Updated trends in poaching for West Coast rock lobster from modelling the "old" and the "new" databases simultaneously

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Abstract

Updated results are given for an approach which simultaneously models the "old" and the "new" databases as recommended by the Panel for the 2018 International Fisheries Stock Assessment Workshop, with poaching data for 2019 now included. These results are compared to those obtained previously. For cases where the "old" database is upweighted, the 2019 poaching indices estimated for both the northern Super-areas (3-7) and for the southern Super-area 8+ show statistically significant increases compared to 2018. A three-point smoothing approach is used for converting the poaching series obtained as outputs to the input series used in the assessments.

Keywords: west coast rock lobster; poaching trends; confiscations; policing effort

Introduction

The analyses for estimating poaching trends recommended by the Panel for the 2018 International Fisheries Stock Assessment Workshop (Cox *et al*. 2018), and implemented by Brandão and Butterworth (2019a), are updated to include data for 2019. To aid comparison, the results for this approach reported in Brandão and Butterworth (2019b), which included data to 2018, are duplicated as well.

Data

Monthly data on confiscations and policing effort obtained from one of the Directorates within the CD (Directorate: Compliance) for the period of April 2008 to December 2019 form the "old" database. Data for the period 2012 to 2019 on rock lobster confiscations that are linked to a policing effort type form the "new" database. The first three months of the 2016 compliance data have been omitted from the analyses to remove the effect of the greatly enhanced policing levels during those months when Operation Phakisa was launched.

Methods

The recommendation by the International Panel to obtain poaching trends is to apply the models of Brandão and Butterworth (2018) to analyse the "new" database, together with the "old" database for which confiscations were not linked to the associated policing effort type, in a way that combines these two databases. This keeps some parameter values common between the two models to improve the precision of parameter estimates for the "new" database model of Brandão and Butterworth (2018). The Panel also recommended assuming that the number of confiscations follow a Negative Binomial distribution, instead of an overdispersed Poisson as assumed by Brandão and Butterworth (2018). In the case of the "new" database, only positive confiscations are reported. Thus, because instances of zero confiscations are never recorded in the "new" database, a Zero-Truncated Negative Binomial distribution is assumed.

The number of confiscations from the "new" and the "old" databases are modelled together assuming the following distributions:

$$C_{y,m,t}^{new} \sim \text{Zero-Truncated Negative Binomial}\left(exp\left(\lambda^{new} + \alpha_m + \beta_t + \delta_y\right), \xi^{new}\right)$$

$$C_{y,m}^{old} \sim \text{Negative Binomial}\left(\sum_t \left(Q_t e^{\beta_t} E_{y,m,t}^{old}\right) exp\left(\lambda^{old} + \alpha_m + \delta_y\right), \xi^{old}\right)$$

where

$C_{y,m,t}^{new}$ is the number of confiscations made in a single compliance event in year *y*, month *m* and by policing type *t* as reported in the "new" database,

$C_{y,m}^{old}$ is the total number of confiscations made in year *y* and month *m* as reported in the "old" database,

$E_{y,m,t}^{old}$ is the total policing effort reported in the "old" database for year *y*, month *m* and by policing type *t*,

Q_t is a factor to account for the absences of inspections with zero rock lobster confiscations in the "new" database; the adjustments made are the averages over years of proportions of successful (illegally caught rock lobster confiscated) inspections as given in Table 1,

λ^{new} is the intercept for the "new" database,

λ^{old} is the intercept for the "old" database,

α_m is a common month effect for both databases,

β_t reflects the type of policing effort which is linked to the confiscations, where the "type" factor is associated with the different types of policing such as coastal patrols, slipway inspections and vehicles inspections; they provide relative policing effort efficiencies which can be used in the "old" database to link policing effort to the number of confiscations,

δ_y is the common year effect for both databases (2008 to 2019 for Super Area 8+ and 2009 to 2019 for the northern Super-areas 3 to 7) whose estimates provide the poaching trend, and

$\xi^{new/old}$ is the dispersion parameter of the Negative Binomial distribution for the "new"/"old" databases.

