2001); *Taxonomy* [South Africa] (1979).

## References

- Ang, H. P., 2003. Comparisons of the diets of four species of sparid on the central and lower west coast of Australia, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 59.
- Blaber, S. J. M., 1984. The diet, food selectivity and niche of *Rhabdosargus sarba* (Teleostei: Sparidae) in Natal estuaries. *African Journal of Zoology* 19, 241-246.
- Cusack, R., Roennfeldt, M., 2002. Fishing the Wild West. (Revised). West Australian Newspapers, Perth.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- El-Agamy, A. E., 1989. Biology of *Sparus sarba* Forskal from the Qatari water, Arabian Gulf. *Journal of the Marine Biological Association of India* 31, 129-137.
- Fisher, E. A., Hesp, S. A., Hall, N. G., 2011. Exploration of the effectiveness of alternative management responses to variable recruitment. Murdoch University. Perth, Western Australia. FRDC Project No. 2008/06. pp. 167.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Garratt, P. A., 1993. Comparative aspects of the reproductive biology of seabreams (Pisces: Sparidae), Volume 1, PhD thesis, Rhodes University, Grahamstown, South Africa. pp. 175.
- Gillanders, B. M., Kingsford, M. J., 2003. Spatial variation in elemental composition of otoliths of three species of fish (family Sparidae). *Estuarine, Coastal and Shelf Science* 57, 1049-1064.
- Gray, C. A., McElligott, D. J., Chick, R. C., 1996. Intra- and inter-estuary differences in assemblages of fishes associated with shallow seagrass and bare sand. *Marine and Freshwater Research* 47, 723-735.
- Henry, G. W., Lyle, J. M. (eds) 2003. The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forest, Canberra, Australia.
- Hesp, S. A., 2003. Biology of two species of sparid on the west coast of Australia, PhD thesis, School of Biological Sciences and Biotechnology. Murdoch University, Perth, Western Australia. pp. 216.
- Hesp, S. A., Hall, N. G., Potter, I. C., 2004a. Size-related movements of *Rhabdosargus sarba* in three different environments and their influence on estimates of von Bertalanffy growth parameters. *Marine Biology* 144, 449-462.
- Hesp, S. A., Potter, I. C., 2003. Reproductive biology of *Rhabdosargus sarba* (Sparidae) in Western Australian waters, in which it is a rudimentary hermaphrodite. *Journal of Marine Biological Association of the United Kingdom* 83, 1333-1346.
- Hesp, S. A., Potter, I. C., Schubert, S. R. M., 2004b. Factors influencing the timing and frequency of spawning and fecundity of the goldlined seabream (*Rhabdosargus sarba*) (Sparidae) in the lower reaches of an estuary. *Fishery Bulletin* 102, 648-660.
- Hughes, J. M., Stewart, J., Kendall, B. W., Gray, C. A., 2008. Growth and reproductive biology of tarwhine *Rhabdosargus sarba* (Sparidae) in eastern Australia. *Marine and Freshwater Research* 59, 1111-1123.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Kuiter, R. H., 1993. The complete diver's and fishermen's guide to coastal fishes of south-eastern Australia. Crawford House Press, Bathurst, Australia.
- Leu, M. Y., 1994. Natural spawning and larval rearing of silver bream, *Rhabdosargus sarba* (Forsskal), in captivity. *Aquaculture* 120, 115-122.

- Malseed, B. E., Sumner, N. R., 2001. A 12-month survey of recreational fishing in the Swan-Canning Estuary basin of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 126. pp. 44.
- McNeill, S. E., Worthington, D. G., Ferrell, D. J., Bell, J. D., 1992. Consistently outstanding recruitment of five species of fish to a seagrass bed in Botany Bay, NSW. *Australian Journal of Ecology* 17, 359-365.
- Mihelakakis, A., Kitajima, C., 1994. Effects of salinity and temperature on incubation period, hatching rate, and morphogenesis of the silver sea bream, *Sparus sarba* (Forsk., 1775). *Aquaculture* 126, 361-371.
- Munro, I. S. R., 1949. Revision of Australian silver breams *Mylio* and *Rhabdosargus*. *Memoirs of the Queensland Museum* 12, 182-223.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Neira, F. J., Potter, I. C., 1992. The ichthyoplankton of a seasonally closed estuary in temperate Australia. Does an extended period of opening influence species composition? *Journal of Fish Biology* 41, 935-953.
- Patnaik, S., 1973. Some aspects of the fishery and biology of the Chilka Khuranti, *Rhabdosargus sarba* (Forsk.). *Journal of the Inland Fisheries Society of India* 5, 102-114.
- Radebe, P. V., Mann, B. Q., Beckley, L. E., Govender, A., 2001. Age and growth of *Rhabdosargus sarba* (Pisces: Sparidae), from KwaZulu-Natal, South Africa. *Fisheries Research* 1333, 1-9.
- Smallwood, C. B., Beckley, L. E., Sumner, N. R., 2006. Shore-based recreational angling in the Rottneest Island Reserve, Western Australia: spatial and temporal distribution of catch and fishing effort. *Pacific Conservation Biology* 12, 238-51.
- Smallwood, C. B., Pollock, K. H., Wise, B. S., Hall, N. G., Gaughan, D. J., 2011. Quantifying recreational fishing catch and effort: a pilot study of shore-based fishers in the Perth Metropolitan area. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 216. pp. 60.
- Smallwood, C. B., Sumner, N. R., 2007. A 12-month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002/03. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 159. pp. 56.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012. South Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Smith, K. A., 2006. Review of fishery resources and status of key fishery stocks in the Swan-Canning Estuary. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 156. pp. 84.
- Smith, K. A., Suthers, I. M., 2000. Consistent timing of juvenile fish recruitment to seagrass beds within two Sydney estuaries. *Marine and Freshwater Research* 51, 765-776.
- Smith, M. M., 1979. *Rhabdosargus thorpei*, a new sparid fish from South Africa, with a key to the species of *Rhabdosargus*. *Copeia* 4, 702-709.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Sumner, N. R., Williamson, P. C., Malseed, B. E., 2002. A 12-month survey of recreational fishing in the Gascoyne bioregion of Western Australia during 1998-99. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 53.
- Thomson, J., 1959. Some aspects of the ecology of Lake Macquarie, N.S.W., with regard to an alleged depletion of fish. XII. Summery Review. *Marine and Freshwater Research* 10, 399-408.
- Trnski, T., 2002. Behaviour of settlement-stage larvae of fishes with an estuarine juvenile phase: *in situ* observation sin a warm-temperate estuary. *Marine Ecology Progress Series* 242, 205-214.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.
- Yeung, W. S. B., Chan, S. T. H., 1987. The gonadal anatomy and sexual pattern of the protandrous sex-reversing fish, *Rhabdosargus sarba* (Teleostei: Sparidae). *Journal of the Zoological Society of London* 212, 521-532.

## Mulloway (*Argyrosomus japonicus*)

Reviewed by David Fairclough (DoF)



**Scientific name:** *Argyrosomus japonicus* (Sciaenidae; Drums/Croakers), previously called *Argyrosomus hololepidotus*

**Common names:** Mulloway also river kingfish, silver kingfish, kingfish. Juveniles are termed “soapies” and fish of 2-5 kg are often termed “school mulloway” (Cusack and Roennfeldt, 2002; Farmer, 2008).

**Key identifying features:** Silvery bronze sides often with a dark streak along the lower part of body, dark spot above pectoral fin base, silver spots follow lateral line (Hutchins and Thompson, 1983).

### Distribution of species

**Worldwide:** Widely distributed throughout the Indo-West Pacific (Trewavas, 1977; Griffiths and Heemstra, 1995).

**Western Australia:** Southern Western Australian border to Exmouth (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 2,000 mm, 60 kg (Gomon *et al.*, 2008), 31 years (Farmer *et al.*, 2005).

**Length/weight relationship:** [West Coast and Gascoyne Coast bioregions]  $\ln W = 3.007 * \ln TL - 11.637$  ( $n=328$ ,  $R^2=0.997$ ) (Farmer, 2008). See also Farmer (2008) for South Coast bioregion estimates.

TL (mm)	500	800	1,100
Weight (g)	1,162	4,777	12,447

**Length relationship:** Not applicable.

**Growth:** [West Coast and Gascoyne Coast bioregions] Females  $L_{\infty}=1,213$  mm,  $k=0.274$  year<sup>-1</sup>,  $t_0=0.049$  years ( $n=525$ ,  $R^2=0.930$ ); Males  $L_{\infty}=1,173$  mm,  $k=0.28$  year<sup>-1</sup>,  $t_0=0.087$  years ( $n=512$ ,  $R^2=0.928$ ) (Farmer, 2008). Estimates for South Coast bioregion, and a 4-parameter growth model, which provides a slightly better fit to the length-at-age data, are also available in Farmer (2008).

Age (years)	5	10	15
Females, TL (mm)	909	1,136	1,193
Males, TL (mm)	891	1,103	1,156

**Length and age at maturity:** [West Coast and Gascoyne Coast bioregions] Females  $L_{50}=903$

mm,  $L_{95}=1,015$  mm ( $n=291$ ); Males  $L_{50}=873$  mm,  $L_{95}=973$  mm ( $n=292$ ) (Farmer, 2008). Both sexes attain maturity at a much smaller size and younger age in Oyster Harbour in the South Coast bioregion compared to the West Coast bioregion (Farmer, 2008).

**Reproductive style:** Gonochorist. Multiple spawner (Farmer *et al.*, 2005).

**Adult sex ratio:** [West Coast bioregion, commercial wetline and recreational hook and line] F1.5:M1 (Farmer *et al.*, 2005).

**Length and age at sex change:** Not applicable.

**Spawning season:** [West Coast and South Coast bioregions] November to April. Spawning is more protracted in the warmer waters of the Gascoyne Coast bioregion (Farmer *et al.*, 2005). See also [South Australia] Hall (1986); [South Africa] Griffiths (1996).

**Spawning locality:** In the West Coast and Gascoyne Coast bioregions, spawning occurs at night, typically around reefs in inshore coastal waters. Spawning aggregations known to occur at depths of 20-30 m over reefs (Farmer *et al.*, 2005). Also in the lower reaches of the Swan River Estuary at the commencement of the ebb tide, thereby dispersing eggs and larvae downstream (Farmer, 2008).

**Fecundity:** Indeterminate (Farmer *et al.*, 2005).

**Spawning frequency:** Not reported.

### **Development and habitat use**

**Eggs:** Pelagic, nearshore waters (Neira *et al.*, 1998; Farmer, 2008).

**Larvae:** Nearshore waters (Farmer, 2008).

**Juveniles:** Nearshore waters <10 m deep in protected, low energy environments and in some permanently open estuaries in Western Australia (Farmer, 2008). In New South Wales (Silberschneider and Gray, 2005) and South Africa (Griffiths and Heemstra, 1995; Cowley *et al.*, 2008) juveniles are far more common in estuaries. Description of pelagic larval stages (Neira *et al.*, 1998).

**Adults:** Move between estuaries, rivers, exposed beaches, marine embayments and inshore and offshore reefs at depths of 20–200 m (Griffiths and Heemstra, 1995; Griffiths, 1996; Farmer, 2008).

**Migration:** Mature individuals migrate seasonally into the lower reaches of the Swan River Estuary between October and April. Catches in this environment peak in summer, when fish are in spawning condition. Mulloway are caught seasonally at depths of 80-110 m in coastal waters off Two Rocks and near Rottnest Island. As the fish caught near Rottnest Island are often “tannin stained”, they are thought to move between those waters and the Swan River Estuary, after the first of the freshwater flushes in late autumn (Holt, 1978; Farmer *et al.*, 2005; Farmer, 2008).

**Stock delineation:** Based on morphological characteristics, Australian, South African and Japanese populations have previously been considered to constitute a single species (Griffiths and Heemstra, 1995). More recent studies indicate that the populations in Western Australia, Eastern Australia and South Africa are genetically distinct and may represent different species (Dixon, 1988; 1990; Klopper, 2005; Farmer, 2008).

**Diet:** [South Australia] Feed on a variety of fish species as well as sand crabs, prawns and worms (Hall, 1986).

## Fishery

**Recreational:** Highly-prized recreational fish species, typically caught by rod and line fishing in estuaries and along beaches and in deeper, offshore coastal waters. Occasionally caught in gill nets and by spear fishing (Cusack and Roennfeldt, 2002; Henry and Lyle, 2003).

**Commercial:** Caught commercially by nearshore and estuarine finfish commercial gillnet, haul net and beach seine fisheries that operate in the South Coast and West Coast bioregions (Smith *et al.*, 2012a; Smith *et al.*, 2012b). Mulloway are also caught in temperate Demersal Gillnet and Demersal Longline Fisheries (DGDLF) (McAuley and Simpfendorfer, 2003; McAuley and Rowland, 2012), West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF) (D. Fairclough, DoF, *pers. comm.*, 2012) and Gascoyne Demersal Scalefish Fishery (GDSF) (Jackson *et al.*, 2012).

**Age at full recruitment:** 3 years (Farmer *et al.*, 2005).

**Gear selectivity parameters:** Not reported.

## Management parameters

**Total mortality:** [West Coast and Gascoyne Coast bioregions] Several estimates available. Estimate calculated using method of Hall *et al.* (2004) is 0.34 year<sup>-1</sup> (Farmer *et al.*, 2005).

**Natural mortality:** [West Coast and South Coast bioregions] Several estimates available. Estimate calculated using Hall *et al.* (2004) is 0.24 year<sup>-1</sup> (Farmer *et al.*, 2005).

**Fishing mortality:** [West Coast and Gascoyne Coast bioregions] Using  $F=Z-M$  is 0.11 year<sup>-1</sup> (Farmer *et al.*, 2005).

**Biological reference points:** [West Coast and Gascoyne Coast bioregions]  $F_{0.1}=0.26$  kg year<sup>-1</sup>

$SSB/R_{current}=8.8$  kg year<sup>-1</sup>

$YPR_{current}=0.95$  kg year<sup>-1</sup>

$SPR_{current}=0.50$  (Farmer *et al.*, 2005).

**Current status:** Overall risk to sustainability for the nearshore suite is medium to high in the West Coast bioregion and low in the Gascoyne Coast bioregion (DoF, 2011). Inherent vulnerability of the species moderate (Gascoyne Coast bioregion) or high (West Coast bioregion) and current risk to wild stock is minimal (Gascoyne Coast bioregion) or moderate (West Coast bioregion) (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

## Catch trends

**Recreational:** The total estimated recreational catch in Western Australia was 360 t in 2000/01 (Henry and Lyle, 2003). Small recreational boat catches of this species in the West Coast bioregion were recorded in 1996/97 (56 kept) and 2005/06 (260 kept) (Sumner *et al.*, 2008). Low numbers of this species were retained by shore-based fishers in Oyster Harbour in 2002/03 (Smallwood and Sumner, 2007).

**Commercial:** A total of 15 t (live weight) of this species was taken by commercial fishers in Western Australia in 2010/11 (Fletcher and Santoro, 2012). The total catches of this species in the South Coast bioregion in the nearshore and estuarine fishery, including the Swan River Estuary, have ranged from 0.2 t in 2007 to 0.7 t in 2011 (Smith *et al.*, 2012a). In past years (1912 – 1974), an average of ~2.5 t was caught each year in the Swan River Estuary (Riggert, 1978). Total catch from the DGDLF was 5.8 t, of which 2.0 t was taken from the South Coast bioregion and 3.7 t from the West Coast bioregion (McAuley and Rowland, 2012).

## Management regulations

**Recreational:** Currently listed in the “nearshore/estuarine finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1913)	-	330	
Statewide (1975)	-	400	
Statewide (1983)	-	330	
Statewide (1989)	5	330	
Statewide (1991)	4	450	Only one fish >700mm (until 1996)
West Coast (2003)	2	500	
South Coast (2003)	4	500	
Gascoyne Coast (2003)	4	500	
Statewide (2013)	2	500	

**Commercial:** South Coast and West Coast nearshore and estuarine fisheries are managed primarily through input controls (limited entry, gear restrictions, spatial and temporal closures, and size limits) (Smith *et al.*, 2012a; Smith *et al.*, 2012b). The DGDLF is regulated using various input controls (transferable time/gear effort, mesh and hook sizes, maximum net length), output controls as well as temporal (16 Aug – 15 Oct) and spatial closures (McAuley and Rowland, 2012). The WCDSIMF is regulated using various input controls (restricted entry, total fishing time allocations, maximum number of lines and hooks) (Fairclough *et al.*, 2012).

**Current research:** Studies at Murdoch University on morphological deformities is extending work undertaken by Farmer (2008). Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Aquaculture* [New South Wales] (Battaglione and Talbot, 1994); *Diseases, parasites* [Western Australia] (Farmer, 2008; Hutson *et al.*, 2011). *Acoustic tagging* [South Africa] (Childs *et al.*, 2011); *Commercial fishing by-catch exclusion* [New South Wales] (Broadhurst and Kennelly, 1994; 1995); *Trophodynamics* [New South Wales] (Taylor and Mazumder, 2010); *Release mortality* [New South Wales] (Butcher *et al.*, 2007).

## References

- Battaglione, S. C., Talbot, R. B., 1994. Hormone induction and larval rearing of mulloway, *Argyrosomus japonicus* (Pisces: Sciaenidae). *Aquaculture* 126, 73-81.
- Broadhurst, M. K., Kennelly, S. J., 1994. Reducing the by-catch of juvenile fish (mulloway *Argyrosomus hololepidotus*) using square-mesh panels in codends in the Hawkesbury River prawn-trawl fishery, Australia. *Fisheries Research* 19, 321-331.
- Broadhurst, M. K., Kennelly, S. J., 1995. A trouser-trawl experiment to assess codends that exclude juvenile mulloway (*Argyrosomus hololepidotus*) in the Hawkesbury River prawn-trawl fishery. *Marine and Freshwater Research* 46, 953-958.
- Butcher, P. A., Broadhurst, M. K., Reynolds, D., Reid, D. D., Gray, C. A., 2007. Release method and anatomical hook location: effects on short-term mortality of angler-caught *Acanthopagrus australis* and *Argyrosomus japonicus*. *Diseases of Aquatic Organisms* 74, 17-26.
- Childs, A. R., Næsje, T. F., Cowley, P. D., 2011. Long-term effects of different-sized surgically implanted acoustic transmitters on the sciaenid *Argyrosomus japonicus*: breaking the 2% tag-to-body mass rule. *Marine and Freshwater Research* 62, 432-438.

