SCIENTIFIC COMMITTEE
SECOND REGULAR SESSION

7-18 August 2006
Manila, Philippines

AN UPDATE OF THE STOCK ASSESSMENT FOR SOUTH PACIFIC ALBACORE INCLUDING AN INVESTIGATION OF THE SENSITIVITY TO KEY BIOLOGICAL PARAMETERS INCLUDED IN THE MODEL

WCPFC-SC2-2006/SA WP-4

Paper prepared by

Adam D. Langley and John Hampton

Secretariat of the Pacific Community
Ocean Fisheries Program
Noumea, New Caledonia

An update of the stock assessment for South Pacific albacore tuna, including an investigation of the sensitivity to key biological parameters included in the model.

Adam Langley and John Hampton
Secretariat of the Pacific Community

1. Introduction

The stock assessment for South Pacific albacore tuna was conducted in 2005 and reported to the first Scientific Committee of the WCPFC (Langley & Hampton 2005). The assessment was conducted using MULTIFAN-CL and incorporated catch, effort, size composition (length), and tagging data. The base-case model adopted a single regional structure and included 23 separate fisheries, including key domestic longline fisheries operating in the sub-equatorial area of the South Pacific (Table 1). Details of the individual data sets included in the model are described in Langley & Hampton (2005).

The 2005 assessment concluded that overfishing of South Pacific albacore was not occurring, nor was the stock in an overfished state; current fishing mortality rates were very low relative to the fishing mortality based reference point ($F_{current}/\tilde{F}_{MSY}$ = 0.05) and current biomass levels were well above the biomass based reference points ($B_{current}/\tilde{B}_{MSY}$ = 1.69 and $SB_{current}/S\tilde{B}_{MSY}$ = 4.29) (Langley & Hampton 2005).

Nevertheless, the 2005 assessment further concluded that the current level of longline catch is estimated to be having a measurable impact on the portion of the stock vulnerable to the longline fishery. The magnitude of this impact is uncertain, although the "base case" assessment indicates that the current level of impact was about 30% (i.e., the current longline exploitable biomass is 30% lower than it would be in an unexploited stock) and has increased sharply in recent years. However, the impact on the adult component of the stock is considerably less due to the age-specific exploitation pattern of the longline fisheries (Langley & Hampton 2005).

These conclusions indicate that while there are no biological concerns regarding the status of the South Pacific albacore stock, there are potential management issues relating to the economic viability of some of the Pacific Islands domestic longline fisheries at higher levels of exploitation. Any substantial increase in exploitation rates could reduce the level of biomass vulnerable to these fisheries and, thereby, reducing catch rates of albacore below economically sustainable levels (Hampton et al 2005). On this basis, reference points based on achieving MSY from the fishery are inappropriate from a management perspective. Instead, a reference point that maintains the economic viability of these fisheries should be considered. This issue is considered in more detail in Langley (2006).

While the current stock assessment is relatively optimistic from the perspective of biological sustainability, there remains considerable uncertainty in the assessment, particularly with respect to some of the key biological parameters in the model. The key biological inputs include growth, natural mortality, and age at maturity (Table 2). The purpose of this paper is to investigate the sensitivity of the stock assessment model to these parameters using fishery data updated to include the last few years (2004 and 2005), while maintaining a model structure equivalent to the 2005 assessment (Langley & Hampton 2005, Table 3). The degree of sensitivity of the model results to the range of assumed biological parameters may enable a prioritisation of further research directed at improving the available estimates.

This paper presents only the key conclusions of the various model runs. For further details regarding the input data sets and the 2005 “base-case” assessment results, see Langley & Hampton (2005).

2. Model update

The 2005 “base case” model was rerun with the addition of the available catch, effort, and length data from the 2004 and 2005 years. Recent catch and effort data were available for most fisheries, although data for the key Taiwanese distant-water fleet were incomplete for 2005. Recent catch rates for this fleet were lower then preceding years in each of the four sub-areas of the model (fisheries 2, 8, 14, 18). Similarly, catch rates for many of the Pacific Island domestic longline fleets were lower in 2003–2005 relative to earlier years. Recent length frequency data were dominated by size data from the Pacific Island domestic longline fisheries and the New Zealand troll fishery.

The structure for the base case model is described in Table 3. The initial biological parameters included in the model are presented in Table 2. Of these values, natural mortality and the growth parameters are subsequently estimated within the model fitting procedure.

