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Reproductive Biology of Yellowfin Tuna, *Thunnus albacares* (Bonnaterre, 1788) off Visakhapatnam, North Andhra Pradesh, India

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Tunas are epipelagic, highly migratory species that are widely distributed in the tropical and subtropical waters of the world. The present paper deals with some aspects of reproductive biology such as maturity stages, gonado - somatic index, spawning period, size at first maturity and fecundity of yellowfin tuna, *Thunnus albacares* from the area off north Andhra Pradesh. *Thunnus albacares* in this region showed two peak spawning seasons *viz.,* during April-May and September-October. The size at first maturity of *Thunnus albacares* was estimated as 90 cm fork length for male and 90.1 cm fork length for females. The relations between the fecundity (F), fork length (L), body weight (W) and ovary weight (V) were found as $F= 0.0007L^{4.56676}$ (r = 0.74), $F= 10.615W^{1.6304}$ (r = 0.77) and $F= 9.3054V^{1.0073}$ (r = 0.79).

Key words: Yellowfin tuna, reproduction, fecundity, north Andhra Pradesh, India

Tunas are highly migratory species that are widely distributed in the tropical and subtropical waters of the world. Extensive efforts are underway in many research laboratories around the world to study the importance of the tuna populations in order to keep them at the highest possible level of exploitation. Information on the reproductive biology helps to understand the link between spawning and recruitment. Among the various species of tunas exploited from Indian waters, *Thunnus albacares* (Bonnaterre, 1788) or yellowfin tuna is the major species having very high demand in the domestic as well as international markets. Until 2001 only juveniles of *T. albacares* of length groups 25 cm fork length (FL) to 60 cm FL were represented in the catches along east coast of India, especially north of Chennai (Sujatha & Iswarya, 2005). Only from mid 2002, fishermen have been going into deeper waters off this region to capture large individuals of *T. albacares* from oceanic schools. Specimens of all length groups ranging from 27 to 187 cm FL were being represented in the catches of north Andhra coast while the common size in the commercial catches ranged from 50 to 150 cm FL (Sujatha & Iswarya, 2005).

In Indian waters, the biology of *T. albacares* was studied by Silas *et al.* (1985), John & Sudarshan (1993), Pillai *et al.* (1993), John & Reddy (1989), John (1995), John *et al.* (1998) and Sivraj *et al.* (2005). Even though some aspects of the reproductive biology of *T. albacares* from the Bay of Bengal region were studied by John *et al.* (1998), there is no information on the reproductive biology of *T. albacares* along middle east coast of India especially off Andhra Pradesh. The present paper deals with the reproductive biology *viz.* maturity of gonads, gonado somatic index (GSI), size at first maturity and fecundity of *T. albacares* off north Andhra Pradesh region.

Materials and Methods

Specimens of *T. albacares* were obtained from traditional fish landing centres at Lawson's Bay, Bheemunipatnam, Pudimadaka and Visakhapatnam fisheries harbour where tunas caught by surface trolling at 40 to 110 m depth region, were brought for sale.

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The fishing area was in surface waters of deeper zone off Visakhapatnam, middle east coast of India, 55 nautical miles away from the shore, extending south east up to waters north off Kakinada, in addition to inshore fishing area. Fork length and weight of the specimens were noted. Gonads were weighed to the nearest 0.1 g and preserved in 5% formalin until further analysis was done. A total of 873 specimens of *T. albacares* (659 females and 214 males) of length range 35 to 157 cm FL were examined during the period July 2003 to December 2006. Differentiation of various stages of maturity in female *T. albacares* was undertaken following Orange (1961) and in male following Schaefer (2001). A scale of five stages including two sub stages was adopted to determine the gonadal maturity stages of *T. albacares.*

GSI was calculated using the equation:

