Comparative biology of key inter-reefal labrid species on the Great Barrier Reef

Project Milestone Report

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Acronyms Used In This Report

- ELF Effects of Line Fishing (Experiment)
- FL Fork length
- GBR Great Barrier Reef
- GBRWHA..... Great Barrier Reef World Heritage Area
- GSI..... Gonadosomatic Index
- LRFFT..... Live reef food fish export trade
- TACC Total allowable commercial catch
- TL Total length
- \pmb{W} Whole wet weight

Introduction

Life-history characteristics among families of reef fish are diverse (Gust *et al.*, 2002; Sale, 1991), ranging from long-lived fishes of the family Acanthuridae with low rates of natural mortality (Choat and Axe, 1996), to short-lived, fast-growing species of Gobiidae with a high rate of natural mortality (Hernaman and Munday, 2005). Variability also exists among species within the same family, for example between the epinepheline and plectropomid serranids on the Great Barrier Reef (GBR) and in Torres Strait (Pears *et al.*, 2006; Williams *et al.*, 2008). The species within these subfamilies display different demographic characteristics, with smaller epinephelines (e.g. *Cephalopholis cyanostigma*, 260 mm maximum size (Mosse *et al.*, 2002)) growing to over forty years of age, and species with somewhat shorter lifespans (e.g. *Epinephelus coioides*, eleven years) reaching lengths of greater than one metre (Grandcourt *et al.*, 2009). This variation in the life-history characteristics means that the effects of fishing will also be variable between species. Consequently, some species may be more resilient to fishing and thus management strategies should not assume uniform life history characteristics among species even within the same genus.

The family Labridae (wrasses) is highly diverse, with approximately 600 species in 82 genera distributed worldwide in both coastal and offshore waters, in tropical, subtropical and temperate regions (Westneat and Alfaro, 2005). Fishes in this family display great variation in colour, body shape and size, resulting in much debate as to the exact number and relatedness within the wrasses (Clements *et al.*, 2004; Westneat and Alfaro, 2005). The majority of species occur in the Indo-Pacific region with the most species found in Australian waters (Parenti and Randall, 2000), including the maori wrasse (*Cheilinus undulatus*) and tuskfish (*Choerodon* spp.). Research on these genera has focussed on taxonomy and phylogenetic relationships (Parenti and Randall, 2000; Westneat and Alfaro, 2005), reproductive biology and behaviour (Donaldson, 1995; Nakazono and Kusen, 1991), habitat use (Fairclough *et al.*, 2008) and the effects of fishing pressure (Sadovy *et al.*, 2003; Westera *et al.*, 2003).

The maori wrasse (*Cheilinus undulatus*) is the largest species in the Labridae family, with maximum size exceeding one metre in length. This species occurs in reefal Indo-Pacific waters, yet despite demand from the live reef food fish export trade (LRFFT) and cultural significance in some Pacific countries, it is uncommon to many parts of its distribution (Choat *et al.*, 2006; Sadovy *et al.*, 2003). Studies have estimated fish densities to be naturally low, with lower abundance in areas where fishing is more intense (Sadovy *et al.*, 2003). Thus, only a few studies have provided biological estimates for this species.

In comparison, fishes of the genus *Choerodon* (the tuskfishes) are smaller in size, with the largest species *C. schoenleinii* reaching over 90 cm in maximum length (Randall *et al.*, 1997). This genus is fished commercially and recreationally throughout its distribution (Fairclough, 2005; Fairclough and Nakazono, 2004; Kawabata *et al.*, 2008) and is desired by the aquarium trade (Westneat, 2001). *C. schoenleinii* is a highly sought food fish in southeast Asia, particularly in Sabah, Japan and Hong Kong (Fairclough and Nakazono, 2004; Sadovy and Corning, 2000) and recreationally and commercially targeted in Australia (Fairclough, 2005; Fairclough and Nakazono, 2004; Platten *et al.*, 2002). *C. schoenleinii* is rare in Hong Kong and low abundances of *C. rubescens* (endemic to Western Australia) (Tuya *et al.*, 2009) and other tuskfish species have been recorded in some sites in southwestern Australia where they have previously been more abundant (Westera *et al.*, 2003). In locations of higher abundance, the intensity of fishing pressure causes concern for *Choerodon* populations (Fairclough, 2005).

