ISSN 0970 - 6011

Volume 57, Number 2, 2010

Indian Journal of Fisheries

Indian Council of Agricultural Research

Published by
The Director
Central Marine Fisheries Research Institute
Cochin - 682 018, Kerala, India
www.cmfri.org.in

Indian J. Fish., 57(2) : 7-13, 2010

Fishery, population characteristics and yield estimates of coastal tunas at Veraval

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ABSTRACT

The fishery, population characteristics and yield estimates of coastal tunas *Thunnus tonggol, Euthynnus affinis* and *Auxis thazard* at Veraval were studied during 2003 – 2006. The average annual catch was 731 t, which contributed to 28% to the total gillnet catches. The main species of tunas landed were *T. tonggol* (46.8%), *E. affinis* (17.5%), *Thunnus albacares* (6.4%) and *A. thazard* (5.2%). *E. affinis* and *A. thazard* exhibited isometric growth but for *T. tonggol* it was allometric. The von Bertalanffy growth equation was $L_t = 107.4\ [1 - e^{-0.18\ (t + 0.0729)}]$ for *T. tonggol*, $L_t = 72.5\ [1 - e^{-0.56\ (t + 0.0327)}]$ for *E. affinis* and $L_t = 46.6\ [1 - e^{-0.93\ (t + 0.0153)}]$ for *A. thazard*. The mortality rates M, F and Z for *T. tonggol* were 0.4, 0.72 and 1.12 respectively, while for *E. affinis* and *A. thazard*, the values were 0.94, 1.48 and 0.75 and 4.49, 1.69 and 5.97, respectively. The exploitation ratios for *T. tonggol*, *E. affinis* and *A. thazard* were 0.64, 0.44 and 0.75 respectively. The higher exploitation rate and lower MSY in *T. tonggol* and *A. thazard* was an indication of intensive fishing and overexploitation of these speceis. But for *E. affinis,* the exploitation rate was low and MSY was high indicating further scope for exploitation. Reducing the present fishing effort by 40%, maximum relative yield was realized for *T. tonggol* and *A. thazard* but for *E. affinis*, increasing the fishing effort by 80% provided the maximum relative yield.

Keywords: Coastal tunas, Fishery, Population dynamics, Yield estimates

Introduction

Coastal tunas represent an important group of large pelagics in the waters along the Saurashtra coast and constitute a major component of the exploited marine fishery resources. The annual catch of tunas from Gujarat in 2006 was 0.085 lakh tonnes, which was substantially high when compared to 0.052 lakh tonnes in 2002 (Mohanraj *et al*., 2007). The fishing season for tunas along the coast of Saurashtra is from September to May with peak during October - December. Drift gillnets (mesh size of 110 – 115 mm and 160 – 165 mm) operating from FRP canoes having 9 – 12 m overall length (OAL) fitted with outboard and inboard engines are actively engaged in tuna fishing at a depth of 30 – 50 m. During 2002-2006 period, long tail tuna, *Thunnus tonggol*, a neritic species dominated the landings (50.7%) followed by *Euthynnus affinis* (19.6%), *Katsuwonus pelamis* (13.4% during 2002 - 2006), *Auxis thazard* (11.9%), *Thunnus albacares* (3.5%) and *Sarda orientalis* (1.1%) (Mohanraj *et al*., 2007).

There is considerable information on the fishery and the exploitation status of coastal tunas from Tuticorin (Abdussamad *et al*., 2005), Maharashtra waters (Zafar Khan, 2004), North Andhra Pradesh waters (Sujatha and Deepti, 2006), Chennai (Kasim and Mohan, 2007), Vizhinjam (Gopakumar *et al*., 1989), Cochin (Silas *et al*., 1985), Lakshadweep (Sivadas, 2002; Nasser *et al*., 2002) and Andaman and Nicobar Islands (Madhu *et al*., 2002). However, no published information is available till date on the fishery and population characteristics of coastal tunas from Veraval waters. The present study is aimed to provide an insight into the fishery, population characteristics and yield estimates of coastal tunas landed at Veraval.

