

## Original Article

# Estimating stock status from relative abundance and resilience

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The Law of the Sea and regional and national laws and agreements require exploited populations or stocks to be managed so that they can produce maximum sustainable yields. However, exploitation level and stock status are unknown for most stocks because the data required for full stock assessments are missing. This study presents a new method [abundance maximum sustainable yields (AMSY)] that estimates relative population size when no catch data are available using time series of catch-per-unit-effort or other relative abundance indices as the main input. AMSY predictions for relative stock size were not significantly different from the “true” values when compared with simulated data. Also, they were not significantly different from relative stock size estimated by data-rich models in 88% of the comparisons within 140 real stocks. Application of AMSY to 38 data-poor stocks showed the suitability of the method and led to the first assessments for 23 species. Given the lack of catch data as input, AMSY estimates of exploitation come with wide margins of uncertainty, which may not be suitable for management. However, AMSY seems to be well suited for estimating productivity as well as relative stock size and may, therefore, aid in the management of data-poor stocks.

**Keywords:** Common Fisheries Policy, cpue, data-poor stocks, MSFD, stock assessment, surplus production models, UNCLOS

## Introduction

The Law of the Sea (UNCLOS, 1982) commits its signatories to manage the exploitation of fish and invertebrates so that these populations are large enough to generate maximum sustainable yields (MSY). National and regional implementations of this MSY framework have made it clear that for risk avoidance and economic benefits, biomass ( $B$ ) of stocks must be above the MSY level ( $B_{MSY}$ ) or proxies thereof (CFP, 2013; HSP, 2018) and

fishing pressure ( $F$ ) must be below the MSY level ( $F_{MSY}$ ) (UNFSA, 1995; MSA, 2007). However, exploitation level and stock status are unknown for most exploited populations or stocks because the data required for full stock assessments are missing. Methods that make best use of available data combined with general knowledge and Monte Carlo approaches have recently been developed on the basis of previous work in fish population dynamics (Graham, 1935; Schaefer, 1954, 1957;

Beverton and Holt, 1957; Ricker, 1975), such as CMSY (Froese et al., 2017) for catch data and LBB (Froese et al., 2018a, 2019) to estimate relative biomass levels from length frequency data. This study applies a similar approach to observed trends in the relative abundance of exploited species and thus complements CMSY and LBB.

Fisheries-independent surveys carried out year after year with standardized gear and in a random or stratified fashion produce time series of indices of fish abundance also referred to as catch-per-unit-effort (cpue), conventionally in units of catch in numbers or weight per duration of gear deployment or per swept area. Cpue obtained from such standardized research surveys is a good indicator of abundance (see, e.g. Silliman and Gutsell, 1958 for experimental confirmation). Abundance estimates (relative or absolute) can also be obtained using hydroacoustic methods, as practiced for half a century for the stock of Peruvian anchoveta (*Engraulis ringens*; see Pauly et al., 1987). Time series of abundance are useful in that they allow trend analyses such as comparing current cpue to the average of previous years (e.g. ICES, 2017). However, it is often unclear whether such abundance trajectories refer to a stock fluctuating around unexploited stock size, around a stock size close to collapse, or somewhere in between. If reliable catch data are available, this ambiguity is best addressed by combining cpue trends with catch data, e.g. in surplus production models (Schaefer, 1954; Pella and Tomlinson, 1969; Fox, 1970; Froese et al., 2017; Pedersen and Berg, 2017; Winker et al., 2018).

If no reliable data are available for the total catch taken from a stock, as is often the case in migratory species, widely dispersed stocks, bycatch species, or species with high discard rates, independent assessments of relative stock size can be used as priors for modelling, such as derived from expert opinion or preferably from other data sources such as length frequency data (LBB, Froese et al., 2018a, 2019). One must be conscious, however, that such use of independent assessments of relative stock size to present the observed cpue in an MSY framework fully depends on the quality of the independent assessment and is not informed by the cpue data. This study aims to overcome this limitation by performing a joint analysis of abundance trends, independent stock size information and readily available information on the resilience or productivity of the respective species.

## Material and methods

### Theoretical background

For stocks that lack information on age, natural mortality, or recruitment but have reliable time series of catch and abundance, surplus production models are the method of choice for estimating stock status and exploitation. Based on the Graham (1935), the Schaefer (1954) model estimates surplus production or equilibrium yield ( $Y$ ) from biomass ( $B$ ), maximum intrinsic rate of population increase ( $r$ , sometimes called  $r_{\max}$ ), and carrying capacity ( $k$ ):

$$Y = B r \left(1 - \frac{B}{k}\right). \quad (1)$$

The difference form of the Schaefer model predicts the biomass in the next year ( $B_{t+1}$ ) from the current biomass ( $B_t$ ) plus surplus production or yield ( $Y_t$ ) minus catch ( $C_t$ ):

$$B_{t+1} = B_t + Y_t - C_t = B_t + B_t r \left(1 - \frac{B_t}{k}\right) - C_t. \quad (2)$$

Note that the expression  $(1 - B_t/k)$  describes the linear decline with relative biomass of the applicable fraction of  $r$ , resulting in a factor of 1 when  $B_t = 0$  and zero when  $B_t = k$ .

In surveys that deploy a standard gear in a random or stratified fashion across an area, cpue is usually assumed to be directly proportional to the abundance or biomass of the target species in that area. The relationship between cpue and biomass is then determined by the catchability coefficient  $q$  (Arreguín-Sánchez, 1996; Maunder and Punt, 2004), which is here assumed to be constant over the considered time period (see below for exceptions) such that:

$$\text{cpue}_t = B_t q. \quad (3)$$

Multiplying both sides of (2) with  $q$  and replacing  $B_t q$  with  $\text{cpue}_t$ , gives:

$$\text{cpue}_{t+1} = \text{cpue}_t + \text{cpue}_t r \left(1 - \frac{B_t}{k}\right) - C_t q. \quad (4)$$

Solving (3) for  $B_t$  and inserting in (4) gives (5) (Froese et al., 2017):

$$\text{cpue}_{t+1} = \text{cpue}_t + \text{cpue}_t r \left(1 - \frac{\text{cpue}_t}{kq}\right) - C_t q. \quad (5)$$

For the purpose of estimating relative exploitation and stock status, it is not necessary to know the absolute values of  $C_p$ ,  $B_p$ ,  $k$ , and  $q$ . One can instead treat  $C_t q$  as relative catch  $C_{qt}$  and  $kq$  as relative carrying capacity  $k_q$  or the cpue one would obtain if there were no fishing:

$$\text{cpue}_{t+1} = \text{cpue}_t + \text{cpue}_t r \left(1 - \frac{\text{cpue}_t}{k_q}\right) - C_{qt}. \quad (6)$$

Equation (6) can be rearranged to predict relative catch  $C_q$  up to the second last year in the time series:

$$C_{qt} = \text{cpue}_t + \text{cpue}_t r \left(1 - \frac{\text{cpue}_t}{k_q}\right) - \text{cpue}_{t+1}. \quad (7)$$

In the Schaefer model, the maximum sustainable catch (MSY) is obtained at half of  $k$  and half of  $r$  with  $\text{MSY} = r/2 \times k/2$ . A similar expression is obtained in

$$\text{MSY}_q = \frac{r k_q}{2 \cdot 2} = \frac{r k_q}{4}, \quad (8)$$

where  $\text{MSY}_q$  is the maximum sustainable value of relative catch  $C_q$  and, therefore, the ratio  $C_q/\text{MSY}_q$  is the same as the ratio  $C/\text{MSY}$ . This logic, which is very similar to the matter covered in Ricker (1975, p. 316), also means that the relative catch predicted from (7) can be presented in an MSY framework.

Similarly, since  $k_q$  represents the expected value of cpue in the absence of fishing, the ratio  $\text{cpue}_t/k_q$  is the same as the ratio  $B_t/k$ ; therefore, cpue can be presented as the relative biomass within an MSY framework.

Finally, in the Schaefer model, fishing mortality  $F$  is equal to the ratio of catch to biomass  $C_t/B_t$ , which is identical to the ratio

$C_{qt}/\text{cpue}_t$ . Hence, the fishing mortality that corresponds to  $MSY$  is  $F_{MSY} = 0.5r$ ; therefore, relative exploitation can be presented within an  $MSY$  framework:

$$\frac{F}{F_{MSY}} = \frac{C_{qt}}{\text{cpue}_t} = \frac{2C_{qt}}{r \text{ cpue}_t}. \quad (9)$$

### The abundance $MSY$ approach

A time series of  $\text{cpue}$  and prior ranges for  $r$  and relative stock size  $B/k$  in a given year are required input data for the abundance  $MSY$  method ( $AMSY$ ). A prior range for  $k_q$  is derived from  $B/k$  and  $\text{cpue}_t$  as described below. With this information, the time series of  $\text{cpue}$  can be placed within a preliminary  $MSY$  framework where half of the endpoints of the  $k_q$  range are used as ranges for  $B_{MSY\_q}$ . A multivariate lognormal random sample of  $r-k_q$  pairs is then created based on the variance-covariance matrix ( $VCM$ ) shown in (10), where the prior log ranges of  $r$  and  $k_q$  are assumed to represent four standard deviations ( $SD$ ), and variance is  $SD$  squared. The  $r-k_q$  covariance in log space was obtained from an empirical correlation between  $\log r$  and  $\log k_q$  obtained as median =  $-0.607$  across 140 stocks (*EU\_Stocks\_BSM\_Results.xls*, Froese et al., 2018b) analyzed with a Bayesian Schaefer model (Froese et al., 2017), and from the prior  $SD$  of  $\log r$  and  $\log k_q$  such that covariance  $\log r-k_q = -0.607 \times SD \log(r) \times SD \log(k_q)$  (see cloud of grey dots in Figure 1):

$$VCM_{\log(r), \log(k_q)} = \begin{Bmatrix} \sigma_{\log(r)}^2 & \text{cov}_{\log(r), \log(k_q)} \\ \text{cov}_{\log(r), \log(k_q)} & \sigma_{\log(k_q)}^2 \end{Bmatrix}. \quad (10)$$

As shown in the simulations in Section 1 of the Supplementary material and in Figure 1a, this procedure will result in a predicted central  $r-k_q$  pair in the middle of the prior  $r-k_q$  log space, with approximated confidence limits as wide as that space. To better accommodate “true”  $r-k_q$  pairs that are off the centre and to reduce the amount of uncertainty,  $AMSY$  applies filters to exclude  $r-k_q$  pairs that would give unreasonable results when combined with the priors and  $\text{cpue}$  data. For example, the relative catch predicted from (7) may not become negative or exceed  $\text{cpue}$  anywhere in the time series because it is unlikely that a fishery catches all fish in a given year. Only  $r-k_q$  pairs that fulfil these and additional conditions (see below) are considered “viable” and are retained and used by  $AMSY$  to determine the most likely  $r-k_q$  pair, with approximate confidence limits (see examples in Section 2 of the Supplementary material and in Figure 1b).

### Priors for $r$ , $k_q$ and $F/F_{MSY}$

Priors for  $r$  were derived from FishBase ([www.fishbase.org](http://www.fishbase.org); Froese and Pauly, 2019) for fish and from SeaLifeBase ([www.sealifebase.org](http://www.sealifebase.org); Palomares and Pauly, 2019a) for invertebrates, from the section on the species summary page entitled “Estimates of some properties based on models”, either as lognormal distributions based on previous assessments or as qualitative indications of resilience from very low to high (Table 1). Resilience was then translated into uniform prior ranges as described in Froese et al. (2017) and reproduced here for easy reference.

A prior for relative biomass  $B/k$  can be derived from experts who are asked how stock size was in a year of their choice

compared to past stock size when there was little fishing of the species. For example, if the stock was only lightly fished in the beginning of the time series, it is reasonable to assume that stock size was more than half of the unexploited level in those years. Such qualitative assessment is then translated into  $B/k$  ranges, as indicated in Table 2. Alternatively, and preferably, a quantitative assessment of  $B/k$  or  $B/B_{MSY}$  is derived from a previous assessment or from independent data such as length frequencies analyzed with methods such as LBB (Froese et al., 2018a, 2019; see examples in Section 3 of the Supplementary material). The year for which the  $B/k$  prior is provided depends on the available data, i.e. a year with a good length frequency sample or unanimous expert opinion. For example, if fishing was very light at the beginning of the time series, experts are likely to agree that stock size was close to unexploited, giving a  $B/k$  prior of e.g. 0.75–1.0.

A prior range for  $k_q$  is derived from  $B/k$  as  $k_q = \text{cpue}_t/(B/k)$ . If the lower bound of  $k_q$  resulting from this exercise is less than the maximum  $\text{cpue}$  in the time series,  $\max(\text{cpue})$  is used as the lower  $k_q$  bound because abundance of an exploited species is unlikely to exceed carrying capacity. Also, to avoid unrealistically narrow or wide ranges, the upper bound of  $k_q$  is set at least 30% larger than the lower bound, but not farther away than threefold the lower bound. In other words, the  $B/k$  prior together with population dynamics and scaling considerations is used to put the observed  $\text{cpue}$  into a preliminary  $MSY$  framework. This placement is then refined by the Monte Carlo filtering described below.

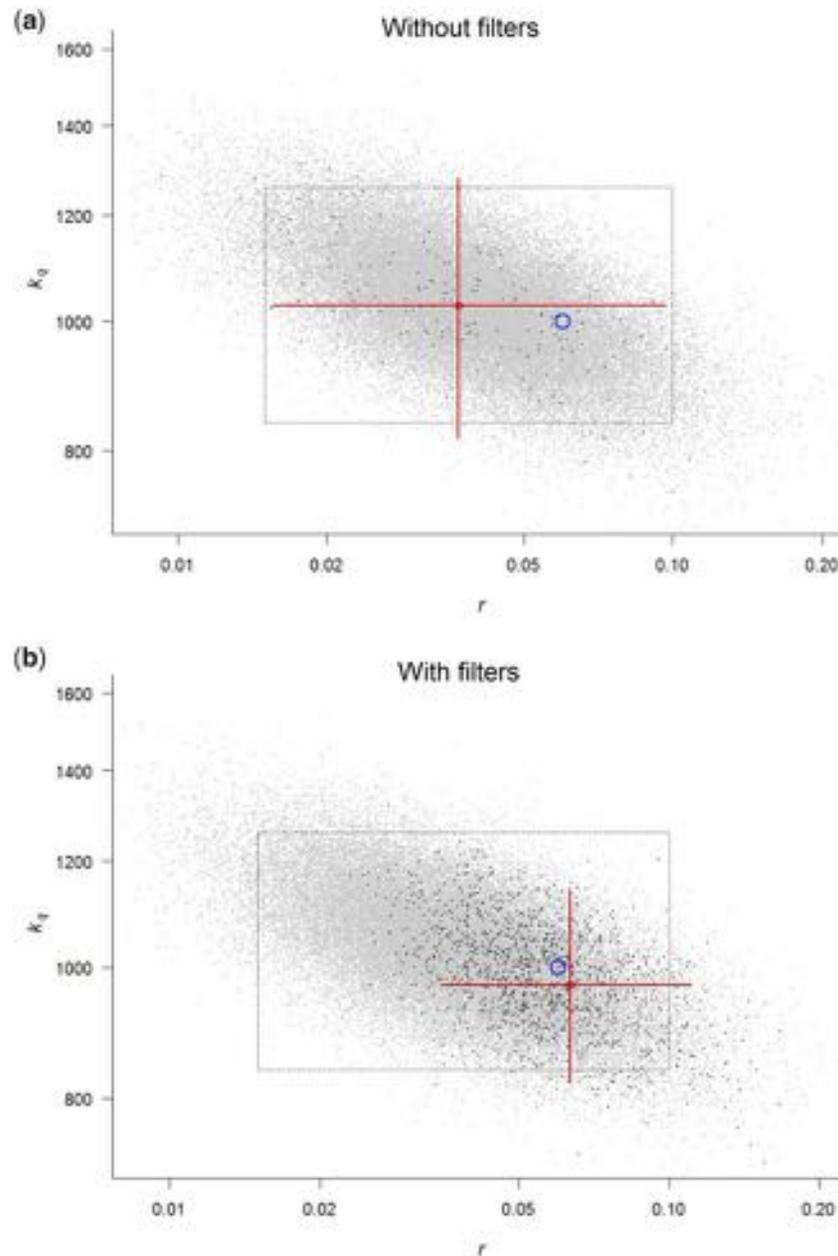
### $AMSY$ Monte Carlo filtering

Based on the prior knowledge of  $B/k$ , a time series of  $\text{cpue}$  can be presented in a preliminary  $MSY$  framework, with the  $\text{cpue}$  range that is capable of producing  $MSY_q$  given by  $\text{cpue}_{MSY} = \text{cpue}_t/(B/k)$ , using the lower and upper limits of  $B/k$ . Pairs of  $r-k_q$  are then randomly selected from their respective prior ranges, and the time series of relative catch  $C_q$  corresponding to the time series of  $\text{cpue}$  is calculated from (7).

To account for reduced recruitment and thus reduced productivity or surplus production at very small stock sizes, (7) is combined with a hockey stick recruitment function (Barrowman and Myers, 2000; Froese et al., 2016a, 2017). Thus, if relative stock size at the end of the time series is smaller than half of  $B_{MSY}$  or 0.25  $\text{cpue}/k_q$ , a linear reduction of surplus production with declining biomass is assumed (similar to the  $MSY_{B_{trigger}}$  rule in ICES, 2016):

$$C_{qt} = \text{cpue}_t + \text{cpue}_t r \left(1 - \frac{\text{cpue}_t}{k_q}\right) \left(4 \frac{\text{cpue}_t}{k_q}\right) - \text{cpue}_{t+1} \left| \frac{\text{cpue}_t}{k_q} < 0.25. \quad (11)$$

$AMSY$  applies a state-space model formulation with an annual multiplicative lognormal random process error  $\exp(\eta_t)$  and observation error  $\exp(\varepsilon_t)$  terms with  $\eta_t \sim N(0, \sigma_\eta^2)$  and  $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$ , respectively. For  $\text{cpue}$  observation error, the default  $\sigma_\varepsilon$  was set to 0.3, and for surplus production process error,  $\sigma_\eta$  was set to 0.05, 0.07, 0.1, or 0.15, depending on the productivity of the stock from very low to high. These error terms are not shown in the equations for the sake of simplicity. The chosen values are preliminary but worked well for the purpose of this proof-of-concept study.



**Figure 1.** AMSY analysis of simulated data for a stock with very low productivity and low biomass. The grey dots are a random sample of 50 000 points drawn from a multivariate distribution of  $r$  and  $k_q$  in log space. The dotted rectangle indicates the prior ranges of  $r$  and  $k_q$  and contains 95% of the random points. The black dots are “viable”  $r$ - $k_q$  pairs, with the cross indicating the most probable value with approximate 95% confidence limits. The circle indicates the “true”  $r$ - $k_q$  pair used in the simulations. In (a), no logical filters are applied and the most probable  $r$ - $k_q$  pair falls in the centre, with confidence limits about equal to the prior ranges. In (b), logical filters are applied to the selection of “viable”  $r$ - $k_q$  pairs, with a central value much closer to the true one and much narrower confidence limits, which slightly exceed the prior range.

For cases where cpue stems not from standardized surveys but from commercial fisheries and where efficiency of commercial fishing may increase with time, an effort-creep correction can be applied by AMSY based on the average percentage of increase in catching efficiency, as provided by the user:

$$\text{cpue}_{\text{corr}t} = \text{cpue}_t (1 - p)^{t-t_0}, \quad (12)$$

where  $\text{cpue}_{\text{corr}}$  is the corrected cpue,  $t$  is a year in the time series,  $p$  is the percentage of average increase of efficiency as a decimal

(e.g. 0.02 for 2%, Palomares and Pauly, 2019a), and  $t_0$  is the first year in the time series.

#### Filters used to find $r$ - $k$ pairs compatible with the provided cpue and priors

The following numerical settings or multipliers for the filters are derived from preliminary test runs against the simulated data. They were accepted as sufficient for the purpose of this presentation and proof-of-concept of AMSY and are

**Table 1.** Translation of resilience categories in FishBase or SeaLifeBase into ranges of  $r$  (year<sup>-1</sup>).

Resilience	Lower limit	Upper limit
Very low	0.015	0.1
Low	0.05	0.5
Medium	0.2	0.8
High	0.6	1.5

**Table 2.** Translation of qualitative stock size information into prior ranges of  $B/k$ .

$B/k$	Lower limit	Upper limit
Very small	0.01	0.2
Small	0.15	0.4
About half	0.35	0.65
More than half	0.5	0.85
Close to unexploited	0.75	1.0

expected to be further refined, also against real data, in subsequent research.

- (i) **Exclusion of  $r-k_q$  pairs if predicted relative catch is negative.** By definition, catch is an extraction of fish from the population and thus may become zero but not negative. Therefore, combinations of productivity and carrying capacity that, in combination with the cpue time series, predict negative relative catches in any given year can be excluded as unrealistic. However, periods of relative catches close to zero are realistic scenarios especially during recovery phases of species with low or very low resilience; during such periods, negative predictions of relative catch may result from the uncertainty and corresponding error terms used in the modelling. Therefore, during such periods, a negative relative catch of 2–6% of  $k_q$  (for low or very low productivity) is allowed by AMSY.
- (ii) **Exclusion of  $r-k_q$  pairs if predicted catch in a given year exceeds biomass.** It is unlikely that a fishery catches all fish of a stock in a given year. Thus,  $r-k_q$  pairs that, in combination with the cpue time series, predict relative catches above the available cpue appear unrealistic. However, looking at (7), the term  $r(1 - \text{cpue}/k_q)$  determines the amount of surplus production and it may exceed 1.0 if e.g.  $r > 1.2$  and  $\text{cpue}/k_q < 0.2$ , i.e. predicted annual catches may exceed biomass in species with high productivity and depleted stock size. AMSY accounts for this dependence on productivity by using empirical multipliers for the cpue value not to be exceeded by relative catch from 1.4 for high productivity to 0.25 for very low productivity. This filter is skipped if, at any point in the time series, cpue approaches zero [ $\text{cpue} < 0.1 \max(\text{cpue})$ ] because catch may exceed mean biomass under those circumstances.
- (iii) **Exclusion of  $r-k_q$  pairs if predicted catch strongly exceeds MSY.** While it is possible for fisheries to catch more than MSY for a few years, the degree of such overfishing is inversely correlated with the  $\text{MSY}/k = r/4$  ratio; in species with very low productivity, MSY is only a small fraction of carrying capacity and can be easily exceeded several fold. In

contrast, in species with high productivity, MSY is a quarter or more of carrying capacity and is unlikely to be overshoot by more than MSY. Accordingly, a multiplier for maximum predicted relative catch was set from tenfold  $\text{MSY}_q$  for very low productivity to twofold  $\text{MSY}_q$  for high productivity.

- (iv) **Exclusion of  $r-k_q$  pairs if  $F/F_{\text{MSY}}$  is negative or unrealistically high.** If the time series of  $F/F_{\text{MSY}}$  ratios predicted by AMSY contains highly unrealistic values, such as less than  $-25$  or more than  $12$ , then that combination or  $r-k_q$  with its specific error patterns is excluded from the analysis. Note that while negative  $F/F_{\text{MSY}}$  ratios require negative catches and, thus, are not possible in the real world, periods of very low or zero catches are realistic scenarios especially during recovery phases of species with low or very low resilience. Thus, during such periods, predictions of negative  $F/F_{\text{MSY}}$  ratios may result from the uncertainty and corresponding error terms used in the modelling.
- (v) **Exclusion of  $r-k_q$  pairs if modelled  $\text{cpue}/k_q$  is outside the prior  $B/k$  range.** If the relative cpue ( $\text{cpue}/k_q$ ) in the year specified for prior  $B/k$  falls outside of that prior range, then the  $r-k_q$  pair is discarded.

Note that all  $r-k_q$  pairs are tested multiple times with different random error settings for surplus production and cpue and are only excluded from further processing if all of these runs fail to pass the filters. This processing leads to a modelled cpue time series slightly different from the observed cpue, as peaks, troughs, and slopes that would lead to unrealistic catches or unrealistic productivity are smoothed.

### Finding the most likely values for $r$ , $k_q$ , $F/F_{\text{MSY}}$ , and $B/B_{\text{MSY}}$

The  $r-k_q$  pairs that passed the filters described above were considered as viable. Median values of viable  $r$  and  $k_q$  were considered to be the most likely estimates, and 2.5th and 97.5th percentiles were taken as approximate confidence limits, respectively. The time series of relative catch predicted by the viable  $r-k_q$  pairs in combination with cpue was stored, and a proxy for median  $F_t$  was obtained by dividing the median predicted catch by the median of cpue. An estimate of recent  $F/F_{\text{MSY}}$  was obtained by dividing  $F_t$  by the median estimate of  $r/2$ , with  $t$  set to the second-to-last year. Approximate 95% confidence limits were obtained similarly from the 2.5th and 97.5th percentiles of predicted catch. The time series of modelled cpue, was stored, and a proxy for recent  $B/B_{\text{MSY}}$  was derived by dividing median  $\text{cpue}_t$  by median  $k_q/2$  and setting  $t$  to the last year. Approximate 95% confidence limits were obtained similarly from the 2.5th and 97.5th percentiles of modelled cpue.

### Simulated data

To assess the performance of AMSY, simulated catch and cpue data were created so that the “true” simulated parameter values and stock status estimates were known and could be used for comparisons. For convenience,  $k_q$  was set to 1000 and  $r$  was set at 0.06, 0.25, 0.5, and 1.0 year<sup>-1</sup> to represent species with very low (VL), low (L), medium (M), and high (H) resilience, respectively (c.f. Table 1). For time series of 50 years, biomass patterns of continuously high (HH), continuously low (LL), high to low (HL), low to high (LH), low–high–low (LHL), and high–low–high

(HLH) were created. From an “above half” ( $0.5\text{--}0.85k$ ) or “small” ( $0.15\text{--}0.4k$ ) starting biomass in the first year, the desired pattern was produced by inserting high or low catches into (6) and calculating the biomass in subsequent years. These first year ranges of relative biomass were used as prior for AMSY to reduce the influence of the prior on the estimated relative biomass 50 years later. If relative biomass fell below  $0.25k_q$  in any given year, surplus production was reduced, as described in (11) to account for potentially reduced recruitment. A catchability coefficient  $q=0.001$  was assumed to turn biomass, catch, and  $k$  into the desired values of  $cpue$ ,  $C_q$ , and  $k_q$ , respectively. The simulated data and the spreadsheet used to produce them are part of the [Supplementary material](#).

### Real data

For the evaluation of AMSY estimates against real data, 140 stocks from the Northeast Atlantic, the Mediterranean, and the Black Sea were used as a subset of the 397 stocks analyzed by [Froese et al. \(2018b\)](#). Criteria for stock selection were uninterrupted time series of catch and abundance ( $cpue$ , indices, or predicted biomass) for at least 15 years. These data were then analyzed with a Bayesian implementation of the Schaefer model (BSM), which is part of the CMSY package ([Froese et al., 2017](#)). AMSY and BSM used the same  $cpue$  time series and the same priors for productivity and relative stock size in the first year of the time series, the only difference being that BSM in addition had time series of catch as input. The BSM results for the 140 stocks were also used to derive the median correlation between  $r$  and  $k_q$  in log space, as required for construction of a variance-covariance matrix (10). The data and the results of the BSM analysis are part of the [Supplementary material](#).

### First assessments of data-limited stocks

To test the usefulness of AMSY for its intended purpose, 38 data-limited stocks were analyzed first with LBB ([Froese et al., 2018a, 2019](#)) to obtain objective prior information on relative stock size from length frequencies and then with AMSY to derive estimates of  $r$ ,  $F_{MSY}$ ,  $F/F_{MSY}$ , and  $B/B_{MSY}$  from  $cpue$  data.

All of the sections in the [Supplementary material](#), data, spreadsheets, and R-code used in this study are available as [Supplementary material](#) from <http://oceanrep.geomar.de/47135/>. The version of LBB (33a) used in this study is available from <http://oceanrep.geomar.de/43182/>.

## Results

### Verification against simulated data

AMSY predictions of population dynamic parameters ( $r$ ,  $k_q$ ,  $MSY_q$ ), fishing pressure ( $F/F_{MSY}$ ), and stock status ( $B/B_{MSY}$ ) at the end of the time series were compared with the “true” values used to produce the simulated data. To better understand the influence of the priors and of the Monte Carlo filtering on the results, the simulated data were analyzed twice by AMSY, first without and then with the Monte Carlo filters described above.

Without the filters, all  $r\text{--}k_q$  pairs of the multivariate prior distribution are “viable”, the central values of predicted  $r$  and  $k_q$  are in the centre of the log space, and the respective approximate 95% confidence limits are wide and equivalent to the respective prior ranges. By design, the “true” values of  $r$  and  $k_q$  were within the prior ranges and thus fall within the approximate 95% confidence limits of the predictions. Similarly, all “true” values of

**Table 3.** Comparison of MARE and MRLCL of the predictions for 24 AMSY runs without and with Monte Carlo filtering, where  $est$  = estimated value,  $true$  = true value used in the simulation, and  $lcl$  = lower approximate 95% confidence limit of the estimate (AMSYSimNoFil\_5.xls and AMSYSimFil\_7.xls).

Estimate	Without filters		With filters	
	MARE	MRLCL	MARE	MRLCL
$r$	0.28	0.55	0.07	0.36
$k_q$	0.09	0.24	0.10	0.18
$F/F_{MSY}$	0.45	1.42	0.20	0.89
$B/B_{MSY}$	0.08	0.44	0.10	0.44

$MSY_q$ ,  $F/F_{MSY}$ , and  $B/B_{MSY}$  fall within the approximate 95% confidence limits of the respective estimates.

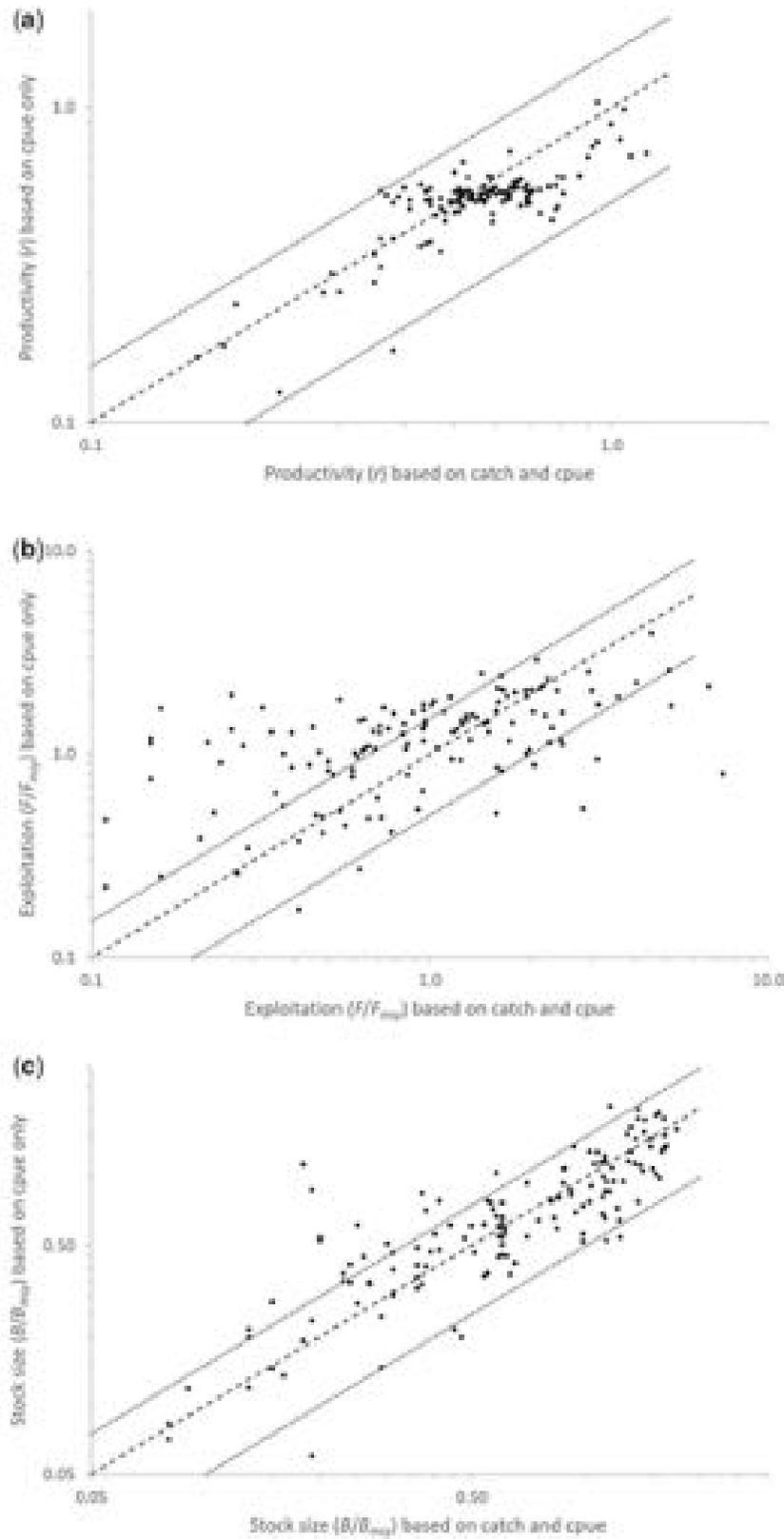
With Monte Carlo filtering, numerous  $r\text{--}k_q$  pairs are excluded because of unrealistic predictions, and consequently the estimated central values of  $r$  and  $k_q$  may move away from the centre of the prior log space and their approximate 95% confidence limits get narrower and may exceed the original prior bounds (see [Figure 1](#) and more examples in Section 2 of the [Supplementary material](#)). With one exception (estimate of  $k_q$  in LHL\_VL, see Section 2 of the [Supplementary material](#)), “true” values of all parameters still fall within the narrower approximate 95% confidence limits. [Table 3](#) shows a comparison of median absolute relative error [ $MARE = \text{abs}(\text{true} - \text{estimate})/\text{true}$ ] and of median relative lower confidence limits [ $MRLCL = (\text{estimate} - \text{lcl})/\text{estimate}$ ] for 24 AMSY runs without and with Monte Carlo filtering. In the runs with filters, MAREs are substantially reduced for  $r$  and  $F/F_{MSY}$  and only slightly increased for  $k_q$  and  $B/B_{MSY}$  and MRLCLs are substantially reduced for all estimates except  $B/B_{MSY}$ .