Both *Cheilinus undulatus* and *Choerodon schoenleinii* are listed on the IUCN Red list as vulnerable and near threatened, respectively. This is due not only to overall low abundance and fishing pressure, but also because of reproductive strategy. Protogynous hermaphroditism – sex change from female to male – is the common reproductive pathway for labrids (Cowen, 1990; Fairclough, 2005; Gillanders, 1995; Nakazono and Kusen, 1991; Sadovy *et al.*, 2003; Westneat, 2001). As for other reef fishes, the mechanism for sex change is not necessarily a particular size threshold, but rather due to a combination of size and social factors (Fairclough, 2005). Thus fishers targeting larger individuals, typically males, could disproportionately remove males from the population. As plasticity exists with sex change, fishing pressure can result in fish changing sex at a smaller size (Choat *et al.*, 2006; Fairclough, 2005; Platten *et al.*, 2002); however this can lead to population collapse.

In the Great Barrier Reef World Heritage Area (GBRWHA), wrasses are taken as part of a multi-sector reef line fishery, constituting 0.03% of commercial catch, 1.19% charter catch and 6.52% catch recreationally (Simpfendorfer *et al.*, 2007). Like other parts of Australia, labrid catch is regulated by a variety of means including input and output controls. Commercially, a total allowable commercial catch (TACC) manages take of labrids, which constitute a component of the 'other species' quota group within the Queensland Coral Reef Finfish Fishery. This group refers to those species which are predominately bycatch (caught in the fishery and released) and byproduct (caught by the fishery and retained at times, but which fetch lower prices). All sectors adhere to minimum legal size limits and bag limits apply to recreational fishers, with a combined limit of six tuskfish allowed at greater than 30 cm total length. *Cheilinus undulatus* is fully protected from harvest as a no-take species in Queensland and Western Australia.

The purpose of this study was to describe the biology of the labrids collected from fishery independent surveys on the GBR providing results of length and weight relationships, length frequencies, spawning seasonality, length at sex change and sex ratios where data is available. The resiliency of the wrasses to fishing in the GBRWHA will be assessed from this data and the existing literature.

Methodology

Sample collection

Labrids were sampled from reefs in four regions of the GBR (Lizard Island, Townsville, Mackay and Storm Cay) over eleven years from 1995 to 2005 during the Effects of Line Fishing (ELF) Experiment structured research fishing surveys (Mapstone *et al.*, 2004) (Figure 1).



Figure 1: Location of the Effects of Line Fishing (ELF) Experiment study areas within the Great Barrier Reef World Heritage Area.

Sample processing

For all samples, fork length (FL) was measured to the nearest millimetre and whole wet weight (W) measured to the nearest 10 g.

Gonads from fish were either removed at sea and stored in 10% phosphate buffered formalin or immediately frozen whole for processing back in the laboratory, where they were removed, thawed and similarly preserved in formalin. After fixation, each pair of ovaries or testes was dried of excess fixative, and gonad weight was measured to the nearest 0.01 g. Where only one gonad lobe was available, due to damage during processing, gonad weight was estimated by multiplying the mass of the single complete lobe by two. It was assumed that this provided a reasonably accurate measure of gonad weight, as the two gonad lobes are generally equal in size for other reef fishes (Adams and Williams, 2001; Bean *et al.*, 2003).

Histological sections were taken from gonads following the procedures outlined by Adams (2003). The stage of ovary development was based on the most advanced non-atretic cell type present (West, 1990). Additional features used in histological staging included the presence of brown bodies, atretic oocytes, vascularisation, and the relative thickness of the gonad wall, all of which may indicate prior spawning (Sadovy and Shapiro, 1987). Ovaries and testes were classified into developmental stages adapted from Ferreira (1995) and Adams (2003). Females were classified into four stages: Resting, Ripening, Ripe and Running Ripe (Hydrated). Males were classified into three stages: Resting, Ripe and Spent.

Biological analyses

The relationship between FL and W was described using a power function of the form,

$$W = a \times FL^b$$

where *a* is the coefficient of the power function and *b* is the exponent. This relationship was plotted for each species for comparison. Length frequency distributions were constructed separately for each species, data permitting.

The data available did not allow estimates of age, growth or mortality to be deduced for any species.

The spawning season was examined using samples collected in different months throughout the year for *Cheilinus undulatus* only, as data was unavailable for the other labrids. A gonadosomatic index (GSI = gonad weight / $W \times 100$) was calculated for each female, which provided a relative measure of reproductive stage. Measurements of W were not always available directly from fish frames. Consequently, W was estimated for some samples using the species-specific length-weight relationship. It was assumed that estimates of W would suffice for use in estimating GSI because only the temporal patterns in GSI, rather than the absolute values of GSI, were required to determine the spawning season. The proportion of samples in each mature female reproductive stage by month were plotted to examine the ovarian development patterns and the degree of spawning activity occurring throughout the year.

