Updated area-disaggregated OMP results for West Coast Rock Lobster

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Background

The proposed new area-disaggregated OMP for the West Coast rock lobster operates on the basis of:

- Combining resource indices for trap CPUE, hoopnet CPUE, FIMS and somatic growth for the various super-areas into single indices for the resource as a whole;
- using these indices and past catches to fit a simple age-aggregated population model;
- using the results from that population model fit, together with some of the resource index data and applying certain constraints, to provide an overall TAC; and
- finally splitting that overall TAC between super-areas making use of information on the trends of resource indices in each.

Full details of the algorithms are given in (Johnston and Butterworth 2007a). The basic formula to set the overall TAC is:

$$TAC_y^G = wTAC_{y-1}^G + (1-w)\alpha\left(\frac{\beta_{y-3,y-2,y-1}}{\overline{\beta}_{89-04}}\right)^{\lambda}\left(\frac{\hat{B}_y}{\hat{B}_{1992}}\right) \quad x$$

$$\left[f_1\left(\frac{CPUE^{trap}_{y-1,y-2,y-3}}{CPUE^{trap}_{93,94,95}}\right) + f_2\left(\frac{CPUE^{hoop}_{y-1,y-2,y-3}}{CPUE^{hoop}_{93,94,95}}\right) + (1-f_1-f_2)\left(\frac{FIMS_{y-3,y-2,y-1}}{FIMS_{92,93,94,95}}\right)\right]^p \qquad (1)$$

The result of this formula is then subject to constraints on the extent of change between years of:

- Maximum TAC downward inter-annual constraint (which varies from 10% to 20% depending on the somatic growth rate) – see Johnston and Butterworth (2007a) for more details.

Equation (1) is complex, but earlier work (Johnston and Butterworth 2007b) showed that attempts at simpler approaches produced inferior performance.

This paper produces updated results for different OMP options, tuned as agreed to four different median average commercial catch levels over the next 10 (2006-2015) years (2030 MT, 2245 MT, 2401 MT and 2596 MT). It incorporates further performance statistics suggested by the July international stock assessment workshop, provides results for different options for possible changes to allowances for limited rights holders dependent on marked changes in abundance indices and hence the overall TAC, and lists results for further robustness tests.

Note: as per usual convention in what follows, 2007 refers to the 2007/08 season.

New Statistic

The recent international assessment workshop recommended that recovery statistics should be reported in the form of biomass levels relative to unexploited levels for recent recruitment, i.e. those levels approached asymptotically when projecting the operating model forward under zero future catches (from all sources).
For each super-area, the model was projected forwards 200 years under a zero catch strategy (i.e. all commercial harvesting, recreational takes and poaching are set to zero). The resource eventually reaches an equilibrium state, and the male 75+ biomass value at this equilibrium state is referred to as K_m^{curr}. K_m^{curr} can be estimated for a range of assumptions regarding future somatic growth rate and future recruitment. Table 1 reports these values for each super-area, based on mean future recruitment.

Table 1: Unexploited equilibrium K_m^{curr} estimates (in MT) for each super-area, for a range of future somatic growth and future recruitment scenarios.

Future somatic growth	Future recruitment	A12	A34	A56	A7	A8	T
low	low	592	2787	1419	8550	15155	28503
low	med	922	12440	16070	16698	29499	75629
low	hi	2200	19559	41004	26523	46108	135394
med	low	592	5198	2433	11111	32776	52110
med	med	922	23197	27549	21700	63799	137167
med	hi	2200	36472	70292	34469	99721	243154

Note that the estimates for a "high" future somatic growth rate will be the same as for the "med" scenario (as these two scenarios differ only in the number of years it takes the future somatic growth rate to increase to the historic average in the future). Similarly, the RC, ALTL and ALTH models will all eventually reach the same equilibrium level under a zero catch (for any given combinations of future somatic growth and recruitment).

Tables 2 and 3a and b report the new statistic $B_m(16)/K_m^{curr}$ – where this statistic refers to the male biomass above 75mm at the start of 2016 ($B_m(16)$) divided by the equilibrium biomass of male lobster (above 75mm) under a zero harvesting strategy

Limited Rights holders

The area-disaggregated OMP results produced so far have assumed that the quota set aside for the limited rights holders (LRHs) in each super-area are fixed amounts which do not change over time. These fixed amounts are:

Area 1-2 = 30 MT
Area 3-4 = 90 MT
Area 5-6 = 40 MT
Area 7 = 0 MT
Area 8 = 400 MT
Total = 560 MT

It has been requested that alternate formulations for the LRHs quotas be examined within the area-disaggregated OMP framework. Here we present results for the "2245" MT OMP where two further methods for allocating LRHs quotas are explored. These two alternate scenarios are:

Scenario 1: The total LRH quota varies in proportion to the "global" TAC (commercial + recreational quotas)

For the 2006 season:

- LRH = 560 MT
- "global" TAC = 2557 MT + 320 MT = 2887 MT

Thus the LRH = 19.5% of the "global" TAC in 2006.

For scenario 1, we thus assume that for all years in the future, the total LRHs quota (LRH^T) will remain 19.5% of the "global" TAC for each year.

The inter-areal split of the total LRHs quota will remain the same as for 2006, i.e.

Area 1-2 LRH = 5.36% of LRH^T
Area 3-4 LRH = 16.07% of LRH^T
Area 5-6 LRH = 7.14% of LRH^T
Area 7 LRH = 0% of LRH^T
Area 8 LRH = 71.43% of LRH^T

Scenario 2: The total LRH quota will vary up and down over time in a similar manner to the recreational take

To recap, for the recreational take, the following algorithm is applied:

$C_t^{rec} = 320$ MT initially

If $C_t^{rec} / TAC_t^G > 0.12 TAC_t^G$ then $C_t^{rec} = 0.10 TAC_t^G$
If $C_t^{rec} / TAC_t^G < 0.08 TAC_t^G$ then $C_t^{rec} = 0.10 TAC_t^G$

If $C_t^{rec} > 450$ MT then $C_t^{rec} = 450$ MT

where C_t^{rec} is the overall recreational take for year *t*, and TAC_t^G is the "global" (commercial plus recreational) TAC for year *t* as output by the OMP.

The following % breakdown of the overall recreational take (C_t^{rec}) by super-area is assumed; these %'s remain unchanged over time:

Area 1-2	= 2%
Area 3-4	= 12.5%
Area 5-6	= 12.5%
Area 7	= 4%
Area 8	= 69%

Thus, for scenario 2, the total LRHs quota each year, LRH^T, is calculated as follows:

$$LRH_t^T = 560 \text{ MT}$$

If $LRH_t^T / TAC_t^G > 0.16\, TAC_t^G$ then $LRH_t^T = 0.195\, TAC_t^G$

If $LRH_t^T / TAC_t^G < 0.24\, TAC_t^G$ then $LRH_t^T = 0.195\, TAC_t^G$

If $LRH_t^T > 800 \text{ MT}$ then $LRH_t^T = 800 \text{ MT}$

As for the other scenarios, the inter-areal split of the LRH^T will remain the same as for 2006, i.e.

Area 1-2 LRH = 5.36% of LRH^T
Area 3-4 LRH = 16.07% of LRH^T
Area 5-6 LRH = 7.14% of LRH^T
Area 7 LRH = 0% of LRH^T
Area 8 LRH = 71.43% of LRH^T

Results

Table 2 compares the three alternate methods described above for allocating the LRHs quotas each year. These results are for the "2245" MT tuning. Figure 1a shows the median LRH quotas for each super-area, with Figure 1b showing the median along with the 90% PIs for the total LRH quotas for scenario 1 and scenario 2.

