Do Dusky Flathead, *Platycephalus fuscus* (Cuvier, 1829), Spawn in Upper Estuarine Areas?

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Abstract

This study is based on monthly samples of dusky flathead (n = 87) in the size range 40 cm TL (total length) to 75 cm TL, collected by angling methods from upper estuarine areas in southern Queensland during the spawning period (September to April). Ovaries at two stages of development were identified by macroscopic and microscopic examination: unyolked (translucent) ovaries, the most common form, in which oocytes are undergoing mass atresia up to α stage; and yolked (vitellogenic) ovaries which are also undergoing mass atresia to both α and β stages. An unusual finding is mass atresia of previtellogenic oocytes, showing multiple irregular vacuoles within the oocyte cytoplasm, which commonly occurs in both ovary types. Mature males have testes that are small and degraded. No ripe or running ripe gonads were found in the upper estuarine fish during the spawning period. It is concluded that these dusky flathead are not spawning, in contrast to the spawning aggregation fish at the Jumpinpin estuarine/oceanic interface which is 10 km to 20 km distant from the study site. Given the major differences in gonads and oocytes between spawning aggregation fish and those from upper estuarine areas, it is unlikely that mixing of the two subpopulations occurs during the spawning period. A review of size at maturity of dusky flathead estimated that L_{50} (length at which 50% of the size class has reached maturity) for females is 35 cm TL to 39 cm TL, and 30 cm TL to 34 cm TL for males.

Keywords: citizen science, degenerate gonads, oocyte atresia, size at maturity, sub-population

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Introduction

The dusky flathead (*Platycephalus fuscus*) is endemic to Australia, and its range is restricted to the east and south-east coastal regions. The species occurs throughout estuarine and coastal areas, ranging from ocean beaches, estuarine entrances to the Pacific Ocean, and estuaries to the limits of saline water (Bray, 2020). Pollock (2014) described characteristics of the annual spawning aggregation at the Jumpinpin Bar, an area where a large estuary meets the entrance to the Pacific Ocean. The present study examines gonad types and gametogenesis of adult dusky flathead which inhabit upper estuarine areas during the spawning period. The study aims to determine, by visual inspection of the gonads and by examining gonad tissues microscopically, whether this subpopulation in upper estuarine areas is capable of spawning. An understanding of the reproductive biology, including periodicity and spatial aspects of spawning aggregations, is of fundamental importance in the management of fish stocks (Morgan, 2008). In addition to the imperative to protect spawning aggregations, information on size at maturity, fecundity and parameters for population modelling is important for fishery management purposes (McPhee, 2008). Studies of the reproductive biology of wild populations of dusky flathead to date have examined populations with a focus on known spawning aggregations, spawning times and duration, oocyte development, egg quality, size and age at maturity, and fecundity (Gray & Barnes, 2008; Hicks et al., 2015; Pollock, 2014, 2019).

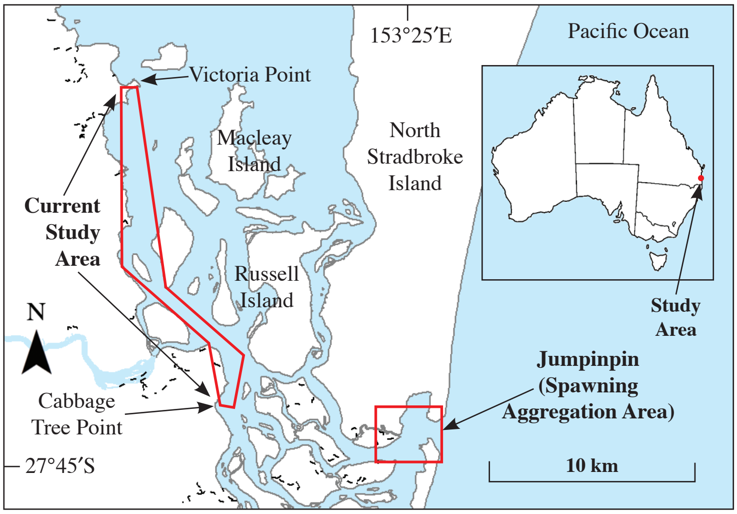
Dusky flathead have a protracted spawning period each year (austral summer, September to April), with spawning aggregations occurring at ocean/estuary interfaces (Gray & Barnes, 2008; Pollock, 2014). They are highly fecund, multiple-batch spawners, producing small planktonic eggs into oceanic waters (Taylor et al., 2020). After a short period of development and growth, the planktonic larvae settle in estuaries (Bell et al., 1987; Kingsford & Suthers, 1996), becoming benthic ambush predators (Baker & Sheaves, 1996). After settlement, dusky flathead show little latitudinal movement across different estuaries (O'Neill, 2000). The genetic study by Taylor et al. (2020) found that dusky flathead form a single stock across a large part of their distribution on the Australian east coast, where mixing most likely occurs during early life phases and through limited adult migration. Dusky flathead is not a densely schooling species. Spawning aggregations are characterised by many small associations of a single large female attended by several males. Bray (2020) provides video footage of this behaviour. Dusky flathead are rudimentary hermaphrodites with sex determined at the early juvenile stage (Pollock, 2014). Sexual dimorphism occurs with females growing to larger sizes. In the present study area, dusky flathead are most abundant at ages one year to five years, but may live to nine years (O'Neill, 2000).