A logistic function was fitted to the proportion of males (relative to mature females) in each length class to estimate the length at sex change for *Cheilinus undulatus*. This was estimated using the logistic equation,

$$P_{s} = (1 + e^{-\ln 19(s - s_{50})/(s_{95} - s_{50})})^{-1}$$

where P_s is the proportion of males in each 10 mm length class *s*, and s_{50} and s_{95} is the length at which 50% and 95% of the population are males.

Results

A total of 771 labrids were collected as part of the fishery independent ELF surveys (Table 1). A large proportion of *Choerodon* spp. were unidentified or unspecified in the field, thus this species group would likely consist of the other three tuskfish species: *Choerodon venustus; C. schoenleinii;* and *C. cyanodus*. This was highlighted by the similar size ranges and length frequency distributions for the tuskfish with a maximum size of 540 mm fork length (Figure 2). Modal age varied slightly, with 340 mm *FL* for both *Choerodon venustus* and *C. cyanodus* and 360 mm *FL* for the *Choerodon* species group. *Cheilinus undulatus* grew much larger to 1300 mm with a mode of 540 mm *FL* and a right-skewed size distribution, with fewer individuals greater than 800 mm. No inferences could be made for *C. schoenleinii* as only six samples were available and no data was collected for *C. fasciatus*. The majority of the *Choerodon* species sampled were larger than the minimum legal size limit of 30 cm total length, approximately 287 mm in fork length (line, Figure 2). It appears the majority of the tuskfish population is exposed to fishing pressure, yet a lack of smaller immature individuals (i.e. below the modal length) present was due to the selectivity of the hook and line gear used in the ELF Experiment.

Species	Common name	n	FL
Cheilinus undulatus	Maori wrasse	220 (122F, 9M)	299-1300
Choerodon venustus	Venus tuskfish	48 (1F, 8M)	297-548
Choerodon schoenleinii	Black-spot tuskfish	6 (6M)	442-548
Choerodon cyanodus	Blue tuskfish	59 (6M)	250-514
Choerodon fasciatus	Harlequin tuskfish	2	NA
Choerodon spp.	Unspecified tuskfish	438 (16F, 88M)	230-508

Table 1: Sample numbers (including numbers of known females (F) and males (M)) and size range in fork length (FL) for each labrid species/species group; NA = Not Available.



Figure 2: Length frequency distributions of each labrid species/species group (note, difference in y-axes). Minimum legal size limit for tuskfish of 30 cm *TL* is represented as \sim 287 mm *FL* by the red vertical line.

The relationship between FL and W was determined for each species/species group, with the slope (*b*) indicating that individuals become more heavy-bodied with increasing size (*FL*) (Table 2, Figure 3). All species displayed positively allometric relationships except *C. cyanodus* displayed isometric growth (Figure 3).

Species	а	b	R ²	Relationship
Cheilinus undulatus	6.92 x 10 ⁻⁸	3.103	0.988	Allometric+
Choerodon venustus	9.24 x 10 ⁻⁹	3.126	0.942	Allometric+
Choerodon schoenleinii	NA	NA	NA	NA
Choerodon cyanodus	9.113 x 10 ⁻⁹	3.124	0.991	Isometric
Choerodon spp.	1.061 x 10 ⁻⁸	3.092	0.932	Allometric+

Table 2: Length-weight relationship parameters for each labrid species;NA = Not Available.



Figure 3: Length at weight data and fitted power curve for labrids on the GBR.

Sixty samples were available to assess the reproductive biology of *Cheilinus undulatus*. Monthly trends in mean GSI indicated female spawning activity was highest in October and November, however, due to data missing in some months; this must be interpreted with caution. One running ripe (hydrated, or soon to spawn) individual and few ripe individuals were observed only in November, indicating the presence of ovaries in active vitellogenesis corresponded to the period of peak mean GSI (Figure 4). Only nine males were observed in the sample, each in ripe condition, with GSI values available for two months only. This precluded the calculation of mean GSI and determination of peak spawning period for males.



Figure 4: Proportions of each female developmental stage and mean gonadosomatic index (GSI) for *Cheilinus undulatus* on the GBR.

Despite the small sample size, a logistic curve fitted to frequencies of mature male and mature female *C. undulatus* suggested this species conformed to the typical protogynous hermaphroditic trend described by other studies (Figure 5). Although sex ratio was female biased (13.6:1), a greater proportion of females were present at smaller length classes whilst males were larger, as usually expected in populations of fish that change sex from males to females. 50% and 95% of females changed sex into males at 1018.7 mm and 1409.8 mm respectively. One transitional individual was observed at 440 mm *FL* and overlap of size distributions further indicates protogyny.