- Cowley, P. D., Kerwath, S. E., Childs, A. R., Thorstad, E. B., Økland, F., Næsje, T. F., 2008. Estuarine habitat use by juvenile dusky kob *Argyrosomus japonicus* (Sciaenidae), with implications for management. *African Journal of Marine Science* 30, 247-253.
- Cusack, R., Roennfeldt, M., 2002. Fishing the Wild West. (Revised). West Australian Newspapers, Perth.
- Dixon, P. I., 1988. Stock identification and discrimination of mulloway in Australian waters. Centre for Marine Science, University of New South Wales. New South Wales, Australia. FIRDC Grant No. 86/16.
- Dixon, P. I., 1990. Identification and discrimination of mulloway in Australian waters based on mitochondrial DNA sequence data. Centre for Marine Science, University of New South Wales. New South Wales, Australia. pp. 38.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Farmer, B. M., 2008. Comparisons of the biological and genetic characteristics of the Mulloway *Argyrosomus japonicus* (Sciaenidae) in different regions of Western Australia, PhD thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 217.
- Farmer, B. M., French, D. J. W., Potter, I. C., Hesp, S. A., Hall, N. G., 2005. Determination of biological parameters for managing the fisheries for mulloway and silver trevally in Western Australia. Murdoch University. Perth, Western Australia. FRDC Project No. 2002/004. pp. 149.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Griffiths, M. A., Heemstra, P. C., 1995. A contribution to the taxonomy of the marine fish genus *Argyrosomus* (Perciformes: Sciaenidae), with descriptions of the two new species from southern Africa. *Ichthyological Bulletin of the JLB Smith Institute of Ichthyology* 65.
- Griffiths, M. H., 1996. Life history of the dusky kob *Argyrosomus japonicus* (Sciaenidae) off the east coast of South Africa. *South African Journal of Marine Science* 17, 135-154.
- Hall, D. A., 1986. An assessment of the Mulloway (*Argyrosomus hololepidotus*) Fishery in South Australia with particular reference to the Coorong lagoon. Department of Fisheries, South Australia. Adelaide, South Australia.
- Hall, N. G., Hesp, S. A., Potter, I. C., 2004. A bayesian approach for overcoming inconsistencies in mortality estimates using, as an example, data for *Acanthopagrus latus*. *Canadian Journal of Fisheries and Aquatic Sciences* 61, 1202-1211.
- Henry, G. W., Lyle, J. M. (eds) 2003. The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forest, Canberra, Australia.
- Holt, C. P., 1978. The biology of three teleost species in the Swan River Estuary, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia.
- Hutchins, B., Thompson, M., 1983. The marine and estuarine fishes of south-western Australia: a field guide for anglers and divers. Western Australian Museum, Perth, Western Australia.
- Hutson, K. S., Catalano, S. R., Whittington, I. D., 2011. Metazoan parasite survey of selected macro-inshore fish of southeastern Australia, including species of commercial importance. James Cook University. Townsville, Queensland. FRDC Project No. 2007/225. pp. 259.
- Jackson, G., Marriott, R., Lai, E., Lunow, C., 2012. Gascoyne demersal scalefish fishery status report, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 146-153.

- Klopper, A. W., 2005. Intraspecific genetic variation in the percoid teleosts *Arygosomus japonicus* (Temminck and Schlegel, 1843) and *Pomadasys commersonnii* (Lacepede, 1801) as inferred from the mitochondrial control region, MSc thesis, University of Pretoria, South Africa, Pretoria.
- McAuley, R., Rowland, F., 2012. Temperate demersal gillnet and demersal longline fisheries status report, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 282-294.
- McAuley, R., Simpfendorfer, C., 2003. Catch composition of the Western Australian temperate demersal gillnet and demersal longline fisheries, 1994 to 1999. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 146. pp. 78.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Riggert, T. L., 1978. The Swan River Estuary. Development, management and preservation. Frank Daniels Pty Ltd. Perth, Western Australia.
- Silberschneider, V., Gray, C. A., 2005. Arresting the decline of the commercial and recreational fisheries for mulloway (*Argyrosomus japonicus*). New South Wales Department of Primary Industries. New South Wales, Australia. FRDC Project No. 2002/05. pp. 71.
- Smallwood, C. B., Sumner, N. R., 2007. A 12-month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002/03. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 159. pp. 56.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012a. South Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Smith, K., Brown, J., Howard, A., Walshe, K., Fissioli, J., 2012b. West Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 80-97.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Taylor, M. D., Mazumder, D., 2010. Stable isotopes reveal post-release trophodynamic and ontogenetic changes in a released finfish, mulloway (*Argyrosomus japonicus*). *Marine and Freshwater Research* 61, 302-308.
- Trewavas, E., 1977. The sciaenid fishes (croakers and drums) of the Indo-West Pacific. *Transactions of the Zoological Society, London* 33, 253-541.

## Blue morwong (*Nemadactylus valenciennesi*)

Reviewed by Peter Coulson (Murdoch University) and David Fairclough (DoF)



**Scientific name:** *Nemadactylus valenciennesi* (Cheilodactylidae; Morwongs)

**Common names:** Blue morwong *also* Queen snapper

**Key identifying features:** Silvery blue sides with yellow tinge, thick and rubbery lips, 1 pectoral fin ray much longer than others, bright blue and yellow lines around eyes (Yearsley *et al.*, 2001).

### Distribution of species

**Worldwide:** Endemic to southern Australia.

**Western Australia:** Southern Western Australian border to Lancelin (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 996 mm, 12 kg (Gomon *et al.*, 2008), 21 years (Coulson *et al.*, 2010).

**Length/weight relationship:** [South-western Australia]  $\ln W = 2.969 * \ln TL - 11.154$  ( $n=330$ ,  $R^2=0.991$ ) (Coulson *et al.*, 2007).

TL (mm)	300	500	700
Weight (g)	324	1,476	4,008

**Length relationship:** [South-western Australia]  $FL = 1.010 * TL - 0.219$  ( $n=643$ ,  $R^2=0.996$ ) (Coulson *et al.*, 2010). See also Coulson *et al.* (2007).

**Growth:** [South-western Australia] Females  $L_{\infty} = 696$  mm,  $k = 0.29$  year<sup>-1</sup>,  $t_0 = 0.36$  years ( $n=356$ ,  $R^2=0.86$ ); Male  $L_{\infty} = 839$  mm,  $k = 0.22$  year<sup>-1</sup>,  $t_0 = 0.52$  years ( $n=460$ ,  $R^2=0.80$ ) (Coulson *et al.*, 2010).

Age (years)	5	10	15
Females, TL (mm)	549	662	688
Males, TL (mm)	590	756	811

**Length and age at maturity:** [South-western Australia]  $L_{50}$  values have not been estimated but 89% of all females and 82% of all males caught on lower west coast were mature (all fish > 400 mm TL and 2 years old were mature) (Coulson *et al.*, 2010). Fish mature at a larger size and older age on the south coast of Western Australia (Coulson *et al.*, 2010).

**Reproductive style:** Gonochoristic (Coulson *et al.*, 2007; Coulson *et al.*, 2010).

**Adult sex ratio:** [South-western Australia, spearfishing] F1:M1.6 (Coulson *et al.*, 2010).

**Length and age at sex change:** Not applicable.

**Spawning season:** January to April (Coulson *et al.*, 2010).

**Spawning location and habitat:** Lower west coast (Coulson *et al.*, 2010).

**Fecundity:** Indeterminate (Coulson *et al.*, 2007).

**Spawning frequency:** Not reported.

### **Development and habitat use**

**Eggs:** [Family Cheilodactylidae] Pelagic (Neira *et al.*, 1998).

**Larvae:** Hypothesised to be transported southwards and distributed eastwards along the south coast (Coulson *et al.*, 2010). Most species of Cheilodactylidae exhibit an extended pelagic ‘paperfish’ stage during which they attain lengths of 60-90 mm (Allen and Heemstra, 1976; Vooren, 1976).

**Juveniles:** Found predominantly in shallow coastal waters on the south coast, with very few observed along the lower west coast (Coulson *et al.*, 2007; Coulson *et al.*, 2010).

**Adults:** Rocky reefs in offshore waters (Coulson *et al.*, 2007).

**Migration:** Proposed that juveniles either move offshore, on the south coast, or migrate north to offshore waters of the lower west coast, where spawning occurs (Coulson *et al.*, 2010).

**Stock delineation:** Not reported.

**Diet:** [Family Cheilodactylidae] Carnivorous (Bell, 1979).

### **Fishery**

**Recreational:** Frequently caught by boat-based rod and line fishers and spear fishers in the South Coast and West Coast bioregions (Sumner *et al.*, 2008; DoF, 2010). This species is also one of the top species retained by charter boat operators in the West Coast and South Coast bioregions (Telfer, 2010).

**Commercial:** One of the top 15 demersal species caught by commercial fishers in the South Coast Demersal Line Fishery (Molony *et al.*, 2012). Also caught in the West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF) and, temperate Demersal Gillnet and Demersal Longline Fisheries (DGDLF) (McAuley and Simpfendorfer, 2003; Fairclough *et al.*, 2012; McAuley and Rowland, 2012).

**Age at full recruitment:** [Commercial, gillnets] 9 years (1 year after the peak in the age composition) (Coulson *et al.*, 2007).

**Gear selectivity parameters:** Not reported.

### **Management parameters**

**Total mortality:** [Catch curve analysis] 0.40 year<sup>-1</sup> (Coulson *et al.*, 2007).

**Natural mortality:** [Hoenig’s (1983) equation for fish] 0.24 year<sup>-1</sup>. Modified value for natural mortality using method of Hall *et al.* (2004) 0.19 year<sup>-1</sup> (Coulson *et al.*, 2007).

**Fishing mortality:** 0.20 year<sup>-1</sup> (Coulson *et al.*, 2007).

**Biological reference points:** [Lower west coast]  $F_{0.1}=0.31$  year<sup>-1</sup>

YPR=0.54 kg

SSB/R<sub>current</sub>=2.40 kg

SPR<sub>current</sub>=0.57 (Coulson *et al.*, 2007).

**Current status:** An indicator species for the inshore demersal suite in the South Coast bioregion (DoF, 2011). Overall risk to sustainability for the suite is medium to high in the West Coast and South Coast bioregions (DoF, 2011). Inherent vulnerability of the species is moderate (West Coast bioregion) to high (South Coast bioregion) and current risk to wild stock is moderate (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

**Recreational:** The total estimated recreational boat-based catch in the West Coast bioregion decreased from 19 t in 1996/97 to 10 t in 2005/06 (Sumner *et al.*, 2008).

**Commercial:** The total catches of this species in the South Coast Demersal Line Fishery have ranged from 5.1 t in 2007 to 8.1 t in 2011, with a low of 4.4 t in 2010 (Molony *et al.*, 2012). Total catch from the DGDLF was 51.1 t, of which 41.7 t was taken from the South Coast bioregion and 9.4 t from the West Coast bioregion (McAuley and Rowland, 2012). Some specimens are also taken in the WCDSIMF in 2011 (430 kg) (D. Fairclough, DoF, *pers. comm.*, 2012).

### Management regulations

**Recreational:** Currently listed in the “demersal finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1972)	-	300	
Statewide (1977)	10	300	
Statewide (1991)	8	300	
Statewide (1995)	8	410	
West Coast (2003)	4	410	
South Coast (2005)	4	410	
West Coast (2009)	2	410	Closed season: 15 Oct - 15 Dec Compulsory possession of release weight
Statewide (except West Coast) (2013)	3	410	

**Commercial:** The DGDLF is regulated using various input controls (transferable time/gear effort, mesh and hook sizes, maximum net length), output controls as well as temporal (16 Aug – 15 Oct) and spatial closures (McAuley and Rowland, 2012). The South Coast Demersal Line Fishery is currently ‘open access’ for the holder of a valid Fishing Boat Licence (for the boat) and a Commercial Fishing Licence (for the fisher) (Molony *et al.*, 2012).

**Current research:** Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Distribution linked to water temperature* (Langlois *et al.*, 2012); *Fish assemblages* (Langlois *et al.*, 2010).

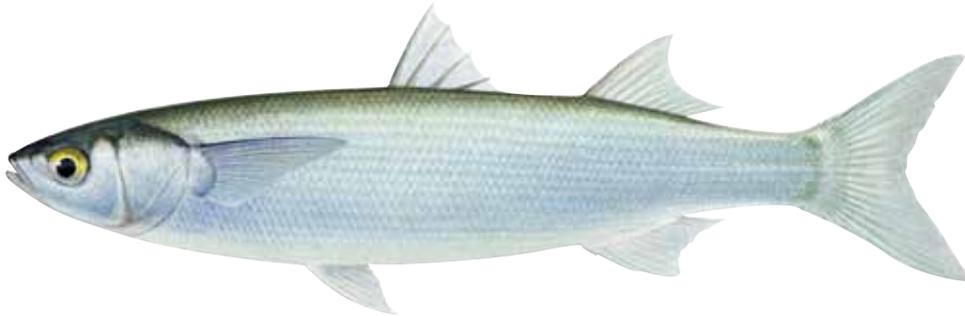
### References

- Allen, G. R., Heemstra, P. C., 1976. *Cheilodactylus rubrolabiatus* a new species of morwong (Pisces: Cheilodactylidae) from Western Australia, with a key to the cheilodactylid fishes of Australia. *Records of the Australian Museum* 4, 311-325.

- Bell, J., 1979. Observations on the diet of red morwong, *Cheilodactylus fuscus* Castelnau (Pisces : Cheilodactylidae). *Marine and Freshwater Research* 30, 129-133.
- Coulson, P. G., Hesp, S. A., Potter, I. C., Hall, N. G., 2010. Life cycle characteristics of the blue morwong *Nemadactylus valenciennesi* compared with those of other species of Cheilodactylidae. *Marine and Freshwater Research* 61, 104-118.
- Coulson, P. G., Potter, I. C., Hesp, S. A., Hall, N. G., 2007. Biological parameters required for managing western blue groper, blue morwong and yellowtail flathead. Murdoch University. Perth Western Australia. FRDC Project No. 2004/057. pp. 167.
- DoF, 2010. Integrated fisheries management report: West Coast Demersal Scalefish Resource. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Management Paper No. 247. pp. 65.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Hall, N. G., Hesp, S. A., Potter, I. C., 2004. A bayesian approach for overcoming inconsistencies in mortality estimates using, as an example, data for *Acanthopagrus latus*. *Canadian Journal of Fisheries and Aquatic Sciences* 61, 1202-1211.
- Hoinig, J., 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82, 898-903.
- Langlois, T., Harvey, E., Fitzpatrick, B., Meeuwig, J., Shedrawi, G., Watson, D., 2010. Cost-efficient sampling of fish assemblages: comparison of baited video stations and diver video transects. *Aquatic Biology* 9, 155-168.
- Langlois, T. J., Radford, B. T., Van Niel, K. P., Meeuwig, J. J., Pearce, A. F., Rousseaux, C. S. G., Kendrick, G. A., Harvey, E. S., 2012. Consistent abundance distributions of marine fishes in an old, climatically buffered, infertile seascape. *Global Ecology and Biogeography* 21, 886-897.
- McAuley, R., Rowland, F., 2012. Temperate demersal gillnet and demersal longline fisheries status report, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 282-294.
- McAuley, R., Simpfendorfer, C., 2003. Catch composition of the Western Australian temperate demersal gillnet and demersal longline fisheries, 1994 to 1999. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 146. pp. 78.
- Molony, B., Lai, E., Holtz, M., 2012. South Coast demersal scalefish resource report: statistics only, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 295-297.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Telfer, C., 2010. The Western Australian charter boat industry: working towards long-term sustainability, MSc thesis, School of Natural Sciences. Edith Cowan University, Perth, Western Australia. pp. 153.
- Vooren, C. M., 1976. Post larvae and juveniles of the tarakihi (Teleostei: Cheilodactylidae) in New Zealand. *New Zealand Journal of Marine and Freshwater Research* 6, 601-618.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## Yelloweye mullet (*Aldrichetta forsteri*)

Reviewed by Brett Crisafulli (Murdoch University)



**Scientific name:** *Aldrichetta forsteri* (Mugilidae; Grey mullets)

**Common names:** Yelloweye mullet

**Key identifying features:** Silvery body, well separated dorsal fins, bright yellow eye and large mouth (Yearsley *et al.*, 2001).

### Distribution

**Worldwide:** New Zealand and southern Australia (Thomson, 1957a).

**Western Australia:** Southern Western Australian border to Murchison River. Abundant south of Geraldton (Thomson, 1954a; 1957a).

**Maximum length weight and age:** 500 mm, 1.15 kg (Hutchins and Swainston, 1986), 7 years (Thomson, 1957a).

**Length/weight relationships:**  $W=7.72*10^{-6}TL^{3.02}$  ( $n=4,236$ ) (Gaughan *et al.*, 2006).

TL (mm)	200	300	400
Weight (g)	69	234	557

**Length relationship:**  $TL=1.08-1.10*FL$  (Thomson, 1954a). See Thomson (1954a) for a range of other body measurements and Orr (2000) for length/girth measurements.

**Growth:** [West Coast bioregion] Females  $L_{\infty}=375$  mm,  $k=0.585$  year<sup>-1</sup>,  $t_0$ =fixed at zero years ( $n=406$ ); Males  $L_{\infty}=286$  mm,  $k=0.953$  year<sup>-1</sup>,  $t_0$ =fixed at zero years ( $n=119$ ) (Gaughan *et al.*, 2006). See also Chubb *et al.* (1981) for Swan River, Orr (2000), Gaughan *et al.* (2006) and Crisafulli (2008) for South Coast bioregion, and Thomson (1957b) for south-western Australia.

Age (years)	1	3	5
Females, TL (mm)	166	310	355
Males, TL (mm)	176	270	284

**Length and age at maturity:** [West Coast bioregion]  $L_{50}=249$  mm (Gaughan *et al.*, 2006). See also Orr (2000) and Crisafulli (2008).

**Reproductive style:** Gonochoristic.

**Adult sex ratio:** [Wilson Inlet, seine and gill nets] F2.4:M1 (Orr, 2000). See also Thomson (1957b).

**Length and age at sex change:** Not applicable.

**Spawning season:** [Swan River] March – August (Chubb *et al.*, 1981). See also Lenanton *et al.* (1984), Lenanton (1984), Orr (2000) and Crisafulli (2008).

**Spawning location and habitat:** Spawning occurs in protected coastal waters close to estuary mouths. It has been suggested that spawning may occur in estuaries if their mouths remain closed during winter and fish are prevented from migrating out into the ocean (Lenanton, 1974; Chubb *et al.*, 1981). However, a study by Crisafulli (2008) in six seasonally-closed estuaries on the south coast of Western Australia provided no evidence that this occurs. Spawning is likely to occur predominantly along the lower West Coast (Potter and Hyndes, 1994).

**Fecundity:** Fish 245 – 391 mm TL produce an estimated 125,000-630,000 eggs (Thomson, 1957a).

**Spawning frequency:** Not reported.

### **Development and habitat use**

**Eggs:** [New Zealand] Pelagic and located in coastal waters (Kingsford and Tricklebank, 1991; Hickford and Schiel, 2003).

**Larvae:** [Victoria] Late larvae/early juveniles immigrate to coastal embayments (Jenkins, 1986).

**Juveniles:** Coastal waters (including the surf zone), estuaries and riverine environments. Often abundances are greatest around the mouths of estuaries (Chubb *et al.*, 1981; Lenanton, 1982; Potter *et al.*, 1993; Ayvazian and Hyndes, 1995; Young *et al.*, 1997).

**Adults:** Coastal waters and estuaries as well as riverine environments, with older adults found predominantly in coastal waters in deeper habitats such as channels (Potter and Hyndes, 1994; Smith, 2006).

**Migration:** During the warmer months of the year, older fish in the Swan River (1+ and 2+ years) move out of the estuary into coastal waters (Chubb *et al.*, 1981).

**Stock delineation:** There are two distinct populations along east and west coasts of Australia (Thomson, 1957b; a). A single stock in estuaries and marine waters in Western Australia, with substantial mixing of eggs, larvae and adults (Smith, 2006).

**Diet:** Omnivorous. Major dietary items include small crustaceans, polychaetes, small molluscs, macro-algae, diatoms and plant detritus (Thomson, 1954b; 1957a; Edgar and Shaw, 1995; Orr, 2000; Platell *et al.*, 2006).