Dusky flathead support popular recreational angling fisheries and commercial net fisheries throughout their range on the Australian east coast. The present study site and adjacent areas are prolific fishing grounds for dusky flathead (Webley et al., 2015; McGilvray et al., 2016). The dusky flathead fisheries are managed separately by three state fisheries agencies within their state boundaries (Queensland, New South Wales and Victoria). Routine stock assessments show that dusky flathead are currently sustainably fished (McGilvray et al., 2016). The current management arrangements for dusky flathead in all states include slot size limits (minimum and maximum size restrictions), bag or possession limits for recreational fishers, and effort controls and gear restrictions on commercial fishing. Information from the present study on the reproductive status of upper estuarine fish during the spawning period and a review of size at maturity estimates are relevant to the future management of this important species.

Materials and Methods

Monthly samples of dusky flathead were obtained by angling methods from upper estuarine areas between Cabbage Tree Point and Victoria Point (Figure 1) from September 2019 to April 2020.

Figure 1. Map showing the study area in upper estuaries and the spawning aggregation area at Jumpinpin (Pollock, 2014).



Fish in this sample (n = 101) ranged in size from 32 cm total length (TL) to 89 cm TL. Since the aim of this study was to determine the reproductive status of adult fish, those less than 40 cm TL, which are mostly immature (Pollock, 2014), were released alive without determining their sex. Three very large females exceeding 75 cm TL were also discarded to comply with Queensland fisheries regulations, requiring such fish to be released. As a result, the fish kept for detailed examination numbered 87, with a size range of 40 cm TL to 75 cm TL (Figure 2).

At capture, each retained fish was killed humanely by the participating citizen science angler in accordance with the Australian national recreational fishing code of practice (Department of Agriculture, Fisheries and Forestry, 2012). Each fish was then immediately supplied to the author for processing. Total length (TL) was recorded to the nearest 1 cm, and total weight to the nearest 5 g. Gonads were removed, photographed and weighed to the nearest 1 g. Gonad tissues, taken from the mid region of one gonad lobe, were fixed (10% neutral buffered formalin). The processed fish was then returned to the angler who caught it. A subsample of fixed tissues from 19 ovaries, including the different ovary types, and three testes were later selected for microscope slide preparations. The slides were prepared by wax embedding, microtome sectioning at 8 µm, and haematoxylin and eosin staining. The microscope slides were examined under magnifications up to 200. Gonosomatic index (GSI) was calculated for each fish (gonad weight/total body weight 100). All ovaries and testes were staged according to the criteria given in Table 1.

Figure 2. Size frequency and sex of all dusky flathead collected from upper estuarine areas during the spawning period, September 2019 to April 2020 (n = 101).

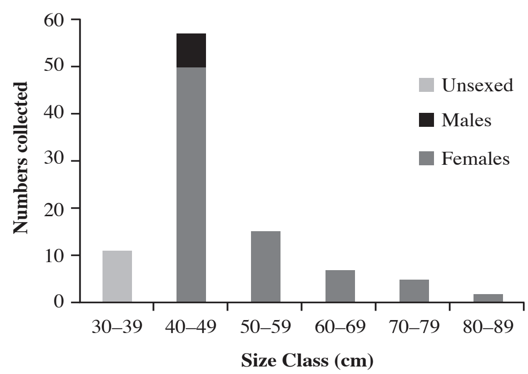


Table 1. Ovarian and testicular developmental stages of adult dusky flathead (*Platycephalus fuscus*) collected from upper estuarine areas during the spawning period. Modified from Bani et al. (2009) and Poortenaar et al. (2001).