3. Sensitivity analyses

The range of model sensitivities included the investigation of a lower value of natural mortality (0.3 per annum compared to 0.435 estimated for the base case) and alternative growth parameters (lower and higher values of *k*). In these two sets of model runs, the estimates of *k* and M were partially constrained by a penalty from deviation from a ratio of M/*k* equal to 1.5 (Jensen 1996, Williams & Shertzer 2003). The various sensitivities are described in the following Table.

Summary of sensitivities investigated for natural mortality and growth parameters.

Model		**Growth parameters**		
	M	**$L_{t=1}$**	**k**	**Linf**
Base case	Estimated (0.435)	Estimated (44.6)	Estimated (0.206)	Estimated (105)
Low M	Fixed (0.3)	Estimated	Estimated	Estimated
Low *k*	Estimated	Estimated	Fixed (0.12)	Estimated
High *k*	Estimated	Estimated	Fixed (0.30)	Estimated

In addition, the sensitivity of the model to the current maturity OGIVE was examined. The sensitivity represented a more conservative scenario, whereby, maturity was reached two years later than currently assumed (Table 2). The sensitivity analysis had 50% maturity at age 7 years and full maturity at age 8 years.

For each model run, a range of reference points were derived and key reference points compared to the “base case” assessment. The level of depletion of the exploitable biomass vulnerable to key fisheries was also compared.

4. Results

The key reference points for each of the model runs are presented in Table 5.

4.1. Base case assessment

The base case assessment, updated to include the more recent fishery data, yields broadly comparable results to the 2005 base case model (Langley & Hampton 2005). The relative trends in both total and adult biomass are comparable between the two models. However, there is a considerable difference in the magnitude of the level of absolute biomass, particularly for the adult component of the stock (Figure 1).

Nevertheless, the key equilibrium based reference points are comparable between the two models: $B_{current}/\tilde{B}_{MSY}$, 1.69 in 2005 compared to 1.34 from the current assessment; $SB_{current}/S\tilde{B}_{MSY}$, 4.29 compared to 4.10; $F_{current}/\tilde{F}_{MSY}$, 0.05 compared to 0.04. Consequently, the key conclusions of the current stock assessment remain essentially unchanged from the results of Langley & Hampton (2005); i.e. that current fishing mortality rates are very low relative to the fishing mortality based reference point and current biomass levels were well above the biomass based reference points.

For the current assessment, the lower level of absolute biomass is attributable to the difference in the estimated value of natural mortality between the two models; estimated to be 0.317 in the 2005 model and 0.435 in the current model. The two models estimate equivalent levels of recruitment and, consequently, the higher natural mortality estimated in the current model results in a substantially lower level adult biomass. The difference between the two estimates of natural mortality indicates that the size and tagging data included in the model are uninformative regarding this parameter. Despite the similarity in recruitment estimates between the two assessments, there is also very limited information in the model to estimate the overall magnitude recruitment of the stock.

Another consistent observation between the 2005 and current base case assessment is that the biomass based reference point for total biomass ($B_{current}/\tilde{B}_{MSY}$) is substantially lower than the equivalent reference point for adult biomass ($SB_{current}/S\tilde{B}_{MSY}$) (Table 5). This is attributable to a lower level of recruitment estimated for the last decade resulting in a lower juvenile and total biomass. The lower recruitment is yet to promulgate fully through to the adult component of the stock and can be expected to reduce the level of adult biomass further over the next five years.

For the current assessment, a comparison of the current level of fishery-specific exploitable (vulnerable) biomass with the estimated biomass level in the absence of fishing indicates an approximate 40% reduction in the exploitable biomass for a number of the key Pacific Island domestic longline fleets (New Caledonia, Fiji, and Samoa; slightly higher for French Polynesia) (Table 6). This is a slightly higher level of impact than estimated in the 2005 assessment (about a 30% reduction).

4.2. Sensitivity analyses

The sensitivity analysis investigating an increase in maturity-at-age resulted in a substantial reduction in adult biomass levels, relative to the current base case, simply due to the change in the definition of adult biomass (Table 5). However, there is no substantive change to the principal reference points. This is due to the very weak stock-recruitment relationship (SSR) estimated by the model (steepness = 0.9), whereby, reducing the spawning biomass has minimal impact on the recruitment potential of the stock.

