Stock status of king mackerel (*Scomberomorus cavalla*)

in the Caribbean

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Abstract

We attempted a stock assessment of king mackerel in the Caribbean using ASPIC. The stock status is concluded as appears to be the overexploited stage because the catch has exceeded MSY for the last 10 years. We recommend that fishing effort and catch from all gears should be reduced to the MSY level.

Introduction

We attempted a stock assessment of king mackerel (*Scomberomorus cavalla)* because it is one of the most commercially important species in the Caribbean and because there is only paucity of information on its stock status of the resource in the region. We used ASPIC (A Surplus Production model Incorporating Catch) to conduct the stock assessment.

Fisheries, Biology and Ecology

King mackerel is a species of importance in commercial and recreational fisheries throughout its range in the western Atlantic (Collette and Nauen, 1983). Annual catches in the western Atlantic ranged from 10 000 to 20 000 tonnes between 1994 and 2003 (FAO, 2005; ICCAT, 2005). The largest catches are reported by Mexico, USA and Venezuela and are exploited mainly by hook & line and gillnet. This species is epipelagic, inhabiting the coastal waters along the continental shelf and outer reef areas and is distributed from Massachusetts, USA to Rio de Janeiro, Brazil (Collette and Nauen, 1983). Distribution of this species has also been reported in the mid Atlantic at St Paul's Rocks (Lubbock and Edwards, 1981). Spawning occurs between May and September in the western Gulf of Mexico (McEachran, Finucane and Hall, 1980 cited in Collette and Nauen, 1983) and from April through September in the northeastern Caribbean (Erdman, 1977). In Trinidad and northeastern Brazil spawning occurs throughout the year with peaks from October through March (Sturm and Salter, 1990; Gesteria and Mesquita, 1976). Sturm and Salter (1990) observed that spawning begins for both sexes at age 1-2. The species grows to a maximum size of 173 cm (FL) and weight of 45 kg (Collette and Nauen, 1983).

Several studies on stock structure suggest that there are likely heterogeneous stocks inhabiting the waters off the North American mainland (Gold et al., 2002; Johnson et. al., 1994; Powers and Thompson, 1993; Sutter et. al., 1991). Information on stock structure in the Caribbean is limited, though it is believed that North American and Caribbean stocks differ (Singh-Renton, 1996). We postulate a Caribbean stock inhabiting waters from the Yucatan region to the mouth of the Amazon (Fig.1).

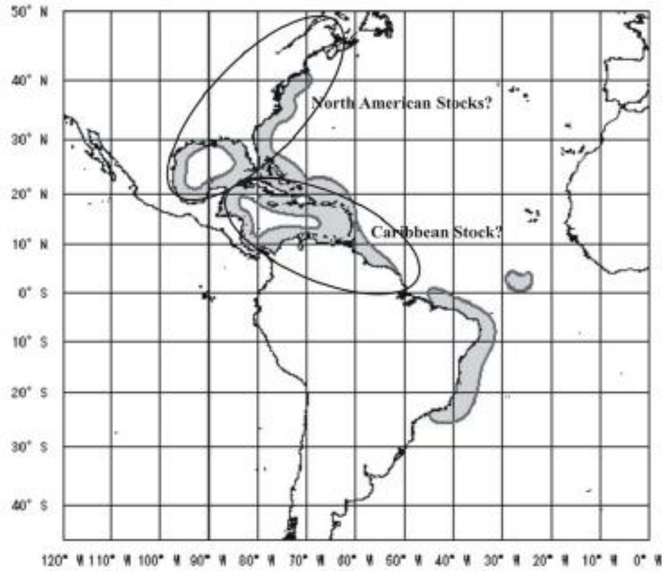

Fig. 1. Postulated stock structure of king mackerel in North America and the Caribbean

Data

In our study we focused on the ‘Caribbean stock’ of king mackerel (Fig. 1). We used annual catch and CPUE data in the ASPIC analyses. To obtain annual catch we used catch statistics available in the FAO and ICCAT databases. The major countries exploiting the Caribbean king mackerel stock are Venezuela, Mexico, Trinidad and Tobago and the Dominican Republic (Table 1 and Fig. 3). The recent total catch (2000-2004) ranges from 7 to 10 thousand tonnes (FAO, 2005).

The catch and effort data for CPUE were obtained from the database available in the Fisheries Division, Ministry of Agriculture, Land and Marine Resources, Trinidad and Tobago. At the time of this study nine years of data (1995-2003) were available. Data for the major methods targeting king mackerel - trolling (with dead and artificial bait) and a-la-vive (a troll type method with live bait) - were extracted from that database. Nominal CPUE was computed by year, month and fishing area (see Fig. 2).

