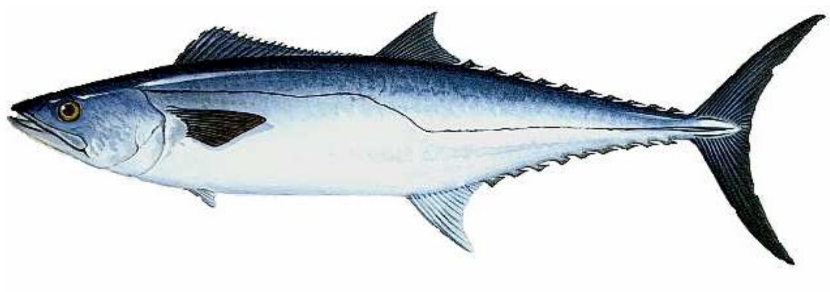
Stock status on king mackerel in the Caribbean Sea (STD_CPUE and ASPIC)



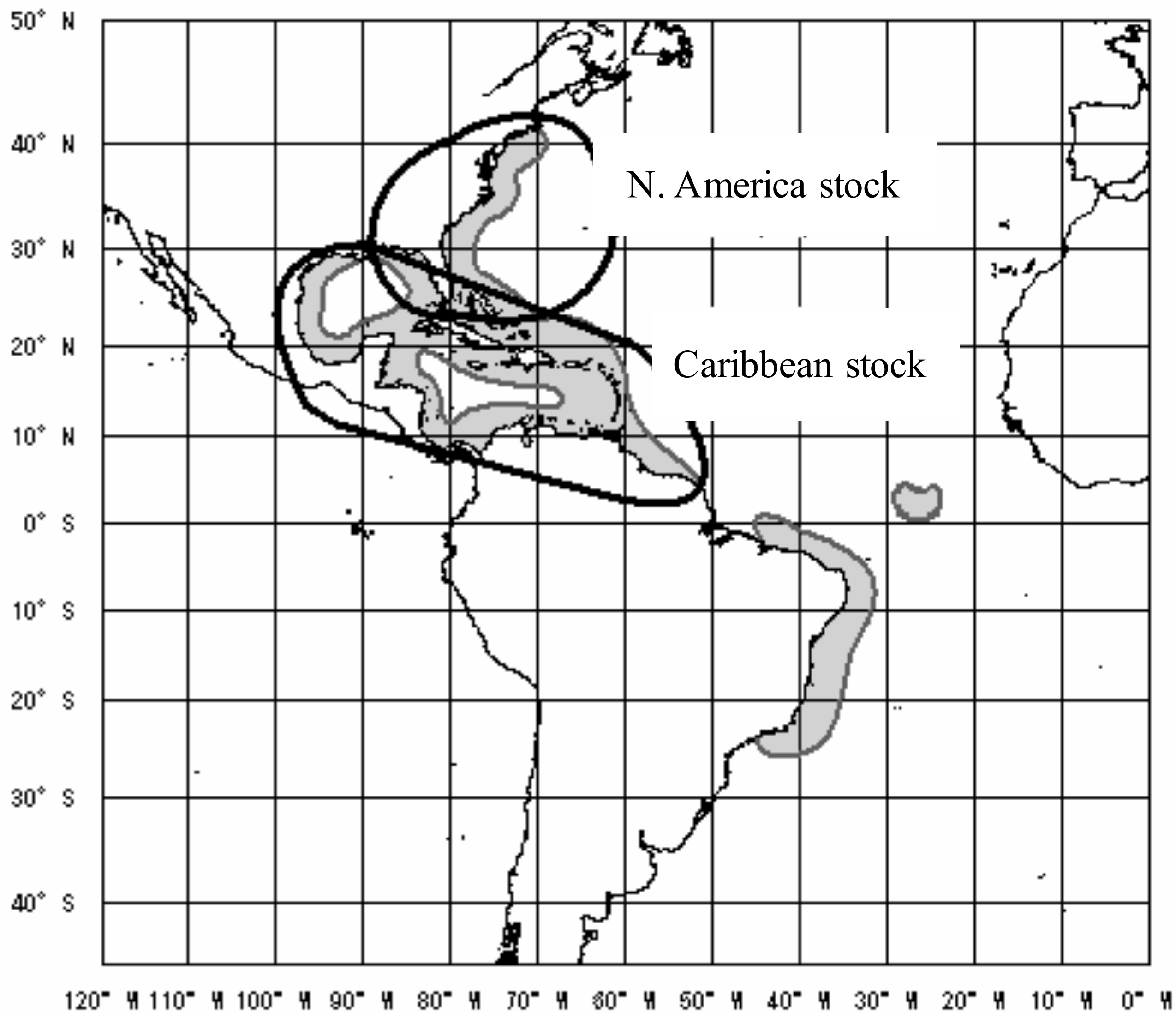
King mackerel (Scomberomorous cavalla)

King Mackerel

Commercially important

(ICCAT species ）

2 stocks（Renton, 1996)



Data

- Global catch by fleet & gear (1950-2003)(53 yrs)

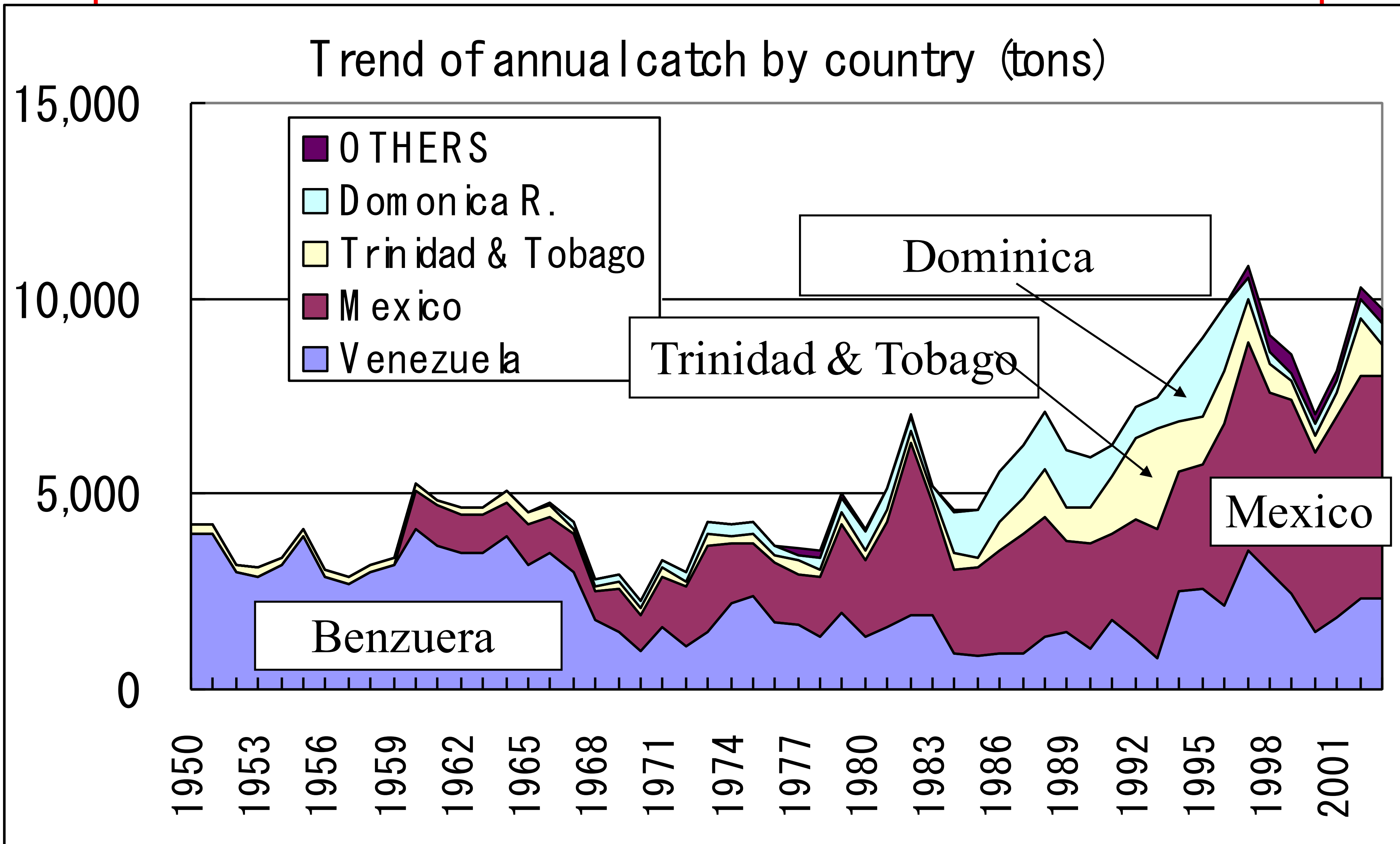
  ICCAT・FAO database

  ➔ Caribbean stock: Venezuela Mexico,

  Dominica and Trinidad & Tobago
- **Catch & Effort (1995-2003)（9years）**

  Trinidad & Tobago (daily troll data)
- No size data

Global catch (Important)



CPUE standardization (comparable indices)

- Why we need ?

Nominal CPUE are biased by year, season

area and environmental factors from the average situation

Thus to see real (comparable) trends, we need to standardize to filter out the biases.

Input data

year	Q	Mo	area	trip	catch	CPUE
1995	1	1	NC	5	45	9

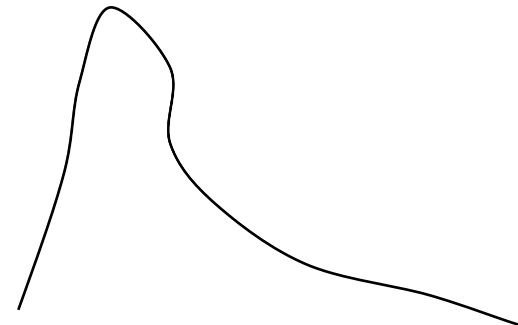
Data process for CPUE

yr	n
1995	56,375
1996	59,389
1997	82,090
1998	91,695
1999	83,664
2000	82,702
2001	93,349
2002	97,080
2003	87,213
total	733,557

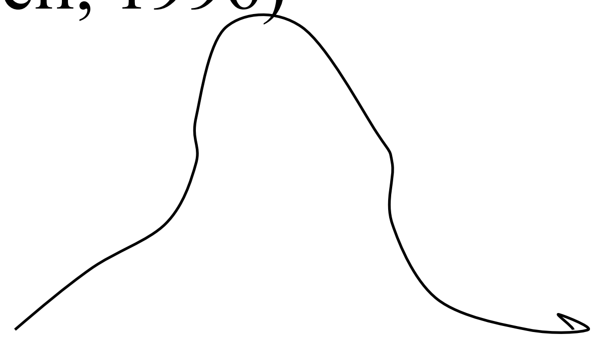
How to standardize ?