The lower value of natural mortality investigated in the sensitivity analysis (0.30 compared to 0.44), results in substantively lower levels of reference biomass, particularly total biomass, and a considerably lower estimate of *MSY* (Table 5). However, the estimate of *MSY* is still considerably higher than current yields. Current levels of fishing mortality are estimated to be substantially lower than reference levels, albeit higher than the base case, while biomass levels, particularly adult biomass, are higher than the corresponding reference points. Overall, fishery impacts on the key domestic longline fisheries are approximately 10% higher than for the base case assessment (Table 6).

The various parameterisations of the growth function investigated in this analysis are illustrated in Figure 2. The slow growth scenario (low *k*) yielded similar results to the base case assessment for all reference points considered (Table 5). This may be due to the very low exploitation rates of the smaller/younger size/age classes over the age range where there was greatest difference in the assumed age at length (5–9 years) between the two growth functions (Figure 2).

The faster growth scenario (high *k*) means that fish reach the size of vulnerability at a younger age compared to the base case (Figure 2). The fast-growth model estimates lower overall levels of equilibrium (total) biomass compared to base case assessment (Table 5). However, the key biological reference points ($B_{current}/\tilde{B}_{MSY}$, $SB_{current}/S\tilde{B}_{MSY}$, and $F_{current}/\tilde{F}_{MSY}$) are all very similar to the base case assessment.

5. Conclusions

In summary, for the range of scenarios examined, the key conclusions of the stock assessment remain insensitive to significant changes to the main biological parameters. This result strengthens the conclusion that there is no concern regarding the biological sustainability of the stock at the current level and age-specific pattern of exploitation; i.e., current biomass levels are well above the biomass-based reference points and exploitation rates are low relative to the F_{MSY} level.

Nevertheless, the comparison with the previous years' assessment reveals that there is a high degree of uncertainty regarding value of natural mortality and limited information in the model data to reliably estimate this parameter. As a priority, further research should focus on attempting to refine current estimates of natural mortality.

A number of other key observations emerge from the current assessment. Firstly, while there is no concern about the biological sustainability of the stock, the level of biomass vulnerable to the Pacific Islands domestic longline fisheries has declined over the last decade. The model attributes the decline to (i) an increase in the overall impact of the total fishery on this component of the stock and (ii) a substantial reduction in the level of recruitment over the last decade. The latter effect will continue to impact on the longline fisheries as the lower levels of recruitment promulgate into the longline vulnerable biomass over the next 5 years.

Variation in South Pacific albacore recruitment has been linked to oceanographic conditions indexed by the ENSO cycle; low recruitment occurring during persistent El Niño conditions and high recruitment during La Niña (Lehodey et al. 2003). This relationship will be examined in more detail during the next full stock assessment of South Pacific albacore. Recent trends in catch rate for the domestic longline fisheries have also been strongly linked to oceanographic conditions (Langley 2006). The interaction between fish availability and stock abundance needs to be more explicitly considered in the assessment model, principally through the development of techniques to standardise the catch rate data for these fisheries.

6. References

Hampton, J., Langley, A., Harley, S., Kleiber, P., Takeuchi, Y., and Ichinokawa, M. 2005. Estimates of sustainable catch and effort levels for target species and the impacts on stocks of potential management measures. WCPFC-SC1 SA WP-10, Noumea, New Caledonia, 8–19 August 2005.

Jensen, A.L. 1996. Beverton and Holt life histiory invariants result from optimal trade-off of reproduction and survival. Can. J. Fish. Aquat. Sci 53:820–822.

Williams, E., and K. Shertzer. 2003. Implications of life-history invariants for biological reference points used in fishery management. Can. J. Fish. Aquat. Sci. 60:710–720.

Langley, A.D. 2006. The South Pacific albacore fishery: a summary of the status of the stock and fishery management issues of relevance to Pacific Island countries and territories. Technical Report 37. Noumea, New Caledonia: Secretariat of the Pacific Community.

Langley, A., and J. Hampton 2005. Stock assessment of albacore tuna in the south Pacific Ocean. Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia. SC1 SA WP-3.

Lehodey, P., Chai, F., and Hampton, J. 2003. Modelling climate-related variability of tuna populations from a coupled ocean–biogeochemical-populations dynamics model. *Fish. Oceanogr.* 12:4/5, 483–494, 2003

Table 1: A description of the fisheries included in the assessment.