Materials and methods

Data on catch and effort expended for coastal tunas were collected weekly from commercial gillnetters of Veraval for a period of four years during 2003 - 2006. A total of 2,976 specimens of *T. tonggol* in the size range of 30 to 97.9 cm, 1,680 specimens of *E. affinis* in the size range of 26 to 69.9 cm and 1,788 specimens of *A. thazard* in the size range of 20 to 47.9 cm collected randomly were used for recording fork length and body weight. The length-weight relationship of the three species of coastal tunas was calculated as described in Le Cren (1951).

Growth parameters *viz.,* asymptotic length (L_α) and growth co-efficient (K) were estimated using the ELEFAN I module of FiSAT software and the Powell – Wetherall plot (Gayanilo *et al*., 1996). The length-based growth performance index, Ø was calculated from $L\alpha$ and K as in

Pauly and Munro (1984). The probability of capture and size at first capture (L_c) were estimated as in Pauly (1984) and the age at zero length (t_0) from Pauly's (1979) empirical equation. Longevity was estimated from $t_{max} = 3/K + t_0$ (Pauly, 1983a).

Natural mortality (M) was calculated by Pauly's empirical formula (Pauly, 1980) and total mortality (Z) from length converted catch curve (Pauly, 1983b). Length structured virtual population analysis (VPA) was used to obtain fishing mortalities per length class. Exploitation ratio was estimated from the equation, E = F/Z and exploitation rate from $U = F/Z*(1-e^{-z})$; where, F is the fishing mortality rate.

Total stock (P) and biomass (B) were estimated from the ratios Y/U and Y/F respectively; where Y is the annual average yield in tonnes. Maximum sustainable yield was calculated as in Gulland (1979) for exploited fish stocks. The relative yield per recruit (Y/R) and biomass per recruit (B/R) at different levels of F was estimated using LFSA package (Sparre, 1987).

Results

Fishery

The average annual catch of tunas for the period 2003 – 2006 was 731 t, which contributed 28% to the total gillnet catches at Veraval. An annual catch of 80 t recorded in 2003, increased sharply by about thirty folds to 2,267 t in 2006 (Fig. 1). The catch rate similarly exhibited an increasing trend over the years with the lowest of 4.3 kg unit^{-1} in 2003 and highest of 104.2 kg unit^{-1} in 2006. The average catch rate during the period was 38 kg unit^{-1}. Contrary to the tremendous increase in catch, the effort expended by gillnetters during the period increased marginally from 18,616 units in 2003 to 21,661 units in 2006. The percentage contribution of tunas to total fish catch by gillnets at Veraval also increased sharply from 5.4 % in 2003 to 47 % in 2006.

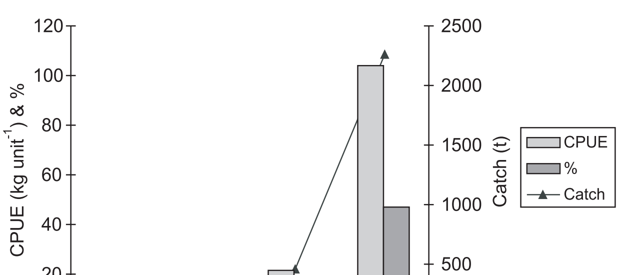


Fig. 1. Annual catch of tuna by gillnetters at Veraval

Catch composition

The main species of tuna landed at Veraval was *T. tonggol* (46.8%), followed by *E. affinis* (17.5%), *T. albacares* (6.4%) and *A. thazard* (5.2%). The remaining contribution to the fishery was of *K. pelamis*, *S. orientalis* and *A. rochei*. There has been a distinct change in species composition of tunas caught by gillnetters over the years. The percentage representation of *T. tonggol* and *A. thazard* in the total tuna catch at Veraval has shown a decreasing trend from 68.1% and 12.5% in 2003 to 46.6% and 3.8% in 2006 respectively. *T. albacares* appeared in the tuna fishery from 2004 onwards and has since shown an increasing trend. There has also been an emergence of fishery for *K. pelamis* and *S. orientalis* in 2005 and since then both species together contributed more than a quarter to the total tuna catch at Veraval.