- GLM

Log(CPUE+constant)
=(mean)+(year)+(season : Q)+(A:areas)
+ (A)*(Q)+(Y)*(Q)+(Y*A)+error



Yr:1995-2003
Season :q1-q4
Area: see next
constant=mean CPUE*10%(Campbell, 1996)

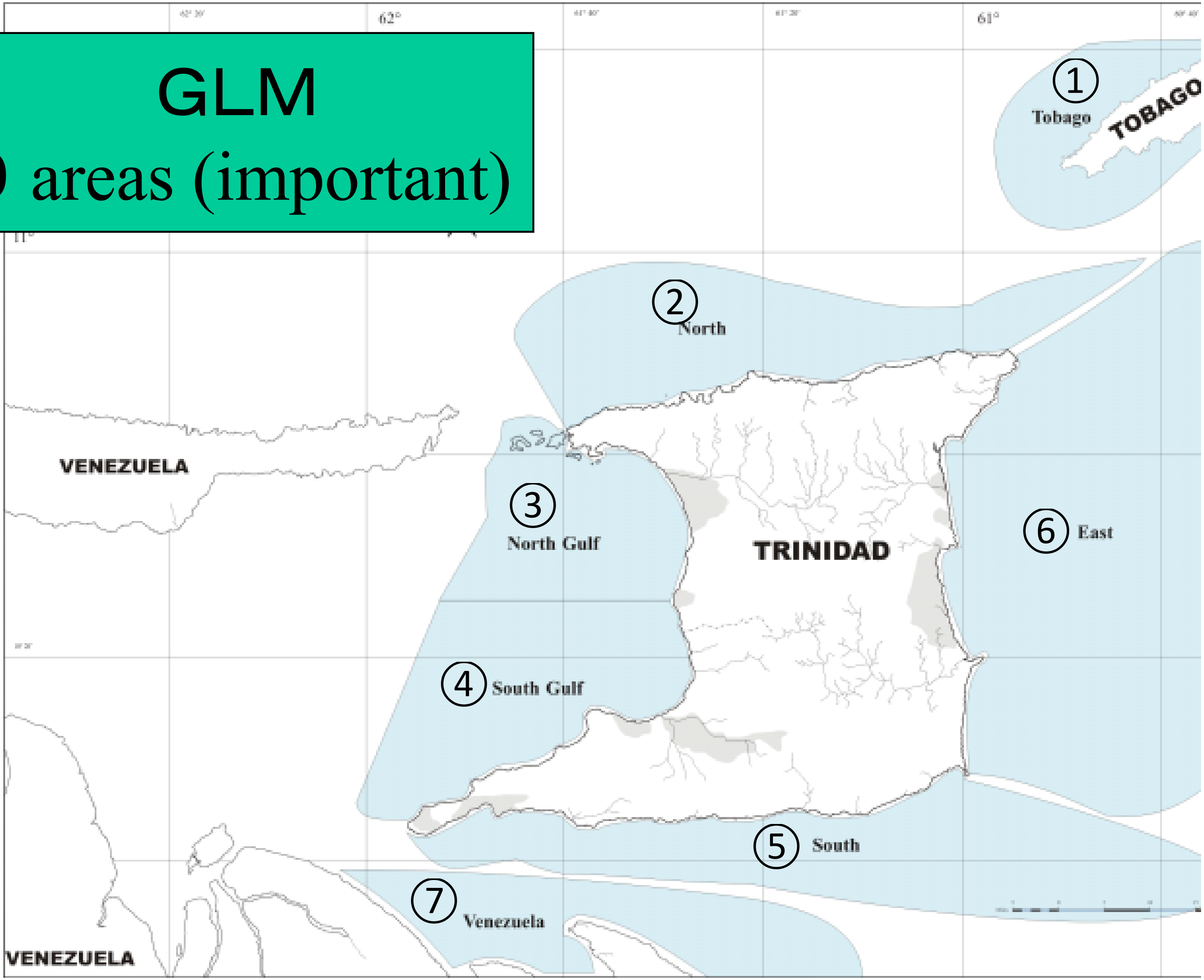


TROLL:29.02x0.1=2.902
A LEVIVE:32.91x0.1=3.291

Fishing grounds(9) (need map)

- E_COAST
- N_COAST
- S_COAST
- W_COAST
- S&W_COAST
- N_GULF
- S_GULF
- TOBAGO
- VENEZUEL

GLM
9 areas (important)



STD_CPUE GLM（YR、Q、Area）
Trinidad & Tobago troll（catch/day）

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

,where

ln	*: natural logarithm*
CPUE	*: nominal CPUE (i.e. king mackerel caught per trip);*
constant	*: 10% of the global mean of the nominal CPUE 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* $N(0, \sigma^2)$ *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)*

SAS PROGRAM

```
proc glm ;
  class yr q a  ;
  model cpue= yr q a  q*a    / solution ss3  ;
  output out=res student=stdresid r=raw p=pred ;
  lsmeans yr  /   stderr out=estim ;
run ;
```

TROLL	N	AVE	SE	MINI	MAX
•	--				
•	4697	29.0193498	47.7454038	0	677.2500000
•	--				

TROLL

Class	Levels	Values
yr	9	1995 1996 1997 1998 1999 2000 2001 2002 2003
q	4	1 2 3 4
a	7	EASTCOAS NORTHCOA NORTHGUL SOUTHCOA SOUTHGUL VENEZUEL WESTCOAS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	35	2516.009797	71.885994	60.48	<.0001
Error	4661	5539.971658	1.188580		
Corrected Total	4696	8055.981455			

R-Square	Coeff Var	Root MSE	cpue Mean
0.312316	41.20835	1.090220	2.645629

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yr	8	169.955672	21.244459	17.87	<.0001
q	3	76.289773	25.429924	21.40	<.0001
a	6	1784.645268	297.440878	250.25	<.0001
q*a	18	166.715179	9.261954	7.79	<.0001

Parameter		Estimate	Error	t Value	Pr > |t|
Intercept		1.756444570 B	0.21203718	8.28	<.0001
yr	1995	0.315436338 B	0.07862924	4.01	<.0001
yr	1996	0.136067258 B	0.07443271	1.83	0.0676
yr	1997	0.093668030 B	0.06984587	1.34	0.1800
yr	1998	0.238167841 B	0.06728410	3.54	0.0004
yr	1999	0.009562693 B	0.06804911	0.14	0.8883
yr	2000	-0.248340466 B	0.06674759	-3.72	0.0002
yr	2001	-0.205320164 B	0.06606183	-3.11	0.0019
yr	2002	0.306348219 B	0.06107469	5.02	<.0001
yr	2003	0.000000000 B	.	.	.
q	1	-0.543812108 B	0.25683444	-2.12	0.0343
q	2	0.141309425 B	0.22934108	0.62	0.5378
q	3	0.480505599 B	0.23916615	2.01	0.0446
q	4	0.000000000 B	.	.	.

a		EASTCOAS	0.693135080 B	0.24797095	2.80	0.0052
a		NORTHCOA	1.294875734 B	0.21892752	5.91	<.0001
a		NORTHGUL	0.746173141 B	0.30306972	2.46	0.0139
a		SOUTHCOA	-0.014115699 B	0.22261450	-0.06	0.9494
a		SOUTHGUL	-0.037572167 B	0.21672209	-0.17	0.8624
a		VENEZUEL	1.692036074 B	0.22872019	7.40	<.0001
a		WESTCOAS	0.000000000 B	.	.	.
q*a	1	EASTCOAS	0.601888932 B	0.33661638	1.79	0.0738
q*a	1	NORTHCOA	0.447394367 B	0.27626160	1.62	0.1054
q*a	1	NORTHGUL	0.642685252 B	0.37754573	1.70	0.0888
q*a	1	SOUTHCOA	0.945856094 B	0.28505662	3.32	0.0009
q*a	1	SOUTHGUL	0.478256439 B	0.27854181	1.72	0.0860
q*a	1	VENEZUEL	0.771559793 B	0.29603530	2.61	0.0092
q*a	1	WESTCOAS	0.000000000 B	.	.	.
q*a	2	EASTCOAS	0.225340433 B	0.28901398	0.78	0.4356
q*a	2	NORTHCOA	-0.033680212 B	0.24612637	-0.14	0.8912

Abundance index (standardized CPUE)

Abundance index：standardized CPUE)

=least mean square (expected value) for yr -2.092

=exp(yr + q + area + A*Q) -2.092

```
data ;
  set estim ;
  llsmean=lsmean-1.96*stderr ;
  ulsmean=lsmean+1.96*stderr ;
  cpue_p=exp(lsmean)-2.902 ;
  cpue_pl=exp(llsmean)-2.902 ;
  cpue_pu=exp(ulsmean)-2.902 ;
run;
```

