Asian Fisheries Science 6(1993):169-182.
Asian Fisheries Society, Manila, Philippines

https://doi.org/10.33997/j.afs.1993.6.2.005

Reproductive Biology of the Narrow Barred Spanish Mackerel (*Scomberomorus commerson* Lacépède, 1800) in Queensland Waters

G.R. McPHERSON

Northern Fisheries Centre
Queensland Department of Primary Industries
P.O. Box 5396
Cairns, 4870
North Queensland, Australia

Abstract

The minimum length at maturity and spawning of female *Scomberomorus commerson* in Queensland waters was 79 cm fork length. A reproductive peak oc-curred in October and November in Queensland east coast waters. Spawning occurred in the late afternoon. Estimates of population spawning frequency during the peak reproductive period varied from every 2 to 6 days, although daily spawning could occur for some fish.

Introduction

Munro (1942) indicated that spawning activity of *Scomberomorus commerson* occurred in Barrier Reef waters between Gladstone and Cooktown over a latitudinal range of 7°. The main concentration of spawning of *S. commerson* was identified as occurring near reefs northeast of Townsville (latitude 19°S). Commercial and recreational fishers identify *S. commerson* spawning reefs on the east coast between Townsville and Cairns (McPherson 1985). These reefs are situated at the inner edge of the Barrier Reef adjacent to the lagoon area that separates the reef from the coast (McPherson 1981).

The existence of two stocks *S. commerson* in Queensland waters has been proposed (Anon. 1978; Shaklee et al. 1990). Fish southeast of Torres Strait form an east coast stock, while those in

the Torres Strait and Gulf of Carpentaria are part of a northern stock that extends from the southern Gulf of Papua to the western part of the Australian continent (Fig. 1). McPherson (1992a) demonstrated differences in length-at-age and the length-weight relationship between the east coast and the northern coast stocks of *S. commerson*.

The broad objective of this study was to investigate the reproductive biology of *S. commerson*, and specifically to: 1) estimate the time of spawning of the species, and 2) evaluate the application of the hydrated oocyte and postovulatory follicle methods (reviewed by Hunter and Macewicz 1985) to identify areas and periods of peak spawning intensity.

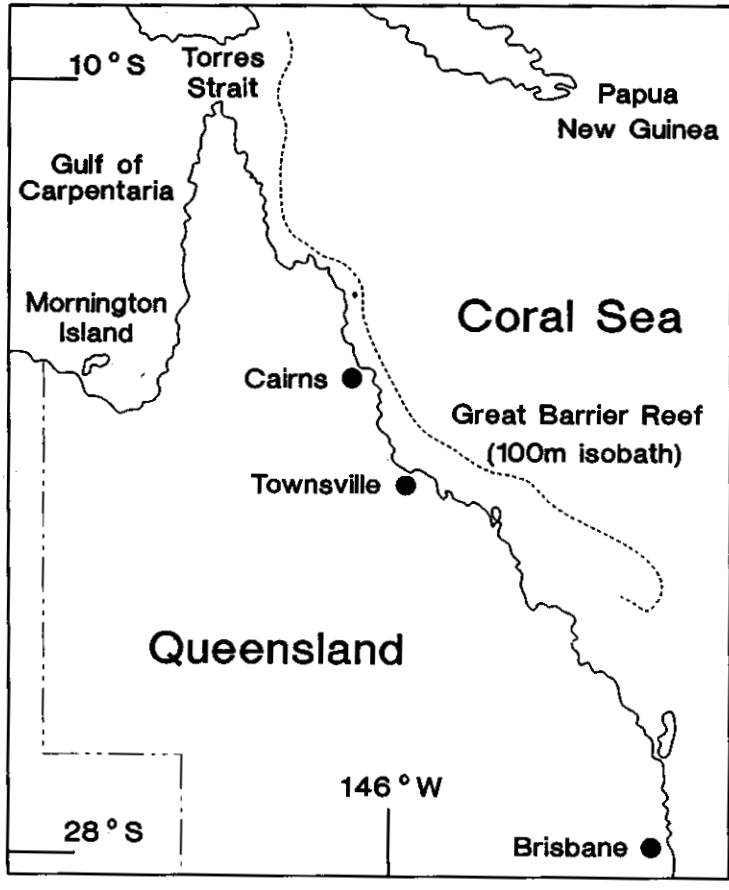

Fig. 1. Sampling areas of *S. commerson*.