### Evaluation against real data

AMSY predictions for 140 real stocks were compared with those of a Bayesian implementation of a regular Schaefer model (BSM). AMSY estimates of  $r$  were similar to those of BSM ([Figure 2](#)), with 128 (91.4%) BSM estimates included in the approximate 95% confidence limits of AMSY. AMSY predictions of relative biomass ( $B/B_{MSY}$ ) in the last year included the BSM estimate in their approximate 95% confidence limits in 122 stocks (87.1%). AMSY predictions of exploitation ( $F/F_{MSY}$ ) included the BSM estimate in their approximate 95% confidence limits in 123 stocks (87.9%). Note, however, that AMSY confidence limits for  $F/F_{MSY}$  estimates were often wide. The median ratios of AMSY vs. BSM predictions for  $r$  (0.92), final  $F/F_{MSY}$  (1.16), and final  $B/B_{MSY}$  (0.99) were used to summarize deviations and detect potential biases. Thus, AMSY predictions were, on average, 8% lower for  $r$ , 16% higher for  $F/F_{MSY}$ , and 1% lower for  $B/B_{MSY}$ . Note that these are not entirely fair comparisons because catchability  $q$  is not estimated by AMSY, and this may cause part of the observed deviations. A spreadsheet (EU\_StocksResults\_2.xls) with the detailed results for every stock is part of the [Supplementary material](#).

### Application to data-limited stocks

Application of AMSY to data-limited stocks without reliable catch data produced the first MSY-level assessments for 38 stocks of mostly bycatch species ([Table 4](#)). This includes 23 species for which these are the first assessments globally (marked bold



**Figure 2.** Comparison of (a) maximum productivity  $r$ , (b) exploitation in the last but one year  $F/F_{MSY}$ , and (c) relative stock size in the last year ( $B/B_{MSY}$ ) between estimates of BSM (x-axis) based on catch and cpue and AMSY (y-axis) based on cpue only for 140 real stocks. The dashed lines indicate identical predictions, and the dotted lines indicate deviations of  $\pm 50\%$  (EU\_StocksResults\_3.xls).

**Table 4.** Exploitation and stock status relative to MSY levels ( $F/F_{MSY}$ ,  $B/B_{MSY}$ ) for 38 stocks comprising 35 species.

Region	Stock	Species	Name	Years	$F/F_{MSY}$	$B/B_{MSY}$
Adriatic Sea	Ille_coi_AD	<i>Illex coindetii</i>	Shortfin squid	2001–2017	0.67/0.07–1.71	1.14/0.64–2.05
	Micr_pou_AD	<i>Micromesistius poutassou</i>	Blue whiting	1994–2017	1.53/0.51–2.84	0.73/0.40–1.32
	Octo_vul_AD	<i>Octopus vulgaris</i>	Common octopus	1995–2017	0.94/0.29–1.74	1.01/0.56–1.81
Aegean Sea	ANN_GSA22 DIPLANN	<i>Diplodus annularis</i>	Annular seabream	1994–2016	0.89/0.11–2.38	0.23/0.13–0.42
	BOC_GSA22 CAPO.APE	<i>Capros aper</i>	Boarfish	1994–2016	1.30/0.21–2.90	0.61/0.34–1.09
	BRF_GSA22 HELI.DAC	<i>Helicolenus dactylopterus</i>	Blackbelly rosefish	1994–2016	0.76/0.07–1.88	1.14/0.63–2.15
	CIL_GSA22 CITHMAC_AEGEAN	<b><i>Citharus linguatula</i></b>	Spotted flounder	1994–2016	1.55/0.31–3.36	0.45/0.25–0.80
	HYS_GSA22HYMEITA_AEGEAN	<b><i>Hymenocephalus italicus</i></b>	Glasshead grenadier	1994–2016	1.07/0.11–3.05	0.26/0.15–0.47
	SNQ_GSA22SCORNOT_AEGEAN	<b><i>Scorpaena notata</i></b>	Small red scorpionfish	1994–2016	1.68/0.26–4.03	0.23/0.13–0.41
Cyprus	MERL_MER_CY	<i>Merluccius merluccius</i>	European hake	2005–2017	0.79/0.07–2.35	0.22/0.15–0.33
	SEPIOFF_CY	<i>Sepia officinalis</i>	Common cuttlefish	2005–2017	0.58/0.04–1.57	1.26/0.71–2.27
North Sea	Agonus cataphractus	<b><i>Agonus cataphractus</i></b>	Hooknose	1983–2017	1.90/0.59–3.68	0.49/0.27–0.86
	Amblyraja radiata	<b><i>Amblyraja radiata</i></b>	Starry ray	1983–2017	1.04/–0.84–3.99	0.21/0.12–0.39
	Buglossidium luteum	<b><i>Buglossidium luteum</i></b>	Solenette	1983–2017	2.16/0.69–4.09	0.42/0.23–0.76
	Callionymus lyra	<b><i>Callionymus lyra</i></b>	Dragonet	1983–2017	1.12/0.12–3.15	0.31/0.17–0.56
	Callionymus maculatus	<b><i>Callionymus maculatus</i></b>	Spotted dragonet	1983–2017	1.23/0.19–2.71	0.79/0.44–1.43
	Chelidonichthys cuculus	<b><i>Chelidonichthys cuculus</i></b>	Red gurnard	1984–2017	0.86/0.13–1.88	1.09/0.61–1.94
	Echiichthys vipera	<b><i>Echiichthys vipera</i></b>	Lesser weever	1983–2017	1.46/0.27–3.03	0.60/0.33–1.06
	Enchelyopus cimbrius	<b><i>Enchelyopus cimbrius</i></b>	Fourbeard rockling	1983–2017	1.91/0.45–4.29	0.25/0.14–0.46
	Lumpenus lampretaeformis	<b><i>Lumpenus lampretaeformis</i></b>	Snake blenny	1983–2017	1.19/0.14–2.88	0.45/0.25–0.82
	Lycodes vahlii	<b><i>Lycodes vahlii</i></b>	Vahl's eelpout	1983–2017	2.36/0.81–4.64	0.23/0.13–0.43
	Myoxocephalus scorpius	<b><i>Myoxocephalus scorpius</i></b>	Shorthorn sculpin	1983–2017	1.93/0.61–3.63	0.52/0.29–0.91
	Myxine glutinosa	<b><i>Myxine glutinosa</i></b>	Atlantic hagfish	1991–2017	1.16/–0.32–3.50	0.70/0.38–1.25
	rjc.27.3a47d	<i>Raja clavata</i>	Thornback ray	1983–2017	0.68/–0.20–2.36	1.25/0.70–2.25
	rjm.27.3a47d	<i>Raja montagui</i>	Spotted ray	1983–2017	1.26/–0.05–3.10	0.92/0.51–1.62
	syc.27.3a47d	<i>Scylliorhinus canicula</i>	Lesser spotted dogfish	1983–2017	0.83/–0.09–2.41	1.11/0.60–2.01
Baltic Sea	Trisopterus luscus	<b><i>Trisopterus luscus</i></b>	Pouting	1983–2017	1.80/0.46–3.83	0.32/0.18–0.58
	Ench_cim22-24	<b><i>Enchelyopus cimbrius</i></b>	Fourbeard rockling	1991–2018	2.43/1.01–4.38	0.29/0.16–0.52
	Eut_gurn_Balt	<i>Eutrigla gurnardus</i>	Grey gurnard	2002–2018	0.88/0.10–2.25	0.67/0.37–1.22
	Myox_scor_22-24	<b><i>Myoxocephalus scorpius</i></b>	Shorthorn sculpin	2000–2017	2.64/1.10–4.87	0.27/0.15–0.48
Northwest Atlantic	Zoar_vivi_Balt	<b><i>Zoarces viviparus</i></b>	Eelpout	1999–2018	5.80/2.89–10.6	0.03/0.01–0.05
	Little skate Eastern Canada	<b><i>Leucoraja erinacea</i></b>	Little skate	1970–2018	1.05/–0.62–4.05	0.35/0.19–0.62
	Smooth skate Laurentian Scotian	<b><i>Malacoraja senta</i></b>	Smooth skate	1970–2018	1.51/–0.32–4.20	0.37/0.21–0.67
South Africa	HELDAC	<i>Helicolenus dactylopterus</i>	Jacopever	1987–2017	0.84/0.07–2.53	0.15/0.08–0.27
	PNSK	<b><i>Cymatoceps nasutus</i></b>	Black musselcracker	1987–2017	0.73/–0.25–2.62	1.08/0.60–1.95
	STKB	<b><i>Argyrosomus thorpei</i></b>	Squaretail kob	1987–2017	1.00/0.12–2.70	0.26/0.15–0.47
	TBSK	<b><i>Raja straeleni</i></b>	Biscuit skate	1991–2017	1.60/–0.41–4.78	0.31/0.17–0.56
	WSTM	<b><i>Rhabdosargus globiceps</i></b>	White stumpnose	1987–2016	0.89/0.11–2.03	1.03/0.57–1.85

For 23 of these species (marked bold), this is the first stock assessment globally. Results are arranged alphabetically by stock identifier within regions [AMSY\_68y.R, Appendix 3].

in Table 4). The details of these assessments are presented in Section 3 of the [Supplementary material](#). We found overall very good agreement of predicted relative biomass trends between LBB (Froese et al., 2018a, 2019) based on length frequencies and AMSY based on cpue. There is also general good agreement between current and retrospective analyses, i.e. AMSY runs where data from the last 1, 2, or 3 years were omitted from the analyses. In two North Sea stocks (syc.27.3a47d, rjc.27.3a47d), the retrospective analysis indicated a substantial deviation of predicted relative biomass estimates ( $B/B_{MSY}$ ) if the respective last years were included because these years suggested a strong increase in biomass. These increases were accepted for the purpose of this study but may turn out to be fluctuations once data for the subsequent years become available.

Predictions of exploitation ( $F/F_{MSY}$ ) in the second-to-last year indicate that 24 stocks (63%) were subject to overfishing, but note the wide margins of uncertainty. Predictions of relative biomass ( $B/B_{MSY}$ ) in the last year indicate that only 9 stocks (24%) were above the biomass level required by UNCLOS (1982) and 21 stocks (55%) were smaller than half of that level, suggesting that successful reproduction may be endangered. Margins of uncertainty for relative biomass are mostly less than 50% with regard to the relevant lower confidence limit (Figure 2c) and, thus, similar to assessments with more input data.

## Discussion

### Choice of Schaefer vs. Fox or Pella–Tomlinson

Several types of surplus production models are used in fisheries, with Schaefer (1954), Fox (1970), and Pella and Tomlinson

(1969) being the most common. Of these three, only the Schaefer model is derived from ecological principles, implementing the sigmoid population growth that has been observed in many animal populations (Hjort *et al.*, 1933; Graham, 1939; Hairston *et al.*, 1970; Smith, 1994; Yoshinaga *et al.*, 2001). The Fox model is a logarithmic transformation of the Schaefer model, resulting in MSY being obtained at 37% of carrying capacity rather than at 50%, as in the Schaefer model. This results in the Fox model predicting higher equilibrium yields for a given biomass at small stock sizes, implying that the Schaefer model is more precautionary in the proposed biomass necessary for producing MSY and in the sustainable catch that a given biomass can support (Cadima, 2003; Figure A1 in Appendix 1 of Froese *et al.*, 2011; Tsikliras and Froese, 2019). The Pella–Tomlinson model is a mathematical generalization introducing a shape parameter  $p$  for the sigmoid curve, corresponding to the Schaefer model if  $p=1$  and to the Fox model if  $p$  approaches zero (Pella and Tomlinson, 1969; Cadima, 2003), or with a shape parameter defined as  $m$ , such that  $m=2$  for the Schaefer model and  $m$  approaching 1 for the Fox model in later implementations (e.g. Pedersen and Berg, 2017; Winker *et al.*, 2018). Beverton and Holt (1957) have shown that the biomass that can produce MSY is actually a function of fishing pressure and selectivity, reaching about half of the unexploited stock size if  $F$  is close to natural mortality  $M$  and length at first capture is close to the optimum length (see Figure 2b in Froese *et al.*, 2016b). For AMSY, the Schaefer (1954) model was chosen over the Fox (1970) model to err on the precautionary side and over the Pella and Tomlinson (1969) model to avoid estimation of a third parameter in a data-poor situation.

### Performance of AMSY

The key point of this study is to explore whether a model that only has a time series of cpue as input can produce similar results vs. a model that, in addition, has a time series of catch data as input, everything else being equal. AMSY uses cpue data combined with independent prior knowledge about the resilience or productivity of the species and prior perceptions or estimates of stock status for the year with the best available estimate. It applies surplus production modelling with randomly selected parameters for  $r$  and  $k_q$  to predict catches that are compatible with the cpue time series and the priors. AMSY aims to improve the precision and plausibility of stock status estimates by applying a set of filters to exclude  $r$ – $k_q$  pairs that result in, e.g. negative catches or unrealistic exploitation values.

To better understand the respective influence of the priors and the filters on the results, AMSY was run against simulated data with and without filters. If no filters were used, the priors determined the central  $r$ – $k_q$  values with 95% confidence limits about equal to the prior ranges and with already reasonable fits of predicted vs. “true” time series of relative catch and stock size, albeit with wide margins of uncertainty (Figure 1a). The addition of the filters moved the estimates of  $r$  and  $k_q$  closer to the “true” values and reduced the confidence limits for all estimates except  $B/B_{MSY}$ , which remained about unchanged (Table 3).

In other words, if the relationship between abundance and catch follows the logic of a surplus production model and if the priors for productivity and relative stock size include the “true” values, then AMSY predictions of  $r$ ,  $F/F_{MSY}$ , and  $B/B_{MSY}$  are not much different from the “true” values in simulated data covering

a wide range of productivity and relative stock size. The question then is how well these assumptions are met in real-world data.

For this purpose, 140 European stocks from the Barents Sea to the Black Sea and including invertebrates from shrimp to octopus and fish from anchovy to halibut (see EU\_Stocks\_ID\_8.csv in the Supplementary material) were analyzed with a Bayesian implementation of a full Schaefer model (BSM) with time series of catch and cpue as input and with AMSY with only cpue as input. Both models used the same priors for productivity and relative stock size at the beginning of the time series.

Results from both models showed good agreement for  $r$ ,  $F/F_{MSY}$ , and  $B/B_{MSY}$ , with more than 87% of the BSM central estimates included in the approximate 95% confidence limits of the AMSY estimates. AMSY predictions for relative exploitation ( $F/F_{MSY}$ ) in the penultimate year had, however, wide margins of uncertainty and thus deviations in predictions could be substantial. Note also that BSM estimates are not free of error and some of the largest differences were found where the filters applied by AMSY prevented it from predicting extreme values of exploitation (compare Figure 2).

Application of AMSY to selected data-poor stocks from the North Atlantic, Mediterranean, and South Africa provided the first MSY-level assessments of exploitation and stock status for 38 stocks and 35 species (Table 4). The stocks were chosen because they had no previous MSY-level assessments and no reliable or no catch data but length frequencies as well as cpue data available. The species range from bycatch, such as eelpout (*Zoarces viviparus*) in the Baltic, to commercially important species such as common octopus (*Octopus vulgaris*) in the Adriatic Sea. Note that for all these stocks, objective prior information on relative biomass depletion was provided from the analysis of length frequency data (LBB, Froese *et al.*, 2018a, 2019). The wide margins of uncertainty for predictions of relative exploitation ( $F/F_{MSY}$ , Table 4) are not surprising, given that no information on catch was available for these stocks. Therefore, these predictions of exploitation should be used with caution. In contrast, the margins of uncertainty for predictions of relative stock size are within usual ranges and, therefore, are suitable for management advice. With few exceptions, the predicted relative biomass  $B/B_{MSY}$  was below the level that can produce MSY, and about half of the stocks were so small that successful reproduction may be endangered. While the selection of stocks was not random and was, therefore, not representative of non-assessed species in general, the results underline the need for MSY-level assessments and management of data-poor stocks.

### Properties and assumptions of AMSY

The Schaefer (1954) surplus production function used by AMSY captures with only two parameters the interplay among somatic growth, reproduction, and natural mortality. AMSY is implemented within a state-space modelling framework (Meyer and Millar, 1999; Froese *et al.*, 2017; Winker *et al.*, 2018) to account for process error due to the real-world variability in size structure, species interactions, natural mortality and recruitment, and observation error resulting from sampling error and variations in catchability. This allows the predicted biomass trajectories to deviate from the deterministic expectations resulting from (6) and (7), while keeping the trajectories within plausible biological limits through the use of the productivity prior, the associated process variance, and the filters imposed to identify viable  $r$ – $k$  pairs.

This means that the time series pattern of the predicted relative abundance ( $B/B_{MSY}$ ) may differ from the pattern of the cpue provided as input to the model, within the bounds determined by the error terms for process and observation, which can be set by the user.

AMSY assumes that there is a direct proportionality between cpue and exploited biomass. However, catch rates in commercial and survey fisheries may be influenced by factors such as fishing vessel type, where and when fishing occurred, gear used, depth of fishing, and whether fishing occurred during day or night. There are also cases of reduced catch rates because of depredation, e.g. on longlines by various predators (Söffker *et al.*, 2015) or because of predator avoidance behaviour by fishers shifting into less optimal cpue areas (Haddon, 2018). Management regulations such as size and catch limits or closed areas and seasons may also impact cpue. These factors, and any changes therein over time, may obscure the interannual changes in cpue resulting from changes in stock size, which are the focus of AMSY (e.g. Sporic and Haddon, 2018).

As shown with the simulated data, predictions of AMSY come with high margins of uncertainty in stocks with very low resilience and periods of very low exploitation. Also, predictions of exploitation ( $F/F_{MSY}$ ) come with wide margins of uncertainty and may be especially misleading during phases of low exploitation (Figure 2b).

When deriving management advice from cpue, it is important to consider situations where the cpue may be significantly biased, potentially resulting in biased advice. One such bias is the continuing increase in the efficiency of fishers to catch a certain species. This is often a combination of an increase in experience about when and where target species are likely to be found and an improvement in technology ranging from more efficient navigation (GPS, autopilots) to more efficient sonars to more efficient gear. Palomares and Pauly (2019b), based on a comprehensive review of published cases, found this “effort creep” to increase efficiency in commercial fisheries by 1–5% per year, with 2% per year being a reasonable assumption if no better information is available. AMSY provides a correction for commercial cpue depending on the percentage value provided by the user (12). Cpue from standardized surveys should not be affected by this.

Another potential bias in commercial cpue data is known as “hyperstability”, where cpue remains stable while abundance is declining, leading to the overestimation of biomass and underestimation of fishing mortality (Quinn and Deriso, 1999; Harley *et al.*, 2001). This may be caused by a fishery expanding into previously less-fished areas or depth zones (Morato *et al.*, 2006; Kleisner *et al.*, 2014) with the new catches masking the overall decline. It may also be caused by aggregating behaviour of the target species, when the centre of the aggregation is fished primarily and the density there remains high even if overall density is declining, as occurred prior to the collapse of northern cod (*Gadus morhua*) in Canada (Hutchings, 1996), or when the spawning aggregations typical of some tropical species are exploited (see Sadovy de Mitcheson *et al.*, 2008 and www.scrfa.org). In contrast, “hyperdepletion” (Quinn and Deriso, 1999) describes a situation where cpue declines faster than overall stock abundance. This occurred, for example, at the onset of some tuna fisheries, where fishers targeted rapidly declining accumulations of old tuna, but whose biomass was not representative of the entire, more resilient population (Ahrens and Walters, 2005). While “hyperdepletion” will lead to overly pessimistic assessment of stock status, the

damage would be limited as fish not caught because of too conservative exploitation will increase the remaining biomass and future catches (Froese *et al.*, 2016b). Cpue from standardized surveys should not be affected by either “hyperstability” or “hyperdepletion”.

## Conclusion

The purpose of this study was to explore whether a standard population dynamics model can approximate regular predictions if given only one instead of two time series of input data, everything else (base model and priors) being equal. This is shown to be the case. The question then is the availability of independent reasonable priors. For productivity, this is solved through online databases, which offer such priors for practically all commercially important species based either on previous stock assessments or on life history traits. The priors on relative stock size can be derived either from expert knowledge or better from typically available independent data such as length frequencies, as shown here for 38 data-limited stocks.

Summarizing the results of this proof-of-concept study, AMSY seems to be well suited for estimating productivity  $r$  and, thus,  $F_{MSY} = (1/2)r$  as well as relative stock size  $B/B_{MSY}$ . Estimates of relative exploitation  $F/F_{MSY}$  may come with wide margins of uncertainty and may be less suitable for management, especially at low levels of exploitation. As a first application of AMSY, the first MSY-level stock assessments are presented for 38 data-poor stocks for which no reliable catch data are available.

## Supplementary data

Supplementary material is available at the ICESJMS online version of the manuscript.

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## **Supplementary material: ICES Journal of Marine Science, 76**

### **Estimating stock status from relative abundance and resilience**

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This Supplementary material, which is also available from <http://oceanrep.geomar.de/47135/>), contains three sections:

- (1) Application of AMSY to 24 simulated stocks without filters (pp. 2–27)
- (2) Application of AMSY to 24 simulated stocks with filters (pp. 28–53)
- (3) Application of AMSY to 38 data-poor stocks (pp. 54–168)
  - a) Adriatic Sea (pp. 55–63)
  - b) Aegean Sea (pp. 64–81)
  - c) Cyprus (pp. 82–87)
  - d) North Sea (pp. 88–135)
  - e) Baltic Sea (pp. 136–147)
  - f) Northwest Atlantic (pp. 148–153)
  - g) South Africa (pp. 154–168)

1. **Results of analysis of simulated data without filters with AMSY\_68v.R (29 October 2019)**

**Table 1.** Comparison of estimated and “true” parameter values ( $r$ ,  $k_q$ ,  $F/F_{msy}$  and  $B/B_{msy}$ ) for 24 simulated stocks. The target value for estimated relative to true value is one. The approximate lower confidence range as fraction of the estimated central value [(est-cl)/est] is an indication of the uncertainty about the estimate. Column 2 shows the median across the 24 simulated stocks. Columns 3 and 4 show the range that includes 95% of the estimated values. Note that this run of AMSY did not filter the potential  $r$ - $k$  pairs, thus making the estimates of  $r$  and  $k_q$  fully depended on and basically equal to the prior ranges for  $r$  and  $k_q$ , as is evident in the graphs displayed below. Source: AMSYResSimNoFilOctober292019\_4.xls

	<b>Median</b>	<b>2.5<sup>th</sup> percentile</b>	<b>97.5<sup>th</sup> percentile</b>
$r$ : est/true	0.72	0.62	0.97
$r$ : (est—lcl)/est	0.55	0.36	0.68
$k_q$ : est /true	1.08	0.82	1.42
$k_q$ : (est—lcl)/est	0.24	0.19	0.43
$F/F_{msy}$ : est/true	1.45	0.96	5.41
$F/F_{msy}$ : (est—lcl)/est	1.42	0.64	5.41
$B/B_{msy}$ : est/true	0.94	0.81	1.19
$B/B_{msy}$ : (est—lcl)/est	0.44	0.44	0.45

Settings for analysis in R-code:

```
#-----  
# Required settings, File names  
#-----  
id_file   <- "SimCPUE_ID_8.csv"  
  
#-----  
# General settings for the analysis ----  
#-----  
smooth.cpue <- T  
filter      <- FALSE  
cor.rk      <- -0.607  
sigma.r     <- c(0.05,0.07,0.1,0.15)  
sigma.cpue  <- 0.3  
n.p         <- 50000  
n.trial     <- 30  
min.viable  <- 20  
max.viable  <- 20000  
creep.graph <- F  
do.plots    <- T  
write.output <- T  
kobe.plot   <- F  
save.plots  <- F  
close.plots <- F  
retros      <- F
```

**Generic legend for the subsequent graphs:**

Panel (a) shows the time series of CPUE data as bold curve, a smoothed version of CPUE as thin dotted line, the prior range for  $kq$  as vertical blue line, and the corresponding upper and lower bounds of the relative  $B_{msy}$  range as dotted horizontal lines.

Panel (b) shows the  $r$ - $kq$  prior space in log scale with a cloud of gray points representing the multivariate log-normal distribution of  $r$  and  $kq$  corresponding to a correlation of  $-0.607$ , derived from full Schaefer models applied to 140 real stocks. The dotted rectangle indicates the prior ranges for  $r$  and  $kq$  and includes 85% of the gray dots. The red cross indicates the estimated central  $r$ - $kq$  pair and the approximate 95% confidence limits. The blue circle indicates the “true”  $r$ - $kq$  pair used in the simulation.

Panel (c) is a zoom-in on the viable  $r$ - $kq$  pairs, with the red cross indicating the estimated central  $r$ - $kq$  pair and its approximate 95% confidence limits and the blue circle indicating the “true”  $r$ - $kq$  pair used in the simulation.

Panel (d) shows the time series of catch predicted by AMSY as bold curve relative to  $MSY$ , indicated by the dashed horizontal line. The dotted curves indicate the approximate 95% confidence limits. The blue curve shows the “true” catch used in the simulations.

Panel (e) shows the predicted time series of  $F$  over  $F_{msy}$  as bold curve with dotted curves indicating the approximate 95% confidence limits. The dashed horizontal line indicates  $F_{msy}$ .

Panel (f) shows the predicted time series of  $B$  over  $B_{msy}$  as bold curve with dotted curves indicating the approximate 95% confidence limits. The dashed horizontal line indicates  $B_{msy}$ , the dotted lines indicate the approximate 95% confidence limits of  $B_{msy}$ , and the dashed red line indicates half of  $B_{msy}$ . The blue curve shows the “true” biomass used in the simulations relative to the “true” value of  $B_{msy}$ , indicated by a blue dashed line.

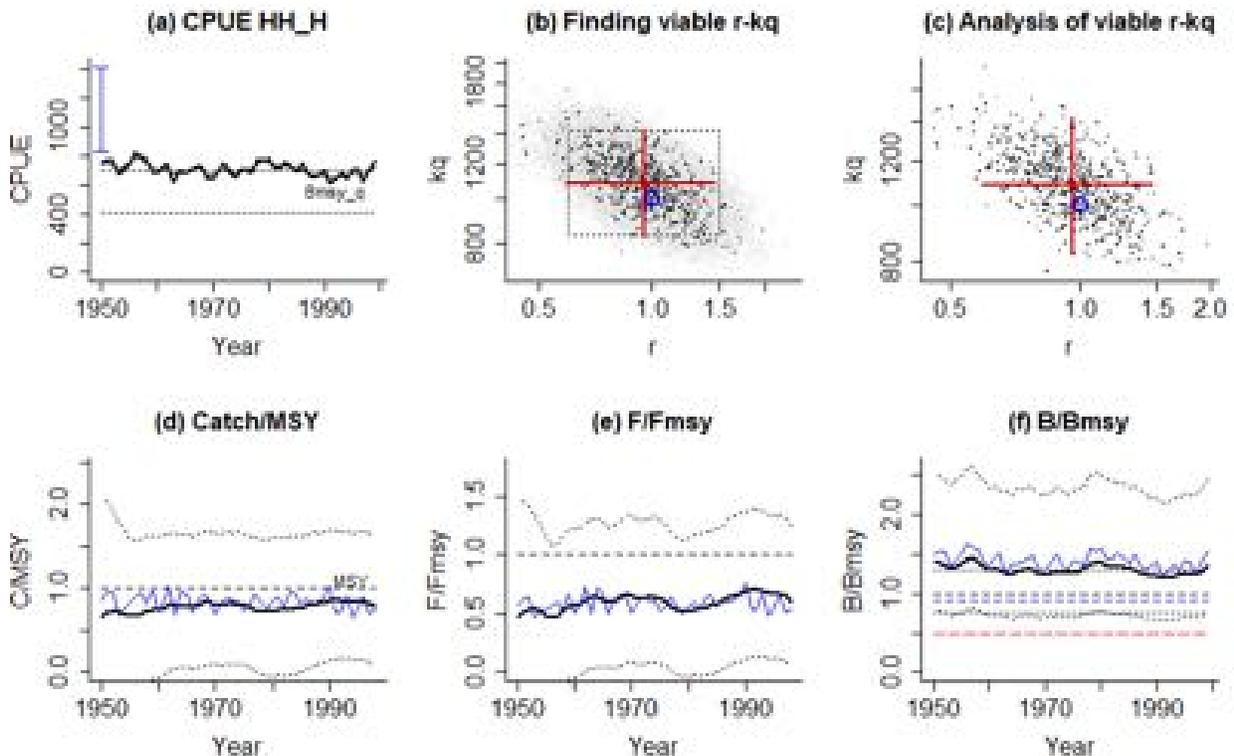
File SimCPUE\_ID\_8.csv read successfully

-----  
AMSY Analysis, Tue Oct 29 17:49:52 2019  
-----

Stock **HH\_H**, , Simulated data  
CPUE data for years 1950 - 1999, CPUE range 656 - 789, smooth = TRUE  
Prior for  $r$  = High, NA - NA  
Used prior range for  $r$  = 0.6 - 1.5  
Prior for 1950 stock status = More than half, NA - NA  
Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
Used prior range for  $kq$  = 832 - 1415 [original range = 832 - 1415]  
Comment: True  $r=1.0$ , true  $kq=1000$ , true  $MSYq=250$

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 20010

Results:  
viable  $r$ - $kq$  pairs = 20010  
median  $kq$  = 1088, 825 - 1424  
median  $MSYq$  = 260, 178 - 374  
 $r$  (4  $MSYq/kq$ ) = 0.955, 0.588 - 1.47  
 $Fmsy$  ( $r/2$ ) = 0.478, 0.294 - 0.734  
 $F/Fmsy$  = 0.602, 0.0529 - 1.25 (1998), true: 0.539  
 $B/Bmsy$  = 1.36, 0.753 - 2.46 (1999), true: 1.54  
-----

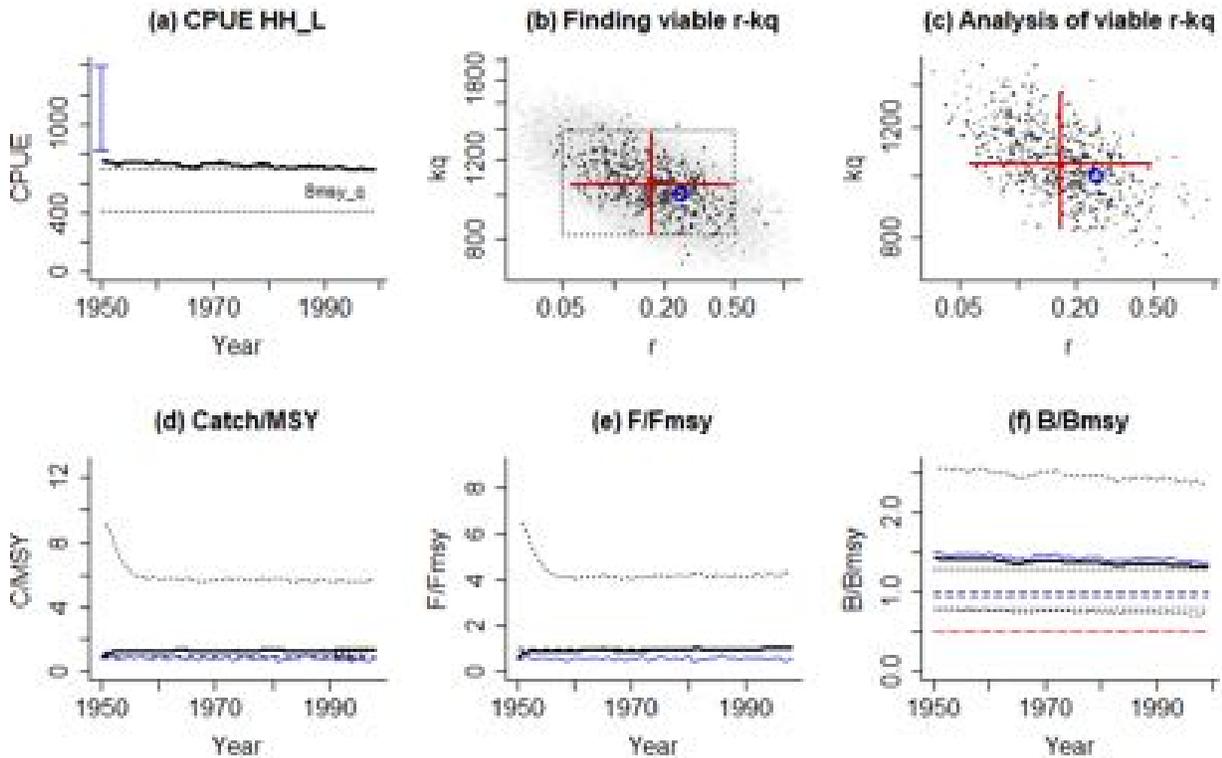


Stock **HH\_L**, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 691 - 747, smooth = TRUE  
 Prior for  $r$  = Low, NA - NA  
 Used prior range for  $r$  = 0.05 - 0.5  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for  $kq$  = 820 - 1394 [original range = 820 - 1394]  
 Comment: True  $r=0.25$ , true  $kq=1000$ , true  $MSYq=62.5$