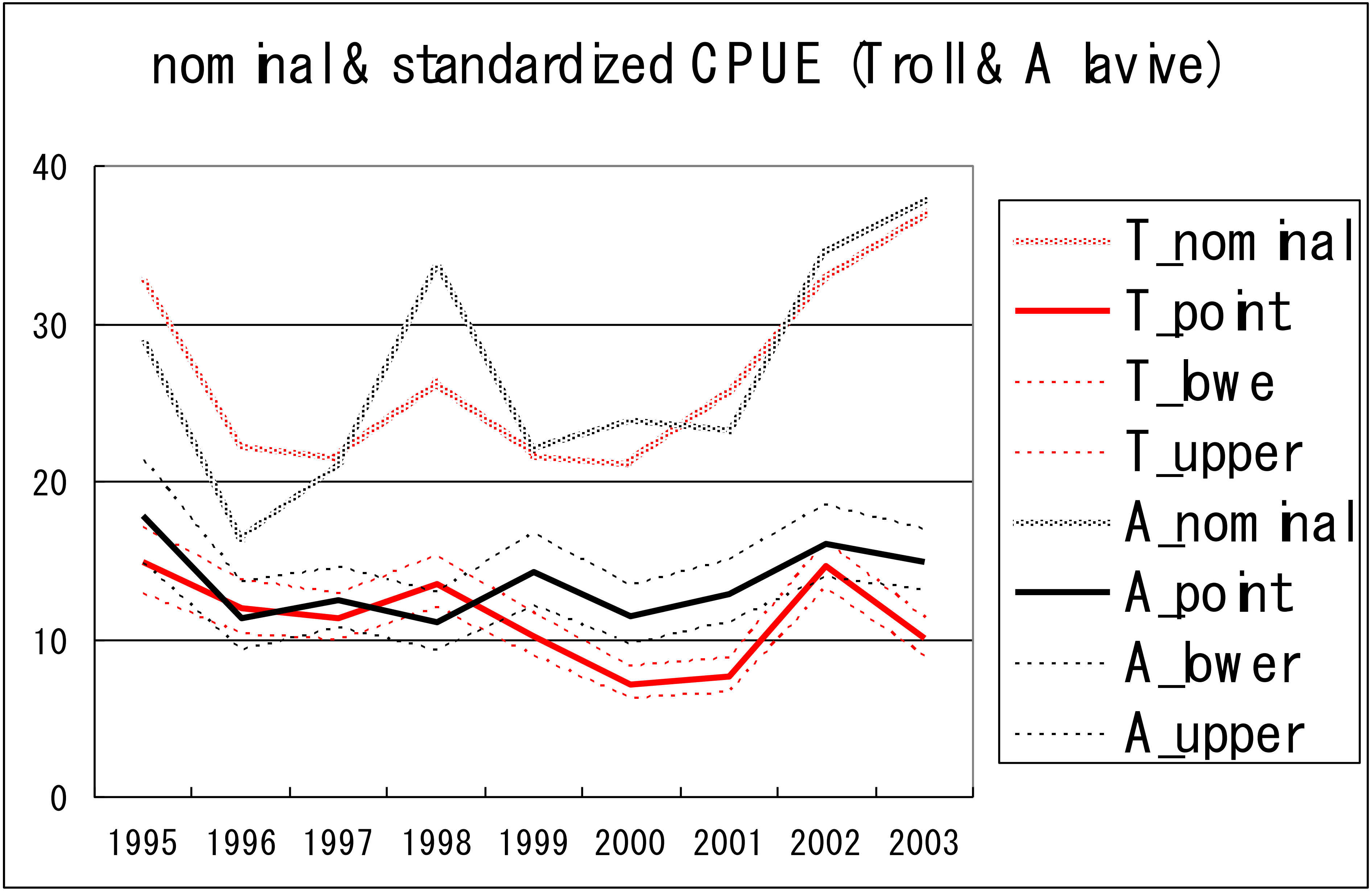
The GLM Procedure

Least Squares Means

yr	cpue LSMEAN	Standard Error	Pr > |t|
1995	2.87618977	0.06142479	<.0001
1996	2.69682069	0.05750016	<.0001
1997	2.65442146	0.05438210	<.0001
1998	2.79892127	0.05065935	<.0001
1999	2.57031612	0.05277524	<.0001
2000	2.31241296	0.05092327	<.0001
2001	2.35543326	0.05049090	<.0001
2002	2.86710165	0.04252348	<.0001
2003	2.56075343	0.04856239	<.0001

NAME	yr	LSMEAN	STDERR	llsmean	ulsmean	cpue_p	cpue_pl	cpue_pu
cpue	1995	2.87619	0.061425	2.75580	2.99658	14.8445	12.8316	17.1150
cpue	1996	2.69682	0.057500	2.58412	2.80952	11.9305	10.3496	13.7000
cpue	1997	2.65442	0.054382	2.54783	2.76101	11.3148	9.8774	12.9138
cpue	1998	2.79892	0.050659	2.69963	2.89821	13.5249	11.9722	15.2397
cpue	1999	2.57032	0.052775	2.46688	2.67376	10.1680	8.8836	11.5923
cpue	2000	2.31241	0.050923	2.21260	2.41222	7.1968	6.2375	8.2567
cpue	2001	2.35543	0.050491	2.25647	2.45440	7.6407	6.6473	8.7374
cpue	2002	2.86710	0.042523	2.78376	2.95045	14.6840	13.2777	16.2125
cpue	2003	2.56075	0.048562	2.46557	2.65594	10.0436	8.8682	11.3363

	nominal	cpue_p point	cpue_pl lower	cpue_pu upper
1995	32.5952	14.8445	12.8316	17.115
1996	22.2769	11.9305	10.3496	13.7
1997	21.4898	11.3148	9.8774	12.9138
1998	26.3859	13.5249	11.9722	15.2397
1999	21.6828	10.168	8.8836	11.5923
2000	21.0964	7.1968	6.2375	8.2567
2001	25.8764	7.6407	6.6473	8.7374
2002	32.7362	14.684	13.2777	16.2125
2003	37.0363	10.0436	8.8682	11.3363



nominal & standardized CPUE (Troll & Alavive)
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
T_nominal
T_point
T_lowe
T_upper
A_nominal
A_point
A_lower
A_upper

CPUE

- Is it real indicator for the whole stock ?
- Multi gear : semi-industrial (no data) 35 vessels recreational fish

AF > multi & rec.

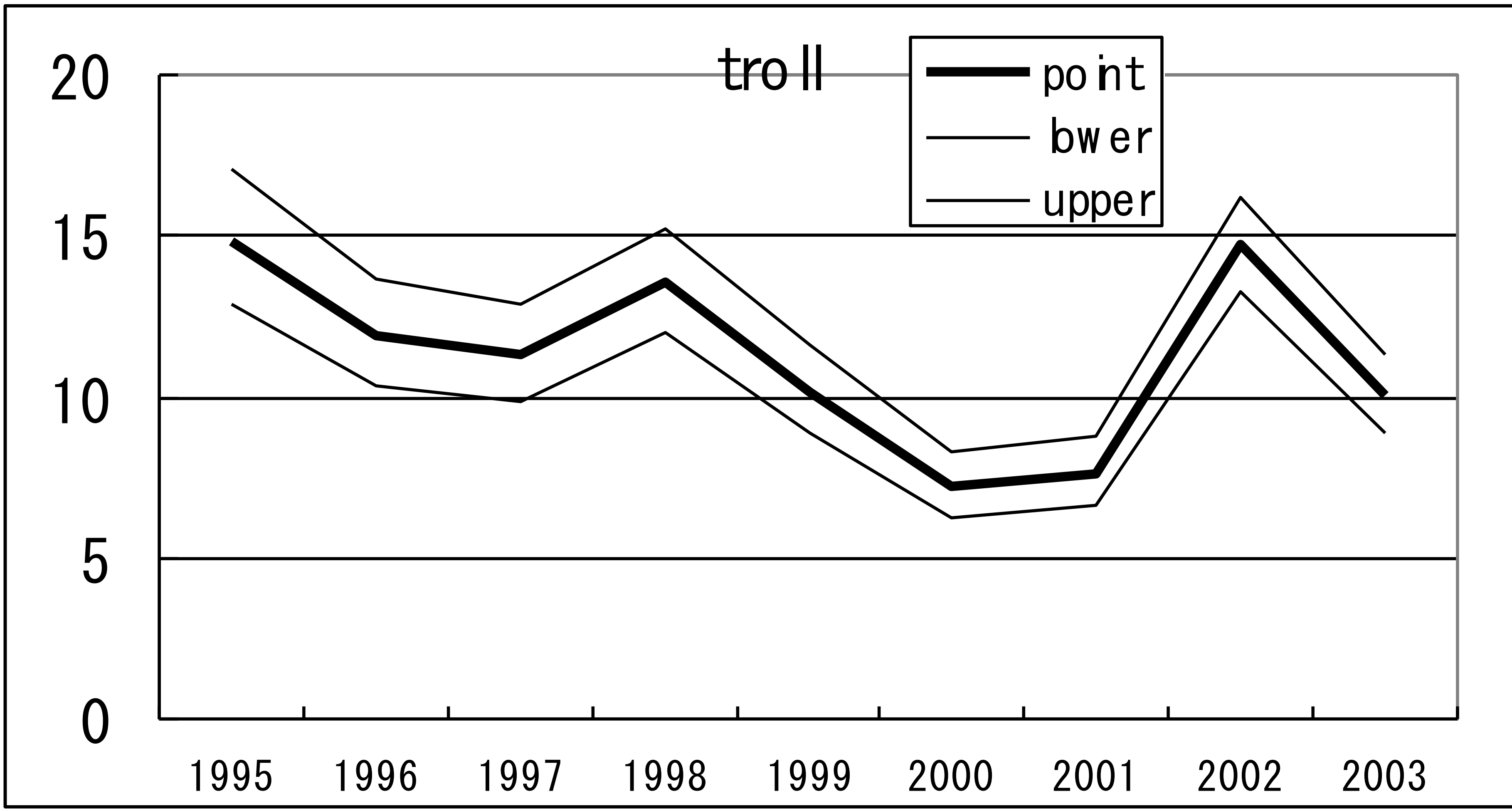
Catch by the AF (T&T) is more than 50% of the Global catch

CPUE (TROLL) can be really representative of the abundance ??

Any other possible CPUE in other countries ? no

Estimated STD_CPUE

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



Outline of the ASPIC

A Surplus Production model Incorporating Catch

Production Model

Non equilibrium PM

ASPIC

A Stock Production Model Incorporating Covariates

(Schaefer)

ICCAT:ASPIC soft (Ver 3.82)　(Prager, 2002)

Global catch＋abundance index（STD_CPUE）

ASPIC

- Software by Prager (SEFSC, NMFS) ver3.82 : logistic PM (Schaefer and Pella)
- Ver5. : generalized PM (PT & Fletcher)
- We use version 3.82 as an initial step
- In the future, we may attempt version 5- for comparisons.

If we fail, we might try De Lury method

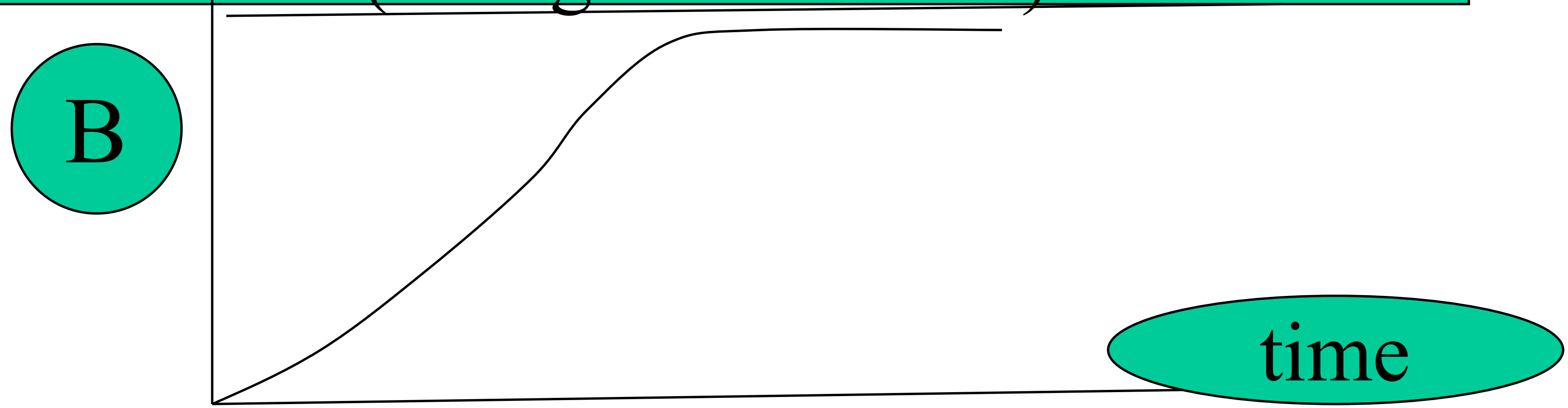
- Russell's equation(19??)

