Results of a surplus production modelling approach for three spatially disaggregated components of the west coast rock lobster resource

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Introduction

Initial results of a simple surplus production modeling approach for the three spatially disaggregated components ("super-areas") of the West Coast rock lobster were reported in Johnston and Butterworth (2002). These results corresponded to fits to CPUE data for the 1981-2000 period only. Here, the reference case (RC) set of analyses is repeated, with CPUE data series that have been updated and that now extend to 2002. The updated data and the various RC assumptions regarding poaching and recreational catches are reported in Johnston and Butterworth (2004). The catch related assumptions are however outlined again below for clarity.

Data

Catch Data

a) Commercial Catch data ($C_{c,t}$)

There are catch records ($C_{c,t}$ where *c* denotes commercial catch and *t* is the season) for 1968-2000 for each super-area. There are also "total" catch records for 1870-1967. (Note that the "year" 1967 denotes the 1967/68 season.)

RC: the historic (1870-1967) catch break-down assumed here is the following:

$$C_{c,t}^{3-6} = 0.60 * C_{c,t}^{T}$$
$$C_{c,t}^{7} = 0.25 * C_{c,t}^{T}$$
$$C_{c,t}^{8} = 0.15 * C_{c,t}^{T}$$

where $C_{c,t}^{T}$ is the total (Areas 1-11) West Coast rock lobster recorded catch for season *t*.

b) Recreational catch data ($C_{r,t}$)

The historical recreational take (denoted by *r* for season *t*) is assumed to be as follows:

$C_{r,t} = 0 \qquad t \leq 1959$

$C_{r,t}$ increases linearly from a value of zero in 1959 to a value of 469 in 1992. Also:

$C_{r,1993} = 391$
$C_{r,1994} = 336$
$C_{r,1995} = 379$
$C_{r,1996} = 496$
$C_{r,1997} = 340$
$C_{r,1998} = 249$
$C_{r,1999} = 360$
$C_{r,2000} = 404$
$C_{r,2001} = 469$
$C_{r,2002} = 583$

[units are MT]

It is assumed that the total recreational catch is caught in each super-area in the following proportions: A3-6 = 0.15
A7 = 0.05
A8 = 0.80

c) Poaching ($C_{p,t}$)

The total poaching take (denoted by *p* for season *t*) is assumed to be as follows:

$C^T_{p,t} = 0 \qquad t \leq 1949$

$C^T_{p,t}$ increases linearly from zero in 1949 to 500 in 1990.

$C^T_{p,t} = 500 \qquad t \geq 1990$

[units are MT]

RC: the total poaching take is assumed to be divided into the three super-areas as follows:

Area 3-6:	5%
Area 7:	15%
Area 8:	80%

CPUE data

CPUE data for each super-area are as reported in Glazer (2004).

FIMS CPUE data

FIMS CPUE are as reported in Johnston and Butterworth (2004).

The Modeling Approach

A surplus production model of the following form is used:

$$B_{t+1} = B_t + z_t r B_t \left[1 - \left(\frac{B_t}{K}\right)\right]^V - C_t \qquad (1)$$

where

B_t is the total (m+f) biomass in the super-area in season t

V is the shape parameter and is set at 4.555, which gives a B_{MSY} level of 0.18K (this assumption of 0.18K has been used frequently in the past for west coast rock lobster)

z_t is the annual scalar multiplier which makes allowance for changes in the "somatic growth rate" of the resource

r is the intrinsic growth rate (when $z_t = 1$)

K is the carrying capacity

C_t is the combined total catch ($C_{c,t} + C_{r,t} + C_{p,t}$) taken in the super-area in season t.

Also we calculate:

$$B_{MSY}/K = \frac{1}{1+V}\text{, and}$$

$$\begin{aligned} MSY &= (z_t rK) B_{MSY} (1 - B_{MSY})^V \\ &= (z_t rK) 0.073 \end{aligned} \qquad (2)$$

[Note that MSY is year dependent as it depends on the z_t value.]