Table 3a reports results for four OMP tunings – these results assume fixed constant LRH quotas each year. Results for a zero (commercial+recreational+poaching) future harvesting scenario are also presented. Figures 2a-d, 3a and b and 4 show further graphical summaries of these OMP results.

Table 3b compares the "2245" tuned OMP results with two constant catch scenarios, being

- CC = 2210 MT where the future catches are fixed across super-areas each season as follows: A1-2 = 30 MT
  A3-4 = 90 MT
  A5-6 = 40 MT
  A7 = 705 MT
  A8 = 1345 MT
  [T = 2210 MT]
- CC = 2210 MT where the future catches in each super-area are calculated using the OMP

[The "2210" value is selected to give an average 2006-2015 average of 2245 MT and thus be comparable with the OMP with the "2245" MT tuning. The 2006 TAC values have all been set previously.]

Robustness Test Results

Tables 4 and 5 report robustness tests results for the category I and as many category II tests as could be completed to date. The robustness test “W1future” has also been run for a zero future commercial (and recreational) harvesting strategy.

Discussion

Limited Rights Holders

Scenario 1 is presented as a “limiting case”, as it is unlikely that varying quotas annually for these LRHs as for the larger scale operators would be acceptable. Scenario 2 is perhaps more realistic, and does slightly improve lower percentiles for recovery statistics B_m(16/06) in super-areas A1-2 and A5-6 which are restricted to LRHs (Table 2). Note also that under scenario 2, reductions in LRH quotas over the 2008-2011 period are to be expected. Note also, that under scenario 2, all LRHs are treated the same if changes are made to the overall LRH allowance. More sophisticated approaches could make such changes differ between super-areas in relation to different trends in the abundance indices for these regions.

Alternative OMP options

The four alternative options put forward correspond to median 10-year recovery targets (compared to current levels) of B_m(16/06) of 1.36, 1.26, 1.16 and 1.07 respectively. As a fraction of the unexploited level given current recruitment, these correspond to about 20% by 2016, contrasting with the 40% if no catch at all is removed (Table 3a). The feedback control mechanism of the OMP does achieve some improvements in lower percentiles compared to constant catch options (Table 3b).

Concerns arise however over the low values for lower percentiles for these statistics, particularly when considered at super-area level and especially for A7 and A8. While one of these OMP options (or one intermediate amongst) could be selected now, further work should be pursued later to include specific exceptional circumstances provisions involving breaches of minimum decrease criteria if resource monitoring indices drop below threshold levels (to be specified in due course).

Nonetheless, it should be noted that the $B_m(16)/\ K_m^{curr}$ refer to only the 75+ male component of the resource, and that the smaller-sized female component would be less depleted.

Robustness Tests

Results in Table 4 show that recovery performance deteriorates in terms of lower percentiles, though not by large amounts in most instances. The situation in A5-6 may need attention if walkouts continue at the 1990s rate. If future somatic growth rate stays low (SG low), the median recovery (B_m(16/06)) statistic drops from 1.26 to 1.07 for the 2245 MT tuned OMP.

References

Johnston, S.J. and D.S. Butterworth. 2007a. The new West Coast rock lobster OMP based on an area-disaggregated approach. ASWS/JUL07/WCRL/MP/1.

Johnston, S.J. and D.S. Butterworth. 2007b. Further area-disaggregated OMP results for the west coast rock lobster resource. MCM document, WG/04/07/WCRL1.

Table 2: Comparison of three alternate methods for dealing with LRH quotas. These results are for the tuning used for the "2245" MT OMP for the Reference Set of operating models.

		LRH = fixed amounts	Scenario 1 LRH vary in proportion with global TAC	Scenario 2 LRH vary similarly to recreationals
10-yr Ave commercial TAC	A1-2	30 [30; 30]	26 [21; 30]	27 [22; 31]
	A3-4	186 [145; 234]	187 [147; 234]	187 [147; 234]
	A5-6	40 [40; 40]	35 [29; 41]	36 [29; 41]
	A7	633 [490; 774]	637 [495; 774]	636 [495; 773]
	A8	1340 [1092; 1578]	1344 [1102; 1583]	1343 [1102; 1578]
	T	2245 [1830; 2587]	2245 [1830; 2587]	2229 [1830; 2587]
2007-2009 Ave commercial TAC	T	2100 [2021; 2229]	2100 [2021; 2229]	2100 [2021; 2229]
10-yr Ave offshore TAC	A1-2	0 [0; 0]	0 [0; 0]	0 [0; 0]
	A3-4	96 [55; 144]	108 [81; 144]	104 [80; 145]
	A5-6	0 [0; 0]	0 [0; 0]	0 [0; 0]
	A7	633 [490; 774]	637 [495; 774]	636 [495; 773]
	A8	940 [692; 1178]	990 [816; 1179]	975 [814; 1175]
	T	1655 [1241; 1997]	1735 [1392; 2097]	1735 [1392; 2097]
Ave Total Recreational Take	T	262 [202; 294]	262 [203; 295]	262 [203; 295]
10-yr Ave LRH quotas	A1-2	30 [30; 30]	26 [21; 30]	27 [22; 31]
	A3-4	90 [90; 90]	79 [64; 91]	82 [65; 91]
	A5-6	40 [40; 40]	35 [29; 41]	36 [29; 41]
	A7	0 [0; 0]	0 [0; 0]	0 [0; 0]
	A8	400 [400; 400]	351 [286; 406]	363 [288; 407]
	T	560 [560; 560]	416 [378; 499]	420 [383; 527]

***B*m(16/06)**	A1-2	0.79 [0.50; 1.32]	0.85 [0.56; 1.38]	0.84 [0.55; 1.36]
	A3-4	1.06 [0.62; 2.58]	1.06 [0.62; 2.58]	1.06 [0.62; 2.58]
	A5-6	1.77 [0.61; 11.30]	1.79 [0.63; 10.37]	1.79 [0.64; 11.31]
	A7	1.26 [0.36; 3.26]	1.25 [0.37; 3.26]	1.25 [0.37; 3.26]
	A8	1.01 [0.39; 2.83]	1.00 [0.38; 2.83]	1.00 [0.39; 2.83]
	T	1.26 [0.62; 3.00]	1.25 [0.62; 2.88]	1.25 [0.62; 2.97]
***B*m(16/80)**	A1-2	0.25 [0.16; 0.42]	0.27 [0.17; 0.43]	0.27 [0.17; 0.43]
	A3-4	0.72 [0.42; 1.79]	0.72 [0.42; 1.79]	0.72 [0.42; 1.79]
	A5-6	0.39 [0.13; 2.45]	0.39 [0.13; 2.45]	0.39 [0.13; 2.45]
	A7	0.54 [0.15; 1.40]	0.54 [0.15; 1.40]	0.54 [0.15; 1.40]
	A8	1.14 [0.44; 3.24]	1.14 [0.43; 3.24]	1.14 [0.43; 3.24]
	T	0.72 [0.35; 1.76]	0.73 [0.35; 1.76]	0.73 [0.35; 1.76]
***B*m(16/1910)**	A1-2	0.01 [0.01; 0.02]	0.01 [0.01; 0.02]	0.01 [0.01; 0.02]
	A3-4	0.04 [0.02; 0.09]	0.04 [0.02; 0.09]	0.04 [0.02; 0.09]
	A5-6	0.02 [0.01; 0.15]	0.02 [0.01; 0.15]	0.02 [0.01; 0.15]
	A7	0.02 [0.01; 0.06]	0.02 [0.01; 0.06]	0.02 [0.01; 0.06]
	A8	0.06 [0.02; 0.17]	0.06 [0.02; 0.17]	0.06 [0.02; 0.17]
	T	0.04 [0.02; 0.09]	0.04 [0.02; 0.09]	0.04 [0.02; 0.09]
***B*m(16)/** K_m^{curr}	A1-2	0.32 [0.15; 0.50]	0.35 [0.16; 0.58]	0.35 [0.16; 0.57]
	A3-4	0.29 [0.14; 0.93]	0.29 [0.14; 0.92]	0.29 [0.14; 0.92]
	A5-6	0.13 [0.05; 1.13]	0.13 [0.05; 1.14]	0.13 [0.05; 1.14]
	A7	0.23 [0.08; 0.50]	0.23 [0.08; 0.50]	0.23 [0.08; 0.50]
	A8	0.18 [0.09; 0.36]	0.18 [0.08; 0.35]	0.18 [0.08; 0.35]
	T	0.21 [0.12; 0.41]	0.21 [0.12; 0.41]	0.21 [0.12; 0.41]
Effort(15/06)	T	0.72 [0.33; 1.72]	0.72 [0.33; 1.72]	0.72 [0.33; 1.72]