Gonad type	Macroscopic appearance	Microscopic details
Unyolked (translucent) ovary	Ovary clear almost transparent. Colour variation from colourless, pale yellow, or red (Figure 3).	Small previtellogenic oocytes, most being degenerate with multiple large vacuoles in the oocyte cytoplasm (early mass oocyte atresia). Atresia to α stage in some oocytes showing disintegration of the nucleus and zona radiata, with only the follicle remaining in advanced stages (Figure 4).
Yolked (vitellogenic) ovary	Ovary yolky and larger than unyolked ovary. Yellow to red in colour. Vitellogenic oocytes observed through the ovary wall (Figure 5).	Previtellogenic and vitellogenic oocytes present, many being degenerate (mass atresia). Previtellogenic oocytes, same as for unyolked (translucent) ovary, with multiple large vacuoles in the oocyte cytoplasm, and others at α stage atresia. β stage atresia common in vitellogenic oocytes, composed of disorganised granulosa cells surrounded by a thin thecal layer (Figure 6).
Testes	Testes small in comparison to spawning aggregation males. Degenerate but producing small amounts of white seminal fluid when dissected (Figure 7).	Spermatozoa present at all stages of development.

Figure 3. Unyolked (translucent) ovaries of dusky flathead from upper estuarine areas showing colour variations: (A) Colourless translucent ovary of specimen collected in April, 61 cm TL; (B) Yellow translucent ovary of specimen collected in September, 54 cm TL; (C) Red translucent ovary of specimen collected in November, 74 cm TL.

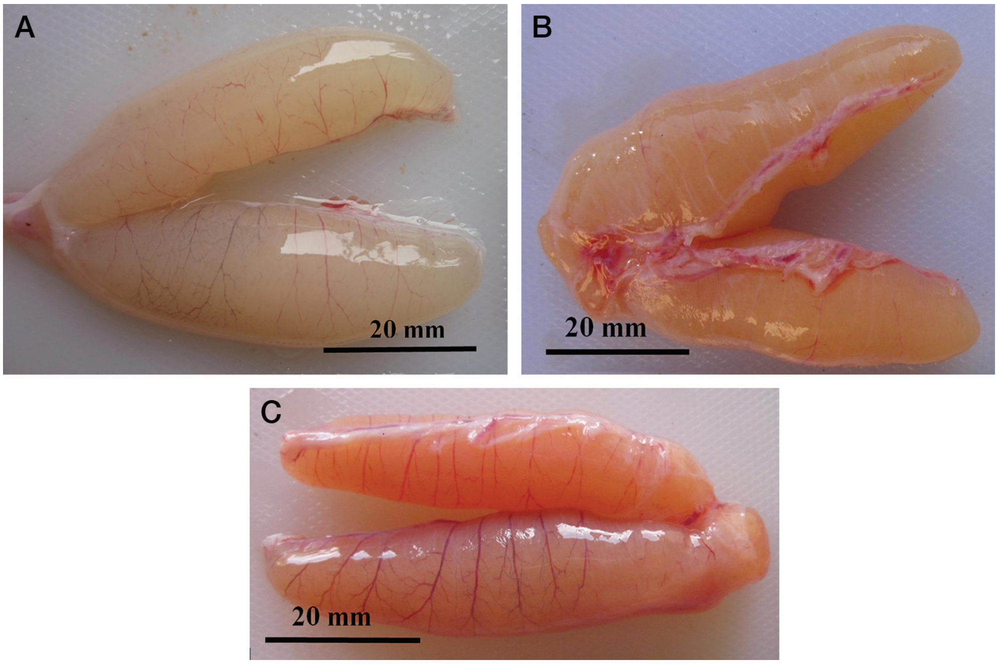


Figure 4. Microphotographs of unyolked (translucent) ovaries of dusky flathead taken from upper estuarine areas showing mass oocyte atresia: (A) Specimen collected in March, 65 cm TL; (B) Specimen collected in January, 75 cm TL. V – previtellogenic oocyte with numerous vacuoles in oocyte cytoplasm. αA – α atretic oocyte.