B(Biomass)(t+1)

=[B+(Recruit)+(Growth)-(Death)-(Catch)](t)

$$\frac{dB}{dt} = r\left(1-\frac{B}{K}\right)B$$: Logistic

(change of biomass)



$$\frac{dB}{dt} = r\left(1-\frac{B}{K}\right)B - \text{Catch}$$

$$dB/dt = r(1-B/K)B - \text{Catch}$$

If $dB/dt=0$: **equilibrium** (classical PM)

Schaefer, Fox, P&T, Bell?

If $dB/dt \neq 0$: **non equilibrium** PM

B=Biomass=αCPUE

$[r(1-B/K)B - \text{Catch}] \neq 0$

$[r(1- \alpha CPUE/K)(\alpha CPUE)]-\text{Catch} \neq 0$ ----(A)

We need to estimate r, K, α

Minimize sum of square error $[\sum_{year}(A^2)]$

INPUT DATA (ASPIC)

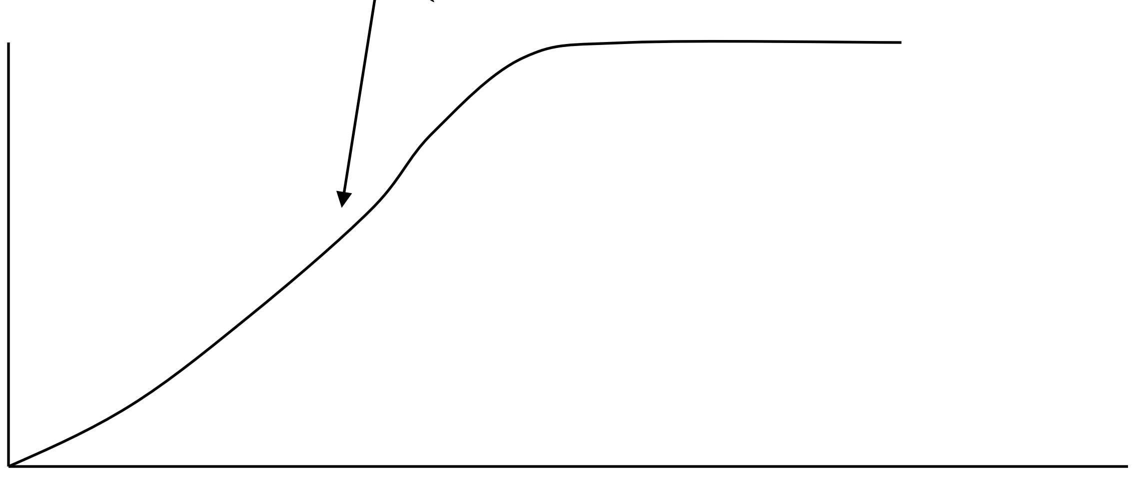
- CPUE & global catch by gear

Venezuela : surface
Mexico : unclassified (surface ?)
Dominica R: troll
T&T : surface (gill & troll)
OTHERS : negligible
A lavive ➔ unique in T&T ?

TROLL will be representative gear for the global catch.
➔ CPUE(TROLL) in TT

Data & INPUT needed

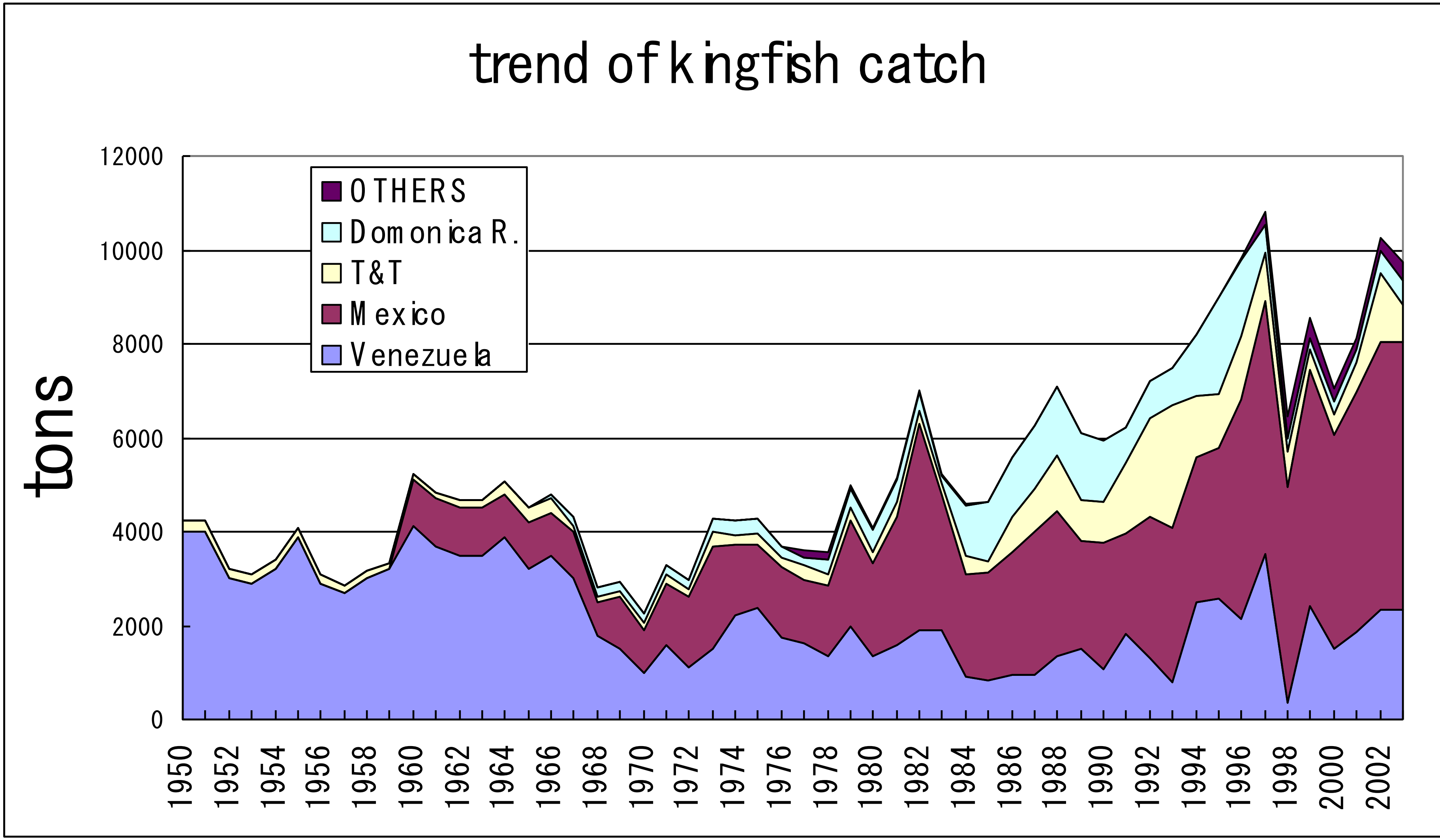
- Global Catch, CPUE(Troll T&T)
- Guess values q MSY, Bratio $=B_1/B_{MSY}$
- Guess values r (intrinsic rate of increase)



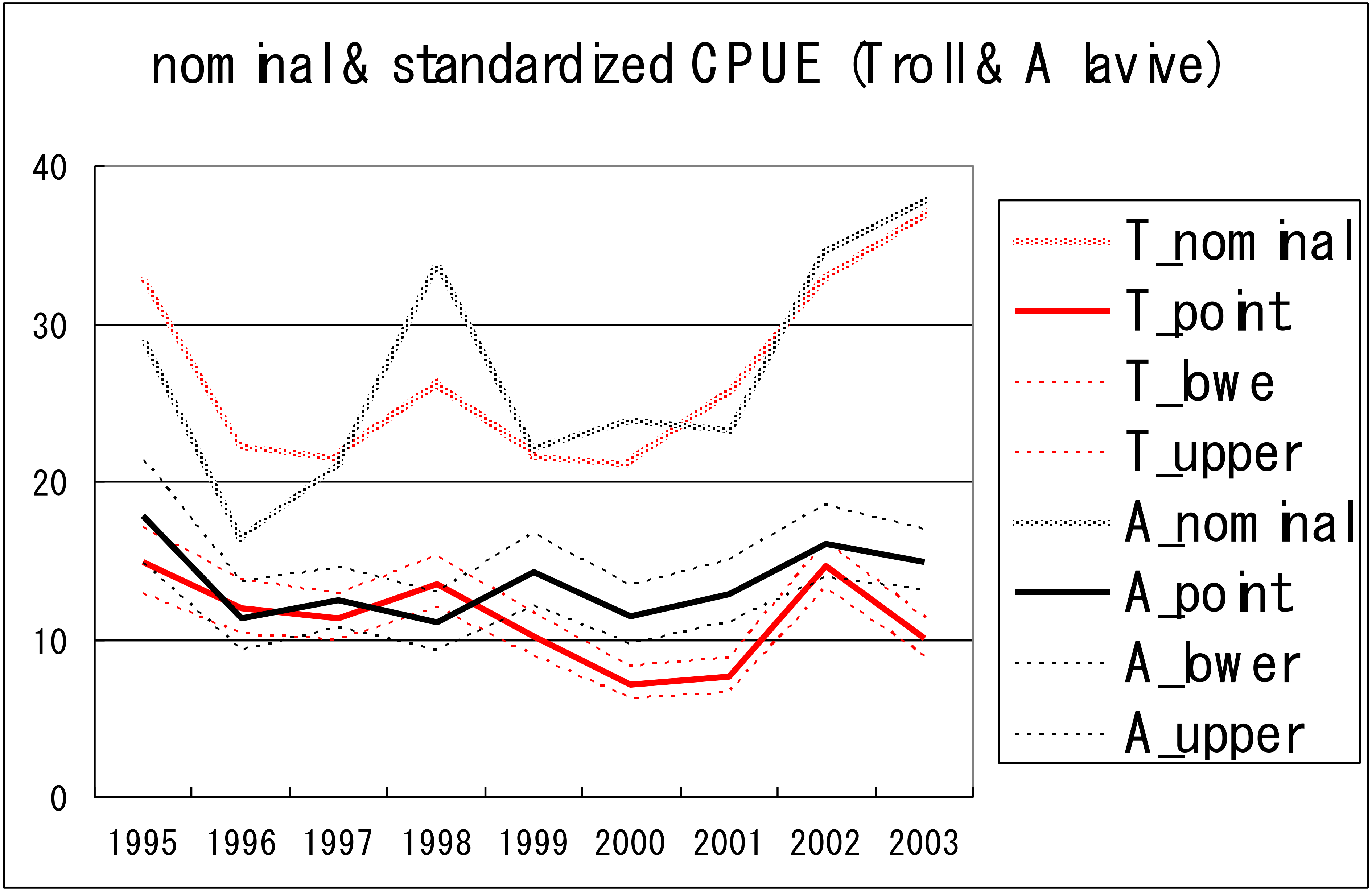
ASPIC INPUT FILE

```
'FIT'                       ## Mode (FIT, IRF, BOT)
'ASPIC 3.82 kingfish '
'EFF'                       ## Error type ('EFF' = condition on yield)
 2                          ## Verbosity (0 to 4)
 600                        ## Number of bootstrap trials, <= 1000
 0 10000                    ## Monte Carlo search enable (0,1,2), N trials
 1.0E-8                     ## Convergence crit. for simplex
 3.0E-8                     ## Convergence crit. for restarts
 1.0d-4                     ## Convergence crit. for estimating effort
 8.0d0                      ## Maximum F when estimating effort
 0.0E+0                     ## Statistical weight for B1 > K as residual
 1                          ## Number of data series (fisheries)
1d0                         ## Statistical weights for fisheries
5.0d0                       ## B1-ratio (starting guess)   B0/B(MSY)
1.0d4                       ## MSY (starting guess)
1.5d0                       ## r (starting guess)
1.0E-5                      ## q (starting guess)
1 1 1 1                     ## Flags to estimate parameters
0.5d3  2.0d4                ## Min and max allowable MSY
0.3d0  3.0d0                ## Min and max allowable r
998868                      ## Random number seed
54                          ## Number of years of data.
'Sample Effort & Catch, Table 2' ## Title for first series
'CC'                  ## Type of series ('CE' = effort, catch)  CC:CPUE
```