Fishery	Fishery label	Region	Method	Flag	Catch	Effort
1	JP,JPDW,KR LL 1	1	Longline	Japan, Korea	Number	Hooks (100s)
2	TWDW LL 1	1	Longline	Taiwan	Number	Hooks (100s)
3	AU LL 1	1	Longline	Australia	Number	Hooks (100s)
4	NC LL 1	1	Longline	New Caledonia	Number	Hooks (100s)
5	FJ LL 1	1	Longline	Fiji	Number	Hooks (100s)
6	OTHER LL 1	1	Longline	Other	Number	Hooks (100s)
7	JP,JPDW,KR LL 2	2	Longline	Japan, Korea	Number	Hooks (100s)
8	TWDW LL 2	2	Longline	Taiwan	Number	Hooks (100s)
9	AS,WS LL 2	2	Longline	American Samoa, Samoa	Number	Hooks (100s)
10	TO LL 2	2	Longline	Tonga	Number	Hooks (100s)
11	PF LL 2	2	Longline	French Polynesia	Number	Hooks (100s)
12	OTHER LL 2	2	Longline	Other	Number	Hooks (100s)
13	JP,JPDW,KR LL 3	3	Longline	Japan, Korea	Number	Hooks (100s)
14	TWDW LL 3	3	Longline	Taiwan	Number	Hooks (100s)
15	AU LL 3	3	Longline	Australia	Number	Hooks (100s)
16	NZ LL 3	3	Longline	New Zealand	Number	Hooks (100s)
17	JP,JPDW,KR LL 4	4	Longline	Japan, Korea	Number	Hooks (100s)
18	TWDW LL 4	4	Longline	Taiwan	Number	Hooks (100s)
19	OTHER LL 4	4	Longline	Other	Number	Hooks (100s)
20	TROLL 3	3	Troll	New Zealand, United States	Number	Days
21	TROLL 4	4	Troll	New Zealand, United States	Number	Days
22	DN 3	3	Drift net	Japan, Taiwan	Weight	Days
23	DN 4	4	Drift net	Japan, Taiwan	Weight	Days

Table 2: Initial values for the biological parameters included in the model.

Parameter	Value	
Proportion mature at age	0,0,0,0,0.5,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1	Fixed
Length-wt relationship	a = 6.9587e-06, b =3.2351	Fixed
Growth (Von bertalanfy)	$L_{t=1}$ = 45 cm, k = 0.2, Linf = 100 cm	Estimated
Natural mortality	0.4	Estimated

Table 3: Main structural assumptions used in the albacore tuna assessment model.

Category	Assumption
Observation model for total catch data	Observation errors small, equivalent to a residual SD on the log scale of 0.07.
Observation model for length-frequency data	Normal probability distribution of frequencies with variance determined by sample size and observed frequency. Effective sample size is assumed to be 0.1 times actual sample size with a maximum effective sample size of 100.
Observation model for tagging data	Tag numbers in a stratum have poisson probability distribution.
Tag reporting	Longline reporting rates within each fleet are constrained to be equal. Relatively uninformative prior for all fisheries. Base-case analysis has maximum reporting rate constrained to be <=0.9. All reporting rates constant over time.
Tag mixing	Tags assumed to be randomly mixed at the model region level after the first year following release.
Recruitment	Occurs as discrete events in June of each year. Recruitment is weakly related to spawning biomass with a 1 year lag via a Beverton-Holt SRR (beta prior for steepness with mode at 0.9 and SD of 0.1).
Initial population	Equilibrium age structure in the region as a function of the estimated natural mortality.
Age and growth	20 annual age-classes, with the last representing a plus group. Age-class 1 allowed an independent mean length; other age-class mean lengths constrained by von Bertalanffy growth curve. Mean weights (W_j) computed internally by estimating the distribution of weight-at-age from the distribution of length-at-age and applying the weight-length relationship $W = aL^b$ (*a*=6.9587e-06, *b*=3.2351 estimated from available length-weight data).
Selectivity	Constant over time. Coefficients for the last 2 age-classes are constrained to be equal. Longline selectivities are non-decreasing with increasing age.
Catchability	Seasonal variation for all fisheries. All fisheries, except Taiwanese longline, have structural time-series variation, with random steps (catchability deviations) taken every 2 years. Catchability deviations constrained by a prior distribution with (on the log scale) mean 0 and SD 0.1.
Fishing effort	Variability of effort deviations constrained by a prior distribution with (on the log scale) mean 0 and SD 0.22 for all fisheries.
Natural mortality	Constant with respect to age; uninformative prior distribution with mean 0.4 (no penalty).
Movement	Not relevant for the single region model.

