REPRODUCTIVE BIOLOGY OF YELLOWFIN TUNA IN THE EASTERN INDIAN OCEAN[1]

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ABSTRACT

Reproductive biology of yellowfin tuna in the Eastern Indian Ocean was conducted from January 2001 to December 2003 which collected the data from surface longline that unloaded their catch at Phuket fishing port, Thailand. The total number of reproductive samples was 495 samples, including 355 ovary and 140 testis samples.

Spawning season of female and male of yellowfin found in November to April. Average monthly sex ratio was 1:0.4, the present result indicated that sex ration equal 1:1 during spawning season. The size at first maturity of female and male was reported 109.69 cm (25 kg) and 104.95cm (22 kg), respectively. Sex ratio by length class indicated small size of yellowfin (95.00-135.00 cm) comprise of female more than male while large size of yellowfin (145.00-155.00 cm) found proportion of female less than those size, the proportion of female and FL equation is $Rf = 2.2327-0.01296xFL$. The estimated from counts of hydrated oocytes, varied from 0.3 to 5.3 million oocytes, while the average diameter of oocytes found 0.56 mm.

INTRODUCTION

Yellowfin tuna (*Thunnus albacares*) are an important component of tuna fisheries throughout the Indian Ocean. Total catch reported 450,000 tonnes in 2003; from longliners (83,480 tonnes) for sashimi market, purse seiners (227,417 tonnes) for tuna cans and other gear (139,100 tonnes). The longline catch of Yellowfin tuna (YF) had increased from approximately 34,000 tonnes during 1970 to 1989 and sharp increasing in 1993 (195,655 tonnes) after that the catch had decreased until in 2003. For trend of purse seine capture has been increasing since 1983 (13,237 tonnes) to 2003 (227,417 tonnes) (IOTC Fishstat Data set 1950-2003). Incase of longliner, they are the target species of the large 'distant-water' longliners from Japan, Taiwan and China and of the smaller 'fresh-tuna' longliners based in several Indian Ocean Island countries, especially Indonesia and Taiwan. Prices paid for both frozen and fresh product on the Japanese sashimi market are the high price for the tropical tunas.

In response to the high exploitation rates of YF, the Indian Ocean Tuna Commission (IOTC) initiated a research program focusing on YF in 1999. The main objectives of this program was to update the knowledge on the biology of the species, and study the stock structure and dynamics in order to assess the effect of the current fishing pressure on the resource. Among the various tasks assigned to the program, emphasis was placed on YF reproductive biology. In 2001, the IOTC Working Party on Tropical Tunas recommended that determine the growth and age (and/or size) at first maturity for YF caught in the north-east Indian Ocean.

Uncertainties exist in the reproductive biology of YF, which limits our ability to manage the stock. In lieu of validated length-at-age data, estimates of the age distribution of the catch are based on the conversion of lengths and weights to ages based on estimated growth curves. In addition, spawning season, size at first mature and sex ratio of YF from throughout the exploited population would improve our understanding of a number of aspects of the species biology and ecology all of which are of importance in the development of optimal management strategies.

Phuket is an important port of foreign purse seine and longline fleets that have landed YF caught in the north-east Indian Ocean since 1994. Then, the result of the present study on reproductive biology of YF is the useful and advantage research study on YF management in the Indian Ocean.

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[1] *This paper presented at the 7 th Working party on Tropical Tunus, IOTC, held at Phuket, Thailand, 18 to 22 July 2005.*

MATERIAL AND METHOD

Port-sampling had been conducted to collect fishing and biological data of YF e.g. fishing ground, individual of processed weight (kg), folk length (cm) and gonad by the staff of Andaman Sea Fisheries Research and Development Center (AFRDEC) and Samplers of Cooperation Project for Enhancing the Data Collection and Processing Systems for Tuna Resources in the Indian Ocean between Department of Fisheries and IOTC-OFCF on a monthly basis at landing ports, namely Phuket fishing port since January 2001 to December 2003. All of gonad samples had collected in monthly and labeled after that transferred to AFRDEC laboratory. Total number of gonad sample was 495 samples, including ovary and testis were 355 and 140 samples, respectively.