Materials and Methods

The fork length (FL) of *S. commerson* was measured to the nearest cm and the total weight taken to the nearest 0.1 kg. Ovaries were sampled from commercial troll fishing vessels and weighed to the nearest 5 g. Ovaries were macroscopically staged using the 9-element scheme described for yellowfin tuna (*Thunnus albacares*) (McPherson 1992b).

Samples obtained for histological analysis were preserved in 10% formalin, embedded in paraffin wax and sectioned at 6 μm. A minimum of three consecutive sections were cut and stained with Harris' hematoxylin and eosin. Oocytes were histologically categorized using the 11-element schematic description for yellowfin tuna oocytes (McPherson 1991). Gonadosomatic indices (GSI) were calculated as ovary weight divided by total weight and multiplied by 10^4.

East coast stock fish were sampled continuously between January 1977 and June 1979 from Barrier Reef waters between Cooktown and Townsville (Fig. 1). Northern stock fish were sampled in July 1983 from Mornington Island in the southern Gulf of Carpentaria, and in October 1978 and 1983 from the Torres Strait (Fig. 1).

Morning (AM) and afternoon (PM) fishing periods are conducted by commercial troll vessels each day. Depending on the time of year, commercial fishing commenced at first light (0500-0600 hours) and ceased by 1000-1100 hours. Fishing in the afternoon was usually conducted from 1500 hours to dusk (1700-1800 hours). Sampling of ovarian tissue was completed between 1000 and 1200 hours, and 1800 and 2000 hours, respectively.

Estimates of spawning frequency of *S. commerson* were made using the hydrated oocyte and postovulatory follicle methods (Hunter and Macewicz 1985). Calculations were restricted to peak reproductive periods of October and November.

Results

Oocyte Maturation Stages

Eleven stages of oocyte development were histologically identified for *S. commerson* within three oocyte development categories: oogenesis and vitellogenesis (pre-maturation categories), and a final

maturation category, similar to those described for yellowfin tuna (McPherson 1991).

As with yellowfin tuna, the final maturation category was represented by six oocyte maturation stages. Using the terminology of McPherson (1991), they are the tertiary yolk globule (TYG), migratory nucleus (MN) and four hydration stages (H-1, H-2, H-3 and H-4). In the TYG stage the fatty droplets formed during vitellogenesis coalesce into several larger droplets around the periphery of the nucleus. In the MN stage these fatty droplets further coalesce into one large droplet as the nucleus commences its migration toward the animal pole. The four hydration stages of final oocyte maturation are categorized by the degree of yolk globule swelling, rupture into yolk platelets and dispersion of the yolk material throughout the oocyte cytoplasm and an increase in oocyte diameter.

In *S. commerson*, TYG oocytes were identified as the most developed stage from the AM and PM samples in almost equal proportions. MN oocytes were identified from PM samples only (Table 1). All four hydrated oocyte stages observed in histological samples of *S. commerson* ovaries were the most advanced stage from AM samples only.

Table 1. Occurrence of most developed final oocyte maturation stages by sampling period from *S. commerson*. Numbers represent individual ovaries examined histologically.