### **Fishery**

**Recreational:** Caught by recreational line fishers from boats and the shore in estuaries and nearshore waters of the West Coast and South Coast bioregions (Malseed and Sumner, 2001a; Smallwood and Sumner, 2007; Smallwood *et al.*, 2011), including the Swan-Canning Estuary (Smith, 2006).

**Commercial:** Caught by set nets, haul nets and beach seines in estuaries and nearshore waters along the West Coast and South Coast bioregions, including the West Coast Beach Bait Managed Fishery (Smith *et al.*, 2012a; Smith *et al.*, 2012b). One of the most commercially important species in the Swan River Estuary (Lenanton, 1978; Smith, 2006).

**Age at full recruitment:** Not reported.

**Gear selectivity parameters:** Length frequency data for yellow eye mullet caught in set nets (Thomson, 1957a). Crisafulli (2008) fitted the Kirkwood and Walker (1986) model to length-frequency data for *A. forsteri* caught by gillnetting in south coast estuaries (model parameter estimates not reported). Orr (2000) fitted the Kirkwood and Walker (1986) and, Sechin (1969) models and a combined/integrated model to gillnet data for *A. forsteri* in Wilson Inlet.

### **Management parameters**

**Total mortality:** Not reported.

**Natural mortality:** Not reported.

**Fishing mortality estimates:** Not reported.

**Biological reference points:** Not reported.

**Current status:** Overall risk to sustainability for the nearshore suite is medium to high in the West Coast bioregion (DoF, 2011). Inherent vulnerability of the species and current risk to wild stock are both minimal (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

**Recreational:** Total estimated catch for April – June 2011 from shore-based fishers in the Perth Metropolitan area was 5,772 fish (Smallwood *et al.*, 2011). Low numbers recorded from the Swan-Canning Estuary (Malseed and Sumner, 2001a). In 2002/03, <1,000 were estimated to be caught by boat-based fishers in South Coast estuaries such as Walpole/Nornalup Inlet, Irwin Inlet and Wilson Inlet (Smallwood and Sumner, 2007).

**Commercial:** A total of 22 t of this species was taken by commercial fishers in Western Australia in 2010/11 (Fletcher and Santoro, 2012). The total catches in the West Coast bioregion nearshore and estuarine fishery have decreased from 37.0 t in 2007 to 11.5 t in 2011 (Smith *et al.*, 2012b). The total catches in the South Coast bioregion nearshore and estuarine fishery have remained relatively static with 3.0 t taken in 2007 and 3.7 t in 2011, with a low of 2.6 t in 2010 (Smith *et al.*, 2012a). See also Thomson (1957a), Chubb *et al.* (1981), Malseed (2000), Malseed and Sumner (2001a) and, Malseed and Sumner (2001b).

### Management regulations

**Recreational:** Currently included in the “all other species of finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1958)	-	230	
Statewide (1991)	40	-	
West Coast (2009)	30	-	
Statewide (2013)	30	-	

**Commercial:** South Coast and West Coast nearshore and estuarine fisheries are managed primarily through input controls (limited entry, gear restrictions, spatial and temporal closures, and size limits) (Smith *et al.*, 2012a; Smith *et al.*, 2012b). Minimum size limit for commercial fishers is 230 mm.

**Current research:** Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Morphology* (Thomson, 1954b); *Effects of thermal effluent* (Jones *et al.*, 1996); *Mullet in the diet of birds in estuaries* (Humphries *et al.*, 1992); *Biology and fisheries* (Harris, 1968; Higham *et al.*, 2005); *Parasites* (Hutson *et al.*, 2011).

### References

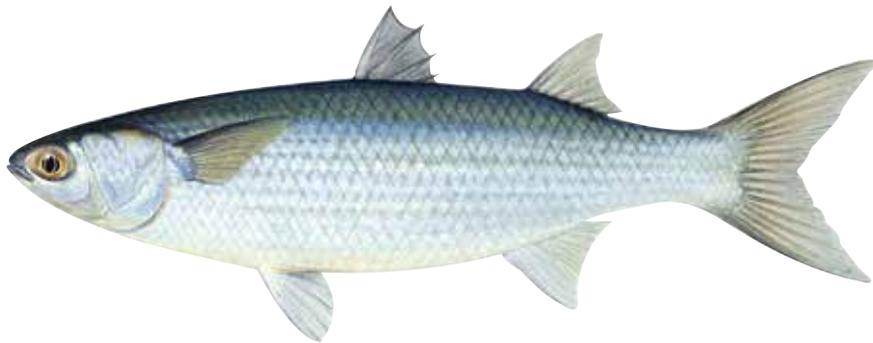
- Ayvazian, S. G., Hyndes, G. A., 1995. Surf-zone fish assemblages in south-western Australia: do adjacent nearshore habitats and the warm Leeuwin Current influence the characteristics of the fish fauna? *Marine Biology* 122, 527-536.
- Chubb, C. F., Potter, I. C., Grant, C. J., Lenanton, R. C. J., Wallace, J. H., 1981. Age structure, growth rates and movements of sea mullet, *Mugil cephalus* L., and yellow eye mullet, *Aldrichetta forsteri* (Valenciennes), in the Swan-Avon River System, Western Australia. *Australian Journal of Marine and*

- Crisafulli, B., 2008. Biology of two fish species of mullet (Mugilidae) in five estuaries on the south coast of Western Australia, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 121.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Edgar, G. J., Shaw, C., 1995. The production and trophic ecology of shallow-water fish assemblages in southern Australia II. Diets of fishes and trophic relationships between fishes and benthos at Western Port, Victoria. *Journal of Experimental Marine Biology and Ecology* 194, 83-106.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gaughan, D. J., Ayzavian, S., Nowara, G., Craine, M., Brown, J., 2006. The development of a rigorous sampling program for a long term annual index of recruitment for finfish species from south-western Australia. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 1999/153, Fisheries Research Report No. 154. pp. 135.
- Harris, J. A., 1968. The yellow-eye mullet. Age structure, growth rate and spawning cycle of a population of yellow-eye mullet, *Aldrichetta forsteri* (Cuv. and Val.) from the Coorong Lagoon, South Australia. *Transactions of the Royal Society of South Australia* 92, 37-50.
- Hickford, M. J. H., Schiel, D. R., 2003. Comparative dispersal of larvae from demersal versus pelagic spawning fishes. *Marine Ecology Progress Series* 252, 255-271.
- Higham, J., Ferguson, G., Ye, Q., 2005. Lakes and Coorong yellow-eye mullet (*Aldrichetta forsteri*) Fishery. SARDI. Adelaide, South Australia. Publication No. RD04/0162. pp. 43.
- Humphries, P., Hyndes, G. A., Potter, I. C., 1992. Comparisons between the diets of distant taxa (Teleost and Cormorant) in an Australian estuary. *Estuaries* 15, 327-334.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Hutson, K. S., Catalano, S. R., Whittington, I. D., 2011. Metazoan parasite survey of selected macro-inshore fish of southeastern Australia, including species of commercial importance. James Cook University. Townsville, Queensland. FRDC Project No. 2007/225. pp. 259.
- Jenkins, G., 1986. Composition, seasonality and distribution of ichthyoplankton in Port Phillip Bay, Victoria. *Marine and Freshwater Research* 37, 507-520.
- Jones, G., Baker, J., Edyvane, K., Wright, G., 1996. Nearshore fish community of the Port River-Barker Inlet Estuary, South Australia. I. Effect of thermal effluent on the fish community structure, and distribution and growth of economically important fish species. *Marine and Freshwater Research* 47, 785-799.
- Kingsford, M. J., Tricklebank, K. A., 1991. Ontogeny and behavior of *Aldrichetta forsteri* (Teleostei: Mugilidae). *Copeia* 1991, 9-16.
- Kirkwood, G., Walker, T., 1986. Gill net mesh selectivities for gummy shark, *Mustelus antarcticus* Gunther, taken in south-eastern Australian Waters. *Marine and Freshwater Research* 37, 689-697.
- Lenanton, R. C. J., 1974. Fish and crustacea of the Western Australian south coast rivers and estuaries. Western Australian Department of Fisheries. Perth Western Australia. Fisheries Research Bulletin of Western Australia No. 13. pp. 1-17.
- Lenanton, R. C. J., 1978. Fish and exploited crustaceans of the Swan-Canning estuary. Western Australian Department of Fisheries and Wildlife. Perth, Western Australia. Western Australian Department of Fisheries and Wildlife Report No. 35. pp. 36.
- Lenanton, R. C. J., 1982. Alternative non-estuarine nursery habitats for some commercially and recreationally important fish species of south-western Australia. *Australian Journal of Marine and Freshwater Research* 33, 881-900.
- Lenanton, R. C. J., 1984. The commercial fisheries of temperate Western Australian estuaries, early settlement to 1975. Western Australian Department of Fisheries and Wildlife. Perth, Western Australia. Western

- Australian Department of Fisheries and Wildlife Report No. 62. pp. 40.
- Lenanton, R. C. J., Potter, I. C., Loneragan, N. R., Chrystal, P. J., 1984. Age structure and changes in abundance of three important species of teleost in a eutrophic estuary (Pisces: Teleostei). *Journal of Zoology, London* 203, 311-327.
- Malseed, B. E., Sumner, N. R., 2001a. A 12-month survey of recreational fishing in the Swan-Canning Estuary basin of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 126. pp. 44.
- Malseed, B. E., Sumner, N. R., 2001b. A 12-month survey of recreational fishing in the Peel-Harvey Estuary of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 127. pp. 48.
- Malseed, B. E., Sumner, N. R., Williamson, P. C., 2000. A 12-month survey of recreational fishing in the Leschenault Estuary of Western Australia during 1998. Western Australian Department of Fisheries. Perth, Western Australia. pp. 36.
- Orr, P., 2000. The biology of four commercial fish species in a seasonally closed estuary, PhD thesis, Murdoch University, Perth, Western Australia. pp. 275.
- Platell, M. E., Orr, P. A., Potter, I. C., 2006. Inter- and intraspecific partitioning of food resources by six large and abundant fish species in a seasonally open estuary. *Journal of Fish Biology* 69, 243-262.
- Potter, I. C., Hyndes, G. A., 1994. Composition of the fish fauna of a permanently open estuary on the southern coast of Australia, and comparisons with a nearby seasonally closed estuary. *Marine Biology* 121, 199-209.
- Potter, I. C., Hyndes, G. A., Baronie, F. M., 1993. The fish fauna of a seasonally closed Australian estuary. Is the prevalence of estuarine-spawning species high? *Marine Biology* 116, 19-30.
- Sechin, Y. T., 1969. A mathematical model for the selectivity curve of a gill net *Rybnoe khozyaistvo [translated from Russian by the International Pacific Halibut Commission, Seattle, Washington]* 49, 56-58.
- Smallwood, C. B., Pollock, K. H., Wise, B. S., Hall, N. G., Gaughan, D. J., 2011. Quantifying recreational fishing catch and effort: a pilot study of shore-based fishers in the Perth Metropolitan area. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 216. pp. 60.
- Smallwood, C. B., Sumner, N. R., 2007. A 12-month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002/03. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 159. pp. 56.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012a. South Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Smith, K., Brown, J., Howard, A., Walshe, K., Fissioli, J., 2012b. West Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 80-97.
- Smith, K. A., 2006. Review of fishery resources and status of key fishery stocks in the Swan-Canning Estuary. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 156. pp. 84.
- Thomson, J. M., 1954a. The Mugilidae of Australia and adjacent seas. *Australian Journal of Marine and Freshwater Research* 5, 70-131.
- Thomson, J. M., 1954b. The organs of feeding and the food of some Australian mullet. *Australian Journal of Marine and Freshwater Research* 5, 469-485.
- Thomson, J. M., 1957a. Biological studies of economic significance of the yellow-eye mullet, *Aldrichetta forsteri* (Cuvier & Valenciennes) (Mugilidae). *Australian Journal of Marine and Freshwater Research* 8, 1-13.
- Thomson, J. M., 1957b. Interpretation of the scales of the yellow-eye mullet, *Aldrichetta forsteri* (Cuvier & Valenciennes) (Mugilidae). *Australian Journal of Marine and Freshwater Research* 8, 14-28.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.
- Young, G. C., Potter, I. C., Hyndes, G. A., de Lestang, S., 1997. The ichthyofauna of an intermittently open estuary: implications of bar breaching and low salinities on faunal composition. *Estuarine, Coastal and Shelf Science* 45, 53-68.

## Sea mullet (*Mugil cephalus*)

Reviewed by Brett Crisafulli (Murdoch University)



**Scientific name:** *Mugil cephalus* (Mugilidae; Grey mullets)

**Common names:** Sea mullet *also* striped mullet, grey mullet, flathead grey mullet

**Key identifying features:** Transparent fatty eyelid covering most of eye, anal fin has 3 spines and 8 (rarely 9) soft rays in adults, dorsal fins widely separated, no dark spots at base of pectoral fin, second dorsal and anal fins with scales only on anterior and basal parts of fins (Harrison and Senou, 1999; Yearsley *et al.*, 2001).

### Distribution of species

**Worldwide:** Worldwide distribution, found almost entirely between ~ 42°N and 42°S (Thomson, 1963; 1966; Rossi *et al.*, 1998).

**Western Australia:** Entire Western Australian coast (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 787mm, 4.9 kg (Hutchins & Swainston, 1986), 16 years (Thomson, 1963).

**Length/weight relationship:** [Lower west and south coast]  $W=4.72*10^{-6}TL^{3.15}$  ( $n=860$ ) (Gaughan *et al.*, 2006).

TL (mm)	200	300	400
Weight (g)	83	300	742

**Length relationship:** [Florida]  $FL=1.112*SL+0.950$  ( $R^2=0.99$ ) (Greeley *et al.*, 1987)

**Growth:** [West Coast] Females  $L_{\infty}=509$  mm,  $k=0.590$  year<sup>-1</sup>,  $t_0$ =fixed at zero years ( $n=170$ )  
Males  $L_{\infty}=398$  mm,  $k=0.793$  year<sup>-1</sup>,  $t_0$ =fixed at zero years ( $n=177$ ) (Gaughan *et al.*, 2006).

Age (years)	1	2	3
Females, TL (mm)	203	325	398
Males, TL (mm)	218	317	361

See also Thomson (1951), Lenanton *et al.* (1984), Lenanton (1977), Chubb *et al.* (1981), Orr (2000), Gaughan *et al.* (2006) and Crisafulli (2008).

**Length and age at maturity:** [West Coast]  $L_{50}=373$  mm (Gaughan *et al.*, 2006). See also (Thomson, 1951).

**Reproductive style:** Gonochoristic (Greeley *et al.*, 1987).

**Adult sex ratio:** [Wilson Inlet, seine and gill nets] F1.5:M1 (Orr, 2000).

**Length and age at sex change:** Not applicable.

**Spawning season:** [South-western Australian] February to September (Chubb *et al.*, 1981; Orr, 2000; Potter *et al.*, 2000).

**Spawning location and habitat:** Spawns in nearshore marine waters and embayments (Chubb *et al.*, 1981; Potter and Hyndes, 1999). Sometimes sexual maturity is approached by individuals in estuaries, but no evidence of spawning (Orr, 2000; Crisafulli, 2008). [Hawaii] Can mature under culture at a range of salinities and then spawn at full strength sea water (Tamaru *et al.*, 1994). [Gulf of Mexico] Shown to spawn 40-50 miles offshore, at 500-900 fathoms depth (Arnold and Thomson, 1958; Ditty and Shaw, 1996). Tides suggested as trigger for spawning (Ibanez and Benitez, 2004).

**Fecundity:** [Queensland] Determinate fecundity;  $F=0.0007*TL^{3.50}$  (presumed as *TL*) (Grant and Spain, 1975). Other estimates available for Florida (Greeley *et al.*, 1987) and South Carolina (McDonough *et al.*, 2003).

TL (mm)	200	300	400
Fecundity (eggs)	79,195	327,358	896,000

### Development and habitat use

**Eggs:** [New South Wales] Pelagic, hatching at ~ 48 h (Kesteven, 1942; Thomson, 1963; Smith and Deguara, 2002)

**Larvae:** [Taiwan] Sink during the first 10 days after hatching and then exhibit positive phototaxis (movement in response to light) (Liao, 1974). Can acclimate to salinities of up to 126 (Hotos and Vlahos, 1998). [Hawaii] Description of larval stages (Leis and Carson-Ewart, 2000).

**Juveniles:** Nearshore, shallow areas of marine embayments and estuarine systems. Typically enter estuaries at 20-30 mm length (Chubb *et al.*, 1981). Strong preference for low salinities all year round in estuaries (Cardona, 2000; Chang *et al.*, 2004), although not necessarily all individuals.

**Adults:** Shallow coastal waters, marine embayments, estuarine systems and rivers (Chubb *et al.*, 1981; Harrison and Senou, 1999; Allen *et al.*, 2002; Smith, 2006; Crisafulli, 2008).

**Migration:** Migrate into upper reaches of estuaries. Mature fish move downstream in warmer months (Chubb *et al.*, 1981). Migrations along the coast are typically northward on the west and east coasts of Australia (Thomson, 1951; Kesteven, 1953; Virgona *et al.*, 1998; Smith and Deguara, 2002). Highly euryhaline (Thomson, 1966; Cardona, 2001).

**Stock delineation:** Low rates of gene flow between non-contiguous populations in the Indian and Pacific Oceans (but higher elsewhere). Highest genetic distance between populations for those of the Indian Ocean between Western Australia and South Africa (Rossi *et al.*, 1998).

**Diet:** Sand, detritus, diatoms, algae and occasionally crustaceans and bivalves (Thomson, 1954; Lenanton, 1978; Orr, 2000). [Queensland] Stable isotope studies useful for dietary studies due to high amount of unidentifiable material in gut contents/empty guts (Hadwen *et al.*, 2007). Ingestion of sand suggested to act as a “grinding paste” for degradation of plant cell walls in the pyloric portion of the stomach (Thomson, 1966). See also [Western Mediterranean] Cardona (2001), [Caspian Sea] Ghadirnejad and Ryland (1996) and [South Africa] Marais (1978).

### Fishery

**Recreational:** Infrequently targeted using nets in estuaries of the West Coast and South Coast bioregions (Smith, 2006; Smith *et al.*, 2012a; Smith *et al.*, 2012b).

**Commercial:** Caught by set nets, haul nets and beach seines in estuaries, and beach seines

in nearshore waters, along the West Coast and South Coast bioregions, including the West Coast Beach Bait Managed Fishery and South Coast Estuarine Managed Fishery (SCEMF) (Kesteven, 1942; Thomson, 1950; Smith *et al.*, 2012a; Smith *et al.*, 2012b). A complete catch trend graph can be found in the 2010/11 State of the Fisheries and Aquatic Resources Report. One of the most commercially important species in the Swan River Estuary (Lenanton, 1978; Smith, 2006). This species is also caught in the Gascoyne Coast bioregion, and is one of the key target species in the Shark Bay Beach Seine and Mesh Net Managed Fishery (SBBSMNMF) (Jackson *et al.*, 2012). See also Ayvazian *et al.* (1997) and Gaughan *et al.* (2006).

**Age at full recruitment:** Not reported.

**Gear selectivity parameters:** Selectivity curves for gillnet stretched mesh sizes of 35, 51, 63, 76, 89, 102 and 155 mm presented by Crisafulli (2008), fitted using the method of Kirkwood and Walker (1986). Selectivity parameter values not reported.