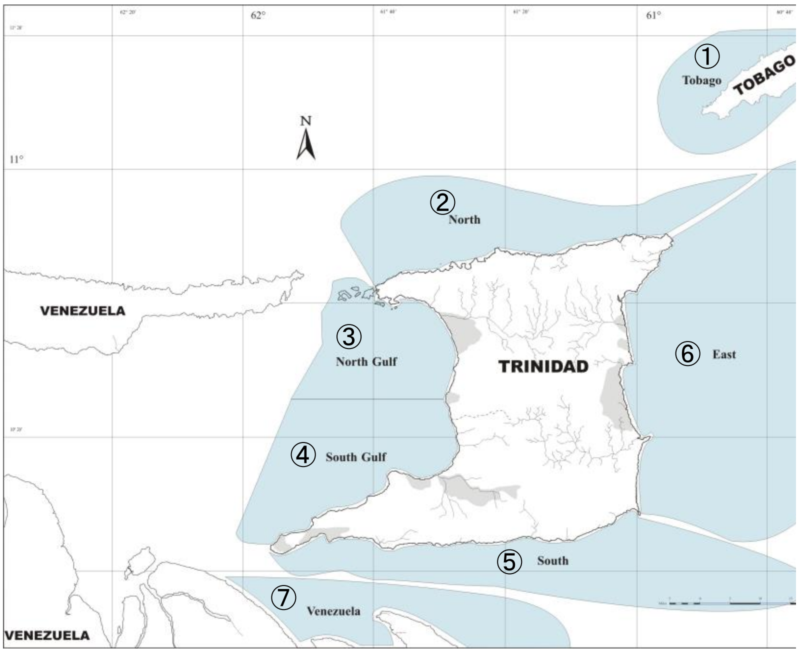

Fig. 2. Fishing areas around Trinidad and Tobago.

Table 1. Annual catch of king mackerel in the Caribeean Region by country (tonnes)

	Venezuela	Mexico	Trinidad & Tobago	Domonica R.	OTHERS	Total Catch
1950	4,000	0	232	0	0	4,232
1951	4,000	0	222	0	0	4,222
1952	3,000	0	213	0	0	3,213
1953	2,900	0	203	0	0	3,103
1954	3,200	0	193	0	0	3,393
1955	3,900	0	184	0	0	4,084
1956	2,900	0	174	0	0	3,074
1957	2,700	0	164	0	0	2,864
1958	3,000	0	154	0	0	3,154
1959	3,200	0	145	0	0	3,345
1960	4,100	1,000	135	0	0	5,235
1961	3,700	1,000	125	0	0	4,825
1962	3,500	1,000	164	0	0	4,664
1963	3,500	1,000	176	0	0	4,676
1964	3,900	900	253	0	0	5,053
1965	3,200	1,000	303	0	0	4,503
1966	3,500	900	305	100	0	4,805
1967	3,000	1,000	105	200	0	4,305
1968	1,800	700	118	200	0	2,818
1969	1,500	1,100	128	200	0	2,928
1970	1,000	907	152	200	0	2,259
1971	1,600	1,300	201	200	0	3,301
1972	1,100	1,520	160	200	0	2,980
1973	1,500	2,189	293	300	0	4,282
1974	2,204	1,531	195	324	0	4,254
1975	2,388	1,354	230	292	0	4,264
1976	1,731	1,497	204	253	0	3,685
1977	1,624	1,331	323	174	162	3,614
1978	1,328	1,535	211	317	175	3,566
1979	1,988	2,249	268	415	73	4,993
1980	1,361	1,946	272	479	25	4,083
1981	1,566	2,740	309	503	30	5,148
1982	1,905	4,409	272	384	43	7,013
1983	1,910	2,874	233	168	40	5,225
1984	924	2,164	415	1,058	19	4,580
1985	833	2,303	219	1,267	0	4,622
1986	933	2,643	729	1,271	0	5,576
1987	940	3,067	916	1,321	0	6,244
1988	1,335	3,100	1,206	1,435	0	7,076
1989	1,500	2,300	874	1,430	0	6,104
1990	1,069	2,689	876	1,323	0	5,957
1991	1,804	2,147	1,514	762	0	6,227
1992	1,308	3,014	2,092	782	0	7,196
1993	801	3,289	2,611	791	1	7,493
1994	2,484	3,097	1,297	1,330	0	8,208
1995	2,558	3,214	1,177	2,042	2	8,993
1996	2,141	4,661	1,351	1,648	2	9,803
1997	3,530	5,370	1,050	589	274	10,813
1998	2,977	4,598	746	288	468	9,078
1999	2,424	5,002	447	230	448	8,551
2000	1,498	4,576	432	271	258	7,035
2001	1,861	5,119	638	261	245	8,124
2002	2,324	5,720	1,457	492	274	10,267
2003	2,324	5,720	801	492	397	9,734