Seasonal abundance

Tunas were exploited round the year except in July due to suspension of the gillnet fishery. Majority of the fish were landed during September - April period (Fig. 2). December and February – April were found to be the most productive period in terms of catch and catch rate. The average monthly catch of tuna was highest in March (163.4 t) followed by December (122 t) and the catch rate was maximum in March (106.6 kg unit^{-1}) followed by April (89.1 kg unit^{-1}). The average month-wise proportion of tuna in the gillnet landings was similarly higher in December (41%) and from February to April (38.6% - 65.8%). *T. tonggol*, *E. affinis*, *T. albacares* and *A. thazard* supported the fishery round the year, but *K. pelamis* and *S. orientalis* were landed only in the first half of the year.

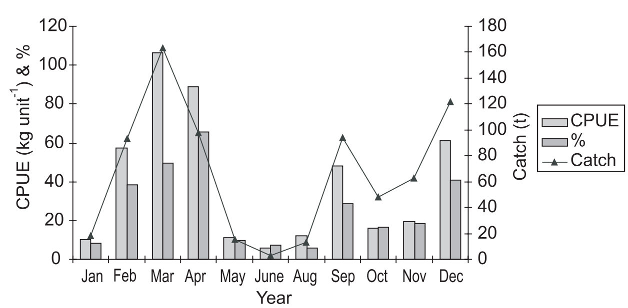


Fig. 2. Seasonal abundance of tuna at Veraval

Length composition

The mean length of all the three species of tuna witnessed an increasing trend during the four year study period. The mean length for *T. tonggol* increased from 59.15 cm in 2003 to 64.9 cm in 2005, but subsequently decreased to 63.36 cm in 2006. For *E. affinis* and *A. thazard*, the mean length of 43.88 cm and 31.21 cm recorded in 2003 increased rapidly to 47.97 cm and 38.7 cm in 2004 and then decreased to 45.63 cm and 33.9 cm respectively in 2006. Higher mean length for *T. tonggol* was recorded in the months of February (73.27 cm) – March (65.17 cm) and September (62.75 cm) – October (68.33 cm), while for *E. affinis* and *A. thazard,* the higher mean lengths were recorded in the months from September (55.23 cm and 34.84 cm) – November (49 cm and 33.4 cm) and January (44.42 cm and 38.39 cm), respectively.

Length-weight relationship

The estimated length-weight relationship for *T. tonggol* is:

log W = -1.031743 + 2.514743 log L (r = 0.97)

For *E. affinis*, the length-weight relationship estimated is:

log W = -1.931304 + 3.055823 log L (r = 0.98) and for

A. thazard it is:

log W = -2.082723 + 3.171805 log L (r = 0.96)

Growth

T. tonggol

The growth parameters, L_α and K estimated using the ELEFAN I programme were 107.4 cm and 0.18 $year^{-1}$ respectively. The growth performance index Ø was 3.317 and t_0 was calculated at -0.0729 years. The von Bertalanffy growth equation was:

$$L_t = 107.4\ [1 - e^{-0.18\ (t + 0.0729)}]$$

The length at first capture (L_c) was estimated at 31.95 cm, which corresponds to an age (t_c) of 1.9 year. The asymptotic weight (W_α) was estimated as 11904.5 g from the length-weight relationship.