Table 4. Description of symbols used in the yield analysis.

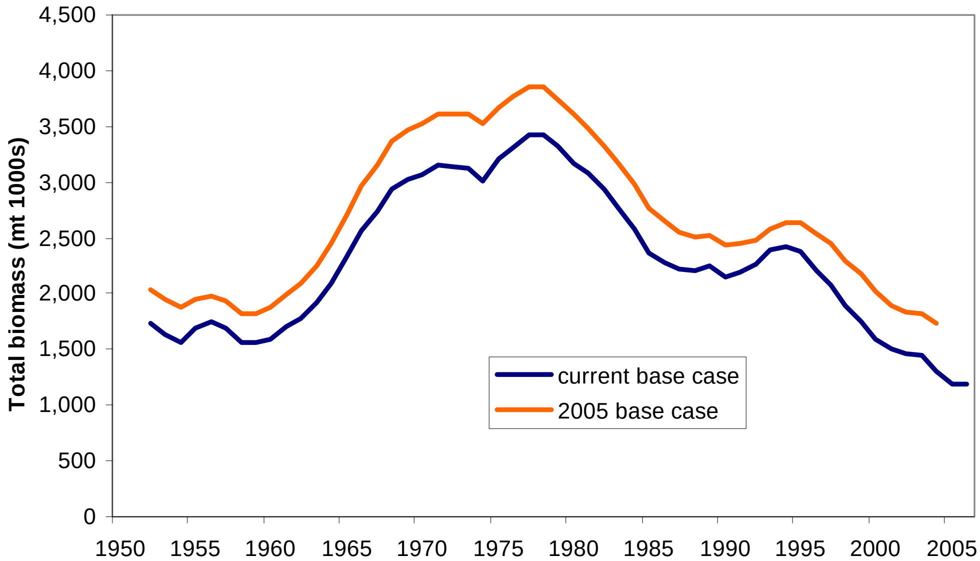
Symbol	Description
$F_{current}$	Average fishing mortality-at-age for 2002–2004
F_{MSY}	Fishing mortality-at-age producing the maximum sustainable yield (*MSY*)
$\tilde{Y}_{F_{current}}$	Equilibrium yield at $F_{current}$
$\tilde{Y}_{F_{MSY}}$ (or *MSY*)	Equilibrium yield at F_{MSY} , or maximum sustainable yield
$\tilde{B}_0$	Equilibrium unexploited total biomass
$\tilde{B}_{F_{current}}$	Equilibrium total biomass at $F_{current}$
$\tilde{B}_{MSY}$	Equilibrium total biomass at MSY
$S\tilde{B}_0$	Equilibrium unexploited adult biomass
$S\tilde{B}_{F_{current}}$	Equilibrium adult biomass at $F_{current}$
$S\tilde{B}_{MSY}$	Equilibrium adult biomass at MSY
$B_{current}$	Average current (2002–2004) total biomass
$SB_{current}$	Average current (2002–2004) adult biomass
$B_{current,F=0}$	Average current (2002–2004) total biomass in the absence of fishing.

Table 5. Estimates of management quantities for the model scenarios. The highlighted rows are ratios of comparable quantities at the same point in time (black shading) and ratios of comparable equilibrium quantities (grey shading).