### Management parameters

**Total mortality:** [North Carolina, tag-return models] 1.71 year<sup>-1</sup> (Bacheler *et al.*, 2005).

**Natural mortality:** [Queensland] 0.33 year<sup>-1</sup> (Bell *et al.*, 2004).

**Fishing mortality:** Not reported.

**Biological reference points:** [Queensland] Stock assessments undertaken for this species include a statistical catch at age analysis and virtual population analysis (Bell *et al.*, 2004).

**Current status:** Stock level acceptable in the West Coast bioregion (Smith *et al.*, 2012b), adequate in the Gascoyne Coast bioregion (Jackson *et al.*, 2012). A proposed indicator species for the nearshore zone in the South Coast bioregion (DoF, 2011). Overall risk to sustainability for the nearshore suite is medium to high in the West Coast bioregion and moderate in the Gascoyne Coast and South Coast bioregions (DoF, 2011). Inherent vulnerability of the species is moderate (all bioregions) and current risk to wild stock are minimal in the Gascoyne Coast bioregion and moderate in the West Coast and South Coast bioregions (DoF, 2011). See DoF (2011) for more detailed risk assessment data. A national assessment by (Rowling *et al.*, 2012) lists the biological stock of this species in Western Australia as sustainable.

### Catch trends

**Recreational:** No recreational catch information available for Western Australia.

**Commercial:** A total of 213 t of this species was taken by commercial fishers in Western Australia in 2010/11, down from a peak of 694 t in 1988 (Smith *et al.*, 2012b). From 2001 to 2010, 42% of the commercial catch of this species was from the West Coast bioregion, 45% from the Gascoyne Coast bioregion, 11% from the South Coast bioregion and 1% from the North Coast bioregion (Smith *et al.*, 2012b). In 2011, the total catch in the West Coast bioregion was 62 t, from an historic peak of 429 t in 1988 (Smith *et al.*, 2012b). Catches of this species have been stable in the South Coast bioregion, with a catch of 31 t in 2011, and an annual average of 36 t since 1976 (Smith *et al.*, 2012a). An additional 108 t was caught in the Gascoyne Coast bioregion in 2011 (Jackson *et al.*, 2012). A complete catch trend graph is shown in the 2010/11 State of the Fisheries and Aquatic Resources Report. See also (Rowling *et al.*, 2012).

### Management regulations

**Recreational:** Not specifically listed, therefore included in the “all other species of finfish” category (DoF, 2013). Regulations for recreational netting also apply (DoF, 2012).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1958)	-	237	
Statewide (1973/74)	-	240	
Statewide (1993/94)	40	-	
West Coast (2009)	30	-	
Statewide (2013)	30	-	

**Commercial:** The West Coast and South Coast nearshore and estuarine fishery and SBBSMNMF are managed primarily through input controls such as limited entry, gear restrictions (*i.e.*, net length and mesh size), spatial and temporal closures (Jackson *et al.*, 2012; Smith *et al.*, 2012a).

**Current research:** Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Heavy metal* (Marks *et al.*, 1980); *Growth/sexual dimorphism* (Grant *et al.*, 1977); *Phylogeny* (Crosetti *et al.*, 1994; Turan *et al.*, 2005; Aurelle *et al.*, 2008; Turan *et al.*, 2011); *Age* [New South Wales] (Smith and Deguara, 2003); *Aquaculture/stock enhancement* (Thomson, 1966), [Hawaii] (Kuo *et al.*, 1973; Leber, 1996), [Egypt] (Saleh, 2008); *Reproduction* [Croatia] (Bartulovic *et al.*, 2011), [Israel] (Aizen *et al.*, 2005); *Diseases and parasitology* [Queensland] (Burke and Rodgers, 1981; Callinan and Keep, 1989), [New South Wales] (Virgona, 1992); *Freshwater* [Israel] (Leventer, 1981; Torras *et al.*, 2000).

## References

- Aizen, J., Meiri, I., Tzchori, I., Levavi-Sivan, B., Rosenfeld, H., 2005. Enhancing spawning in the grey mullet (*Mugil cephalus*) by removal of dopaminergic inhibition. *General and comparative endocrinology* 142, 212-221.
- Allen, G. R., Midgley, S. H., Allen, M., 2002. Field guide to the freshwater fishes of Australia. Western Australian Museum, Perth, Western Australia.
- Arnold, E. L., Thomson, J. R., 1958. Offshore spawning of the striped mullet, *Mugil cephalus*, in the Gulf of Mexico. *Copeia* 2, 130-132.
- Aurelle, D., Barthelemy, R. M., Quingnard, J. P., Trabelsi, M., Faure, E., 2008. Molecular phylogeny of Mugilidae (Teleostei: Perciformes). *Open Marine Biology Journal* 2, 29-37.
- Ayvazian, S., Lenanton, R., Wise, B., Steckis, R., Nowara, G., 1997. Western Australian Salmon and Australian herring creel survey. Fisheries Western Australia. Perth, Western Australia. FRDC Project No. 93/79. pp. 93.
- Bachelor, N. M., Wong, R. A., Buckel, J. A., 2005. Movements and mortality rates of striped mullet in North Carolina. *North American Journal of Fisheries Management* 25, 361-373.
- Bartulovic, V., Dulcic, J., Matic-Skoko, S., Glamuzina, B., 2011. Reproductive cycles of *Mugil cephalus*, *Liza ramada* and *Liza aurata* (Teleostei: Mugilidae). *Journal of Fish Biology* 78, 2067-2073.
- Bell, P. A., O'Neill, M. F., Leigh, G. M., Courtney, A. J., Peel, S. L., 2004. Stock assessment of the Queensland-New South Wales sea mullet fishery (*Mugil cephalus*). Queensland Department of Primary Industries and Fisheries. Queensland, Australia.
- Burke, J., Rodgers, L., 1981. Identification of pathogenic bacteria associated with the occurrence of 'red spot' in sea mullet, *Mugil cephalus* L. in south-eastern Queensland. *Journal of Fish Diseases* 4, 153-159.
- Callinan, R. B., Keep, J. A., 1989. Bacteriology and parasitology of red spot disease in sea mullet *Mugil cephalus* L. from eastern Australia. *Journal of Fish Diseases* 12, 349-356.

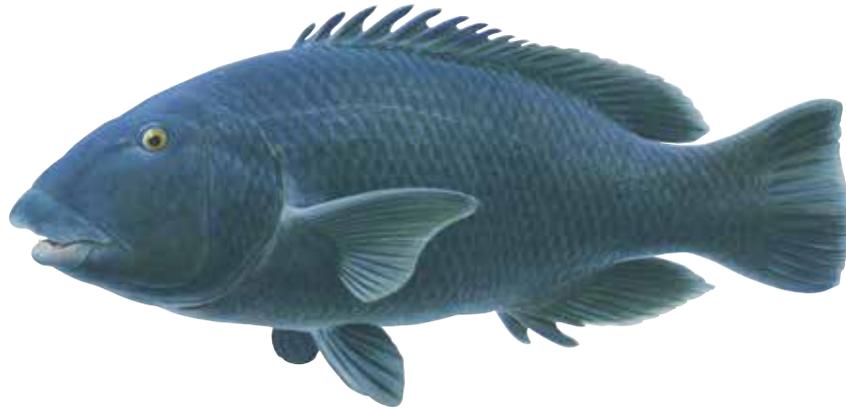
- Cardona, L., 2000. Effects of salinity on the habitat selection and growth performance of Mediterranean flathead grey mullet *Mugil cephalus* (Osteichthyes, Mugilidae). *Estuarine, Coastal and Shelf Science* 50, 727-737.
- Cardona, L., 2001. Non-competitive coexistence between Mediterranean grey mullet: evidence from seasonal changes in food availability, niche breadth and trophic overlap. *Journal of Fish Biology* 59, 729-744.
- Chang, W. C., Iizuka, Y., Tzeng, W. N., 2004. Migratory environmental history of the grey mullet *Mugil cephalus* as revealed by otolith Sr:Ca ratios. *Marine Ecology Progress Series* 269, 277-288.
- Chubb, C. F., Potter, I. C., Grant, C. J., Lenanton, R. C. J., Wallace, J. H., 1981. Age structure, growth rates and movements of sea mullet, *Mugil cephalus* L., and yellow eye mullet, *Aldrichetta forsteri* (Valenciennes), in the Swan-Avon River System, Western Australia. *Australian Journal of Marine and Freshwater Research* 32, 605-628.
- Crisafulli, B., 2008. Biology of two fish species of mullet (Mugilidae) in five estuaries on the south coast of Western Australia, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 121.
- Crosetti, D., Nelson, W. S., Avise, J. C., 1994. Pronounced genetic structure of mitochondrial DNA among populations of the circumglobally distributed grey mullet (*Mugil cephalus*). *Journal of Fish Biology* 44, 47-58.
- Ditty, J. G., Shaw, R. F., 1996. Spatial and temporal distribution of larval striped mullet (*Mugil cephalus*) and white mullet (*M. curema*, Family: Mugilidae) in the Northern Gulf of Mexico, with notes on mountain mullet, *Agonostomus monticola*. *Bulletin of Marine Science* 59, 271-288.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2012. Recreational net fishing - 2012/13 guide. Department of Fisheries, Western Australia. Perth, Western Australia. pp. 48.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Gaughan, D. J., Ayvazian, S., Nowara, G., Craine, M., Brown, J., 2006. The development of a rigorous sampling program for a long term annual index of recruitment for finfish species from south-western Australia. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 1999/153, Fisheries Research Report No. 154. pp. 135.
- Ghadirnejad, H., Ryland, J. S., 1996. A study of food and feeding of grey mullets in the southern of the Caspian Sea, *In* CUTSHOP 96 - Feeding ecology and Nutrition in Fish Symposium. pp. 137-144.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Grant, C., Spain, A., 1975. Reproduction, growth and size allometry of *Valamugil seheli* (Forsk.) (Pisces : Mugilidae) from north Queensland inshore waters. *Australian Journal of Zoology* 23, 463-474.
- Grant, C., Spain, A., Jones, P., 1977. Studies of sexual dimorphism and other variation in nine species of Australian mullets (Pisces : Mugilidae). *Australian Journal of Zoology* 25, 615-630.
- Greeley, M. S., Calder, D. R., Wallace, R. A., 1987. Oocyte growth and development in the striped mullet, *Mugil cephalus*, during seasonal ovarian recrudescence: relationship to fecundity and size and maturity. *Fisheries Bulletin* 85, 187-200.
- Hadwen, W. L., Russell, G. L., Arthington, A. H., 2007. Gut content- and stable isotope-derived diets of four commercially and recreationally important fish species in two intermittently open estuaries. *Marine and Freshwater Research* 58, 363-375.
- Harrison, J. J., Senou, H., 1999. Order Mugiliformes, *In* The living marine resources of the Western Central Pacific, FAO Species Identification Guide for Fisheries Purposes. Carpenter, K. E., Niem, V. H. (eds), FAO, Rome, Italy, pp. 2069-2790.
- Hotos, G. N., Vlahos, N., 1998. Salinity tolerance of *Mugil cephalus* and *Chelon labrosus* (Pisces: Mugilidae) fry in experimental conditions. *Aquaculture* 167, 329-338.
- Ibanez, A. L., Benitez, O. G., 2004. Climate variables and spawning migrations of the striped mullet and white mullet in the north-western area of the Gulf of Mexico. *Journal of Fish Biology* 65, 822-831.

- Jackson, G., Norriss, J., Lunow, C., 2012. Inner Shark Bay scalefish fishery status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 154-160.
- Kesteven, G., 1953. Further results of tagging sea mullet, *Mugil cephalus* Linnaeus, on the eastern Australia coast. *Marine and Freshwater Research* 4, 251-306.
- Kesteven, G. L., 1942. Studies in the biology of Australian mullet. 1. Account of the fishery and preliminary statement of the biology of *Mugil dobula* Gunther. CSIRO. Report No. 9. pp. 47.
- Kirkwood, G., Walker, T., 1986. Gill net mesh selectivities for gummy shark, *Mustelus antarcticus* Gunther, taken in south-eastern Australian Waters. *Marine and Freshwater Research* 37, 689-697.
- Kuo, C. M., Nash, C. E., Shehadeh, Z. H., 1973. The effects of temperature and photoperiod on ovarian development in captive grey mullet (*Mugil cephalus* L.). *Aquaculture* 3, 25-43.
- Leber, K. M., 1996. Stock enhancement in a commercial mullet, *Mugil cephalus* L., fishery in Hawaii. *Fisheries Management and Ecology* 3, 261-278.
- Leis, J. M., Carson-Ewart, B. M., 2000. The larvae of Indo-pacific coastal fishes: a guide to identification (Fauna Malesiana Handbook 2). Brill: Leiden.
- Lenanton, R. C. J., 1977. Aspects of the ecology of fish and commercial crustaceans of the Blackwood River estuary Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Bulletin of Western Australia No. 19. pp. 72.
- Lenanton, R. C. J., 1978. Fish and exploited crustaceans of the Swan-Canning estuary. Western Australian Department of Fisheries and Wildlife. Perth, Western Australia. Western Australian Department of Fisheries and Wildlife Report No. 35. pp. 36.
- Lenanton, R. C. J., Potter, I. C., Loneragan, N. R., Chrystal, P. J., 1984. Age structure and changes in abundance of three important species of teleost in a eutrophic estuary (Pisces: Teleostei). *Journal of Zoology, London* 203, 311-327.
- Leventer, H., 1981. Biological control of reservoirs by fish. *Israeli Journal of Aquaculture* 33, 3-23.
- Liao, I. C., 1974. The experiments on the induced breeding of the grey mullet in Taiwan from 1963 to 1973. *Aquaculture* 6, 31-58.
- Marais, J. F. K., 1978. Routine oxygen consumption of *Mugil cephalus*, *Liza dumerili* and *L. richardsoni* at different temperatures and salinity levels. *Marine Biology* 50, 9-16.
- Marks, P., Plaskett, D., Potter, I., Bradley, J., 1980. Relationship between concentration of heavy metals in muscle tissue and body weight of fish from the Swan-Avon Estuary, Western Australia. *Marine and Freshwater Research* 31, 783-793.
- McDonough, C. J., Roumillat, W. A., Wenner, C. A., 2003. Fecundity and spawning season of striped mullet (*Mullet cephalus* L.) in South Carolina estuaries. *Fishery Bulletin* 101, 822-834.
- Orr, P., 2000. The biology of four commercial fish species in a seasonally closed estuary, PhD thesis, Murdoch University, Perth, Western Australia. pp. 275.
- Potter, I. C., Chalmer, P. N., Tiivel, P. N., Steckis, R. A., Platell, M. E., Lenanton, R., 2000. The fish fauna and finfish fishery of the Leschenault Estuary in south-western Australia. *Journal of the Royal Society of Western Australia* 83, 481-501.
- Potter, I. C., Hyndes, G. A., 1999. Characteristics of the ichthyofaunas of southwestern Australian estuaries, including comparisons with holarctic estuaries and estuaries elsewhere in temperate Australia: a review. *Australian Journal of Ecology* 24, 395-421.
- Rossi, A. R., Capula, M., Crosetti, D., Campton, D. E., Sola, L., 1998. Genetic divergence and phylogenetic inferences in five species of Mugilidae (Pisces: Perciformes). *Marine Biology* 131, 213-218.
- Rowling, K., Roelofs, A., Smith, K., 2012. Sea mullet *Mugil cephalus*, In Status of key Australian fish stocks reports 2012. Flood, M., Stobutzki, I., Andrews, J., Begg, G., Fletcher, W., Gardner, C., Kemp, J., Moore, A., O'Brien, A., Quinn, R., Roach, J., Rowling, K., Sainsbury, K., Saunders, T., Ward, T., Winning, M. (eds), Fisheries Research and Development Corporation, Canberra, Australia, pp. 280-284.

- Saleh, M., 2008. Capture-based aquaculture of mullets in Egypt, In Capture-based aquaculture. Global overview. *FAO Fisheries Technical Paper No. 508*. Lovatelli, A., Holthuis, P. F. (eds), FAO, Rome, Italy, pp. 109-126.
- Smith, K., Brown, J., Howard, A., Stadler, M., 2012a. South Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 266-278.
- Smith, K., Brown, J., Howard, A., Walshe, K., Fissioli, J., 2012b. West Coast nearshore and estuarine finfish resources status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 80-97.
- Smith, K. A., 2006. Review of fishery resources and status of key fishery stocks in the Swan-Canning Estuary. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 156. pp. 84.
- Smith, K. A., Deguara, K., 2002. Review of biological information and stock assessment for the NSW sea mullet resource. New South Wales Fisheries. Cronulla, NSW. NSW Fisheries Resource Assessment Series No. 12. pp. 23.
- Smith, K. A., Deguara, K., 2003. Formation and annual periodicity of opaque zones in sagittal otoliths of *Mugil cephalus* (Pisces: Mugilidae). *Marine and Freshwater Research* 54, 57-67.
- Tamaru, C. S., Lee, C. S., Kelley, C. D., Miyamoto, G., Moriwake, A., 1994. Oocyte growth in the striped mullet *Mugil cephalus* L. maturing at different salinities. *Journal of the World Aquaculture Society* 25, 109-115.
- Thomson, J. M., 1950. The effect of a period of increased minimum legal length of sea mullet in Western Australia. *Australian Journal of Marine and Freshwater Research* 1, 199-220.
- Thomson, J. M., 1951. Growth and habits of the sea mullet, *Mugil dobula*, Gunther, in Western Australia. *Australian Journal of Marine and Freshwater Research* 2, 193-225.
- Thomson, J. M., 1954. The organs of feeding and the food of some Australian mullet. *Australian Journal of Marine and Freshwater Research* 5, 469-485.
- Thomson, J. M., 1963. Synopsis of biological data on the grey mullet *Mugil cephalus* Linnaeus 1758. Division of Fisheries and Oceanography, CSIRO. Fishery Synopsis No. 1. pp. 66.
- Thomson, J. M., 1966. The grey mullets. *Annual Review of Oceanography and Marine Biology* 4, 301-335.
- Torras, X., Cardona, L., Gisbert, E., 2000. Cascading effects of the flathead grey mullet *Mugil cephalus* in freshwater eutrophic microcosmos. *Hydrobiologia* 429, 49-57.
- Turan, C., Caliskan, M., Kucuktas, H., 2005. Phylogenetic relationships of nine mullet species (Mugilidae) in the Mediterranean Sea. *Hydrobiologia* 532, 45-51.
- Turan, C., Gurlek, M., Erguden, D., Yaghoglu, D., Osturk, B., 2011. Systematic status of nine mullet species (Mugilidae) in the Mediterranean sea. *Turkish Journal of Fisheries and Aquatic Sciences* 11, 315-321.
- Virgona, J., Deguara, K., Sullings, D., Halliday, I., Kelly, K., 1998. Assessment of the stocks of sea mullet in New South Wales and Queensland waters. NSW Fisheries Research Institute. Cronulla, NSW. FRDC Project No. 94/024. pp. 133.
- Virgona, J. L., 1992. Environmental factors influencing the prevalence of a cutaneous ulcerative disease (red spot) in the sea mullet, *Mugil cephalus* L., in the Clarence River, New South Wales, Australia. *Journal of Fish Diseases* 15, 363-378.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## Western blue groper (*Achoerodus gouldii*)

Reviewed by Brett Molony (DoF)



**Scientific name:** *Achoerodus gouldii* (Labridae; Wrasses)

**Common names:** Western blue groper

**Key identifying features:** Prominent fleshy lips, peg-like teeth, yellow spots around eyes (Hutchins and Swainston, 1986).