Table 3a: Median and 5th and 95th percentile values for four candidate OMPs tuned so that median 10-year average commercial TAC =2030 MT, 2245 MT, 2401 MT and 2596 MT, as well as for a CC=Zero scenario (zero commercial+recreational+poaching). Results are for the full stochastic integration over the Reference Set.

		CC=Zero	OMP Tuning 2030 MT	OMP Tuning 2245 MT	OMP Tuning 2401 MT	OMP Tuning 2596 MT
10-yr Ave commercial TAC	A1-2	0 [0; 0]	30 [30; 30]	30 [30; 30]	30 [30; 30]	30 [30; 30]
	A3-4	0 [0; 0]	166 [130; 209]	186 [145; 234]	203 [158; 252]	222 [174; 267]
	A5-6	0 [0; 0]	40 [40; 40]	40 [40; 40]	40 [40; 40]	40 [40; 40]
	A7	0 [0; 0]	573 [460; 710]	633 [490; 774]	677 [523; 832]	728 [570; 866]
	A8	0 [0; 0]	1216 [1013; 1451]	1340 [1092; 1578]	1438 [1162; 1666]	1540 [1253; 1738]
	T	0 [0; 0]	2030 [1679; 2393]	2245 [1830; 2587]	2401 [1954; 2744]	2596 [2115; 2838]
2007-2009 Ave commercial TAC	T	0 [0; 0]	2043 [2021; 2144]	2100 [2021; 2229]	2151 [2021; 2229]	2223 [2048; 2229]
10-yr Ave offshore TAC	A1-2	0 [0; 0]	0 [0; 0]	0 [0; 0]	0 [0; 0]	0 [0; 0]
	A3-4	0 [0; 0]	75 [40; 120]	96 [55; 144]	113 [68; 162]	132 [84; 177]
	A5-6	0 [0; 0]	0 [0; 0]	0 [0; 0]	0 [0; 0]	0 [0; 0]
	A7	0 [0; 0]	573 [460; 710]	633 [490; 774]	677 [523; 832]	728 [570; 866]
	A8	0 [0; 0]	817 [613; 1051]	940 [692; 1178]	1038 [762; 1266]	1140 [853; 1138]
	T	0 [0; 0]	1438 [1080; 1812]	1655 [1241; 1997]	1811 [1364; 2165]	2005 [1526; 2248]
Ave Total Recreational Take	T	0 [0; 0]	228 [188; 279]	262 [202; 294]	281 [214; 308]	298 [232; 320]
Ave V commercial	A1-2	0 [0; 0]	0 [0; 0]	0 [0; 0]	0 [0; 0]	0 [0; 0]
	A3-4	0 [0; 0]	12 [9; 16]	13 [10; 18]	14 [11; 19]	16 [12; 20]
	A5-6	0 [0; 0]	0 [0; 0]	0 [0; 0]	0 [0; 0]	0 [0; 0]
	A7	0 [0; 0]	17 [13; 22]	17 [14; 22]	18 [14; 22]	19 [15; 22]
	A8	0 [0; 0]	7 [5; 10]	7 [5; 9]	6 [4; 9]	6 [4; 9]
	T	0 [0; 0]	9 [7; 11]	9 [6; 11]	9 [6; 11]	9 [7; 10]

***B_m*(16/06)**	A1-2	1.41 [0.12; 1.96]	0.80 [0.51; 1.33]	0.79 [0.50; 1.32]	0.78 [0.50; 1.31]	0.77 [0.49; 1.31]
	A3-4	1.45 [0.97; 3.03]	1.11 [0.66; 2.62]	1.06 [0.62; 2.58]	1.02 [0.58; 2.56]	0.99 [0.54; 2.53]
	A5-6	2.11 [0.90; 11.68]	1.79 [0.62; 11.31]	1.77 [0.61; 11.30]	1.77 [0.60; 11.28]	1.75 [0.59; 11.27]
	A7	2.65 [1.75; 4.80]	1.39 [0.49; 4.47]	1.26 [0.36; 3.26]	1.16 [0.26; 3.12]	1.07 [0.18; 2.99]
	A8	2.73 [1.88; 4.78]	1.18 [0.54; 2.98]	1.01 [0.39; 2.83]	0.90 [0.25; 2.69]	0.77 [0.13; 2.55]
	T	2.42 [1.69; 4.25]	1.36 [0.73; 3.10]	1.26 [0.62; 3.00]	1.16 [0.52; 2.92]	1.07 [0.43; 2.81]
***B_m*(16/80)**	A1-2	0.44 [0.34; 0.62]	0.25 [0.16; 0.42]	0.25 [0.16; 0.42]	0.25 [0.15; 0.42]	0.24 [0.15; 0.42]
	A3-4	0.99 [0.66; 2.11]	0.76 [0.45; 1.82]	0.72 [0.42; 1.79]	0.70 [0.39; 1.78]	0.68 [0.37; 1.76]
	A5-6	0.46 [0.19; 2.53]	0.39 [0.13; 2.45]	0.39 [0.13; 2.45]	0.39 [0.13; 2.45]	0.38 [0.12; 2.44]
	A7	1.12 [0.72; 2.06]	0.61 [0.21; 1.48]	0.54 [0.15; 1.40]	0.51 [0.11; 1.34]	0.45 [0.07; 1.27]
	A8	3.09 [2.12; 5.51]	1.34 [0.61; 3.40]	1.14 [0.44; 3.24]	1.03 [0.28; 3.09]	0.88 [0.15; 2.94]
	T	1.41 [0.96; 2.48]	0.78 [0.41; 1.82]	0.72 [0.35; 1.76]	0.68 [0.30; 1.70]	0.61 [0.24; 1.64]
***B_m*(16/1910)**	A1-2	0.02 [0.02; 0.03]	0.01 [0.01; 0.02]	0.01 [0.01; 0.02]	0.01 [0.01; 0.02]	0.01 [0.001; 0.02]
	A3-4	0.05 [0.03; 0.11]	0.04 [0.02; 0.09]	0.04 [0.02; 0.09]	0.03 [0.02; 0.09]	0.03 [0.002; 0.01]
	A5-6	0.03 [0.01; 0.16]	0.02 [0.01; 0.15]	0.02 [0.01; 0.15]	0.02 [0.01; 0.15]	0.02 [0.01; 0.15]
	A7	0.05 [0.03; 0.09]	0.03 [0.01; 0.07]	0.02 [0.01; 0.06]	0.02 [0.004; 0.06]	0.02 [0.003; 0.06]
	A8	0.16 [0.11; 0.28]	0.07 [0.03; 0.17]	0.06 [0.02; 0.17]	0.05 [0.01; 0.16]	0.04 [0.01; 0.15]
	T	0.07 [0.05; 0.13]	0.04 [0.02; 0.09]	0.04 [0.02; 0.09]	0.03 [0.02; 0.09]	0.03 [0.01; 0.08]
***B_m*(16)/ K_m^{curr}**	A1-2	0.61 [0.28; 0.91]	-	0.32 [0.15; 0.50]	-	0.31 [0.15; 0.49]
	A3-4	0.38 [0.22; 1.00]	-	0.29 [0.14; 0.93]	-	0.27 [0.13; 0.83]
	A5-6	0.15 [0.07; 1.00]	-	0.13 [0.05; 1.13]	-	0.12 [0.05; 1.00]
	A7	0.48 [0.32; 0.82]	-	0.23 [0.08; 0.50]	-	0.19 [0.04; 0.46]
	A8	0.47 [0.29; 0.83]	-	0.18 [0.09; 0.36]	-	0.13 [0.03; 0.31]
	T	0.40 [0.26; 0.86]	-	0.21 [0.12; 0.41]	-	0.18 [0.09; 0.36]
Effort(15/06)	T		0.55 [0.25; 1.12]	0.72 [0.33; 1.72]	0.90 [0.37; 2.42]	1.16 [0.46; 3.76]

