4 REPRODUCTION

4.1 *Lethrinus* spp.

4.1.1 Sexuality

Examination of the size/sex relationships, gonad structure and histology of eight species of Lethrinidae (*L. nematacanthus* (= *genivittatus*), *L. choerorhyncus*, *L. lentjan*, *L. variegatus* (= *Lethrinus* sp.2), *L. rubrioperculatus*, *L. chrysostomus* (= *L. miniatus*), *L. nebulosus* and *L. fraenatus* (= *L. laticaudis*)) from the North-West Shelf and Gulf of Carpentaria led Young and Martin (1982) to conclude that **protogynous hermaphroditism** is the typical mode of sexuality in lethrinids:

> A linear relationship between size and sex ratio, in which females predominate at smaller sizes and males at larger sizes, was demonstrated for the five species for which sufficient data was available. All five of these species showed considerable overlap in the size distribution of the sexes but there was no evidence for the occurrence of primary males in the populations sampled. The testes of all species examined showed typical 'secondary male' morphology and the presence of atretic ovarian material ('brown bodies'). Individuals with intersex gonads were observed in five species.' (Young and Martin 1982).

Unfortunately Young and Martin had access to only eight *L. miniatus*. They did, however, observe small crypts of gonia adjacent to the germinal epithelium in mature ovaries of this species and some gonads exhibited proliferation of spermatogonia from these crypts concomitant with cellular infiltration and degeneration of oocytes. Ferreira (pers. comm.) and Brown (pers. comm.) have demonstrated a predominance of females in small size classes of *L. miniatus* from the GBR. Ferreira has observed intersex gonads in this species. Loubens (1980b) found size-related bias in sex ratios in *L. miniatus* and concluded that this may be due to sequential hermaphroditism. Tony Church (pers. comm.) has confirmed protogynous hermaphroditism in the Norfolk Island population of *L. miniatus*.

Interestingly Young and Martin (1982) could not demonstrate a linear relationship between sex ratio and length in *L. nebulosus* like they could in the other species. Larger samples (approximately 300 individuals) from North-Western Australia have confirmed the lack of any clear relationship between sex and size in *L. nebulosus* in that region (M.Moran, pers. comm.). Geoff McPherson (pers. comm.) has confirmed from histological studies that *L. nebulosus* is a protogynous hermaphrodite on the northern GBR. Working on *L. nebulosus* from Okinawa, Ebisawa (1990) described ovarian development based on histology. He suggests that *L. nebulosus* is a juvenile hermaphrodite with sex being determined at 24 to 30cm FL but the fish not maturing until approximately >40cm FL.

As pointed out by Young and Martin (1982), the mechanisms controlling sex change are not known in any of the lethrinids.

4.1.2 Size and Age at Maturity

Minimum size and age at maturity and size and age at which 50% of each sex are mature have been determined for five lethrinids in New Caledonia by Loubens (1980b) (Table 7). Walker (1975) concluded that *L. miniatus* were mature at 3 years (35cm SL) and could be mature at 2 years (31cm SL), that *L. nebulosus* matured at 28cm SL, *L. semicinctus* (=*L. reticulatus*) at approximately 19cm SL and *Lethrinus* sp.2 (= variegatus) 22cm SL). These estimates of size at first maturity for *L. miniatus* and *L. nebulosus* are below the current legal minimum sizes of

30cmTL (see Section 12). Ebisawa (1990) found that *L. nebulosus* in Okinawa matured at approximately 40cm FL.

4.1.3 Seasonality

On the basis of gonado-somatic-indices (GSI's) and maximum ova diameters, Walker (1975) concluded that reproduction of *L. miniatus* in the central GBR (off Townsville) peaked in July-August, the coldest months of the year. Based on smaller numbers of fish, reproductive activity of *L. nebulosus* peaked in June to July, *L. semicinctus* in December-January and *Lethrinus* sp.2 in September-October (Walker 1975). McPherson et al. (1988) reported monthly GSI's of *L. nebulosus* 'between about May and October'. In New Caledonia GSI's of *L. nebulosus* peaked in August and September and of *Lethrinus* sp.2 in December and January (Loubens 1980b).

4.1.4 Spawning

Little published data is available on whether lethrinids are serial or annual spawners. Nor is data available on time of day or behaviour during spawning. Ebisawa (1990) determined that - *L. nebulosus* in Okinawa is a serial spawner.

4.1.5 Fecundity

No data available.

4.2 *Lutjanus* spp.

4.2.1 Sexuality

Unlike *Lethrinus* and *Plectropomus* spp., lutjanids in general appear to be **gonochoristic** i.e. following sexual differentiation, sex remains fixed throughout life (Grimes 1987). Population sex ratios as well as sex ratio at size is frequently skewed. However, this appears to result from differential growth and mortality rates between sexes, rather than hermaphroditism. Growth of male and female *L. sebae* and *L. malabaricus* on the northern GBR, for example, differ in the older year classes with males being the larger (McPherson et al. 1988).