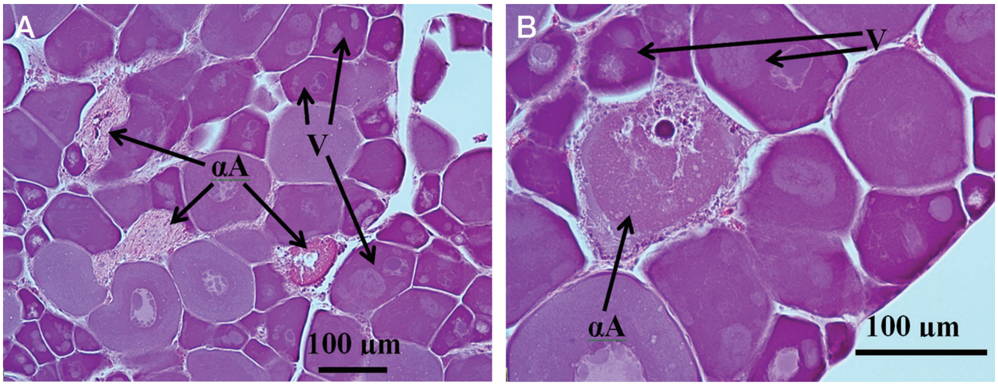


Figure 5. Yolked (vitellogenic) ovary of a dusky flathead taken from the upper estuarine area in November, 54 cm TL. Vitellogenic oocytes are visible through ovary wall.

Figure 6. Microphotographs of yolked (vitellogenic) ovaries of dusky flathead taken from upper estuarine areas showing mass oocyte atresia: (A) Specimen collected in April, 69 cm TL; (B) Specimen collected in November, 74 cm TL. VO – vitellogenic oocyte. V – previtellogenic oocyte with numerous vacuoles in oocyte cytoplasm. αA – α atretic oocyte. βA – β atretic oocyte.

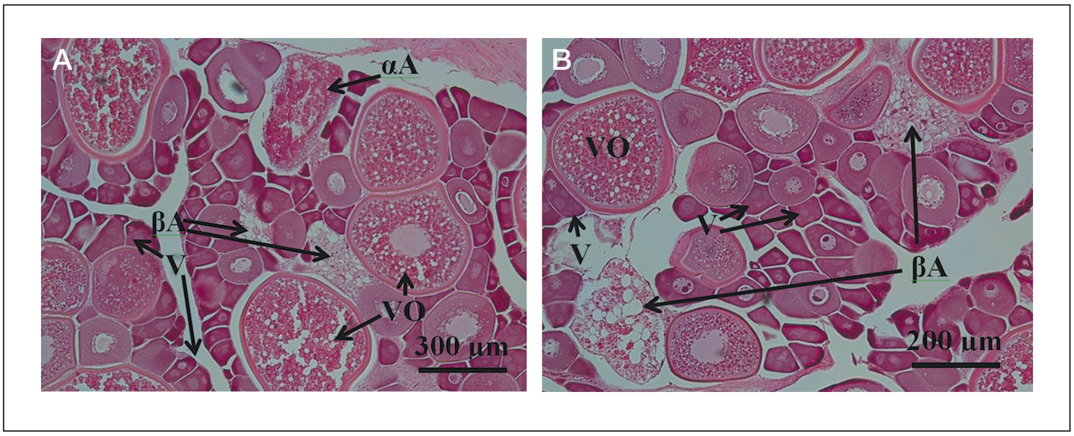
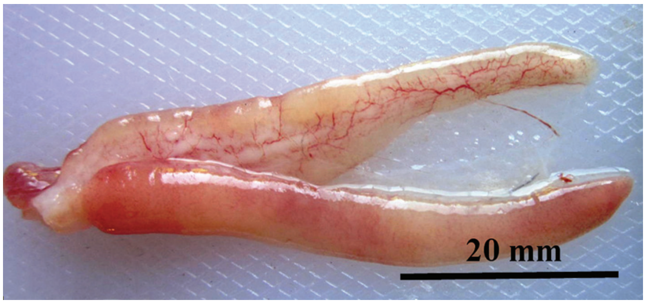


Figure 7. Testis of a dusky flathead which is small and degenerate. Specimen collected from upper estuarine area in December 2019, 41 cm TL.



Results

The sample of dusky flathead for detailed examination was dominated by female fish (females = 80, males = 7; Figure 8). The sampling period was from September to April and corresponded with the annual spawning period in southern Queensland. Male fish were relatively small (40 cm TL to 49 cm TL). Female fish were present in all size classes (40 cm TL to 75 cm TL), but more common in the smaller sizes (Figure 8). Staging of gonads showed all males possessed degenerate testes. Male GSI was small throughout the sample (GSI = 0.52 ± 0.06. Mean ± 1SE, n = 7). Small amounts of white seminal fluid were released during dissections of testes from the fish. Staging of ovaries (Figure 8) established that the unyolked (translucent) type was numerically dominant and occurred in all size classes, including the large size classes, 55 cm TL to 75 cm TL. Yolked (vitellogenic) ovaries were less common but also occurred in all size classes except for the 55 cm TL to 59 cm TL group, which is most likely due to the small sample size. Mean GSI values for females were relatively low throughout the spawning period (Figure 9). In September–October, GSI variability was greatest, indicating variations in ovary size during early development at the commencement of the spawning period. Mean GSI for females from November to April ranged from 1.0 to 1.4, and GSI showed less variability during this period (Figure 9), indicating less variation in ovary development later in the spawning period.