The z_t values

The model externally fixes three values of z_t: z_{1990}, z_{1996} and z_{1999}. The following assumptions are then made for the RC:

- $z_t = 1.0$ for t = 1870 … 1987
- linearly interpolate between 1987 and 1990, between 1990 and 1996 and between 1996 and 1999.

The values of z_{1990}, z_{1996} and z_{1999} are obtained from the size structured model estimates of MSY for different levels of somatic growth rate. Taking proportions, the values are set as follows:

$z_{1990} = 0.40$
$z_{1996} = 0.70$
$z_{1999} = 0.34$

It is also assumed, following updated somatic growth GLM analyses that:

$z_{2000} = 0.376$

$z_{2001} = 0.412$

$z_{2002} = 0.45$

(Clearly different time-series of values for z could be argued over the 1990+ period, but this would not cause qualitative differences to the results reported here.)
The model is run from 1879-2002, being fitted to trap, hoopnet and FIMS CPUE data for the period 1981-2002 by minimising a negative log likelihood function.

The estimable parameters of the model are r and K.

Parameter constraints

$0 < r < 0.6$

$0 < K$

[an r above 0.60 is likely biologically unrealistic for this resource].

The model fits to the trap, hoopnet and FIMS CPUE data as follows. It is assumed that the observed abundance index is log-normally distributed about its expected value:

$$CPUE_t^g = q_1^g \hat{B}_t e^{\varepsilon_y} \quad \text{for } t = 1981\ldots1991 \tag{3}$$
$$CPUE_t^g = q_2^g \hat{B}_t e^{\varepsilon_y} \quad \text{for } t = 1992\ldots2002$$

where

$CPUE_t^g$	is the CPUE index for year t for either trap, hoopnet or FIMS,
q_1^g	is the catchability coefficient for that index for the period 1981-1991 (when minimum size was 89mm),
q_2^g	is the catchability coefficient for that index for the period 1992-2002 (when minimum size was 75mm),
$\hat{B}_t$	is the model estimate of population biomass at the start of year t, and
ε_y	is from $N(0,\sigma_g^2)$.

The contribution of the three CPUE data sources to the negative of the log-likelihood function is given by:

$$-\ln L = \sum_g n^g \ln\sigma_g + \frac{1}{2\sigma_g^{\ 2}} \sum_t \left(\ln CPUE_t^g - \ln q_{1or2}^g - \ln \hat{B}_t\right)^2 \tag{4}$$

where:

g is either gear type trap, hoopnet or FIMS,

σ_g is the residual standard deviation estimated in the fitting procedure by its maximum likelihood value:

$$\hat{\sigma}_g = \sqrt{1/n^g \sum_t \left(\ln CPUE_t^g - \ln q_{1or2}^g - \ln \hat{B}_t\right)^2} \tag{5}$$

where

n^g is the total number of data points in the full CPUE series, and

q_{1or2}^g is the catchability coefficient, estimated by its maximum likelihood value:

$$\ln \hat{q}_1^g = 1/n_1^g \sum_{t=1981}^{1991} \left(\ln CPUE_t^g - \ln \hat{B}_t\right)$$

and (6)

$$\ln \hat{q}_2^g = 1/n_1^g \sum_{t=1992}^{2000} \left(\ln CPUE_t^g - \ln \hat{B}_t\right)$$

where

n_1^g refers to the number of data points in the 1981-1991 period, and

n_2^g refers to the number of data points in the 1992-2002 period.