### Distribution

**Worldwide:** Endemic to southern Australia.

**Western Australia:** Southern Western Australian border to Abrolhos Islands (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 1,750 mm (Gomon *et al.*, 2008), 39.5 kg (Hutchins and Swainston, 1986), 70 years (Coulson *et al.*, 2009).

**Length/weight relationship:** [South Coast]  $\ln W = 3.041 * \ln TL - 11.017$  ( $n=756$ ,  $R^2=0.997$ ) (Coulson *et al.*, 2009).

TL (mm)	300	600	900
Weight (g)	560	4,610	18,820

**Length relationship:** [South Coast]  $TL = 1.201 * SL - 11.883$  ( $n = 101$ ,  $R^2 = 0.995$ ) (Coulson *et al.*, 2009).

**Growth:** [South Coast] Females  $L_{\infty} = 682$  mm,  $k = 0.14$  year<sup>-1</sup>,  $t_0 = 0.06$  years ( $n = 1,561$ ,  $R^2 = 0.93$ );

Males  $L_{\infty} = 982$  mm,  $k = 0.08$  year<sup>-1</sup>,  $t_0 = -0.48$  years ( $n = 132$ ,  $R^2 = 0.93$ ) (Coulson *et al.*, 2009).

Age (years)	10	30	50
Females, TL (mm)	512	671	681
Males, TL (mm)	557	896	965

**Length and age at maturity:** [South Coast]  $L_{50} = 653$  mm,  $L_{95} = 926$  mm,  $A_{50} \sim 17$  years (Coulson *et al.*, 2007; Coulson *et al.*, 2009)

**Reproductive style:** Monandric protogynous hermaphrodite (Coulson *et al.*, 2009).

**Adult sex ratio:** [South coast, spear fishing, commercial gill nets] 1F: 0.05M (Coulson *et al.*, 2009).

**Length and age at sex change:** [South Coast]  $L_{50} = 821$  mm,  $L_{95} = 930$  mm, 15 – 19 years=9% males; 35 – 39 years=67% males,  $\geq 50$  years=100% males (Coulson *et al.*, 2009).

**Spawning season:** Early winter and mid-spring (Coulson *et al.*, 2009).

**Spawning location and habitat:** Predominantly offshore coastal waters, over hard substrate (Coulson *et al.*, 2009).

**Fecundity:** Indeterminate (Coulson *et al.*, 2007). Batch fecundity ranged from 150,400 to 402,900 eggs in 12 fish ranging between 530 – 850 mm TL) (Coulson *et al.*, 2007).

**Spawning frequency:** Not reported (Coulson *et al.*, 2007).

### **Development and habitat use**

**Eggs:** [Labridae] Pelagic (Leis and Carson-Ewart, 2000).

**Larvae:** Not reported.

**Juveniles:** Shallow and relatively protected waters, including estuaries (Crowe *et al.*, 1999; Coulson *et al.*, 2009).

**Adults:** Coastal to offshore (~20-100 m) rocky reefs, with both high and low profile characteristics to 40 m (Crowe *et al.*, 1999; Chatfield *et al.*, 2010).

**Migration:** Adult males are territorial and site-attached (Shepherd, 2005).

**Diet:** [South Australia] Crustaceans, molluscs and echinoderms (Baker, 2009).

### **Fishery**

**Recreational:** Targeted by recreational anglers using lines and by spearfishing (Shepherd, 2005; Gomon *et al.*, 2008).

**Commercial:** Second most frequently caught species in the temperate Demersal Gillnet and Demersal Longline Fisheries (DGDLF) which operate in the South Coast and West Coast bioregions (McAuley and Rowland, 2012). This species is also targeted in the South Coast Demersal Scalefish Fishery (Molony *et al.*, 2012).

**Length and age at first capture:** Not reported.

**Age at full recruitment:** Not reported.

**Recreational:** Not reported.

**Commercial:** [South Coast, gillnet] ~15 years (Coulson *et al.*, 2009).

**Gear selectivity parameters:** Not reported.

### **Management parameters**

**Total mortality:** [Catch curve analysis] 0.086 year<sup>-1</sup> (Coulson *et al.*, 2009)

**Natural mortality:** [Hoenig's (1983) equation for fish] 0.072 year<sup>-1</sup> (Coulson *et al.*, 2009)

**Fishing mortality:** 0.039 year<sup>-1</sup> (Coulson *et al.*, 2009)

**Biological reference points:**  $F_{0.1}$  achieved at  $F=0.051$  year<sup>-1</sup>

$YPR_{current} = 1.88$  kg recruit<sup>-1</sup>

$SSB/R_{current}$  (for females and males combined)=44.2 kg recruit<sup>-1</sup>

$SPR_{current}$  (SSB/R) (for females and males combined)=0.56 (Coulson *et al.*, 2007)

**Current status:** A proposed indicator species for inshore demersal suite in the South Coast bioregion (DoF, 2011). Overall risk to sustainability for the inshore demersal suite is medium to high in the West Coast bioregion and South Coast bioregions (DoF, 2011). Inherent

vulnerability of the species is extreme in the South Coast bioregion and moderate in the West Coast bioregion while current risk to wild stock is moderate (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

**Recreational:** Total estimated recreational boat-based catch in the West Coast bioregion was 2.7 t for 1996/97 (Sumner and Williamson, 1999).

**Commercial:** A total of 49 t (live weight) of this species was taken by commercial fishers in Western Australia in 2010/11 (Fletcher and Santoro, 2012). Total catch from the DGDLF was 47.5 t, of which 30.9 t was taken from the South Coast bioregion and 16.6 t from the West Coast bioregion (McAuley and Rowland, 2012). The total catch of this species in the South Coast Demersal Line Fishery has remained static, with 1.1 t taken in 2007 and 1.3 t in 2011 (Molony *et al.*, 2012).

### Management regulations

**Recreational:** Currently listed in the “demersal finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1958)	-	300	
Statewide (1973/74)	-	305	
Statewide (1975)	-	400	
Statewide (1977)	10	400	
Statewide (1983)	1	400	
South Coast (2003)	1	500	
West Coast (2003)	1	500	
West Coast (2009)	1	500	Closed season: 15 Oct - 15 Dec Compulsory possession of release weight
Statewide (2013)	1	500	

**Commercial:** The DGDLF is regulated using various input controls (transferable time/gear effort, mesh and hook sizes, maximum net length), output controls as well as temporal (16 Aug – 15 Oct) and spatial closures (McAuley and Rowland, 2012). The South Coast Demersal Line Fishery is currently ‘open access’ for the holder of a valid Fishing Boat Licence (for the boat) and a Commercial Fishing Licence (for the fisher) (Molony *et al.*, 2012).

**Current research:** Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

### References

- Baker, J. L., 2009. Marine Species of Conservation Concern in South Australia: Volume 1 - Bony and Cartilaginous Fishes. Report for the South Australian Working Group for Marine Species of Conservation Concern. Science and Conservation Division, and Coast and Marine Conservation branches of S.A. Department for Environment and Heritage (DEH); Marine and Coastal Community Network of S.A. (MCCN), and Threatened Species Network (TSN). Web version published by Reef Watch, South Australia.
- Chatfield, B. S., Van Niel, K. P., Kendrick, G. A., Harvey, E. S., 2010. Combining environmental gradients to explain and predict the structure of demersal fish distributions. *Journal of Biogeography* 37, 593-605.

- Coulson, P. G., Hesp, S. A., Hall, N. G., Potter, I. C., 2009. The western blue groper (*Achoerodus gouldii*), a protogynous hermaphroditic labrid with exceptional longevity, late maturity, slow growth, and both late maturation and sex change. *Fishery Bulletin* 107, 57-75.
- Coulson, P. G., Potter, I. C., Hesp, S. A., Hall, N. G., 2007. Biological parameters required for managing western blue groper, blue morwong and yellowtail flathead. Murdoch University. Perth Western Australia. FRDC Project No. 2004/057. pp. 167.
- Crowe, F., Lehre, W., Lenanton, R. C. J., 1999. A study in Western Australia's open access and wetline fisheries. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 118.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Hoening, J., 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82, 898-903.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Leis, J. M., Carson-Ewart, B. M., 2000. The larvae of Indo-pacific coastal fishes: a guide to identification (Fauna Malesiana Handbook 2). Brill: Leiden.
- McAuley, R., Rowland, F., 2012. Temperate demersal gillnet and demersal longline fisheries status report, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 282-294.
- Molony, B., Lai, E., Holtz, M., 2012. South Coast demersal scalefish resource report: statistics only, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 295-297.
- Shepherd, S. A., 2005. Ontogenetic changes in diet, feeding behaviour and activity of the western blue groper, *Achoerodus gouldii*, In The Marine Flora and Fauna of Esperance, Western Australia. Wells, F. E., Walker, D. I., Kendrick, G. A. (eds), Western Australian Museum, Perth, Western Australia, pp. 477-494.
- Sumner, N. R., Williamson, P. C., 1999. A 12-month survey of coastal recreational boat fishing between Augusta and Kalbarri on the west coast of Western Australia during 1996-97. Western Australian Department of Fisheries. Fisheries Research Report No. 117. pp. 52.

## Foxfish (*Bodianus frenchii*)

Reviewed by Ross Marriott (DoF)



**Scientific name:** *Bodianus frenchii* (Labridae; Wrasses)

**Common names:** Foxfish *also* western foxfish, red groper, hogfish, pigfish

**Key identifying features:** Reddish body colour with two yellow splotches on back, black circular blotches on juveniles disappear with maturity (Hutchins and Thompson, 1983).

### Distribution of species

**Worldwide:** Endemic to southern Australian waters (Gomon, 2001).

**Western Australia:** Southern Western Australian border to the Dampier Archipelago (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 483 mm, 2 kg (Hutchins and Swainston, 1986), 78 years (Cossington *et al.*, 2010).

**Length/weight relationship:** [West Coast]  $\ln TW = 2.996 * \ln TL - 10.916$  ( $R^2 = 0.993$ ,  $n = 183$ ,  $ms = 0.007$ ) (Cossington *et al.*, 2010). See also Cossington *et al.* (2010) for South Coast.

TL (mm)	200	300	400
Weight (g)	143	480	1,134

**Length relationship:** Not reported.

**Growth:** [West coast, Schnute growth curve]  $y_1 = 0.00$  mm,  $y_2 = 370$  mm,  $a = 0.02$ ,  $b = 3.6$ ,  $\tau_1 = 1$  year,  $\tau_2 = 50$  years ( $R^2 = 0.83$ ,  $n = 301$ ) (Cossington *et al.*, 2010). See also Cossington *et al.* (2010) for South Coast.

Age (years)	10	30	50
Females, TL (mm)	256	336	370

**Length and age at maturity:** [West Coast]  $L_{50} = 223$  mm,  $A_{50} = 9.14$  years,  $L_{95} = 243$  mm,  $A_{95} = 14.1$  years (Cossington *et al.*, 2010).

**Reproductive style:** Monandric protogynous hermaphrodite (Cossington, 2006; Cossington *et al.*, 2010).

**Adult sex ratio:** [West Coast, hook and line and spear fishing] F1:M1 (Cossington, 2006).

**Length and age at sex change:** [West Coast]  $L_{50} = 365$  mm,  $A_{50} = 29.2$  years (Cossington *et al.*, 2010). See also Cossington *et al.* (2010) for South Coast.

**Spawning season:** [West Coast and South Coast] October to February (Cossington *et al.*, 2010).

**Spawning location and habitat:** Over reefs in West Coast and South Coast regions at depths ranging from at least 5-40 m (Cossington *et al.*, 2010).

**Fecundity:** Indeterminate. [West Coast] Batch fecundity  $BF=3.5102*TL-10.444$  ( $R^2=0.502$ ,  $n=48$ ); (Cossington *et al.*, 2010). See also Cossington *et al.* (2010) for South Coast.

TL (mm)	250	300	400
Annual fecundity (eggs)	982,000	1,960,000	4,606,000

**Spawning frequency:** [West Coast and South Coast] Approximately daily (using both the hydrated oocyte and post ovulatory follicle methods) (Cossington *et al.*, 2010).

### Development and habitat use

**Eggs:** [Labridae] Pelagic (Leis and Carson-Ewart, 2000).

**Larvae:** Not reported.

**Juveniles:** Shallow, nearshore waters under ledges and in limestone caves on the west coast and under overhangs of granite boulders on the south coast (Cossington, 2006).

**Adults:** Over reefs in coastal waters between 5–100m (Gomon *et al.*, 2008). Also recorded over reefs with dense cover of large brown macroalgae (Harvey *et al.*, 2004).

**Migration:** Not reported.

**Stock delineation:** There are no distinct morphological differences between *B.frenchii* in eastern and western Australia. Due to the spatial separation, it has been suggested there may be distinct stocks (Cossington, 2006).

**Diet:** Consume a wide variety of benthic prey, predominantly, crustaceans and echinoderms as well as small quantities of annelids, macrophytes, teleosts and protochordates (Cossington, 2006). Frequently ingests taxa attached to or lodged in reefs. Dentition indicates “biting” as its feeding mode. Differences in diet between the West Coast and South Coast regions are negligible (Platell *et al.*, 2010).

### Fishery

**Recreational:** Targeted by recreational line fishers and spear fishers (Cossington, 2006). Also caught by fishers on charter boats (Telfer, 2010).

**Commercial:** An inshore demersal species caught within the West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF), but not of major commercial importance (Cossington, 2006).

**Age at full recruitment:** ~30 years (Cossington, 2006).

**Gear selectivity parameters:** Not reported.

### Management parameters

**Total mortality:** [Catch curve analysis incorporating age-based selectivity]  $0.109 \text{ year}^{-1}$  (Cossington, 2006).

**Natural mortality:** [Hall *et al.* (2004)]  $0.062 \text{ year}^{-1}$  (Cossington, 2006). See also Cossington (2006) for other estimates.

**Fishing mortality:**  $0.057 \text{ year}^{-1}$  (*i.e.*, from  $F = Z-M$ ) (Cossington, 2006).

**Biological reference points:**  $YPR_{\text{current}} = 0.07 \text{ kg recruit}^{-1}$

$SSB/R_{\text{current}} = 3.70 \text{ kg recruit}^{-1}$

$SPR (SSB/R - \text{females}) = 0.88$

$SPR (SSB/R - \text{males}) = 0.44$ ,  $SPR (SSB/R - \text{sexes combined}) = 0.69$

$SPR (E/R)_{\text{current}} = 0.86$

$SPR (M:F \text{ ratio}) = 0.37$  (Cossington, 2006)

**Current status:** Overall risk to sustainability for the inshore demersal suite of species is medium to high in the West Coast bioregion and South Coast bioregions (DoF, 2011). Inherent vulnerability of the species is high while current risk to wild stock is moderate (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

**Recreational:** The total estimated annual recreational boat-based catch in the West Coast bioregion was 2 t for 1996/97 and 2 t in 2005/06 (Sumner *et al.*, 2008). The overall estimated catch of this species in Western Australia was 8261 fish in 2000/2001 (Henry and Lyle, 2003). See also Harvey (2004) and Smallwood *et al.* (2006) and (Telfer, 2010) for additional catch information.

**Commercial:** No commercial catch information was reported in the most recent State of the Fisheries report (Fletcher and Santoro, 2012).

### Management regulations

**Recreational:** Currently listed in the “demersal finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
West Coast (2009)	2		Closed season (15 Oct – 15 Dec) Compulsory possession of release weight
South Coast (2010)	8	-	
Statewide (except West Coast) (2013)	3	-	

**Commercial:** The WCDSIMF is regulated using various input controls (restricted entry, total fishing time allocations, maximum number of lines and hooks) (Fairclough *et al.*, 2012).

**Current research:** Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Distribution linked to water temperature* (Langlois *et al.*, 2012).

### References

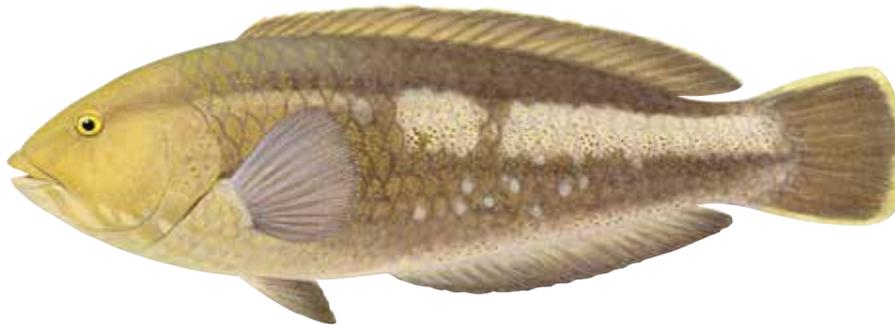
Cossington, S., 2006. Biology of the foxfish *Bodianus frenchii* in coastal marine waters of south-western Australia, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 130.

Cossington, S., Hesp, S. A., Hall, N. G., Potter, I. C., 2010. Growth and reproductive biology of the foxfish *Bodianus frenchii*, a very long-lived and monandric protogynous hermaphroditic labrid. *Journal of Fish Biology* 77, 600-626.

- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gomon, M. F., 2001. Descriptions of two new species of *Bodianus* (Perciformes: Labridae) from Australian waters. *New Zealand Journal of Zoology* 28, 407-416.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Hall, N. G., Hesp, S. A., Potter, I. C., 2004. A bayesian approach for overcoming inconsistencies in mortality estimates using, as an example, data for *Acanthopagrus latus*. *Canadian Journal of Fisheries and Aquatic Sciences* 61, 1202-1211.
- Harvey, E., Cappo, M., Kendrick, G., 2004. Fishes of the Recherche Archipelago, In Characterising fish habitats of the Recherche Archipelago. Kendrick, G., Harvey, E., McDonald, J., Pattiaratchi, C., Cappo, M., Fromont, J., Shortis, M., Grove, S., Bickers, A., Baxter, K., Goldberg, N., Kletczkowski, M., Butler, J. (eds), University of Western Australia, Perth, Western Australia.
- Harvey, M. J., 2004. An evaluation of Western Australian recreational fishing regulations with a case study from a metropolitan boat ramp, Honours thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 97.
- Henry, G. W., Lyle, J. M. (eds) 2003. The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forest, Canberra, Australia.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Hutchins, B., Thompson, M., 1983. The marine and estuarine fishes of south-western Australia: a field guide for anglers and divers. Western Australian Museum, Perth, Western Australia.
- Langlois, T. J., Radford, B. T., Van Niel, K. P., Meeuwig, J. J., Pearce, A. F., Rousseaux, C. S. G., Kendrick, G. A., Harvey, E. S., 2012. Consistent abundance distributions of marine fishes in an old, climatically buffered, infertile seascape. *Global Ecology and Biogeography* 21, 886-897.
- Leis, J. M., Carson-Ewart, B. M., 2000. The larvae of Indo-pacific coastal fishes: a guide to identification (Fauna Malesiana Handbook 2). Brill: Leiden.
- Platell, M. E., Hesp, S. A., Cossington, S. M., Lek, E., Moore, S. E., Potter, I. C., 2010. Influence of selected factors on the dietary compositions of three targeted and co-occurring temperate species of reef fishes: implications for food partitioning. *Journal of Fish Biology* 76, 1255-1276.
- Smallwood, C. B., Beckley, L. E., Sumner, N. R., 2006. Shore-based recreational angling in the Rottneest Island Reserve, Western Australia: spatial and temporal distribution of catch and fishing effort. *Pacific Conservation Biology* 12, 238-51.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Telfer, C., 2010. The Western Australian charter boat industry: working towards long-term sustainability, MSc thesis, School of Natural Sciences. Edith Cowan University, Perth, Western Australia. pp. 153.