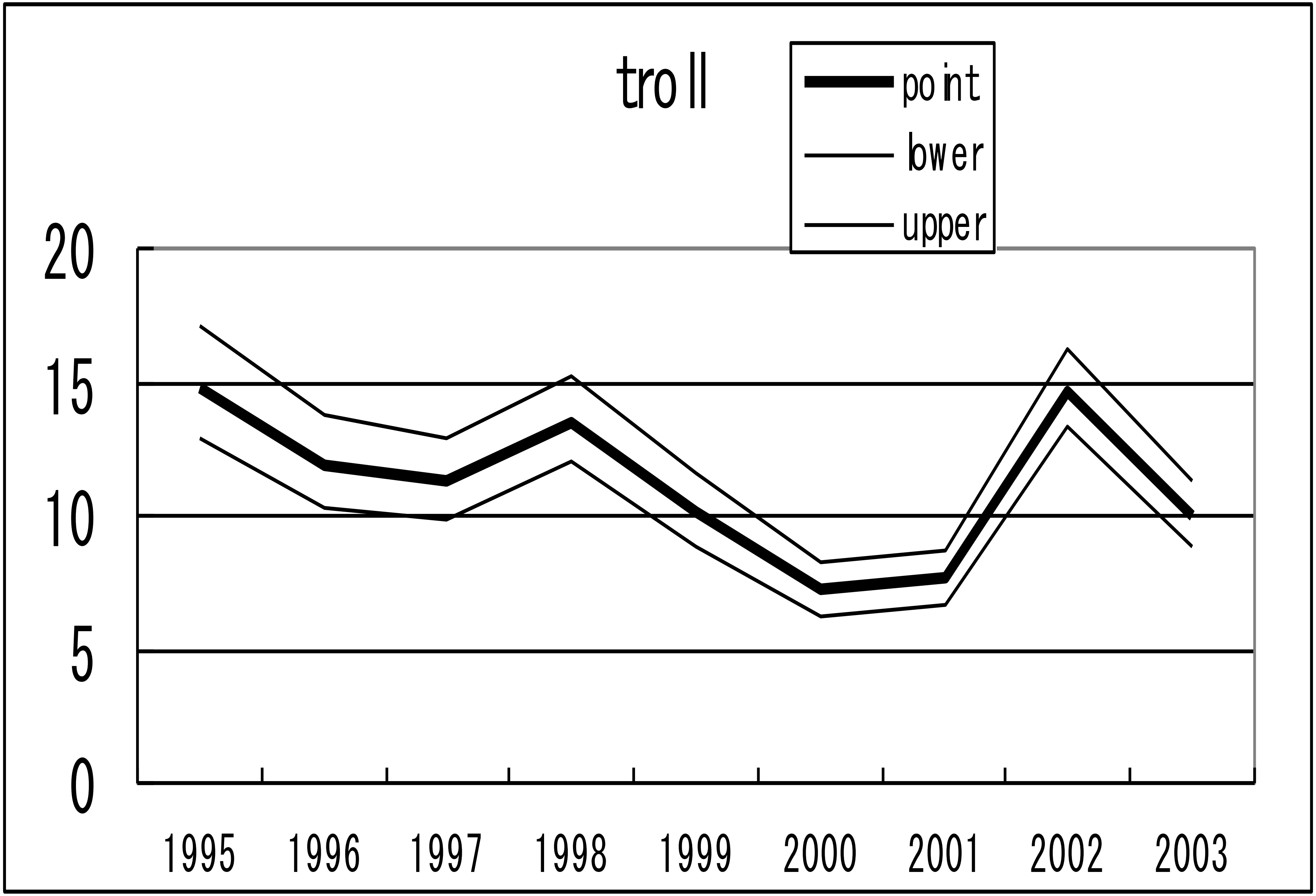
Default



trend of kingfish catch
tons
12000
10000
8000
6000
4000
2000
0
OTHERS
Domonica R.
T&T
Mexico
Venezuela
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002

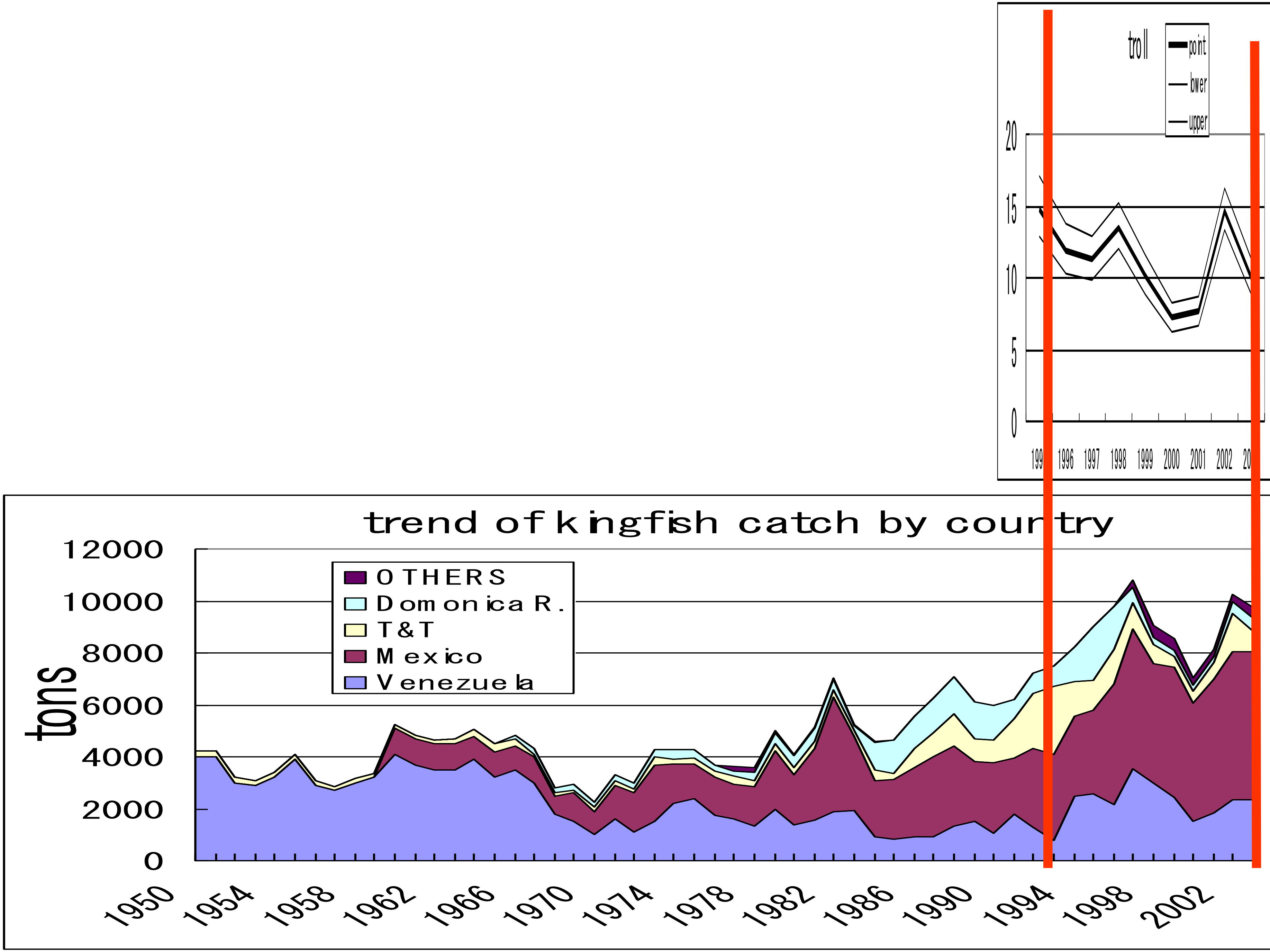


nominal& standardized CPUE (Troll& Alavive)
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
T_nominal
T_point
T_lowe
T_upper
A_nominal
A_point
A_lower
A_upper


troll
point
lower
upper
20
15
10
5
0
1995
1996
1997
1998
1999
2000
2001
2002
2003

'Sample Effort & Catch, Table 2' ## Title for first series
'CC' ## Type of series ('CE' = effort, catch)