E. affinis

The growth parameters, Lα and K estimated using the ELEFAN I programme were 72.5 cm and 0.56 $year^{-1}$, respectively which was close to the value (L_α = 72.71 cm) obtained from the Powell – Wetherall plot. The results of growth parameters obtained by ELEFAN were selected for further estimation. The asymptotic weight was 5669.7 g and size at first capture (L_c) was 27.42 cm at an age (t_c) of 0.82 year. The growth performance index was calculated at 3.469 and t_0 at -0.0327 years. The von Bertalanffy growth equation was:

$$L_t = 72.5\ [1 - e^{-0.56\ (t + 0.0327)}]$$

The relationship showed that *E. affinis* attained a size of 31.84 cm, 49.27 cm, 59.23 cm, 64.92 cm and 68.17 cm, respectively by the end of 1, 2, 3, 4 and 5 years. The longevity of *E. affinis* was estimated to be 5.4 years. The size composition showed that 1+ and 2+ year fishes dominated the fishery.

A. thazard

Using ELEFAN I programme, the growth parameters estimated were L_α - 46.6 cm and K - 0.93 $year^{-1}$. The L_α (46.1 cm) estimate obtained from Powell – Wetherall plot was close to the value obtained through ELEFAN I. The growth performance index, t_0 and asymptotic weight calculated were 3.305, -0.0153 years and 1618.35 g respectively. Length at first capture was 20.64 cm at an age of 0.61 year and the von Bertalanffy growth equation was:

$$L_t = 46.6\ [1 - e^{-0.93\ (t + 0.0153)}]$$

The longevity of *A. thazard* was 3.23 years and the length attained by the fish was 28.47 cm, 39.45 cm and 43.78 cm, respectively at the end of 1, 2 and 3 years. The fishery was constituted primarily by 1+ year fishes.

Recruitment

The smallest length of recruitment was 30.95 cm, 26.95 cm and 20.95 cm, respectively for *T. tonggol*, *E. affinis* and *A. thazard*. The peak recruitment (58.2%) for *E. affinis* was during September–December, while for *T. tonggol* and *A. thazard*, the recruitment occurred continuous from May – October and March – September, respectively and this pulse produced on an average 85% of the recruits.

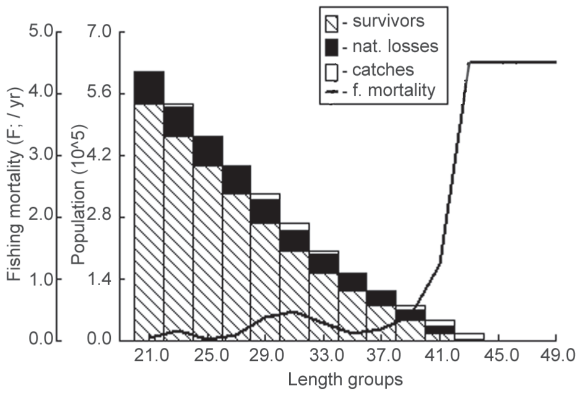
Mortality, exploitation and Virtual Pupulations Analysis (VPA)

The mortality and exploitation rates of the three tuna species are presented in Table 1. The exploitation ratio for *T. tonggol* and *A. thazard* were higher than their E_{max} of 0.54 and 0.65 indicating overexploitation of these two species. Exploitation ratio of *E. affinis* was lower than the E_{max} of 0.6 indicating further scope for exploitation.

The VPA indicated that main loss in the stock upto 50.95 cm for *T. tonggol* (Fig. 3), 34.95 cm for *E. affinis* (Fig. 4) and 26.95 cm for *A. thazard* (Fig. 5) was due to

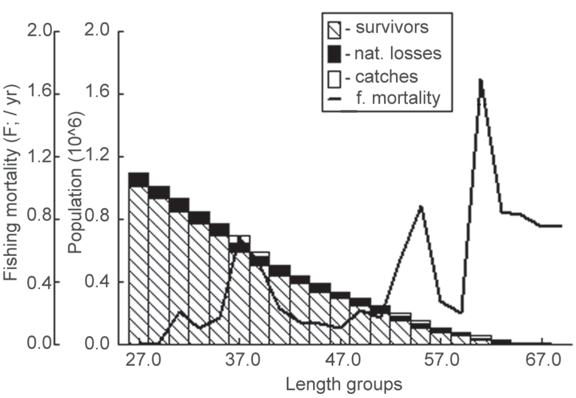
Table 1. Mortality and exploitation rates of coastal tunas landed at Veraval