Note that "year" refers to a calendar year throughout this document.

The contribution of the "old" database to the negative log-likelihood function in terms of individual observations is given by:

$$-\ln L_{old} = \sum_i \left\{ w_i \left[\left(C_i^{old} + (\phi^{old})^{-1}\right) \ln\left(1 + \phi^{old}\mu_i^{old}\right) - C_i^{old} \ln\left(\phi^{old}\mu_i^{old}\right) - \sum_{j=0}^{C_i^{old}-1} \ln\left(j + (\phi^{old})^{-1}\right) \right] \right\} \quad (1)$$

where

C_i^{old} represents a single record of $C_{y,m}^{old}$ for a particular year (y) and month (m),

ϕ^{old} is the reciprocal of the dispersion parameter ξ^{old},

w_i is a weighting factor applied to upweight the contribution of the "old" database to the overall negative log-likelihood (see later discussion), and

μ_i^{old} is determined by a set of k indicator variables to represent the categorical variables λ^{old}, α_m and δ_y and is given by:

$$\mu_i^{old} = \sum_t \left(Q_t e^{\beta_t} E_{i,t}^{old}\right) exp\left(\theta_1 X_{1,i} + \theta_2 X_{2,i} + \cdots + \theta_k X_{k,i}\right),$$

where $X_{1,i} = 1$ to represent the intercept λ^{old}, and $E_{i,t}^{old}$ represents the single records of $E_{y,m,t}^{old}$ for a particular year (y) and month (m) for policing type t.

Similarly, the contribution of the "new" database to the negative log-likelihood function in terms of individual observations and assuming a Zero-Truncated Negative Binomial distribution is given by:

$$-\ln L^{new} = \sum_i \left\{ \begin{array}{l} \left(C_i^{new} + (\phi^{new})^{-1}\right) \ln\left(1 + \phi^{new}\mu_i^{new}\right) - C_i^{new} \ln\left(\phi^{new}\mu_i^{new}\right) - \\ \displaystyle\sum_{j=0}^{C_i^{new}-1} \ln\left(j + (\phi^{new})^{-1}\right) - \ln\left(1 - \left(1 + \phi^{new}\mu_i^{new}\right)^{-(\phi^{new})^{-1}}\right) \end{array} \right\} \quad (2)$$

where

C_i^{new} represents the single records of $C_{y,m,t}^{new}$ for a particular year (y), month (m) and policing type (t),

ϕ^{new} is the reciprocal of the dispersion parameter ξ^{new},

μ_i^{new} is determined by a set of s indicator variables to represent the categorical variables $\lambda^{new}, \alpha_m, \delta_y$ and β_t and is given by:

$\mu_i^{new} = exp\left(\zeta_1 Y_{1,i} + \zeta_2 Y_{2,i} + \cdots + \zeta_s Y_{s,i}\right)$, where $Y_{1,i} = 1$ to represent the intercept λ^{new}. Note that the regression coefficients θ and ζ (of μ_i^{old} and μ_i^{new} respectively) that correspond to the categorical variables for month and year will be the same as in equation (1) as they are common between both model components.

In the equations above of the contributions to the negative log-likelihood function, the following relationship for the gamma function is used:

$$ln\left(\frac{\Gamma(C_i+\phi^{-1})}{\Gamma(\phi^{-1})}\right)=\sum_{j=0}^{C_i-1} ln(j+\phi^{-1}).$$

The w_i weighting factor in equation (1) may be set at a value of more than 1 to upweight the contribution of data in the "old" database to the overall negative log-likelihood, compared to those in the "new" database in equation (2). The reason that this factor is introduced is that the "old" and the "new" databases are not comparable in the sense that the confiscation entries in the "old" database have been summed for a month in a particular year, while those in the "new" database represent individual incidents of non-zero confiscations that occurred in a particular month and year. Thus, by upweighting the contribution of data in the "old" database, one is compensating for the information that has been lost by the summations of the confiscations in a month; these entries pertain to multiple rather than single incidents.