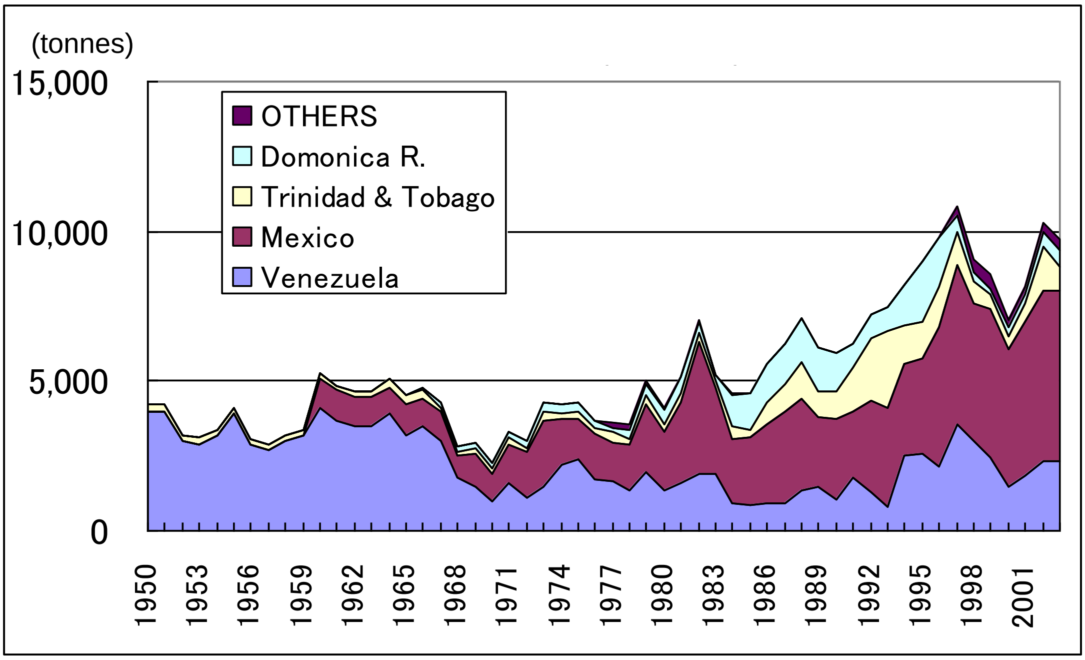

Fig. 3. Annual catch of king mackerel (1950-2003) in the Caribbean region by country.

Analyses

CPUE standardization

To conduct the ASPIC analyses, standardized CPUE is needed to tune the model and also to estimate necessary parameters. For the unit of effort, we used trips as no other effective fishing effort unit was available. As an initial attempt, we used the Generalized Linear Model (GLM) with full terms to standardize the nominal CPUE as described in equation 1:

$$\ln(CPUE_{ijkl} + constant) = INTERCEPT + YR_i + Q_j + A_k + (YR*Q)_{ij} + (YR*A)_{ik} + (Q*A)_{jk} + \varepsilon_{ijk} \quad \text{------ (1)}$$

,where

ln	*: natural logarithm*
CPUE	*: nominal CPUE (i.e. king mackerel caught per trip);*
constant	*: 10% of the global mean of the nominal CPUE (2.902 for troll and 3.291 for a-la-vive) in order to mitigate the problem of zero catch (Campbell et al., 1996);*
INTERCEPT	*: mean CPUE;*
YR_i *(i=1 to I)*	*: effect of year from 1995 to 2003;*
Q_j *(j=1 to J)*	*: effect of season (quarter: 1 to 4);*
A_k *(k=1 to K)*	*: effect of nine sub-area (see Map 1).*
ε_{ijk}	*: error term, assumed to be independently, identically distributed (i.i.d) with N(0,* σ^2 *) for all i, j and k.*
9 sub-areas (codes)	*: E_COAST, N_COAST, S_COAST, W_COAST, S&W_COAST, N_GULF, S_GULF, TOBAGO and VENEZUELA (refer to Map 1)*