Species	Natural Mortality (M)	Fishing Mortality (F)	Total Mortality (Z)	Exploitation rate (U)	Exploitation ratio (E)
T. tonggol	0.4	0.72	1.12	0.43	0.64
E. affinis	0.94	0.75	1.69	0.36	0.44
A. thazard	1.48	4.49	5.97	0.75	0.75



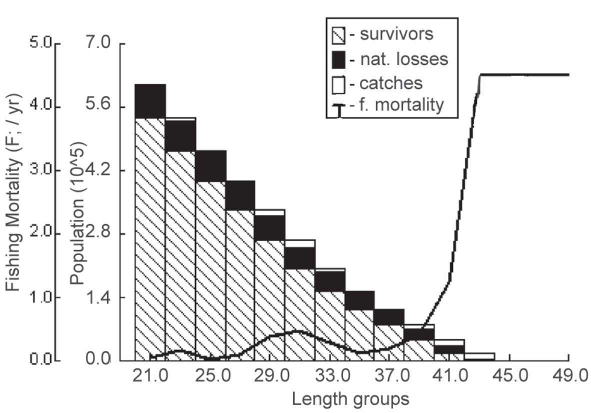
L_α = 107.4 cm, K = 0.18, M = 0.4, Term. F = 0.72,
Mean F = 0.16 and Mean E = 0.14

Fig. 3. Length structured VPA for *T. tonggol* for the years 2003 - 2006



L_α = 72.5 cm, K = 0.56, M = 0.94, Term. F = 0.75,
Mean F = 0.43 and Mean E = 0.26

Fig. 4. Length structured VPA for *E. affinis* for the years 2003 – 2006



L_α = 46.6 cm, K = 0.93, M = 1.48, Term. F = 4.49,
Mean F = 0.66 and Mean E = 0.11

Fig. 5. Length structured VPA for *A. thazard* for the years 2003 - 2006

natural causes. Fishes became more vulnerable to the gear after this size and mortality due to fishing increased and eventually in *T. tonggol* and *A. thazard,* outnumbered the natural losses.

Stock and Maximum Sustainable Yield (MSY)

The annual total stock, biomass and MSY of *T. tonggol* were estimated at 789 t, 475 t and 266 t, respectively. For *E. affinis*, the annual total stock, biomass and MSY calculated were 353 t, 170 t and 144 t and for *A. thazard*, the annual total stock, biomass and MSY were 50 t, 8 t and 25 t, respectively.

Yield/recruit

T. tonggol

The yield and biomass/recruit and yield and biomass curves showed that the maximum yield and yield/recruit could be obtained by decreasing the present level of fishing by 40% (Fig. 6). The maximum yield and yield per recruit that can be obtained at 60% of the present fishing effort is 353 t and 543.2 g, respectively. At the present level of fishing, it is 342 t and 526.1 g. The biomass and biomass per recruit achieved at 60% of the present effort is 817 t and 1257.4 g, respectively but with the present rate, the biomass and biomass per recruit is 475 t and 730.7 g. At the reduced effort, the relative yield would be 103.26%. So to get optimum yield and biomass per recruit, the present fishing effort has to be reduced by 40%.