Figure 5: Size at sex change: Proportions of males and females and predicted males (logistic curve) for *Cheilinus undulatus* on the GBR (n = 131).

Samples of the tuskfish species group were male dominated, and despite the few males (6) and no females present at the smallest length classes (285-305 mm), a logistic curve could be fitted (Figure 6). As protogynous hermaphrodites, 50% and 95% of sex change occurs at 322 mm *FL* and 362 mm *FL* respectively. No females were observed at lengths greater than 358 mm *FL* and no transitional individuals were recorded.



Figure 6: Size at sex change: Proportions of males and females and predicted males (logistic curve) for *Choerodon* species on the GBR (n = 104).

Discussion

Labrids are one of the four families comprising the key reef line fishery 'Other Species' quota group which the current study (MTSRF Project 4.8.3) has investigated. As minor species of the reef line fishery, the data collected during the ELF project provided few samples. However, it is important to obtain biological estimates to ensure sustainable management. Age information was not obtained thus estimates of growth and mortality was unable to be determined. Despite this, comparisons of length for these species and length-weight relationships and reproductive development could be compared amongst the literature.

In order to determine resiliency of labrids to fishing, biological characteristics need to be understood. Three factors that may influence the effects of fishing pressure on wrasses include natural abundance, size distribution and reproductive strategy.

Abundance

The low numbers of labrids in the catch during the eleven years of surveys suggests they are rarer than other families in the 'Other Species' category, such as the lethrinids, serranids and lutjanids (Currey *et al.*, 2008; Heupel *et al.*, 2009; Mapleston *et al.*, 2009). Sadovy and others (2003) observed substantial variation in densities of *C. undulatus* across a wide range of locations and studies; however this was correlated with fishing intensity. Approximately ten fish were recorded per hectare in unfished areas whilst 4-5 fish per hectare were observed in lightly fished areas (Sadovy *et al.*, 2003).

As a highly sought after food fish, *C. schoenleinii* has experienced declines in abundance due to fishing in Hong Kong and Japan (Cornish, 2003) is rare in the Houtman-Abrolhos Islands, but more common in other areas of Western Australia and Queensland (Cornish, 2003; Hutchins, 2001). *C. cyanodus* is common along the Western Australian coast and other tuskfish species have been recorded in low numbers at particular sites in Ningaloo Reef (Westera *et al.*, 2003). A total of 553 tuskfish were sampled in the present study, however samples were probably biased to larger individuals due to the gear used for collection.

Size structure

Investigation of the size structure of a population can provide important information to ensure management of a species is effective. For example, the largest *C. undulatus* sampled from this study was 1,300 mm, which compares to the species maximum size (of a confirmed identification) recorded at 1,500 mm (Choat *et al.*, 2006). Choat and others (2006) suggested the larger individuals would be less resilient to fishing pressure as few individuals were observed more than one metre in length, demonstrated by a right-skewed size distribution. Like Choat and others (2006), large females were observed in the present study that did not change sex into males. Great potential for these large-sized females to significantly contribute to the reproductive output of the population exists because their sizeable gonads contain numerous eggs. Although this species reaches maturity at 350-500 mm *TL* (Sadovy *et al.*, 2003), the rarity of these large females and the target and harvest of these individuals by fishers evokes concern of lower offspring production (Choat *et al.*, 2006). Within the GBRWHA however, this species is totally protected due to its listing as a no-take species. More research investigating post-release survival would be valuable.

The tuskfish were smaller in size than *C. undulatus* but are harvested in the GBRWHA above a minimum legal size limit of 30 cm total length (approximately 287 mm fork length). The effectiveness of this minimum legal size limit is related to the species-specific size distributions. Size limits should be set at the length at which allows fifty percent of the population to become mature and reproduce at least once, however maturity information is lacking in the present study. Literature suggests that fifty percent of females mature at 24 cm total length for *C. venustus* and *C. schoenleinii* (Ebisawa and Kana, 1995; Platten *et al.*, 2002) and 12.9 cm for *C. cyanodus* (Fairclough, 2005). Few *C. schoenleinii* and *C. cyanodus* attain lengths greater than the minimum legal size limit of 40 cm *TL* in Western Australia, indicating the larger *C. schoenleinii* is under substantial fishing pressure and *C. cyanodus* does not reach its maximum size in that region (Fairclough, 2005). If maturity schedules are similar in the GBRWHA and for *C. venustus*, it appears the current size limit of 30 cm *TL* should allow individuals become mature and spawning to occur before harvest.

