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Age-specific demographic parameters, and their implications for management of the red bass, *Lutjanus bohar* (Forsskal 1775): A large, long-lived reef fish

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Abstract

Red bass, *Lutjanus bohar*, is a large tropical snapper (Lutjanidae) that is harvested to varying extents throughout a widespread Indo-Pacific distribution. The objective of this study was to estimate vital life history characteristics (age, growth, maturity) of red bass on the Great Barrier Reef, Australia, relevant to its management. The maximum estimated age of 55+ years is the oldest reported for any tropical snapper to date. The sampling of red bass from different depth ranges resulted in different age frequency distributions, suggesting that many older red bass reside at greater depths. The fit of the von Bertalanffy growth model described a trend of relatively slow growth: L_F (fork length; mm) = 630 × (1 − $e^{-0.10t+3.05}$), with no significant difference in fitted parameter estimates between males and females. Female red bass matured at a much larger size (L_{50} = 428 mm) and older age (t_{50} = 9.39 years) than males (L_{50} < 300 mm, t_{50} = 1.46 years) and were reproductively active over many months, from August to April. These results suggest that the red bass has a relatively *K*-selected life history strategy among the tropical snappers, and fish in general. This type of life history strategy predicts slow rates of turnover and a susceptibility of red bass populations to rapid over-exploitation.

Keywords: Tropical reef fish; Red bass; Two-spot red snapper; *Lutjanus bohar*; Age; Growth; Maturity; Reproduction; Great Barrier Reef

1. Introduction

Knowledge of vital life history characteristics of an exploited fish population can provide an indication of its vulnerability to over-exploitation prior to any formal stock assessment (Parent and Schriml, 1995; Jennings et al., 1998; Musick, 1999). A meaningful stock assessment may not be possible in many fisheries due to data limitations and, in these cases, biological proxies can be particularly useful for management. Simple yield-per-recruit (Beverton and Holt, 1957) and surplus production (Ricker, 1975) models predict that populations with slow growth and low rates of natural mortality will produce a relatively low yield for a given level of fishing effort and can be over-exploited rapidly (Adams, 1980; Kirkwood et al., 1993). A delayed maturity can result in immature juveniles being susceptible to fishing mortality for a longer period, reducing their chances of reproducing and thus limiting contribution to future recruitment (Myers and Mertz, 1998; Crouse, 1999). The urgency to gather such biological data to inform management planning has contributed greatly towards our current understanding of the biology of many exploited species and formulation of current management strategies for sustainable fisheries and ecosystems.

Biological research for the management of tropical fisheries did not emerge until the late 1960s and 1970s when it was realised that many tropical stocks were vulnerable to over-exploitation because of increasing harvest rates (Munro, 1996; Choat and Robertson, 2002). Tropical snappers or “lutjanids” (Pisces: Lutjanidae) are among the main species targeted by tropical reef fisheries (Dalzell, 1996) and some have high value on the international market (Birkeland, 1997; Lee and Sadovy, 1998). Generally, lutjanids are gonochoristic, highly fecund species (Grimes, 1987) that have relatively protracted spawning seasons (e.g., Druzhinin, 1970). An increasing number of

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recent studies have also found that some lutjanids are relatively long-lived, with maximum estimates of age exceeding 30 years (Newman et al., 1996, 2000; Rocha-Olivares, 1998; Wilson and Nieland, 2001; Russell et al., 2003).

The two-spot red snapper, vara vara, or red bass, *Lutjanus bohar* (Forsskal, 1775), is a large piscivorous lutjanid that has a widespread tropical Indo-Pacific distribution (Allen, 1985). Aspects of its biology have been studied in the Seychelles (Wheeler, 1953), East Africa (Talbot, 1960), New Caledonia (Loubens, 1980a,b) and Papua New Guinea (Wright et al., 1986). These studies, however, reported large differences in results. Estimates of maximum age, for instance, ranged from 3 years (Wheeler, 1953) to 38 years (Loubens, 1980b). It was clear that the biology of this species needed to be resolved because markedly different perceptions of its biology could lead to markedly different management decisions.