The GLM analyses were conducted by the GLM option available in the SPSS software (SPSS 1999). Using the parameters (P) estimated by the GLM, annual standardized CPUE (abundance index) was computed by the least squares method using equation (2):

$$\text{Standardized CPUE (abundance index)} = \exp(P_{year} + P_{quarter} + P_{area} + P_{interactions}) - constant \quad \text{-------------(2)}$$

However, due to missing values for some areas and/or quarters in the data set, we were unable to estimate annual CPUE for some years in the full GLM models. After further attempts, we determined that this problem could be solved if we excluded the interaction terms of year*quarter and year*area for troll and all interaction terms for a-la-vive. The following reduced GLM models were finally used for CPUE standardization:

For troll $\quad ln(CPUE_{ijkl} + constant) = INTERCEPT + YR_i + Q_j + A_k + (Q{*}A)_{jk} + \varepsilon_{ijk}$ ----(3)

For a-la-vive $\quad ln(CPUE_{ijkl} + constant) = INTERCEPT + YR_i + Q_j + A_k + \varepsilon_{ijk}$ -----------------(4)

Using equations (3) and (4), annual standardized CPUE for troll and a-la-vive were obtained as shown in Fig. 4.

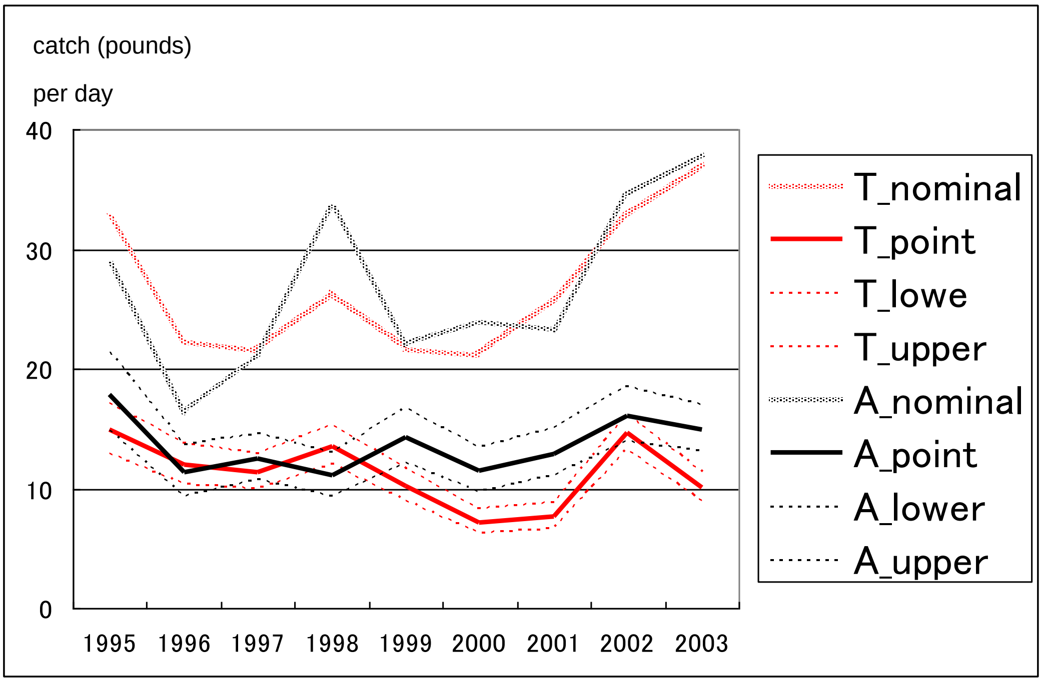

Fig. 4. Trends of standardized CPUE with 95% confidence intervals in dotted lines and nominal CPUE in upper diffuse lines (1995 - 2003) by gear.