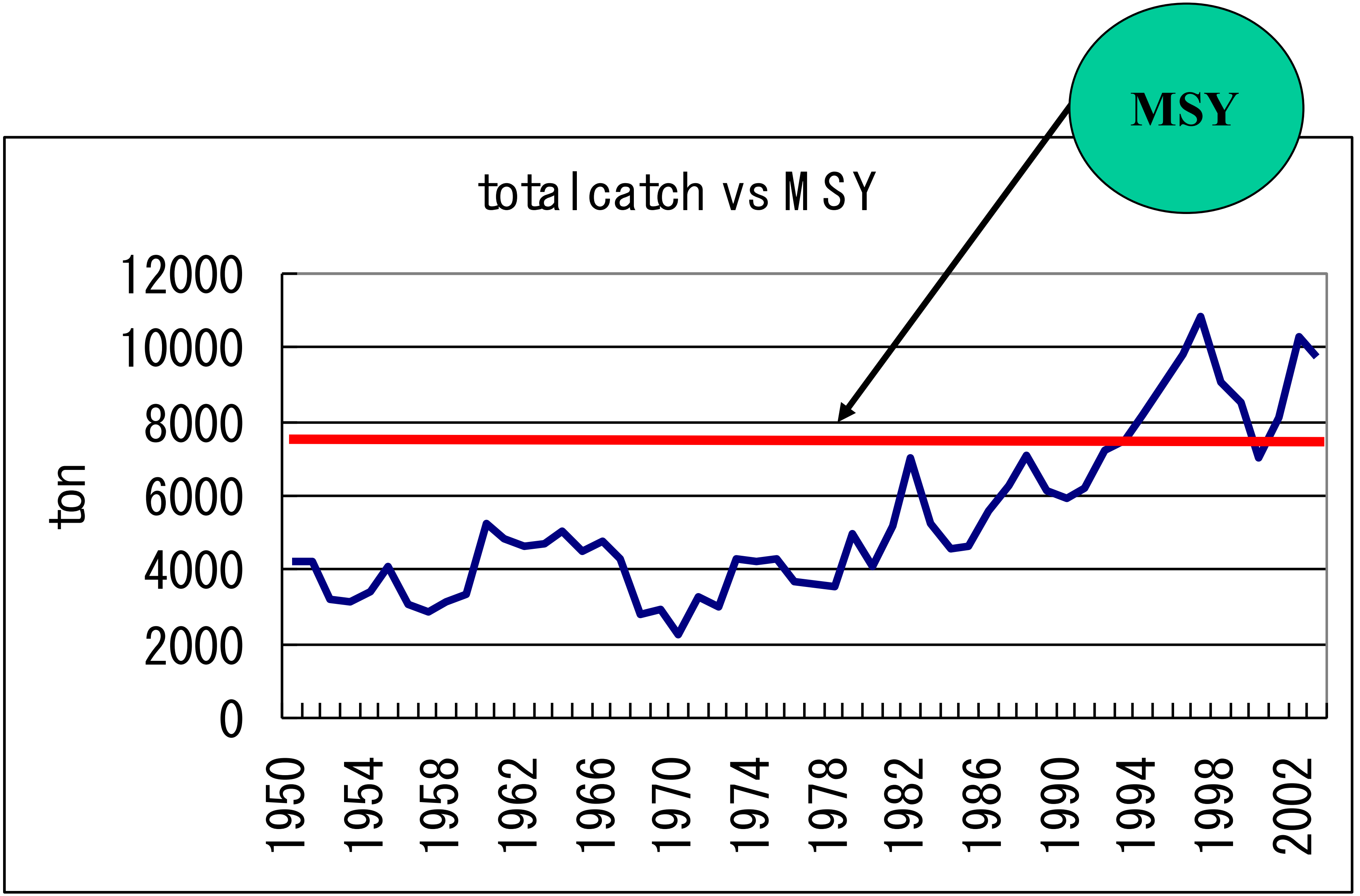
1950	-1	4232
1951	-1	4222
1952	-1	3213
1953	-1	3103
1954	-1	3393
1955	-1	4084
1956	-1	3074
1957	-1	2864
1958	-1	3154
1959	-1	3345
1960	-1	5235
1961	-1	4825
1962	-1	4664

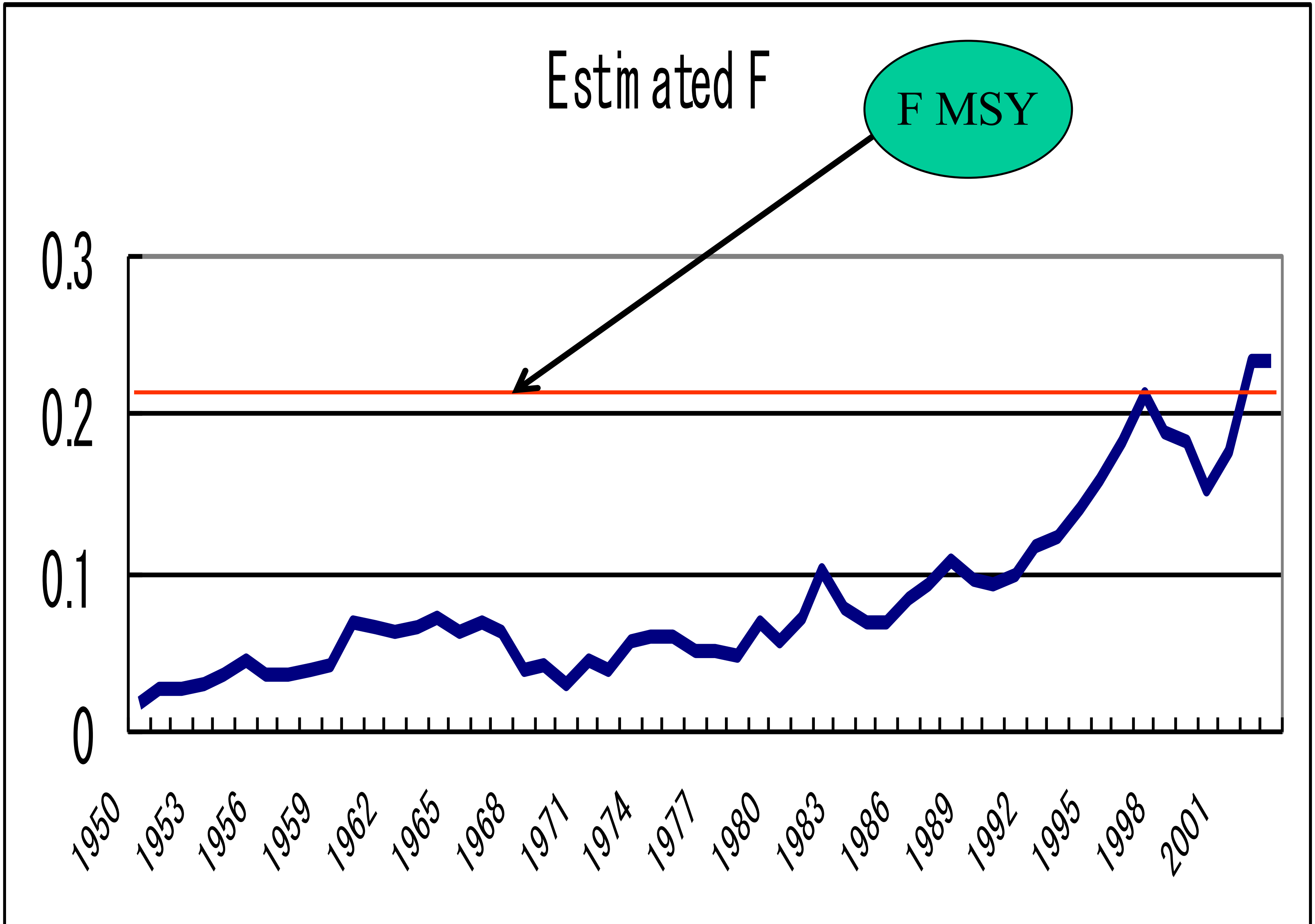


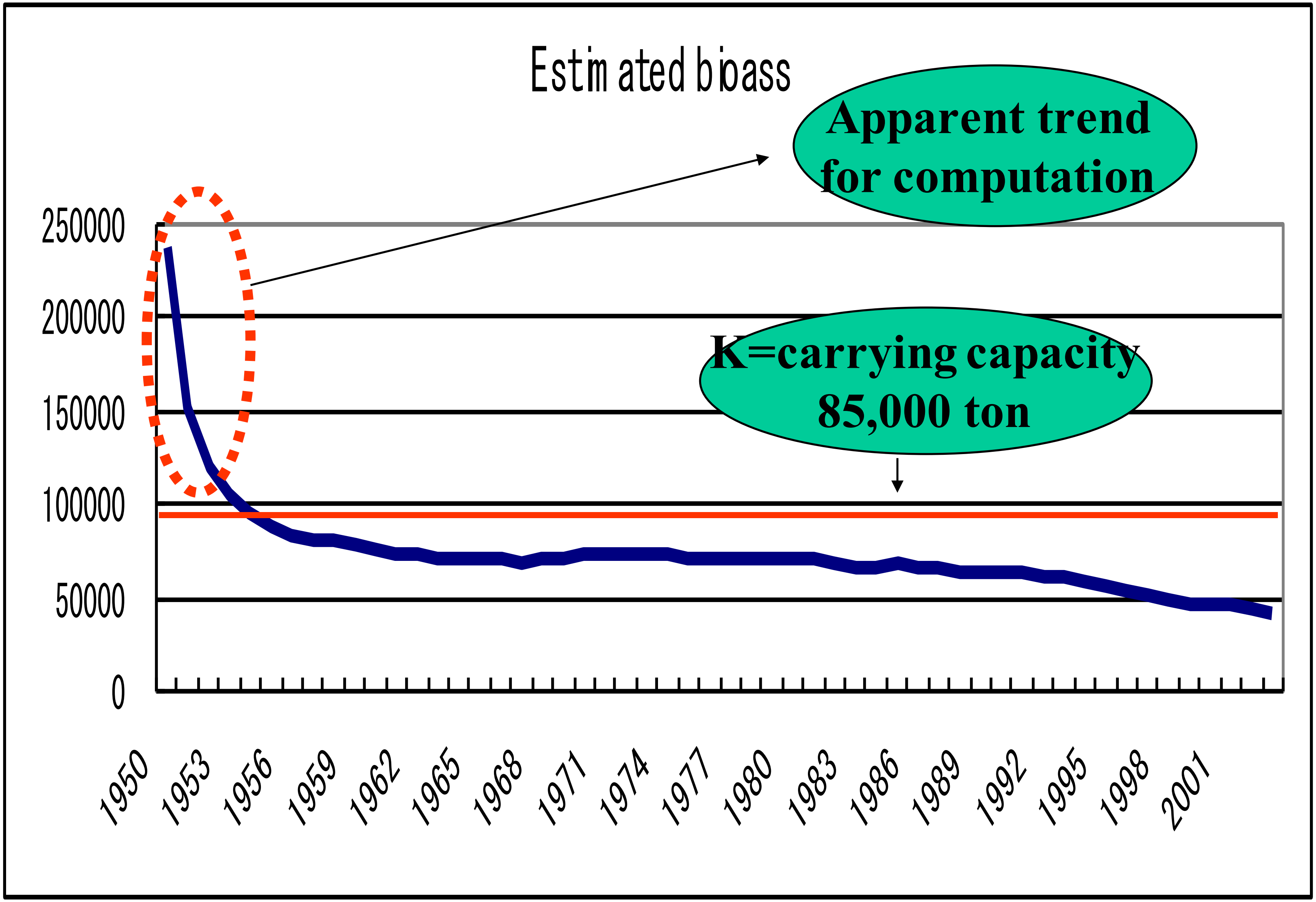
troll
point
lower
upper
20
15
10
5
0
1996
1997
1998
1999
2000
2001
2002
trend of kingfish catch by country
OTHERS
Domonica R.
T&T
Mexico
Venezuela
tons
12000
10000
8000
6000
4000
2000
0
1950
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
1998
2002