In some areas, such as the Seychelles Republic, red bass is one of the main species caught by local fishers for consumption. In 2000, for instance, the red bass ranked fifth in total annual catch out of all reef fish harvested by the Seychelles Whaler Handline Fishery (the total annual catch of red bass peaked at 127.5 tonnes in 2000, out of 2875 tonnes of total reef fish caught; this has declined to 44.9 tonnes in 2003, out of 2441 tonnes of total reef fish caught; Government of Seychelles, 2004). In other areas, throughout much of its distribution, the red bass has a reputation for causing ciguatera poisoning (Lewis, 2001). For instance, on the Great Barrier Reef (GBR), Australia, red bass have been avoided historically by most fishers because of its reputed toxicity (Gillespie et al., 1986) and it has recently (from 9 November 2003) been made a No-Take species because of this risk and its life history characteristics (reported here). Accordingly, red bass populations on the GBR are expected to be relatively little impacted by fishing and so provide good insights to its unperturbed biology.

The objective of this study was to estimate vital life history characteristics (e.g., age, growth, maturity) of red bass relevant to its management. This was done for lightly exploited populations of red bass on the GBR. We used the most accurate and widely accepted methods available (transverse sections of otoliths and gonad histology) for this purpose. We then provide comment on the implications of this new information for the harvest management of red bass.

2. Methods

2.1. Sample collection

Samples of red bass were collected from several methods, reefs and habitats of the Great Barrier Reef (GBR), Australia, to ensure the underlying population structures were adequately represented (Fig. 1). Samples were gathered from research catch surveys of the CRC Reef "Effects of Line Fishing" (ELF) Experiment, catches of commercial line fishers and recreational spearfishers, and targeted spearfishing of small (<300 mm fork length; L_F) red bass (Table 1). Samples from the research catch surveys were collected by line fishing methods similar to those used by commercial fishers, but were standardised, uniformly distributed, and stratified by depth on six experimental reefs within four spatially separated clusters of reefs on the GBR (Mapstone et al., 2004). The majority of red bass (∼99%) caught on these surveys, however, were from the "Lizard Island" and "Townsville" reef clusters in depths of 5–35 m (Fig. 1, insets 1 and 2). Whole weights (g; 1999–2001) and fork lengths (mm; all years) of red bass were recorded and otoliths and gonads were dissected shortly after capture on research vessels whilst at sea.

Monthly samples (July 2001–June 2002) of red bass were also collected from the catch of commercial reef line fishers operating from Whyborn Reef to Reef 20385 in depths less than 30 m (Fig. 1) to analyse seasonal trends in gonad development. Additional samples of larger red bass were collected from the catch of the Australian Underwater Federation (AUF) national spearfishing titles at Centipede Reef (Fig. 1, inset (b)) on 28 November 2001 and a deep-water commercial fisher from April to September 2003. The "deep-water" catch was predominantly taken at night from depths greater than 30 m. Targeted research spearfishing of smaller (<300 mm fork length) red bass was done in shallow waters (to ∼5 m deep) on fringing reefs of the Lizard Island cluster in October 2002. Whole red bass and red bass frames from commercial line fishers were frozen after capture and otoliths and gonads were dissected from frozen samples on return to the laboratory, where fork lengths and whole fish weights (from whole fish only) were recorded. Whole weights and fork lengths of all speared samples were recorded and otoliths and gonads were dissected shortly after capture. Large otoliths were stored in paper envelopes and smaller otoliths were dried and stored in plastic vials, whilst gonads were stored in vials of 10% phosphate buffered formaldehyde. Sex was determined macroscopically from inspecting freshly dissected gonads in the field or preserved gonads in the laboratory ($n = 308$) or microscopically from histological examination ($n = 532$; Table 2).

2.2. Age and maturity estimation

Sagittal otoliths were transversely sectioned using a standard age preparation procedure for tropical reef fish (Ferreira and Russ, 1994). Otolith sections were further processed by grinding and polishing the sectioned surface with 1200-grade wet and dry emery paper and running tap water either with a Kemet (300 series) variable speed lapping machine or by hand. Fish age in years was then estimated by counting opaque increments along the ventral sulcus of transverse otolith sections, from the nucleus to the proximal surface margin, when viewed with transmitted light under low (40×) to medium (100×) power magnification. An independent study verified that these opaque increments were deposited on an approximately annual basis and so could produce reliable estimates of fish age (Marriott and Mapstone, 2006b). Opaque increments were categorised as pseudo-annuli and excluded from estimates of age if their position or optical density relative to other opaque increments in the otolith was interpreted to be irregular. Two or more opaque increments were grouped and interpreted as a single annulus when they were interpreted to be confluent (Crabtree et al., 1995). All readings were done by the same reader (RJM).