Table 3b: Median and 5th and 95th percentile values for the "2245" tuned OMP, compared to two constant catch scenarios which differ in how the areal TAC split is calculated. Results are for the full stochastic integration over the Reference Set.

		OMP Tuning 2245 MT	**CC 2210 MT Fixed areal-split**	**CC 2210 MT OMP computes areal split**
10-yr Ave commercial TAC	A1-2	30 [30; 30]	30 [30; 30]	30 [30; 30]
	A3-4	186 [145; 234]	91 [91; 91]	186 [172; 208]
	A5-6	40 [40; 40]	40 [40; 40]	40 [40; 40]
	A7	633 [490; 774]	717 [717; 717]	641 [535; 698]
	A8	1340 [1092; 1578]	1365 [1365; 1365]	1347 [1298; 1433]
	T	2245 [1830; 2587]	2245 [2245; 2245]	2245 [2245; 2245]
2007-2009 Ave commercial TAC	T	2100 [2021; 2229]	2349 [2349; 2349]	2210 [2210; 2210]
10-yr Ave offshore TAC	A1-2	0 [0; 0]	0 [0; 0]	0 [0; 0]
	A3-4	96 [55; 144]	1.1 [1.1; 1.1]	96 [82; 118]
	A5-6	0 [0; 0]	0 [0; 0]	0 [0; 0]
	A7	633 [490; 774]	717 [717; 717]	641 [535; 698]
	A8	940 [692; 1178]	967 [967; 967]	947 [898; 1033]
	T	1655 [1241; 1997]	1685 [1685; 1685]	1654 [1654; 1654]
Ave Total Recreational Take	T	262 [202; 294]	320 [320; 320]	320 [320; 320]
Ave V commercial	A1-2	0 [0; 0]	0 [0; 0]	0 [0; 0]
	A3-4	13 [10; 18]	2 [2; 2]	11 [10; 14]
	A5-6	0 [0; 0]	0 [0; 0]	0 [0; 0]
	A7	17 [14; 22]	3 [3; 3]	13 [12; 17]
	A8	7 [5; 9]	2 [2; 2]	6 [5; 7]
	T	9 [6; 11]	2 [2; 2]	2 [2; 2]

B_m**(16/06)**	A1-2	0.79 [0.50; 1.32]	0.77 [0.48; 1.30]	0.77 [0.48; 1.30]
	A3-4	1.06 [0.62; 2.58]	1.22 [0.77; 2.80]	1.05 [0.58; 2.60]
	A5-6	1.77 [0.61; 11.30]	1.75 [0.56; 11.26]	1.75 [0.58; 11.26]
	A7	1.26 [0.36; 3.26]	1.05 [0.20; 3.19]	1.23 [0.36; 3.31]
	A8	1.01 [0.39; 2.83]	0.93 [0.18; 2.82]	0.95 [0.19; 2.86]
	T	1.26 [0.62; 3.00]	1.24 [0.53; 2.98]	1.23 [0.52; 2.98]
B_m**(16/80)**	A1-2	0.25 [0.16; 0.42]	0.24 [0.15; 0.41]	0.24 [0.15; 0.41]
	A3-4	0.72 [0.42; 1.79]	0.83 [0.52; 1.95]	0.71 [0.40; 1.80]
	A5-6	0.39 [0.13; 2.45]	0.38 [0.12; 2.44]	0.38 [0.12; 2.44]
	A7	0.54 [0.15; 1.40]	0.45 [0.08; 1.37]	0.53 [0.15; 1.42]
	A8	1.14 [0.44; 3.24]	1.05 [0.20; 3.29]	1.08 [0.22; 3.31]
	T	0.72 [0.35; 1.76]	0.71 [0.30; 1.73]	0.71 [0.30; 1.73]
B_m**(16/1910)**	A1-2	0.01 [0.01; 0.02]	0.01 [0.01; 0.02]	0.01 [0.01; 0.02]
	A3-4	0.04 [0.02; 0.09]	0.04 [0.03; 0.10]	0.04 [0.03; 0.10]
	A5-6	0.02 [0.01; 0.15]	0.02 [0.01; 0.15]	0.02 [0.01; 0.15]
	A7	0.02 [0.01; 0.06]	0.02 [0.004; 0.06]	0.02 [0.004; 0.06]
	A8	0.06 [0.02; 0.17]	0.05 [0.01; 0.17]	0.05 [0.01; 0.17]
	T	0.04 [0.02; 0.09]	0.04 [0.02; 0.09]	0.04 [0.02; 0.09]
B_m**(16)/** K_m^{curr}	A1-2	0.32 [0.15; 0.50]	-	-
	A3-4	0.29 [0.14; 0.93]	-	-
	A5-6	0.13 [0.05; 1.13]	-	-
	A7	0.23 [0.08; 0.50]	-	-
	A8	0.18 [0.09; 0.36]	-	-
	T	0.21 [0.12; 0.41]	-	-
Effort(15/06)	T	0.72 [0.33; 1.72]	0.91 [0.34; 3.11]	0.70 [0.28; 2.26]

Table 4: Robustness test results using the "2245 MT" tuned OMP. Median values are presented with values in parenthesis being the 5th and 95th %iles. These results refer to the resource as a whole. Tests marked * involve refitting the assessment model; other tests use the Reference Set of operating models, changing only some assumptions regarding the future.