Gonad samples was removed by worker at the processing plant, AFRDEC staff collected and labeled, placed in a sample bag and put on ice. The tuna carcass will be given a matching label so that the fish and reproductive organ can be identified when the catch is landed from which vessel. Each sample was to be labeled with sample number, vessel name and landing date matching these entries on the landings form. Folk lengths (cm) and dressed weight (kg) of each fish sampled was to be measured. Conversion factors for estimating the whole weight from the processed weight have been published by Data summary for 1987-1996 (Anon., 1998), the factor is used 1.10. Gonad was classified and weighted in gram. In addition, coefficient valves (a and b) from length and weight relationship equal 3.0×10^{-5} and 2.90 followed Nootmorn *et al*. (2001). Fecundity study, the ovaries at stage 3-5 were fixed in 10% formalin and counted only counts of hydrated oocytes (Farley and Davis, 1998).

The gross classification studied on maturity stages that was applied follow Schaefer (1987):

Ovary: Stage 1 Immature, Thin hollow tubes 3-4 mm diameter and colour translucent/white.

Stage 2 Early developing, recover spent, Oocytes visible on inner ovary wall. Blood vessel visible distinctly on external of ovary wall. Colour pale reddish/orange.

Stage 3 Later developing, Ovary and oocytes develop, oocytes shape not round and tight attached. Blood vessel visible less than previous stage. Colour pale orange.

Stage 4 Mature, Ovary has well develop. Oocytes slip off inner of ovary wall, shape rounded and translucent area surround opaque oocytes. Colour pale orange/yellow.

Stage 5 Spawned, Characteristic ovary soften, deflated and flaccid. The rest of oocytes found in ovary. Colour dark orange/yellow

Testis: Stage 1 Immature, Thin hollow tubes 3-4 mm diameter and colour translucent/white.

Stage 2 Early developing, recover spent, Testis tubes develop and blood vessel visible in the tube. Spermatogonia and spermatocytes present and mitotically divide in nests. Colour pale white/reddish.

Stage 3 Later developing, Testis tubes well develop and blood vessel visible in the tube less than previous stage. All stages of sperm development, ripe sperm becoming abundant in cysts and lobule lumen but not in ducts. Colour white/reddish.

Stage 4 Mature, Gonad full of sperm, packed with ripe sperm in lobules and ducts. Colour white/reddish.

Stage 5 Spawned, Gonad soften, deflated and flaccid. Colour dark white.

Data Analysis

Sex ratio, the monthly proportion of male and female was used to expect the spawning capability of fish (Hamano and Matsuura, 1987). In this study is hypothesis that sex ratio of male and female equal 1 at 95 % of confident interval, the method to analyze is Chi-square test (Snedecor and Cochran, 1973) ($\chi^2_{0.05,1} = 3.8415$) followed the equation as :

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

When, Observed = Value from sampling
Expected = Value from calculation

The relationship of folk length frequency of male and female of YF with female sex ratio in each length class interval were calculated follow Boonyanich (1998) as:

$$Rf = a+bxFL$$

When, Rf = Nf/(Nf+Nm) = Female sex ratio
FL = Median of each Fork length class
Nf = Number of female
Nm= Number of male
a, b =Coefficient valve from regression model

The average of maturity stage by monthly follow Dixon and Massey (1957) method as:

$$\bar{x} = \left(\frac{f}{N}\right) x100$$

When, $\bar{X}$ = Average of maturity stage
f = Number of maturity stage 3 and 4
N =Total number of ovary

Gonadosomatic Index (GI) is followed the Kikawa (1964) and Shingu (1970) method as the equation:

$$GI = (w_i/FL_i^{3P}) \times 10P^{4P}$$

When, w_i =Ovary or testis weights (gram)
FL_i = Folk length (cm)

The individual GI will be calculated the mean of GI (Mean Gonadosomatic Index).

Size at first maturity was estimated follow Bakhayokho (1983), 50 % of maturity stage 3-5 of female and male is used to be initial value to estimation. The proportion of maturity stage each frequency of length class is followed Somerton (1980) as:

$$Y = \frac{1}{(1+e^{(A+Bx)})}$$

When, Y =Proportion of maturity stage from total number at length x.
X =Mode of FL in each class interval.
A, B =Coefficient valve from regression model.