Results and Discussion

The RC assessment results are reported in Table 1. The fits to the CPUE data are illustrated in Figures 1a-c. The fits to super-area 3-6 seem reasonable (Figure 1a), but for super-area 7 (Dassen Island, Figure 1b) the model does not fully capture the increasing trend in the indices over the last decade. For super-area 8 the model fits the slightly declining trend suggested by the FIMS index, but is able to reproduce the contrary trend in the two commercial indices only by estimating a much larger increase in catchability in 1992 following the change in minimum size than was estimated for the other two super-areas (see Table 1). Note that the estimate of r = 0.60 for super-area 8 hits the upper constraint level. The very large B(2002) estimate for super-area 8 (80 673 MT) also seems unrealistically high. The 95% CIs were calculated (using a likelihood profile approach) for a few key parameters for the super-area 8 fit, and these show extremely high CIs associated with both K and B(2002). Thus the fit for super-area 8 cannot be considered particularly satisfactory.

Biomass and catch trajectories are illustrated in Figures 2a-c. Figure 2c shows that the catch is estimated to have had a relatively small impact on the biomass estimated for super-area 8, compared to a much larger impact in super-areas 2-6 and 7, which are both estimated to be heavily depleted.

References

Glazer, J. 2004. Short note on deriving area-specific indices of abundance from the commercial data. MCM document, WG/03/04/WCRL3. 6pp.

Johnston, S.J. and D.S. Butterworth. 2002. Initial results of a surplus production modelling approach for three spatially disaggregated components of the West Cost rock lobster resource. BENEFIT document, BEN/DEC02/WCRL/5.

Johnston, S.J. and D.S. Butterworth. 2004. A compilation of data to be used for spatial disaggregated assessments of the West Coast rock lobster resource. MCM document, WG/03/04/WCL8.

Table 1: Results of the RC model fits. Likelihood profile 95% CIs are provided in parentheses for a few parameters.

	Super-area 3-6	**Super-area 7**	**Super-area 8**
r	0.449	0.500	0.600* (0.52-0.60*)
K	169 500	65 6472	161 652 (44 279-785 572)
-*lnL* trap CPUE	-14.74	-5.42	-16.18
-*lnL* hoop CPUE	-13.56	-5.62	-12.18
-*lnL* FIMS CPUE	7.28	3.52	-12.48
-*lnL* TOTAL	-21.02	-7.526	-40.84
σ_{trap}	0.310	0.474	0.290
σ_{hoop}	0.327	0.469	0.349
σ_{FIMS}	1.256	0.863	0.195
B_{2002}	6 555	5 320	80 673 (4 156-505 672)
q_1^{trap}	$1.64 .10^{-4}$	$2.35 .10^{-4}$	$5.18 .10^{-6}$
q_2^{trap}	$2.24 .10^{-4}$	$2.29 .10^{-4}$	$1.72 .10^{-5}$
q_1^{hoop}	$1.63 .10^{-4}$	$2.32 .10^{-4}$	$5.15 .10^{-6}$
q_2^{hoop}	$2.23 .10^{-4}$	$2.25 .10^{-4}$	$1.70 .10^{-5}$
B_{2002}/K	0.038	0.081	0.499
MSY 1980	5 560	2 395	7 078
MSY 1990	2 224	958	2 831
MSY 1995	3 614	1 557	4 601
MSY 2000	2 090	900	2 661
B_{MSY}	30 510	11816	29 097
B_{MSY}/K	0.180	0.180	0.180

* a maximum constraint of 0.6 is set.

Figure 1a: Super-area 3-6 model fits to CPUE data for the RC.