TEST		***B*(16/06)**	TAC^{ave}_{comm}	**Effort(16/06)**
Reference Set		**1.26 [0.62; 3.00]**	**2245 [1831; 2587]**	**0.72 [0.33; 1.72]**
CC fixed (2210 MT)		**1.24 [0.53; 2.98]**	**2245 [2245; 2245]**	**0.91 [0.34; 3.11]**
CC flexible (2210 MT)		**1.23 [0.52; 2.98]**	**2245 [2245; 2245]**	**0.70 [0.28; 2.26]**
Priority I tests				
NS1*	Male natural survivorship = 0.88	1.22 [0.52; 3.29]	2230 [1835; 2580]	1.01 [0.49; 2.22]
NS2*	Male natural survivorship = 0.92	1.27 [0.60; 3.66]	1954 [1632; 2458]	0.57 [0.25; 1.31]
D2*	Discard mortality = 0.20	1.24 [0.56; 3.89]	2145 [1755; 2524]	0.64 [0.29; 1.55]
SG2*	1910-1967 growth = 68-88 average	1.28 [0.60; 3.54]	2054 [1696; 2491]	0.56 [0.25; 1.42]
W1 future*	Future walkouts continue at 1990s rate	1.19 [0.51; 3.17]	2203 [1807; 2585]	0.66 [0.32; 1.48]
W1 future* With Zero future commercial catch	Future walkouts continue at 1990s rate	2.27 [1.48; 4.30]	0 [0; 0]	0 [0; 0]
Priority II tests				
SG low	Future somatic growth remains low for all simulations	1.07 [0.54; 2.21]	2118 [1788; 2385]	0.73 [0.31; 1.66]
SG1	Adult growth is 0.5mm more than thought			
SG3	Pre-1990 growth shifted down to 1990+ average level			
D3	Discard mortality increases 5 yrs prior to min size change			
B1	CPUE 2007+ stays constant			
B3	Future adult somatic growth 0.5mm less than reported			
E1	R drops 50% for 3 years, once in 1998-2006	1.03 [0.49; 2.54]	2203 [1805; 2568]	0.85 [0.35; 2.10]
E3	25% all lobsters die once during 2006-2015	0.81 [0.35; 2.31]	2125 [1699; 2540]	1.02 [0.38; 2.88]
P1	Poaching reduced next 5 years to 200 MT			

Table 5: Robustness test results using the "2245 MT" tuned OMP. Median values are presented with values in parenthesis being the 5th and 95th %iles. These results refer to the individual super-areas *B*(16/06) values.

	A12	A34	A56	A7	A8
Reference Set	0.79 [0.50; 1.32]	1.06 [0.62; 2.58]	1.78 [0.61; 11.29]	1.26 [0.36; 3.26]	1.06 [0.39; 2.83]
CC fixed (2210 MT)	0.77 [0.48; 1.30]	1.22 [0.77; 2.80]	1.75 [0.56; 11.26]	1.05 [0.20; 3.19]	0.93 [0.18; 2.82]
CC flexible (2210 MT)	0.77 [0.48; 1.30]	1.05 [0.58; 2.60]	1.75 [0.58; 11.26]	1.23 [0.36; 3.31]	0.95 [0.19; 2.86]
NS1*	0.81 [0.51; 1.33]	1.00 [0.50; 3.67]	1.30 [0.22; 19.32]	2.06 [0.88; 4.70]	0.79 [0.21; 2.42]
NS2*	0.77 [0.54; 1.23]	0.98 [0.54; 4.54]	1.08 [0.47; 11.56]	1.51 [0.39; 3.85]	1.01 [0.31; 3.13]
D2*	0.78 [0.50; 1.33]	0.88 [0.42; 5.17]	1.10 [0.34; 18.29]	1.49 [0.42; 3.93]	0.99 [0.37; 2.78]
SG2*	0.66 [0.53; 0.85]	0.94 [0.44; 4.19]	1.26 [0.29; 20.56]	1.42 [0.30; 3.96]	1.11 [0.46; 2.97]
W1 future*	0.79 [0.51; 1.32]	0.78 [0.30; 3.53]	0.86 [0.02; 17.77]	1.36 [0.55; 3.33]	1.02 [0.41; 2.82]
W1 future* with zero future commercial catch	1.34 [1.05; 1.89]	1.20 [0.68; 4.06]	1.32 [0.16; 18.42]	2.54 [1.64; 4.70]	2.43 [1.60; 4.45]
SG low	0.79 [0.51; 1.33]	0.95 [0.56; 2.01]	1.55 [0.55; 8.48]	1.25 [0.41; 3.10]	0.77 [0.33; 1.53]
SG1					
SG3					
D3					
B1					
B3					
E1	0.66 [0.42; 1.12]	0.94 [0.57; 2.21]	1.55 [0.56; 9.88]	1.09 [0.27; 3.01]	0.77 [0.30; 2.19]
E3	0.52 [0.29; 0.96]	0.78 [0.43; 2.01]	1.33 [0.43; 0.78]	0.89 [0.17; 2.69]	0.58 [0.16; 1.94]

Figure 1a: Comparison between three alternate methods for setting LRH quotas. Median LRH quotas for each super-area shown.

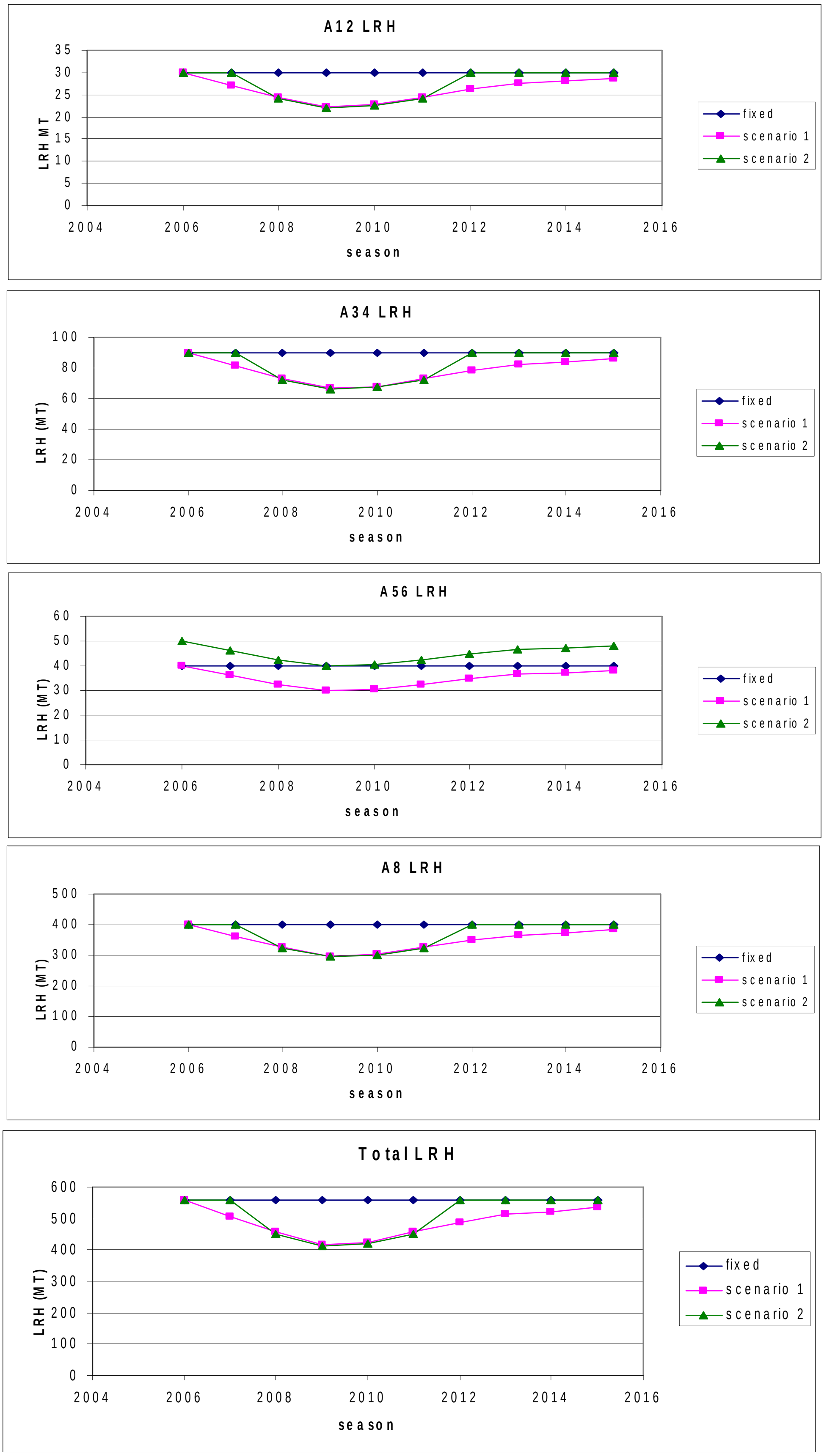
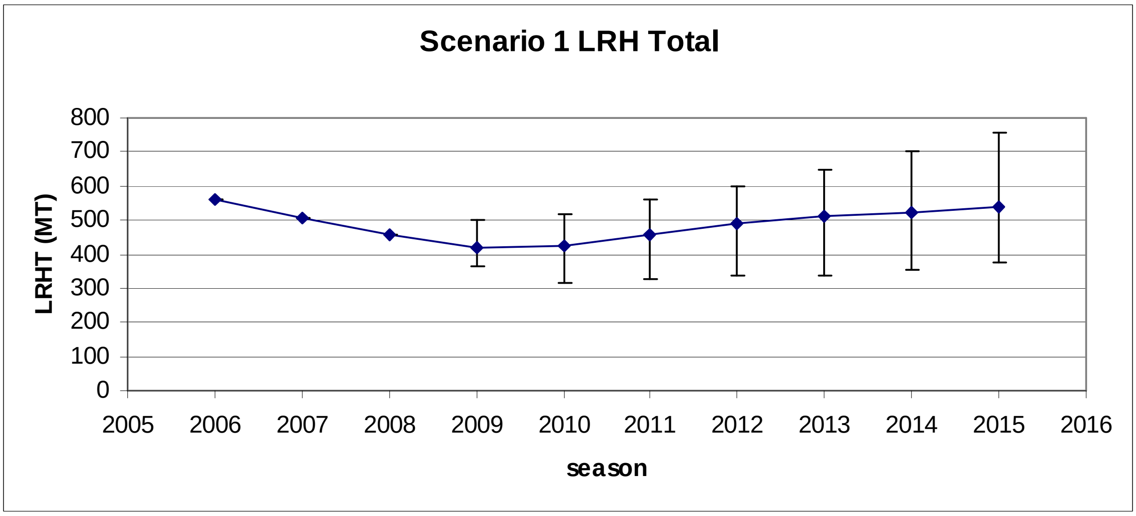