Most advanced oocyte stage	Sampling period AM	PM
Secondary yolk globule (SYG)	19	15
Tertiary yolk globule (TYG)	6	4
Migratory nucleus (MN)	0	4
Hydrated -1 (H-1)	1	0
Hydrated -2 (H-2)	4	0
Hydrated -3 (H-3)	9	0
Hydrated -4 (H-4)	18	0

Females with hydrating ovaries identified by macroscopic examination were only rarely identified from PM samples (approx. 1500-1800 hours) taken from the east coast and Torres Strait in 1978, and Torres Strait in 1983 (Table 2).

Table 2. Occurrence of hydrated ovaries by time of sampling period. Numbers represent individual ovaries examined macroscopically.

Location and date of sample	Mature ovaries observed			
	Hydrated		Total mature	
	AM	PM	AM	PM
East coast, October-November 1978	44	0	179	154
Torres Strait, October 1978	16	1	50	59
Torres Strait, October 1978	56	1	106	85

Description of Postovulatory Follicles

Three age groups of postovulatory follicles (POFs) were observed in ovaries of *S. commerson*, and classified as early, middle and late age. The early and middle POFs were comparable to the photomicrographs of the 0 and 12-hour postovulatory follicles given by Hunter et al. (1986). The late POFs of *S. commerson* were comparable to the late POFs of yellowfin tuna which appeared to degenerate in less than 24 hours (McPherson 1991).

The early POFs were restricted to PM samples, and middle POFs distributed approximately equally between AM and PM samples (Table 3). Late stage POFs were far more common from *S. commerson* AM samples (Table 3).

Table 3. Frequency of ovaries with dominant postovulatory follicles by sampling period. Numbers represent individual fish examined histologically.

Age of dominant postovulatory follicles	Sampling period	
	AM	PM
early	0	17
middle	4	2
late	25	1

The restricted occurrence of early POFs to the PM sample indicated that *S. commerson* spawning activity occurred during this period (that is, 1500-1800 hours). The preponderance of late POFs from the AM sample with an estimated age since ovulation of 12 to 18 hours since the previous PM fishing period, suggested that the maximum age of identifiable POFs was in the order of 24 hours.

Macroscopic Ovary Assessment

The ovary macroscopic scheme differed from those used for other *Scomberomorus* species [Prado (1970), Rohan et al. (1981) and

Donohue et al. (1982) for *S. commerson*; Beaumariage (1973), Finucane et al. (1984) for *S. cavalla*] in that a postovulatory stage (stage VI) was included. A description of the macroscopic ovary stages for *S. commerson* is given in Table 4.

Ovaries were considered to be mature when in stages IV-IX. These stages included yolk globule vitellogenic or atretic oocyte stages which were indicative of maturity in other scombrids, e.g., yellowfin tuna (Orange 1961; McPherson 1991) and black skipjack tuna (*Euthynnus lineatus*, Schaefer 1987).

POFs were not identified from histological sections of early mature (stage IV) or mature-resting (stage V) ovaries. Trials during 1977 had previously demonstrated that ovaries of this stage did not possess POFs <24 hours old (n=15).

Follicles were observed from postovulatory (stage VI) ovaries sampled during the AM and PM sampling periods (Table 5). Early follicles dominated PM sampled stage VI ovaries, while middle and late follicles dominated AM sampled stage VI ovaries. Late POs were observed from hydrating ovaries sampled during the AM period (Table 5).

Length at Maturity

Mature ovaries were observed between August and February from the east coast stock, and in July and October from the northern stock. The minimum lengths of mature fish with hydrated or postovulatory ovaries were 79 cm from the east coast and 80 cm from the northern stock.

Gonadosomatic Indices (GSI) and Gonad Seasonal Cycles

Two-way ANOVA of $\log_e$GSI data from the east coast demonstrated a significant difference ($P<0.05$) between months, and significant differences ($P<0.01$) between macroscopic ovary stages. The natural log and original scale GSI of the macroscopic stages are given in Table 6. Significant differences ($P<0.01$) were apparent between stages III and IV which represented the attainment of maturity with the formation of yolk globule stage oocytes. The GSI of

Table 4. Macroscopic ovary stages for *S. commerson*.