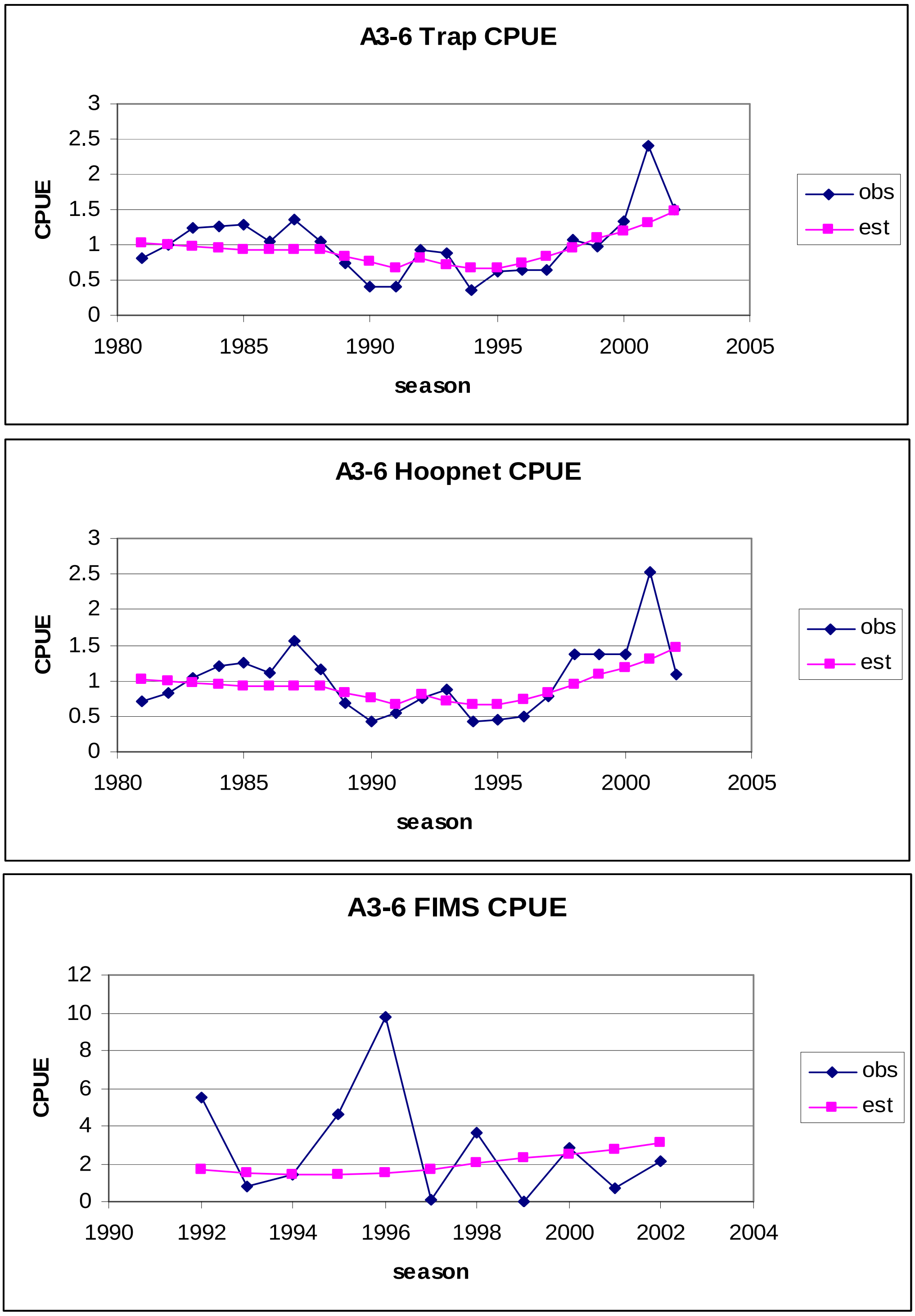


Figure 1b: Super-area 7 model fits to CPUE data for the RC.