RESULT AND DISCUSSION

Fishing ground and Size frequency distribution

Their fishing grounds were located from latitude 15° N to 6° S and longitude 78° to 96° E, the Eastern Indian Ocean (Fig. 1). Size frequency distribution of female and male YF in weight and FL illustrated in Fig. 2, range of size distribution in weight and FL of female and male were 16.50-58.30 and 17.60-70.40 kg and 95.38-147.39 and 97.52-157.29 cm. Mode in weight and FL of female and male YF is 40 kg and 130 cm. Chantawong *et al.*(1999) reported that YF was caught by surface fisheries was predominantly of small size to be juvenile, whereas longline catches give a big size to be mature. Due to fishing method of surface fisheries use the drifting fish aggregating devices (FADs) to aggregate tuna, the target species of this method are small size of tuna for canning. Whereas the target species of longline are the depth free swimming school is the big size of tuna for the Japanese sashimi market.

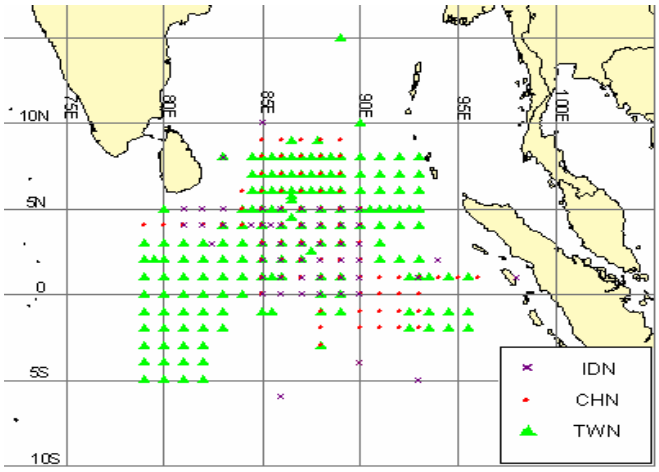

Fig1 . Fishing ground of tuna longline fleets in the EIO. Symbol:CHN=Chinese,IDN=Indonesian, TWN=Taiwanese.

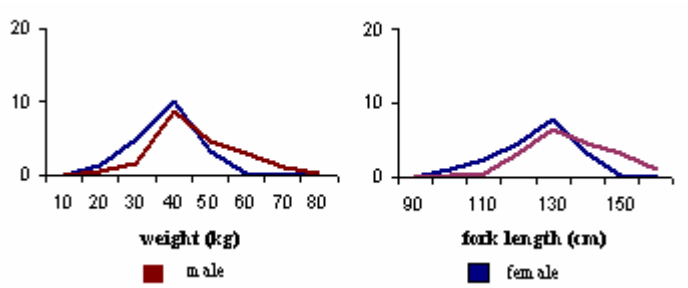

Fig 2. Weight and length frequency distribution of YF by tuna longliner from 2001 to 2003.

Sex ratio, Spawning Season and Size at first maturity

Sex Ratio of YF male and female was 1:0.40, varied from 1:0.0 to 1:7. Figure 3 show monthly percentage of male and female, the ratio equal 1:1 that only reported in January, February, April, May, September and November in 2001 and January, April, June, October, November and December 2002 and January and March 2003. As well as, sex ratio by length class indicated small size of YF (45.00-155.00 cm) comprise of female more than male while large size of YF (145.00 cm) found proportion of female less than small size of YF (Figure 4). The equation and Figure 5 showed the proportion of female and FL equal as:

$$Rf = 2.2327-0.01296xFL \ (r^2 = 0.8507, p=0.0317, n=6)$$

The result was same as sex ration by length class, when size of YF was longer the proportion of male was more than female, especially YF was larger than 145 cm. Sex ratio at size of yellowfin shows a similar identical percentages of males and females at sizes lower than 135 cm. Males are increasigly dominant at sizes greater than 140 cm, reaching levels close or over 80% of males at 160 cm in every oceans (Fonteneau, 2005).

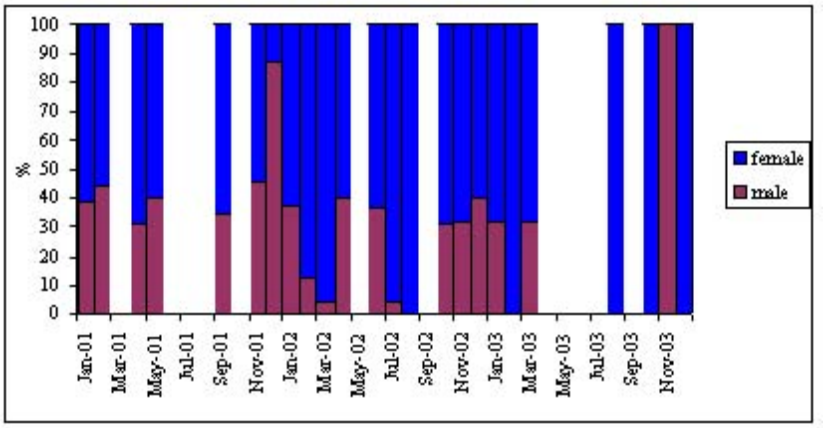

Fig 3. Monthly sex ratio YF from January 2001-December 2003.