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
 Viable  $r$ - $kq$  pairs = 20010

Results:

viable  $r$ - $kq$  pairs = 20010  
 median  $kq$  = 1050, 827 - 1366  
 median  $MSYq$  = 43.7, 16.9 - 110  
 $r$  (4  $MSYq/kq$ ) = 0.167, 0.0564 - 0.484  
 $F_{msy}$  ( $r/2$ ) = 0.0833, 0.0282 - 0.242  
 $F/F_{msy}$  = 1.03, -1.49 - 4.26 (1998), true: 0.577  
 $B/B_{msy}$  = 1.32, 0.737 - 2.37 (1999), true: 1.38

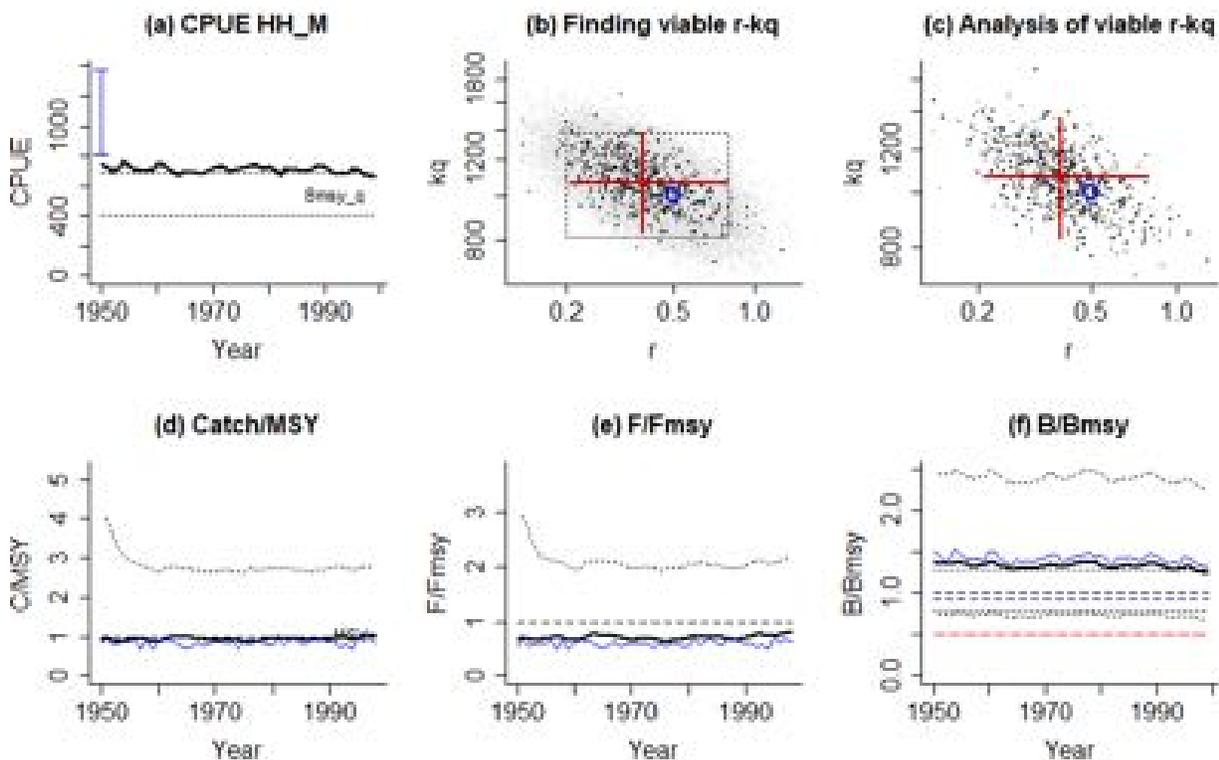


Stock HH\_M, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 665 - 737, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 809 - 1375 [original range = 809 - 1375]  
 Comment: True r=0.5, true kq=1000, true MSYq=125, true q=0.001

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

viable r-kq pairs = 20010  
 median kq = 1066, 830 - 1365  
 median MSYq = 103, 60.6 - 177  
 r (4 MSYq/kq) = 0.387, 0.206 - 0.779  
 Fmsy (r/2) = 0.193, 0.103 - 0.389  
 F/Fmsy = 0.819, -0.303 - 2.18 (1998), true: 0.623  
 B/Bmsy = 1.24, 0.691 - 2.22 (1999), true: 1.32

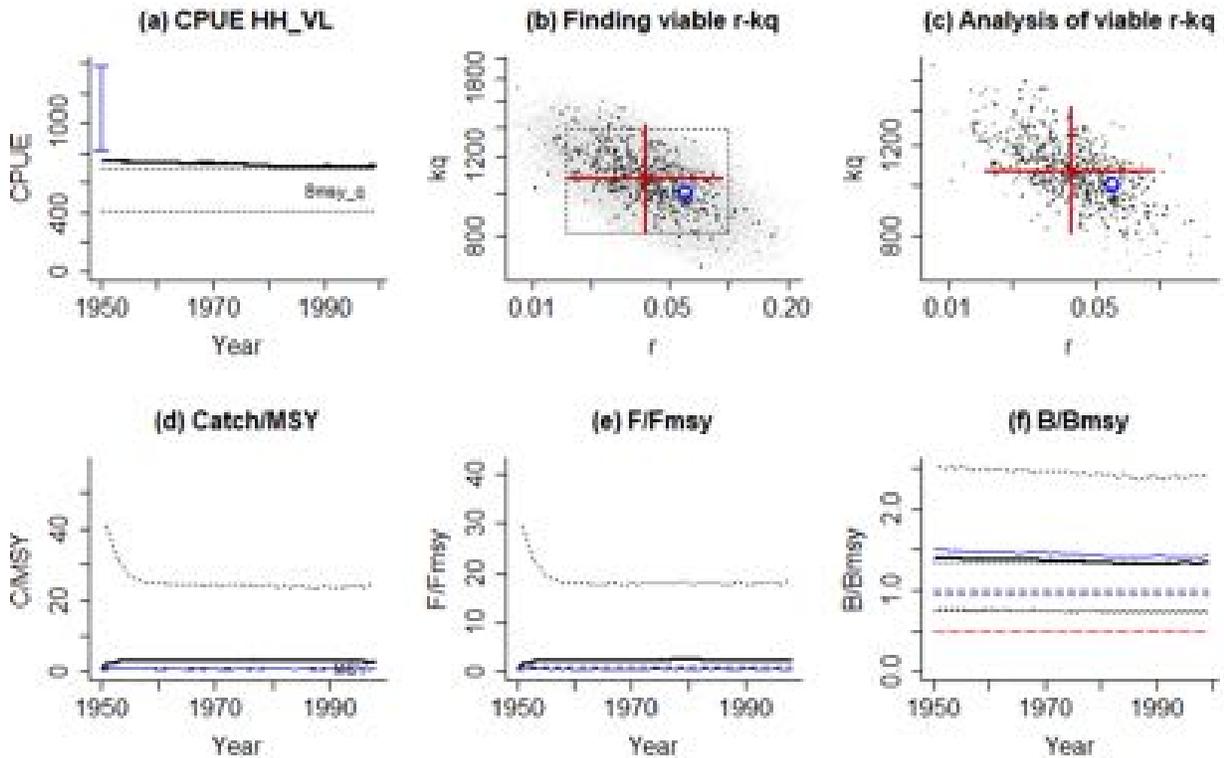


Stock **HH\_VL**, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 708 - 742, smooth = TRUE  
 Prior for  $r$  = Very low, NA - NA  
 Used prior range for  $r$  = 0.015 - 0.1  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior  $B/B_0$  range = 0.5 - 0.85, prior  $B/B_{msy}$  = 1 - 1.7  
 Used prior range for  $kq$  = 814 - 1385 [original range = 814 - 1385]  
 Comment: True  $r=0.06$ , true  $kq=1000$ , true  $MSYq=15$

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
 Viable  $r$ - $kq$  pairs = 20010

Results:

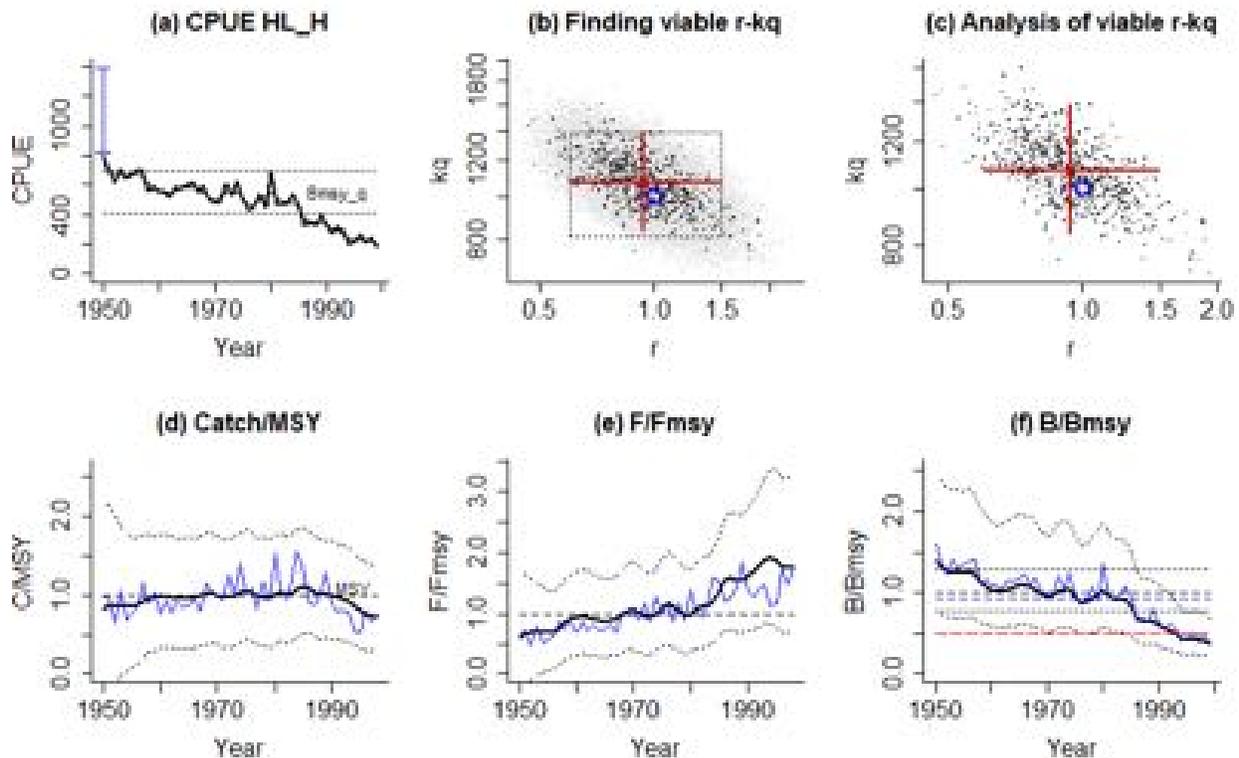
viable  $r$ - $kq$  pairs = 20010  
 median  $kq$  = 1066, 814 - 1417  
 median  $MSYq$  = 10.2, 4.51 - 21.7  
 $r$  (4  $MSYq/kq$ ) = 0.0381, 0.0148 - 0.0936  
 $F_{msy}$  ( $r/2$ ) = 0.0191, 0.0074 - 0.0468  
 $F/F_{msy}$  = 2.31, -8.75 - 18 (1998), true: 0.612  
 $B/B_{msy}$  = 1.33, 0.737 - 2.4 (1999), true: 1.42



Stock HL\_H, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 204 - 745, smooth = TRUE  
 Prior for r = High, NA - NA  
 Used prior range for r = 0.6 - 1.5  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 818 - 1390 [original range = 818 - 1390]  
 Comment: True r=1.0, true kq=1000, true MSYq=250

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:  
 viable r-kq pairs = 20010  
 median kq = 1070, 838 - 1387  
 median MSYq = 251, 175 - 359  
 r (4 MSYq/kq) = 0.938, 0.599 - 1.49  
 Fmsy (r/2) = 0.469, 0.3 - 0.743  
 F/Fmsy = 1.77, 0.687 - 3.32 (1998), true: 1.75  
 B/Bmsy = 0.382, 0.212 - 0.691 (1999), true: 0.36

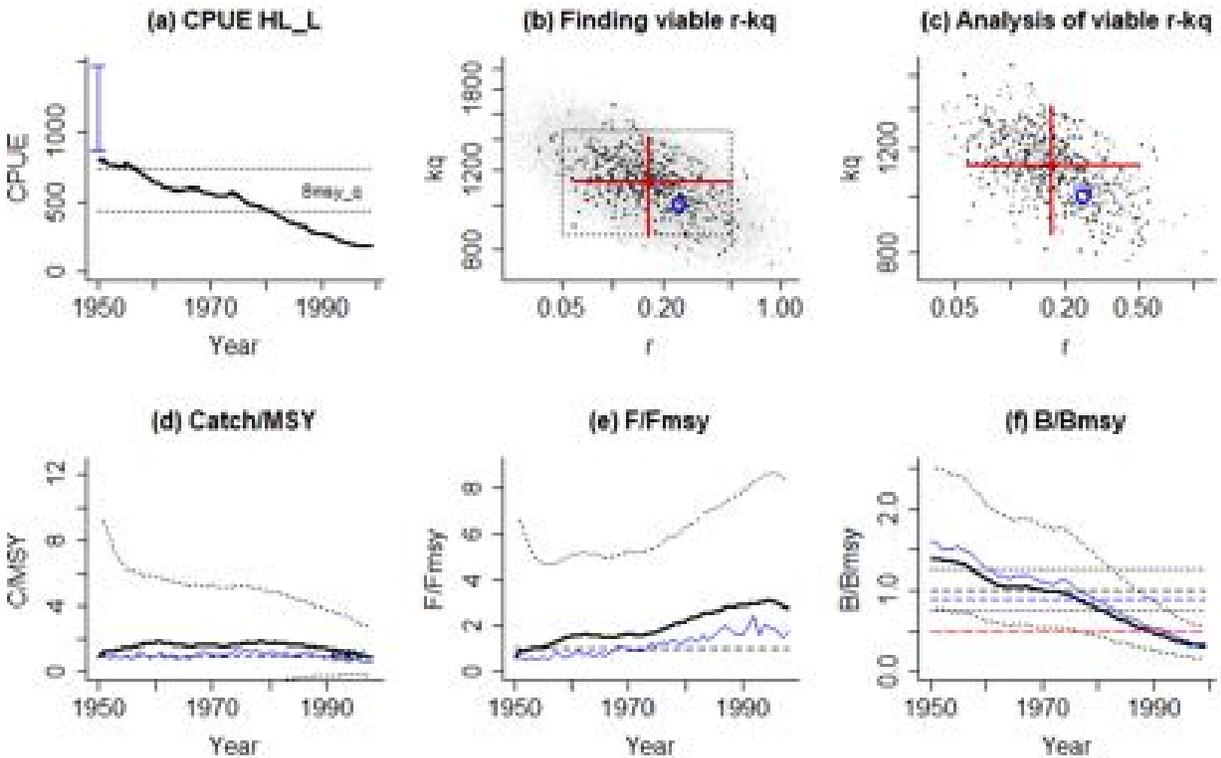


Stock HL\_L, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 177 - 787, smooth = TRUE  
 Prior for r = Low, NA - NA  
 Used prior range for r = 0.05 - 0.5  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 864 - 1469 [original range = 864 - 1469]  
 Comment: True r=0.25, true kq=1000, true MSYq=62.5

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

viable r-kq pairs = 20010  
 median kq = 1125, 859 - 1417  
 median MSYq = 46.7, 16.6 - 122  
 r (4 MSYq/kq) = 0.166, 0.0582 - 0.516  
 Fmsy (r/2) = 0.083, 0.0291 - 0.258  
 F/Fmsy = 2.75, -0.728 - 8.3 (1998), true: 1.79  
 B/Bmsy = 0.314, 0.175 - 0.57 (1999), true: 0.36

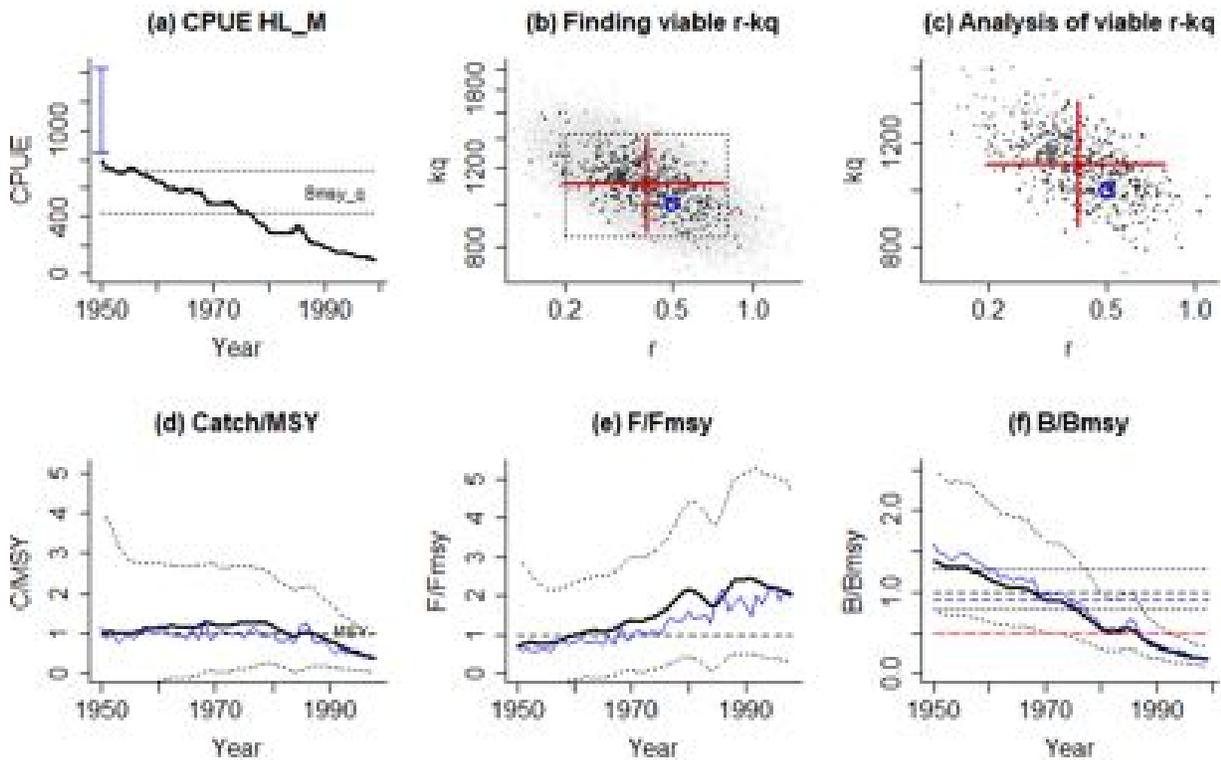


Stock HL\_M, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 101 - 770, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 845 - 1437 [original range = 845 - 1437]  
 Comment: True r=0.5, true kq=1000, true MSYq=125, true q=0.001

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

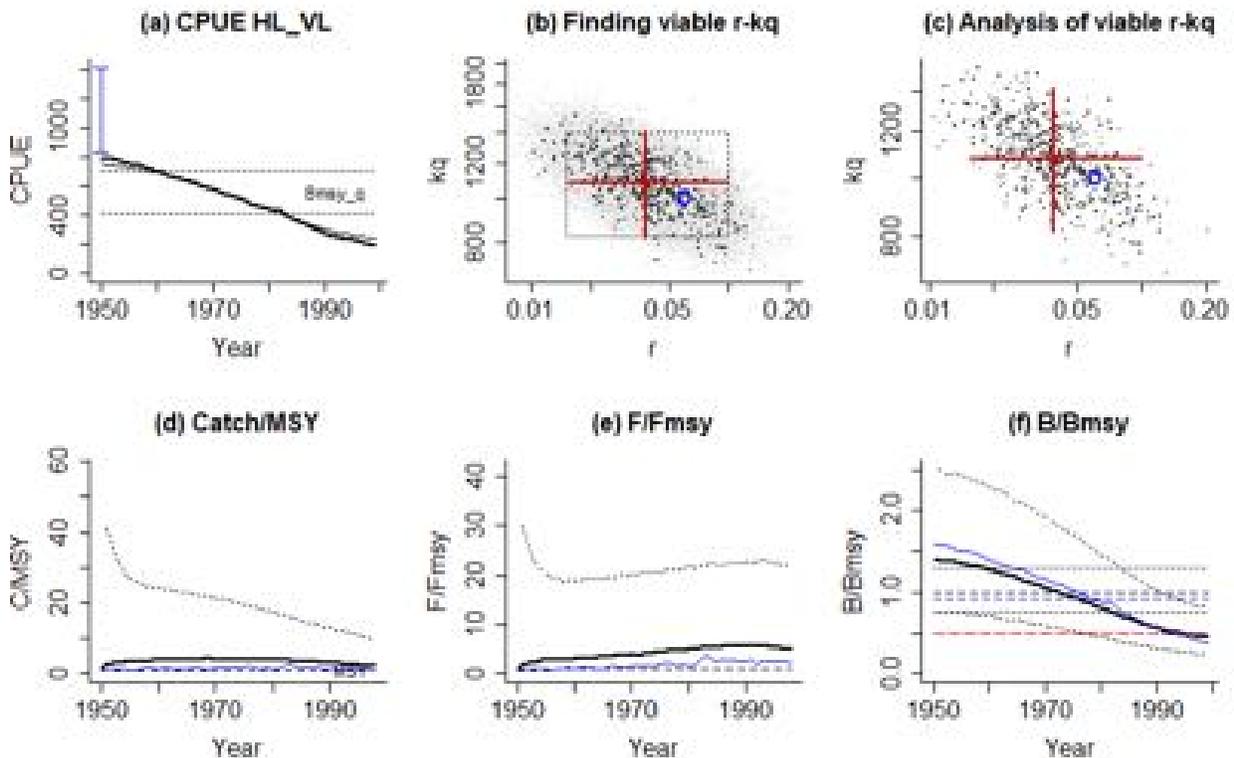
viable r-kq pairs = 20010  
 median kq = 1104, 865 - 1406  
 median MSYq = 112, 60.5 - 195  
 r (4 MSYq/kq) = 0.404, 0.196 - 0.787  
 Fmsy (r/2) = 0.202, 0.0978 - 0.394  
 F/Fmsy = 2, 0.262 - 4.69 (1998), true: 2.09  
 B/Bmsy = 0.183, 0.101 - 0.332 (1999), true: 0.18



Stock HL\_VL, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 244 - 754, smooth = TRUE  
 Prior for r = Very low, NA - NA  
 Used prior range for r = 0.015 - 0.1  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 828 - 1407 [original range = 828 - 1407]  
 Comment: True r=0.06, true kq=1000, true MSYq=15

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

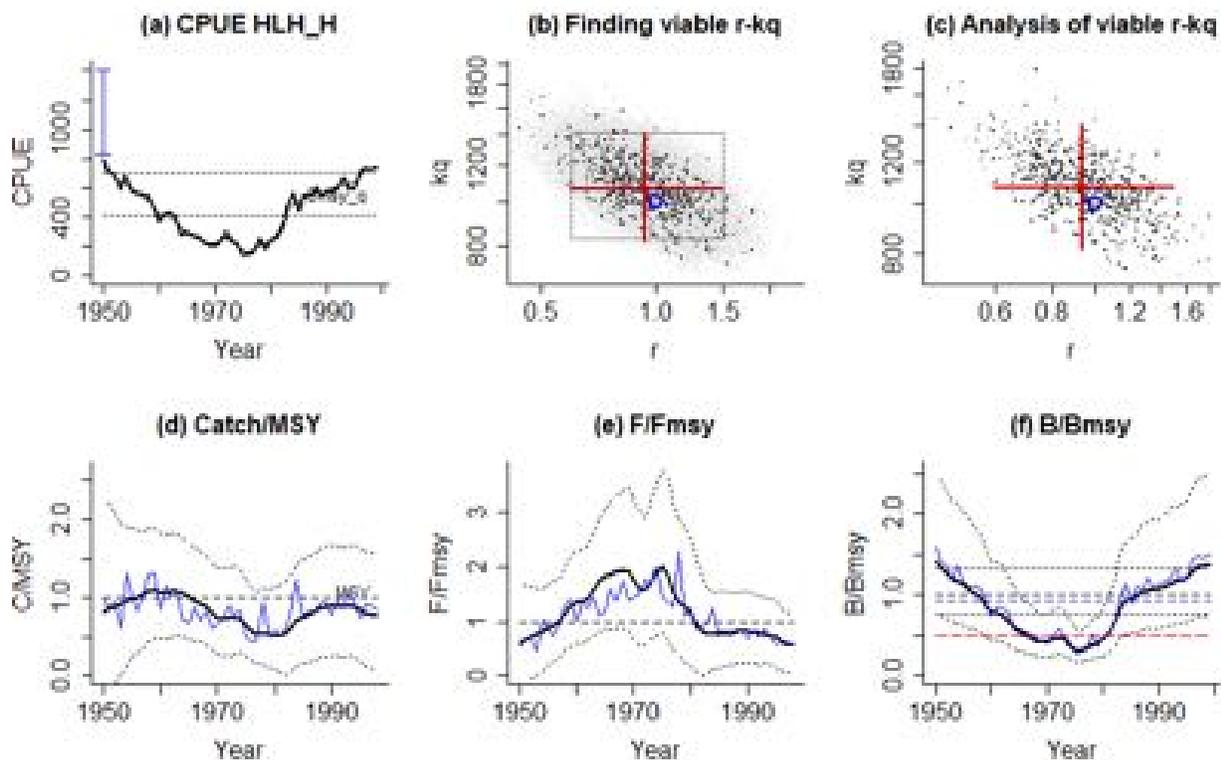
Results:  
 viable r-kq pairs = 20010  
 median kq = 1083, 817 - 1413  
 median MSYq = 10.3, 4.71 - 23.6  
 r (4 MSYq/kq) = 0.038, 0.0153 - 0.0987  
 Fmsy (r/2) = 0.019, 0.00767 - 0.0493  
 F/Fmsy = 5.12, -6.94 - 21.8 (1998), true: 2.41  
 B/Bmsy = 0.45, 0.249 - 0.811 (1999), true: 0.38



Stock HLH\_H, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 165 - 753, smooth = TRUE  
 Prior for r = High, NA - NA  
 Used prior range for r = 0.6 - 1.5  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 827 - 1405 [original range = 827 - 1405]  
 Comment: True r=1.0, true kq=1000, true MSYq=250

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

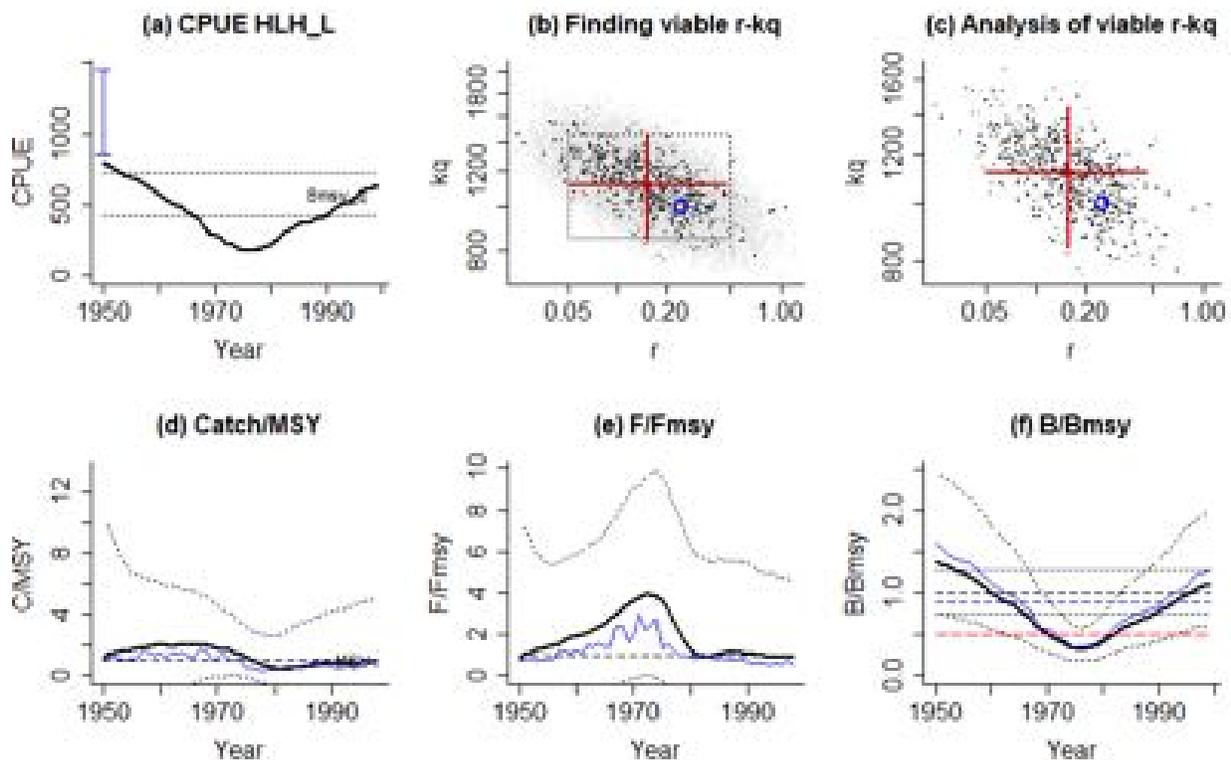
Results:  
 viable r-kq pairs = 20010  
 median kq = 1065, 819 - 1408  
 median MSYq = 250, 179 - 363  
 r (4 MSYq/kq) = 0.941, 0.594 - 1.5  
 Fmsy (r/2) = 0.47, 0.297 - 0.75  
 F/Fmsy = 0.564, 0.0348 - 1.16 (1998), true: 0.577  
 B/Bmsy = 1.38, 0.776 - 2.5 (1999), true: 1.5



Stock HLH\_L, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 186 - 777, smooth = TRUE  
 Prior for r = Low, NA - NA  
 Used prior range for r = 0.05 - 0.5  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 852 - 1449 [original range = 852 - 1449]  
 Comment: True r=0.25, true kq=1000, true MSYq=62.5

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:  
 viable r-kq pairs = 20010  
 median kq = 1121, 842 - 1441  
 median MSYq = 43.5, 15.8 - 115  
 r (4 MSYq/kq) = 0.155, 0.0489 - 0.464  
 Fmsy (r/2) = 0.0777, 0.0245 - 0.232  
 F/Fmsy = 0.961, -1.83 - 4.72 (1998), true: 0.546  
 B/Bmsy = 1.11, 0.62 - 2 (1999), true: 1.28