Figure 8. Ovarian stages of size classes of dusky flathead taken from upper estuarine areas during the spawning period, September 2019 to April 2020 (n = 80).

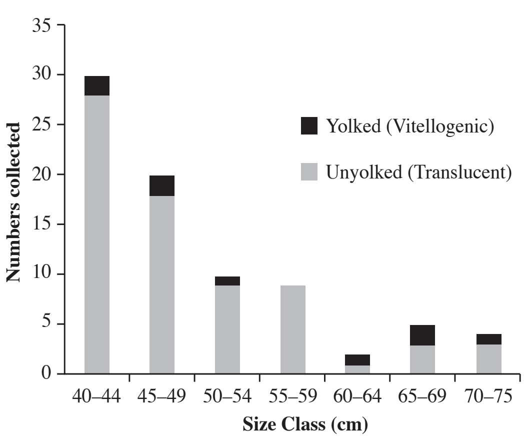
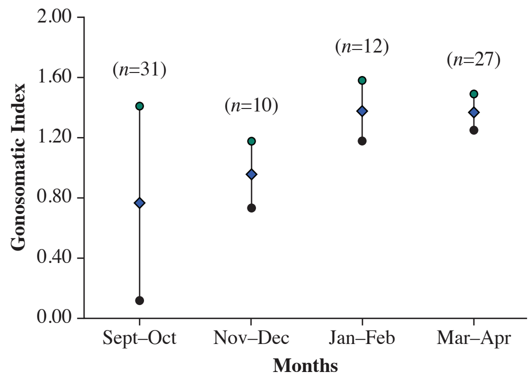
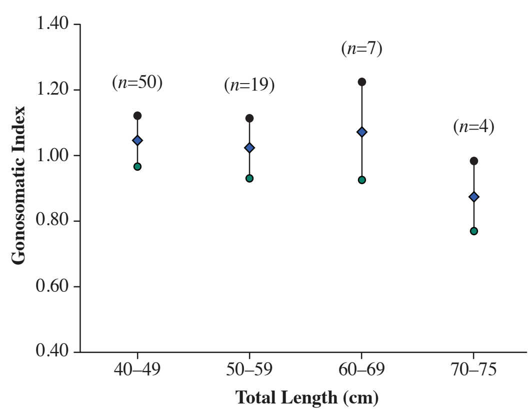


Figure 9. Bimonthly gonosomatic index values (mean ± 1SE) of female dusky flathead taken from upper estuarine areas during the spawning period, September 2019 to April 2020.



Mean GSI values for females were relatively stable with little variability across size classes (Figure 10), which is an indication of similar levels of ovarian development in females of different size classes.

Figure 10. Gonosomatic index values (mean ± 1SE) of size classes of female dusky flathead taken from upper estuarine areas during the spawning period, September 2019 to April 2020.



Microscopic examinations of oocytes revealed similarities and differences in the two ovarian stages. The unyolked (translucent) ovaries were dominated by previtellogenic oocytes at an early stage of mass oocyte atresia, namely multiple irregular vacuoles in the oocyte cytoplasm (Figure 4). Also present, but less common, were α atretic oocytes. The yolked (vitellogenic) ovaries had previtellogenic oocytes at the early stage of atresia (multiple large vacuoles), and α atretic oocytes, similar to unyolked (translucent) ovaries. However, vitellogenic oocytes were also common, many at β stage atresia. Mass oocyte atresia was also occurring in all yolked (vitellogenic) ovaries. Macroscopic and microscopic examinations of the ovaries from upper estuarine female dusky flathead revealed that ripe and running ripe individuals were absent during the spawning period (September to April).