Reproductive strategy

Wrasses display evidence of protogyny, presence of transitional individuals and overlap in female and male size distributions, and this reproductive strategy may make them less resilient to fishing. Although only one transitional fish was observed in the present study, literature confirms protogyny as the usual pathway for labrids (Cowen, 1990; Fairclough, 2005; Gillanders, 1995; Nakazono and Kusen, 1991; Sadovy *et al.*, 2003; Westneat, 2001). The population structure of protogynous hermaphrodites has typically more females at smaller and younger age classes and more males at larger and older age classes, as observed for species in the present study.

This strategy means fishing pressure targeting larger individuals, removing males from the population, can cause sperm limitation, decreased fertilisation rates and decreased population size, even for species with high sperm production (Alonzo and Mangel, 2004). Few *Cheilinus undulatus* males were seen in the present study and although males were observed in greater number for tuskfish, few *Choerodon schoenleinii* males have been recorded in Western Australia, suggesting support for this theory (Ebisawa and Kana, 1995).

Some plasticity exists with size at sex change however, shown by Sadovy *et al.* (2003) and Choat *et al.* (2006) for *Cheilinus undulatus*, Fairclough (2005) for *C. rubescens*, *C. schoenleinii* and *C. cauteroma*, and by Platten *et al.* (2002) for *C. cyanodus*. In the present study, *Cheilinus undulatus* attained over one metre in length before half had changed sex to males, with the smallest male observed at 730 mm *FL* and one individual undergoing transition at 440 mm *FL*. The smallest male from a study by Sadovy *et al.* (2003) was much smaller, at 295 mm *FL*. The *Choerodon* species group in the present study achieved fifty percent sex change at 322 mm *FL*, compared to 556 mm and 221 mm for *C. schoenleinii* and *C. cyanodus*, respectively (Fairclough, 2005), suggesting size at sex change is probably species-specific. Yet research highlights that sex change is not initiated at a particular size, but rather related to social cues, which can shift to occur at smaller sizes and recently changed males can undergo fast growth as a response to male depletion (Choat *et al.*, 2006; Fairclough, 2005; Platten *et al.*, 2002).

Intense fishing of species that aggregate to spawn, for example the well-known Nassau grouper (*Epinephelus striatus*), can experience population declines, to the point where aggregations no longer form or contain fewer individuals, thus reproductive function is limited (Sadovy de Mitcheson *et al.*, 2008). *Cheilinus undulatus* spawns in aggregations and inhabits shallow areas resulting in easy access to fishers throughout its lifecycle in areas where fishing is permitted (Choat *et al.*, 2006; Sadovy *et al.*, 2003). In contrast, the small size of male gonads, large male size, and female biased sex ratio of *C. cyanodus* and *C. schoenleinii* suggests males would likely spawn with only one to a few females at a time, in permanent (haremic) or temporary (lek-like) territories (Fairclough, 2005; Fairclough and Nakazono, 2004). Thus it is unlikely tuskfish form large spawning aggregations and aggregation fishing pressure should not concern these *Choerodon* species.

Spawning information is scant for wrasses on the Queensland coast, and despite few samples, the present study indicates spawning for *Cheilinus undulatus* occurs around November (late spring). Literature states *C. undulatus* spawns between several months to throughout the year, depending on location (Sadovy *et al.*, 2003). In Western Australia spawning for *Choerodon* species varies for each species, occurring in spring to summer (Fairclough, 2005; Fairclough *et al.*, 2004). It would be expected that like most reef fish, similar timing would occur for these species on the eastern Australian coast.

Management implications

As *Cheilinus undulatus* is protected from fishing and catch of *Choerodon* species is relatively low in all sectors within the GBRWHA, the concern of overexploitation of these species is low. However, if fishing pressure of tuskfish were to intensify, males may be more vulnerable to depletion and increased removal of the few larger females could negatively influence tuskfish populations. In Western Australia, the tightening of regulations for snapper harvest caused a shift in fishing pressure to *C. schoenleinii*, resulting in fewer males recorded in some sites (Ebisawa and Kana, 1995; Fairclough, 2005). More research for tuskfish species is needed along the Queensland coast as resilience to fishing pressure is still widely unknown. Additionally, continuous monitoring of wrasses within the recreational sector and the commercial 'Other Species' quota group is necessary to ensure sustainable populations within the GBRWHA.

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