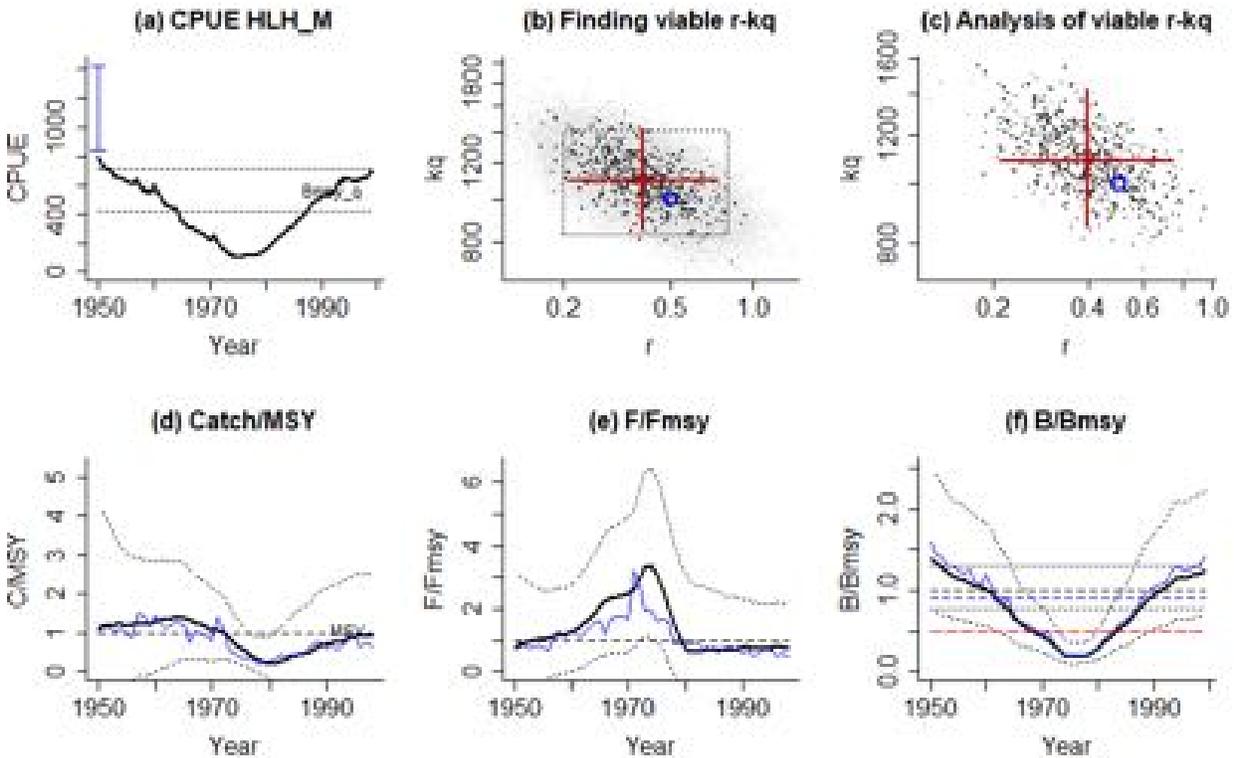


Stock HLH\_M, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 108 - 760, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 835 - 1419 [original range = 835 - 1419]  
 Comment: True r=0.5, true kq=1000, true MSYq=125, true q=0.001

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

viable r-kq pairs = 20010  
 median kq = 1091, 854 - 1429  
 median MSYq = 108, 63.9 - 185  
 r (4 MSYq/kq) = 0.395, 0.209 - 0.747  
 Fmsy (r/2) = 0.197, 0.104 - 0.373  
 F/Fmsy = 0.755, -0.353 - 2.09 (1998), true: 0.522  
 B/Bmsy = 1.25, 0.688 - 2.22 (1999), true: 1.4

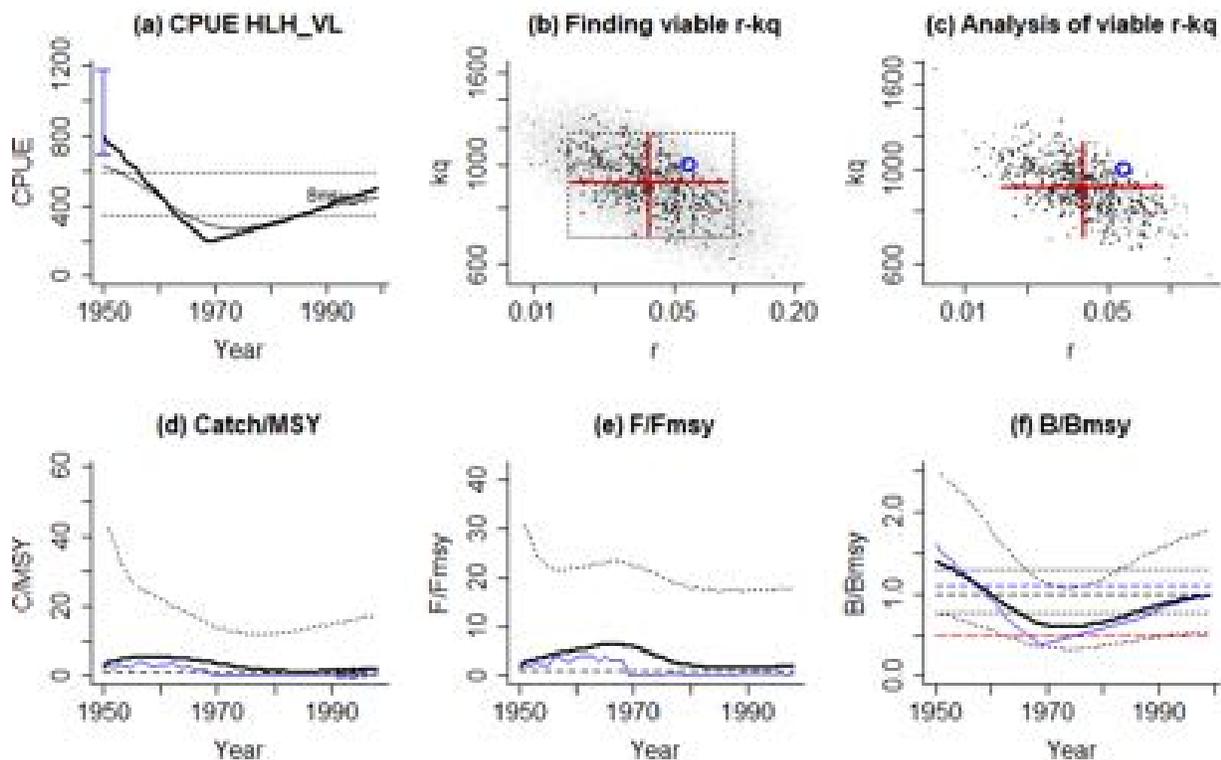


Stock HLH\_VL, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 270 - 631, smooth = TRUE  
 Prior for r = Very low, NA - NA  
 Used prior range for r = 0.015 - 0.1  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 692 - 1176 [original range = 692 - 1176]  
 Comment: True r=0.06, true kq=1000, true MSYq=15

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

viable r-kq pairs = 20010  
 median kq = 905, 697 - 1166  
 median MSYq = 8.61, 3.84 - 18.6  
 r (4 MSYq/kq) = 0.0381, 0.015 - 0.0933  
 Fmsy (r/2) = 0.019, 0.00752 - 0.0466  
 F/Fmsy = 2.04, -9.09 - 17.9 (1998), true: 0.377  
 B/Bmsy = 0.987, 0.548 - 1.79 (1999), true: 1

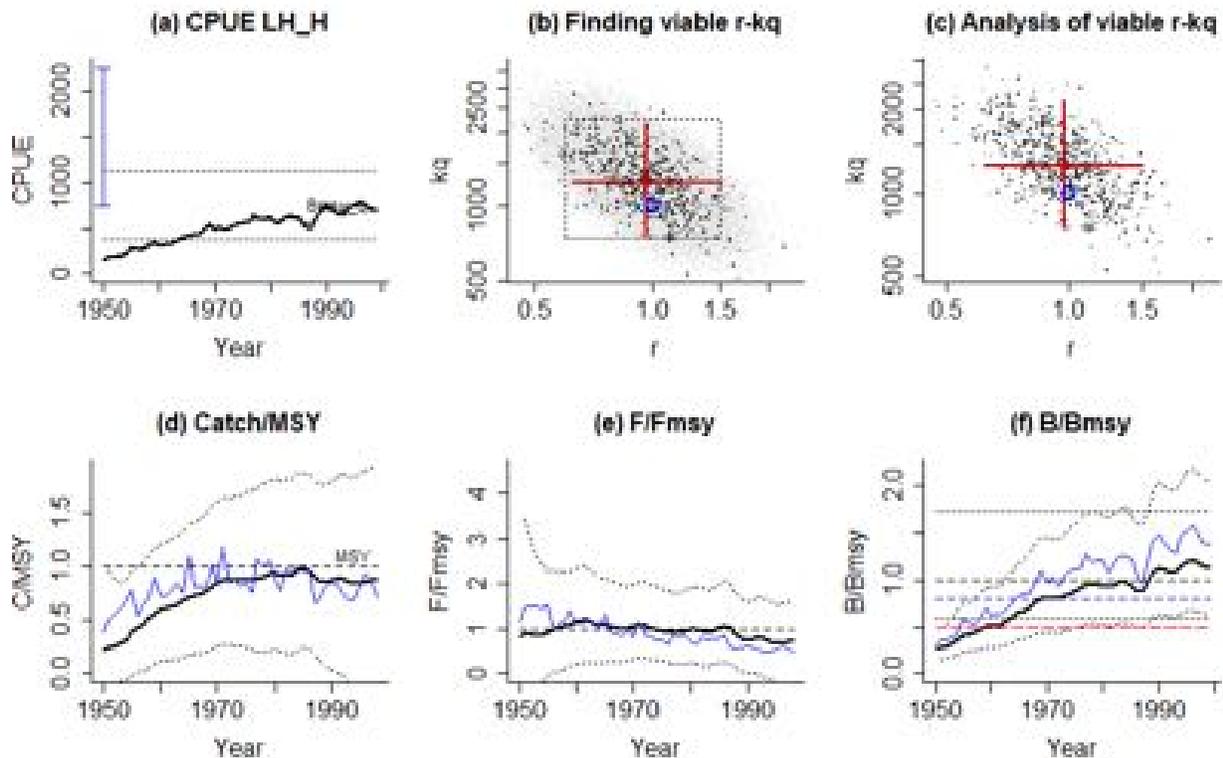


Stock LH\_H, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 164 - 761, smooth = TRUE  
 Prior for r = High, NA - NA  
 Used prior range for r = 0.6 - 1.5  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 749 - 2248 [original range = 149 - 2981]  
 Comment: True r=1.0, true kq=1000, true MSYq=250

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

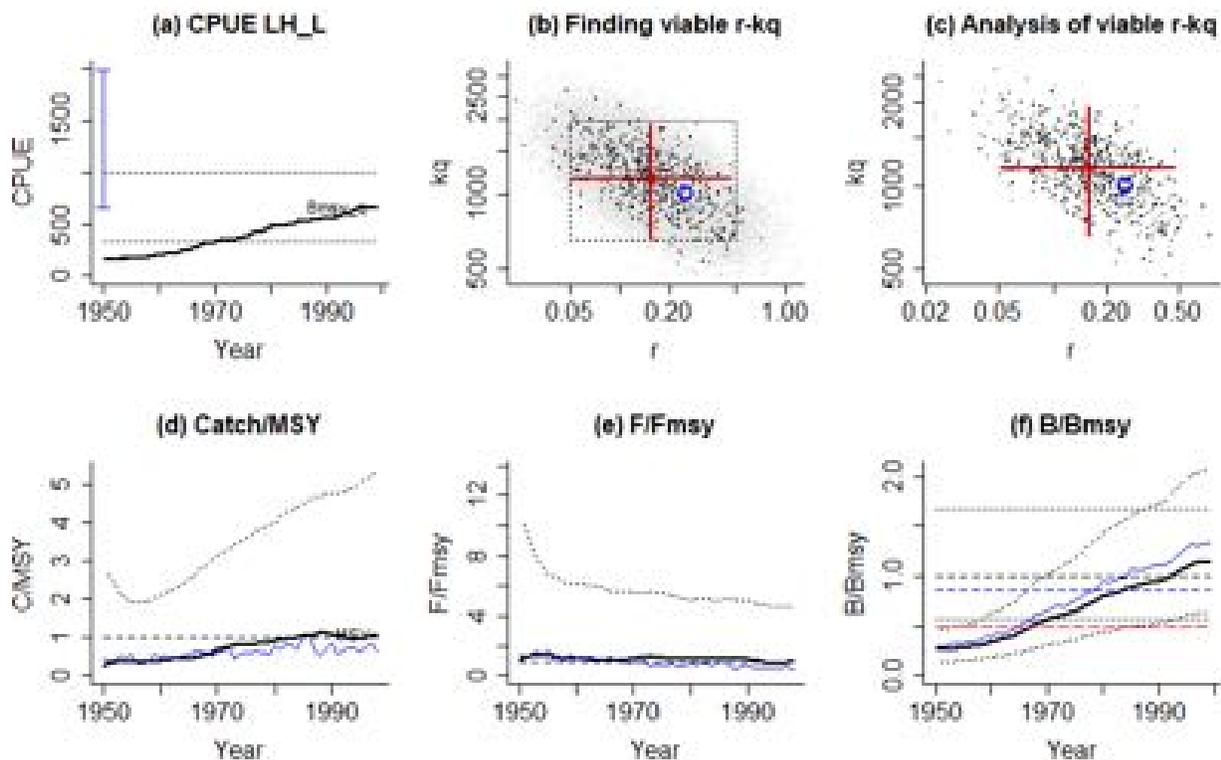
viable r-kq pairs = 20010  
 median kq = 1253, 747 - 2162  
 median MSYq = 304, 187 - 487  
 r (4 MSYq/kq) = 0.971, 0.617 - 1.51  
 Fmsy (r/2) = 0.485, 0.309 - 0.756  
 F/Fmsy = 0.771, -0.199 - 1.66 (1998), true: 0.5  
 B/Bmsy = 1.12, 0.619 - 2.02 (1999), true: 1.4



Stock LH\_L, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 152 - 663, smooth = TRUE  
 Prior for r = Low, NA - NA  
 Used prior range for r = 0.05 - 0.5  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 661 - 1982 [original range = 138 - 2750]  
 Comment: True r=0.25, true kq=1000, true MSYq=62.5

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:  
 viable r-kq pairs = 20010  
 median kq = 1157, 658 - 1926  
 median MSYq = 45.1, 17.1 - 110  
 r (4 MSYq/kq) = 0.156, 0.0513 - 0.464  
 Fmsy (r/2) = 0.078, 0.0257 - 0.232  
 F/Fmsy = 0.943, -1.84 - 4.71 (1998), true: 0.484  
 B/Bmsy = 1.15, 0.638 - 2.06 (1999), true: 1.34

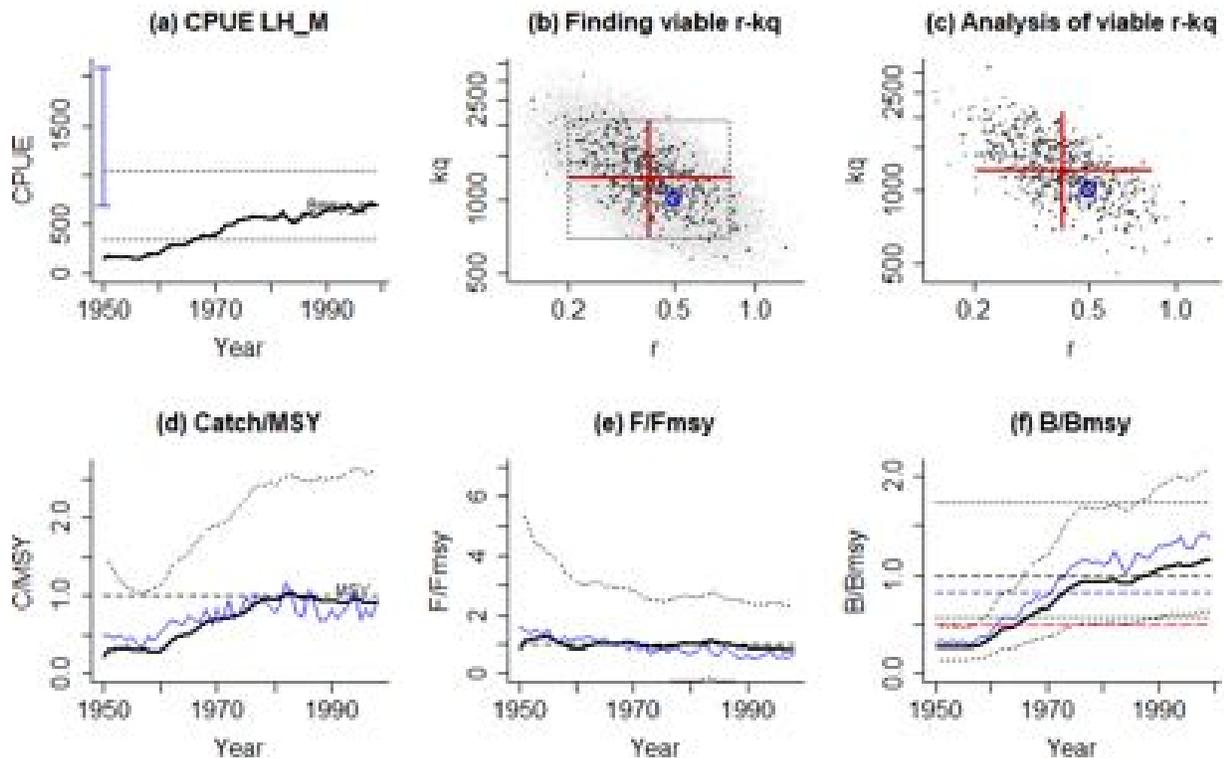


Stock LH\_M, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 159 - 697, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 695 - 2086 [original range = 144 - 2886]  
 Comment: True r=0.5, true kq=1000, true MSYq=125, true q=0.001

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

viable r-kq pairs = 20010  
 median kq = 1208, 699 - 2090  
 median MSYq = 122, 71.7 - 203  
 r (4 MSYq/kq) = 0.405, 0.206 - 0.823  
 Fmsy (r/2) = 0.203, 0.103 - 0.412  
 F/Fmsy = 0.794, -0.445 - 2.29 (1998), true: 0.679  
 B/Bmsy = 1.16, 0.639 - 2.08 (1999), true: 1.38

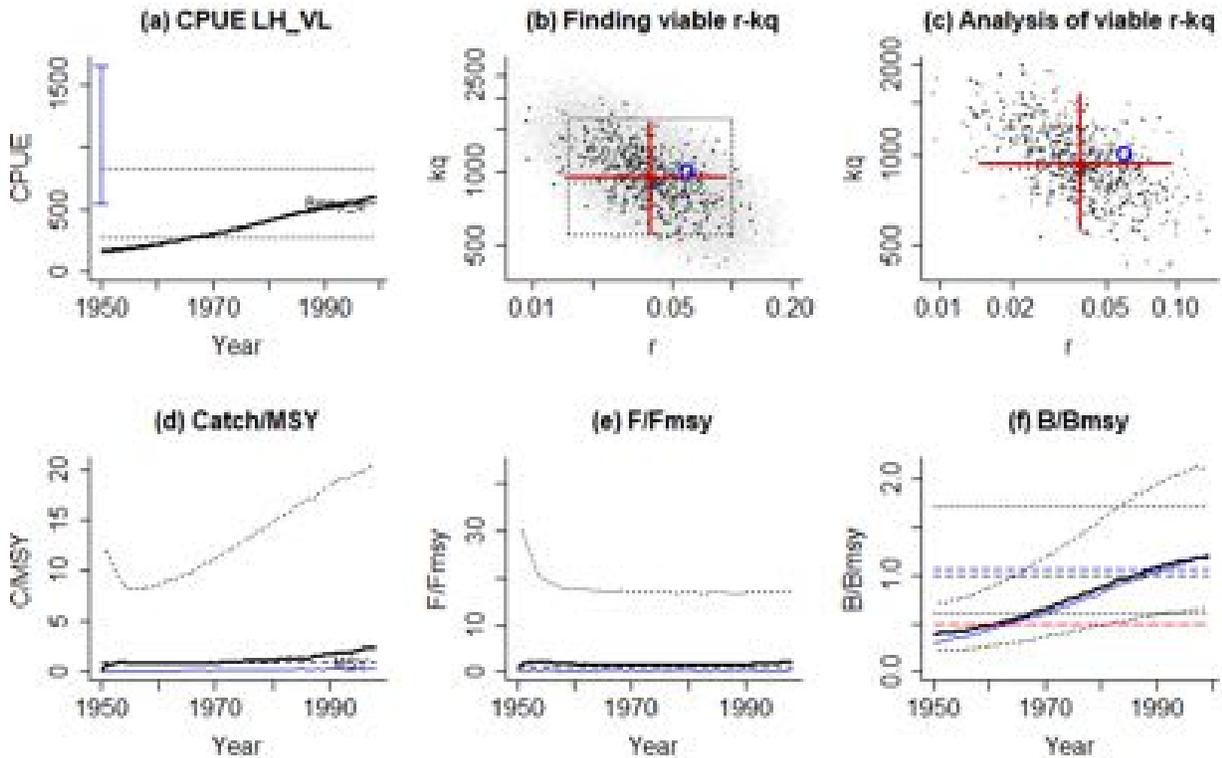


Stock LH\_VL, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 182 - 555, smooth = TRUE  
 Prior for r = Very low, NA - NA  
 Used prior range for r = 0.015 - 0.1  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 551 - 1654 [original range = 165 - 3305]  
 Comment: True r=0.06, true kq=1000, true MSYq=15

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

viable r-kq pairs = 20010  
 median kq = 936, 563 - 1606  
 median MSYq = 9.12, 4.39 - 19.1  
 r (4 MSYq/kq) = 0.039, 0.0144 - 0.0948  
 Fmsy (r/2) = 0.0195, 0.00722 - 0.0474  
 F/Fmsy = 1.96, -8.57 - 17.2 (1998), true: 0.362  
 B/Bmsy = 1.18, 0.659 - 2.13 (1999), true: 1.2

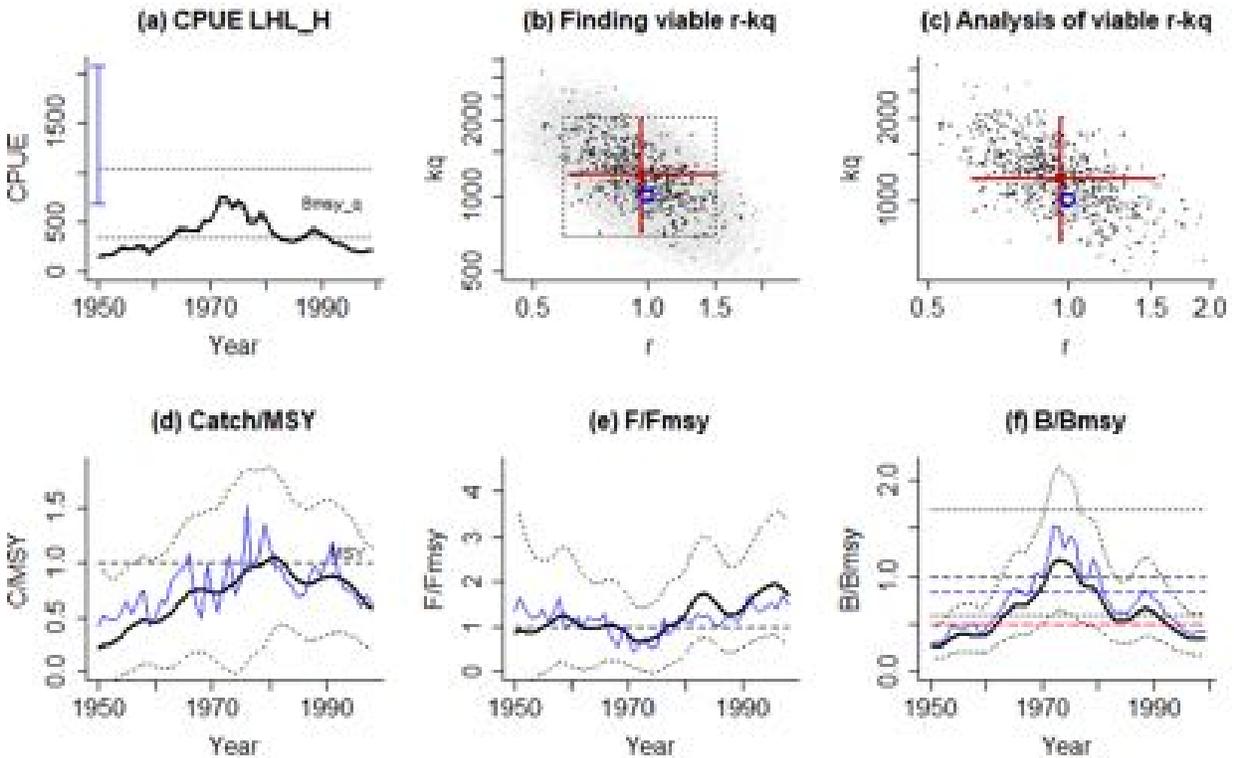


Stock LHL\_H, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 155 - 708, smooth = TRUE  
 Prior for r = High, NA - NA  
 Used prior range for r = 0.6 - 1.5  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 693 - 2079 [original range = 140 - 2807]  
 Comment: True r=1.0, true kq=1000, true MSYq=250

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

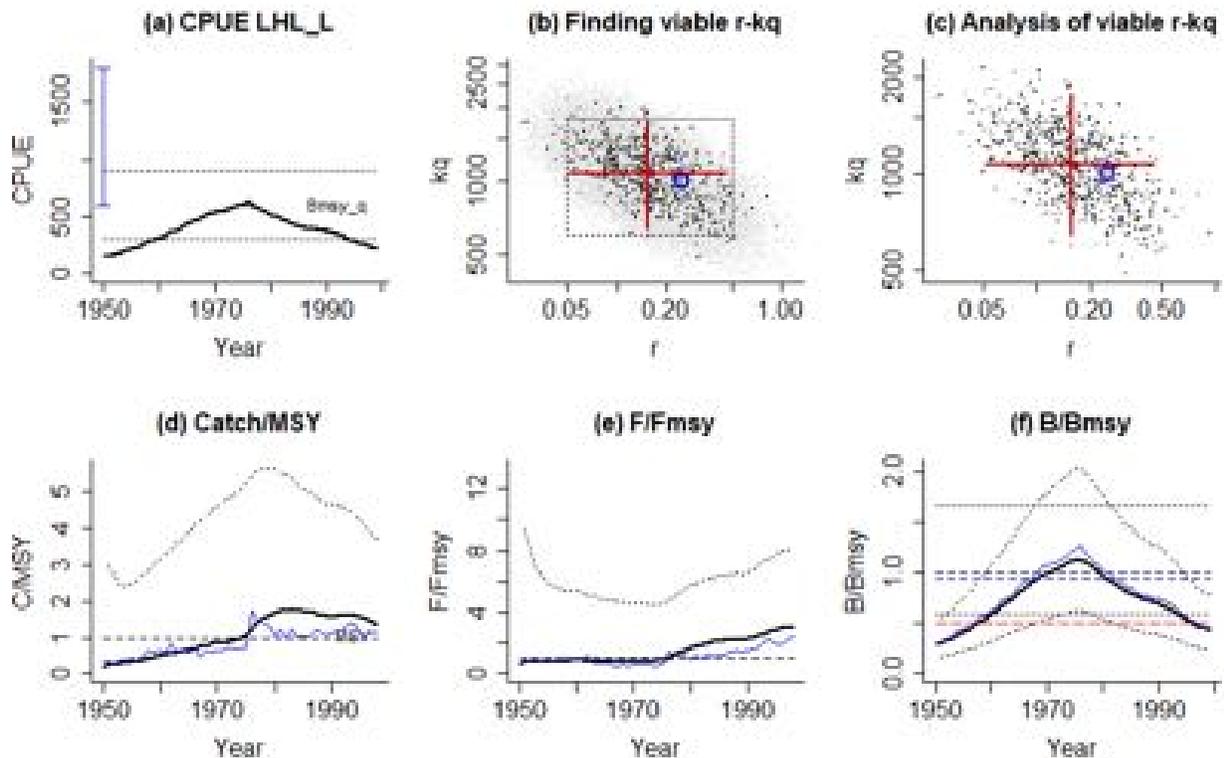
viable r-kq pairs = 20010  
 median kq = 1207, 711 - 2038  
 median MSYq = 290, 190 - 442  
 r (4 MSYq/kq) = 0.961, 0.62 - 1.53  
 Fmsy (r/2) = 0.48, 0.31 - 0.765  
 F/Fmsy = 1.71, 0.595 - 3.33 (1998), true: 1.5  
 B/Bmsy = 0.345, 0.192 - 0.622 (1999), true: 0.42



Stock LHL\_L, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 160 - 602, smooth = TRUE  
 Prior for r = Low, NA - NA  
 Used prior range for r = 0.05 - 0.5  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 600 - 1801 [original range = 145 - 2909]  
 Comment: True r=0.25, true kq=1000, true MSYq=62.5

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

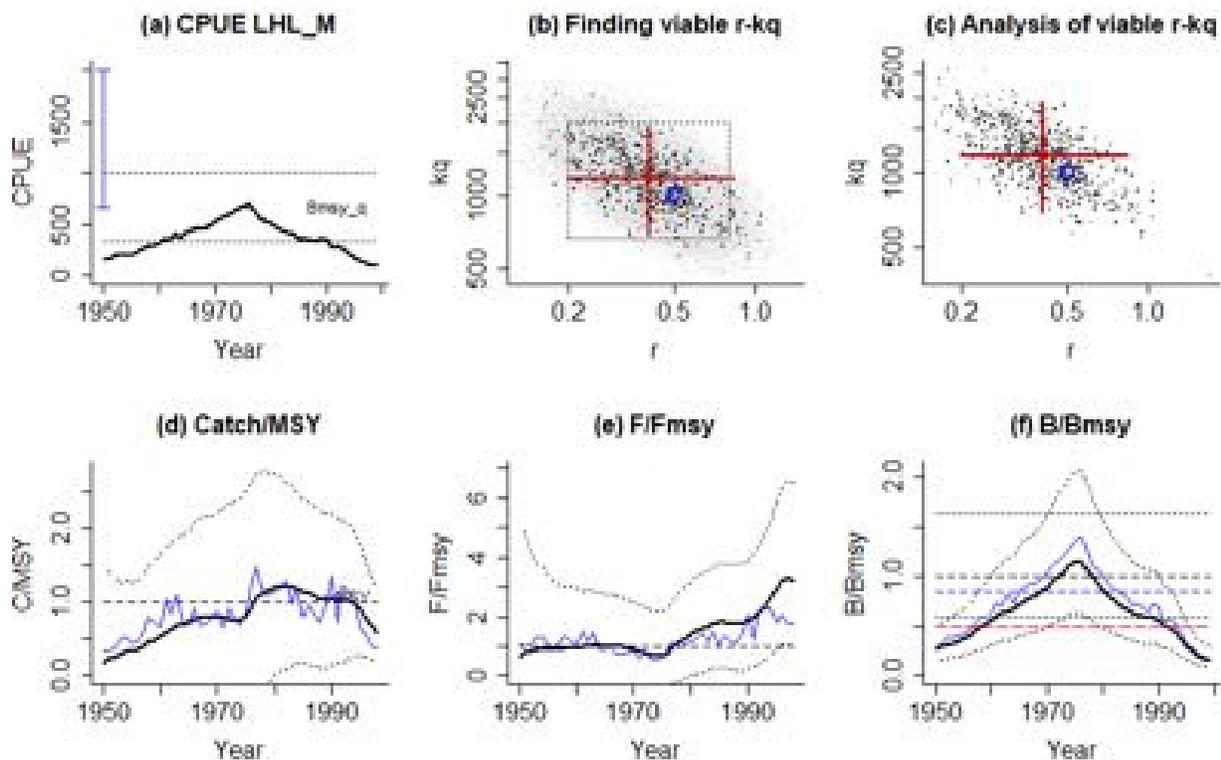
Results:  
 viable r-kq pairs = 20010  
 median kq = 1065, 639 - 1787  
 median MSYq = 41.5, 17.1 - 105  
 r (4 MSYq/kq) = 0.156, 0.0514 - 0.461  
 Fmsy (r/2) = 0.0779, 0.0257 - 0.23  
 F/Fmsy = 2.99, -0.641 - 8.15 (1998), true: 2.38  
 B/Bmsy = 0.439, 0.245 - 0.79 (1999), true: 0.42



Stock LHL\_M, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 96.7 - 669, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 668 - 2005 [original range = 144 - 2875]  
 Comment: True r=0.5, true kq=1000, true MSYq=125, true q=0.001

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:  
 viable r-kq pairs = 20010  
 median kq = 1164, 693 - 1908  
 median MSYq = 117, 64.1 - 196  
 r (4 MSYq/kq) = 0.401, 0.196 - 0.831  
 Fmsy (r/2) = 0.2, 0.098 - 0.415  
 F/Fmsy = 3.22, 1.01 - 6.48 (1998), true: 1.77  
 B/Bmsy = 0.166, 0.0911 - 0.295 (1999), true: 0.18