(Note: T=Troll and A=a-la-vive)

ASPIC analyses

ASPIC is a non-equilibrium Production Model (PM) developed by Prager (2000). We used version 3.82 based on the logistic production model. The estimation procedures are described as follows:

Let the logistic population growth model be $dB/dt=r(1-B/K)B$ ------ (5)

If there is catch, equation (5) will be $dB/dt=r(1-B/K)B - C$ ------- (6)

When dB/dt=0 it is the equilibrium PM, which produces large biases (Polacheck et al, 1993). Hence we use the non-equilibrium PM, i.e., the situation when dB/dt‡0. Assuming biomass is roughly proportional to standardized CPUE, then we have B= (1/α) CPUE which is substituted in equation (6)

$$dB/dt=r(1-CPUE/\alpha K)(CPUE/\alpha) - C \qquad (7)$$

where

CPUE = *standardized CPUE or abundance index (no unit)*
α = *constant proportional to the abundance index*
(if CPUE is nominal, it is equivalent to catchability)
B = *biomass (tonnes)*
C = *catch (tonnes)*
r = *intrinsic growth rate of the population*
K = *carrying capacity*

In equation (7), we need to estimate r, α and K. To estimate the parameters, we need to search for the values of r, α and K which minimize the sum of square errors for equation (7). ASPIC performs this function using the non-linear regression technique.

In the ASPIC analyses we used standardized CPUE and catch by gear as the input data. As CPUE information for other countries was not available, standardized CPUE for troll and a-la-vive in Trinidad and Tobago were used. However, a-la-vive (essentially troll with live bait) is a unique gear in the region, while the troll is a general gear for the surface fisheries exploiting king mackerel. Furthermore, CPUE by a-la-vive is usually higher than the troll CPUE (see Fig. 4). Hence, if we used a-la-vive CPUE, ASPIC would produce biased results. We therefore used only troll CPUE as the input CPUE because we considered the gear to be standard and representative for the region according to Table 2.

Table 2. Gear types used to harvest king mackerel in countries exploiting the postulated 'Caribbean stock' (FAO, 2005)

Country	gear type
Venezuela	surface
Mexico	unclassified (surface)
Dominican Republic	troll
Trinidad and Tobago	surface (troll and others)
Others	surface (negligible catch)

Results of the ASPIC analyses

Parameters estimated by ASPIC and other relevant information are shown in Table 3. The annual trend of production in relation to MSY, the annual trend of F in relation to F (MSY) and the annual trend of biomass in relation to K(carrying capacity) are shown in Figs. 5-7.

Table 3 Estimated parameters from the ASPIC analyses

Parameters	Estimated values
MSY	7,443 tonnes
Catch (2003)	9,734 tonnes
r	0.35
α	0.0002279
K	84,710 tonnes
F(MSY)	0.18
F(2003)	0.23
F ratio (F_{2003}/F_{MSY})	1.33
TB (1950:vrigin)	237,900 tonnes
TB (2003)	41,560 tonnes
TB (MSY)	42,350 tonnes
B0 ratio ($TB_{2003}/TB_{1950:virgin}$)	0.17
B1 ratio (TB_{2003}/TB_{MSY})	0.98

TB: Total Biomass

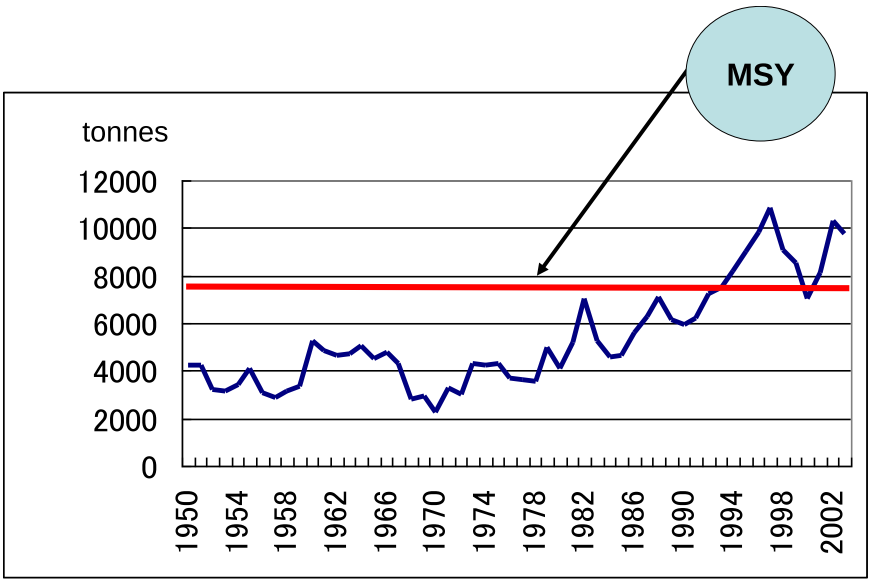

Fig. 5. Trend of annual catch of 'Caribbean stock' king mackerel relative to estimated