Management quantity	Units	Base case	Maturity	Low M	Low *k*	High *k*
$\tilde{Y}_{F_{current}}$	t per year	58,880	58,570	52,700	55,960	60,440
$\tilde{Y}_{F_{MSY}}$ (or MSY)	t per year	180,800	137,900	90,080	201,800	158,300
$\tilde{B}_0$	t	2,124,000	2,126,000	1,215,000	2,745,000	1,643,000
$\tilde{B}_{F_{current}}$	t	1,931,000	1,921,000	956,900	2,553,000	1,446,000
$\tilde{B}_{MSY}$	t	1,050,000	1,240,000	532,500	1,444,000	747,300
$S\tilde{B}_0$	t	834,000	432,600	687,100	794,100	920,100
$S\tilde{B}_{F_{current}}$	t	661,200	278,300	448,000	629,600	736,300
$S\tilde{B}_{MSY}$	t	131,600	46,670	135,300	99,330	202,800
$B_{current}$	t	1,405,100	1,405,533	787,463	1,835,233	1,082,267
$SB_{current}$	t	539,600	285,007	418,373	527,390	579,470
$B_{current,F=0}$	t	1,549,000	1,549,400	997,410	1,981,767	1,226,733
$B_{current} / \tilde{B}_0$		0.662	0.661	0.648	0.669	0.659
$B_{current} / \tilde{B}_{F_{current}}$		0.728	0.732	0.823	0.719	0.748
$B_{current} / \tilde{B}_{MSY}$		1.338	1.133	1.479	1.271	1.448
$B_{current} / B_{current,F=0}$		0.907	0.907	0.790	0.926	0.882
$SB_{current} / S\tilde{B}_0$		0.647	0.659	0.609	0.664	0.630
$SB_{current} / S\tilde{B}_{F_{current}}$		0.816	1.024	0.934	0.838	0.787
$SB_{current} / S\tilde{B}_{MSY}$		4.100	6.107	3.092	5.309	2.857
$\tilde{B}_{F_{current}} / \tilde{B}_0$		0.909	0.904	0.788	0.930	0.880
$S\tilde{B}_{F_{current}} / S\tilde{B}_0$		0.793	0.643	0.652	0.793	0.800
$\tilde{B}_{MSY} / \tilde{B}_0$		0.494	0.583	0.438	0.526	0.455
$S\tilde{B}_{MSY} / S\tilde{B}_0$		0.158	0.108	0.197	0.125	0.220
F_{MSY}		0.172	0.111	0.169	0.140	0.212
$F_{current} / \tilde{F}_{MSY}$		0.039	0.094	0.114	0.031	0.053
$\tilde{B}_{F_{current}} / \tilde{B}_{MSY}$		1.839	1.549	1.797	1.768	1.935
$S\tilde{B}_{F_{current}} / S\tilde{B}_{MSY}$		5.024	5.963	3.311	6.338	3.631
$\tilde{Y}_{F_{current}} / MSY$		0.326	0.425	0.585	0.277	0.382

Table 6. Fishery specific current exploitable biomass as a proportion of "unexploited" current biomass for each model scenario. Fishery definitions are provided in Table 1.

Fishery	Base case	Maturity	Low M	Low *k*	High *k*
JP,JPDW,KR LL 1	0.692	0.692	0.593	0.651	0.722
TWDW LL 1	0.691	0.691	0.594	0.652	0.714
AU LL 1	0.571	0.571	0.481	0.514	0.609
NC LL 1	0.571	0.571	0.481	0.514	0.609
FJ LL 1	0.632	0.632	0.534	0.587	0.649
OTHER LL 1	0.671	0.671	0.571	0.632	0.698
JP,JPDW,KR LL 2	0.648	0.648	0.550	0.603	0.680
TWDW LL 2	0.651	0.651	0.555	0.604	0.684
AS,WS LL 2	0.662	0.661	0.556	0.625	0.670
TO LL 2	0.588	0.589	0.490	0.542	0.600
PF LL 2	0.489	0.488	0.408	0.411	0.498
OTHER LL 2	0.596	0.596	0.496	0.538	0.622
JP,JPDW,KR LL 3	0.732	0.732	0.678	0.698	0.812
TWDW LL 3	0.783	0.783	0.706	0.732	0.814
AU LL 3	0.857	0.857	0.757	0.869	0.862
NZ LL 3	0.857	0.857	0.757	0.869	0.862
JP,JPDW,KR LL 4	0.755	0.755	0.674	0.702	0.803
TWDW LL 4	0.729	0.729	0.644	0.674	0.772
OTHER LL 4	0.843	0.843	0.719	0.816	0.834
TROLL 3	0.984	0.984	0.954	0.988	0.975
TROLL 4	0.977	0.977	0.936	0.981	0.970
DN 3	0.960	0.960	0.926	0.929	0.967
DN 4	0.960	0.960	0.926	0.929	0.967