The weighting factors were determined by examining the maximum number of positive confiscations that took place in each month over the years of the "new" database (unfortunately raw data with this information are not available). This examination showed clearly that there were months of typically higher and of typically lower numbers of positive confiscations. The values for w_i based on this exercise, and applied in this paper for the months December to May were 20 for the southern area and 15 for the northern areas, while for the months of June to November, a weight of 10 was applied to both the southern and the northern areas. These choices were made based on the values listed in Table 1 of Brandão and Butterworth (2019a).

Results

Tables 2 and 3 show parameter estimates for Super-areas 3+4+5+6+7 and 8+ respectively for GLMs fitted as follows:

- to the combined "old" and "new" databases with data from the "old" database weighted by some factor (see text immediately above for details); and
- to the combined "old" and "new" databases with a weight of 1 (i.e. unweighted) applied to data from the "old" database.

Figure 1 shows the poaching trends obtained from the two different analysis approaches, as detailed above for the results shown in Tables 2 and 3, for the two Super-area combinations.

For the preferred approach of upweighting the "old" database contributions to the likelihood, the poaching indices for 2019 show appreciable increases in relative terms compared to those for 2018, for both the northern Super-areas (3-7) and for the southern Super-area 8+.

Figure 2 and Tables 4a-b report these trends relative to 2008 (for Super-area 8+) or 2009 (for the northern areas). Figure 2 also compares these trends to the smoothing method proposed by Brandão and Butterworth (2019b). This is simply three-point smoothing, where each value is replaced by the average of itself with the values for the years immediately before and after. For the points at the end of the series, this simplifies further to averaging their values with those for the single adjacent year.

Table 5 shows the ratio of 2019 estimated poaching indices to the 2018 value together with the lower and upper bounds of the 95% confidence intervals. For both the northern Super-areas 3-7 and the southern Super-area 8+, a statistically significant increase in the poaching indices for 2019 compared to 2018 is evident.

References

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Table 1. Difference between the number of observations in the “old” and the “new” databases that might be assumed to be the number of “zero” confiscations in the “new” database. Results are shown by common policing effort types and Super-areas. Percentages of observations in the “new” database that would constitute non-zero confiscations are also shown.

	Difference in number of observations between “old” and “new”			**Percentage of observations that would constitute non-zero confiscations in the “new” database**		
Northern Super-areas 3+4+5+6+7						
	Coastal Patrols	Slipway inspections	Vehicle inspections	Coastal Patrols	Slipway inspections	Vehicle inspections
2008	—	—	—	—	—	—
2009	1822	1939	3724	—	—	—
2010	2510	3287	3587	—	—	—
2011	3223	4197	3953	—	—	—
2012	2935	3537	7068	0.17%	0.06%	0.24%
2013	2513	2902	6464	0.28%	0.68%	0.68%
2014	2646	2722	4174	0.94%	1.45%	0.69%
2015	2742	2994	3551	0.47%	1.22%	0.84%
2016	2623	3134	2442	0.57%	0.22%	0.12%
2017	2545	2781	1841	0.90%	0.36%	0.22%
2018	2122	2315	1108	0.47%	0.30%	0.09%
2019	1876	1982	1373	0.90%	0.65%	0.65%
Average	***2505***	***2890***	***3571***	***0.59%***	***0.62%***	***0.44%***
Southern Super-area 8+						
2008	3923	2585	3179	—	—	—
2009	4857	3766	3951	—	—	—
2010	5540	3507	3847	—	—	—
2011	7722	4876	2604	—	—	—
2012	5991	4547	3366	0.02%	0.57%	0.03%
2013	4931	4291	2966	0.78%	0.44%	0.00%
2014	4208	3848	1806	0.82%	0.67%	0.06%
2015	5656	4621	2593	0.88%	0.75%	0.04%
2016	5579	3661	3539	0.46%	0.97%	0.06%
2017	6161	4534	4567	0.63%	0.74%	0.00%
2018	4858	3258	3838	0.39%	0.82%	0.00%
2019	4503	3323	3501	0.27%	0.39%	0.00%
Average	***5327***	***3901***	***3313***	***0.53%***	***0.67%***	***0.02%***

