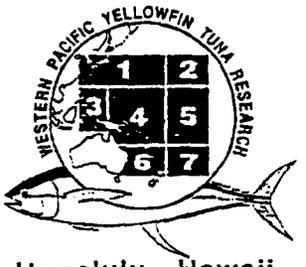

Honolulu, Hawaii
June 17-24, 1992

WESTERN PACIFIC YELLOWFIN TUNA RESEARCH GROUP WORKSHOP

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A REVIEW OF REPRODUCTIVE BIOLOGY OF YELLOWFIN TUNA IN THE CENTRAL AND WESTERN PACIFIC OCEAN

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INTRODUCTION

An understanding of the reproductive biology of a species is important for the assessment of stock (Schaefer, 1987). This paper is to briefly review the reproductive biology of yellowfin tuna in central and western Pacific Ocean with respect to 1) stages of ovary maturity, 2) size at first maturity, 3) spawning season, 4) sex ratio and 5) fecundity.

The following three papers were referred to extensively for the preparation of this review:

1) Synopsis on the biology of yellowfin tuna *Thunnus (Neothunnus) albacares* (Bonnaterre) 1788 (Pacific Ocean), by Schaefer, Broadhead and Orange (1963);

2) Synopsis of biological data on yellowfin tuna *Thunnus albacares* (Bonnaterre, 1788), in the Pacific Ocean, by Cole (1980);

3) A review of biology and fisheries for yellowfin tuna, *Thunnus albacares*, in the western and central Pacific, by Suzuki (1991).

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STAGES OF OVARY DEVELOPMENT

Based on physical characteristics, the ovaries were classified into the following stages of maturity by June (1953) and Yuen and June (1957):

1. Immature:
   The ova are translucent and range from 0.01 to 0.18 mm in diameter.

2. Intermediate:
   The ova are semiopaque owing to the deposition of yolk granules; The diameter range from 0.18 to 0.40 mm.

3. Maturity:
   The ova are fully opaque; The diameters range from 0.4 to 1.00 mm.

4. Ripe:
   The ova are transparent and loose; The diameters range 0.76 to 1.23 mm.

5. Spawn out:
   Toward the end of the spawning season, the ovaries decrease in size, become hollow and flaccid and gradually resume the appearance of those in the immature stage.

Table 1 summarizes these principle features of the ovaries during the five different stages. This Table also shows the values of the diameter of ova, gonad index (GI) and fork length (FL). In the immature stage, the GI value is less than 1.0, fish body length (FL) is less than 70 cm (Yuen and June, 1957) or between 80-100 cm (Kikawa, 1966 and Suzuki, et al., 1978). In the intermediate stage, the GI value is between 1.0 to 1.5 (Kikawa, 1959; 1966) or 1.0 to 2.0 (Kikawa 1962; Sun and Yang, 1983), the fish length is between 101-120 mm (Yuen and June, 1957; Kikawa, 1966 and Suzuki et al., 1974). In the maturity stage, the GI value is greater than 1.6 (Kikawa, 1959, 1966) or greater than 2.0 (Shung, 1973; Sun and Yang, 1983) or greater than 2.1 (Kikawa, 1962), while the fish length greater than 100 cm (Koido and Suzuki, 1989) or 120 cm (Yuen and June, 1957; Kikawa, 1966; Suzuki et al., 1978).

SIZE AT FIRST MATURITY

Table 2 shows the study of size at the first maturity of yellowfin by different authors at different specific area. The size at first maturity range from 52.5 cm (Wade, 1950) to the size greater than 110 cm (Kikawa, 1962) or 120 cm (Yuen and June, 1957), or between 106-112 cm (Sun and Yang, 1983). The length at which a certain fraction (e.g. 50%) of the population reach maturity is an important parameter for stock assessment (Schaefer, 1987). The size at which 50% of the female reaches maturity were estimated to range between 110 and 120 cm (Yuen and June, 1957; Kikawa, 1962).