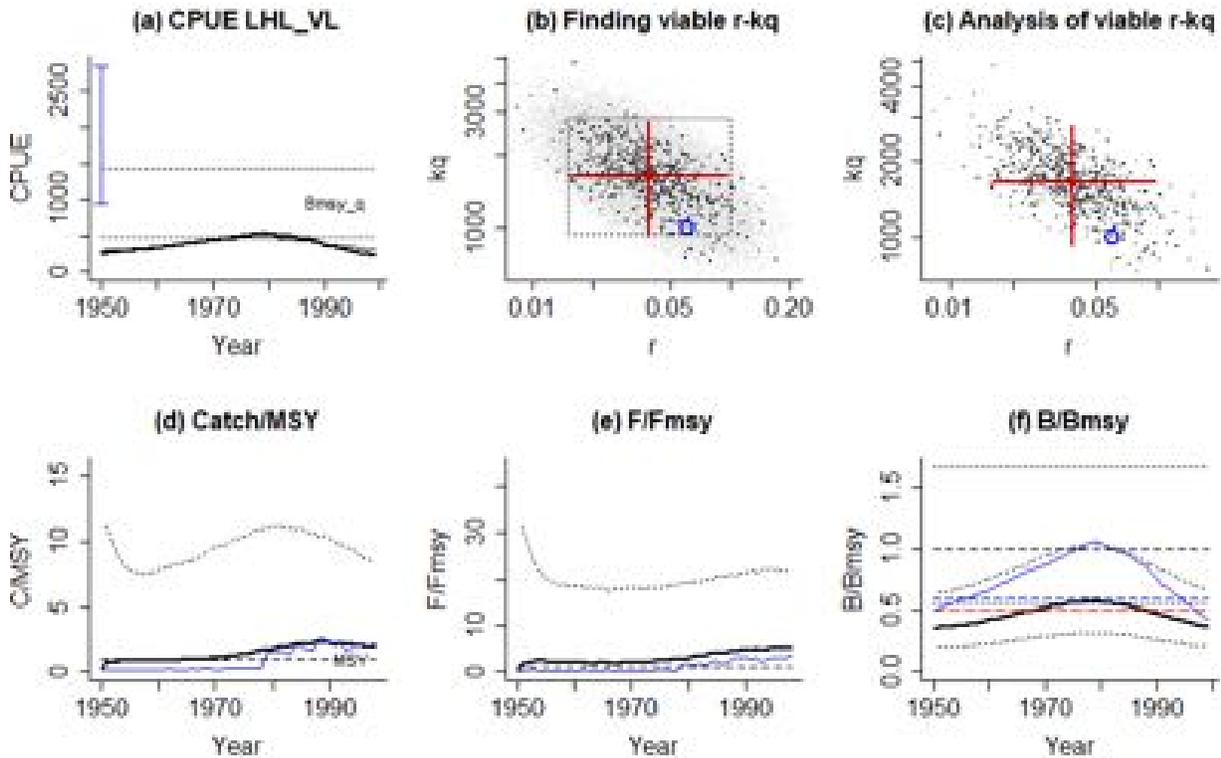


Stock LHL\_VL, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 293 - 475, smooth = TRUE  
 Prior for r = Very low, NA - NA  
 Used prior range for r = 0.015 - 0.1  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 949 - 2848 [original range = 266 - 5322]  
 Comment: True r=0.06, true kq=1000, true MSYq=15

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

viable r-kq pairs = 20010  
 median kq = 1647, 936 - 2756  
 median MSYq = 15.9, 7.37 - 32.8  
 r (4 MSYq/kq) = 0.0386, 0.0157 - 0.0965  
 Fmsy (r/2) = 0.0193, 0.00785 - 0.0483  
 F/Fmsy = 4.95, -7.03 - 22.1 (1998), true: 3.4  
 B/Bmsy = 0.373, 0.207 - 0.668 (1999), true: 0.42

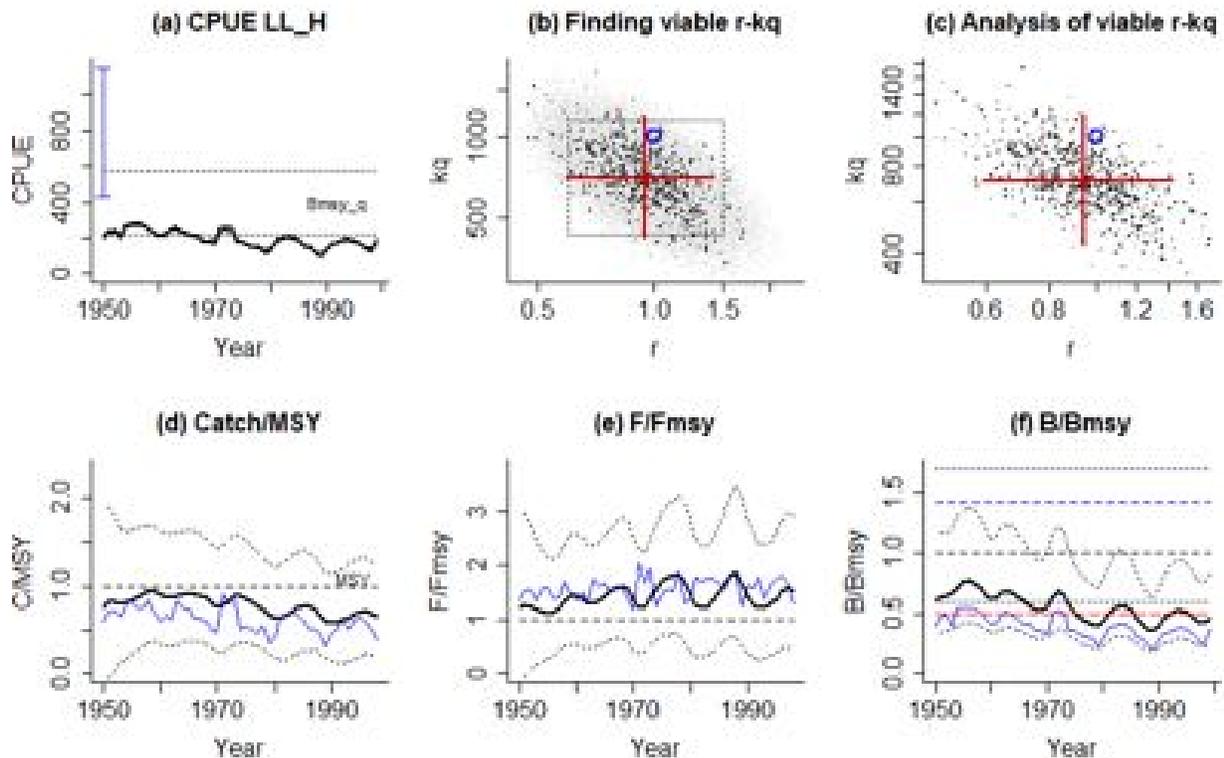


Stock LL\_H, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 125 - 272, smooth = TRUE  
 Prior for r = High, NA - NA  
 Used prior range for r = 0.6 - 1.5  
 Prior for 1950 stock status = Small, NA - NA  
 Used 1950 prior B/B0 range = 0.15 - 0.4, prior B/Bmsy = 0.3 - 0.8  
 Used prior range for kq = 431 - 1149 [original range = 431 - 1149]  
 Comment: True r=1.0, true kq=1000, true MSYq=250

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

viable r-kq pairs = 20010  
 median kq = 704, 421 - 1196  
 median MSYq = 166, 110 - 255  
 r (4 MSYq/kq) = 0.944, 0.585 - 1.42  
 Fmsy (r/2) = 0.472, 0.293 - 0.712  
 F/Fmsy = 1.53, 0.439 - 2.91 (1998), true: 1.31  
 B/Bmsy = 0.455, 0.255 - 0.821 (1999), true: 0.38

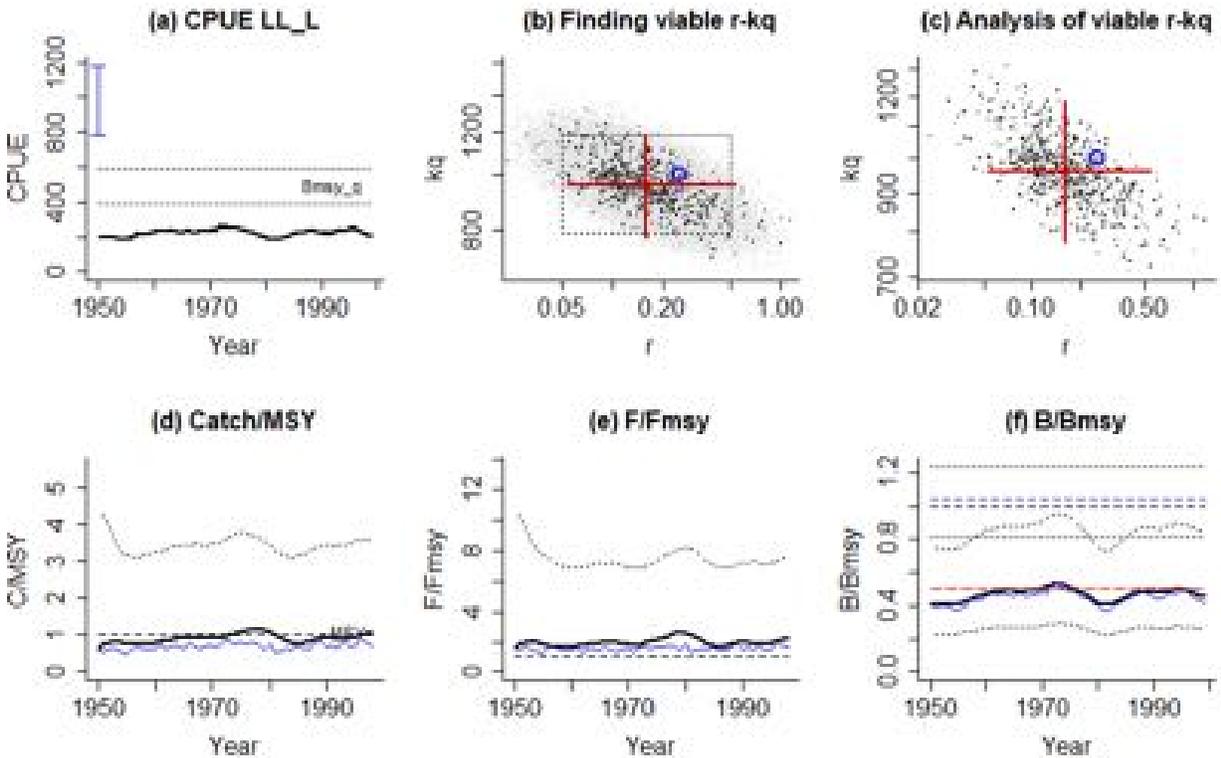


Stock LL\_L, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 195 - 254, smooth = TRUE  
 Prior for r = Low, NA - NA  
 Used prior range for r = 0.05 - 0.5  
 Prior for 1950 stock status = Small, NA - NA  
 Used 1950 prior B/B0 range = 0.15 - 0.4, prior B/Bmsy = 0.3 - 0.8  
 Used prior range for kq = 787 - 1180 [original range = 393 - 1049]  
 Comment: True r=0.25, true kq=1000, true MSYq=62.5

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

viable r-kq pairs = 20010  
 median kq = 958, 779 - 1184  
 median MSYq = 38.1, 13.8 - 108  
 r (4 MSYq/kq) = 0.159, 0.0533 - 0.54  
 Fmsy (r/2) = 0.0796, 0.0266 - 0.27  
 F/Fmsy = 2.25, -1.21 - 7.65 (1998), true: 1.64  
 B/Bmsy = 0.456, 0.253 - 0.829 (1999), true: 0.42

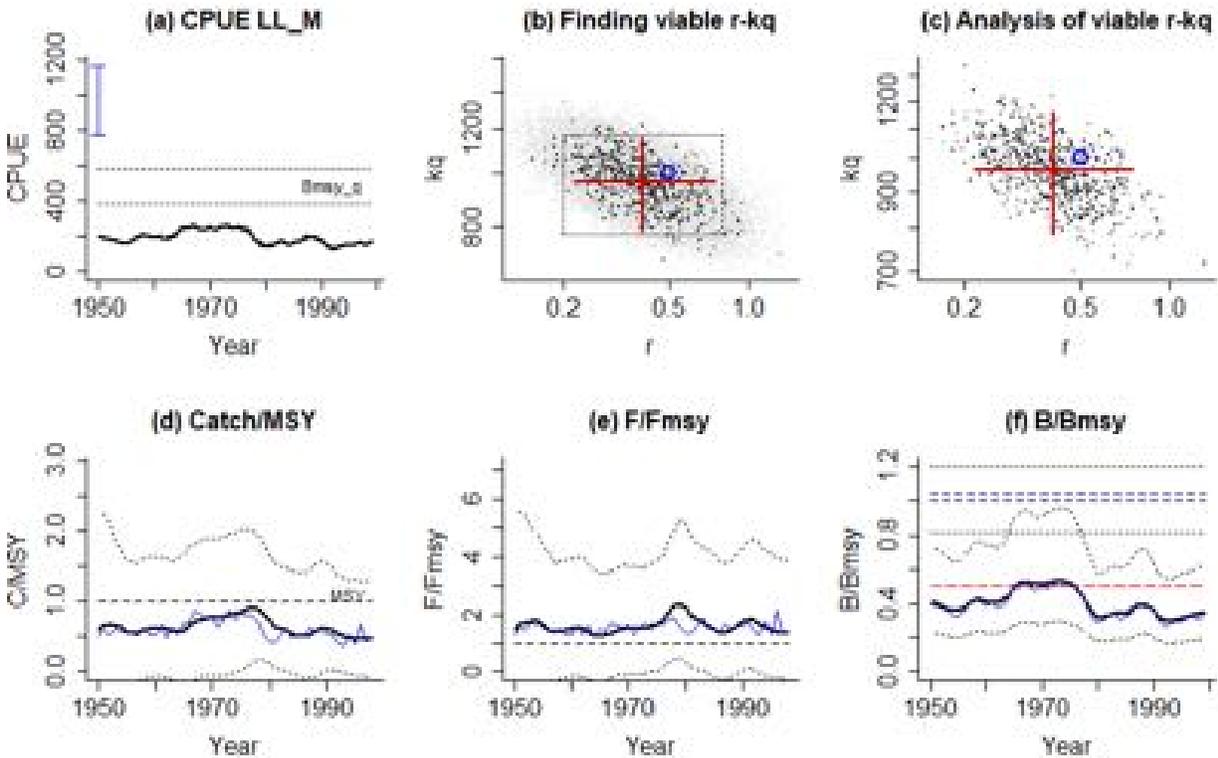


Stock LL\_M, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 144 - 257, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 1950 stock status = Small, NA - NA  
 Used 1950 prior B/B0 range = 0.15 - 0.4, prior B/Bmsy = 0.3 - 0.8  
 Used prior range for kq = 779 - 1168 [original range = 389 - 1038]  
 Comment: True r=0.5, true kq=1000, true MSYq=125, true q=0.001

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

viable r-kq pairs = 20010  
 median kq = 964, 786 - 1155  
 median MSYq = 96.6, 55 - 169  
 r (4 MSYq/kq) = 0.401, 0.215 - 0.752  
 Fmsy (r/2) = 0.2, 0.108 - 0.376  
 F/Fmsy = 1.35, -0.23 - 3.87 (1998), true: 1.4  
 B/Bmsy = 0.348, 0.192 - 0.627 (1999), true: 0.36

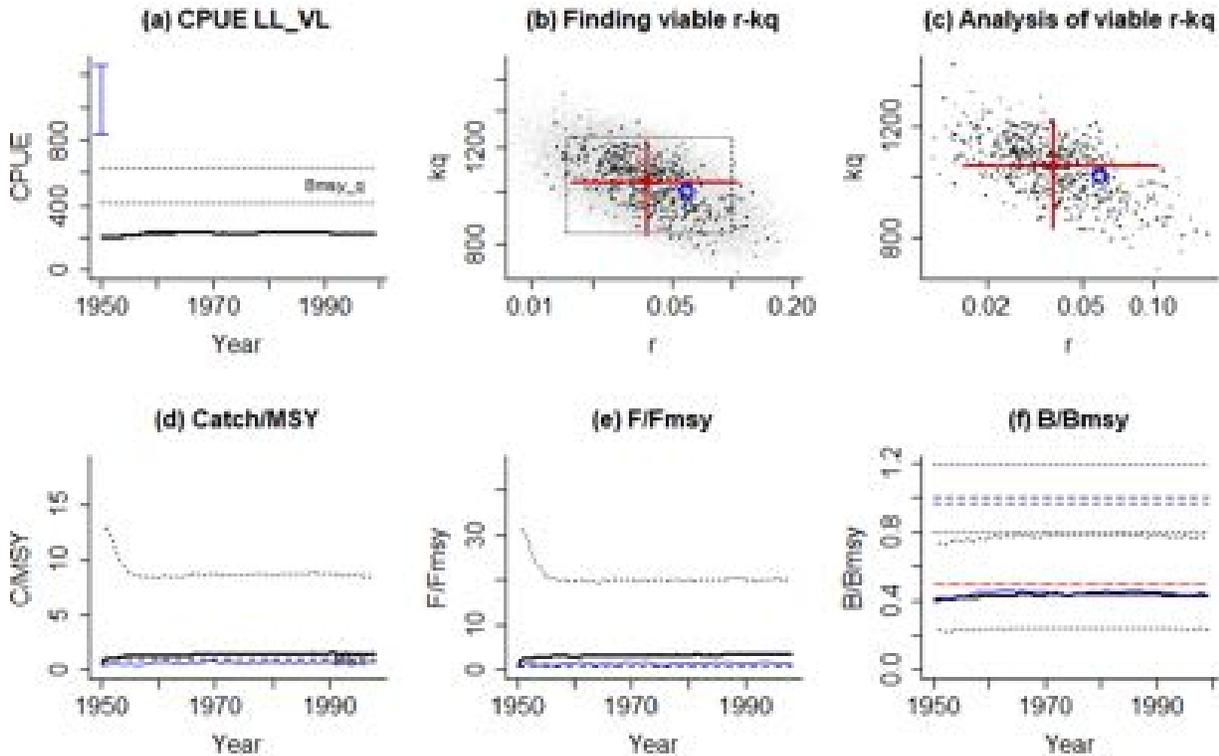


Stock LL\_VL, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 212 - 226, smooth = TRUE  
 Prior for r = Very low, NA - NA  
 Used prior range for r = 0.015 - 0.1  
 Prior for 1950 stock status = Small, NA - NA  
 Used 1950 prior B/B0 range = 0.15 - 0.4, prior B/Bmsy = 0.3 - 0.8  
 Used prior range for kq = 840 - 1260 [original range = 420 - 1120]  
 Comment: True r=0.06, true kq=1000, true MSYq=15

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 20010

Results:

viable r-kq pairs = 20010  
 median kq = 1039, 829 - 1234  
 median MSYq = 9.89, 4.6 - 24.4  
 r (4 MSYq/kq) = 0.0381, 0.0157 - 0.106  
 Fmsy (r/2) = 0.019, 0.00787 - 0.0528  
 F/Fmsy = 3.38, -8.35 - 20.1 (1998), true: 1.66  
 B/Bmsy = 0.426, 0.237 - 0.774 (1999), true: 0.44



## 2. Results of analysis of simulated data with filters with AMSY\_68x.R (01 November 2019)

**Table 2.** Comparison of estimated and “true” parameter values ( $r$ ,  $k_q$ ,  $F/F_{msy}$  and  $B/B_{msy}$ ) for 24 simulated stocks. The target value for estimated relative to true value is one. The approximate lower confidence range as fraction of the estimated central value [(est-cl)/est] is an indication of the uncertainty about the estimate. Column 2 shows the median across the 24 simulated stocks. Columns 3 and 4 show the range that includes 95% of the estimated values. Note that this run of AMSY applied several logical filters to the potential  $r$ - $k$  pairs, thus making the estimates of  $r$  and  $k_q$  less depended on the priors and basically reducing the cloud of viable  $r$ - $k_q$  pairs and moving it towards the “true” value within the original prior ranges for  $r$  and  $k_q$ , as is evident in the graphs displayed below. Source: AMSYResSimFil\_6.xls

	<b>Median</b>	<b>2.5<sup>th</sup> percentile</b>	<b>97.5<sup>th</sup> percentile</b>
$r$ : est/true	1.04	0.89	1.51
$r$ : (est—lcl)/est	0.36	0.29	0.47
$k_q$ : est /true	1.07	0.83	1.48
$k_q$ : (est—lcl)/est	0.18	0.15	0.34
$F/F_{msy}$ : est/true	1.19	0.79	4.14
$F/F_{msy}$ : (est—lcl)/est	0.89	0.60	3.53
$B/B_{msy}$ : est/true	0.93	0.79	1.17
$B/B_{msy}$ : (est—lcl)/est	0.44	0.43	0.45

Settings for analysis in the R-code:

```
#-----  
# Required settings, File names  
#-----  
id_file   <- "SimCPUE_ID_8.csv"  
  
#-----  
# General settings for the analysis ----  
#-----  
smooth.cpue <- T  
filter      <- TRUE  
cor.rk      <- -0.607  
sigma.r     <- c(0.05,0.07,0.1,0.15)  
sigma.cpue  <- 0.3  
n.p         <- 50000  
n.trial     <- 30  
min.viable  <- 20  
max.viable  <- 5000  
creep.graph <- F  
do.plots    <- T  
write.output <- T  
kobe.plot   <- F  
save.plots  <- F  
close.plots <- F  
retros      <- F
```

**Generic legend for the subsequent graphs:**

Panel (a) shows the time series of CPUE data as bold curve, a smoothed version of CPUE as thin dotted line, the prior range for  $kq$  as vertical blue line, and the corresponding upper and lower bounds of the relative  $B_{msy}$  range as dotted horizontal lines.

Panel (b) shows the  $r$ - $kq$  prior space in log scale with a cloud of gray points representing the multivariate log-normal distribution of  $r$  and  $kq$  corresponding to a correlation of  $-0.607$ , derived from full Schaefer models applied to 140 real stocks. The dotted rectangle indicates the prior ranges for  $r$  and  $kq$  and includes 85% of the gray dots. The red cross indicates the estimated central  $r$ - $kq$  pair and the approximate 95% confidence limits. The blue circle indicates the “true”  $r$ - $kq$  pair used in the simulation.

Panel (c) is a zoom-in on the viable  $r$ - $kq$  pairs, with the red cross indicating the estimated central  $r$ - $kq$  pair and its approximate 95% confidence limits and the blue circle indicating the “true”  $r$ - $kq$  pair used in the simulation.

Panel (d) shows the time series of catch predicted by AMSY as bold curve relative to MSY, indicated by the dashed horizontal line. The dotted curves indicate the approximate 95% confidence limits. The blue curve shows the “true” catch used in the simulations.

Panel (e) shows the predicted time series of  $F$  over  $F_{msy}$  as bold curve with dotted curves indicating the approximate 95% confidence limits. The dashed horizontal line indicates  $F_{msy}$ .

Panel (f) shows the predicted time series of  $B$  over  $B_{msy}$  as bold curve with dotted curves indicating the approximate 95% confidence limits. The dashed horizontal line indicates  $B_{msy}$ , the dotted lines indicate the approximate 95% confidence limits of  $B_{msy}$ , and the dashed red line indicates half of  $B_{msy}$ . The blue curve shows the “true” biomass used in the simulations relative to the “true” value of  $B_{msy}$ , indicated by a blue dashed line.

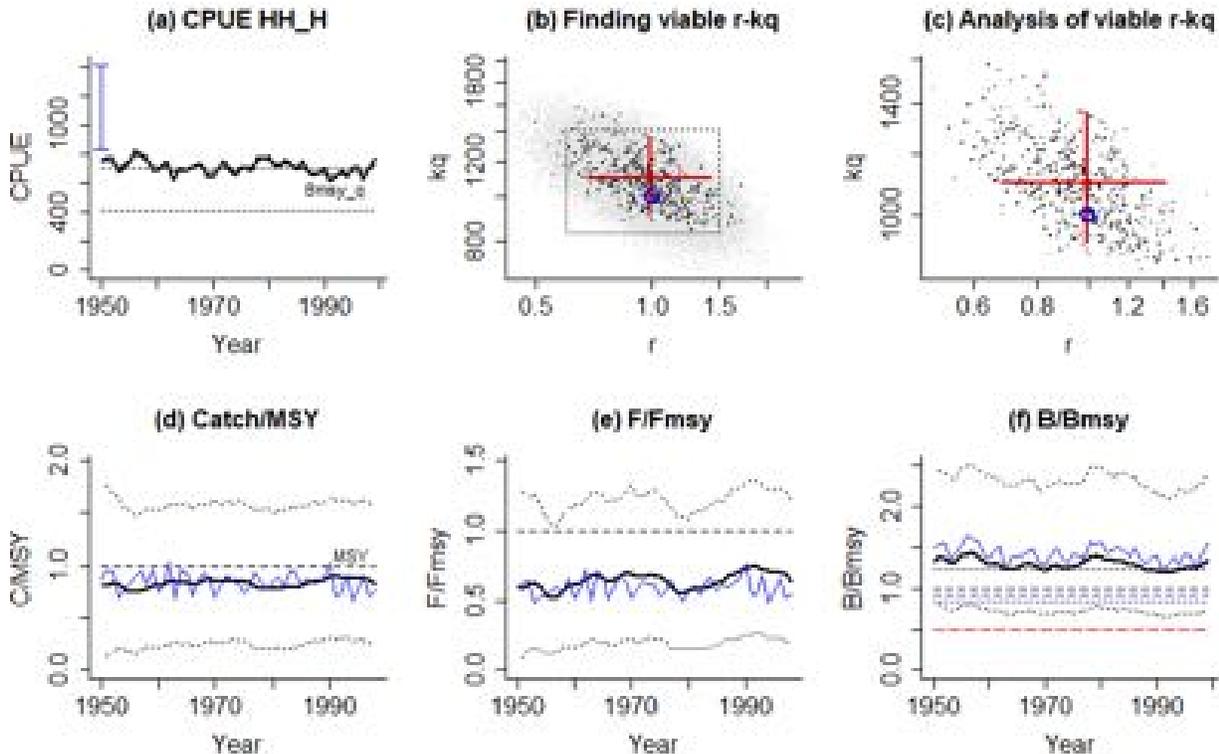
```
> source('D:/RF_Documents/AMSY/Review/SimFilt/AMSY_68x.R')
File SimCPUE_ID_8.csv read successfully
```

-----  
 AMSY Analysis, Fri Nov 01 14:03:00 2019  
 -----

Stock **HH\_H**, , simulated data  
 CPUE data for years 1950 - 1999, CPUE range 656 - 789, smooth = TRUE  
 Prior for r = High, NA - NA  
 Used prior range for r = 0.6 - 1.5  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 832 - 1415 [original range = 832 - 1415]  
 Comment: True r=1.0, true kq=1000, true MSYq=250

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5002

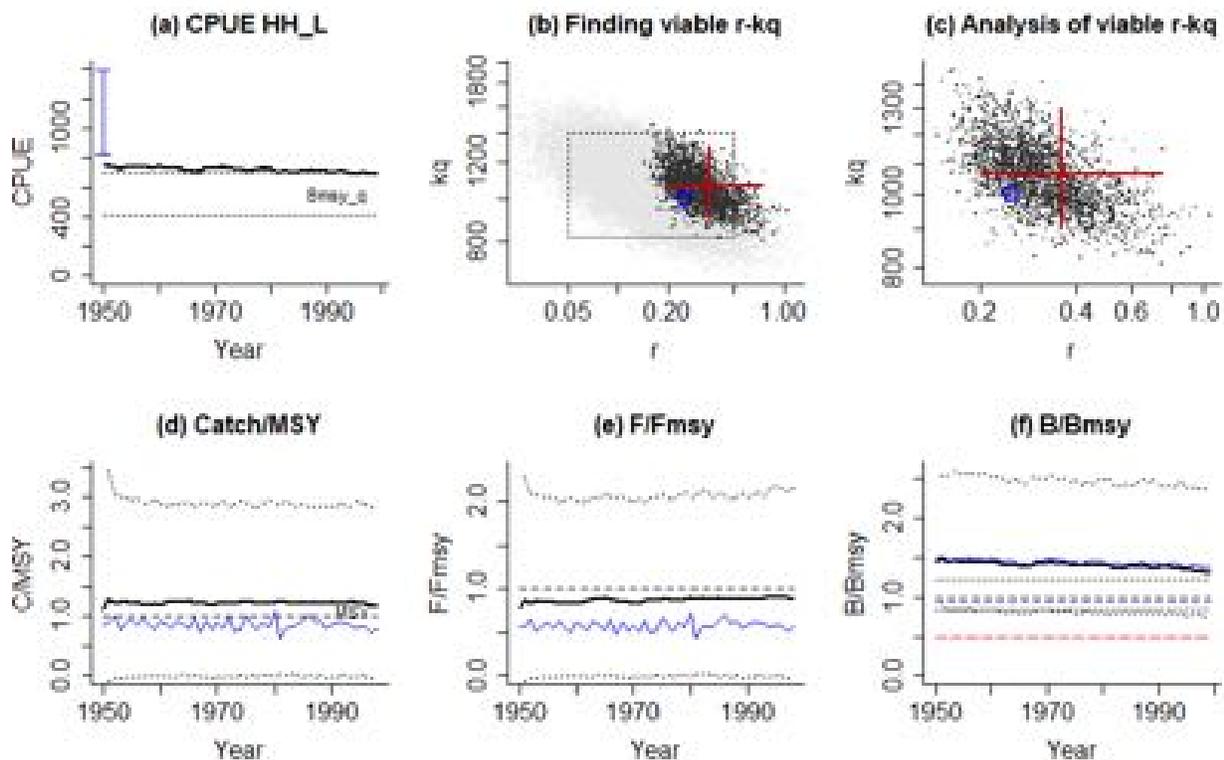
Results:  
 viable r-kq pairs = 5002  
 median kq = 1097, 918 - 1363  
 median MSYq = 273, 198 - 362  
 r (4 MSYq/kq) = 0.996, 0.677 - 1.42  
 Fmsy (r/2) = 0.498, 0.339 - 0.708  
 F/Fmsy = 0.631, 0.178 - 1.2 (1998), true: 0.536  
 B/Bmsy = 1.35, 0.742 - 2.43 (1999), true: 1.54



Stock **HH\_L**, Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 691 - 747, smooth = TRUE  
 Prior for  $r$  = Low, NA - NA  
 Used prior range for  $r$  = 0.05 - 0.5  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior  $B/B_0$  range = 0.5 - 0.85, prior  $B/B_{msy}$  = 1 - 1.7  
 Used prior range for  $kq$  = 820 - 1394 [original range = 820 - 1394]  
 Comment: True  $r=0.25$ , true  $kq=1000$ , true  $MSYq=62.5$

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
 Viable  $r$ - $kq$  pairs = 5003

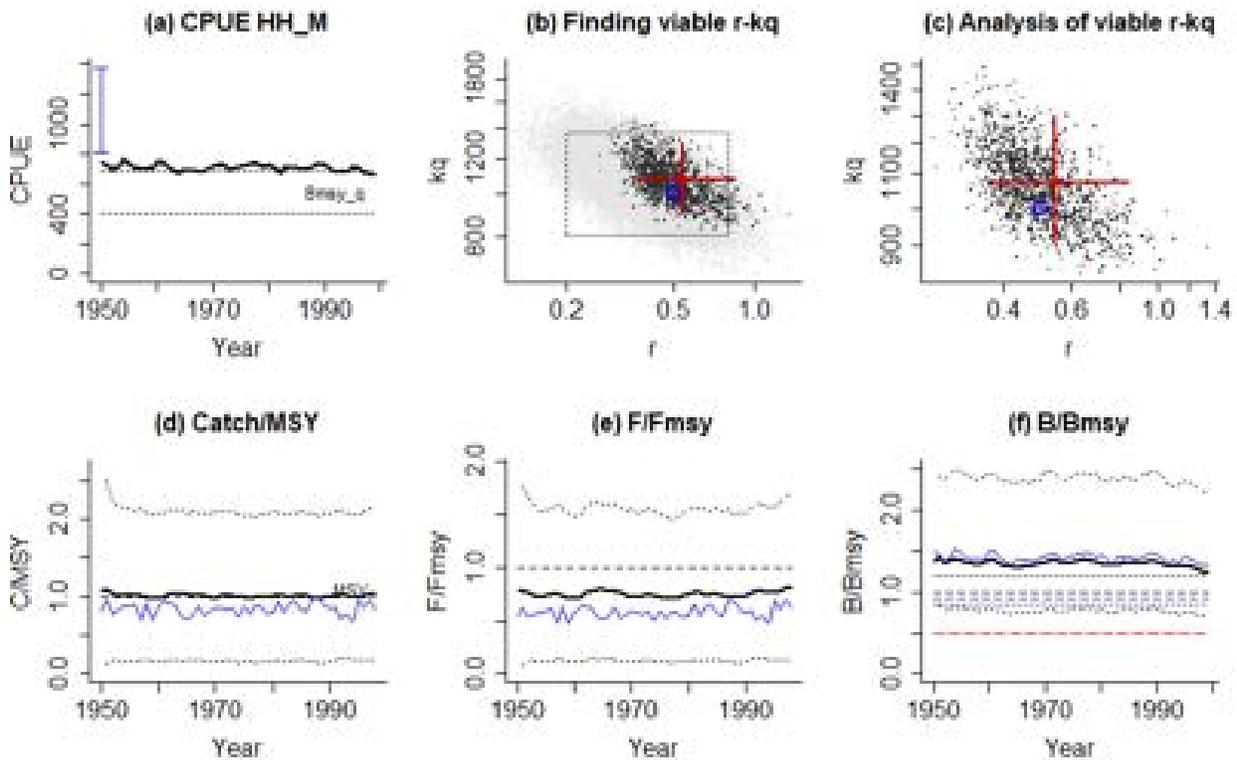
Results:  
 viable  $r$ - $kq$  pairs = 5003  
 median  $kq$  = 1062, 900 - 1298  
 median  $MSYq$  = 95, 55.6 - 177  
 $r$  (4  $MSYq/kq$ ) = 0.358, 0.199 - 0.741  
 $F_{msy}$  ( $r/2$ ) = 0.179, 0.0995 - 0.37  
 $F/F_{msy}$  = 0.889, -0.0313 - 2.15 (1998), true: 0.572  
 $B/B_{msy}$  = 1.31, 0.726 - 2.34 (1999), true: 1.38