## Brown spotted wrasse (*Notolabrus parilus*)

Reviewed by David Fairclough (DoF)



**Scientific name:** *Notolabrus parilus* (Labridae; Wrasses)

**Common names:** Brownspeckled wrasse

**Key identifying features:** Variable base colour (from grey, green and red) usually with a row of white spots along the lateral line (Hutchins and Swainston, 1986).

### Distribution

**Worldwide:** Endemic to southern Australia (Gomon *et al.*, 2008).

**Western Australia:** Southern Western Australian border to Carnarvon (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 385 mm, 1.8 kg (Hutchins and Swainston, 1986), 12 years (Lek, 2012).

**Length/weight relationship:** [Perth]  $\ln W = 2.998 * \ln TL - 10.966$  ( $n=521$ ,  $R^2=0.990$ ) (Lek, 2012). See also Lek (2012) for estimates for the Jurien Bay Marine Park.

TL (mm)	150	200	250
Weight (g)	58	137	267

**Length relationship:** Not applicable.

**Growth:** [Perth] Combined sexes (growth expressed in relation to length)  $L_{\infty}=410$  mm,  $k=0.15$  year<sup>-1</sup>,  $t_0=-1.35$  years ( $n=495$ ), (growth expressed in relation to mass)  $M_{\infty}=835$  g,  $k=0.21$  year<sup>-1</sup>,  $t_0=-0.8$  years ( $n=479$ ) (Lek *et al.*, 2012). See also Lek (2012) for Jurien Bay Marine Park. See also Lek (2012) data on instantaneous growth rates with respect to length and weight, for each location.

Age (years)	3	6	9
TL (mm)	196	274	323

**Length and age at maturity:** [Perth, Female]  $L_{50}=195$  mm,  $A_{50}=2.9$  years,  $L_{95}=215$  mm,  $A_{95}=3.9$  years (Lek, 2012). See also Lek (2012) for Jurien Bay Marine Park.

**Reproductive style:** Protogynous hermaphrodites, probably monandric (Lek, 2012).

**Adult sex ratio:** [Perth, trapping, line and spear fishing ] F1.9:M1 (calculated using sample sizes for growth curves) (Lek, 2012).

**Length and age at sex change:** [Perth] Females  $L_{50}=282$  mm,  $A_{50}=6.3$  years,  $L_{95}=323$  mm,  $A_{95}=8.1$  years (Lek, 2012). See also Lek (2012) for Jurien Bay Marine Park.

**Spawning season:** [Perth] Mid-winter to mid- or late spring (Lek, 2012).

**Spawning location and habitat:** Mature fish caught over reefs and seagrass (Fairclough *et al.*, 2011; Lek *et al.*, 2011). As seagrass sampling sites were sometimes a considerable distance from reefs, this species presumably spawns in both habitats (Fairclough *et al.*, 2011).

**Fecundity:** Not reported.

**Spawning frequency:** Not reported.

### **Development and habitat use**

**Eggs:** [Labridae] Pelagic (Leis and Carson-Ewart, 2000).

**Larvae:** Not reported.

**Juveniles:** Macroalgae-dominated limestone or granite reefs and seagrass meadows in coastal waters (Harman *et al.*, 2003; Hyndes *et al.*, 2003; Harvey *et al.*, 2004; Valesini *et al.*, 2004; Bivoltsis, 2007; MacArthur and Hyndes, 2007; Fairclough *et al.*, 2011).

**Adults:** Limestone or granite reefs and seagrass meadows in coastal waters (Harman *et al.*, 2003; Hyndes *et al.*, 2003; MacArthur and Hyndes, 2007; Vanderklift *et al.*, 2007; Tuya *et al.*, 2009; Chatfield *et al.*, 2010; Lek, 2012). Fish in seagrass meadows are typically smaller than those on reefs (Bivoltsis, 2007; Fairclough *et al.*, 2011).

**Migration:** Strong site association (Baker, 2009).

**Stock delineation:** Not reported.

**Diet:** Carnivorous, feeding predominantly on molluscs, gastropods, echinoderms and crustaceans (MacArthur and Hyndes, 2007; Lek *et al.*, 2011).

### **Fishery**

**Recreational:** Not targeted by recreational fishers but often caught as by-catch using lines from boats and the shore (Smallwood *et al.*, 2006; Sumner *et al.*, 2008) and sometimes used as bait (Pollard *et al.*, 2010).

**Commercial:** Not targeted by commercial fishers but often caught as by-catch (Fletcher and Santoro, 2012).

**Age at full recruitment into the fishery:** Not applicable.

**Gear selectivity parameters:** Not reported.

### **Management parameters**

**Total mortality:** Not reported.

**Natural mortality:** Not reported.

**Fishing mortality:** Not reported.

**Biological reference points:** Not reported.

**Current status:** Assessed in IUCN Red List in 2010 as species of Least Concern (Pollard *et al.*, 2010).

### **Catch trends**

**Recreational:** Catches of this species cannot often be determined as it is grouped together with all other wrasses (Labridae), which are more often released than retained by recreational boat and shore-based fishers (Sumner and Williamson, 1999; Malseed *et al.*, 2000; Malseed and Sumner, 2001a; b; Sumner *et al.*, 2002; Sumner, 2008; Sumner *et*

*al.*, 2008). Low numbers of this species were recorded in catches from Rottneest Island (Smallwood *et al.*, 2006), estuaries of the South Coast bioregion (Smallwood and Sumner, 2007) and along the Perth Metropolitan coast (Harvey, 2004; Smallwood *et al.*, 2011).

**Commercial:** Commercial fishers retained 1 t of wrasses (Family Labridae) throughout Western Australia in 2010/11 (Fletcher and Santoro, 2012).

### Management regulations

**Recreational:** Currently included in the “all other species of finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1991)	40	-	
South Coast (2003)	40	-	
South Coast (2005)	8	-	
West Coast (2009)	30	-	
Statewide (2013)	8	-	

**Commercial:** Not applicable.

**Current research:** Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Parasitology* (Pichelin, 1999; Aken’Ova *et al.*, 2003; Jones *et al.*, 2004); *Marine protected areas* (Kleczkowski *et al.*, 2008); *Distribution linked to water temperature* (Langlois *et al.*, 2012); *Behaviour towards SCUBA divers* (Watson and Harvey, 2007). *Response to baited video* (Birt *et al.*, 2012); *Biology of co-occurring wrasse species* (Lek, 2012; Lek *et al.*, 2012).

### References

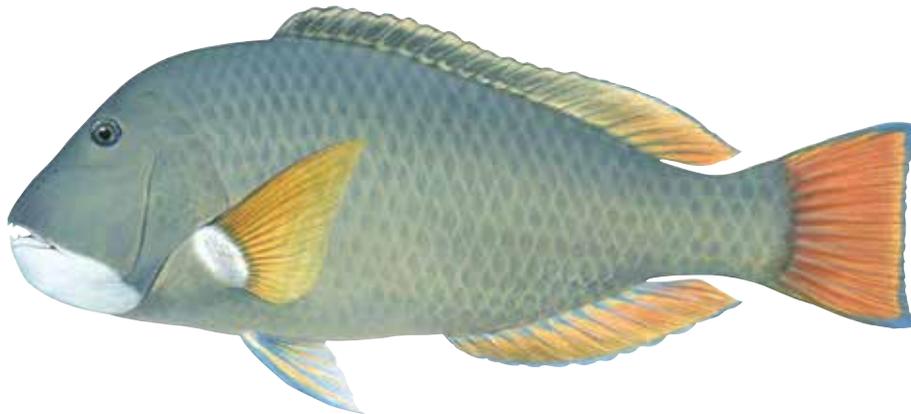
- Aken’Ova, T. O. L., Cribb, T. H., Bray, R. A., 2003. A new species of *Dactylostomum* Woolcock, 1935 (Digenea: Opecoelidae) from the goatfish *Openeichthys lineatus* (Bloch & Schneider) (Mullidae) in Western Australian waters. *Systematic Parasitology* 56, 63-68.
- Baker, J. L., 2009. Marine Species of Conservation Concern in South Australia: Volume 1 - Bony and Cartilaginous Fishes. Report for the South Australian Working Group for Marine Species of Conservation Concern. Science and Conservation Division, and Coast and Marine Conservation branches of S.A. Department for Environment and Heritage (DEH); Marine and Coastal Community Network of S.A. (MCCN), and Threatened Species Network (TSN). Web version published by Reef Watch, South Australia.
- Birt, M. J., Harvey, E. S., Langlois, T. J., 2012. Within and between day variability in temperate reef fish assemblages: learned response to baited video. *Journal of Experimental Marine Biology and Ecology* 416-417, 92-100.
- Bivoltsis, A. K., 2007. A baited video study of the fish faunas in the main habitat types and management zones of the Jurien Bay Marine Park, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 127.
- Chatfield, B. S., Van Niel, K. P., Kendrick, G. A., Harvey, E. S., 2010. Combining environmental gradients to explain and predict the structure of demersal fish distributions. *Journal of Biogeography* 37, 593-605.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairclough, D. V., Potter, I. C., Lek, E., Bivoltsis, A. K., Babcock, R. C., 2011. The fish communities and main fish populations of the Jurien Bay Marine Park. Murdoch University. Perth, Western Australia. Strategic Research Fund for the Marine Environment Collaborative Research Project. pp. 363.

- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Harman, N., Harvey, E. S., Kendrick, G. A., 2003. Differences in fish assemblages from different reef habitats at Hamelin Bay, south-western Australia. *Marine and Freshwater Research* 54, 1-8.
- Harvey, E., Cappo, M., Kendrick, G., 2004. Fishes of the Recherche Archipelago, In Characterising fish habitats of the Recherche Archipelago. Kendrick, G., Harvey, E., McDonald, J., Pattiaratchi, C., Cappo, M., Fromont, J., Shortis, M., Grove, S., Bickers, A., Baxter, K., Goldberg, N., Kletczkowski, M., Butler, J. (eds), University of Western Australia, Perth, Western Australia.
- Harvey, M. J., 2004. An evaluation of Western Australian recreational fishing regulations with a case study from a metropolitan boat ramp, Honours thesis, School of Environmental Science. Murdoch University, Perth, Western Australia. pp. 97.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Hyndes, G. A., Kendrick, A. J., MacArthur, L. D., Stewart, E., 2003. Differences in the species- and size-composition of fish assemblages in three distinct seagrass habitats with differing plant and meadow structure. *Marine Biology* 142, 1195-1206.
- Jones, C. M., Grutter, A. S., Cribb, T. H., 2004. Cleaner fish become hosts: a novel form of parasite transmission. *Coral Reefs* 23, 521-529.
- Kletczkowski, M., Babcock, R. C., Clapin, G., 2008. Density and size of reef fishes in and around a temperate marine reserve. *Marine and Freshwater Research* 59, 165-176.
- Langlois, T. J., Radford, B. T., Van Niel, K. P., Meeuwig, J. J., Pearce, A. F., Rousseaux, C. S. G., Kendrick, G. A., Harvey, E. S., 2012. Consistent abundance distributions of marine fishes in an old, climatically buffered, infertile seascape. *Global Ecology and Biogeography* 21, 886-897.
- Leis, J. M., Carson-Ewart, B. M., 2000. The larvae of Indo-pacific coastal fishes: a guide to identification (Fauna Malesiana Handbook 2). Brill: Leiden.
- Lek, E., 2012. Comparisons between the biological characteristics of three co-occurring and reef-dwelling labrid species at two different latitudes, PhD thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 173.
- Lek, E., Fairclough, D. V., Hall, N. G., Hesp, S. A., Potter, I. C., 2012. Do the maximum sizes, ages and patterns of growth of three reef-dwelling labrid species at two latitudes differ in a manner conforming to the metabolic theory of ecology? *Journal of Fish Biology* 81, 1936-1962.
- Lek, E., Fairclough, D. V., Platell, M. E., Clarke, K. R., Tweedley, J. R., Potter, I. C., 2011. To what extents are the dietary compositions of three abundant, co-occurring labrid species different and related to latitude, habitat, body size and season? *Journal of Fish Biology* 78, 1913-1943.
- MacArthur, L. D., Hyndes, G. A., 2007. Varying foraging strategies of Labridae in seagrass habitats: herbivory in temperate seagrass meadows? *Journal of Experimental Marine Biology and Ecology* 340, 247-258.
- Malseed, B. E., Sumner, N. R., 2001a. A 12-month survey of recreational fishing in the Peel-Harvey Estuary of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 127. pp. 48.
- Malseed, B. E., Sumner, N. R., 2001b. A 12-month survey of recreational fishing in the Swan-Canning Estuary basin of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 126. pp. 44.
- Malseed, B. E., Sumner, N. R., Williamson, P. C., 2000. A 12-month survey of recreational fishing in the Leschenault Estuary of Western Australia during 1998. Western Australian Department of Fisheries. Perth, Western Australia. pp. 36.
- Pichelin, S., 1999. *Hypoechinorhynchus robustus* sp. n. from *Notolabrus parilus* (Labridae) from Western Australia with a discussion on the validity of the Hypoechinorhynchidae (Acanthocephala: Palaeacanthocephala). *Folia Parasitologica* 46, 311-315.

- Pollard, D., Russell, B. C., Fairclough, D., 2010. *Notolabrus parilus*. 2012 IUCN Red List of Threatened Species. Available: <http://www.iucnredlist.org/> (Accessed August 2012).
- Smallwood, C. B., Beckley, L. E., Sumner, N. R., 2006. Shore-based recreational angling in the Rottne Island Reserve, Western Australia: spatial and temporal distribution of catch and fishing effort. *Pacific Conservation Biology* 12, 238-51.
- Smallwood, C. B., Pollock, K. H., Wise, B. S., Hall, N. G., Gaughan, D. J., 2011. Quantifying recreational fishing catch and effort: a pilot study of shore-based fishers in the Perth Metropolitan area. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 216. pp. 60.
- Smallwood, C. B., Sumner, N. R., 2007. A 12-month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002/03. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 159. pp. 56.
- Sumner, N. R., 2008. An assessment of the finfish catch by recreational fishers, tour operators, commercial lobster fishers and commercial wetline fishers from the Houtman Abrolhos Islands during 2006. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 175. pp. 32.
- Sumner, N. R., Williamson, P. C., 1999. A 12-month survey of coastal recreational boat fishing between Augusta and Kalbarri on the west coast of Western Australia during 1996-97. Western Australian Department of Fisheries. Fisheries Research Report No. 117. pp. 52.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Sumner, N. R., Williamson, P. C., Malseed, B. E., 2002. A 12-month survey of recreational fishing in the Gascoyne bioregion of Western Australia during 1998-99. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 53.
- Tuya, F., Wernberg, T., Thomsen, M., 2009. Habitat structure affect abundances of labrid fishes across temperate reefs in south-western Australia. *Environmental Biology of Fishes* 86, 311-319.
- Valesini, F. J., Potter, I. C., Wildsmith, M. D., Hourston, M., Platell, M. E., Coen, N. J., Schafer, L. N., Seidel, S. T., Whitehead, A. L., 2004. The importance to fish species of the various habitats in nearshore marine waters of south-western Australia. Murdoch University. Perth, Western Australia. FRDC Project No. 2000/159. pp. 452.
- Vanderklift, M. A., How, J., Wernberg, T., MacArthur, L. D., Heck, K. L., Valentine, J. F., 2007. Proximity to reef influences density of small predatory fishes, while type of seagrass influences intensity of their predation on crabs. *Marine Ecology Progress Series* 340, 235-243.
- Watson, D. L., Harvey, E. S., 2007. Behaviour of temperate and sub-tropical reef fishes towards a stationary SCUBA diver. *Marine and Freshwater Behaviour and Physiology* 40, 85-103.

## Baldchin groper (*Choerodon rubescens*)

Reviewed by David Fairclough (DoF)



**Scientific name:** *Choerodon rubescens* (Labridae; Wrasses)

**Common names:** Baldchin groper *also* baldie, bluebone

**Key identifying features:** Abruptly pale/white chin with an additional pale/white pectoral peduncle, and two pairs of tusk-like forward teeth (Yearsley *et al.*, 2001; Allen, 2009).

### Distribution of species

**Worldwide:** Endemic to Western Australia.

**Western Australia:** Geographe Bay to Coral Bay (Allen, 2009).

**Maximum length, weight, and age:** 650 mm TL, 6.3 kg (Allen, 2009), 26 years (D. Fairclough, DoF, unpublished data).

**Length/weight relationship:** [Abrolhos Islands]  $\ln W = 3.024 * \ln TL - 10.891$  ( $n=373$ ,  $R^2=0.998$ ) (Fairclough, 2005). See also Fairclough *et al.* (2004) and Nardi *et al.* (2006).

TL (mm)	200	400	600
Weight (g)	160	1,347	4,621

**Length relationship:** Not reported.

**Growth:** [Abrolhos Islands]  $L_{\infty}=534.7$  mm,  $k=0.192$  year<sup>-1</sup>,  $t_0=0.162$  years ( $n=580$ ,  $R^2=0.789$ ) (Fairclough, 2005). See also Fairclough *et al.* (2004) and Nardi *et al.* (2006).

Age (years)	5	10	15
TL (mm)	336	459	506

**Length and age at maturity:** [Abrolhos Islands]  $L_{50}=279$  mm,  $L_{95}=352$  mm;  $A_{50}=4.1$  years,  $A_{95}=6.2$  years (Fairclough, 2005). See also Fairclough *et al.* (2004) and Nardi *et al.* (2006).

**Reproductive style:** Monandric protogynous hermaphrodite. Multiple spawner (Fairclough, 2005; Nardi *et al.*, 2006).

**Adult sex ratio:** [Abrolhos Islands, rod and line and spear fishing, and commercial fishing] F1.5:M1 ( $n=536$ ) (Fairclough, 2005). See also Fairclough *et al.* (2004) and Nardi *et al.* (2006)

**Length and age at sex change:** [Abrolhos Islands]  $L_{50}=479$  mm,  $L_{95}=595$  mm,  $A_{50}=11.9$  years,  $A_{95}=14.7$  years (Fairclough, 2005). For data on Shark Bay see Fairclough (2005).

**Spawning season:** Spring and early summer (Fairclough, 2005; Nardi *et al.*, 2006).

**Spawning location and habitat:** Spawn near or in benthic reef habitats (Wise *et al.*, 2007) and at all depths throughout its distribution (Fairclough, 2005).

**Fecundity:** Indeterminate. [Abrolhos Islands] Batch fecundity  $BF=5.050*\ln TL-19.614$  ( $n=27$ ,  $R^2=0.808$ ,  $ms=0.127$ ) (Fairclough, 2005). For data on Shark Bay see Fairclough (2005).

TL (mm)	300	400	500
Fecundity (eggs)	10,442	41,893	129,284

**Spawning frequency:** Not reported.

### Development and habitat use

**Eggs:** [Labridae] Pelagic (Leis and Carson-Ewart, 2000). Buoyant (Fairclough *et al.*, 2011).

**Larvae:** Pelagic (Fairclough *et al.*, 2011).

**Juveniles:** Juveniles have been observed in shallow, weedy rock habitats. They possibly exhibit an offshore movement (Fairclough, 2005).