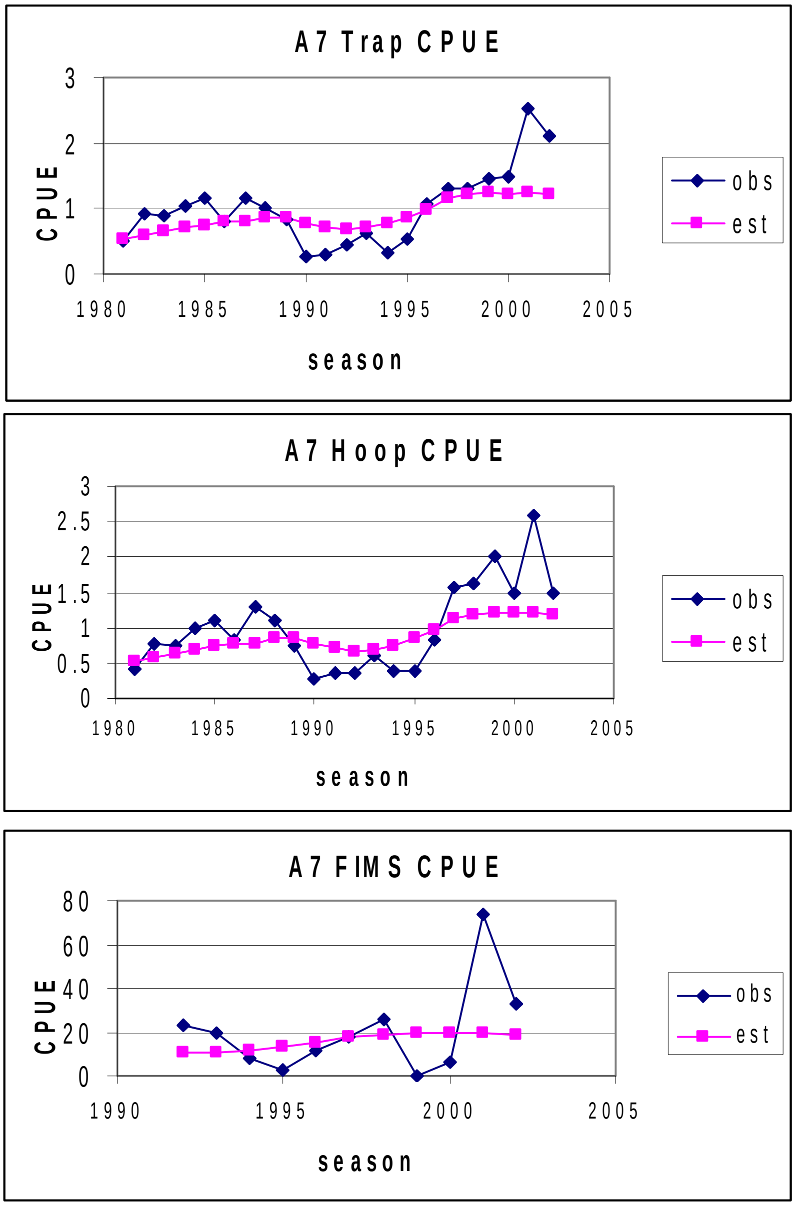
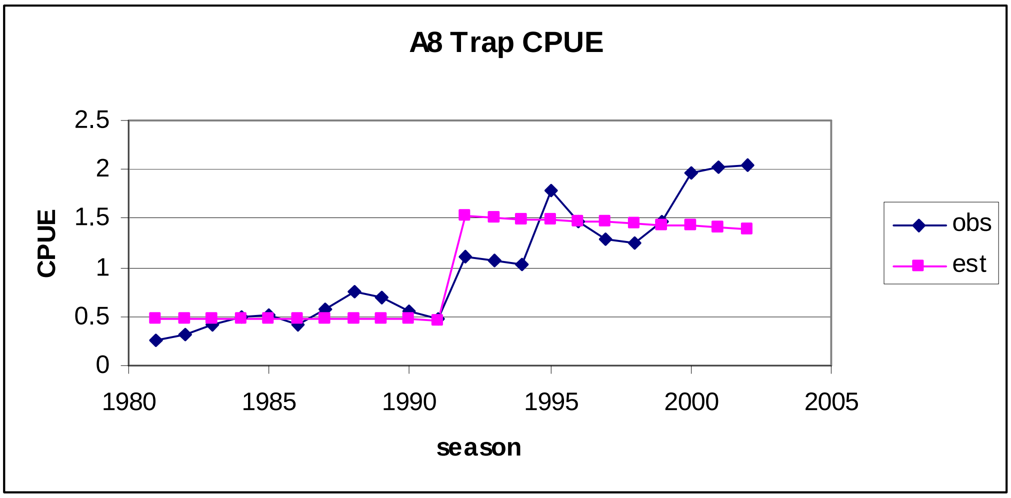
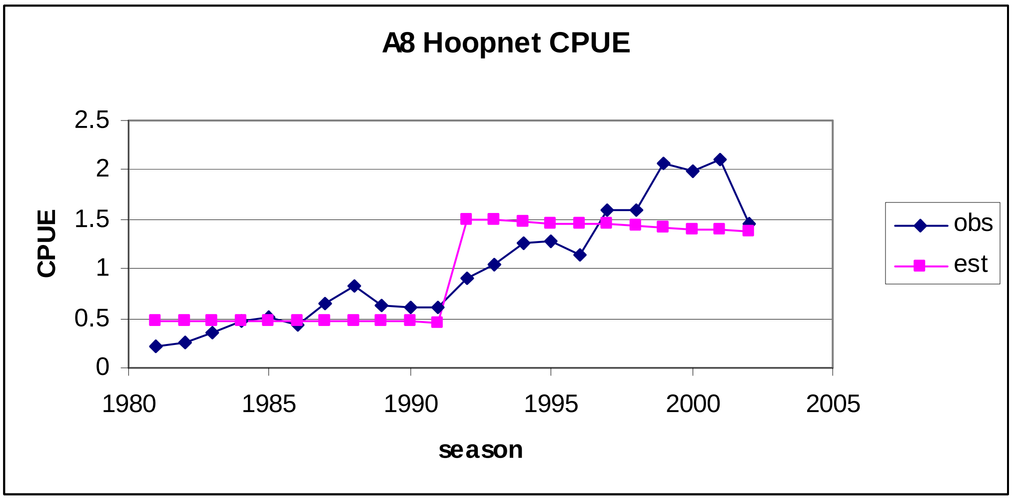