GSI = (gonad weight / body weight) x100

Mean GSI values were calculated by pooling the month wise data. For estimation of fecundity, total number of mature ova (obtained from females at stages III and IV) was estimated by multiplying the number of mature ova in the sample taken from anterior, middle and posterior regions of ovaries by the ratio of ovary weight to sample weight. Relationships between fecundity and three variables such as fork length (FL), total weight of the fish and weight of gonads were also studied from the following equation (Nikolsky, 1969).

$$F = aL^b$$

where L=Fork length/fish weight/ovary weight; a and b are constants

Results and Discussion

Based on macroscopic as well as microscopic characteristics of several developmental groups of ova present in the ovaries of *T. albacares*, five stages (with two sub stages in the first and second stages) *viz.*, stage I-P (Immature-primitive), stage I-A (Immature-advanced), stage II-P (Early maturing - primitive), stage II-A (Late maturing-advanced), stage III (Mature), stage IV (Ripe) and stage V (Spent-recently spawned/post spawning) were identified. Specimens of *T. albacares* with ovaries in immature primitive (stage I-P) and spent stage (stage V) were not encountered in any of the samples. Percentage occurrence of females of *T. albacares* in different stages of maturity in various months are given in Table 1. Specimens with mature and ripe gonads were encountered almost throughout the year except during the months January to February, June to July and October. It may be inferred that the spawning period extends throughout the year with peak periods from

Table 1. Percentage occurrence of females of *Thunnus albacares* in different stages of maturity in various months represented in the catches off north Andhra region during July 2003 to December 2006

(n = 487)

Maturity stages	Jan n=8	Feb n=10	Mar n=59	Apr n=65	May n=68	Jun n=8	Jul n=27	Aug n=65	Sept n=29	Oct n=35	Nov n=68	Dec n=45
Stage I - P	-	-	-	-	-	-	-	-	-	-	-	-
Stage I - A	-	25	-	-	-	60	-	5	5	5	-	-
Stage II - P	40	45	-	-	-	40	55	10	25	10	10	8
Stage II - A	60	30	10	10	10	-	45	40	10	30	55	45
Stage III	-	-	45	40	45	-	-	45	50	55	25	35
Stage IV	-	-	45	50	45	-	-	-	10	-	10	12
Stage V	-	-	-	-	-	-	-	-	-	-	-	-

n =No. of specimens, P=Primitive, A=Advanced

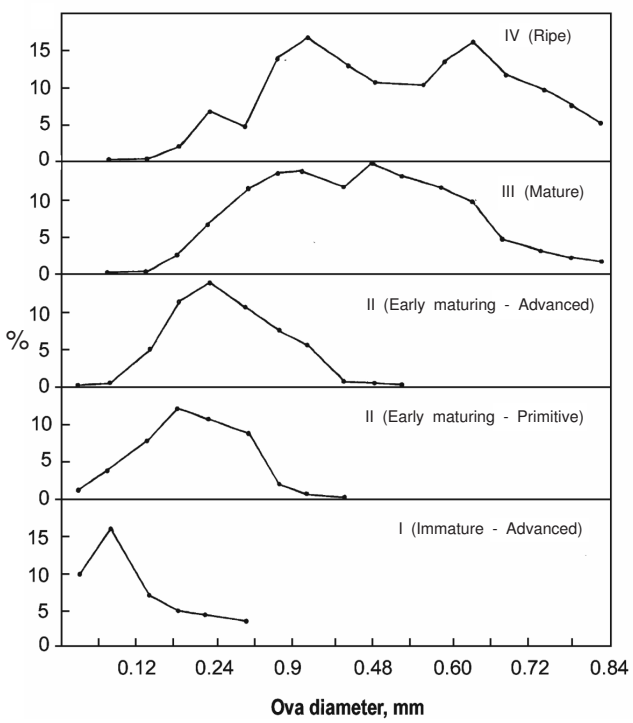

Fig. 1. Ova diameter frequency polygon of different maturity stages of *Thunnus albacares* off north Andhra region

April to May and another from September to October (Fig. 2). John & Sudarshan (1993) estimated the spawning season of *T. albacares* in Indian EEZ mainly along west coast from January to May. According to John *et al.* (1998) in Andaman and Nicobar sector of Bay of Bengal, the spawning season was from November to April. Govindraj *et al.* (2000) reported that the spawning potential of *T. albacares* in northwest sector of Indian EEZ was observed to be relatively low compared to Andaman and Nicobar waters.