MSY

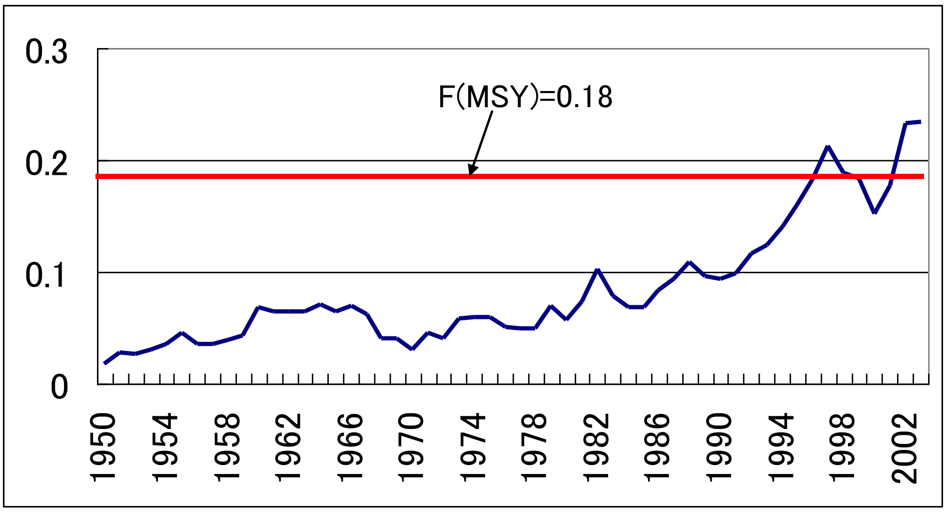

Fig. 6. Trend of estimated annual F for ‘Caribbean stock’ king mackerel relative to estimated F at MSY level (0.18).

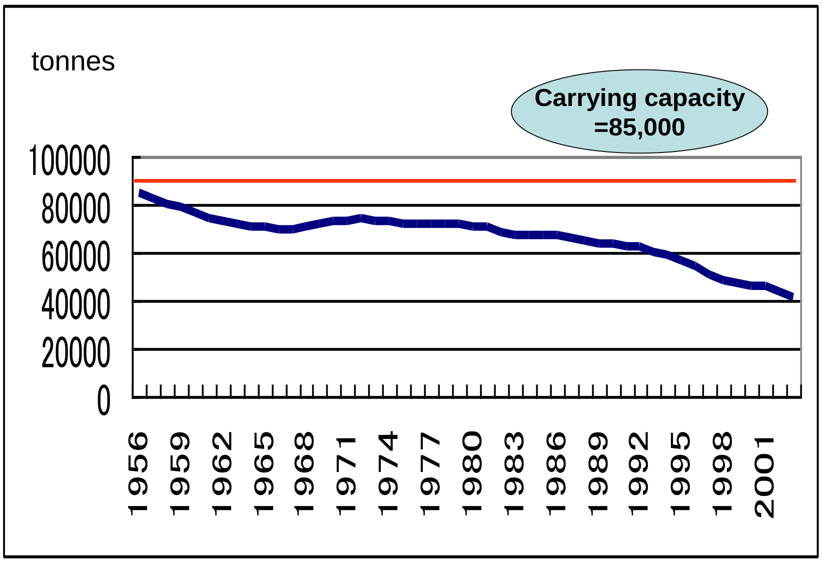

Fig. 7. Trend of estimated annual biomass of ‘Caribbean stock’ king mackerel relative to the estimated carrying capacity

Discussion and conclusion

Catches of king mackerel in the Caribbean region have surpassed the MSY level (7,443 tonnes) for 10 years (1993-2002). In addition F in recent years is above F (MSY) (fishing mortality that can maintain the MSY level). As a result we conclude that the king mackerel of the ‘Caribbean stock’ is currently at the overexploited stage. Thus, it is recommended that catch and fishing effort of all gears should be reduced to the MSY level.

The International Commission for the Conservation of Atlantic Tunas (ICCAT), the regional management body responsible for the management of king mackerel, endorses smaller scale management of the less widely distributed fisheries resources in the Atlantic, which includes several other commercially important shared stocks in the Caribbean region. However to achieve effective fisheries management for such shared stocks in the region may require the establishment of a Caribbean regional fisheries commission.

In this study troll CPUE (Trinidad and Tobago) is used as a crude representation of the king mackerel abundance index although the corresponding catch level is very small.

Hence in the future other CPUE series producing the large catch should be used if available in order to obtain more realistic and robust stock assessment results from ASPIC.

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