Table 2. GLM parameter/coefficient (and standard error) estimates for **Super-areas 3+4+5+6+7.**

	Previous weight = 1	**Previous weight = 15; 10**	**Updated weight = 1**	**Updated weight = 15; 10**
January	0	0	0	0
February	1.181(0.430)	0.636(0.149)	1.380 (0.449)	0.668 (0.143)
March	1.388(0.447)	0.494(0.158)	1.281 (0.431)	0.424 (0.153)
April	0.320(0.567)	-0.186(0.150)	0.484 (0.401)	0.108 (0.148)
May	-0.024(0.645)	-0.901(0.152)	0.039 (0.502)	-0.848 (0.148)
June	-1.534(0.600)	-3.091(0.169)	-1.533 (0.449)	-2.986 (0.165)
July	-1.964(0.493)	-2.913(0.169)	-2.092 (0.478)	-3.048 (0.165)
August	-1.325(0.488)	-2.380(0.163)	-1.449 (0.473)	-2.444 (0.159)
September	-0.534(0.591)	-2.085(0.180)	-0.687 (0.537)	-2.070 (0.174)
October	-0.238(0.537)	-2.001(0.161)	-0.209 (0.471)	-1.954 (0.155)
November	-0.807(0.606)	-1.522(0.164)	-0.898 (0.534)	-1.492 (0.158)
December	0.626(0.632)	-0.487(0.163)	0.630 (0.667)	-0.127 (0.157)
2008	—	—	—	—
2009	0.607(0.614)	0.363(0.162)	0.613 (0.603)	0.479 (0.161)
2010	1.492(0.511)	1.097(0.149)	1.504 (0.588)	1.216 (0.150)
2011	0.632(0.508)	0.173(0.161)	0.682 (0.589)	0.355 (0.159)
2012	-0.218(0.657)	-0.211(0.155)	-0.204 (0.512)	-0.085 (0.154)
2013	-0.383(0.601)	-0.926(0.148)	-0.417 (0.469)	-0.755 (0.151)
2014	0	0	0	0
2015	0.553(0.485)	-0.008(0.143)	0.525 (0.575)	0.104 (0.142)
2016	-0.817(0.680)	-0.938(0.166)	-0.815 (0.638)	-0.799 (0.164)
2017	0.184(0.483)	-0.957(0.145)	0.091 (0.648)	-0.884 (0.146)
2018	-0.637(0.507)	-1.376(0.157)	-0.681 (0.544)	-1.277 (0.157)
2019	—	—	-0.048 (0.541)	-0.560 (0.142)
coastal	0	0	0	0
slipway	0.703(0.551)	0.139(0.365)	0.409 (0.433)	-0.189 (0.319)
vehicles	1.051(0.749)	0.844(0.259)	0.747 (0.376)	0.435 (0.217)

Table 3. GLM parameter/coefficient (and standard error) estimates for **Super-area 8+.**