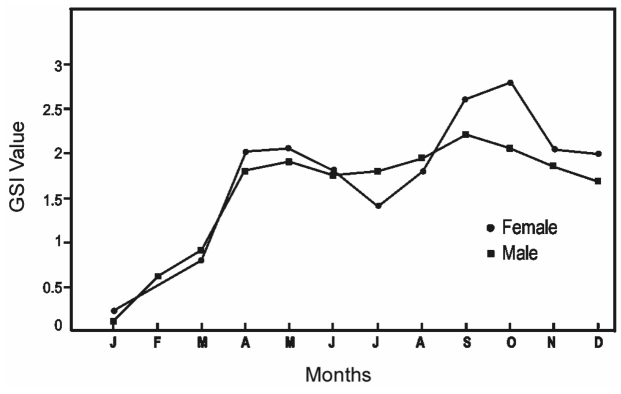

Fig. 2. Monthly trends in gonado somatic index of female and male *Thunnus albacares* off north Andhra region

Sivaraj *et al.* (2005) reported two peak spawning seasons for *T. albacares* in Andaman and Nicobar waters, one in April and another in September with lean period during October to November. Observations in the present study are in agreement with that from Andaman and Nicobar waters. *T. albacares* from Revillegigedo islands of Pacific ocean (June, 1953; Schaefer & Orange, 1956) and from southern Mexican waters (Knudsen, 1977) had peak spawning season from April to October. Intense spawning activity was reported for *T. albacares* of western Pacific waters during January to February (Koido & Suzuki, 1989). According to Shung (1973) the spawning season of *T. albacares* from western Indian ocean was from January to March and that from eastern Indian ocean was from October to April.

Ova diameter frequency polygons of different maturity stages of *T. albacares* are given in Fig.1. Based on ova diameter frequency polygons in determining maturity stages, presence of multiple modes indicated that *T. albacares* in this region is a multiple spawner (Fig.1). Similar studies in the past have revealed that ovary of *T. albacares* is considerably asynchronous because oocytes in various developmental stages were present in the ovary simultaneously (Schaefer & Orange, 1956; Bunag, 1956; Yamamoto, 1956; Otsu & Uchida, 1959; Orange,1961; Kikawa, 1962; Mc Pherson, 1991; Schaefer, 1998). The observations in the present study are in agreement with the above findings. During the entire study period, specimens with ovaries in recently spawned and post spawning stages were not encountered in the catches. This may probably be either due to the reason that *T. albacares* being a multiple spawner matured ova released are continuously replaced by maturing group of ova or females move into deeper waters for spawning which generally are not fishing grounds.

In the male *T. albacares* five maturity stages were identified based on the morphological features and microscopic examination of small sections taken from different regions

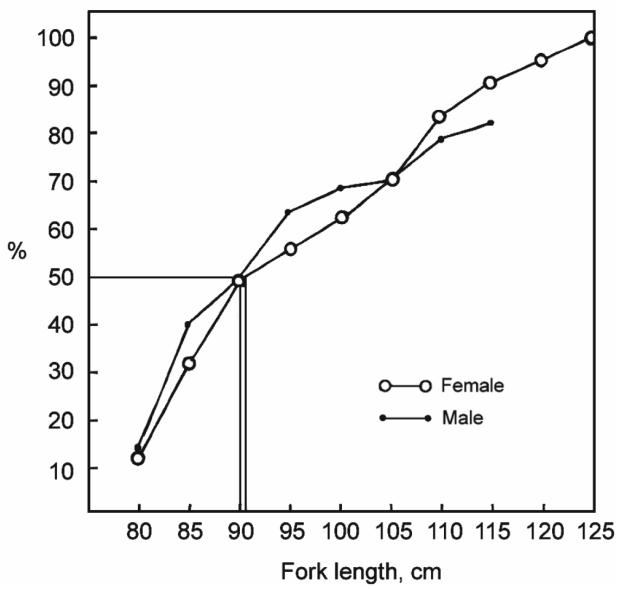

Fig. 3. Size at first maturity of female and male *Thunnus alabacares* off north Andhra region