Figure 1c: Super-area 8 model fits to CPUE data for the RC.





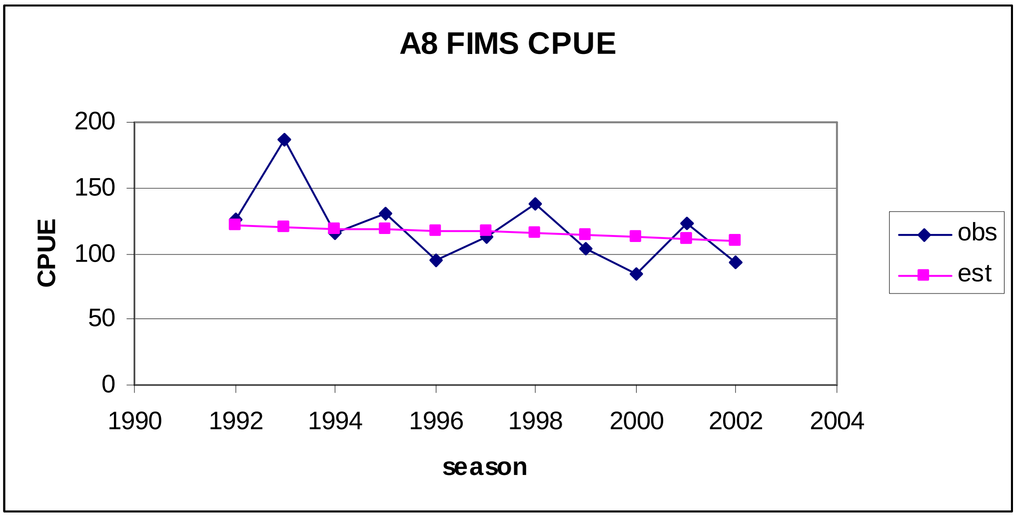
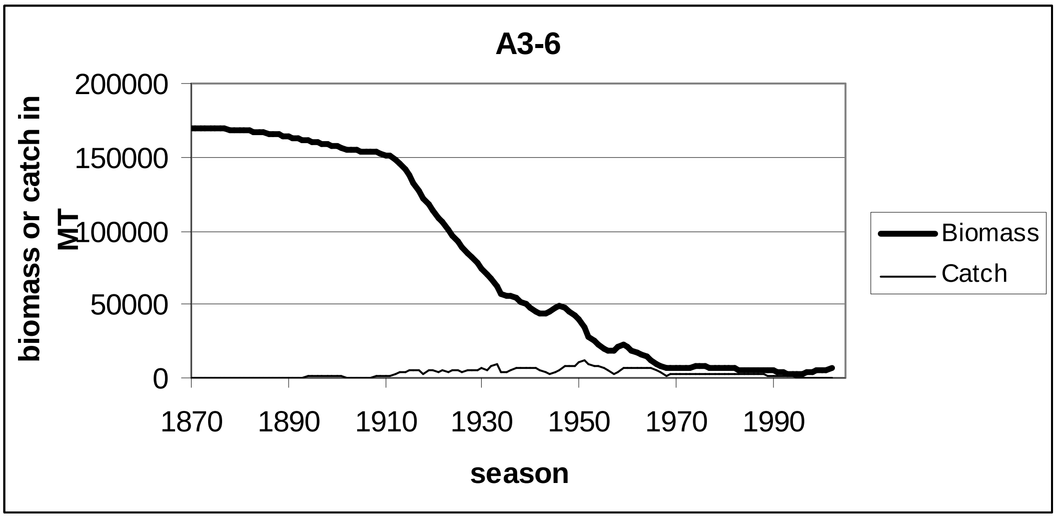