Stock **HH\_M**, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 665 - 737, smooth = TRUE  
 Prior for  $r$  = Medium, NA - NA  
 Used prior range for  $r$  = 0.2 - 0.8  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior  $B/B_0$  range = 0.5 - 0.85, prior  $B/B_{msy}$  = 1 - 1.7  
 Used prior range for  $kq$  = 809 - 1375 [original range = 809 - 1375]  
 Comment: True  $r=0.5$ , true  $kq=1000$ , true  $MSYq=125$ , true  $q=0.001$

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
 Viable  $r$ - $kq$  pairs = 5001

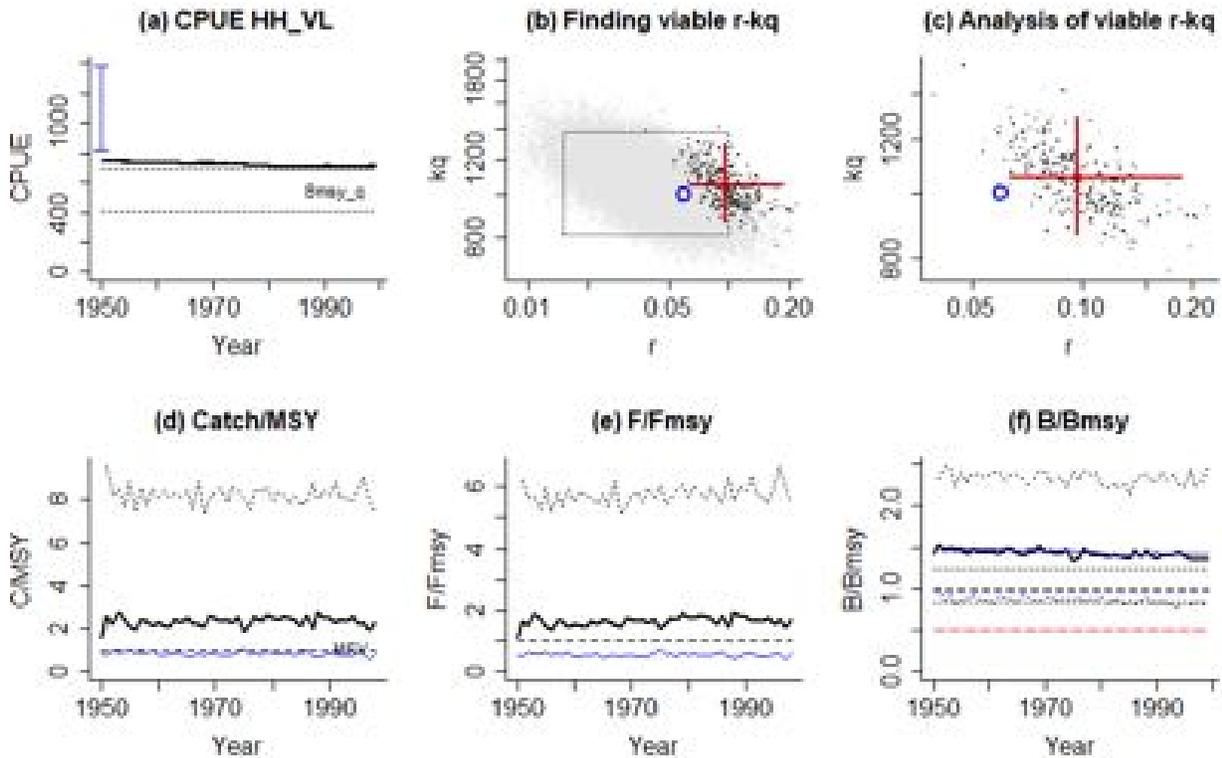
Results:  
 viable  $r$ - $kq$  pairs = 5001  
 median  $kq$  = 1076, 909 - 1299  
 median  $MSYq$  = 146, 103 - 213  
 $r$  (4  $MSYq/kq$ ) = 0.542, 0.364 - 0.838  
 $F_{msy}$  ( $r/2$ ) = 0.271, 0.182 - 0.419  
 $F/F_{msy}$  = 0.817, 0.135 - 1.71 (1998), true: 0.621  
 $B/B_{msy}$  = 1.24, 0.698 - 2.21 (1999), true: 1.32



Stock **HH\_VL**, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 708 - 742, smooth = TRUE  
 Prior for  $r$  = Very low, NA - NA  
 Used prior range for  $r$  = 0.015 - 0.1  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior  $B/B_0$  range = 0.5 - 0.85, prior  $B/B_{msy}$  = 1 - 1.7  
 Used prior range for  $kq$  = 814 - 1385 [original range = 814 - 1385]  
 Comment: True  $r=0.06$ , true  $kq=1000$ , true  $MSYq=15$

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
 Viable  $r$ - $kq$  pairs = 320

Results:  
 viable  $r$ - $kq$  pairs = 320  
 median  $kq$  = 1050, 868 - 1296  
 median  $MSYq$  = 25.4, 17.5 - 43.8  
 $r$  (4  $MSYq/kq$ ) = 0.0969, 0.0631 - 0.186  
 $F_{msy}$  ( $r/2$ ) = 0.0485, 0.0316 - 0.093  
 $F/F_{msy}$  = 1.68, -1.47 - 5.46 (1998), true: 0.61  
 $B/B_{msy}$  = 1.35, 0.752 - 2.46 (1999), true: 1.42

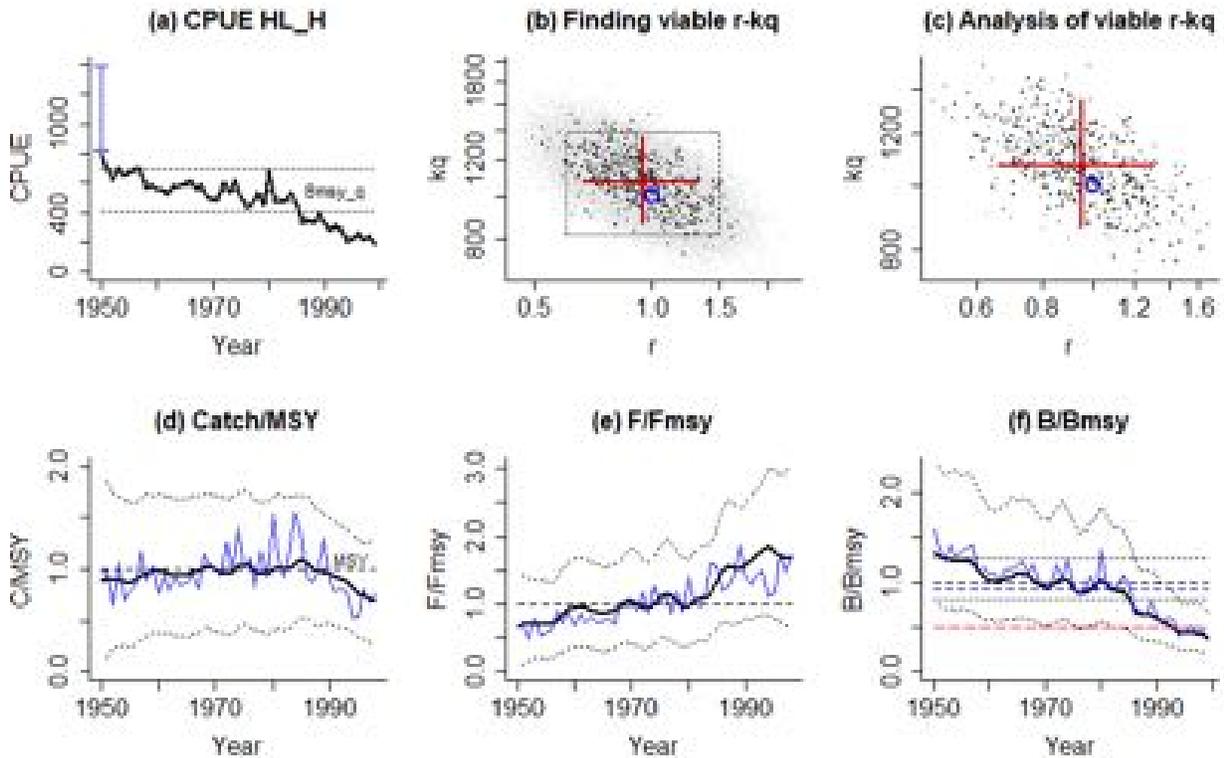


Stock HL\_H, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 204 - 745, smooth = TRUE  
 Prior for r = High, NA - NA  
 Used prior range for r = 0.6 - 1.5  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 818 - 1390 [original range = 818 - 1390]  
 Comment: True r=1.0, true kq=1000, true MSYq=250

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5015

Results:

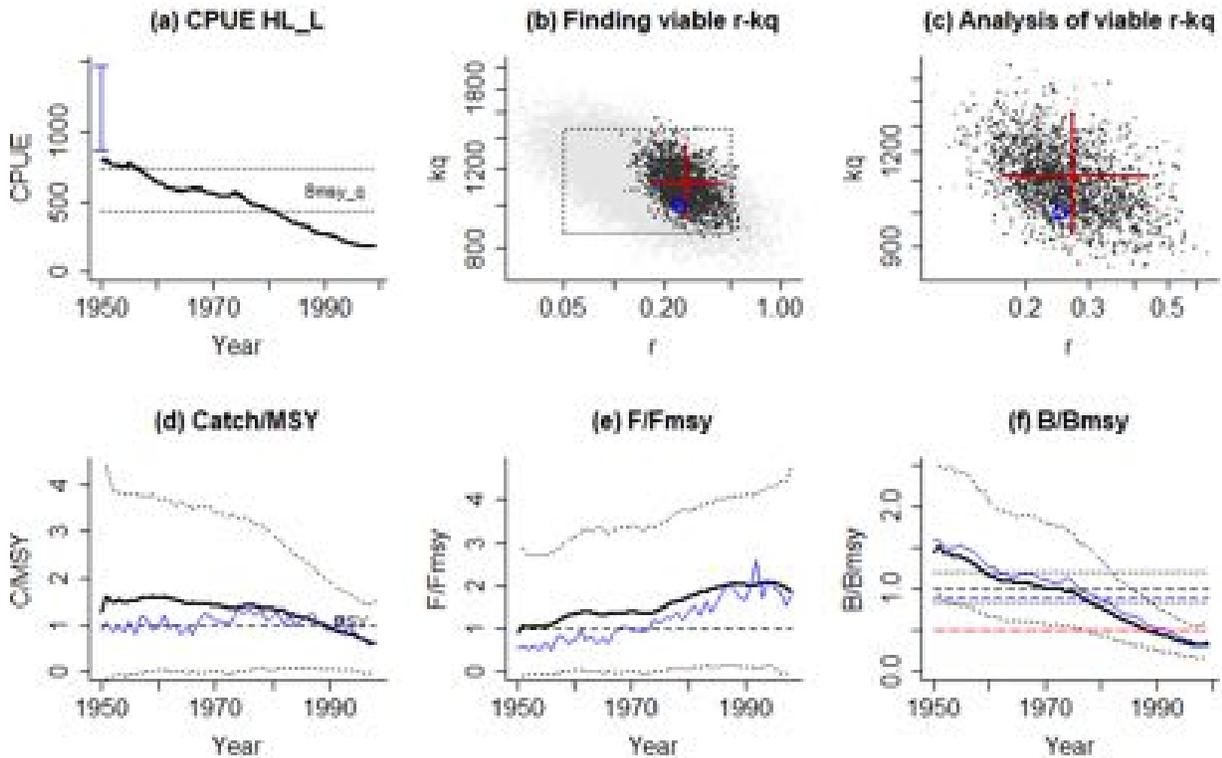
viable r-kq pairs = 5015  
 median kq = 1073, 867 - 1353  
 median MSYq = 256, 189 - 343  
 r (4 MSYq/kq) = 0.953, 0.66 - 1.31  
 Fmsy (r/2) = 0.477, 0.33 - 0.655  
 F/Fmsy = 1.7, 0.706 - 3.03 (1998), true: 1.73  
 B/Bmsy = 0.379, 0.21 - 0.675 (1999), true: 0.36



Stock HL\_L, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 177 - 787, smooth = TRUE  
 Prior for r = Low, NA - NA  
 Used prior range for r = 0.05 - 0.5  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 864 - 1469 [original range = 864 - 1469]  
 Comment: True r=0.25, true kq=1000, true MSYq=62.5

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5001

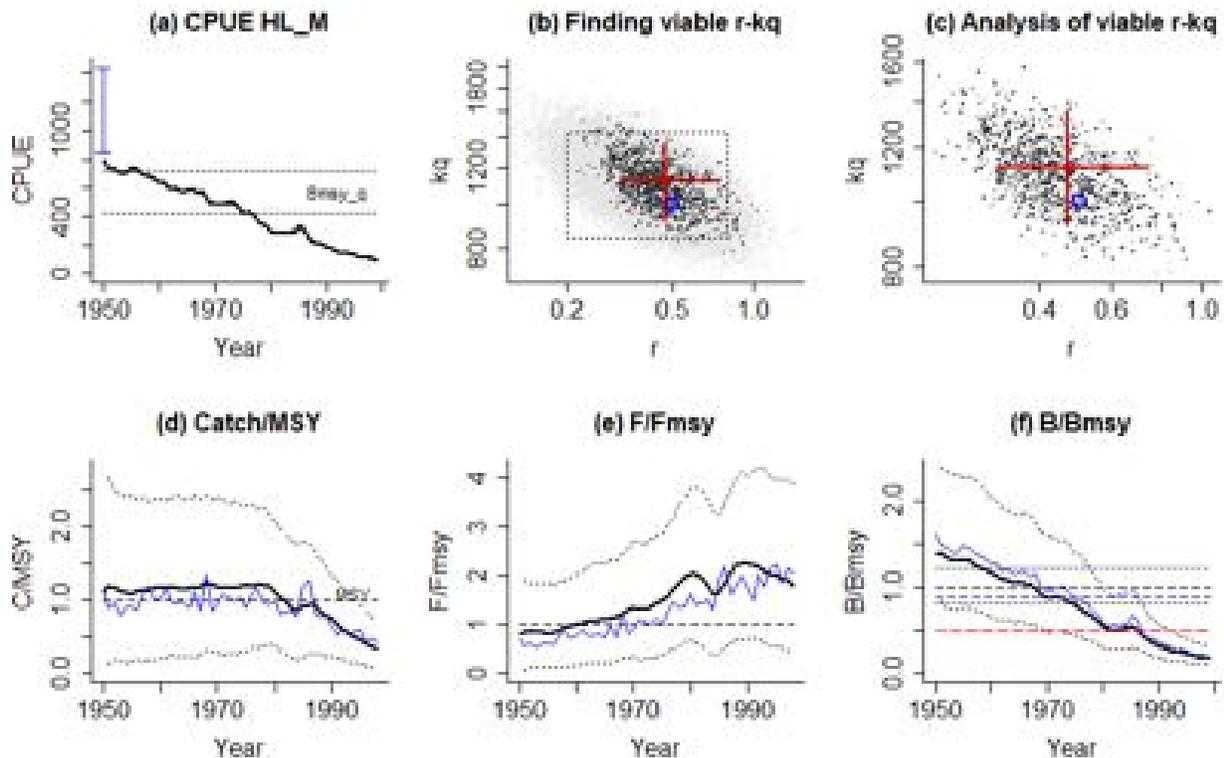
Results:  
 viable r-kq pairs = 5001  
 median kq = 1115, 935 - 1350  
 median MSYq = 75.4, 49.9 - 118  
 r (4 MSYq/kq) = 0.271, 0.172 - 0.438  
 Fmsy (r/2) = 0.135, 0.0859 - 0.219  
 F/Fmsy = 1.85, -0.141 - 4.76 (1998), true: 1.8  
 B/Bmsy = 0.32, 0.177 - 0.56 (1999), true: 0.36



Stock HL\_M, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 101 - 770, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 845 - 1437 [original range = 845 - 1437]  
 Comment: True r=0.5, true kq=1000, true MSYq=125, true q=0.001

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5000

Results:  
 viable r-kq pairs = 5000  
 median kq = 1121, 920 - 1357  
 median MSYq = 131, 90.1 - 195  
 r (4 MSYq/kq) = 0.468, 0.311 - 0.743  
 Fmsy (r/2) = 0.234, 0.155 - 0.371  
 F/Fmsy = 1.8, 0.436 - 3.89 (1998), true: 2.07  
 B/Bmsy = 0.179, 0.1 - 0.328 (1999), true: 0.18

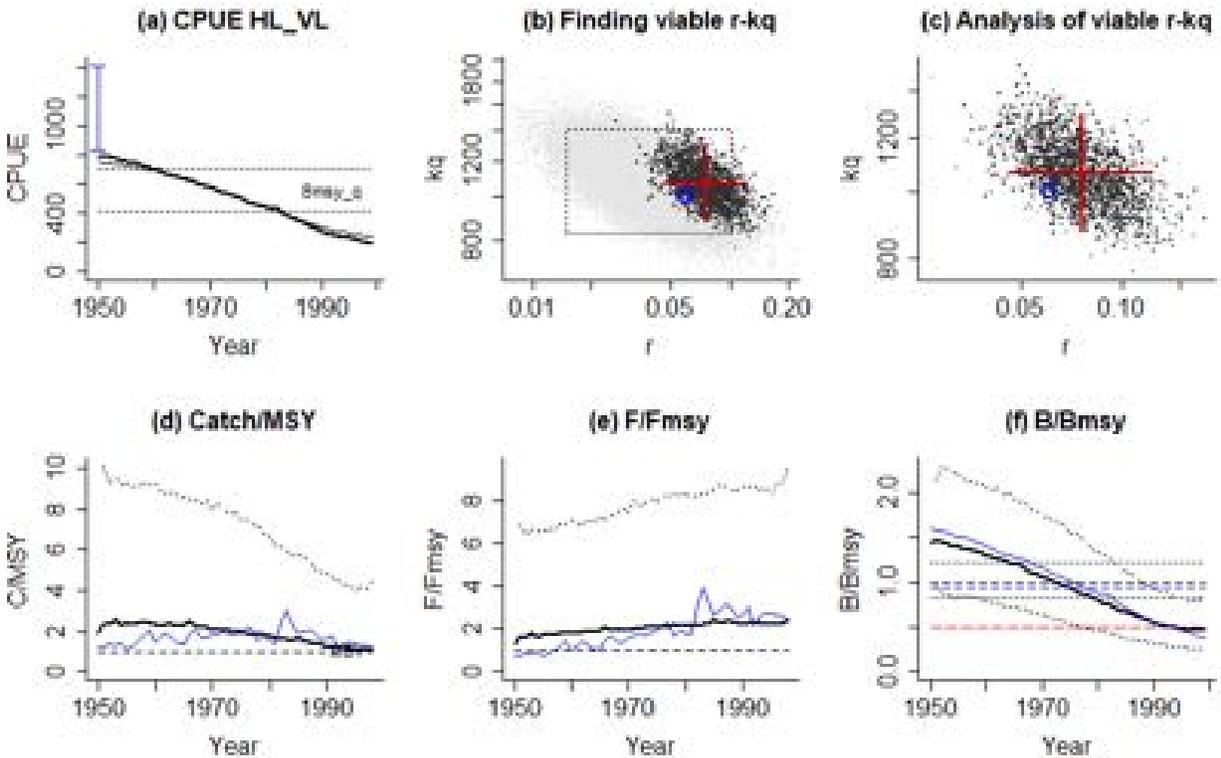


Stock HL\_VL, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 244 - 754, smooth = TRUE  
 Prior for r = Very low, NA - NA  
 Used prior range for r = 0.015 - 0.1  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 828 - 1407 [original range = 828 - 1407]  
 Comment: True r=0.06, true kq=1000, true MSYq=15

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 2549

Results:

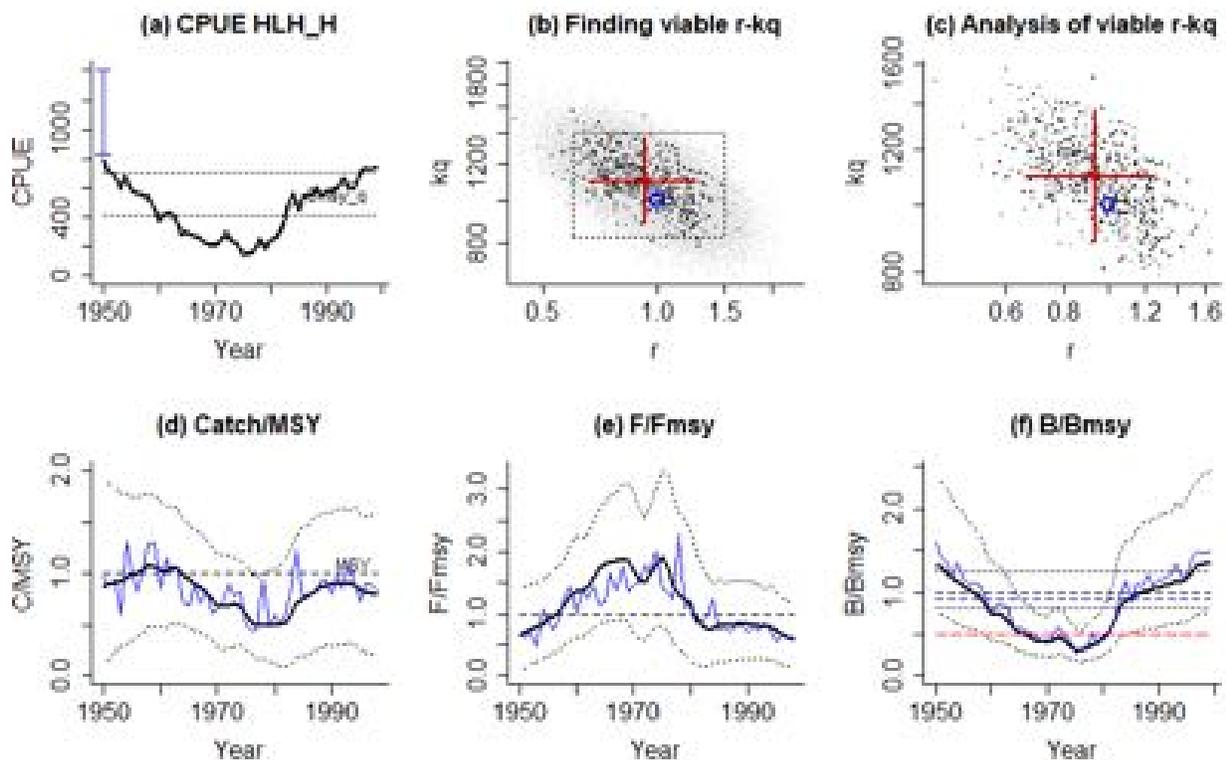
viable r-kq pairs = 2549  
 median kq = 1067, 883 - 1299  
 median MSYq = 20.3, 13.3 - 32.1  
 r (4 MSYq/kq) = 0.076, 0.0453 - 0.124  
 Fmsy (r/2) = 0.038, 0.0226 - 0.0618  
 F/Fmsy = 2.46, -3.32 - 9.57 (1998), true: 2.4  
 B/Bmsy = 0.46, 0.249 - 0.824 (1999), true: 0.38



Stock HLH\_H, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 165 - 753, smooth = TRUE  
 Prior for r = High, NA - NA  
 Used prior range for r = 0.6 - 1.5  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 827 - 1405 [original range = 827 - 1405]  
 Comment: True r=1.0, true kq=1000, true MSYq=250

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5004

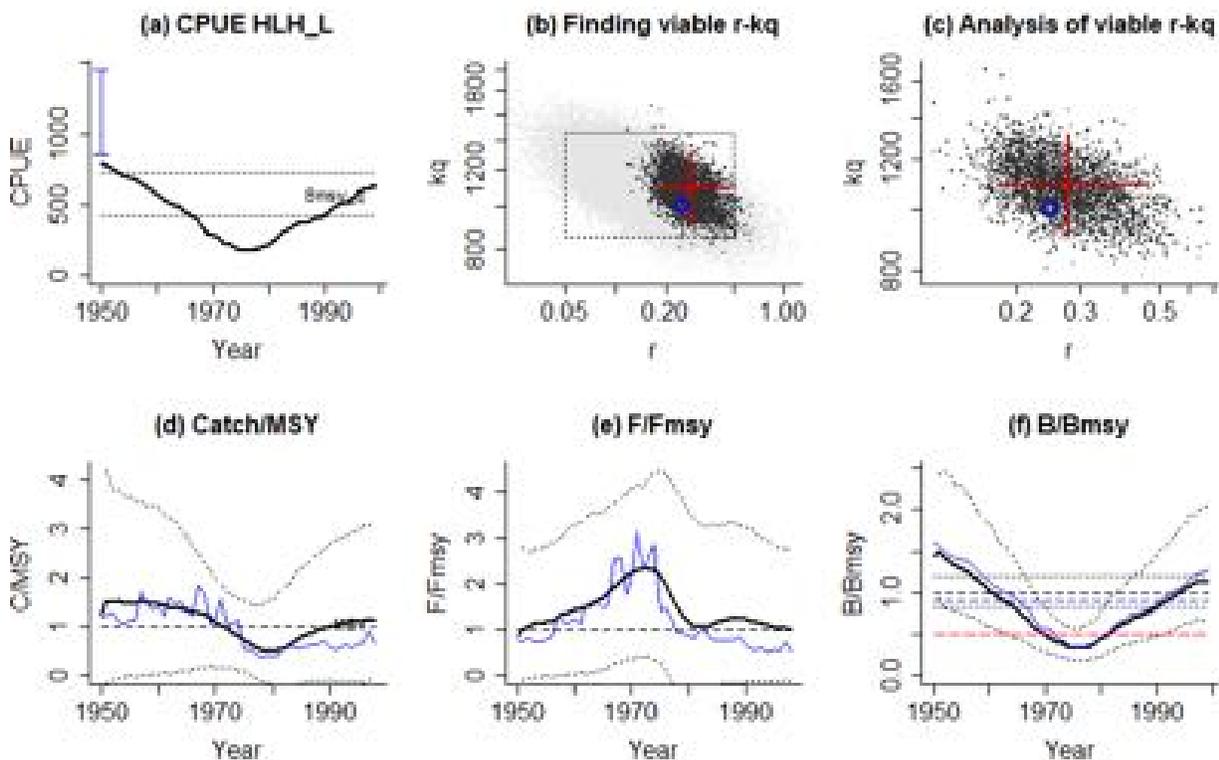
Results:  
 viable r-kq pairs = 5004  
 median kq = 1096, 884 - 1372  
 median MSYq = 256, 189 - 345  
 r (4 MSYq/kq) = 0.933, 0.66 - 1.25  
 Fmsy (r/2) = 0.467, 0.33 - 0.627  
 F/Fmsy = 0.599, 0.141 - 1.18 (1998), true: 0.577  
 B/Bmsy = 1.34, 0.753 - 2.45 (1999), true: 1.5



Stock HLH\_L, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 186 - 777, smooth = TRUE  
 Prior for r = Low, NA - NA  
 Used prior range for r = 0.05 - 0.5  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 852 - 1449 [original range = 852 - 1449]  
 Comment: True r=0.25, true kq=1000, true MSYq=62.5

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5000

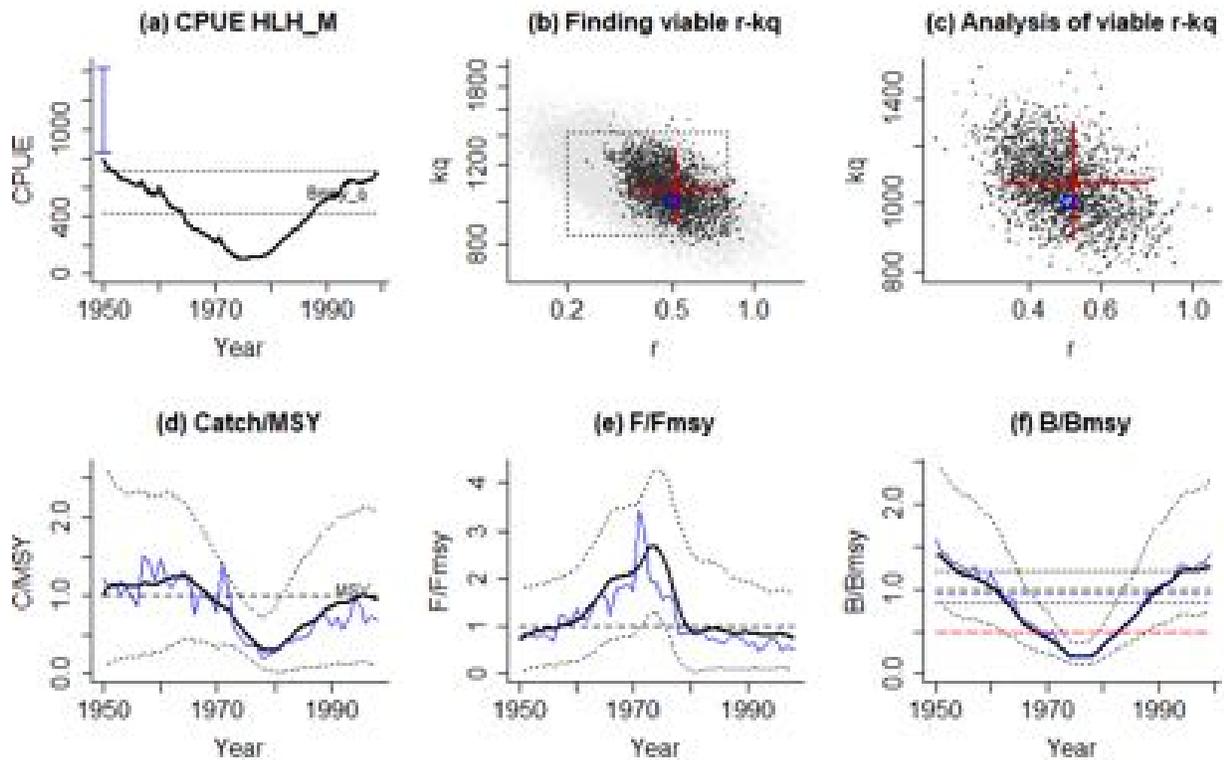
Results:  
 viable r-kq pairs = 5000  
 median kq = 1097, 911 - 1312  
 median MSYq = 76.5, 50.4 - 120  
 r (4 MSYq/kq) = 0.279, 0.18 - 0.462  
 Fmsy (r/2) = 0.139, 0.0899 - 0.231  
 F/Fmsy = 1, -0.12 - 2.82 (1998), true: 0.543  
 B/Bmsy = 1.13, 0.645 - 2.05 (1999), true: 1.28



Stock HLH\_M, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 108 - 760, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for kq = 835 - 1419 [original range = 835 - 1419]  
 Comment: True r=0.5, true kq=1000, true MSYq=125, true q=0.001

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5004

Results:  
 viable r-kq pairs = 5004  
 median kq = 1074, 885 - 1310  
 median MSYq = 137, 95.6 - 193  
 r (4 MSYq/kq) = 0.51, 0.342 - 0.747  
 Fmsy (r/2) = 0.255, 0.171 - 0.373  
 F/Fmsy = 0.765, 0.103 - 1.74 (1998), true: 0.515  
 B/Bmsy = 1.26, 0.699 - 2.31 (1999), true: 1.4