of the testes as per Schaefer (2001). In the present study, specimens in maturity stages of I to IV were encountered in the catch. However, specimens in stage V corresponding to the recently spawned stage in which specimens with testes in spent condition were not encountered in the catches.

Monthly trends in GSI values obtained from pooled data from July 2003 to December 2006 of male and female *T. albacares* off north Andhra region were represented in Fig. 2. Both in males and females GSI value showed two peaks, one in April-May and another in September-October period. In males, GSI value was high during the months April, May and June. GSI values showed steady increase from July to December with a peak from September to October.

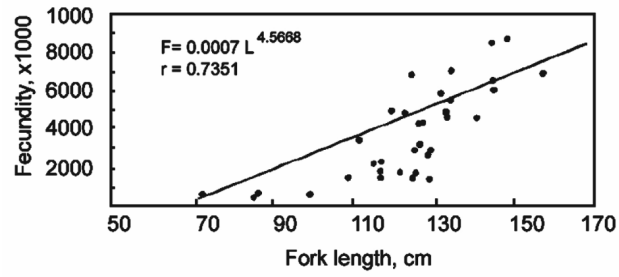

Fig. 4. Relationship between fecundity and fork length in *Thunnus albacares* off north Andhra region

The mean GSI values of female *T. albacares* steadily increased from January to April reaching peak during April and May. The values decreased after June but again showed consistent increase from September to December with peak GSI values in the months of September and October.

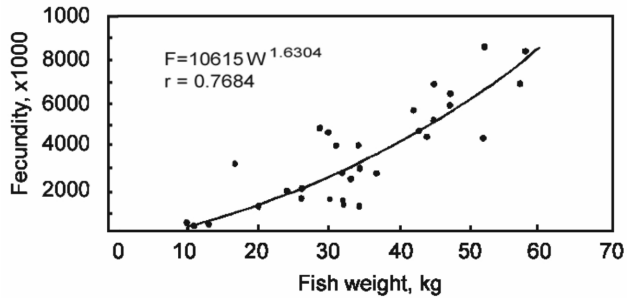

Fig. 5. Relationship between fecundity and body weight in *Thunnus albacores* off north Andhra region

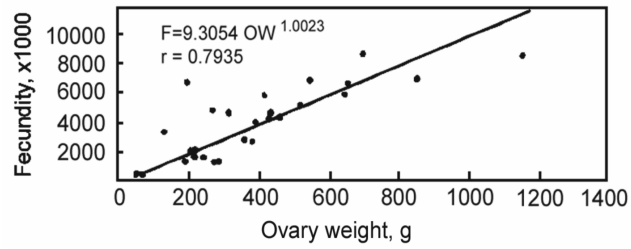

Fig. 6. Relationship between fecundity and ovary weight in *Thunnus albacores* off north Andhra region

The size at first maturity has been estimated to be 90.1 cm FL for female and 90 cm FL for male *T. albacares* from a plot of percentage of mature fish against fork length (Fig. 3). The LFM values of *T. albacares* from different waters of the world range from 56.7 to 120 cm. *T. albacares* from Philippine waters were reported to mature very early at 56.7 cm FL (Bunag, 1956) while those from western Pacific mature on reaching a size of 120 cm FL only (Suzuki et al., 1978). The LFM reported for *T. albacares* from eastern Pacific was 91-100 cm FL (Shingu *et al.* (1974) and in females from eastern Pacific waters it was at 59 cm FL (Schaefer, 1998).