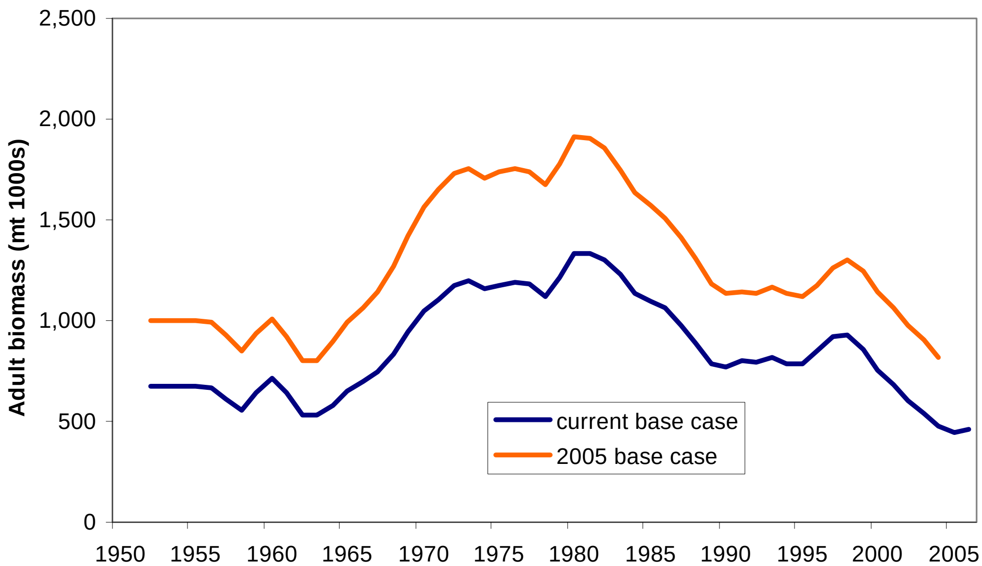


Figure 1. A comparison of the total (top) and adult (bottom) biomass trajectories from the 2005 (Langley & Hampton 2005) and current base case assessments.

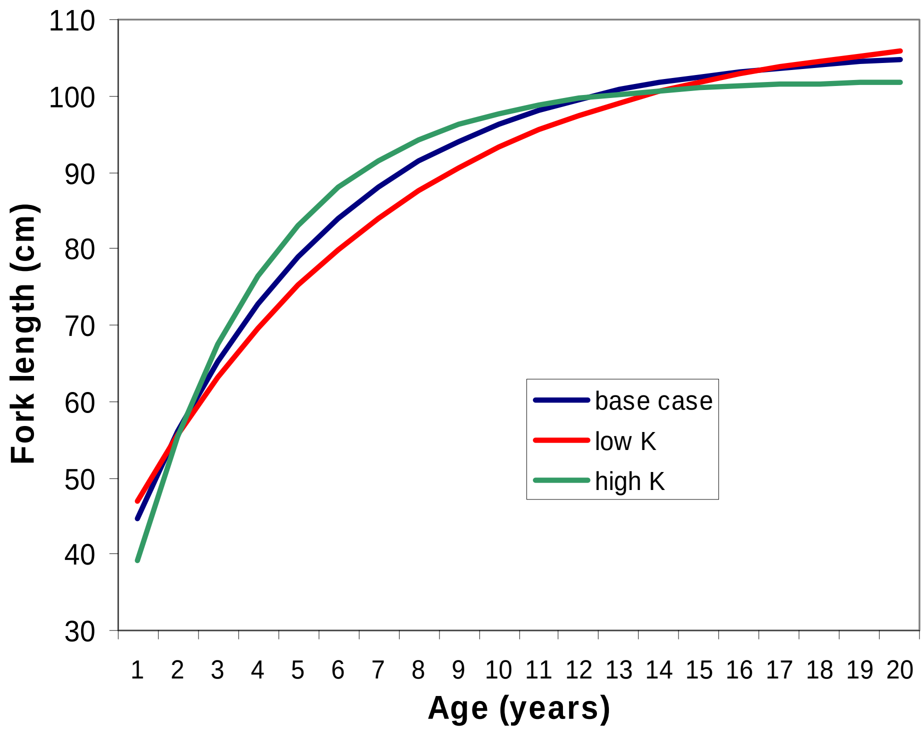


Figure 2. Growth functions estimated for the base case assessment and alternative parameterisations of growth investigated in the sensitivity analyses.