	Previous weight = 1	Previous weight = 20; 10	Updated weight = 1	Updated weight = 20; 10
January	0	0	0	0
February	1.778(0.476)	1.243(0.135)	1.804 (0.450)	1.355 (0.134)
March	0.236(0.506)	-0.593(0.140)	0.526 (0.498)	-0.561 (0.140)
April	0.939(0.458)	1.280(0.142)	0.992 (0.444)	1.289 (0.143)
May	0.079(0.431)	0.163(0.138)	0.246 (0.427)	0.335 (0.139)
June	0.213(0.481)	0.219(0.159)	0.458 (0.465)	0.547 (0.160)
July	-0.497(0.526)	-0.784(0.160)	-0.148 (0.503)	-0.298 (0.160)
August	-2.084(0.502)	-2.267(0.160)	-1.959 (0.471)	-2.147 (0.159)
September	1.255(0.532)	0.435(0.163)	1.352 (0.522)	0.473 (0.164)
October	-0.816(0.497)	-0.416(0.163)	-0.758 (0.480)	-0.399 (0.164)
November	-0.927(0.434)	-0.893(0.157)	-0.679 (0.418)	-0.556 (0.158)
December	-1.827(0.354)	-0.789(0.134)	-1.729 (0.343)	-0.813 (0.136)
2008	-1.175(0.601)	-1.211(0.163)	-1.285 (0.611)	-1.264 (0.170)
2009	-1.269(0.535)	-0.982(0.151)	-1.425 (0.541)	-1.081 (0.157)
2010	-0.898(0.535)	-0.845(0.146)	-0.979 (0.540)	-0.890 (0.153)
2011	-0.283(0.537)	-0.302(0.138)	-0.318 (0.558)	-0.337 (0.144)
2012	-0.608(0.448)	-0.929(0.137)	-0.628 (0.459)	-0.989 (0.141)
2013	0.858(0.412)	0.460(0.141)	0.870 (0.412)	0.507 (0.147)
2014	0	0	0	0
2015	0.157(0.397)	-0.328(0.138)	0.139 (0.392)	-0.281 (0.145)
2016	-0.372(0.449)	0.158(0.158)	-0.499 (0.443)	0.054 (0.165)
2017	-1.097(0.376)	-0.102(0.140)	-1.132 (0.375)	-0.132 (0.146)
2018	-1.139(0.398)	-0.862(0.153)	-1.157 (0.399)	-0.864 (0.161)
2019	—	—	-0.504 (0.460)	-0.236 (0.153)
coastal	0	0	0	0
slipway	0.343(0.290)	0.420(0.262)	0.349 (0.281)	0.379 (0.260)
vehicles	3.879(1.050)	2.920(0.398)	4.481 (1.076)	3.576 (0.347)

Table 4a. Poaching series obtained from a) the unweighted (i.e. weight = 1) combined "old" and "new" databases, and b) the weighted (see text for details) combined "old" and "new" databases for the northern **Super-areas 3+4+5+6+7**. The results shown are normalised to a 2009 value of 1. Previous results for these two approaches are given as well.

	Previous weight = 1	Previous weight = 15; 10	Updated weight = 1	Updated weight = 15; 10
2008	—	—	—	—
2009	1.000	1.000	1.000	1.000
2010	2.418	2.084	2.437	2.090
2011	1.025	0.827	1.072	0.883
2012	0.438	0.564	0.442	0.569
2013	0.372	0.276	0.357	0.291
2014	0.545	0.696	0.542	0.619
2015	0.947	0.690	0.916	0.687
2016	0.241	0.272	0.240	0.279
2017	0.655	0.267	0.593	0.256
2018	0.288	0.176	0.274	0.173
2019	—	—	0.516	0.354

Table 4b. Poaching series obtained from a) the unweighted (i.e. weight = 1) combined "old" and "new" databases, and b) the weighted (see text for details) combined "old" and "new" databases for the southern **Super-area 8+**. The results shown are normalised to a 2008 value of 1. Previous results for these two approaches are given as well.

	Previous weight = 1	Previous weight = 20; 10	Updated weight = 1	Updated weight = 20; 10
2008	1.000	1.000	1.000	1.000
2009	0.910	1.258	0.870	1.200
2010	1.319	1.441	1.358	1.454
2011	2.440	2.481	2.631	2.527
2012	1.763	1.326	1.930	1.317
2013	7.639	5.316	8.632	5.874
2014	3.238	3.357	3.616	3.540
2015	3.788	2.417	4.154	2.673
2016	2.231	3.933	2.196	3.736
2017	1.081	3.030	1.166	3.100
2018	1.036	1.417	1.137	1.492
2019	—	—	2.184	2.796

Table 5. The ratio of 2019 poaching indices to the 2018 values, together with the lower and upper bounds provided by 95% confidence intervals, for the northern Super-areas 3-7 and the southern Super-area 8+.