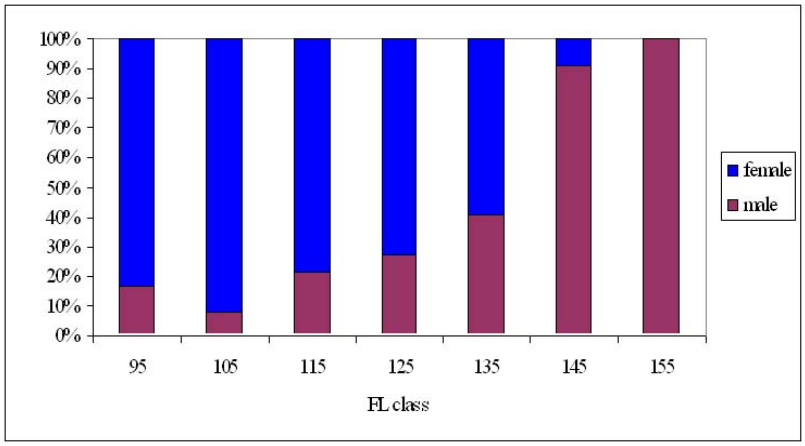

Fig 4. Change of Sex ratio by FL class of YF.

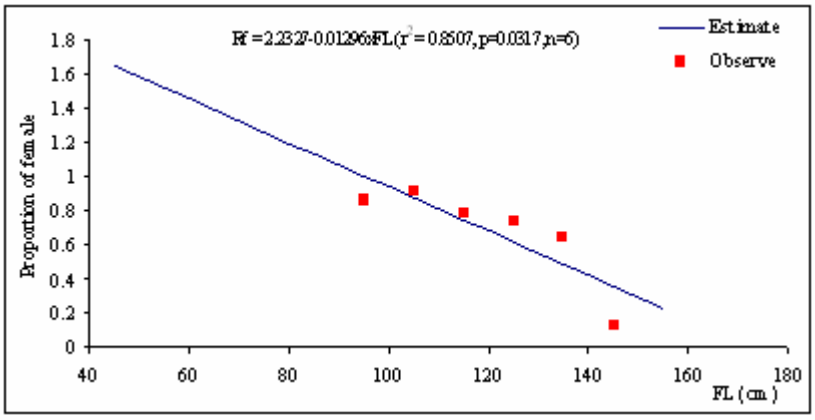

Fig 5. Relationship of female proportion and FL of YF.

Maturity of female and male YF was classified stage 1-5 and 1-4, respectively. Mean GI of female varied from 0.84 to 4.66 while male ranged 0.44 to 8.46 (Table 1). Stequert and Marsac (1989) cited after Shung (1973) showed that females in advanced ovarian development (therefore, capable of reproduction) produced GSI levels between 1.5 and 2.5. He also ploted the distribution of mature females with GSI levels greater than 2, indicted spawning season and area. Romena (2000) reported the spawning ground of YF using same as method of Shung (1973), which pointed out main spawning ground in the Bay of Bengal and the Eastern Indian Ocean during January to April. Figure 6 and 7 plot monthly percentage of female and male maturity with mean GSI that indicated spawning season of YF predominate in November to April 2002. In addition, the spawning season of male show the same result of female. The previous study by Shung (1973) cited Stequert and Marsac (1989) reported the spawning intensity between January and March, as well as, IOTC (2003) also reported that the spawning season of YF occurs from December to March in the equatorial area (0-10^{o} S),but the main spawning grounds seem to be between 50 and 70^{0} E. Whereas, Romena (2000) reported the spawning ground of YF using same as method of Shung (1973), which pointed out main spawning ground of YF in the Bay of Bengal and the Eastern Indian Ocean during January to April. The result was similar with the present study. Figure 8 and 9 show size at first maturity of female and male that was observed from sampling data equal 95.40 cm (16.5kg) and 99.60 cm (18.7 kg). While, size at first maturity that was estimated of female and male equal 109.69 cm and 104.95 cm, respectively, that longer more the observed data. Stequert and Marsac (1989) cited after Shung (1973) reported that YF was observed to reach the size at first maturity 120 cm to 140 cm, but some rare individuals displayed only 80 cm. Romena (2000) cited after Froese (1999) found that YF attain sexual maturity at lengths ranging from 75.9 cm to 134.5 cm and age was estimated to be 1.8 years. He also reported YF have an external mode of fertilization. Eggs and sperm are released into the water column for fertilization. No parental care is given to the eggs or the young after spawning. IOTC (2003) reported size at first maturity at 110 cm. Fonteneau (2005) said the first spawning of yellowfin appears to significantly (50% of mature females) take place in every ocean at sizes smaller than 100 cm, e.g. at ages between 2 and 3 years. The observation by Hassani and Stequert 1991 showing a late spawning at sizes over 115 cm and a limited sexual activity of females over 1,20m in the Indian Ocean are probably biased. That mean all of previous reports are the same result of present study. The fecundity of YF from 7 samples, FL 108.8-147.4 cm., gonad weight 535-1,318 gram are 297,598 to 5,345,361 eggs and average of egg diameter 0.56 mm.