Figure 1b: Median and 90% PIs of the total LRH quotas for scenario 1 and scenario 2.



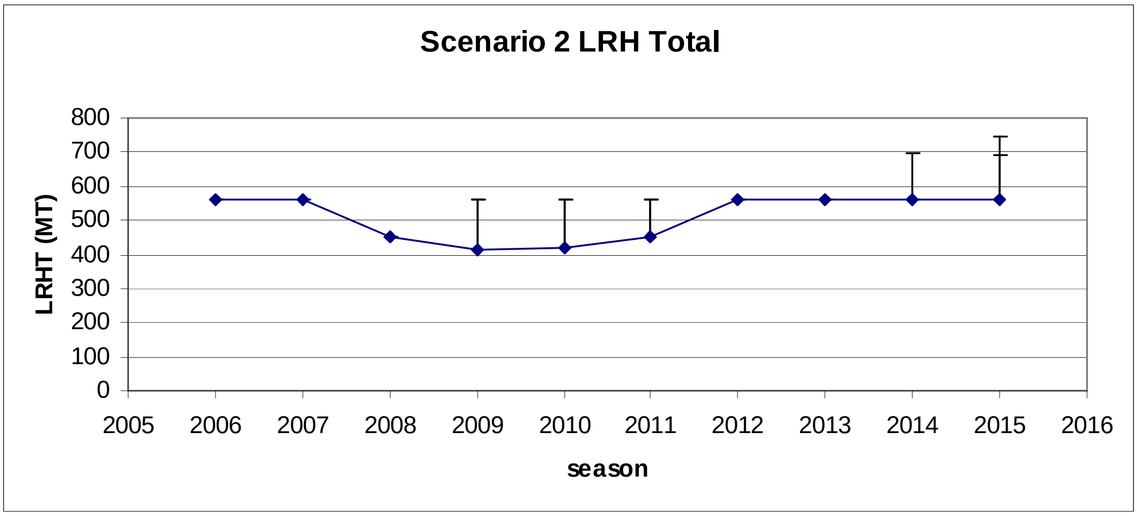


Figure 2a: OMP results for the tuning of average commercial **TAC = 2030 MT**. **Plot A** is the commercial TAC showing the median, with 50%-iles (black), 75-iles (dark-grey) and 90-iles (light grey). **Plot B** is the commercial TAC annual variation, showing the median, with 50-iles, 765-iles and 90%iles (shading as for plot A).
Plot C shows the total recreational take showing the median with the 5th and 95th percentiles. **Plot D** indicates the male biomass above 75mm trend showing the median with 5th and 95th percentiles. In each plot, the vertical hashed line indicates the start of the projection period.