4.2.2 Size and Age at Maturity

Sexual maturity in lutjanids generally occurs at approximately 40 - 50% of maximum length (Grimes 1987). Druzhinin (1970) reports male and female *L. johnii* from the Andaman Sea as reaching maturity at 30.1 and 29.1cm LCF respectively. Age of both sexes is given as 2 years. Lim et al. (1985) indicate considerably larger and older sizes at maturity for the same species in Singapore: females attain maturity at the age of about 3 to 4 years (3.5 to 4.5kg), while males mature at about 2.5 to 3 years (2.3 to 3.0kg).

Talbot (1960) gives the following lengths at maturity for the larger species of lutjanid in East Africa: *L. bohar* 45cm (6 to 7 years), *L. sebae* 49cm SL, *L. argentimaculatus* 35cm. Further sizes and ages at maturity for the smaller species of lutjanid are given in Talbot (1960) and Loubens (1980a).

Allen (1985) gives the following (unsourced) estimates of size (Total Length) at maturity in *Lutjanus*: *L. adettii* 20 to 30cm; *L. bohar* 50 to 55cm; *L. ehrenbergi* approx. 12cm; *L. fulviflamma* 20 to 25cm; *L. fulvus* 20 to 30cm; *L. gibbus* 30cm; *L. kasmira* 20-25cm; *L. lutjanus* 12cm; *L. rivulatus* 50cm; *L. vitta* 20cm.

4.2.3 Seasonality

Raised monthly gonad indices of *L. sebae* and *L. malabaricus* females from September to January indicate that these species reach peak reproductive activity [on the northern GBR] during the spring and summer months' (McPherson et al. 1988). Reproductive activity of the smaller lutjanids, *L. fulviflamma*, *L. quinquelineatus* and *L. vitta*, in New Caledonia peaks in November to January (Loubens 1980).

4.2.4 Spawning

Distributions of egg diameters provides consistent evidence that lutjanids in general are serial or batch spawners (Grimes 1987). This has been verified for at least *L. vitta* on the North West Shelf (T. Davis pers. comm.). Egg diameters of *L. johnii* are also clearly polymodal (Anon 1975). The number of batches of eggs produced each spawning season under natural conditions has not been evaluated for any lutjanid species (Grimes 1987).

4.2.5 Fecundity

Lutjanids are highly fecund with large females (approximately 100cm TL) producing up to at least 5 to 7 million eggs per season (Grimes 1987).

4.3 *Plectropomus* spp.

4.3.1 Sexuality

All serranids that have been closely studied have proven to be **protogynous hermaphrodites** (Shapiro 1987). *P. leopardus* is the only *Plectropomus* spp. whose reproductive biology has been examined closely and, as expected, it proves to be a protogynous hermaphrodite (Goeden 1978). It has been confirmed recently that *P. maculatus* is also a protogynous hermaphrodite (Ferreira and Russ, MS). It is likely that the other species will prove similar.

4.3.2 Size and Age at Maturity

The smallest mature female *P. leopardus* found by Goeden (1978) was 205mm SL. *All* mature females were estimated to be 2 to 4 years old (except one that was 4 or older). The smallest mature male was 303mm SL and estimated to be 3 years old. Goeden thought that sex reversal generally occurred when fish were 3 or 4 years old. The Heron Island population examined by Goeden had a strong sex ratio bias overall (2.9 females for every male) and a strong bias in sex-ratio with age. All 2 y.o. fish were believed to be females, 93% of fish in their sixth year to be male.

Ferreira and Russ (MS) suggested that age at first reproduction of *P. maculatus* may be 2 years (around 25cmTL). Age at sex change appeared to be variable with females as old as 7 years and males as young as 3 years.

4.3.3 Seasonality

Spawning of *P. leopardus* at Heron Island occurred in November-December (Goeden 1978). Based on GSI's, September to November appear to be the months of peak reproductive activity of this species on the northern GBR (McPherson et al. 1988). Johannes and Squire (1988) report that spawning aggregations of *P. laevis* occur from September to January. Timing of these aggregations is site-specific and may vary by one month from year-to-year and gets progressively later the further north the location.

4.3.4 Spawning

Goeden (1978) believes *P. leopardus* to be a serial spawner. 'Courtship' behaviour of this species is described in Goeden (1978) and the spawning aggregations of this and other species of *Plectropomus* are described in Johannes and Squire (1988) and referred to elsewhere in this report. Spawning appears to be concentrated around the new moon (Samoilys and Squire unpubl. data).