YF are multiple spawners and spawn every few days over the spawning period (Froese, 1999; Suzuki, 1994 cited after Romena, 2000). In Suzuki's review, YF in western Pacific spawned every 1.7 day while an interval of 1.3 days was observed in the eastern Pacific. Further, he cited that spawning occurs at 20.00 to 24.00 hours. He mentioned that some authors believe that spawning occurs during new moon and further suggested that it may be affected by the monsoon season, specifically in Philippine waters. Father, YF are multi-batch spanners. They spawn 6-7 batches of eggs during spawning period in the western Indian Ocean. Sexual activity occurs during the months of November to February, while lasted inactivity from June to September.

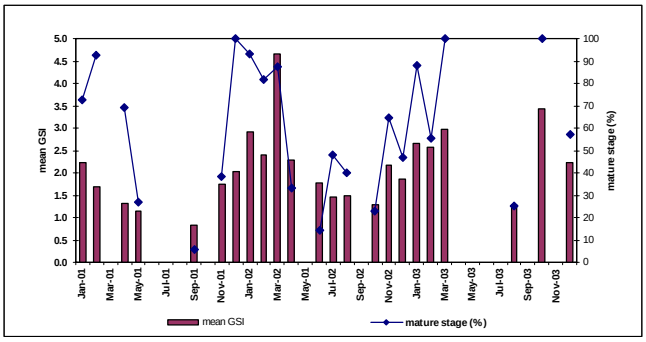

Fig 6. Monthly change of percent of maturity and GSI of female YF from January 2001-December 2003.

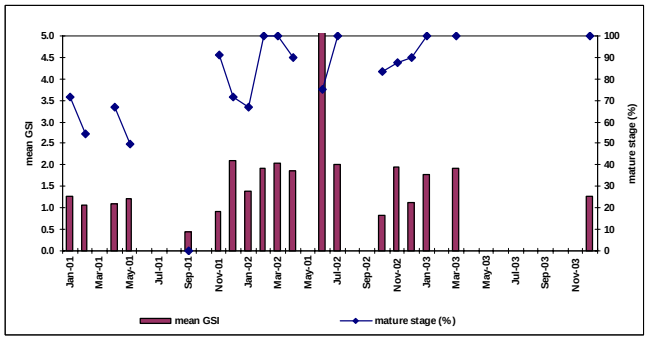

Fig 7. Monthly change of percent of maturity and GSI of male YF from January 2001-December 2003.

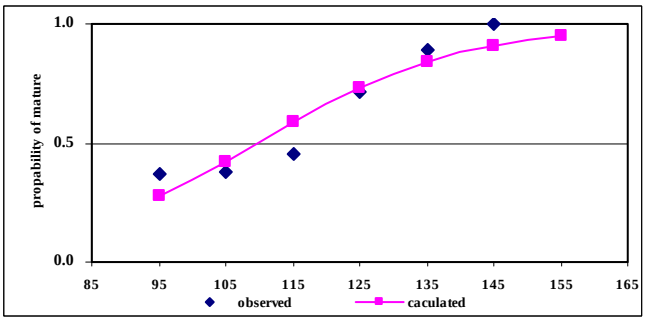

Fig 8. Size at first maturity at 50% of female.