Figure 2a: RC super-area 3-6 biomass estimates and the total catch (commercial + poaching + recreational). Note that the top panel is for 1870-2002, whilst the bottom panel is for 1950-2002 only.



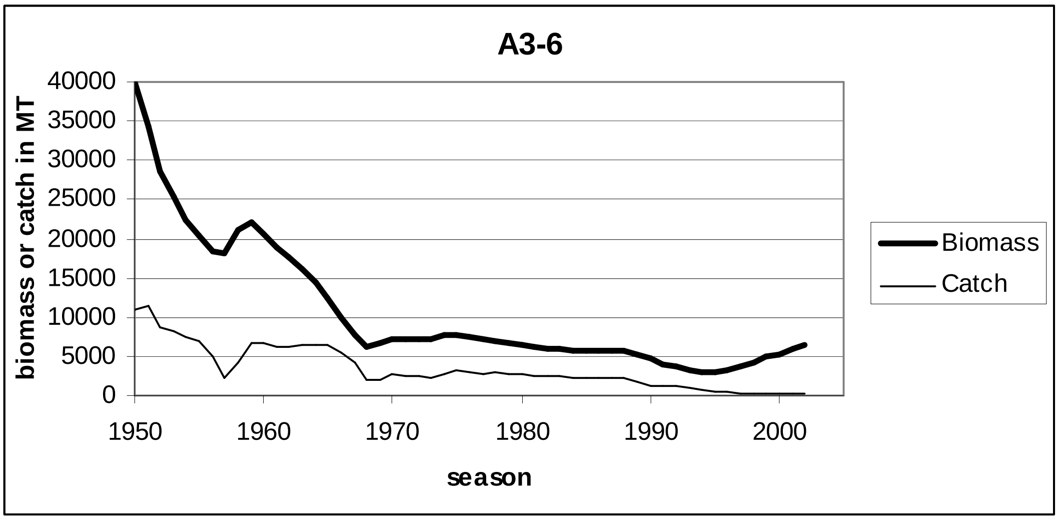
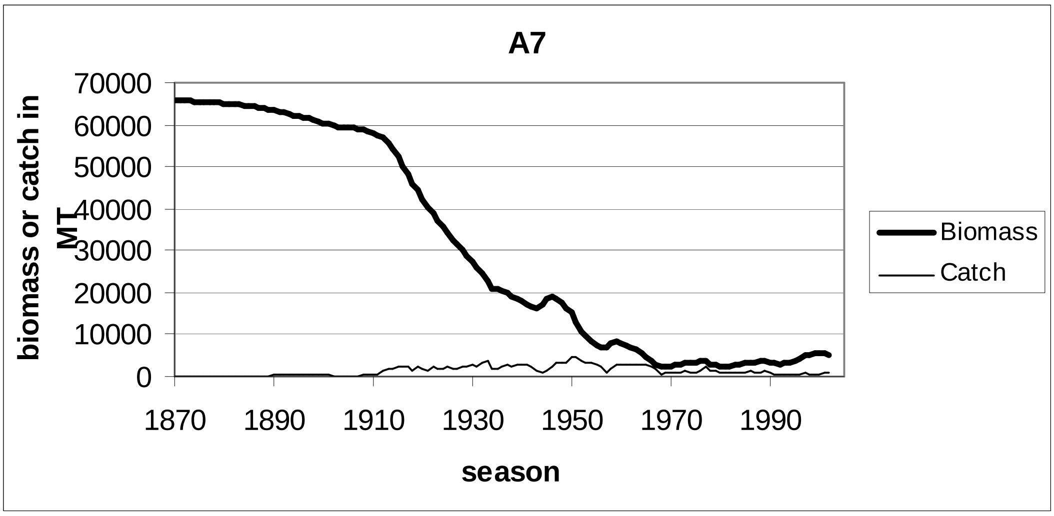