Macroscopic ovary stage		Description
I	Virgin	Very small and straplike. Color - translucent to white.
II	Resting	Firm and round. Oocytes microscopic. Color - translucent pink exterior, tending orange/pink interior.
III	Early development	Firm and round. Scattered oocytes (yolk vesicle stage) just becoming visible. Color tending light yellow white.
IV	Developing	Shape less rounded, more 'flabby' if placed on a flat surface. Opaque oocytes increasing in size with translucent areas between oocytes. Color - yellow to white.
V	Mature	Opaque oocytes occupy entire ovary. Color - distinct light orange exterior, slightly darker interior.
VI	Post-ovulatory	Opaque oocytes as previous stage with scattered translucent hydrated oocytes. Shape distinctly flabbier than V, blood vessels very prominent and stretched. Color - white/yellow exterior, white/pale orange interior.
VII	Ripe	Ovaries firm, rounded turgid appearance. Translucent hydrated oocytes predominate, ovary wall thin and translucent. Ovary lumen empty. Color - grey/pink exterior and interior.
VIII	Running ripe	Appearance of above externally. Ovary lumen filled with translucent oocytes. Oocytes released with slight pressure on abdomen.
IX	Spent	Flabby shape. Ovary lumen relatively large, ovary lamellae small. Opaque or translucent oocytes rare. Distended veins common. Color - light yellow/white exterior, interior more light yellow/orange.

Table 5. Frequency of postovulatory follicles by age group, within sampling periods from histological examination by ovary stages from macroscopic ovary stages.

Macroscopic ovary stage	Sampling period							
	AM				PM			
	Early	Middle	Late	(n)	Early	Middle	Late	(n)
V	0	0	0	(14)	0	0	0	(4)
VI	0	4	7	(11)	16	2	1	(19)
VII	0	0	18	(32)	-	-	-	(0)

Table 6. Mean east coast GSI for ovary maturity states.

Macroscopic ovary state	Sample size	Log_eGSI (±S.E.)	GSI
I	21	-0.34 (0.18)	0.71
II	21	1.58 (0.11)[1]	4.84
III	22	1.88 (0.11)[1,2]	6.56
IV	7	2.52 (0.19)[3,5]	12.47
V	33	3.36 (0.09)[4]	28.83
VI	22	3.25 (0.09)[4,5]	25.83
VII	14	3.90 (0.13)	49.17
IX	4	1.98 (0.25)[1,2,3]	7.22

[1,2,3,4,5]Macroscopic ovary states that do not differ significantly $P<0.05$.

stage VII ovaries was significantly greater than that of stage V and VI ovaries ($P<0.01$).

The proportion of mature ovaries by month varied significantly (ANOVA, $P<0.01$) throughout the year on the east coast. The percentages of grouped macroscopic gonad stages (resting II and III; developing to maturity IV and V; spawning VI, VII and VIII; spent IX) by month are shown in Fig. 2. Ovaries demonstrated signs of oocyte maturity in August. Ovaries in spawning condition were observed in October-December, and in February.