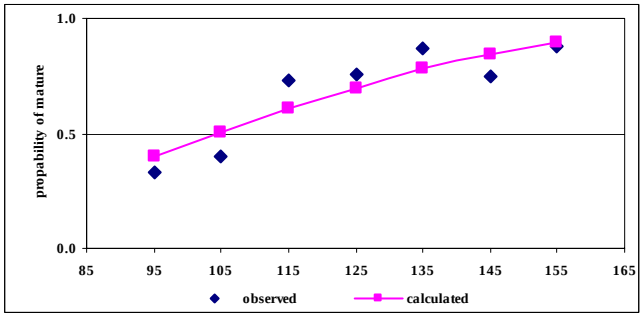

Fig 9. Size at first maturity at 50% of male.

CONCLUSION

1.Monthly sex ratio of male and female YF was 1:0.40. The proportion of male and female equal 1:1 only in January, Febuary, April, May, September and November in 2001 and January, April, June, October, November and December 2002 and January and March 2003.

2.Sex ratio by each length class indicated small size of YF (95.00-135.00 cm) comprise of female more than male while large size of BE (145 cm) have the proportion of male more the small size of YF. The equation of proportion of female YF and median FL equaled Rf = 2.2327-0.01296xFL (r^2 = 0.8507, p=0.0317, n=6).
3.Spawning season of female and male of YF found in November to March.
4.The size at first maturity of female and male was reported 109.69 and 104.95 cm.
5.The fecundity of yellowfin was 297598 to 5345361 eggs while the average of egg diameter was 0.56 mm.

PROBLEMS ENCOUNTERED AND RECOMMENDATION

1.The lack of gonad sample of YF in some months, especially during the low fishing season (May to September).
2.Histological classification on reproductive study should be concern, a subsample was removed from 200 ovaries and fixed in 10 % buffered formalin. It was necessary to assess whether histological sections prepared for determine gonad stage and spawning activity. Although considerable cell was observed in oocytes, atretic oocytes and postovulatory follicles and classified nonspawning or post spawning. In this study will use the ovary stage 3 to 5 for counting and estimation fecundity. We estimated batch fecundity from nonspawning ovary (the number of hydrated oocytes released per spawning) by the gravimetric method.

Table1. Development of YF maturity stage in EIO.

	Number of specimens			mean GSI		Mature stage (%)	
month	female	male	total	female	male	female	male
Jan-01	11	7	18	2.22	1.26	72.73	71.43
Feb-01	14	11	25	1.68	1.07	92.86	54.55
Mar-01							
Apr-01	13	6	19	1.31	1.10	69.23	66.67
May-01	15	10	25	1.15	1.20	26.67	50.00
Jun-01							
Jul-01							
Aug-01							
Sep-01	17	9	26	0.84	0.44	5.88	0.00
Oct-01							
Nov-01	13	11	24	1.73	0.91	38.46	90.91
Dec-01	1	7	8	2.03	2.10	100.00	71.43
Jan-02	15	9	24	2.92	1.40	93.33	66.67
Feb-02	22	3	25	2.39	1.92	81.82	100.00
Mar-02	24	1	25	4.66	2.03	87.50	100.00
Apr-02	15	10	25	2.28	1.85	33.33	90.00
May-02							
Jun-02	7	4	11	1.76	8.46	14.29	75.00
Jul-02	25	1	26	1.46	2.01	48.00	100.00
Aug-02	10	0	10	1.49		40.00	
Sep-02							
Oct-02	13	6	19	1.29	0.82	23.08	83.33
Nov-02	17	8	25	2.16	1.94	64.71	87.50
Dec-02	15	10	25	1.86	1.12	46.67	90.00
Jan-03	17	8	25	2.65	1.77	88.24	100.00
Feb-03	27	0	27	2.58		55.56	
Mar-03	17	8	25	2.96	1.92	100.00	100.00
Apr-03							
May-03							
Jun-03							
Jul-03							
Aug-03	8	0	8	1.29		25.00	
Sep-03							
Oct-03	25	0	25	3.44		100.00	
Nov-03	0	11	11				
Dec-03	14	0	14	2.22	1.28	57.14	100.00
Total	355	140	495				

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