Figure 2b: RC super-area 7 biomass estimates and the total catch (commercial + poaching + recreational). Note that the top panel is for 1870-2002, whilst the bottom panel is for 1940-2002 only.



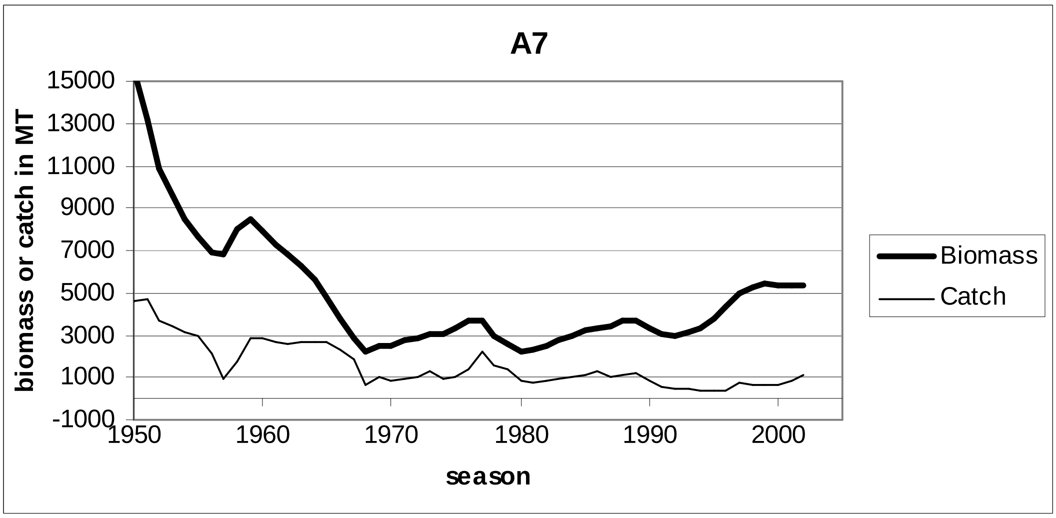


Figure 2c: RC super-area 8 biomass estimates and the total catch (commercial + poaching + recreational). Note that the top panel is for 1870-2002, whilst the bottom panel is for 1940-2002 only.