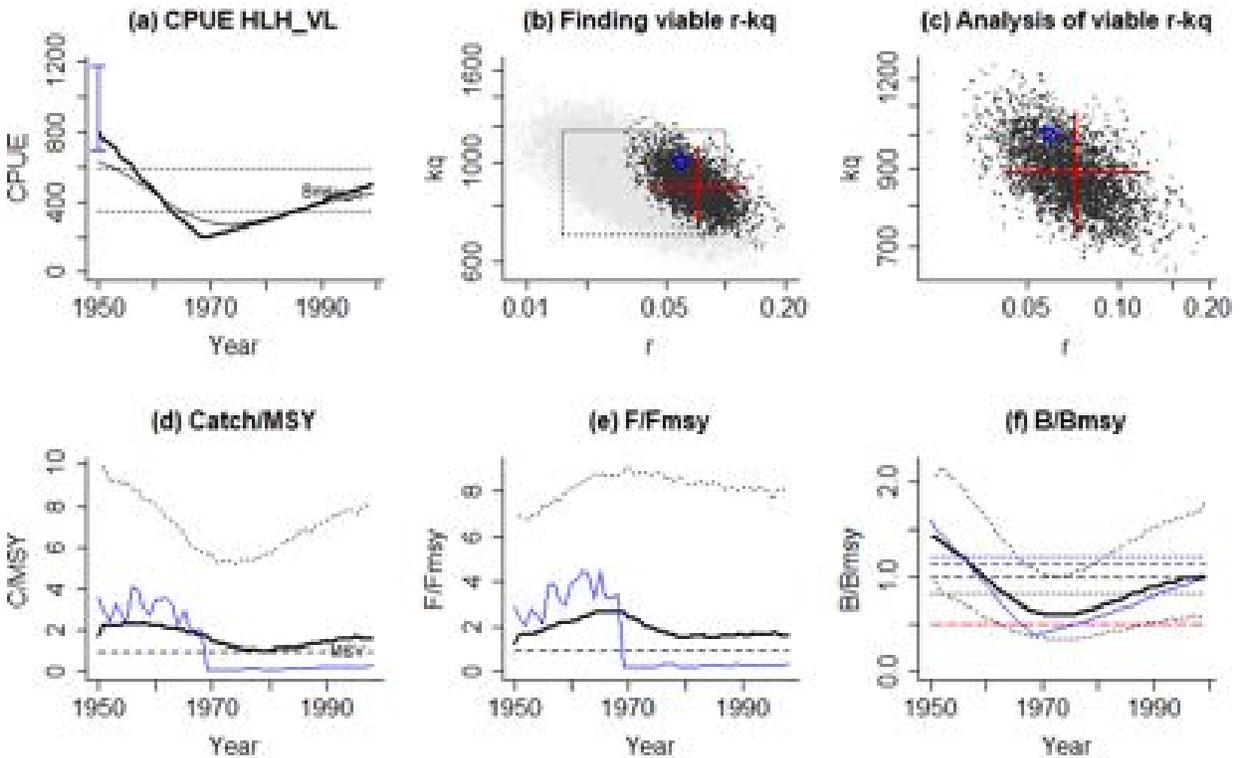


Stock HLH\_VL, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 270 - 631, smooth = TRUE  
 Prior for  $r$  = Very low, NA - NA  
 Used prior range for  $r$  = 0.015 - 0.1  
 Prior for 1950 stock status = More than half, NA - NA  
 Used 1950 prior B/B0 range = 0.5 - 0.85, prior B/Bmsy = 1 - 1.7  
 Used prior range for  $kq$  = 692 - 1176 [original range = 692 - 1176]  
 Comment: True  $r=0.06$ , true  $kq=1000$ , true  $MSYq=15$

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
 Viable  $r$ - $kq$  pairs = 5000

Results:

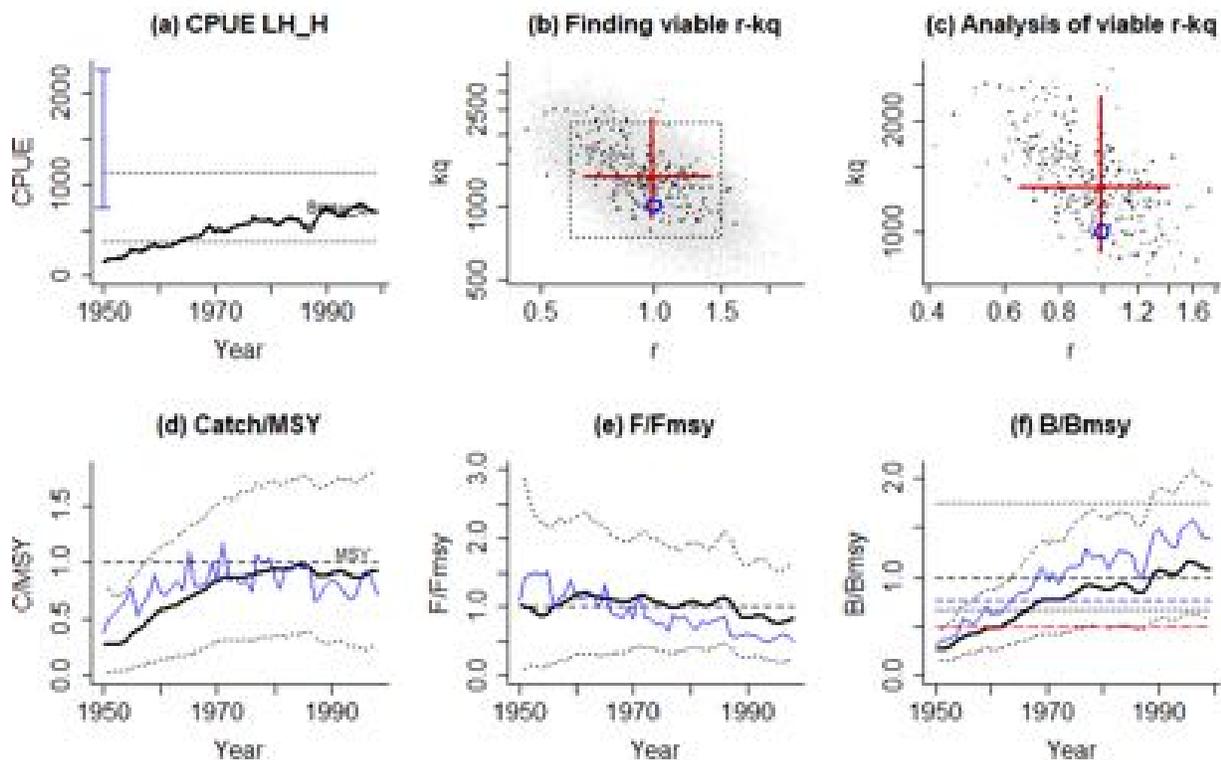
viable  $r$ - $kq$  pairs = 5000  
 median  $kq$  = 883, 735 - 1080  
 median  $MSYq$  = 16, 10.2 - 26  
 $r$  (4  $MSYq/kq$ ) = 0.0725, 0.043 - 0.125  
 $F_{msy}$  ( $r/2$ ) = 0.0363, 0.0215 - 0.0623  
 $F/F_{msy}$  = 1.56, -2.76 - 8.15 (1998), true: 0.374  
 $B/B_{msy}$  = 1, 0.568 - 1.79 (1999), true: 1



Stock LH\_H, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 164 - 761, smooth = TRUE  
 Prior for r = High, NA - NA  
 Used prior range for r = 0.6 - 1.5  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 749 - 2248 [original range = 149 - 2981]  
 Comment: True r=1.0, true kq=1000, true MSYq=250

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5002

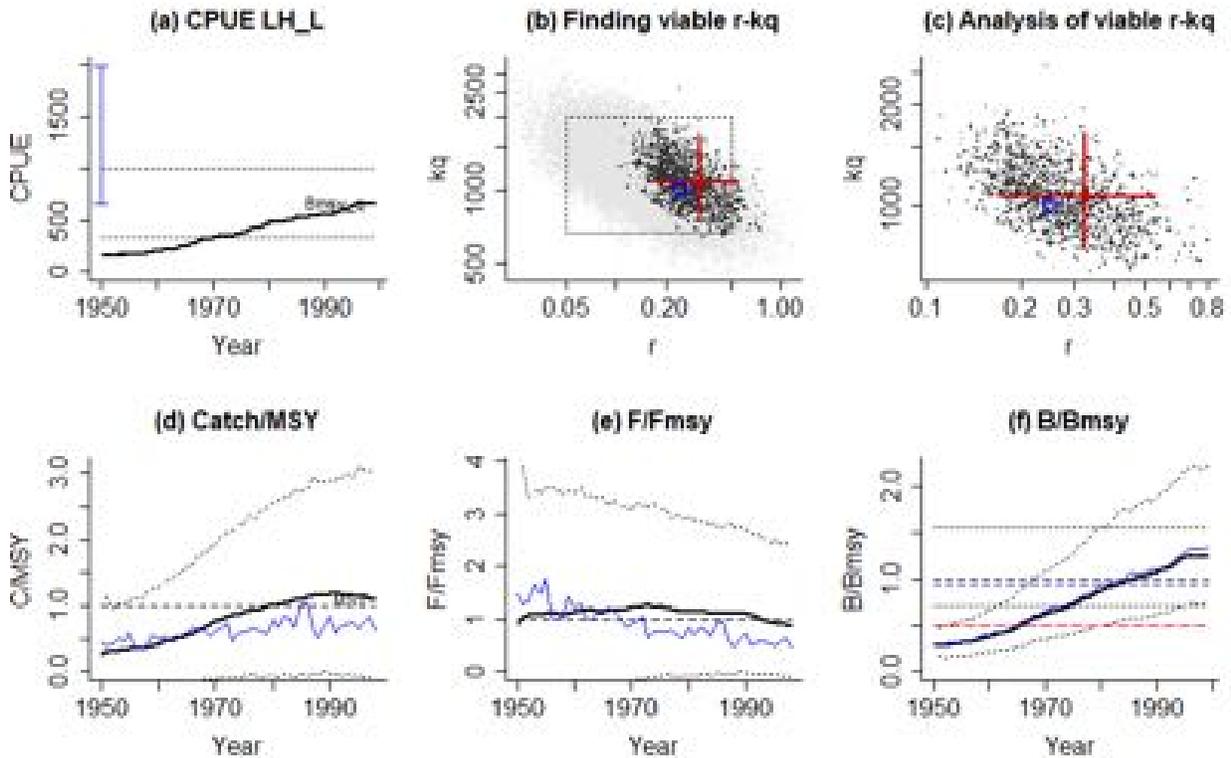
Results:  
 viable r-kq pairs = 5002  
 median kq = 1320, 891 - 2315  
 median MSYq = 327, 225 - 484  
 r (4 MSYq/kq) = 0.99, 0.642 - 1.41  
 Fmsy (r/2) = 0.495, 0.321 - 0.703  
 F/Fmsy = 0.854, 0.238 - 1.67 (1998), true: 0.5  
 B/Bmsy = 1.08, 0.597 - 1.91 (1999), true: 1.4



Stock LH\_L, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 152 - 663, smooth = TRUE  
 Prior for r = Low, NA - NA  
 Used prior range for r = 0.05 - 0.5  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 661 - 1982 [original range = 138 - 2750]  
 Comment: True r=0.25, true kq=1000, true MSYq=62.5

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5001

Results:  
 viable r-kq pairs = 5001  
 median kq = 1068, 763 - 1649  
 median MSYq = 85.9, 49 - 141  
 r (4 MSYq/kq) = 0.322, 0.169 - 0.544  
 Fmsy (r/2) = 0.161, 0.0845 - 0.272  
 F/Fmsy = 0.876, -0.097 - 2.43 (1998), true: 0.48  
 B/Bmsy = 1.23, 0.691 - 2.21 (1999), true: 1.34

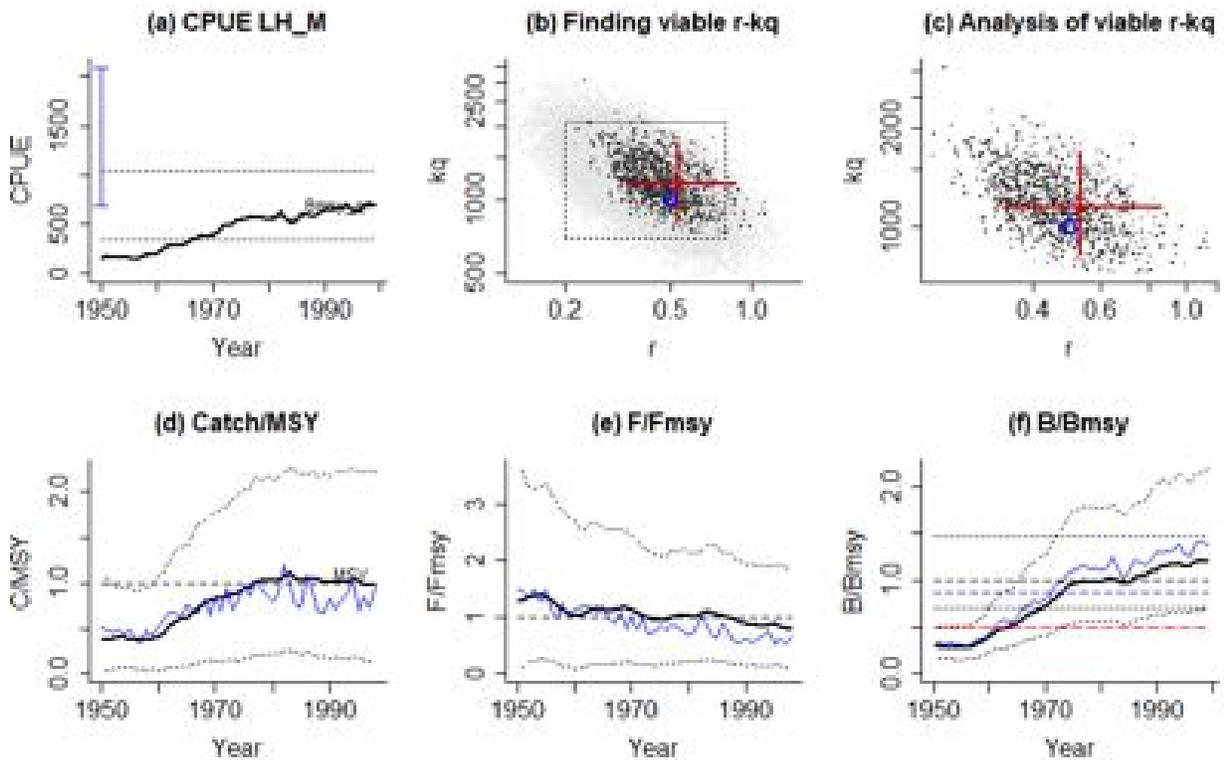


Stock LH\_M, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 159 - 697, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 695 - 2086 [original range = 144 - 2886]  
 Comment: True r=0.5, true kq=1000, true MSYq=125, true q=0.001

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5005

Results:

viable r-kq pairs = 5005  
 median kq = 1154, 826 - 1699  
 median MSYq = 154, 99.9 - 244  
 r (4 MSYq/kq) = 0.533, 0.334 - 0.865  
 Fmsy (r/2) = 0.266, 0.167 - 0.433  
 F/Fmsy = 0.807, 0.111 - 1.83 (1998), true: 0.672  
 B/Bmsy = 1.2, 0.666 - 2.19 (1999), true: 1.38



Stock LH\_VL, , Simulated data

CPUE data for years 1950 - 1999, CPUE range 182 - 555, smooth = TRUE

Prior for  $r$  = Very low, NA - NA

Used prior range for  $r$  = 0.015 - 0.1

Prior for 1950 stock status = Very small, NA - NA

Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4

Used prior range for  $kq$  = 551 - 1654 [original range = 165 - 3305]

Comment: True  $r=0.06$ , true  $kq=1000$ , true  $MSYq=15$

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
 Viable  $r$ - $kq$  pairs = 5003

Results:

viable  $r$ - $kq$  pairs = 5003

median  $kq$  = 1097, 801 - 1604

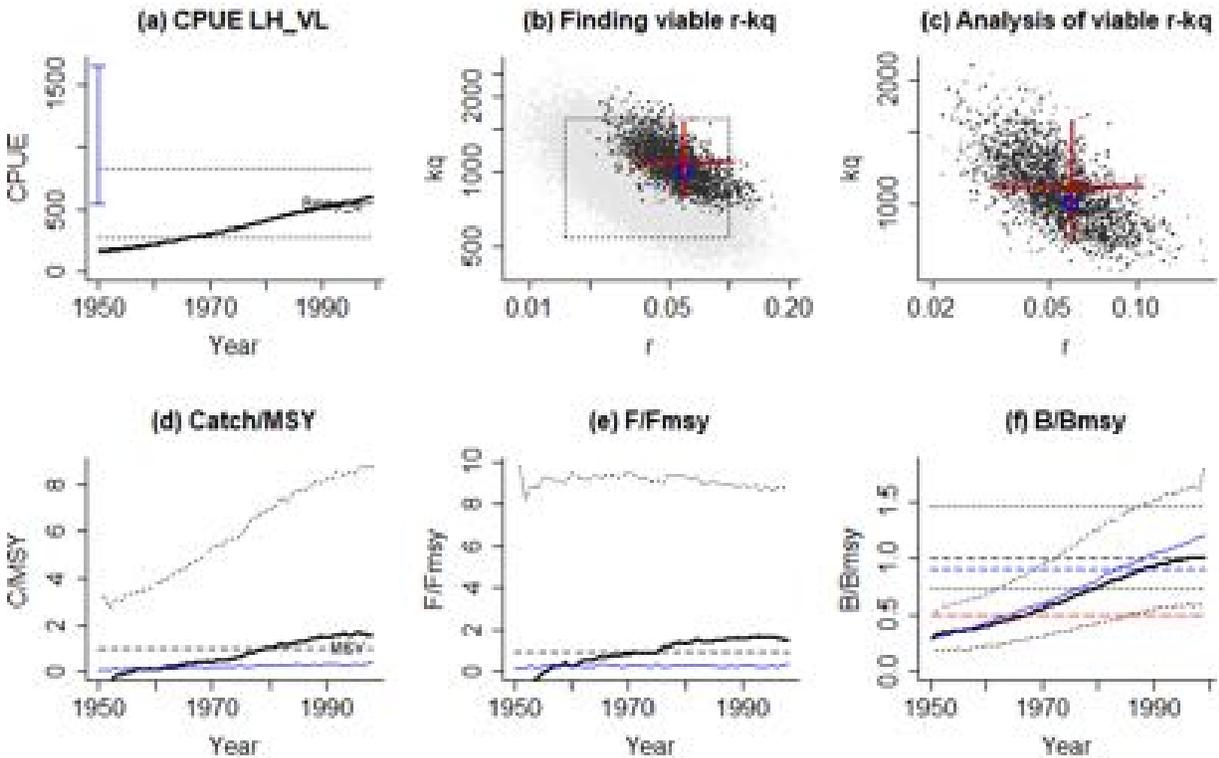
median  $MSYq$  = 16.5, 9.87 - 26.2

$r$  (4  $MSYq/kq$ ) = 0.0601, 0.0321 - 0.105

$F_{msy}$  ( $r/2$ ) = 0.03, 0.0161 - 0.0524

$F/F_{msy}$  = 1.51, -3.51 - 8.75 (1998), true: 0.365

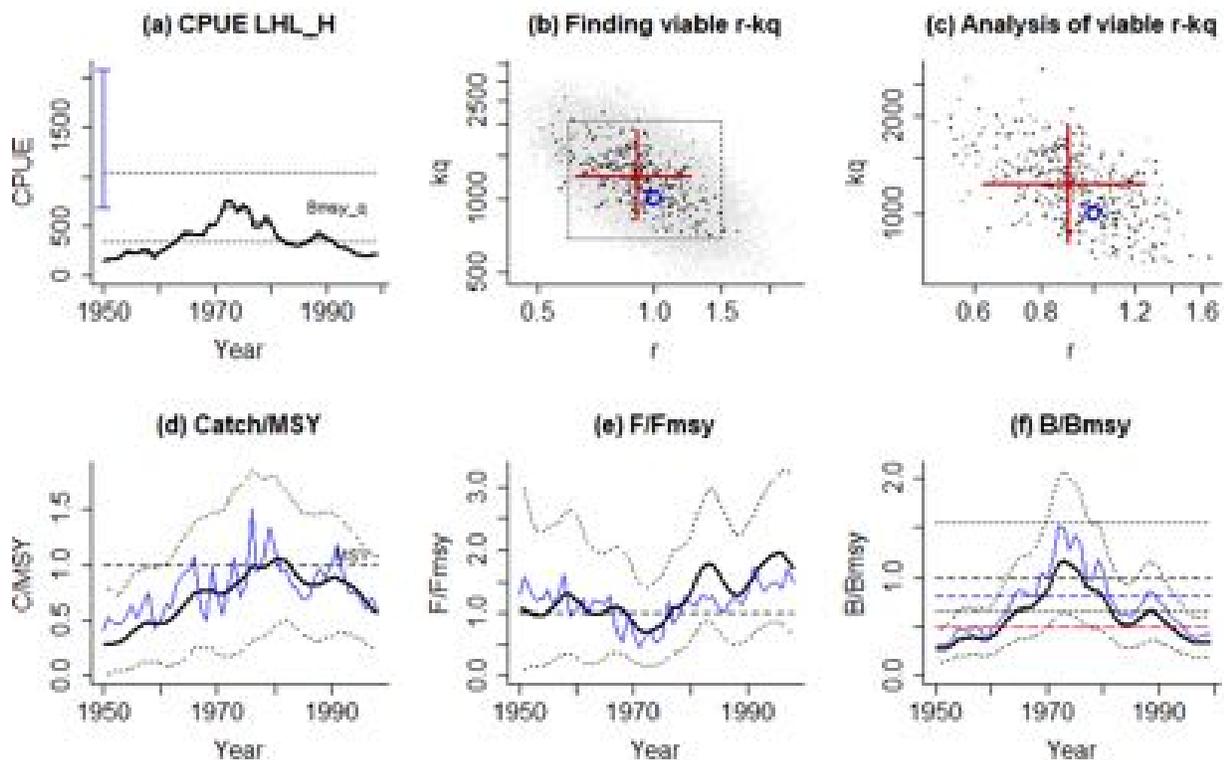
$B/B_{msy}$  = 1.02, 0.56 - 1.82 (1999), true: 1.2



Stock LHL\_H, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 155 - 708, smooth = TRUE  
 Prior for r = High, NA - NA  
 Used prior range for r = 0.6 - 1.5  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 693 - 2079 [original range = 140 - 2807]  
 Comment: True r=1.0, true kq=1000, true MSYq=250

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5000

Results:  
 viable r-kq pairs = 5000  
 median kq = 1224, 813 - 1901  
 median MSYq = 276, 196 - 407  
 r (4 MSYq/kq) = 0.903, 0.623 - 1.25  
 Fmsy (r/2) = 0.451, 0.312 - 0.625  
 F/Fmsy = 1.7, 0.666 - 3.19 (1998), true: 1.49  
 B/Bmsy = 0.339, 0.188 - 0.621 (1999), true: 0.42

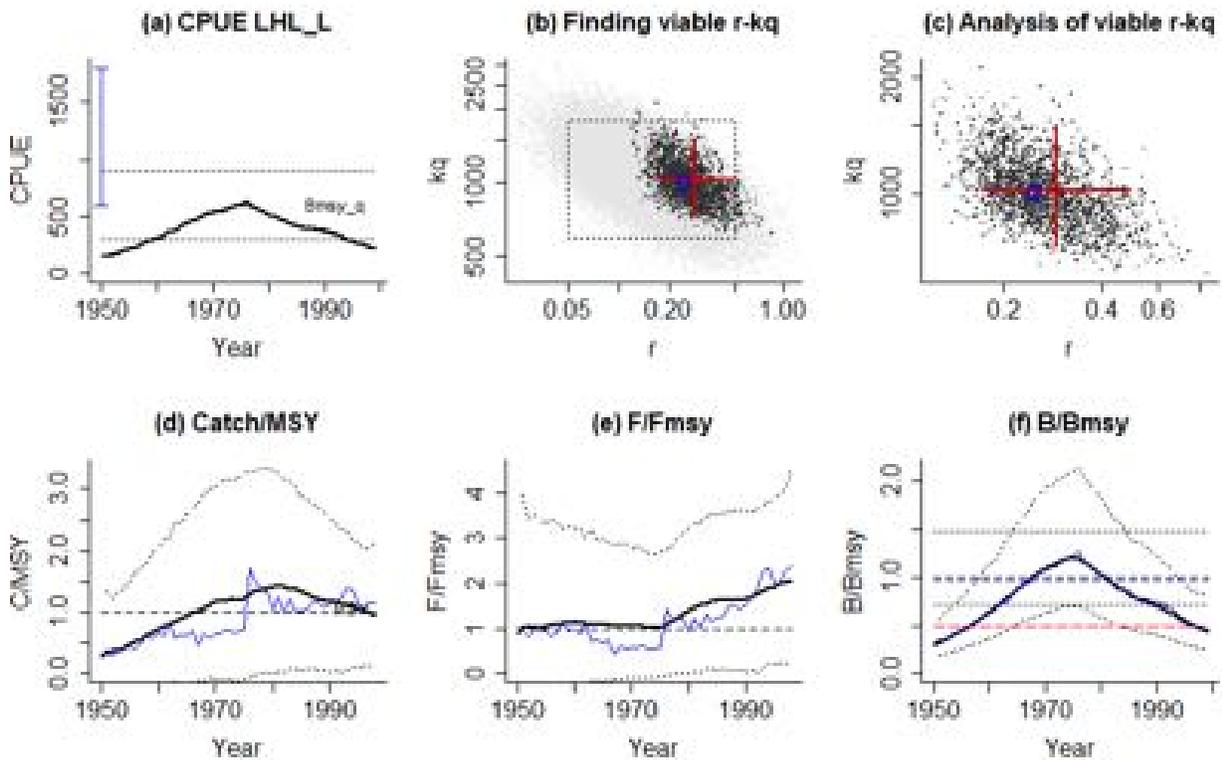


Stock LHL\_L, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 160 - 602, smooth = TRUE  
 Prior for r = Low, NA - NA  
 Used prior range for r = 0.05 - 0.5  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 600 - 1801 [original range = 145 - 2909]  
 Comment: True r=0.25, true kq=1000, true MSYq=62.5

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5001

Results:

viable r-kq pairs = 5001  
 median kq = 1022, 738 - 1509  
 median MSYq = 74, 45.4 - 120  
 r (4 MSYq/kq) = 0.29, 0.171 - 0.489  
 Fmsy (r/2) = 0.145, 0.0855 - 0.245  
 F/Fmsy = 2.03, 0.161 - 4.53 (1998), true: 2.38  
 B/Bmsy = 0.457, 0.251 - 0.811 (1999), true: 0.42

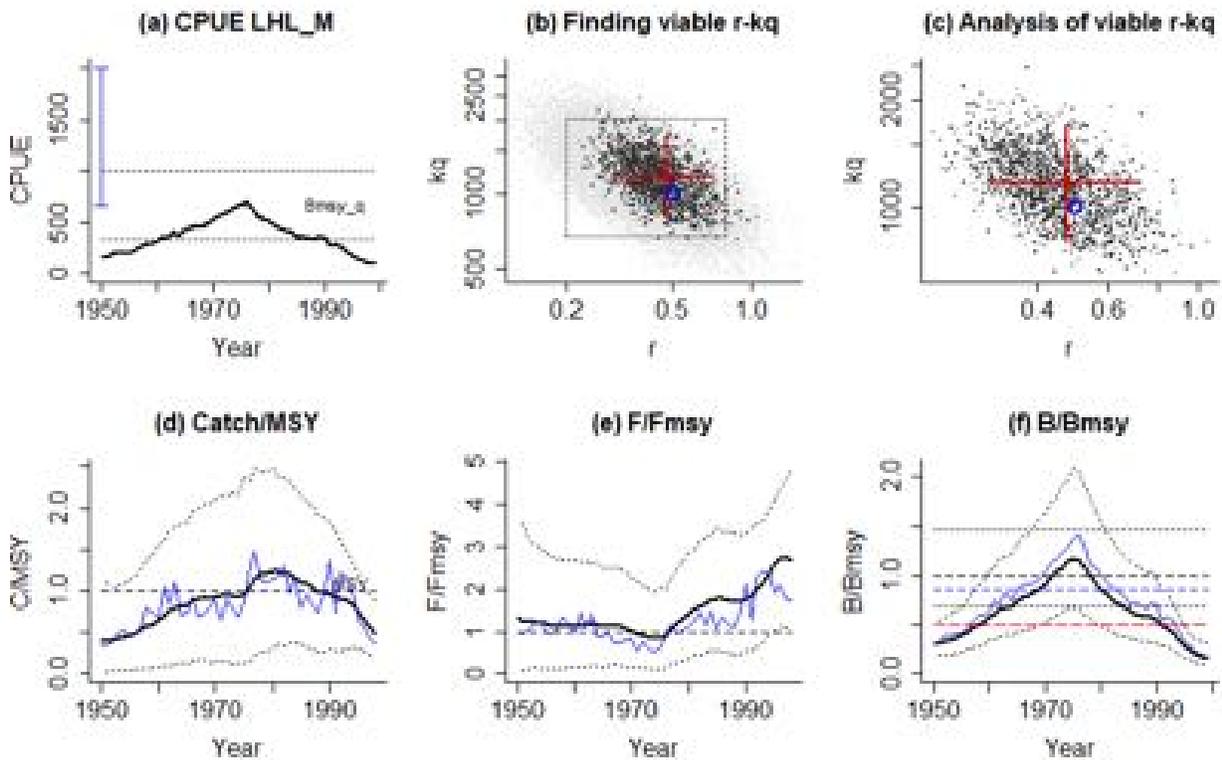


Stock LHL\_M, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 96.7 - 669, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 668 - 2005 [original range = 144 - 2875]  
 Comment: True r=0.5, true kq=1000, true MSYq=125, true q=0.001

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5002

Results:

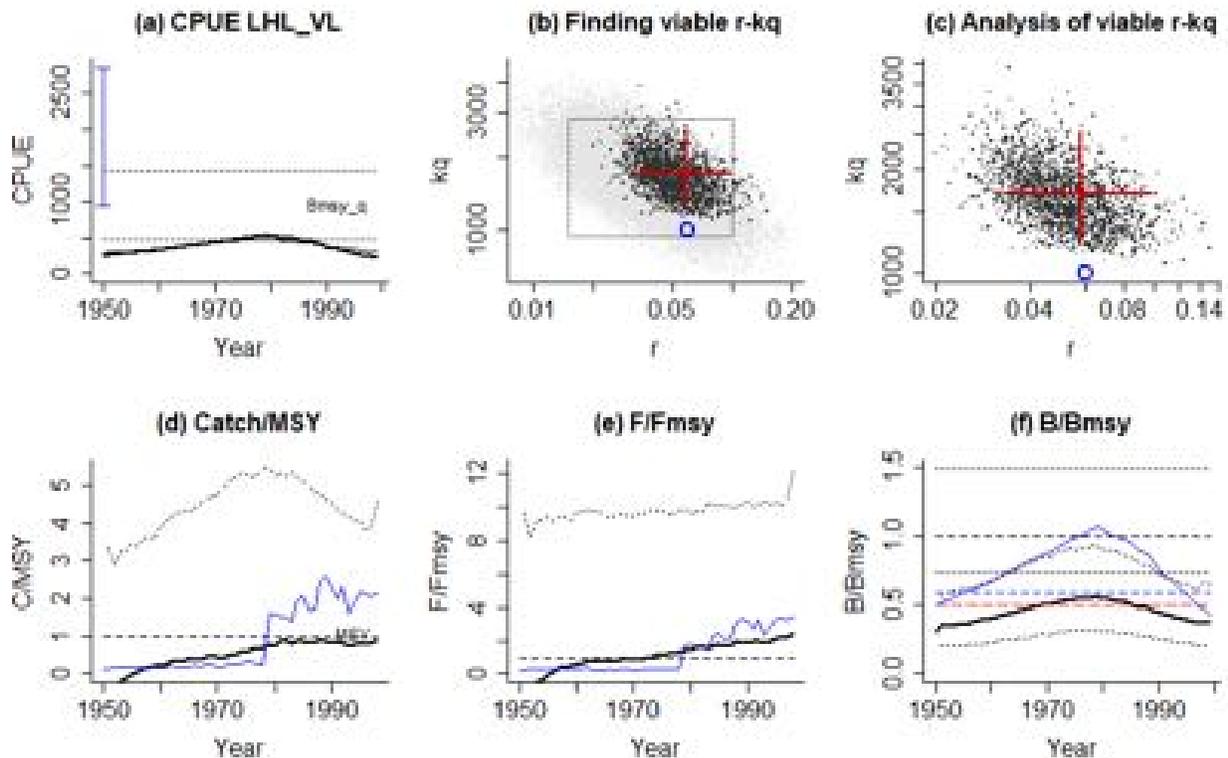
viable r-kq pairs = 5002  
 median kq = 1165, 803 - 1703  
 median MSYq = 138, 90.2 - 211  
 r (4 MSYq/kq) = 0.473, 0.307 - 0.714  
 Fmsy (r/2) = 0.236, 0.153 - 0.357  
 F/Fmsy = 2.66, 1.05 - 4.83 (1998), true: 1.74  
 B/Bmsy = 0.165, 0.0921 - 0.302 (1999), true: 0.18



Stock LHL\_VL, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 293 - 475, smooth = TRUE  
 Prior for r = Very low, NA - NA  
 Used prior range for r = 0.015 - 0.1  
 Prior for 1950 stock status = Very small, NA - NA  
 Used 1950 prior B/B0 range = 0.01 - 0.2, prior B/Bmsy = 0.02 - 0.4  
 Used prior range for kq = 949 - 2848 [original range = 266 - 5322]  
 Comment: True r=0.06, true kq=1000, true MSYq=15