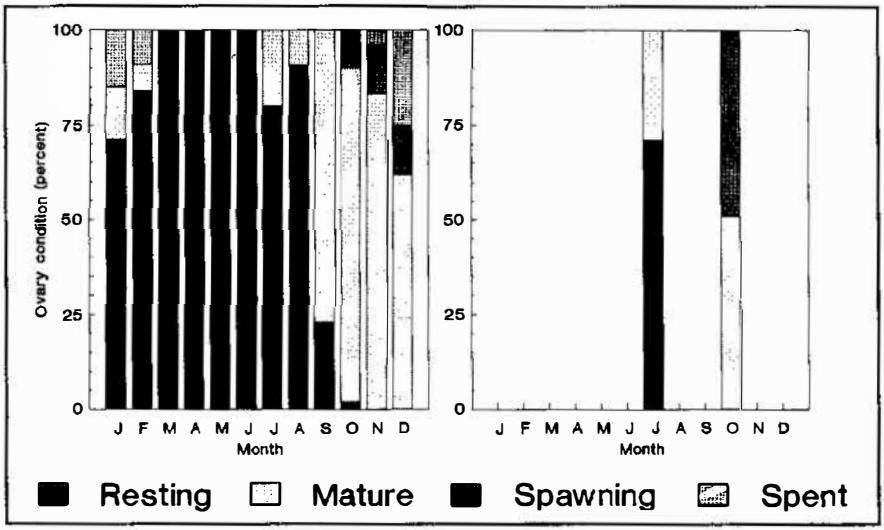

Fig. 2. Seasonal variation of grouped ovary macroscopic stages from east coast (left) and northern Australian (right; that is, Mornington Island and Torres Strait) stocks of *S. commerson*.

From northern stock waters, mature ovaries were sampled in July (Fig. 2) from around Mornington Island. In October, the ovaries of Torres Strait fish displayed comparable percentages of mature and spawning ovaries to those from the east coast (Fig. 2).

The GSI of ovaries (stage II and above) from east coast *S. commerson* demonstrated a minimum during the winter months of May-August, with an increase to a maximum during October and November (Fig. 3). GSI declined during the late summer months of January and February. From the northern stock, the mean GSI of fish at Mornington Island in July was more comparable to the GSI of September fish from the east coast (Fig. 3). The mean GSI of ovaries from fish in Torres Strait during October was higher than for the same period in east coast waters.

Spawning Frequency

Samples used to estimate spawning frequency using the hydrated oocyte method were restricted to AM periods. This was to minimize biases caused by possible nonfeeding behavior toward baited hooks during the PM spawning period. The spawning fractions were calculated as the number of hydrated ovaries divided by

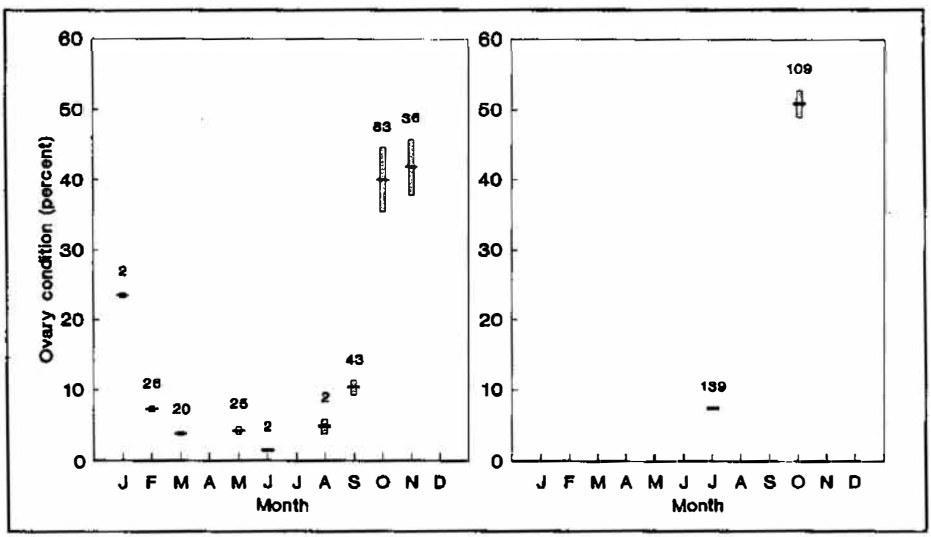

Fig. 3. GSI of east coast and northern stock *S. commerson*. Numbers represent sample size.

the total number of mature ovaries observed (Hunter and Macewicz 1985; Schaefer 1987). Estimates of the spawning frequency (the inverse of the spawning fraction) ranged from 1.9 to every 5.9 days (Table 7).