Fecundity was estimated from 35 specimens of length range 72.7 to 157 cm FL. Number of ova ranged from 3,78,589 to

86,82,341 with the highest fecundity in a specimen measuring 149 cm FL with 700 g ovary weight. The relations between fecundity (F) and fork length (L) was $F= 0.0007L^{4.56676}$; r = 0.74 (Fig. 4). The relation between fecundity (F) and body weight (W) was $F= 10.615W^{1.6304}$; r = 0.77 (Fig. 5). The fecundity (F) and ovary weight (V) relationship was $F= 9.3054V^{1.0073}$; r = 0.79 (Fig. 6). It was inferred that fecundity increases with increase in fork length, fish weight and ovary weight (Fig. 4,5, 6). Fecundity estimates of *T. albacares* were made by June (1953) and Joseph (1963) in central and eastern Pacific respectively and by Kikawa (1966) in central and western Pacific. It was estimated that *T. albacares* measuring 100, 130 and 150 cm FL produced approximately 2.1, 4.4 and 6.6 million ova respectively. The batch fecundity estimates of *T. albacares* in eastern Pacific ranged from 1,62,918 to 80,26,026 in specimens of 118 to 146 cm FL (Schaefer, 1998). Fecundity estimated in the present study is in agreement with the estimates from eastern Pacific Ocean.

The study indicates *Thunnus albacares* caught off Vishakhapatnam, north Andra Pradesh to be a multiple spawner with multiple modes in the ova diameter frequency polygons. The spawning periods extended throughout the year with two peak spawning periods *viz.,* April-May and September-October in both males and females. The size at first maturity of *T. albacares* was estimated at 90 cm fork length for males and at 90.1 cm fork length for females. *Thunnus albacares* of 149 cm FL was estimated to produce 8.6 million ova. The information on the maturity, fecundity and spawning season of *T. albacares* would help in formulating management measures for sustainable harvesting of the resource.

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References

Bunag, D. M. (1956) Spawning habits of some Philippine tuna based on diameter measurements of the ovarian ova. *Philipp. J. Fish.* **4**(2), 145-175

Govindraj, K., John, M. E., Premchand, Unnikrishnan, N., Jacob Thomas and Somvanshi, V.S. (2000) Oceanic tuna resources in the north west region of Indian EEZ. *Bull. Fish. Surv. India*. **27**, 20

John, M. E. (1995) *Studies on yellowfin tuna, Thunnus albacares (Bonnaterre, 1788) in the Indian Seas*. Ph.D. Thesis, University of Mumbai, India

John, M. E., and Reddy, K. S. N. (1989) Some considerations on the population dynamics of yellowfin tuna, *Thunnus albacares* (Bonnaterre) in Indian seas. Studies on fish stock assessment in Indian waters. *FSI Spl. Publ.,* **2,** 33-54

John, M. E. and Sudarsan, D. (1993) Fishery and biology of yellowfin tuna occurring in oceanic fishery in Indian seas. (Sudarsan, D. and John, M.E., Eds), pp 39-62

John, M. E., Neelakandan, M., Sivaji, V., Premchand, Parasuraman, P. S., Sajeevan, M. K. and Sivaraj, P. (1998) Some aspects on the reproductive biology of yellowfin tuna (*Thunnus albacares*) in the Bay of Bengal. *Bull. Fish. Surv. India,* **26,** 42-50

Joseph, J. (1963) Fecundity of yellowfin tuna (*Thunnus albacares*) and skipjack (*Katsuwonus pelamis*) from the eastern Pacific Ocean. *Inter-Am. Trop. Tuna. Comm. Bull.* **7(4)**, pp 255-292

June, F. C. (1953) Spawning of yellowfin tuna in Hawaiian waters. *U. S. Fish Wild. Serv. Fish. Bull.* **54,** pp 47- 64

Kikawa, S. (1962) Studies on the spawning activity of Pacific tunas, *Parathunnus mebachi* and *Neothunnus macropterus*, by the gonad index examination. *Nankai Reg. Fish. Res. Lab. Rep.* **1,** pp 43-56