Super-area	Ratio	Lower bound	Upper bound
Northern 3-7	2.050	1.534	2.738
Southern 8+	1.875	1.389	2.530

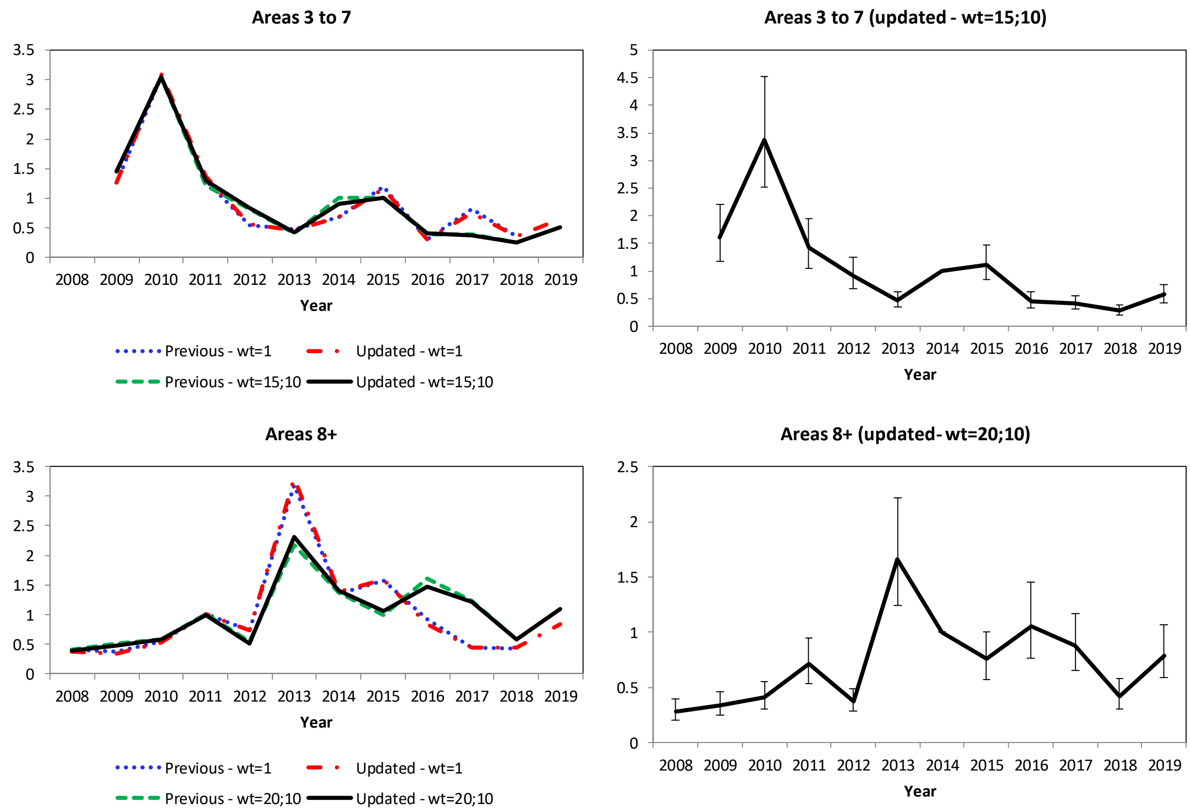
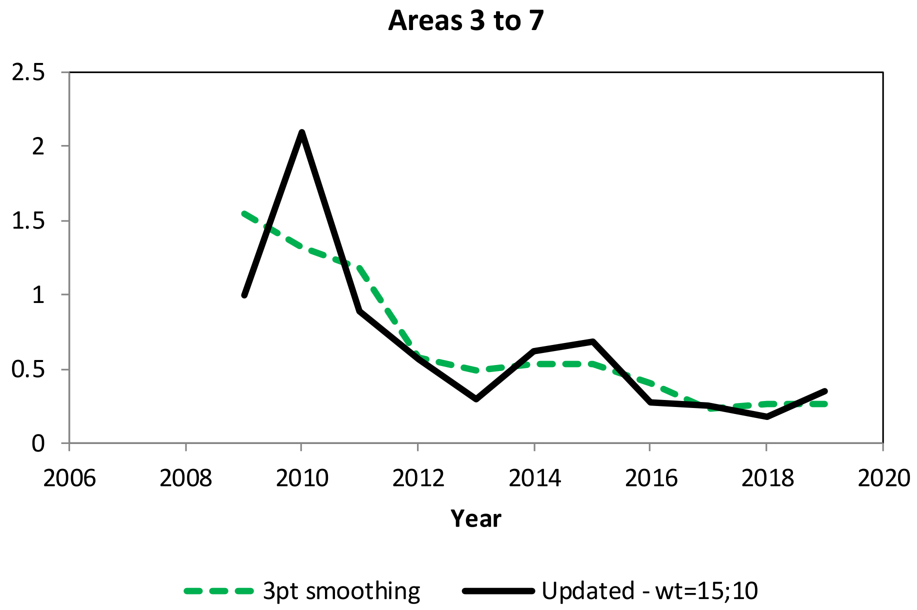