Spawning fraction of the histological samples by the postovulatory follicle method was calculated from the ratio of ovaries with POFs <24 hours old to the total number of mature ovaries. Only stage VI and VII ovaries contained POFs.

To estimate the total number of ovaries likely to have POFs, the proportion of hydrating and postovulatory ovaries (that is, stages VI, VII and VIII) with POFs from histological assessment was multiplied by the total number of hydrating and postovulatory ovaries (that is, stages VI, VII and VIII) macroscopically examined on the same days the histological samples were taken. To estimate spawning fraction and frequency the total number of ovaries with POFs was expressed as a proportion of the total number of mature ovaries examined macroscopically.

Estimates of the spawning fraction and frequency of *S. commerson* by the postovulatory follicle method varied between every 2.2 and 2.9 days (Table 7).

Table 7. Spawning frequencies (SF) of east coast (EC), and northern stock (N) fish estimated by the hydrated oocyte and postovulatory follicle methods (AM, PM sampling period; Macro-macroscopic assessment; Histo-histological assessment; POs, postovulatory follicles).

	HYDRATED OOCYTE METHOD			
Location and date of sample	Days sampled (AM-Macro)	Hydrated ovaries (AM-Macro)	Mature ovaries	SF days
EC Oct 1978	9	6	36	5.9
EC Nov 1978	24	38	143	3.7
N Oct 1978	6	16	50	3.1
N Oct 1986	14	56	106	1.9

	POSTOVULATORY FOLLICLE METHOD					
	Days sampled (Histo)	Stage VI+VII with PO (Histo)	Stage VI+VII (Histo)	Total stage VI+VII (Macro)	Total mature IV+V+ VI+VII	SF (Days)
EC Oct-Nov 1978	26	20	32	107	193	2.2
N Oct 1978	6	11	12	39	103	2.9
N Oct 1986	12	17	24	106	194	2.6

Discussion

Ovarian Cycles

In general, GSI and macroscopic staging of *S. commerson* ovaries indicated a peak in reproductive activity during October and November, with mature fish present in the sampled east coast populations during the spring and summer months. Ovaries matured earlier in fish of the northern stock.

McPherson (1981) indicated that reproductive activity occurred earlier in northern Queensland waters. In Torres Strait waters of the northern *S. commerson* stock, the spawning season as indicated by fish with ripe or partially spent ovaries begins in August and ends between December and March. In contrast the spawning season in east coast waters appeared less protracted (October to early December) in waters between Lizard Island and Townsville and even more restricted further south between Gladstone and Bundaberg. A peak in reproductive activity was suggested for northern stock fish in Northern Territory waters (Rohan et al. 1981) prior to November.

Observations of gonad index and size at maturity are available for the species in Fiji (Lewis et al. 1983). Madagascar (Prado 1970), east Africa (van der Elst 1981), Papua New Guinea (Lewis et al. 1974) and Saudi Arabia (Kedidi and Abushusha 1987) waters. Spawning seasons included the spring and summer months, while some authors identified peaks in reproductive activity within each spawning season.

Individual female *S. commerson* attained maturity in the northern and east coast stocks between 79 and 82 cm. Lewis et al. (1983) recorded mature females at 70 cm in Fiji waters while van der Elst (1981) reported that the species attained maturity between 90 and 100 cm in east African waters.

Timing of Spawning

Final oocyte maturation commenced in either the AM or PM period during one day and concluded the following day with ovulation and spawning of the hydrated oocytes sometime during the PM period. Immediate postovulatory fish were sampled from fish

captured between 1500 and 1800 hours. The single hydrated-running ripe ovary sampled was from the later afternoon period. The relative absence of fish in immediate spawning condition from the afternoon hours is uncertain. Isolation of these fish from the main fishing grounds or nonfeeding behavior prior to spawning are considered to be likely reasons.