Kikawa, S. (1966) The distribution of maturing big eye and yellow fin and an evaluation

of their spawning potential in different areas in the tuna longline grounds in the Pacific. *Nankai Reg. Fish. Res. Lab. Rep.* **23,** pp 131-208

Knudsen, P. F. (1977) Spawning of yellowfin tuna and the discrimination of subpopulations. *Inter-Am. Trop. Tuna. Comm. Bull.* **17**(2), pp 117-169

Koido, T. and Suzuki, Z. (1989) Main spawning season of yellowfin tuna, *Thunnus albacares,* in western tropical Pacific Ocean based on the gonad index. *Bull. Far. Seas Fish. Res. Lab.* **26,** pp153-163

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**(5), pp 465-477

Nikolsky, G. V. (1969) *Theory of fish population dynamics*. Otto Science Publishers, Koenigstein, 317 p

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)**, pp 459-526

Otsu, T. & Uchida, R. N. (1959) Sexual maturity and spawning of albacore in the Pacific Ocean. *Fish. Bull. U. S.* **59(148)**, pp 287-305

Pillai, P. P., Said Koya, K. P., Pillai, N. G. K., and Jayaprakash, A. A. (1993). Fishery and biology of yellowfin tuna occurring in coastal fishery in Indian seas. *In:* (Sudarsan, D. and John, M. E., Eds), pp 23-38

Schaefer, K. M. (2001) Reproductive biology of tunas. *Fish Physiology.* **19,** pp 225 – 265

Schaefer, K. M. (1998) Reproductive biology of yellowfin tuna (*Thunnus albacares*) in the eastern Pacific ocean. *Inter-Am. Trop. Tuna. Comm. Bull.* **21**, pp 201-272

Schaefer, M. B. and Orange, C. J. (1956) Studies on the sexual development and spawning of yellowfin tuna (*Neothunnus macropterus)* and skipjack (*Katsuwonus pelamis*) in three areas of the eastern Pacific Ocean, by examination of gonads. *Inter-Amer. Trop. Tuna. Comm. Bull.* **1(6),** pp 281-349

Shingu, C., Tomlinson P. K. and Peterson, C. L. (1974) A review of the Japanese longline fishery for tunas and billfishes in the eastern Pacific Ocean, 1967-1970. *Inter-Amer. Trop. Tuna. Comm. Bull.* **16(2),** pp 65-230

Shung, S. H. (1973) The sexual activity of yellowfin tuna caught by the longline fishery in the Indian Ocean based on the examination of ovaries. *Bull. Far Seas Fish. Res. Lab.* **(9)** pp 123-142

Silas, E. G., Pillai, P. P., Jayaprakash, A. A., & Pillai, M. A. (1985) Observations on the fishery and certain aspects of the biology of yellowfin tuna *Thunnus albacares* (Bonnaterre) taken by longline gear in the EEZ of India, *Bull. Cent. Mar. Fish. Res. Inst.,* **36**, pp 176-183

Sivaraj, P., Sinha, M. K., Rajkumar, S. A., Kar A. B., & Pattanayak, S. K. (2005) Fishery and biology of yellowfin tuna in Andaman and Nicobar waters. (Somvanshi, V. S., Varghese, S. and Bhargava, A. K., Eds), pp 153-167

Sujatha, K. and Iswarya Deepti, V. A. (2005) Tuna fish resources of north Andhra Pradesh – sustainable development; In: *Sustain fish* (Kurup, B. M. and Ravindran, K., Eds), pp 421 – 433, School of Industrial Fisheries, CUSAT

Suzuki, Z., Tomlinson, P. K. and Honma, M. (1978) Population structure of Pacific yellowfin tuna. *Inter-Am. Trop. Tuna. Comm. Bull.* **17(5),** pp 273-441

Yamamoto, K. (1956) Studies on the formation of fish eggs. 1. Annual cycle in the development of ovarian eggs in the flounder, *Liopsetta obscura. J. Faculty Sci.,* Hokkaido University, *Series VI,* **12,** pp 362-374