Discussion

Sampling Methodology and Study Area Characteristics

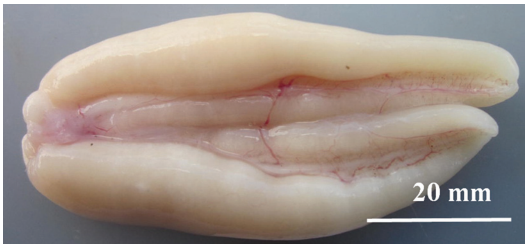
In the present study dusky flathead were obtained from upper estuarine areas by citizen science recreational fishers, using hook-and-line angling methods. The author was present at all times during the collection of samples, enabling data to be obtained from recently caught fish, quality photographs to be taken of fresh gonads from all retained fish, and fixation of good-quality tissue biopsies of gonads for subsequent histological processing. The author was also able to ensure that all dusky flathead were treated humanely when released alive or when killing was necessary.

The study location for collection of dusky flathead within upper estuarine areas is 10 km to 20 km distant from the closest spawning aggregation site, the Jumpinpin estuary/oceanic interface (Figure 1). Water quality characteristics vary considerably between the two sites. Most notably, turbidity is higher, and temperature and salinity are more variable in the upper estuarine sites (Blaber & Blaber, 1980; Abal & Dennison, 1996). The present study location is also influenced by summer rain events and is occasionally subject to flooding. The larval stages of dusky flathead are sensitive to water quality, especially salinity (Pham et al., 1998).

Gonad Staging of Dusky Flathead from Upper Estuarine Areas

Male dusky flathead in the upper estuarine areas during the spawning period are all mature, releasing seminal fluid from freshly dissected testes. However, the testes are small and degenerate with very low GSI values (GSI = 0.52 ± 0.06. Mean ± 1SE). Given the poor condition of testes of males from the upper estuarine areas, it is unlikely that they are capable of spawning during the reproductive period. In comparison, spawning aggregation males have large testes in good condition (Figure 11) and much higher GSI values with monthly means ranging from 1.5 to 1.9 (Pollock, 2014). The sex ratio of dusky flathead in upper estuarine areas during the spawning period is dominated by females (11.4 to 1). Within the Jumpinpin spawning aggregation during the spawning period, the proportion of females to males is approximately equal (Pollock, 2014). This is an indication that the males are more likely to participate in spawning aggregations.

Figure 11. Testis from a running ripe male dusky flathead collected in the study by Pollock (2014) from the spawning aggregation at the Jumpinpin estuarine/oceanic interface in January, 44 cm TL.



Ovaries at two stages of development are present in female fish of all size classes in the upper estuarine areas during the spawning period: unyolked (translucent) ovaries and yolked (vitellogenic) ovaries. In both ovary types, mass oocyte atresia is occurring. The common occurrence of atresia in previtellogenic oocytes, with large irregular vacuoles in the oocyte cytoplasm and fewer α atretic oocytes, is unusual (Figure 4). There are few reports of previtellogenic oocyte atresia in other species of fish, showing multiple irregular vacuoles within the oocytes (Miranda et al., 1999). Oocyte atresia commonly commences at the vitellogenic oocyte stage in other species of fish (Roe Hunter & Macewicz, 1985; Lubers et al., 2010). Mass oocyte atresia was not observed in spawning aggregation dusky flathead smaller than 70 cm TL (Pollock, 2014). However, degenerate ovaries with mass oocyte atresia are present in approximately half of the very large females examined in spawning aggregations at estuarine/oceanic interface areas during the spawning period (Pollock, 2014, 2019). Mean bimonthly GSI values for upper estuarine female dusky flathead during the spawning period ranged from 0.9 to 1.4 (Figure 9). In comparison, mean monthly values of GSI for spawning aggregation females are much higher, 3.3 to 4.5 (Pollock, 2014). Mass oocyte atresia has been reported in many wild populations of fish (Rideout et al., 2005) and is attributed mainly to poor nutrition (Rideout & Tomkeiwicz, 2011).

Ovaries of immature dusky flathead within spawning aggregation sites are unyolked (translucent). Microscopic examination of these immature ovaries shows that previtellogenic oocytes are present in good condition (Pollock, 2014, 2019). These immature dusky flathead have clear oocyte cytoplasm, lacking multiple vacuoles which commonly occur in previtellogenic oocytes of the two ovarian stages of upper estuarine fish. In addition, oocyte atresia is rare in immature dusky flathead at the spawning aggregation sites (Pollock, 2019). It was not possible to distinguish immature from mature dusky flathead females with previtellogenic (translucent) ovaries taken in upper estuarine areas in the present study. At the Jumpinpin spawning aggregation area, immature dusky flathead of both sexes are present in low frequencies during the spawning period. The proportion of immature females is approximately 10% of all females in the 40 cm TL to 50 cm TL size classes at the spawning aggregation area (Pollock, 2014). In these size classes at Jumpinpin, mature females dominate abundance. It is expected that immature females may also be present in small numbers at upper estuarine areas during the spawning period in the size class range 40 cm TL to 50 cm TL. This size class contains females from ages 1+ to 5+ (Gray & Barnes, 2008), and therefore this size class in upper estuarine areas is expected to contain mature females which skipped their first spawning and mature females that had spawned in previous years, as well as a small proportion of immature females.