Maturation and ovulation of oocytes was estimated to occur over 24-36 hours. The precise time scale of final oocyte maturation could not be determined as ovary samples were not obtained from the fishery during the night. McPherson (1991) demonstrated a faster rate of final oocyte maturation for yellowfin tuna. Twelve hours elapsed between the appearance of the first (TYG) and last (H-4) final oocyte maturation stage, and less than 24 hours elapsed between commencement of final oocyte maturation and spawning.

Munro (1942) considered that *S. commerson* females spawned before the early hours of darkness. The only completely ripe ovaries (that is, running ripe) of *S. commerson* observed by Munro in waters off Townsville were in the late afternoon.

Spawning Frequency

The hydrated oocyte method indicated that female *S. commerson* in Queensland waters have a frequency of spawning activity during the spring months of October and November of between every 1.9 and 5.9 days. Schaefer (1987) estimated the average interval between spawning of black skipjack tuna in the eastern Pacific as every 2.1-5.7 days depending on the area.

The categorization of *S. commerson* POFs into three age groups that persist for about 24 hours verified their use in determining spawning frequency in the species. The postovulatory follicle method provided estimates of the spawning frequency of *S. commerson* populations in east coast and northern stock waters during October and November ranging between every 2.2 and 2.9 days. The spawning frequency of skipjack tuna (*Katsuwonus pelamis*) in the south Pacific was estimated by the postovulatory follicle method to be every 1.18 days (Hunter et al. 1986).

As *S. commerson* oocytes take 24-36 hours to undergo final maturation, and as POFs degenerate within 24 hours, then the observations of some fish with hydrated ovaries and late POFs during

the AM period demonstrate that individual females can spawn on consecutive afternoons. Yellowfin tuna were shown to spawn on successive nights (McPherson 1991), although larger fish usually demonstrated a higher spawning frequency.

The estimate of spawning frequency obtained by both methods are merely indicative as sample sizes were small and not directly comparable due to possible variation between sampling years. The estimates are indicative of the maximum spawning rates, as the calculations were based on October and November data when GSI and macroscopic stage data suggested peak reproductive activity. Spawning frequency would be less frequent in other months when spawning activity was recorded.

The hydrated oocyte method tended to provide lower estimates of spawning frequency. This may have been due to the disproportionate representation of fish with prespawning hydrated ovaries in the catch.

Estimation of spawning frequency for *S. commerson* would assist with the definition of the overall duration of the spawning season and identification of peaks of spawning activity which provide management options for the protection of the spawning stock. The precise definition and estimation of the size of spawning stocks is essential because recruitment overfishing is prevented only by maintaining adequate spawning stocks (Cushing 1983).

Acknowledgments

Peter Cooper assisted with the collection of samples; Beth Perkins produced the histological sections. The statistical assistance of Allan Lisle is gratefully acknowledged. David Die commented on drafts of the manuscript.

The work was supported by the Queensland Department of Primary Industries and the Fishing Industry Research Trust Account.

References

Anon. 1978. Major Queensland bid to track Spanish mackerel. Aust. Fish. 37(3):18-19.

Beaumariage, D.S. 1973. Age, growth and reproduction of king mackerel, *S. cavalla*, in Florida. Fla. Mar. Res. Publ. 1, 45 p.

Cushing, D.H. 1983. The regularity of the spawning season of some fishes. J. Cons. CIEM 33:81-92.

Donohue, K., P. Edsall, J. Robins and R. Tregonning. 1982. Exploratory fishing for Spanish mackerel in waters off Western Australia during the period June 16 to October 16, 1981. Fish. Wild., Western Australia, Rep. 57, 46 p.

Elst, R. van der. 1981. A guide to the common sea fishes of southern Africa. C. Struik, Capetown, 274 p.

Finucane, J.H., L.A. Collins, H.A. Brusher and C.H. Saloman. 1984. Reproductive biology of king mackerel, *S. cavalla*, from the southeastern United States. U.S. Fish. Bull. 84:841-850.