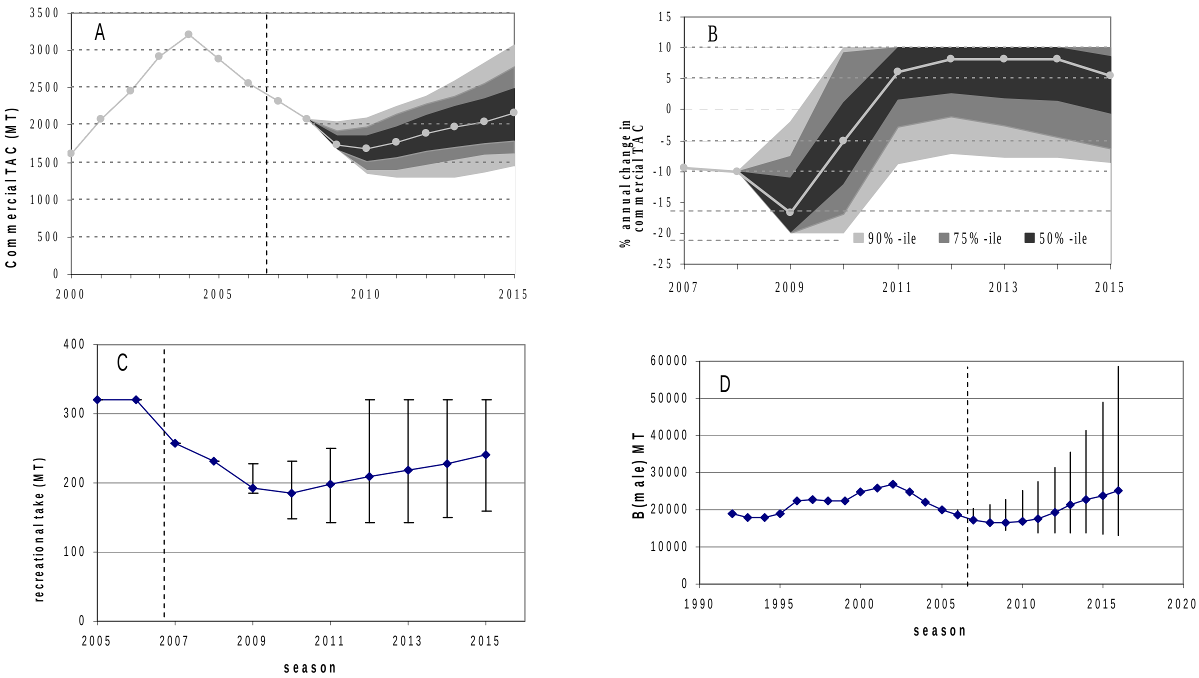


Figure 2b: OMP results for the tuning of average commercial **TAC = 2245 MT**. **Plot A** is the commercial TAC showing the median, with 50%-iles (black), 75-iles (dark-grey) and 90-iles (light grey). **Plot B** is the commercial TAC annual variation, showing the median, with 50-iles, 765-iles and 90%iles (shading as for plot A).
Plot C shows the total recreational take showing the median with the 5^{th} and 95^{th} percentiles. **Plot D** indicates the male biomass above 75mm trend showing the median with 5^{th} and 95^{th} percentiles. In each plot, the vertical hashed line indicates the start of the projection period.

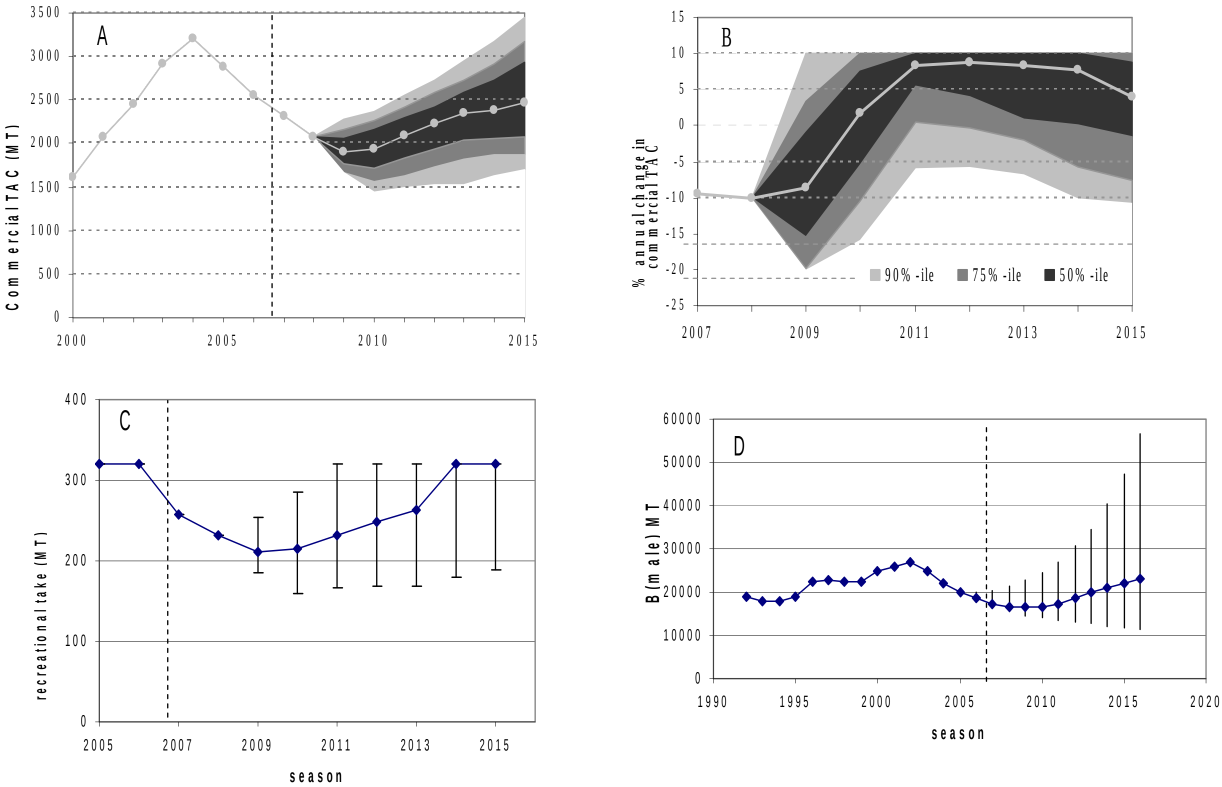


Figure 2c: OMP results for the tuning of average commercial **TAC = 2401 MT**. **Plot A** is the commercial TAC showing the median, with 50%-iles (black), 75-iles (dark-grey) and 90-iles (light grey). **Plot B** is the commercial TAC annual variation, showing the median, with 50-iles, 765-iles and 90%iles (shading as for plot A).

Plot C shows the total recreational take showing the median with the 5th and 95th percentiles. **Plot D** indicates the male biomass above 75mm trend showing the median with 5th and 95th percentiles. In each plot, the vertical hashed line indicates the start of the projection period.

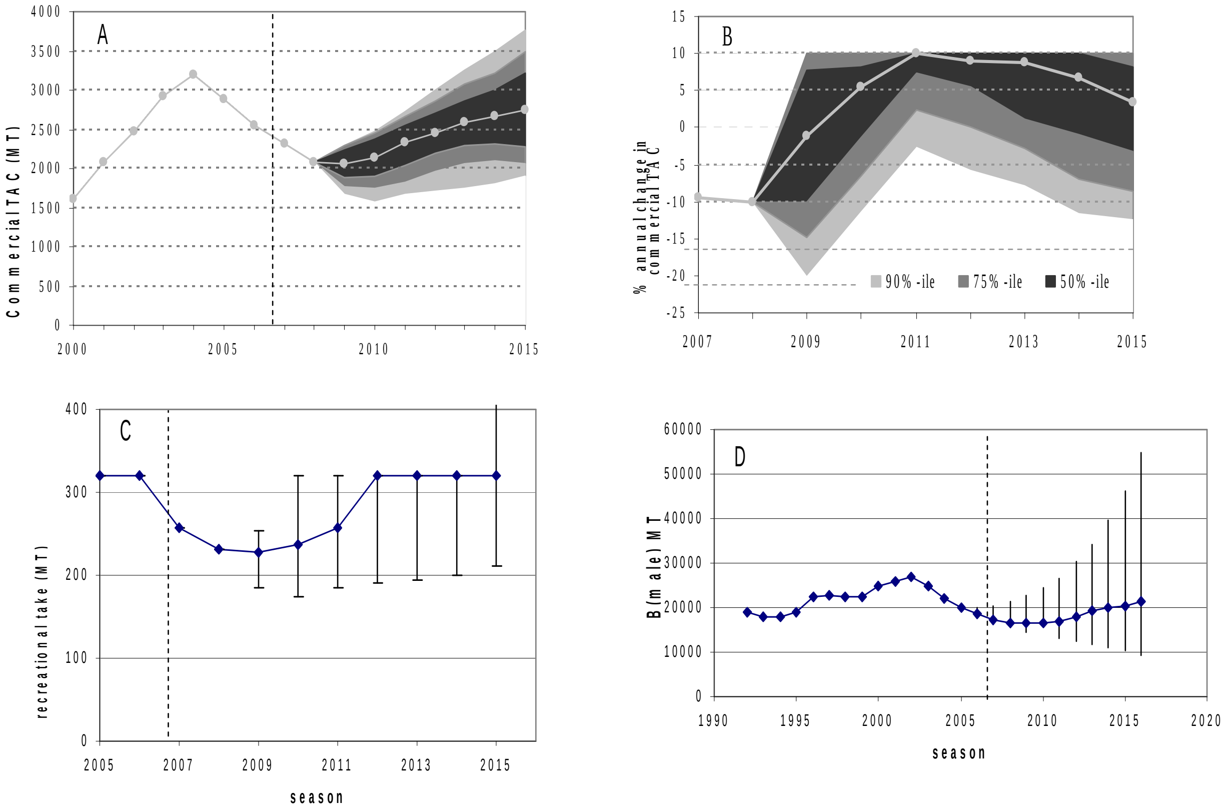


Figure 2d: OMP results for the tuning of average commercial **TAC = 2596 MT**. **Plot A** is the commercial TAC showing the median, with 50%-iles (black), 75-iles (dark-grey) and 90-iles (light grey). **Plot B** is the commercial TAC annual variation, showing the median, with 50-iles, 765-iles and 90%iles (shading as for plot A).
Plot C shows the total recreational take showing the median with the 5th and 95th percentiles. **Plot D** indicates the male biomass above 75mm trend showing the median with 5th and 95th percentiles. In each plot, the vertical hashed line indicates the start of the projection period.