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

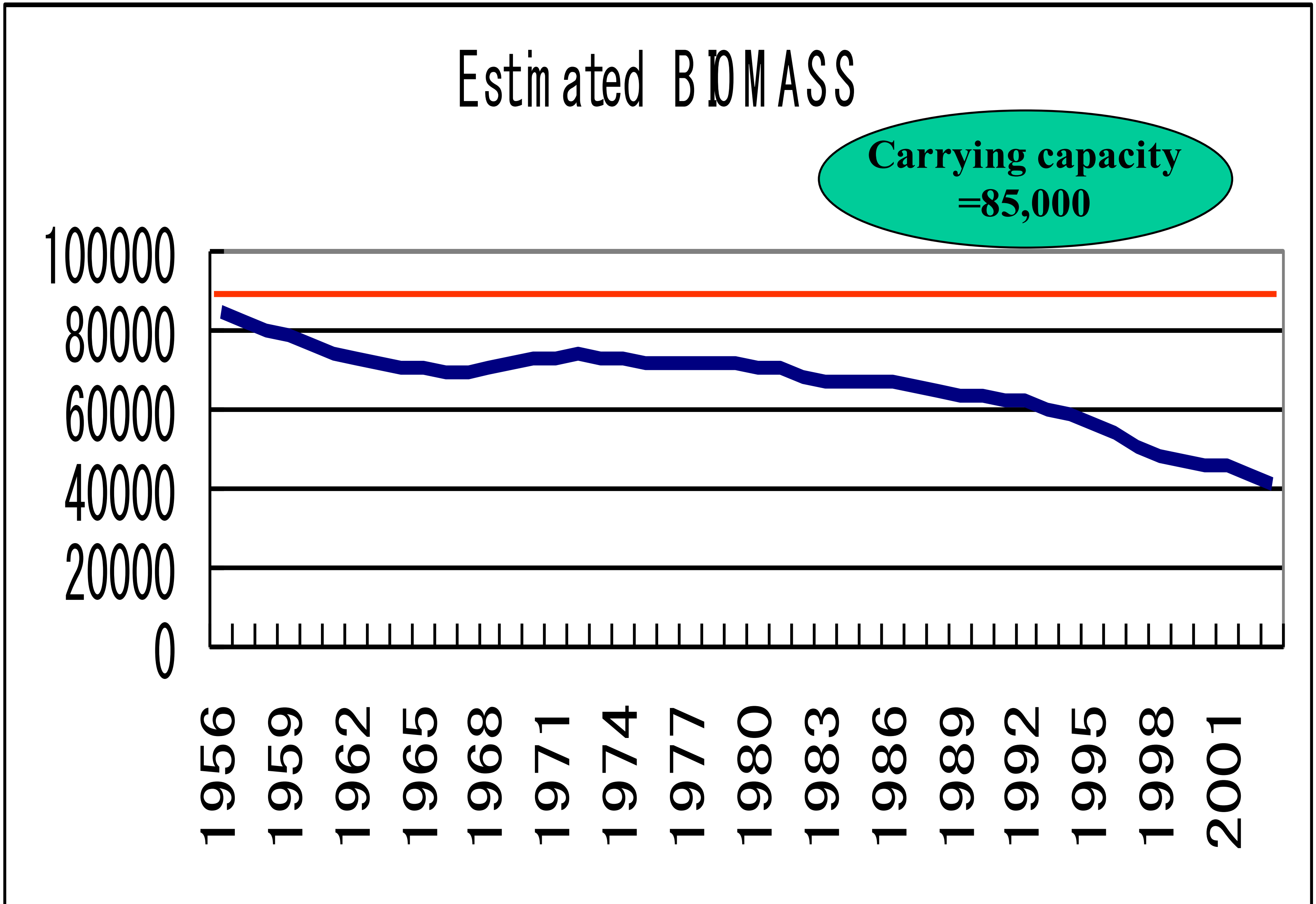
Parameter		Estimate	Starting guess	Estimated	User guess
B1R	Starting B/Bmsy, year 1950	2.284E+01	5.000E+00	1	1
MSY	Maximum sustainable yield	7.443E+03	5.000E+03	1	1
r	Intrinsic rate of increase	3.516E-01	3.000E-01	1	1
Catchability coefficients by fishery:					
q(1)					
Sample Effort & Catch, Table 2		2.279E-04	1.000E-05	1	1


MSY
totalcatch vs MSY
ton
12000
10000
8000
6000
4000
2000
0
1950
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
1998
2002

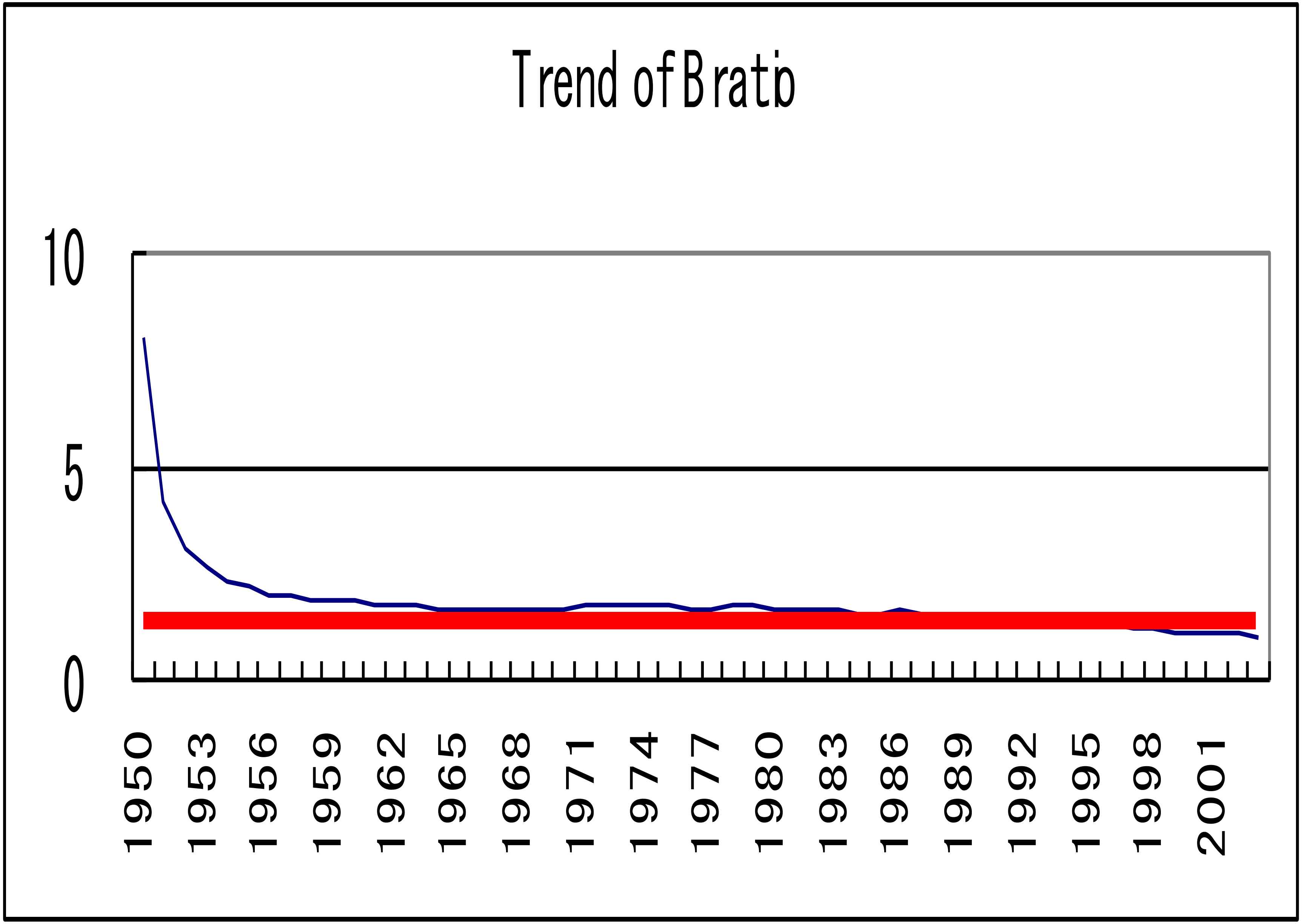

Estimated F
F MSY
0.3
0.2
0.1
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001