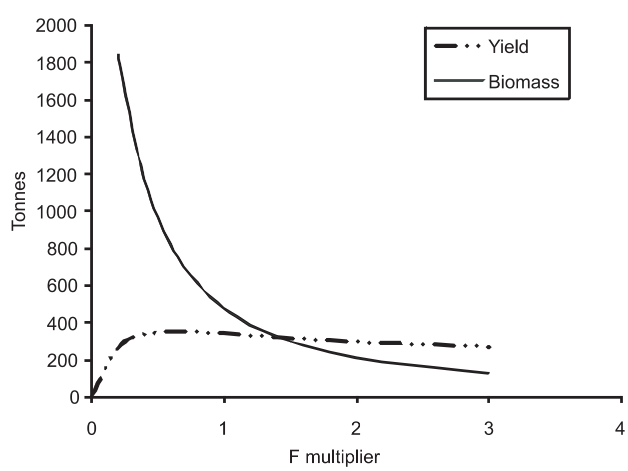


Fig. 6. Yield and biomass of *T. tonggol* for different multiples of F

E. affinis

A maximum yield of 136 t and yield per recruit of 464.5 g could be obtained by increasing the present level of fishing by 80 % (Fig. 7). At the present fishing effort, it is 128 t and 435 g, respectively. The relative yield at 180% of the present fishing effort is 106.78 %. Hence for optimum yield, the present fishing effort has to be increased by 80%.

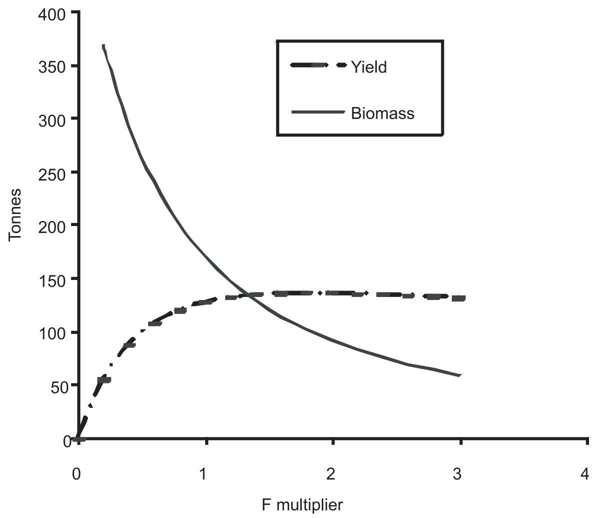


Fig. 7. Yield and biomass of *E. affinis* for different multiples of F

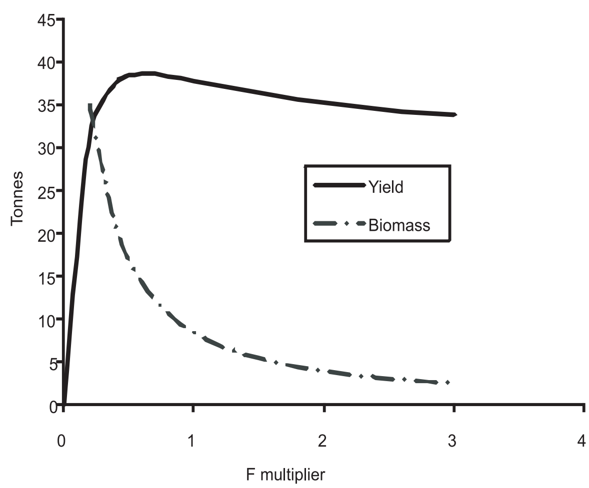


Fig. 8. Yield and biomass of *A. thazard* for different multiples of F

A. thazard

Decreasing the present level of fishing by 40%, the yield and yield per recruit could be increased from 38 t to 39 t and from 181.2 g to 184.9 g, respectively (Fig. 8). The biomass and biomass per recruit at 60% of the present effort would also increase from 8 t to 14 t and from 40.4 g to 68.6 g, respectively. The relative yield would be 102.06 % at the reduced effort. Therefore, to achieve optimum yield and biomass per recruit, the present fishing effort has to be reduced by 40%.

Discussion

The sharp increase in catch and catch rate of tunas recorded in the present study is because of the expansion of tuna fishing grounds coupled with improvement in net design and multi-day fishing operations. Longtail tuna, *T. tonggol*, being a neritic species dominates the landings at Veraval. The species composition of tuna in recent years indicated a shift of fishing grounds to more offshore areas with representation of oceanic species such as *T. albacares* and *K. pelamis*.