**Adults:** Habitats overlapping and adjacent to juveniles as well as coral and rocky reefs with associated algae to depths of at least 100 m (Hutchins and Swainston, 1986; Fairclough, 2005).

**Migration:** Limited movements (Fairclough *et al.*, 2011).

**Stock delineation:** Movement of juveniles and adults is likely to occur at a limited spatial scale (Fairclough *et al.*, 2011). Microsatellite tagging suggests this species consists of a series of overlapping stocks connected mainly by larval dispersal within the West Coast bioregion, and possibly over its entire range (Gardner, 2011).

**Diet:** Predominantly invertebrates (crustaceans, bivalves, echinoderms and gastropods) (Lek, 2004).

### Fishery

**Recreational:** Targeted predominantly by boat-based fishers (including charter operators) by spearfishing and line fishing, especially at the Abrolhos Islands (Sumner *et al.*, 2002; Fairclough, 2005; Sumner, 2008; Telfer, 2010).

**Commercial:** One of the most frequently caught species in the West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF), especially at the Abrolhos Islands, and is targeted using handlines and droplines (Crowe *et al.*, 1999; Fairclough *et al.*, 2012). Small numbers are also caught as by-catch in rock lobster pots (De Lestang *et al.*, 2012) and in the temperate Demersal Gillnet and Demersal Longline Fisheries (DGDLF) (McAuley and Rowland, 2012).

**Age at full recruitment:** Varies with location, *i.e.*, 8 years at the Abrolhos Islands and 11 years in the mid-West (D. Fairclough, DoF, unpublished data). Other estimates also found in Nardi *et al.* (2006) and Wise *et al.* (2007).

**Gear selectivity parameters:** Not reported.

### Management parameters

**Total mortality:** [West Coast bioregion,  $Z=M+F$  using  $M=0.21$  year<sup>-1</sup>] 0.33 – 0.49 year<sup>-1</sup> (Wise *et al.*, 2007). Estimates for the Abrolhos Islands also available in Nardi *et al.* (2006).

**Natural mortality:** Several estimates available including; [Abrolhos Islands, Pauly's (1980) equation] 0.577 year<sup>-1</sup> (Nardi *et al.*, 2006); [West Cost bioregion, maximum age method

of Hewitt and Hoenig (2005)] 0.21 year<sup>-1</sup> (Wise *et al.*, 2007) and [West Coast bioregion, Hoenig's (1983) regression method] 0.22 year<sup>-1</sup> (Wise *et al.*, 2007).

**Fishing mortality:** [Abrolhos Islands] 0.12–0.28 year<sup>-1</sup> (Wise *et al.*, 2007).

**Biological reference points:** YPR<sub>max</sub> achieved at  $F=0.3$  year<sup>-1</sup>

SPR (EPR)=0.2 occurs when  $F>0.1$

YPR<sub>current</sub> ~140 g recruit<sup>-1</sup>

SPR<sub>current</sub> (EPR) ~0.5 (Wise *et al.*, 2007).

**Current status:** Stock listed as recovering in the West Coast bioregion (Fairclough *et al.*, 2012). An indicator species for the inshore demersal suite in the West Coast bioregion, which has a medium to high overall risk to sustainability (DoF, 2011). Inherent vulnerability of the species is moderate and current risk to wild stock is high (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

**Recreational:** The total estimated recreational boat-based catch in the West Coast bioregion increased from 19 t in 1996/97 to 37 t in 2005/06 (Sumner *et al.*, 2008), but decreased again 19 t in 2009/10 (Fairclough *et al.*, 2012). In this same bioregion, catch from charter vessels was 9 t in 2010/11 (Fairclough *et al.*, 2012). A total retained catch of 4,805 fish was recorded in the Gascoyne Coast bioregion in 1998/99 (Sumner *et al.*, 2002).

**Commercial:** A total of 16 t (live weight) of this species was taken by commercial fishers in Western Australia in 2010/11 (Fletcher and Santoro, 2012). The catch of this species in the WCDSIMF was 15 t in 2010/11, with an additional 3 t caught in other commercial fisheries (*i.e.* DGDLF) (Fairclough *et al.*, 2012). A complete catch trend graph is shown in the 2009/10 State of the Fisheries and Aquatic Resources Report. The total by-catch of this species in rock lobster pots was 1.1 t in 2010/11 (De Lestang *et al.*, 2012).

### Management regulations

**Recreational:** Currently listed in the “demersal finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1973/74)	-	400	
Statewide (1988)	10	400	
Statewide (1991)	8	400	
West Coast (2003)	4	400	Abrolhos (1 Nov – 31 Jan)
Gascoyne Coast (2004)	4	400	
West Coast (2009)	2	400	15 Oct – 15 Dec; Abrolhos (1 Nov – 31 Jan) Compulsory possession of release weight
Gascoyne Coast (2009)	2	400	
Statewide (except West Coast) (2013)	3	400	

**Commercial:** The WCDSIMF is regulated using various input controls (restricted entry, total fishing time allocations, maximum number of lines and hooks) (Fairclough *et al.*, 2012). The DGDLF is regulated using various input controls (transferable time/gear effort, mesh and hook sizes, maximum net length), output controls as well as temporal (16 Aug – 15 Oct) and spatial closures (McAuley and Rowland, 2012).

**Current research:** A stock assessment will be conducted in 2012/2013 by DoF. Monitoring of abundance and size structure is being undertaken at the Abrolhos Islands by UWA. Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Effects of protection from fishing* (Nardi *et al.*, 2004; Watson *et al.*, 2007; Watson *et al.*, 2009); *Abundance linked to increased water temperatures* (Langlois *et al.*, 2012a); *Length frequency using stereo-video techniques* (Langlois *et al.*, 2012b); *Behaviour towards SCUBA divers* (Watson and Harvey, 2007); *Barotrauma* (Lenanton *et al.*, 2009).

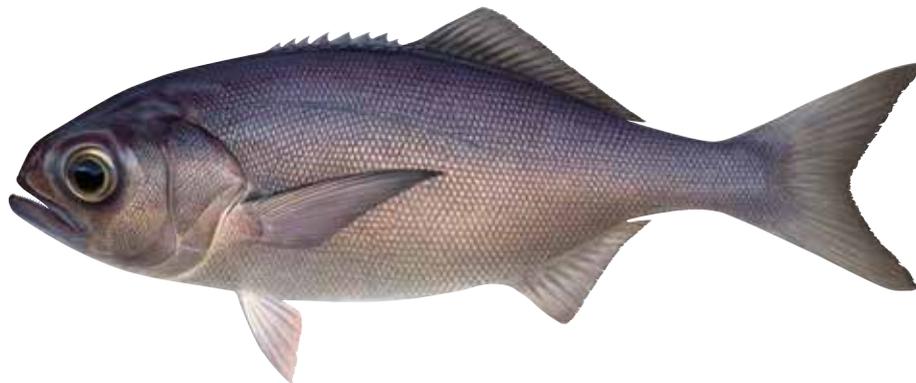
## References

- Allen, G. R., 2009. Field guide to marine fishes of tropical Australia and south-east Asia, 4th edn. Western Australian Museum, Perth, Western Australia.
- Crowe, F., Lehre, W., Lenanton, R. C. J., 1999. A study in Western Australia's open access and wetline fisheries. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 118.
- De Lestang, S., Thomson, A., Rossbach, M., Kennedy, J., Baudains, G., Steele, A., 2012. West Coast rock lobster fishery status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 37-47.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairclough, D., 2005. The biology of four tuskfish species (*Choerodon*: Labridae) in Western Australia, PhD thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 204.
- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Fairclough, D. V., Edmonds, J. S., Lenanton, R. C. J., Jackson, G., Keay, I. S., Crisafulli, B. M., Newman, S. J., 2011. Rapid and cost-effective assessment of connectivity among assemblages of *Choerodon rubescens* (Labridae), using laser ablation ICP-MS of sagittal otoliths. *Journal of Experimental Marine Biology and Ecology* 403, 46-53.
- Fairclough, D. V., Hesp, S. A., Potter, I. C., Hall, N. G., 2004. Determination of the biological parameters for managing the fisheries of four tuskfish species and western yellowfin bream. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2000/137. pp. 163.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gardner, M. J., 2011. Genetic determination of the stock structures of pink snapper (*Pagrus auratus*) and baldchin groper (*Choerodon rubescens*) in Western Australian waters. Perth, Western Australia. WAMSI Final Report September 2011. pp. 17.
- Hewitt, D. A., Hoenig, J. M., 2005. Comparison of two approaches for estimating natural mortality based on longevity. *Fisheries Bulletin* 103, 433-437.
- Hoenig, J., 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82, 898-903.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Langlois, T. J., Radford, B. T., Van Niel, K. P., Meeuwig, J. J., Pearce, A. F., Rousseaux, C. S. G., Kendrick, G. A., Harvey, E. S., 2012a. Consistent abundance distributions of marine fishes in an old, climatically buffered, infertile seascape. *Global Ecology and Biogeography* 21, 886-897.

- Langlois, T. J., Fitzpatrick, B. R., Fairclough, D. V., Wakefield, C., Hesp, A., McLean, D., Harvey, E. S., Meeuwig, J. J., 2012b. Similarities between line fishing and baited stereo-video estimations of length-frequency: novel application of kernel density estimates. *PLoS One* 7, (e45973).
- Leis, J. M., Carson-Ewart, B. M., 2000. The larvae of Indo-pacific coastal fishes: a guide to identification (Fauna Malesiana Handbook 2). Brill: Leiden.
- Lek, E., 2004. Diets of three carnivorous fish species in marine waters of the west coast of Australia, Honours thesis, School of Biological Sciences. Murdoch University, Perth, Western Australia. pp. 99.
- Lenanton, R., St John, J., Wise, B., Keay, I., Gaughan, D. J., 2009. Maximising survival of released undersize west coast reef fish. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2000/194, Fisheries Research Report No. 191. pp. 130.
- McAuley, R., Rowland, F., 2012. Temperate demersal gillnet and demersal longline fisheries status report, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 282-294.
- Nardi, K., Jones, G. P., Moran, M. J., Cheng, Y. W., 2004. Contrasting effects of marine protected areas on the abundance of two exploited reef fishes at the sub-tropical Houtman Abrolhos Islands, Western Australia. *Environmental Conservation* 31, 160-168.
- Nardi, K., Newman, S. J., Moran, M. J., Jones, G. P., 2006. Vital demographic statistics and management of the baldchin groper (*Choerodon rubescens*) from the Houtman Abrolhos Islands. *Marine and Freshwater Research* 57, 485-496.
- Pauly, D., 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *Journal du Conseil International pour l'Exploration de la Mer* 39, 175-192.
- Sumner, N. R., 2008. An assessment of the finfish catch by recreational fishers, tour operators, commercial lobster fishers and commercial wetline fishers from the Houtman Abrolhos Islands during 2006. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 175. pp. 32.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Sumner, N. R., Williamson, P. C., Malseed, B. E., 2002. A 12-month survey of recreational fishing in the Gascoyne bioregion of Western Australia during 1998-99. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 53.
- Telfer, C., 2010. The Western Australian charter boat industry: working towards long-term sustainability, MSc thesis, School of Natural Sciences. Edith Cowan University, Perth, Western Australia. pp. 153.
- Watson, D. L., Anderson, M. J., Kendrick, G. A., Nardi, K., Harvey, E. S., 2009. Effects of protection from fishing on the lengths of targeted and non-targeted fish species at the Houtman Abrolhos Islands, Western Australia. *Marine Ecology Progress Series* 384, 241-249.
- Watson, D. L., Harvey, E. S., 2007. Behaviour of temperate and sub-tropical reef fishes towards a stationary SCUBA diver. *Marine and Freshwater Behaviour and Physiology* 40, 85-103.
- Watson, D. L., Harvey, E. S., Kendrick, G. A., Nardi, K., Anderson, M. J., 2007. Protection from fishing alters the species composition of fish assemblages in a temperate-tropical transition zone. *Marine Biology* 152, 1197-1206.
- Wise, B. S., St John, J., Lenanton, R., 2007. Spatial scales of exploitation among populations of demersal scalefish: implications for management. Part I: Stock status of the key indicator species for the demersal scalefish fisheries in the West Coast Bioregion. Western Australian Department of Fisheries. Perth, Western Australia. FRDC Project No. 2003/052. Fisheries Research Report No. 163. pp. 130.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## Blue-eye trevalla (*Hyperoglyphe antarctica*)

Reviewed by Corey Wakefield (DoF)



**Scientific name:** *Hyperoglyphe antarctica* (Centrolophidae; Medusafishes)

**Common names:** Blue-eye trevalla

**Key identifying features:** Blunt snout, eyes blue with golden ring, distinct spinous part of the dorsal fin with 7 – 9 spines and 18 – 21 soft rays, anal fin has 3 spines and 13 – 16 soft rays, no dark blotch above pectoral-fin base, long upper jaw reaches to mid-eye (Hutchins and Swainston, 1986; Yearsley *et al.*, 2001).

### Distribution

**Worldwide:** Temperate waters of South America, South Africa, New Zealand and Australia.

**Western Australia:** Southern Western Australian border to Geraldton (Duffy *et al.*, 2000; Gomon *et al.*, 2008).

**Maximum length, weight and age:** 140 cm, 21.4 kg (Hutchins and Swainston, 1986), 32 years (Wakefield and Newman, 2008), [New Zealand] 76 years (Horn *et al.*, 2010).

**Length/weight relationship:** [Western Australia]  $W=0.000015897*TL^{2.9908}$  ( $n=126$ ) (C. Wakefield, DoF, unpublished data). New Zealand estimates also available (Horn *et al.*, 2010).

FL (cm)	50	70	90
Weight (kg)	1.9	5.2	11.1

**Length relationship:** [Western Australia]  $TL=1.0946*FL+12.708$  (C. Wakefield, DoF, unpublished data)

**Growth:** [Tasmania] Females  $L_{\infty}=1,199$  mm,  $k=0.03$  year<sup>-1</sup>,  $t_0=13.8$  years ( $n=1,148$ )

Males  $L_{\infty}=750$  mm,  $k=0.07$  year<sup>-1</sup>,  $t_0=11.7$  years ( $n=1,178$ ) (Morrison and Robertson, 1995). See also Horn *et al.* (2010) for New Zealand estimates.

Age (years)	10	30	50
Females, TL (mm)	612	877	1,022
Males, TL (mm)	586	710	740

**Length and age at maturity:** [New Zealand] Females  $A_{50}=17$  years; Males  $A_{50}=15$  years (Horn and Sutton, 2010). See also [Tasmania] (Baelde, 1996).

**Reproductive style:** [Tasmania] Serial spawner (Baelde, 1996). Unclear if this species is gonochoristic or hermaphroditic. A study of a closely-related species has shown substantial

numbers of males containing both ovarian and testicular tissues, which may reflect hermaphroditism (whether functional or not) (Filer and Sedberry, 2008).

**Sex ratio:** [New Zealand] F1:M1.1 (obtained from number of fish used to construct growth curves) (Morrison and Robertson, 1995).

**Length and age at sex change:** Not applicable.

**Spawning season:** [Tasmania] Early March to early May. Fish begin aggregating prior to March (Baelde, 1996). The timing is likely to differ in Western Australia (C.Wakefield, DoF, unpublished data).

**Spawning location and habitat:** [Tasmania] Predominantly off the northeast coast of Tasmania, but also in other locations (Baelde, 1996) including waters of the continental slope throughout southern Australia (C. Wakefield, DoF, *pers. comm.*, 2012).

**Fecundity:** [Tasmania] Determinate. Batch fecundity  $BF=0.097*FL-6.28$  (Baelde, 1996). See also Horn and Massey (1989).

FL (mm)	700	800	900
Fecundity (eggs)	510,000	1,480,000	2,450,000

**Spawning frequency:** [Tasmania] Individuals release 3 or 4 batches of eggs during a spawning season (Baelde, 1996).

### Development and habitat use

**Eggs:** [Centrolophidae] Pelagic (Neira *et al.*, 1998).

**Larvae:** [Centrolophidae] Often associated with jellyfish or inanimate floating objects in surface waters and are likely to be widely dispersed by currents (Neira *et al.*, 1998).

**Juveniles:** [New Zealand] Surface and mid-water region in offshore waters, possibly dependent on drift algae for shelter (Last *et al.*, 1993; Duffy *et al.*, 2000). [Eastern Australia] Distinct morphological differences evident between juveniles (“small eye” and yellow in colouration) and adults (‘big-eye’) (Bolch *et al.*, 1993; Last *et al.*, 1993).

**Adults:** Benthic-pelagic and associated with rocky ground on the continental slope and seamounts at 200 – 600 m depth. Occasionally found over smooth muddy substrates (Hindell *et al.*, 2005).

**Migration:** [New Zealand] Tagging studies indicate species is sedentary in the short term (6 – 8 months) but that fish can migrate vast distances (Horn, 2003). Possible vertical migration (Winstanley, 1978).

**Stock delineation:** [Eastern Australia] Single panmictic stock (Bolch *et al.*, 1993; Robinson *et al.*, 2008), although some evidence of subpopulations identified (Hindell *et al.*, 2005).

**Diet:** [Eastern Australia] Pelagic tunicates and squid, small fish and crustaceans (Winstanley, 1978).

### Fishery

**Recreational:** Boat-based recreational fishers target this species in Western Australian waters (DoF, 2011) and Commonwealth waters in eastern Australia (Griffiths *et al.*, 2010).

**Commercial:** It is one of a suite of deepwater demersal species caught using drop lines and longlines in the West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF) and South Coast Demersal Line Fishery (Fairclough *et al.*, 2012; McAuley and Rowland,

2012; Molony *et al.*, 2012). This species is also caught by the Commonwealth trawl and hook sectors along the eastern Australian coast and in the Great Australian Bight Trawl Sector (GABTS) (Tilzey and Rowling, 2001; Moore and Pham, 2011; Woodhams *et al.*, 2012).

**Age at full recruitment into the fishery:** [GABTS] 2 – 3 years,  $FL=50$  cm (BRS, 2008).

**Gear selectivity parameters:** Not reported.

### Management parameters

**Total mortality:** [New Zealand, 1984-86] 0.11–0.26 year<sup>-1</sup> (Horn and Sutton, 2011).

**Natural mortality:** [New Zealand, 1984-86] 0.07–0.14 year<sup>-1</sup> (Horn and Sutton, 2011).

**Fishing mortality:** Not reported.

**Biological reference points:** Not reported.

**Current status:** Not overfished in the Commonwealth trawl and scalefish hook sectors (Woodhams *et al.*, 2012). A proposed indicator species for West Coast and South Coast offshore demersal suite (DoF, 2011), whose overall risk to sustainability is medium to high (DoF, 2011). Inherent vulnerability of the species is high while current risk to wild stock is moderate (DoF, 2011). See DoF (2011) for more detailed risk assessment data.