4.3.5 Fecundity

Goeden (1978) determined the following equation for the relationship between total number of eggs and the standard length of *P. leopardus*:

$$\text{Log}_{10} \text{ Total Eggs} = 3.712 + 0.0046 \text{ SL (mm)}.$$

4.4 Hermaphroditism and the Effects of Fishing

Management of a fishery is considerably complicated by the presence of sequential hermaphrodites such as *Lethrinus* and *Plectropomus* spp.. This is particularly so when the mechanism of sex-change is unknown (e.g. Young and Martin 1982, Munro and Williams 1985) as it is for the GBR species. One scenario is that if these species only turn into males at a certain large size or age, heavy fishing may seriously limit the number of males in the population with potentially disastrous results. An entirely different scenario is that sex-change may be socially controlled and the removal of males from the population simply causes a female to change sex at a smaller size and earlier age. The reality is unlikely to be as simple as either scenario and the effects of fishing are likely to be much more difficult to predict.

Bannerot et al. (1987) have recently modelled the consequences of protogynous hermaphroditism and gonochorism on fisheries management of groupers (Serranidae) and snappers (Lutjanidae) in the Caribbean. They conclude that:

> Generally, there are parametric regions where hermaphroditism is more resilient to exploitation than is gonochorism; this parametric space is increased if hermaphrodites exercise some social behaviour during spawning which decreases randomness in gamete encounters'. (Bannerot et al. 1987).

These authors point out that, in particular, there is a definite risk if grouper populations are managed strictly by Yield-per-Recruit models at high fishing mortality and in the absence of knowledge about population compensation mechanisms for sperm limitation.

Bannerot et al.'s comments are particularly relevant to management of coral trout and lethrinids:

> Populations under exploitation should be monitored to deduce whether or not a significant proportion of eggs go unfertilised as...[fishing]...mortality increases, and to follow any change in population sex ratio over a range of exploitation levels. Specific research is needed to characterise population compensatory mechanisms for avoiding sperm limitation, and to determine the time required for hermaphroditic individuals to change sex and the range of sizes capable of changing sex. In addition to these parameters, studies of mating strategies, as indicated by spawning behaviour and gonad condition over time, would be valuable for making inferences about potential fishing-induced disruption of spawning. Until field data show otherwise, the predictions of both static and dynamic models indicate that the management decision environment [sic!] of exploited ...[hermaphroditic]... populations should be conservative'. (Bannerot et al. 1987).

4.5 Studies in Progress

(i) McPherson, Squire, O'Brien and colleagues from the Northern Fisheries Research Centre (NFRC QDPI) in Cairns have been involved in reproductive studies within the Demersal Reef Fish Project of NFRC. They have examined gonad material from 9 species of lutjanid, 15 serranids 9 lethrinids plus *Diagramma pictum* and *Choerodon schoenlieni.* A paper has been submitted on the reproductive biology of *Lutjanus sebae, L. malabaricus* and *L. erythropterus* (Asian Fisheries Science).

(ii) A joint QDPI-JCU-AIMS project entitled 'Growth, reproductive strategies and recruitment of the dominant demersal food fish species on the Great Barrier Reef' is presently being funded by FIRDC. The project is coordinated by Ian Brown (QDPI-Deception Bay) and aims to examine reproductive biology (as well as age and growth) of *Plectropomus leopardus* and *Lethrinis miniatus* in the northern, central and southern GBR.

(iii) Beatrice Ferreira (JCU) is carrying out a PhD project on reproductive biology (as well as age and growth) of *Plectropomus* (3 spp.), *Lethrinus miniatus* and *L. nebulosus*, principally in the Townsville and Lizard Is. areas of the GBR (in collaboration with (ii)).

(iv) Studies of the reproductive biology of a wide range of *Lutjanus* spp. (excluding the three 'reds' in (a) above) is being carried out by Stephen Newman and Marcus Sheaves (both PhD students) at AIMS.

(v) An MSc (Qual.) project on reproductive biology (and age and growth) of several of the smaller species of *Lethrinus* by P. Laycock will begin at JCU (Marine Biology) in 1992.

Table 7. Age and size at maturity of lethrinids in the New Caledonia lagoon. l_m and a_m = minimum length and age at maturity. L_m and A_m = length and age at which 50% of the population is mature. Lengths in mm, ages in years (from Loubens 1980a,b). *L. olivaceus* was published as *L. miniatus*, *L. atkinsoni* as *L. mahsena*, *Lethrinus* sp. 2 as *L. variegatus*.

Species	Sex	l_m	L_m	a_m	A_m
L. olivaceus	M	352	370	5.1	6
	F	340		4.1	
L. lentjan	M	190	200	2.7	3.5
	F	181		2.0	
L. atkinsoni	M	233		3.7	
	F	282		5.0	
L. nebulosus	M	355	420	6.0	8
	F	408	450	7.0	9
Lethrinus sp.2	M	202	210	1.8	2.5
	F	175		1.8	