Hisada (1973), Suzuki (1988), Koido and Suzuki (1989) and Suzuki (1991) noted that surface fisheries (such as surface handline and purse seine) caught more mature yellowfin than longline fishery did. This results supports the hypothesis that the spawning takes place near the surface as suggested by Hisada (1973).

SPAWNING SEASON

Yellowfin tuna in the central and western Pacific Ocean spawn during all months of the year, with the peak activity occurring at different time of the year (Table 3). Cole (1980) noted that the yellowfin spawning in the western and central regions of Pacific Ocean take place in the northern latitudes during the spring and summer of the Northern Hemisphere and in the southern latitudes during the spring and summer of the Southern Hemisphere. In the equatorial waters of the western and central Pacific spawning takes place year-around.

After Cole (1980), there were several scientists examining the spawning seasons of the yellowfin in western Pacific Ocean. Sun and Yang (1983) noted that the main spawning seasons in the area between 10-23^{o}N and 110-135^{o}E seem to occur in the second and third quarters while the area between 0-10^{o}S and 110-135^{o}E was year around. Yesaki (1983) considered two spawning peaks occurred in the philippine water, the major peak, March-May and lesser peak, Nov-Dec. Based on purse seine sample, Koido and Suzuki (1989) noted that main spawning seasons in the area between 5^{o}S and

10°N and between 130°E and 170°E was from November to April. Yamanaka (1990) showed that the two spawning seasons in the Philippine water were one in April, the other in October.

SEX RATIO

The sex ratio of the yellowfin from central and western Pacific Ocean is about 1:1 until a length of about 120 cm is reached. Male predominate the larger fish (Table 4). The phenomenon of the predominance of males for large sizes class may be due to differential growth rate, differential mortality rate or some sex-connected differential behavior making larger males more amenable to capture than large females (Schaefer et al., 1963). These possibilities needed be verified by further evidence.

FECUNDITY

June (1953) noted that there was a linear regression between the weight and fecundity of the eleven yellowfin tuna (weight range from 47.2 to 88.0 kg) taken by Hawaiian longline fishery. The linear regression equation is following:

$$Y = 125200X - 2,853,000$$

where Y is the number of the maturing ova and X is the fish weight in kilograms. The number of eggs was estimated to be $2,379 \times 10^3$ to $8,590 \times 10^3$ by the above equation.

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Table 1. Definition of the various maturity stages of yellowfin tuna.

Stage of Maturity	Principle Feature (June, 1953) (Yuen & June, 1957)	Stage of Maturity (June, 1953)	Mode of the Egg Diameters (mm) (June, 1953) (Yuen & June, 1957)
Immature	The eggs are translucent	A	0.08-0.18
Inter-mediate	The largest eggs are semiopaque	B	0.19-0.29
		C	0.29-0.39
Maturity	The largest eggs are fully opaque	D	0.39-0.49
		E	0.49-0.59
		F	0.59-0.69
		G	0.69-0.79
		H	0.79-0.89
		I	0.89-0.99
Ripe	The largest eggs are transparent and loose (A prominent oil globule is present in each egg)	J	1.0
Spawn out	Ovaries with a few loose ova in the lumina including somewhich are undergoing degeneration	K	

Table 1. Definition of the various maturity stages of yellowfin tuna (Continued).

Stage of Maturity	Gonad Index (GI)	Fork Length (FL) (cm)
Immature	<=1.0 (Kikawa, 1962) (Sun & Yang, 1983)	<=70 (Yuen & June, 1957) or 80-100 (Kikawa, 1966) (Suzuki et al., 1978)
Inter-mediate	1.0-1.5 (Kikawa, 1959, 1966) or 1.0-2.0 (Kikawa, 1962) (Sun & Yang, 1983)	101-120 (Yuen & June, 1957) (Kikawa, 1966) (Suzuki et al., 1978)
Maturity	>1.6 (Kikawa, 1959;1966) or >2.0 (Shung, 1973) (Sun & Yang, 1983) or >2.1 (Kikawa, 1962)	>120 (Yuen & June, 1957) (Kikawa, 1966) (Suzuki et al., 1978) or >100 (Koido & Suzuki, 1989)
Ripe		
Spawn out		

Table 2. Size at first maturity of yellowfin tuna in central and western Pacific Ocean.