### Catch trends

**Recreational:** No recreational catch information available for Western Australia.

**Commercial:** The total catch of this species by commercial fishers in 2009/10 in Western Australia was 3 t (Fletcher and Santoro, 2012). The WCDSIMF took <1 t (Fairclough *et al.*, 2012). Commercial catches in the South Coast Demersal Line Fishery have decreased from 4.9 t in 2007 to 3.4 t in 2011, with a low of 2.4 t in 2009 (Molony *et al.*, 2012). Prior to 1992 it was seldom caught by commercial fishers (Duffy *et al.*, 2000). A total of 351 t was caught in 2011/12 by the Commonwealth trawl and scalefish hook sectors (Woodhams *et al.*, 2012).

### Management regulations

**Recreational:** Currently listed in the “demersal finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1991)	40	-	
South Coast (2005)	2	-	
West Coast (2005)	2	-	
West Coast (2009)	2	-	Closed season (15 Oct – 15 Dec) Compulsory possession of release weight
Statewide (except West Coast) (2013)	3	-	

**Commercial:** The WCDSIMF is regulated using various input controls (restricted entry, total fishing time allocations, maximum number of lines and hooks) (Fairclough *et al.*, 2012). Management arrangements for commercial fisheries include input controls such as limited entry, gear restrictions and catch limits (Woodhams *et al.*, 2012). The South Coast Demersal Line Fishery is currently ‘open access’ for the holder of a valid Fishing Boat Licence (for the boat) and a Commercial Fishing Licence (for the fisher) (Molony *et al.*, 2012).

**Current research:** There is ongoing research on this species by DoF in the West Coast and South Coast bioregions, including studies investigating age-based demography, reproductive biology and fish ecology with respect to latitude and depth (C. Wakefield, DoF, *pers. comm.*, 2012). Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Systematics of Family Centrolophidae* [Eastern Australia] (Bolch *et al.*, 1994).

## References

- Baelde, P., 1996. Biology and dynamics of the reproduction of blue-eye trevalla, *Hyperoglyphe antarctica* (Centrolophidae), off Tasmania, southern Australia. *Fishery Bulletin* 94, 199-211.
- Bolch, C., Elliott, N., Ward, R., 1993. Enzyme variation in south-eastern Australian samples of the blue-eye or deepsea trevalla, *Hyperoglyphe antarctica* Carmichael 1818 (Teleostei: Stromateoidei). *Marine and Freshwater Research* 44, 687-697.
- Bolch, C., Ward, R., Last, P., 1994. Biochemical systematics of the marine fish family Centrolophidae (Teleostei:Stromateoidei) from Australian waters. *Marine and Freshwater Research* 45, 1157-1172.
- BRS, 2008. Great Australian Bight Trawl Fishery, In Fishery Status Reports. Canberra, ACT, pp. 173-185.
- DoF, 2011. Resource assessment framework (RAF) for finfish resources in Western Australia. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Occasional Publication No. 85. pp. 24.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Duffy, C. A. J., Stewart, A. L., Yarrall, R., 2000. First record of pre-settlement juvenile bluenose, *Hyperoglyphe antarctica*, from New Zealand. *New Zealand Journal of Marine and Freshwater Research* 34, 353-358.
- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Filer, K. R., Sedberry, G. R., 2008. Age, growth and reproduction of the barrelfish *Hyperoglyphe perciformis* (Mitchill) in the western North Atlantic. *Journal of Fish Biology* 72, 861-882.
- Fletcher, W. J., Santoro, K. (eds) 2012. Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries, Perth, Western Australia.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Griffiths, S., Pepperell, J., Tonks, M., Fay, G., Venables, W., Lyle, J. M., Olyott, L., Sawynok, W., Edgar, S., 2010. Developing innovative and cost-effective tools for monitoring recreational fishing in Commonwealth fisheries. Canberra, Australia. FRDC Project No 2007/014. pp. 211.
- Hindell, J., Hamer, P. A., McPartlan, H., Robertson, S. G., 2005. Preliminary assessment of the utility of otolith microchemistry, otolith shape analysis and mitochondrial DNA analyses in stock discrimination of blue-eye trevalla (*Hyperoglyphe antarctica*) from Australian shelf waters and offshore seamounts and New Zealand. Primary Industries Research. Queenscliff, Victoria. FRDC Project No 2003/045. pp. 97.
- Horn, P. L., 2003. Stock structure of bluenose (*Hyperoglyphe antarctica*) off the north-east coast of New Zealand based on the results of a detachable hook tagging programme. *New Zealand Journal of Marine and Freshwater Research* 37, 623-631.
- Horn, P. L., Massey, B. R., 1989. Biology and abundance of alfonsino and bluenose off the lower east coast North Island, New Zealand. New Zealand Department of Fisheries. New Zealand. New Zealand Fisheries Technical Report 15. pp. 32.
- Horn, P. L., Neil, H. L., Paul, L. J., Marriott, P., 2010. Age validation and growth of bluenose *Hyperoglyphe antarctica* using the bomb chronometer method of radiocarbon ageing. *Journal of Fish Biology* 77, 1552-1563.

- Horn, P. L., Sutton, C. P., 2010. The spatial and temporal age structure of bluenose (*Hyperoglyphe antarctica*) commercial catches from Fishstock BNS 1. Ministry of Fisheries. New Zealand. New Zealand Fisheries Assessment Report 2010/8. pp. 22.
- Horn, P. L., Sutton, C. P., 2011. The age structure of bluenose (*Hyperoglyphe antarctica*) commercial catches from the Palliser Bank (Fishstock BNS 2) in 1984-86, and estimates of mortality rates. Ministry of Fisheries. New Zealand. New Zealand Fisheries Assessment Report 2011/30. pp. 17.
- Hutchins, B., Swainston, R., 1986. Sea fishes of southern Australia. Swainston Publishing, New South Wales.
- Last, P. R., Bolch, C., Baelde, P., 1993. Discovery of juvenile blue-eye. *Australian Fisheries* 52, 16-17.
- McAuley, R., Rowland, F., 2012. Temperate demersal gillnet and demersal longline fisheries status report, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 282-294.
- Molony, B., Lai, E., Holtz, M., 2012. South Coast demersal scalefish resource report: statistics only, Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 295-297.
- Moore, A., Pham, T., 2011. Great Australian Bight Trawl Sector, In Fisheries status reports 2010: status of fish stocks and fisheries managed by the Australian Government. Woodhams, J., Stobutzki, I., Vieira, S., Curotti, R., Begg, G. (eds), Bureau of Rural Sciences & Australian Bureau of Agricultural and Resource Economics, Canberra, Australia, pp. 197-211.
- Morrison, A. K., Robertson, S. G., 1995. Growth, age composition and mortality of blue-eye trevalla (*Hyperoglyphe antarctica*). Marine Science Laboratories. Queenscliff, Victoria. Internal Report 220.
- Neira, F. J., Miskiewicz, A. G., Trnski, T., 1998. Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press, Perth, Western Australia.
- Robinson, N., Skinner, A., Sethuraman, L., McPartlan, H., Murray, N., Knuckey, I., Smith, D. C., Hindell, J., Talman, S., 2008. Genetic stock structure of blue-eye trevalla (*Hyperoglyphe antarctica*) and warehouse (*Seriolella brama* and *Seriolella punctata*) in south-eastern Australian waters. *Marine and Freshwater Research* 59, 502-514.
- Tilzey, R. D. J., Rowling, K. R., 2001. History of Australia's South East Fishery: a scientist's perspective. *Marine and Freshwater Research* 52, 361-375.
- Wakefield, C. B., Newman, S. J., 2008. Age estimation and reproductive status of an exceptionally large blue-eye trevalla (*Hyperoglyphe antarctica*, Centrolophidae) captured off the south coast of Western Australia. *Cybium* 32, 321-324.
- Winstanley, R. H., 1978. Food of the trevalla *Hyperoglyphe porosa* (Richardson) off southeastern Australia (Note). *New Zealand Journal of Marine and Freshwater Research* 12, 77-79.
- Woodhams, J., Vieira, S., Stobutzki, I., 2012. Fishery status reports 2011. Australian Bureau of Agricultural Resource Economics and Sciences. Canberra, Australia. pp. 440.
- Yearsley, G. K., Last, P. R., Ward, R. D. (eds) 2001. Australian seafood handbook: an identification guide to domestic species. CSIRO Marine Research & FRDC, Canberra, Australia.

## Banded toadfish (*Torquigener pleurogramma*)

Reviewed by Ian Potter (Murdoch University)



**Scientific name:** *Torquigener pleurogramma* (Tetraodontidae; Pufferfish)

**Common names:** Weeping toadfish *also* banded toadfish, common blowfish, striped toadfish, blowie

**Key identifying features:** Dark brown line on side with narrow bars down cheek (Hutchins and Thompson, 1983).

### Distribution

**Worldwide:** Endemic to southern Australian and New Zealand waters

**Western Australia:** Southern Western Australian border to Coral Bay (Gomon *et al.*, 2008).

**Maximum length, weight and age:** 230 mm, 0.22 kg, 6 years (Potter *et al.*, 1988)

**Length/weight relationships:** Not reported.

**Length relationship:** Not reported.

**Growth curves:** [Swan River, combined sexes]  $L_{\infty}=255$  mm,  $k=0.24$  year<sup>-1</sup>,  $t_0=0.56$  years ( $n = 991$ ) (Potter *et al.*, 1988). Note that the growth curve was based on back-calculated lengths at ages, determined from counts of growth rings in scales.

Age (years)	2	4	6
Combined, TL (mm)	117	170	202

**Length and age at maturity:** [Swan River Estuary] Very few females and males mature by 1 year. All fish are mature by 2 years (Potter *et al.*, 1988).

**Reproductive style:** Gonochoristic (Potter *et al.*, 1988).

**Sex ratio:** Not reported.

**Length and age at sex change:** Not applicable.

**Spawning season:** [Swan River Estuary] November to January (Potter *et al.*, 1988).

**Spawning location and habitat:** Moves from estuarine waters to marine waters to spawn.

**Fecundity:** [Swan River Estuary] Determinate. Annual fecundity  $\log_{10}F = -2.972 + 3.602 * \log_{10}TL$  ( $n=33$ ,  $r=0.95$ ) (Potter *et al.*, 1988).

TL (mm)	100	150	200
Fecundity (eggs)	17,000	73,500	207,000

**Spawning frequency:** Not reported.

## **Development and habitat use**

**Eggs:** Small, demersal adhesive eggs (Leis and Carson-Ewart, 2000).

**Larvae:** Pelagic (Leis and Carson-Ewart, 2000).

**Juveniles:** Estuaries (Potter *et al.*, 1988).

**Adults:** Coastal waters, including marine embayments and estuaries (Loneragan *et al.*, 1986; Potter *et al.*, 1988; Loneragan and Potter, 1990). Found predominantly over bare sand and some seagrass (Travers and Potter, 2002; Hyndes *et al.*, 2003; Heithaus, 2004). In estuaries, this species is most abundant over sand and seagrass habitats (Potter *et al.*, 1988). Common in nearshore surf zones (Ayvazian and Hyndes, 1995). In marine waters, it is most abundant in habitats that are highly sheltered and contain dense seagrass or are moderately sheltered and contain sparse seagrass (Valesini *et al.*, 2004a).

**Migration:** [Swan River] Migrates out of estuaries to spawn and is more active at night (Valesini *et al.*, 2004b), moving into shallower waters during this time (Potter *et al.*, 1988).

**Stock delineation:** Not reported.

**Diet:** Molluscs, crustaceans and polychaetes (Potter *et al.*, 1988).

## **Fishery**

**Recreational:** Not targeted by recreational fishers, but often taken as by-catch (Smith, 2006).

**Commercial:** Not targeted by commercial fishers, but often taken as by-catch (Fairclough *et al.*, 2012).

**Age at full recruitment:** Not reported.

**Gear selectivity parameters:** Not reported.

## **Management parameters**

**Total mortality:** Not reported.

**Natural mortality:** Not reported.

**Fishing mortality estimates:** Not reported.

**Biological reference points:** Not reported.

**Current status:** Not reported.

## **Catch trends**

**Recreational:** 4,052 individuals of this species were kept in the West Coast bioregion by recreational boat-based fishers in 2005/06, compared with 1,035 in 1996/97 (Sumner *et al.*, 2008). An additional estimated 96,027 fish were released in 2005/06 compared with 19,545 in 1996/97. Substantially greater numbers of this species were released than kept by boat and shore-based recreational fishers in the Swan-Canning Estuary and Peel-Harvey Estuary during 1998/99 (Malseed and Sumner, 2001a; b). See also Malseed *et al.* (2000), Smith (2006), Smallwood *et al.* (2006), Smallwood and Sumner (2007), Sumner (2008) and Smallwood *et al.* (2012).

**Commercial:** Quantity of by-catch of this species is not reported.

## **Management regulations**

**Recreational:** Currently included in the “all other species of finfish” category (DoF, 2013).

Bioregion (Year)	Bag limit	MLL	Other
Statewide (1991)	40	-	
West Coast (2009)	30	-	

**Commercial:** Not applicable.

**Current research:** Ongoing data collection occurs through commercial and charter fishing logbooks. A survey of boat-based fishing in the West Coast bioregion during 2009/10 together with a statewide phone/diary survey of boat-based fishing in 2011/12 may also provide additional catch information.

**Comments/other published information:** *Ecosystem modelling* (Platell and Hall, 2006); *Visualisation* (Collin *et al.*, 2000); *Habitat utilization* [Queensland] (Miller and Skilleter, 2006); *Parasites* (Williams, 1986); *By-catch in commercial fisheries* [South Australia] (Steer *et al.*, 2011).

## References

- Ayvazian, S. G., Hyndes, G. A., 1995. Surf-zone fish assemblages in south-western Australia: do adjacent nearshore habitats and the warm Leeuwin Current influence the characteristics of the fish fauna? *Marine Biology* 122, 527-536.
- Collin, S. P. M., Collin, H., M., B. A., 2000. The corneal endothelium in the blowfish (*Torquigener pleurogramma*). *Cornea* 19, 231-235.
- DoF, 2013. Recreational fishing guide 2013. Western Australian Department of Fisheries. Perth, Western Australia. pp. 43.
- Fairclough, D., Lai, E., Sawyer, M., Holt, M., Nicholas, T., 2012. West Coast demersal scalefish resource status report, In Status reports of the fisheries and aquatic resources of Western Australia 2011/2012: The State of the Fisheries. Fletcher, W. J., Santoro, K. (eds), Perth, Western Australia, pp. 100-110.
- Gomon, M. F., Bray, C. D., Kuitert, R. H. (eds) 2008. Fishes of Australia's southern coast. Reed New Holland, Sydney, Australia.
- Heithaus, M. R., 2004. Fish communities of subtropical seagrass meadows and associated habitats in Shark Bay, Western Australia. *Bulletin of Marine Science* 75, 79-99.
- Hutchins, B., Thompson, M., 1983. The marine and estuarine fishes of south-western Australia: a field guide for anglers and divers. Western Australian Museum, Perth, Western Australia.
- Hyndes, G. A., Kendrick, A. J., MacArthur, L. D., Stewart, E., 2003. Differences in the species- and size-composition of fish assemblages in three distinct seagrass habitats with differing plant and meadow structure. *Marine Biology* 142, 1195-1206.
- Leis, J. M., Carson-Ewart, B. M., 2000. The larvae of Indo-pacific coastal fishes: a guide to identification (Fauna Malesiana Handbook 2). Brill: Leiden.
- Loneragan, N. R., Potter, I. C., 1990. Factors influencing community structure and distribution of different life-cycle categories of fishes in shallow waters of a large Australian estuary. *Marine Biology* 106, 25-37.
- Loneragan, N. R., Potter, I. C., Lenanton, R. C. J., Caputi, N., 1986. Spatial and seasonal differences in the fish fauna in the shallows of a large Australian estuary. *Marine Biology* 92, 575-586.
- Malseed, B. E., Sumner, N. R., 2001a. A 12-month survey of recreational fishing in the Swan-Canning Estuary basin of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 126. pp. 44.
- Malseed, B. E., Sumner, N. R., 2001b. A 12-month survey of recreational fishing in the Peel-Harvey Estuary of Western Australia during 1998-99. Western Australian Department of Fisheries. Fisheries Research Report No. 127. pp. 48.
- Malseed, B. E., Sumner, N. R., Williamson, P. C., 2000. A 12-month survey of recreational fishing in the Leschenault Estuary of Western Australia during 1998. Western Australian Department of Fisheries. Perth, Western Australia. pp. 36.

- Miller, S. J., Skilleter, G. A., 2006. Temporal variation in habitat use by nekton in a subtropical estuarine system. *Journal of Experimental Marine Biology and Ecology* 337, 82-95.
- Platell, M. E., Hall, N. G., 2006. Synthesis and gap assessment of fish dietary data required for modelling ecosystems in south-western Australia. Perth, Western Australia. FRDC Project No. 2002/016. pp. 126.
- Potter, I. C., Cheal, A. J., Loneragan, N. R., 1988. Protracted estuarine phase in the life cycle of the marine pufferfish *Torquigener pleurogramma*. *Marine Biology* 98, 317-329.
- Smallwood, C. B., Beckley, L. E., Sumner, N. R., 2006. Shore-based recreational angling in the Rottneest Island Reserve, Western Australia: spatial and temporal distribution of catch and fishing effort. *Pacific Conservation Biology* 12, 238-51.
- Smallwood, C. B., Pollock, K. H., Wise, B. S., Hall, N. G., Gaughan, D. J., 2012. Expanding roving-aerial surveys to include counts of recreational shore fishers from remotely-operated cameras: benefits, limitations and cost-effectiveness. *North American Journal of Fisheries Management* 32, 1265-1276.
- Smallwood, C. B., Sumner, N. R., 2007. A 12-month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002/03. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 159. pp. 56.
- Smith, K. A., 2006. Review of fishery resources and status of key fishery stocks in the Swan-Canning Estuary. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 156. pp. 84.
- Steer, M. A., McGarvey, R., Fowler, A. J., Jackson, W. B., Lloyd, M. T., 2011. Promoting stock recovery through the standardisation of fishing gear: streamlining the haul net sector of South Australia's Garfish Fishery. SARDI. Adelaide, South Australia. SARDI Research Report Series No. 578. pp. 55.
- Sumner, N. R., 2008. An assessment of the finfish catch by recreational fishers, tour operators, commercial lobster fishers and commercial wetline fishers from the Houtman Abrolhos Islands during 2006. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 175. pp. 32.
- Sumner, N. R., Williamson, P. C., Blight, S. J., Gaughan, D. J., 2008. A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Western Australian Department of Fisheries. Perth, Western Australia. Fisheries Research Report No. 139. pp. 44.
- Travers, M. J., Potter, I. C., 2002. Factors influencing the characteristics of fish assemblages in a large subtropical marine embayment. *Journal of Fish Biology* 61, 764-784.
- Valesini, F. J., Potter, I. C., Clarke, K. R., 2004a. To what extent are the fish compositions at nearshore sites along a heterogeneous coast related to habitat type? *Estuarine, Coastal and Shelf Science* 60, 737-754.
- Valesini, F. J., Potter, I. C., Wildsmith, M. D., Hourston, M., Platell, M. E., Coen, N. J., Schafer, L. N., Seidel, S. T., Whitehead, A. L., 2004b. The importance to fish species of the various habitats in nearshore marine waters of south-western Australia. Murdoch University. Perth, Western Australia. FRDC Project No. 2000/159. pp. 452.
- Williams, A., 1986. Taxonomy of 2 new species of *Heterobothrium* (Monogenea, Diclidophoridae) from *Torquigener pleurogramma* (Pisces, Tetraodontidae) from Western Australia. *Australian Journal of Zoology* 34, 707-715.