The length-weight relationship showed that while *E. affinis* and *A. thazard* exhibited isometric growth, the growth rate of *T. tonggol* was allometric. Similar 'b' values of 2.44, 2.70 and 2.64 for *T. tonggol* were recorded from Hormuzgan waters (Khorshidian and Carrara, 1993), Veraval (Pillai *et al*., 1995) and Mangalore (Muthiah, 1985), respectively. However, contrary to the present study, Davarpanah *et al*. (2007) reported that longtail tuna from Hormuzgan waters has isometric growth. This variation is possibly due to factors related to ecosystem and biological condition like maturity stages, feeding behavior and competition for food.

The asymptotic length and growth coefficient recorded in the present study for *T. tonggol* varied from the estimates of Davarpanah *et al*. (2007) from the Hormuzgan waters, Pillai *et al*. (1995) from Veraval and Silas *et al*. (1985) from the EEZ. Similar variations for *E. affinis* and *A. thazard* were observed in the present growth parameter estimates and those calculated by Kasim and Mohan (2007), Abdussamad *et al*. (2005) and Zafar Khan (2004) at Chennai, Tuticorin and Mumbai, respectively. This could be due to the differences in the environmental parameters, availability and competition for food. The growth rate in length recorded at the end of each year for *E. affinis* and *A. thazard* was akin to that reported by Silas *et al*. (1985) and Abdussamad *et al*. (2005). The present study revealed that both for *E. affinis* and *A. thazard,* the maximum growth rate in length was observed during the first year of life but after which the annual increment decreased with increasing age.

Beverton and Holt (1956) pointed out that the natural mortality coefficient of a fish is directly related to the growth coefficient (K) and inversely related to the asymptotic length (L_{α}) and the life span. The same was true for all the three species studied. Similar values of natural mortality for *T. tonggol* were recorded by Prabhakar and Dudley (1989) from Oman and Davarpanah *et al*. (2007) from Hormuzgan. The natural mortality in the present study for *E. affinis* was identical to 1.16 and 1.03 reported by Abdussamad *et al*. (2005) at Tuticorin and Zafar Khan (2004) at Mumbai and the natural mortality for *A. thazard* was also identical to 1.4 recorded by Abdussamad *et al*. (2005). The higher exploitation ratios observed in *T. tonggol* and *A. thazard* was an indication of intensive fishing and overexploitation of this two species, but for *E. affinis* the ratio of exploitation was low hinting at possible further scope for exploitation. The fact that MSY estimated is lower than the annual catches recorded for *T. tonggol* and *A. thazard* but higher than the annual catch for *E. affinis* provides further evidence for the above statement.

A maximum relative yield of 103.26% and 102.06%, respectively for *T. tonggol* and *A. thazard* was achieved by reducing the present fishing effort by 40%, whereas for *E. affinis* by increasing the fishing effort by 80% the relative yield will be a maximum of 106.78 %. Multispecies stock assessment of coastal tunas, therefore reveals very less possibility of further exploitation. Hence, the surplus effort in the present fishing grounds can be diverted to deeper unexploited waters. Moreover, large factory vessels should not be permitted in our EEZ as it may overexploit the stock and also obstruct their migration into the present fishing grounds. Tunas being highly migratory; multiple fisheries occur at different locii on the overall migratory routes and stock abundance depends on the condition prevailing elsewhere also. So information gained from stock assessment will have its own limitations but will provide valid evidence necessary for management guidelines and can be taken as an indicator of the present status of the fishery at Veraval.

Acknowledgements

The authors express their gratitude to Dr. G. Syda Rao, Director, CMFRI for providing necessary support and encouragement.

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Date of Receipt : 09.10.2008
Date of Acceptance : 15.06.2010

INDIAN JOURNAL OF FISHERIES
Volume 57 Number 2 (2010)

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Indexed/Abstracted in: Aquatic Sciences and Fisheries Abstracts, Biological Abstracts, BIOSIS Previews, CAB Abstracts, Fish and Fisheries Worldwide (NISC), Science Citation Index Expanded, SCOPUS and Zoological Records