Figure 1. The plots on the left hand side show poaching trends (corresponding to year effects) for two different analysis approaches, with the previous results (to 2018 - Brandão and Butterworth, 2019b) also plotted for comparison:

- modelling of the combined "old" and "new" databases with the "old" database data weighted by some factor (see text for details) – the approach now recommended; and
- modelling of the combined "old" and "new" databases with a weight of one (i.e. unweighted) applied to the "old" database data.

The plots on the right hand side show poaching trends for the weighted combined "old" and "new" databases (the recommended approach), together with 95% confidence limits. The plots described above are given for the northern **Super-areas 3+4+5+6+7 (top)** and the southern **Super-area 8+ (bottom)**. The series plotted on the left hand side have been normalised to the period from 2012 to 2018 for which they overlap.



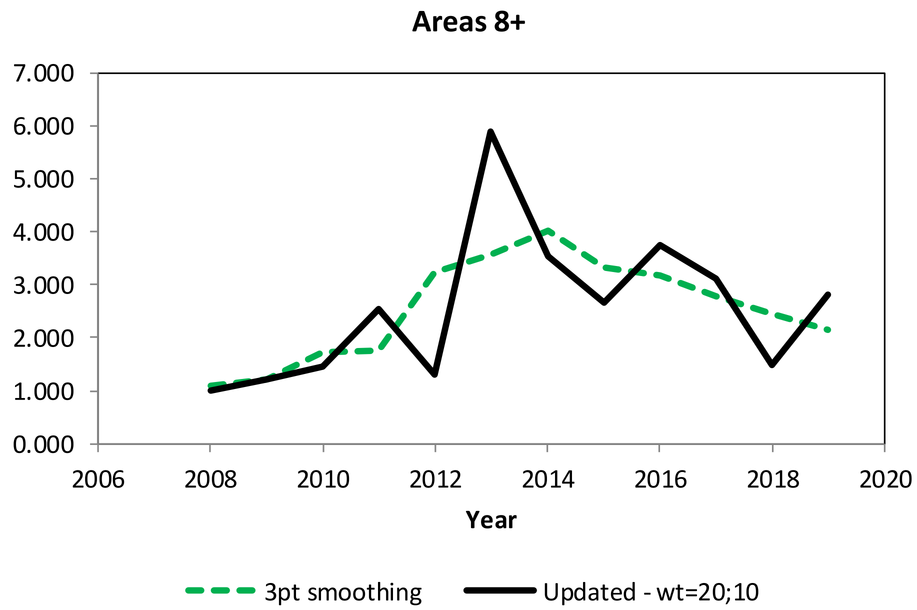


Figure 2. Poaching trends obtained using two different approaches:

- modelling of the combined "old" and "new" databases with the "old" database weighted by some factor – the approach now recommended (see text for details); and
- applying three-point smoothing to the poaching indices from the approach above.

The plots described above are given for **Super-areas 3+4+5+6+7 (top)** and **Super-area 8+ (bottom)**. Results shown are normalised to a 2008 value of 1 for Super-area 8+ or to a 2009 value of 1 for Super-areas 3+4+5+6+7, as assumed for the 2016 assessment and projections for the first approach, but not the second.