O'Neill (2000) staged dusky flathead gonads in samples taken 100 km to 300 km to the north of the present study site, with the aim of determining reproductive status throughout the year. The resulting stages for adult female dusky flathead, based on macroscopic examination alone, were limited to two categories: Stage 2 (resting/recovering), which matches the unyolked (translucent) ovary classification in the present study, and Stage 3 (developing) which matches the yolked (vitellogenic) ovary classification of the present study. No ripe or running ripe dusky flathead, indicative of estuarine entrance spawning aggregation fish, were reported in that study. The results obtained by O'Neill (2000) for ovary stages are similar to the findings of the present study, indicating that samples in that study were obtained from upper estuarine areas.

Spawning Strategies

The present study shows that female dusky flathead in upper estuarine areas are not spawning in those areas during the spawning period. Non-spawning mature dusky flathead in poor reproductive condition, both males and females, in upper estuarine areas may provide a reservoir of potential spawners in subsequent years as condition and energy reserves improve. This reproductive strategy, involving a large subpopulation of mature fish not participating in an annual spawning aggregation, occurs in other teleost species. Examples of this from the Australian east coast are yellowfin bream (*Acanthopagrus australis*) (Pollock, 1984) and sea mullet (*Mugil cephalus*) (Stewart et al., 2017).

The spawning of dusky flathead close to oceanic waters at the entrance to estuaries in preference to upper estuarine areas is most likely an adaptation to ensure maximum survival and dispersal of the early life stages. Several other teleost fish of importance to fisheries on the Australian east coast have similar reproductive strategies. Examples are the yellowfin bream (*Acanthopagrus australis*), tailor (*Pomatomus saltatrix*) and sea mullet (*Mugil cephalus*) which all have seasonal spawning aggregations at coastal oceanic locations or at the estuarine/oceanic interface, planktonic early life stages in oceanic waters, and postlarval settlement in inshore waters, estuaries or streams, dependent on the strategy of the particular species (Pollock et al., 1983; Zeller et al., 1996; Stewart et al., 2017).

Subpopulation Mixing of Upper Estuarine Fish with Estuarine/Oceanic Interface Spawners

The degree of mixing of the subpopulation of dusky flathead from upper estuarine areas with the subpopulation from the estuarine entrance spawning aggregation was not directly investigated in the present study. Tagging studies of dusky flathead within estuaries (O'Neill, 2000; Gray & Barnes,

2015) found that of the fish recaptured, more than 90% were taken in the same estuary. However, in these studies, information on the sex of the recaptured fish and details of movements within the estuary were not recorded. Within an annual spawning period, mixing of the two subpopulations is unlikely, based on the major differences in gonad morphology and oocyte differences established in this study and Pollock (2014). In the case of males, the degenerate testes of upper estuarine fish would need to undergo rapid development to achieve the condition of testes of the spawning aggregation fish during the annual spawning period. Such a major change of the degenerate testes is unlikely. Males in the estuarine entrance spawning aggregation all have testes in good condition, and it is also unlikely that males in this subpopulation would undergo rapid testicular degeneration and move to upper estuarine areas in a given spawning period.

In the case of female dusky flathead, a change from small ovaries with mass oocyte atresia associated with the upper estuarine areas to reproductive condition of ovaries of spawning aggregation fish (ripe and running ripe) within a given spawning period again seems unlikely. Similarly, change in the advanced ovaries of spawning aggregation fish to small degenerate ovaries with mass oocyte atresia within a given spawning period is not expected. Mixing of the two subpopulations from one spawning period to the next has also not been determined but is expected to occur. The strategy in dusky flathead of having part of the adult population as a discrete spawning subpopulation at an estuarine/oceanic interface and another subpopulation in non-spawning condition in alternative feeding grounds in the upper estuarine areas in a given year is possibly an adaptive mechanism. This adaptation could act to balance reproductive output and adult population survival in a species which has several potential spawning age classes.