Hunter, J.R. and B.J. Macewicz. 1985. Measurement of spawning frequency in multiple spawning marine fishes, p. 79-94. *In* R. Lasker (ed.) An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy *Engraulis mordax*. U.S. NMFS NOAA Tech. Rep. 36.

Hunter, J.R., B.J. Macewicz and J.R. Sibert. 1986. The spawning frequency of skipjack tuna, *Katsuwonus pelamis*, from the south Pacific. U.S. Fish. Bull. 84:895-903.

Kedidi, S.M. and T.L. Abushusha. 1987. Stock assessment of the "derak" *S. commerson* caught off the southern Saudi Red Sea coast. Saudi Fish. Res. 3, 36 p.

Lewis, A.D., B.R. Smith and R.E. Kearney. 1974. Studies on tuna and baitfish in Papua New Guinea waters II. Dept. Agric. Stock Fish, Fish. Bull. 11, 113 p.

Lewis, A.D., L.B. Chapman and A. Sesewa. 1983. Biological notes on coastal pelagic fishes in Fiji. Tech. Rep. Fish. Div. (Fiji) 4, 68 p.

McPherson, G.R. 1981. Preliminary report: Investigation of Spanish mackerel *S. commerson* in Queensland waters, p. 50-58. *In* C.J. Grant and D.G. Walter (eds.) Northern Pelagic Programme. Aust. Gov. Publ. Serv., Canberra.

McPherson, G.R. 1985. Development of the northern Queensland mackerel fishery. Aust. Fish. 44(8):15-17.

McPherson, G.R. 1991. Reproductive biology of yellowfin tuna in the eastern Australian Fishing Zone with special reference to the north-western Coral Sea. Aust. J. Mar. Freshwat. Res. 42:465-477.

McPherson, G.R. 1992a. Age and growth of the narrow barred Spanish mackerel (*Scomberomorus commerson* Lacépède, 1800) in northeastern Queensland waters. Aust. J. Mar. Freshwat. Res. 43.

McPherson, G.R. 1992b. Assessing macroscopic and histological stageing of yellowfin tuna ovaries in the north-western Coral Sea. Inf. Ser. Dep. Primary Ind. (Queensl.) Q192021, 19 p.

Munro, I.S.R. 1942. The eggs and early larvae of the Australian barred Spanish mackerel, *Scomberomorus commersoni* (Lacepede) with the preliminary notes on the spawning of that species. Proc. R. Soc. Queensl. 54(4):33-48.

Orange, C.J. 1961. Spawning of yellowfin tuna and skipjack in the eastern tropical Pacific, as inferred from studies of gonad development. Inter-Am. Trop. Tuna Comm. Bull. 5(6):457-526.

Prado, J. 1970. Notes sur *S. commerson* Lacépède, 1800, de la Côte nord-ouest de Madagascar. Trav. Fac. Sci. Univ. Rennes (Ser. Oceanogr. Biol.) 3:91-116.

Rohan, G., A. Church and A. Clark. 1981. Northern Territory mackerel fishing programme 1980/81. Fish. Rep. Dep. Prim. Prod., Fish Div. No. 4, 55 p.

Schaefer, K.M. 1987. Reproductive biology of the black skipjack, *Euthynnus lineatus*, an eastern Pacific tuna. Bull. I-ATTC 19:169-227.

Shaklee, J.B., S.R. Phelps and J. Salini. 1990. Analysis of fish stock structure and mixed-stock fisheries by the electrophoretic characterization of allelic isozymes, p. 173-196. *In* D.H. Whitmore (ed.) Applications of electrophoresis and isoelectric focussing techniques in fisheries management. CRC Press, Boca Raton, Florida.

Manuscript received 1 August 1991; revised ms received 3 September 1992; accepted 25 May 1993.