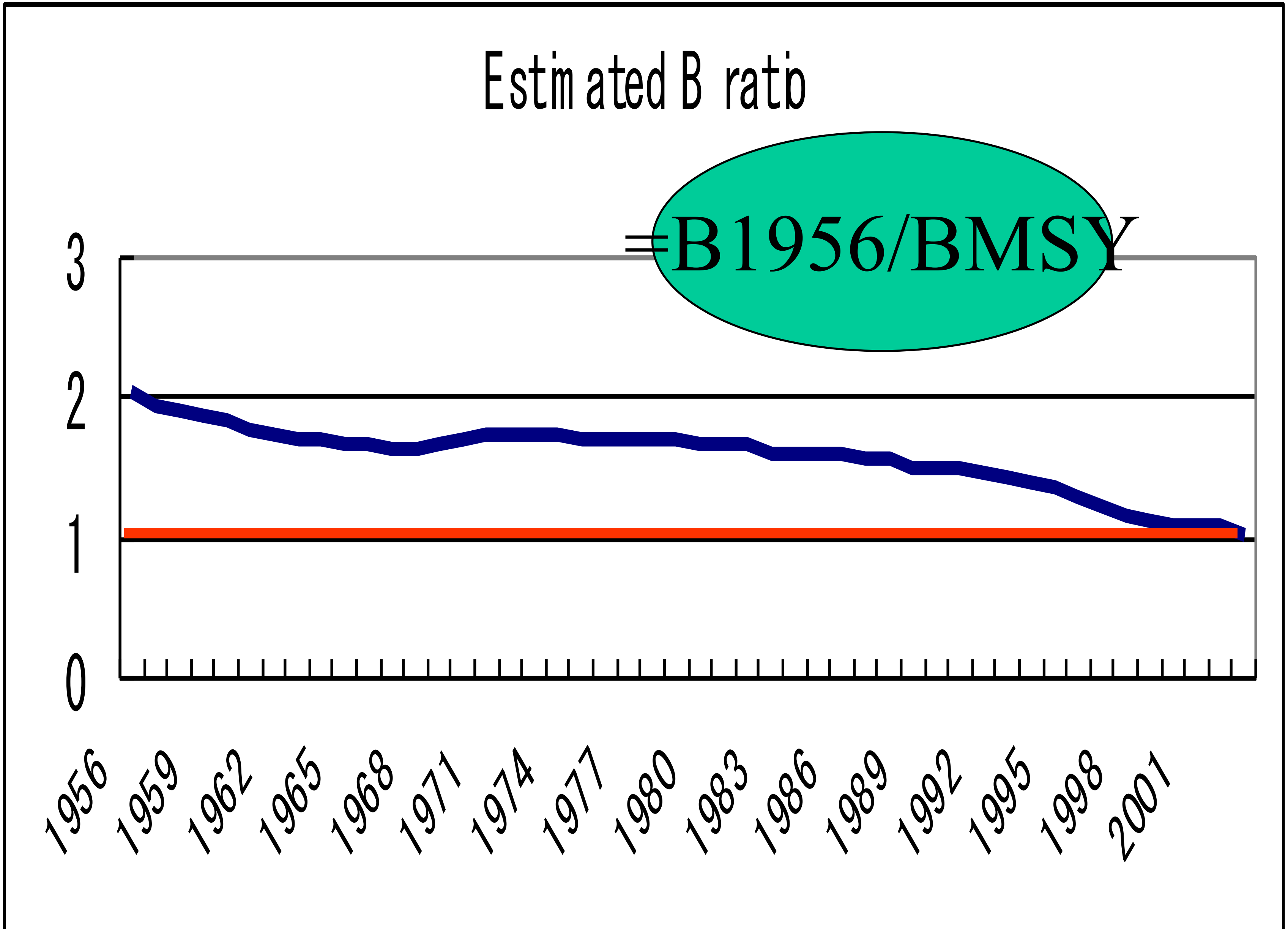
Estimated biass
Apparent trend for computation
K=carrying capacity 85,000 ton
250000
200000
150000
100000
50000
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001



Estimated BIOMASS
Carrying capacity
=85,000
100000
80000
60000
40000
20000
0
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001



Trend of B ratio
10
5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001



Estimated B ratio
=B1956/BMSY
3
2
1
0
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001

flow

1. Process Catch & effort data for gears targeting kingfish
2. Compute nominal CPUE by year, month,

   Day and area.

4. Standardize nominal CPUE by GLM
5. ASPIC (CPUE & global catch)

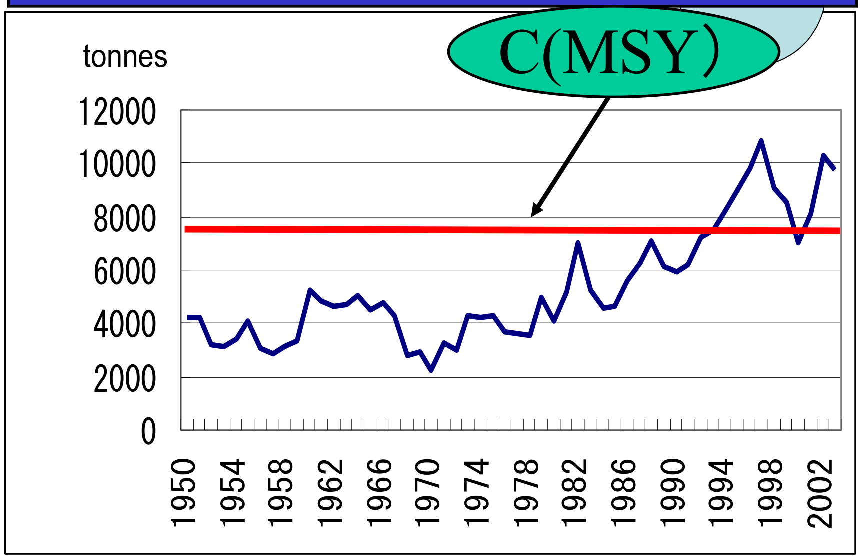
results

Table 3 Estimated parameters from the ASPIC analyses

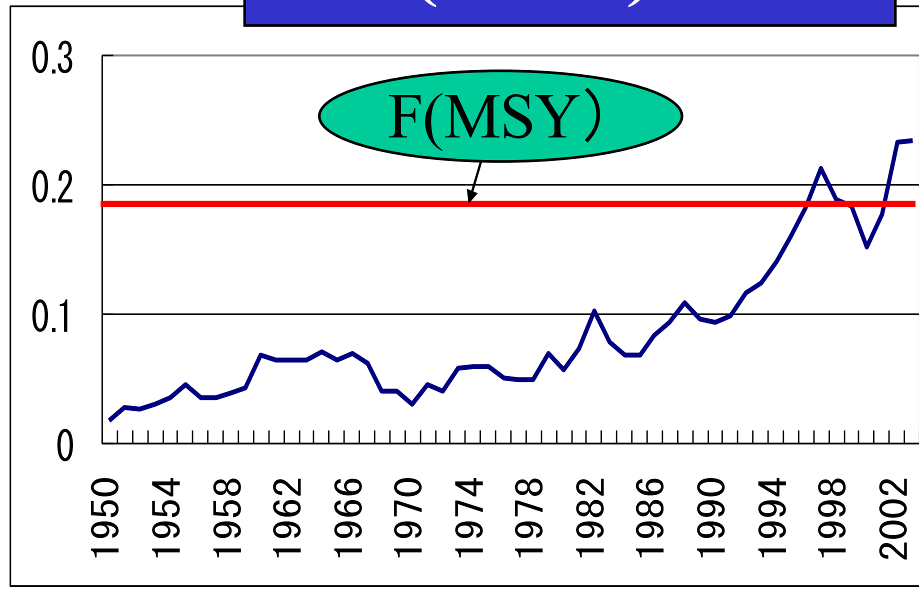
	Parameters	Estimated values
	MSY	7,443 tonnes
	Catch (2003)	9,734 tonnes
parameters	r	0.35
	q	0.0002279
	K	84,710 tonnes
Fishing mortality	F(MSY)	0.18
	F(2003)	0.23
	F ratio (F_{2003}/F_{MSY})	1.33
Total biomass	TB (2003)	41,560 tonnes
	TB (MSY)	42,350 tonnes
	B1 ratio (TB_{2003}/TB_{MSY})	0.98

TB: Total Biomass

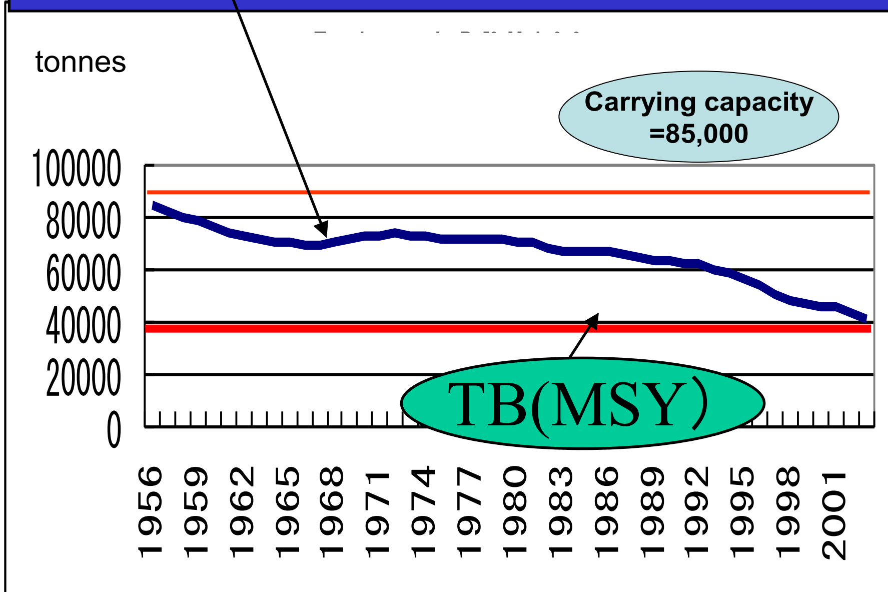
C(2003)/C(MSY)=1.31



F/F(MSY)=1.33



TB/TB(MSY)=0.98



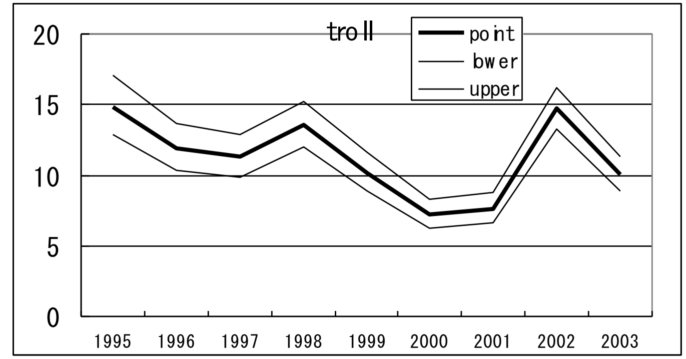
King Mackerel

(begininig) Overfishing

Catch and effort
➔ MSY

Future works（1）

STD_CPUE (TT Troll)



➔ representative？ Catch (5-10%)

➔ short term（9yrs）vs. catch（53yers）

- search other ＣＰＵＥ（other country, gear)

Future works (2)

Commercially important species

size data

size (age) based approach : ASPM

need 2 or more assessments

(cross validation)

Country	area	year	KAW
Oman	W	1978	89