Study Area	Study Method	Size at First Maturity	Investigators
Philippine water	External features of the ovaries	mimimum: 52.5 cm (M)	Wade, 1950
Philippine water	Microscopic examination of egg diameter	mimimum: 56.7 cm (F)	Bunag, 1956
Central Equatorial Pacific	GI analysis	mimimum: 70 cm usually at > 120 cm (50% maturity at 110-120 cm)*	Yuen & June, 1957
Western & Central Pacific	GI analysis	a few at 80-110 cm (F) majority at > 110 cm (50% maturity at 110-120 cm)*	Kikawa, 1962
10-23N 110-135E	GI analysis	112 cm	Sun & Yang, 1983
0-10N 110-140E	GI analysis	106 cm	Sun & Yang, 1983

* size at 50% maturity.

Table 3. Spawning seasons of yellowfin tuna in central and western Pacific Ocean.

Study Area	Spawning Season	Investigator
WESTERN PACIFIC		
North of 10N (Kuroshiwo current area)	May & June	Yabe & Ueyanagi, 1962
30-35N 130-145E (Pacific coast of Japan)	summer months around June-July	Mori, 1970
The water off Luzon Island to southern Japan	April, May and June	Kikawa, 1961
10-23N 110-135E	April-Sept	Sun & Yang, 1983
Philippine water	peak: May-August	Wade, 1950
Philippine water	Major peak: March-May Lesser peak: Nov-Dec	Yesaki, 1983
Philippine water	Major peak: April Lesser peak: Oct	Yamanaka, 1990
Western equatorial Pacific (northern Marshall Island)	summer months	Marr, 1948
Western equatorial Pacific	summer months	Shimada, 1951
Western tropical Pacific (120E-180)	peak: Dec-Jan	Kikawa, 1966

Table 3. Spawning seasons of yellowfin tuna in central and western Pacific Ocean (Continued).

Study Area	Spawning Season	Investigator
Western tropical Pacific 5S-10N 130-170 E	peak: Nov-April	Koido and Suzuki, 1989
0-10N & 110-140E	year round	Sun & Yang, 1983
East Australia current area	Nov-Dec	Yabe & Ueyanagi, 1961
The Coast of New Caledonia	Oct through March peak: during summer	Legand, 1961
Western Pacific 130-170E south of equator	peak: Jul-Dec	Suzuki et al., 1978
CENTRAL PACIFIC		
Hawaiian Island	May-Sept peak: June-Aug	June, 1953; Matsumoto, 1966
10N-10S 180-120W	year round peak: March-Sept	Matsumoto, 1966; Suzuki et al., 1978
Central equatorial Pacific 8-10N 120W-180	throughout most of year with lowest in Nov-Jan	Yuen & June, 1957
Central tropical Pacific 140W-180	peak: April-May	Kikawa, 1966
10-25S 150-130W	Oct-March	Kikawa, 1961

Table 4. Sex ratio of yellowfin tuna in central and western Pacific Ocean.

Study Area	Sex Ratio	Investigator
Western Pacific	1:1 up to 122 cm thereafter male dominate	Murpphy & Shomura, 1955; Shomura & Murphy, 1955
Central Pacific & easterward of 120W	The size at which males dominated was somewhat larger	Murpphy & Shomura, 1955; Shomura & Murphy, 1955
Western & central Pacific	F:M=1:1 up to 120 cm decrease steadily for the larger fish	Kikawa, 1966; Yesaki, 1983; Yamanaka, 1990
0-23N 110-140E	F:M=1:1 at around 100-110 cm decreasing with the increasing fish size F:M=1:2 for the total sample collected	Sun & Yang, 1983
Western equatorial Pacific	Proportion of male > female F:M=1:4	Shimada, 1951
Hawaii water Central equatorial region (155W-180)	F:M=0.6:1.0 in favor of male	Iversen, 1956