The present study has examined adult dusky flathead in the upper estuarine areas which are 10 km to 20 km from the nearest spawning aggregation site. Marked differences in gonad and oocyte condition have been identified when comparing fish from the two different sites. A topic for further research is the reproductive status of dusky flathead between the two extremes – between the upper estuaries and the estuarine/oceanic interface spawning aggregation sites. An understanding of mixing and boundaries between the two subpopulations over time would be an important addition to understanding the reproductive biology of this species.

Size at Maturity Estimates for Dusky Flathead – An Update

Information on size at maturity is important for fishery management purposes. It is often used to determine minimum sizes or lower slot limits, as well as being a parameter for population modelling. It is also important in estimating fecundity. There are several ways to estimate size at maturity, but a common method is to determine the size at which a given proportion of the population reaches maturity (Tripple & Harvey, 1991). Gray & Barnes (2008) estimated the mean length at maturity (L_{50}), the length at which half of the population is mature, for male (32 cm TL) and female (57 cm TL) dusky flathead in New South Wales. Hicks et al. (2015) determined L_{50} for female dusky flathead in Victoria (33 cm TL) and noted the large difference in comparison to the Gray & Barnes (2008) estimate. The L_{50} estimate by Gray & Barnes (2008) uses Stage I (ovaries appear as small clear threads) and Stage II (ovaries appear as clear lobes) to determine immature female dusky flathead during the spawning period. The sample in that study included dusky flathead from all areas, including fish from upper estuarine areas as well as those close to spawning aggregation sites. Gonad staging was carried out without microscopic examinations to determine the developmental stage of oocytes. The use of macroscopic examination to stage gonads with either no complementary microscopic comparisons or limited microscopic examination can lead to errors in gonad staging (West, 1990). Female dusky flathead classified as immature (Stage II with clear lobed ovaries) by Gray & Barnes (2008) are expected to include mature non-spawning females from upper estuarine areas. The result is that a large proportion of mature female fish, which dominate the unyolked (translucent) stage in upper estuarine areas, were excluded from the calculation of L_{50} because they were classified as immature by Gray & Barnes (2008). The present study shows that mature females with unyolked (translucent) ovaries occur in all size classes but are most common in smaller size classes (Figure 8). The estimate of female size at maturity of 57 cm would be lower if mature females in the upper estuarine areas were correctly staged. The calculation of L_{50} for female dusky flathead in the present study was not possible because immature and mature females could not be separated, both possessing unyolked (translucent) ovaries. L_{50} for spawning aggregation fish was not determined in the previous study (Pollock, 2014). However, from the graph of length–frequency of mature male and female dusky flathead within the spawning aggregation in Pollock (2014), abundance of mature fish peaks at 35 cm TL to 39 cm TL for males and 40 cm TL to 49 cm TL for females. L_{50} is expected to occur in slightly smaller size classes in comparison to the peak abundance of mature fish. Therefore, based on qualitative examination of Figure 3 in Pollock (2014), an approximation of 30 cm to 34 cm TL for males and 35 cm to 39 cm TL for females is estimated for L_{50}. This L_{50} value for females is similar to the estimate by Hicks et al. (2015) of 33 cm TL, but much smaller than that by Gray & Barnes (2008) of 57 cm TL. In the subsequent paper, Gray & Barnes (2015) added details of a microscopic examination of ovaries, but information on the source of the tissue samples and a thorough examination detailing macroscopic and microscopic features of all gonad types are not provided. Gonad staging results given in the subsequent paper (Gray & Barnes, 2015) are identical to those given without microscopic examination (Gray & Barnes, 2008). In the case of male dusky flathead, mature fish in the upper estuarine areas can be identified by the macroscopic examination of testes because these males have small white (degenerate) testes (Figure 7). The estimates of L_{50} for male fish are similar in the two studies: 32 cm TL (Gray & Barnes, 2008), compared to 30 cm TL to 34 cm TL (Pollock, 2014).

Acknowledgements

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Author Profile

Barry Pollock is the voluntary Scientific Officer of Sunfish, a peak body for recreational fishing in Queensland advocating responsible fishing practices and sustainable fish stocks. He was raised at Redcliffe on the shores of Moreton Bay. After high school he was awarded an undergraduate Commonwealth scholarship to attend The University of Queensland, and has degrees to doctorate level in zoology and fisheries science. He held senior positions in fisheries agencies: Deputy Director, Pacific Islands Forum Fisheries Agency (2000–2004); General Manager, Fisheries Resource Management; and Director, Fisheries Branch, Queensland Department of Primary Industries (1989–2000). His research interests are Queensland's coastal finfish fisheries. Since retirement he has been appointed to several Queensland Government fisheries advisory bodies.