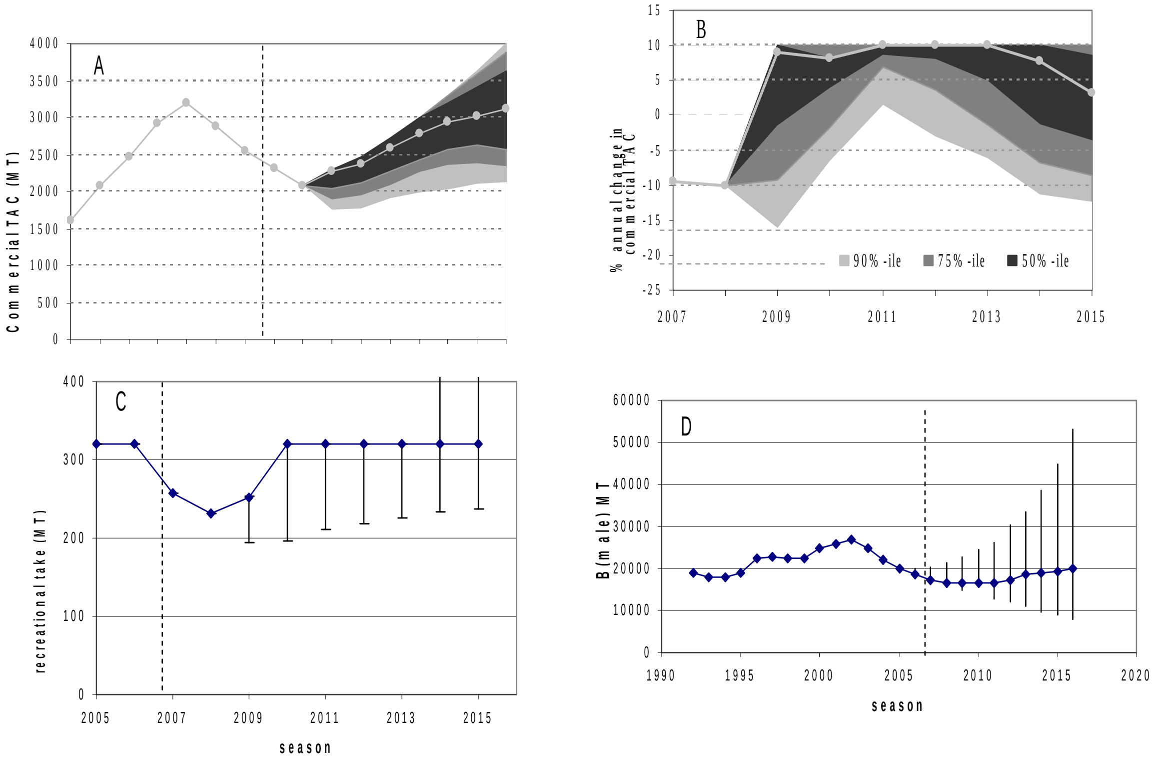


Figure 3a: Comparative plots of commercial TAC for the four OMPs presented. Only medians are indicated. The vertical hashed line indicates the start of the projection period.

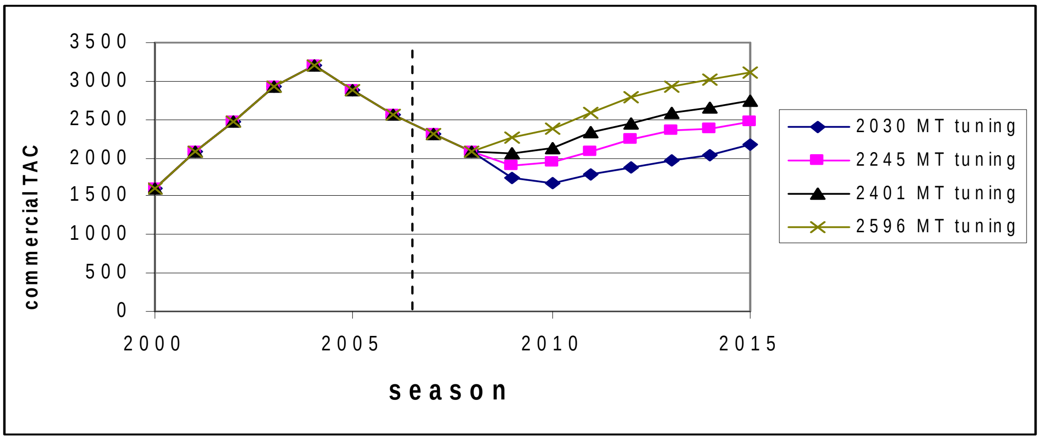


Figure 3b: Comparative plots of Effort(*y*/06) for the four OMPs presented. Only medians are indicated. The vertical hashed line indicates the start of the projection period.

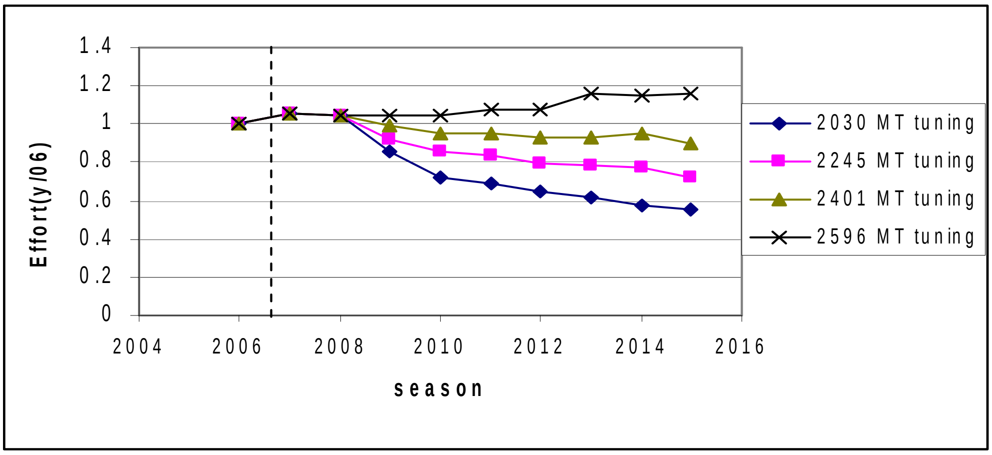


Figure 4: Median and 90% PI of commercial TAC (left panel) and *B*75(male) (right panel) for each of the five super-areas, for the "2245 MT" tuning.