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5001

Results:  
 viable r-kq pairs = 5001  
 median kq = 1687, 1238 - 2509  
 median MSYq = 24.5, 14.2 - 40.1  
 r (4 MSYq/kq) = 0.0581, 0.0326 - 0.0978  
 Fmsy (r/2) = 0.0291, 0.0163 - 0.0489  
 F/Fmsy = 2.42, -4.96 - 12.3 (1998), true: 3.41  
 B/Bmsy = 0.366, 0.202 - 0.654 (1999), true: 0.42

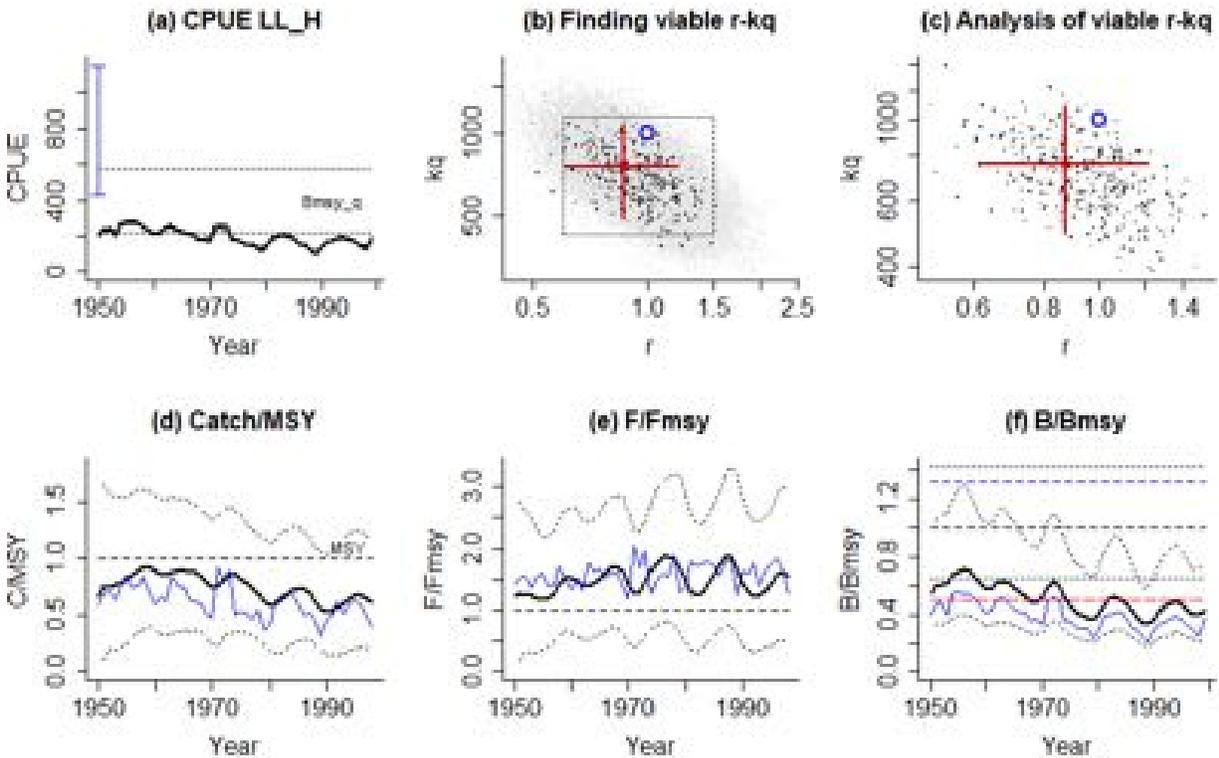


Stock LL\_H, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 125 - 272, smooth = TRUE  
 Prior for r = High, NA - NA  
 Used prior range for r = 0.6 - 1.5  
 Prior for 1950 stock status = Small, NA - NA  
 Used 1950 prior B/B0 range = 0.15 - 0.4, prior B/Bmsy = 0.3 - 0.8  
 Used prior range for kq = 431 - 1149 [original range = 431 - 1149]  
 Comment: True r=1.0, true kq=1000, true MSYq=250

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5013

Results:

viable r-kq pairs = 5013  
 median kq = 759, 491 - 1084  
 median MSYq = 165, 115 - 244  
 r (4 MSYq/kq) = 0.869, 0.613 - 1.21  
 Fmsy (r/2) = 0.434, 0.307 - 0.607  
 F/Fmsy = 1.54, 0.472 - 2.91 (1998), true: 1.29  
 B/Bmsy = 0.424, 0.242 - 0.769 (1999), true: 0.38

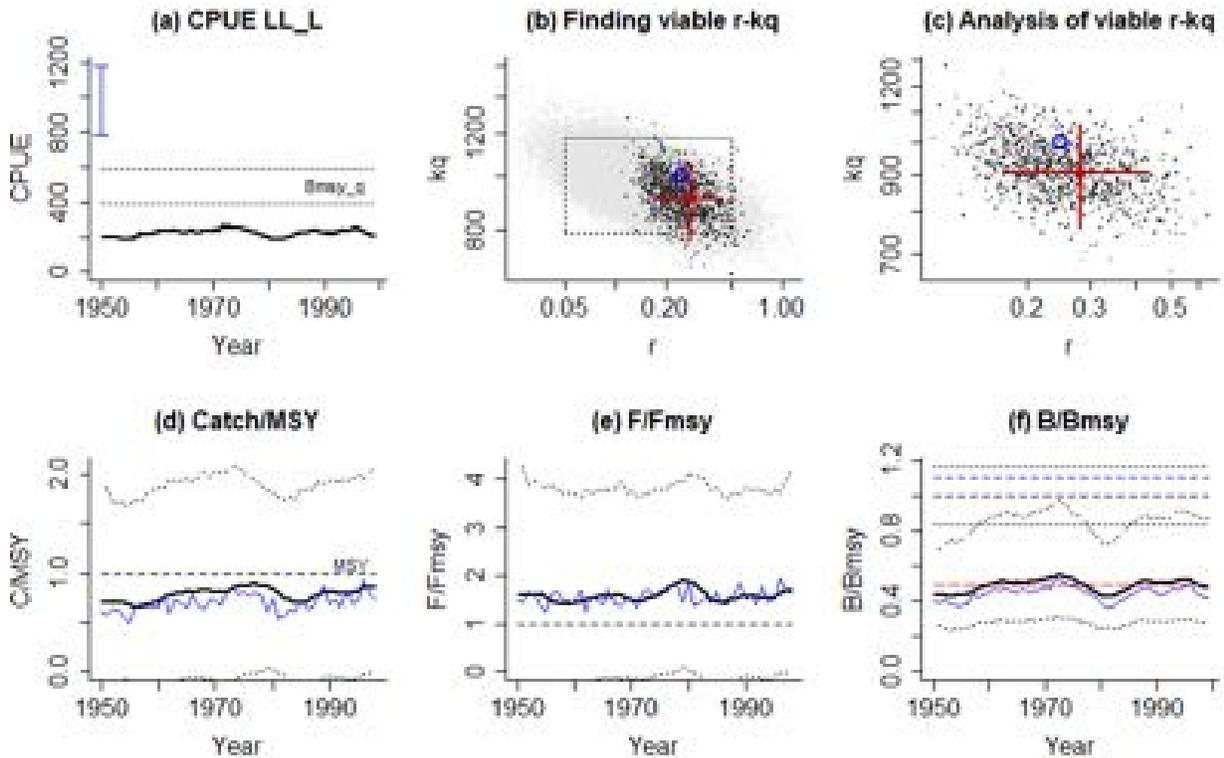


Stock LL\_L, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 195 - 254, smooth = TRUE  
 Prior for r = Low, NA - NA  
 Used prior range for r = 0.05 - 0.5  
 Prior for 1950 stock status = Small, NA - NA  
 Used 1950 prior B/B0 range = 0.15 - 0.4, prior B/Bmsy = 0.3 - 0.8  
 Used prior range for kq = 787 - 1180 [original range = 393 - 1049]  
 Comment: True r=0.25, true kq=1000, true MSYq=62.5

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5002

Results:

viable r-kq pairs = 5002  
 median kq = 906, 761 - 1060  
 median MSYq = 63.7, 40.3 - 96.7  
 r (4 MSYq/kq) = 0.282, 0.171 - 0.438  
 Fmsy (r/2) = 0.141, 0.0857 - 0.219  
 F/Fmsy = 1.73, -0.06 - 4.2 (1998), true: 1.65  
 B/Bmsy = 0.481, 0.264 - 0.871 (1999), true: 0.42

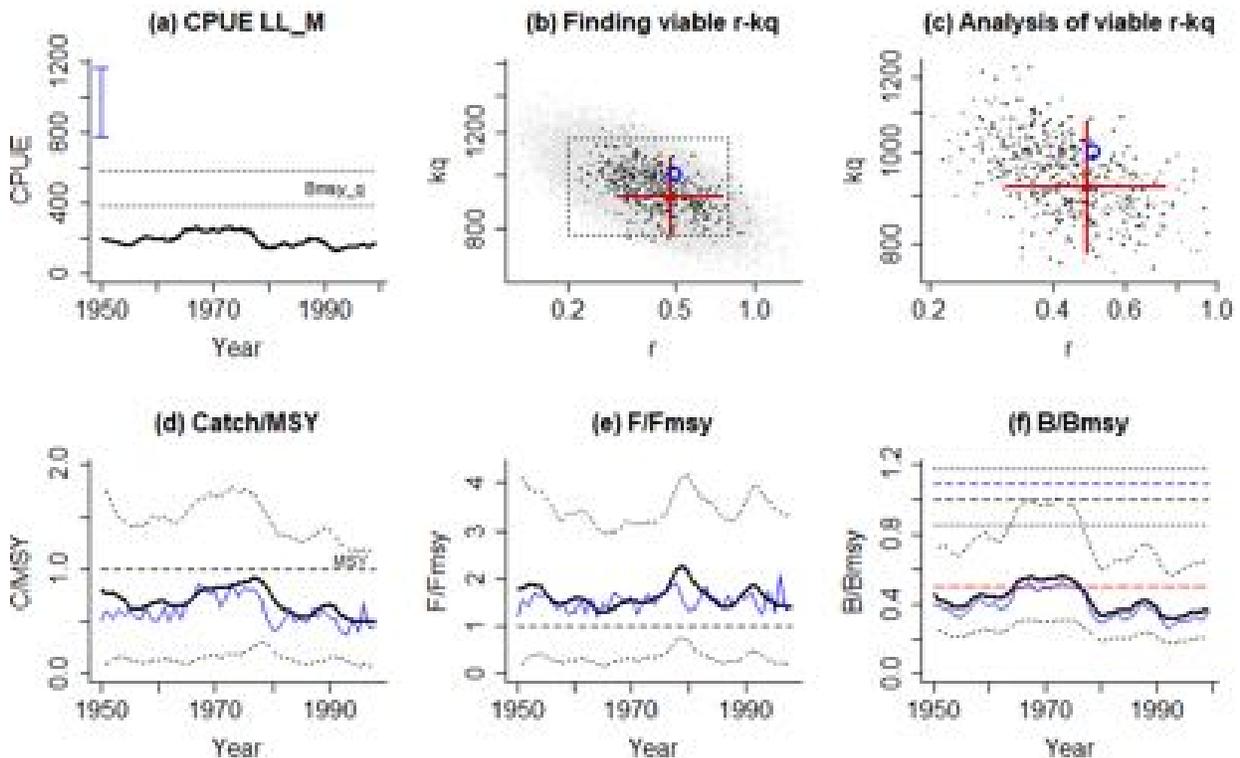


Stock LL\_M, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 144 - 257, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 1950 stock status = Small, NA - NA  
 Used 1950 prior B/B0 range = 0.15 - 0.4, prior B/Bmsy = 0.3 - 0.8  
 Used prior range for kq = 779 - 1168 [original range = 389 - 1038]  
 Comment: True r=0.5, true kq=1000, true MSYq=125, true q=0.001

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5003

Results:

viable r-kq pairs = 5003  
 median kq = 919, 784 - 1081  
 median MSYq = 111, 74 - 169  
 r (4 MSYq/kq) = 0.483, 0.306 - 0.752  
 Fmsy (r/2) = 0.241, 0.153 - 0.376  
 F/Fmsy = 1.4, 0.217 - 3.41 (1998), true: 1.38  
 B/Bmsy = 0.364, 0.203 - 0.65 (1999), true: 0.36

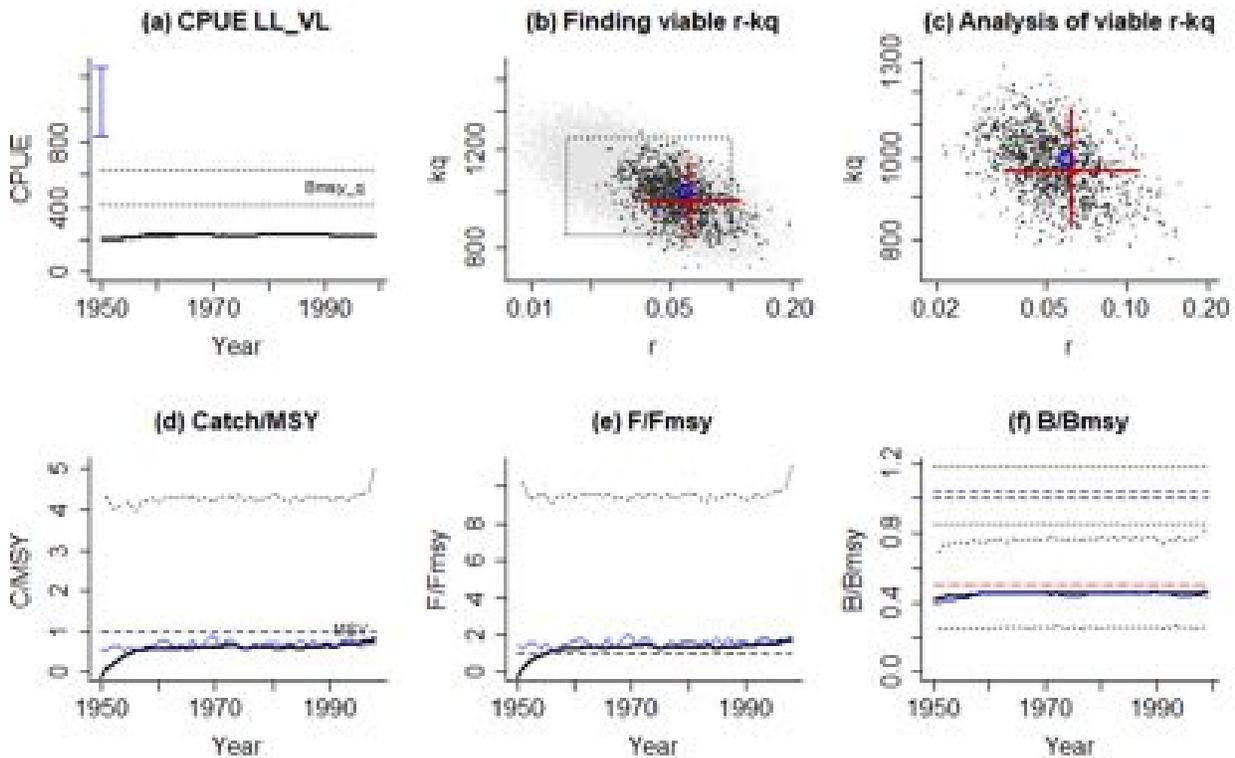


Stock LL\_VL, , Simulated data  
 CPUE data for years 1950 - 1999, CPUE range 212 - 226, smooth = TRUE  
 Prior for r = Very low, NA - NA  
 Used prior range for r = 0.015 - 0.1  
 Prior for 1950 stock status = Small, NA - NA  
 Used 1950 prior B/B0 range = 0.15 - 0.4, prior B/Bmsy = 0.3 - 0.8  
 Used prior range for kq = 840 - 1260 [original range = 420 - 1120]  
 Comment: True r=0.06, true kq=1000, true MSYq=15

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5000

Results:

viable r-kq pairs = 5000  
 median kq = 967, 829 - 1141  
 median MSYq = 15.2, 8.99 - 25.9  
 r (4 MSYq/kq) = 0.063, 0.0356 - 0.111  
 Fmsy (r/2) = 0.0315, 0.0178 - 0.0554  
 F/Fmsy = 1.85, -5.19 - 11 (1998), true: 1.66  
 B/Bmsy = 0.456, 0.255 - 0.84 (1999), true: 0.44



### 3. Stocks and species for which AMSY provides the first assessment

This section presents details of the first MSY-level stock assessments for 38 stocks comprising 35 species. For 23 species, these are the first assessments globally. For all stocks, length frequencies were analyzed with the LBB method (Froese *et al.*, 2018, 2019) to obtain priors for relative stock size  $B/B_0$  in a given year. These priors were then used in the analysis of cpue data obtained from research surveys with the AMSY method presented in this study. R-code and data mentioned below are available as part of the material available at the link indicated on the first page of this document.

Length frequencies and cpue in numbers by length and area for the Adriatic Sea and Cyprus were obtained from the Mediterranean and Black Sea data call - 2018, after explicit request to the DCF national correspondents. (<https://datacollection.jrc.ec.europa.eu/dc/medbs>)

Length frequencies and cpue in  $\text{kg km}^{-2}$  by area for the Aegean Sea were obtained from the MEDITS bottom trawl survey (MEDITS Working Group, 2012).

Length frequencies and cpue in  $\text{kg h}^{-1}$  by length and area for the North Sea were obtained from the GNSIntOT3 survey as standardized in Greenstreet and Moriarty (2018). The data were aggregated with R-code SMFS\_kg2B\_4.R.

Length frequencies and cpue in numbers by length and area for the Baltic Sea were obtained from the BITS survey in DATRAS ([https://datras.ices.dk/Data\\_products/Download/Download\\_Data\\_public.aspx](https://datras.ices.dk/Data_products/Download/Download_Data_public.aspx)), accessed in April 2019. The data were aggregated and transformed from numbers to weight with R-code Nh2kghAr\_3.R.

Stocks are arranged alphabetically by regions and by stock acronyms with region.

#### References

- Froese, R., Winker, H., Coro, G., Demirel, N., Tsikliras, A. C., Dimarchopoulou, D., Scarcella, G., *et al.* 2018. A new approach for estimating stock status from length frequency data. ICES Journal of Marine Science, 75(6): 2004–2015.
- Froese, R., Winker, H., Coro, G., Demirel, N., Tsikliras, A. C., Dimarchopoulou, D., Scarcella, G., *et al.* 2019. On the pile-up effect and priors for  $L_{inf}$  and  $M/K$ : response to a comment by Hordyk *et al.* on “A new approach for estimating stock status from length frequency data”. ICES Journal of Marine Science, 76(2): 461–465.
- Greenstreet, S. P. R., and Moriarty, M. 2018. Manual for Version 3 of the Groundfish Survey Monitoring and Assessment Data Product. Scottish Government, Scottish Marine and Freshwater Science Report, Volume 8, No. 18. 77 pp.
- MEDITS Working Group. 2012. MEDITS. International bottom trawl survey in the Mediterranean. Instruction manual. Version 6. MEDITS-Handbook. Revision n.6, April 2012, MEDITS Working Group. <https://archimer.ifremer.fr/doc/00117/22783/>

## Adriatic Sea

LBB results for *Illex coindettii*, stock Ille\_coi\_AD, 1996-2016  
Files: LBB4AMSY\_ID\_2.csv, Ille\_coi\_AD.csv

Linf prior = 23, SD = 0.23 cm (user-defined), Lmax = 23.5, median Lmax = 20.5  
Z/K prior = 3.2, SD = 0.12, M/K prior = 1.5, SD = 0.15  
F/K prior = 1.71 (wide range with tau = 4 in log-normal distribution)  
Lc prior = 5.1, SD = 0.51 cm, alpha prior = 42, SD = 4.2, Lm50 = 16 cm

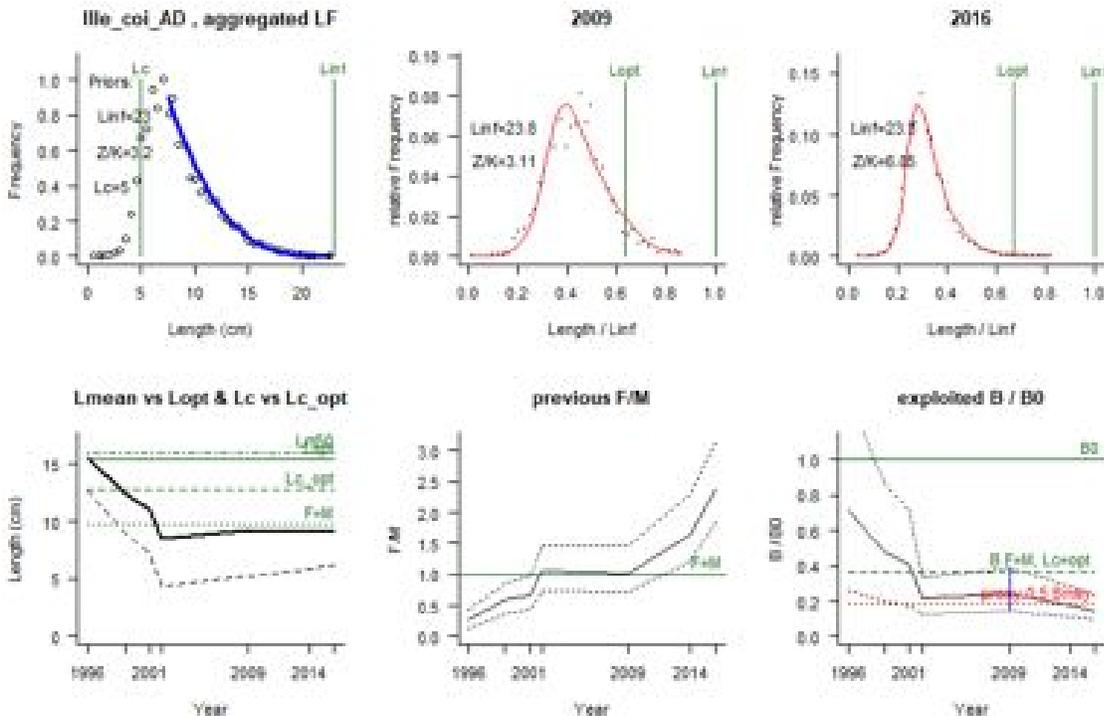
General reference points (median across years):

Linf = 23.3 (22.8-23.6) cm  
Lopt = 15 cm, Lopt/Linf = 0.66  
Lc\_opt = 13 cm, Lc\_opt/Linf = 0.55, Lmean if F=M 9.75 cm  
M/K = 1.52 (1.29-1.79)  
F/M = 0.92 (0.611-1.3), F/K = 1.49 (1.12-1.79), Z/K = 3.14 (2.95-3.36)  
B/B0 = 0.26 (0.14-0.38), B/B0 F=M Lc=Lc\_opt 0.37  
Y/R' = 0.017 (0.011-0.033), Y/R' F=M Lc=Lc\_opt 0.045

Estimates for 2016 (mean of last 3 years with data):

Lc50 = 6.21 (6.1-6.33) cm, Lc/Linf = 0.27 (0.26-0.27)  
Lc95 = 8.26, alpha = 1.44 (1.38-1.49)  
Lmean/Lopt = 0.6, Lc/Lc\_opt = 0.49, L95th = 19.5 cm, L95th/Linf = 0.84, Mature = 0.34%  
F/M = 2.4 (1.8-3.2), F/K = 3.5 (3.2-3.9), Z/K = 5.1 (4.8-5.3)  
Y/R' = 0.015 (0.0091-0.024)  
B/B0 = 0.15 (0.09-0.24), best LF fit year 2002 = 0.22 (0.13-0.33)  
B/Bmsy = 0.4 (0.25-0.64), **selected B/B0 2009 = 0.24 (0.14-0.39)**

RF: removed years with chaotic LF; set Linf to 23 cm between median 20.5 and max 23.5, instead of 24.6 suggested by aggregated data. Selected 2009 for AMSY prior because of reasonable fit, CL, not too low B/B0 which makes predictions of k uncertain.



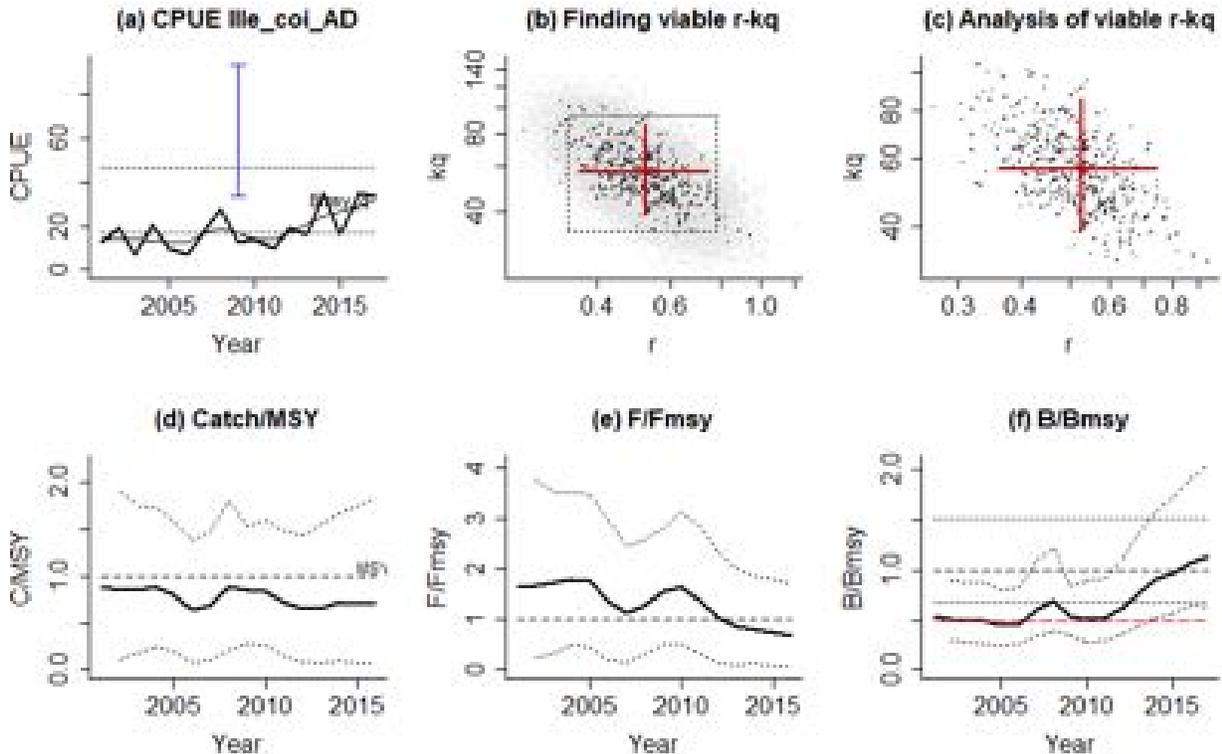
File FirstAss\_ID\_4.csv read successfully

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AMSY Analysis, Fri Nov 01 16:34:11 2019  
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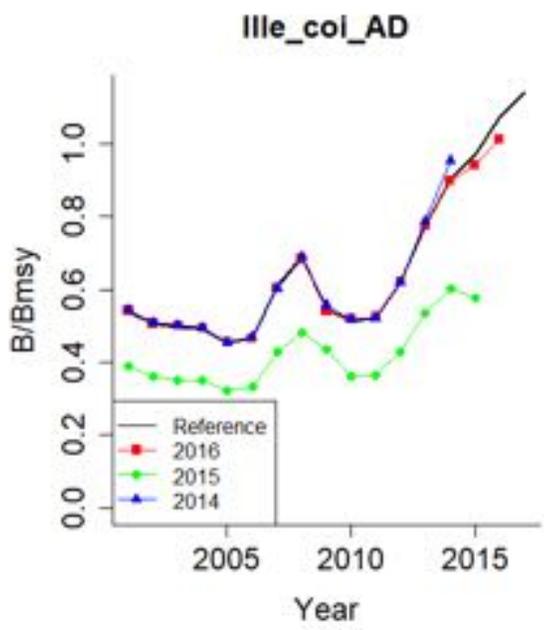
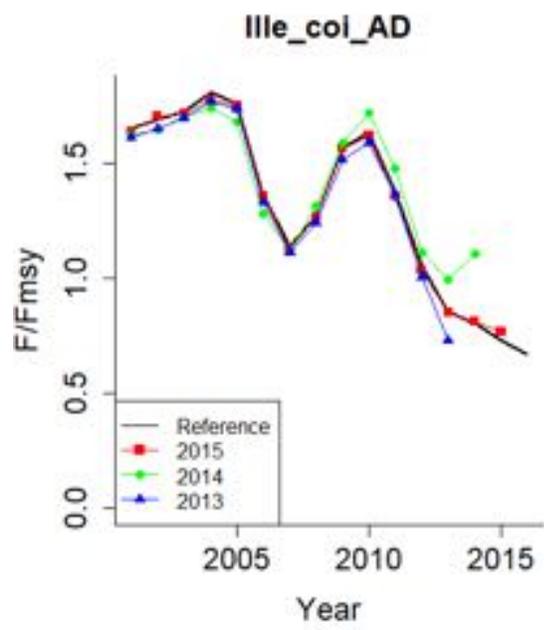
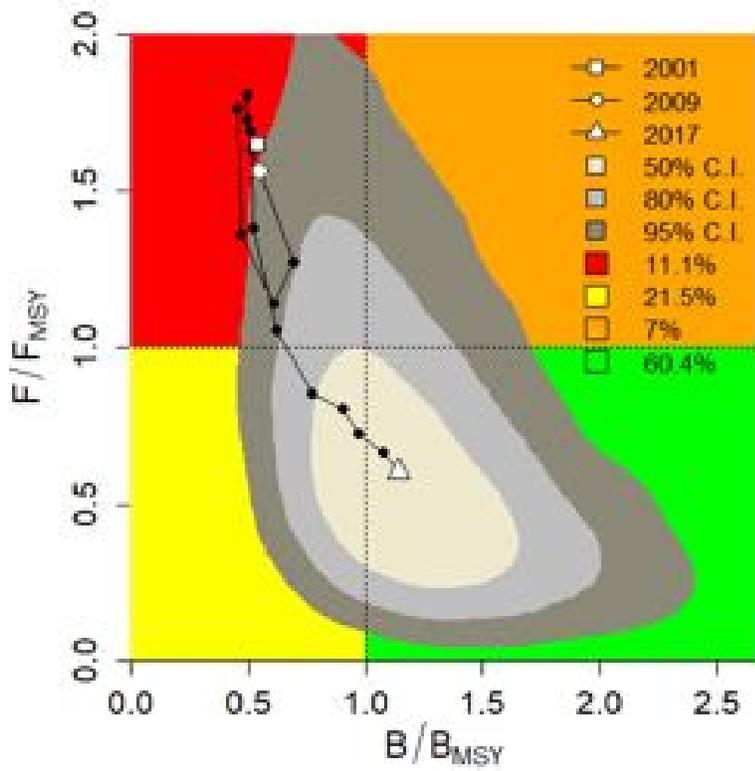
Stock **Ille\_coi\_AD**, *Illex coindettii*, shortfin squid  
CPUE data for years 2001 - 2017, CPUE range 12.6 - 32.5, smooth = TRUE  
Prior for  $r$  = Medium, 0.34 - 0.78  
Used prior range for  $r$  = 0.319 - 0.833  
Prior for 2009 stock status = Small, 0.14 - 0.39  
Used 2009 prior B/B0 range = 0.14 - 0.39, prior B/Bmsy = 0.28 - 0.78  
Used prior range for  $kq$  = 33.5 - 93.3 [original range = 33.5 - 93.3]  
Comment: B/B0 prior from LBB. RF: Initial low abundance of stock doubtful.  
Starting analysis in 2001. OK  
Source:

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5003

Results:  
viable  $r$ - $kq$  pairs = 5003  
median  $kq$  = 56.6, 38.8 - 85.9  
median MSYq = 7.46, 5.2 - 11  
 $r$  (4 MSYq/ $kq$ ) = 0.527, 0.359 - 0.745  
Fmsy ( $r/2$ ) = 0.264, 0.18 - 0.372  
F/Fmsy = 0.665, 0.0673 - 1.71 (2016)  
B/Bmsy = 1.14, 0.64 - 2.05 (2017)



AMSY kobe and retrospective plots for *Ille\_coi\_AD*, *Illex coindettii*



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 LBB results for *Micromesistius poutassou*, stock **Micr\_pou\_AD**, 1994-2001  
 Files:LBB4AMSY\_ID\_2.csv, Micr\_pou\_AD.csv  
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Linf prior= 40, SD=0.4 cm (user-defined), Lmax=44, median Lmax=35  
 Z/K prior = 2.5, SD=0.39, M/K prior=1.5, SD=0.15  
 F/K prior = 1.05 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 21.9, SD=2.2 cm, alpha prior=37.2, SD=3.7, Lm50=18 cm

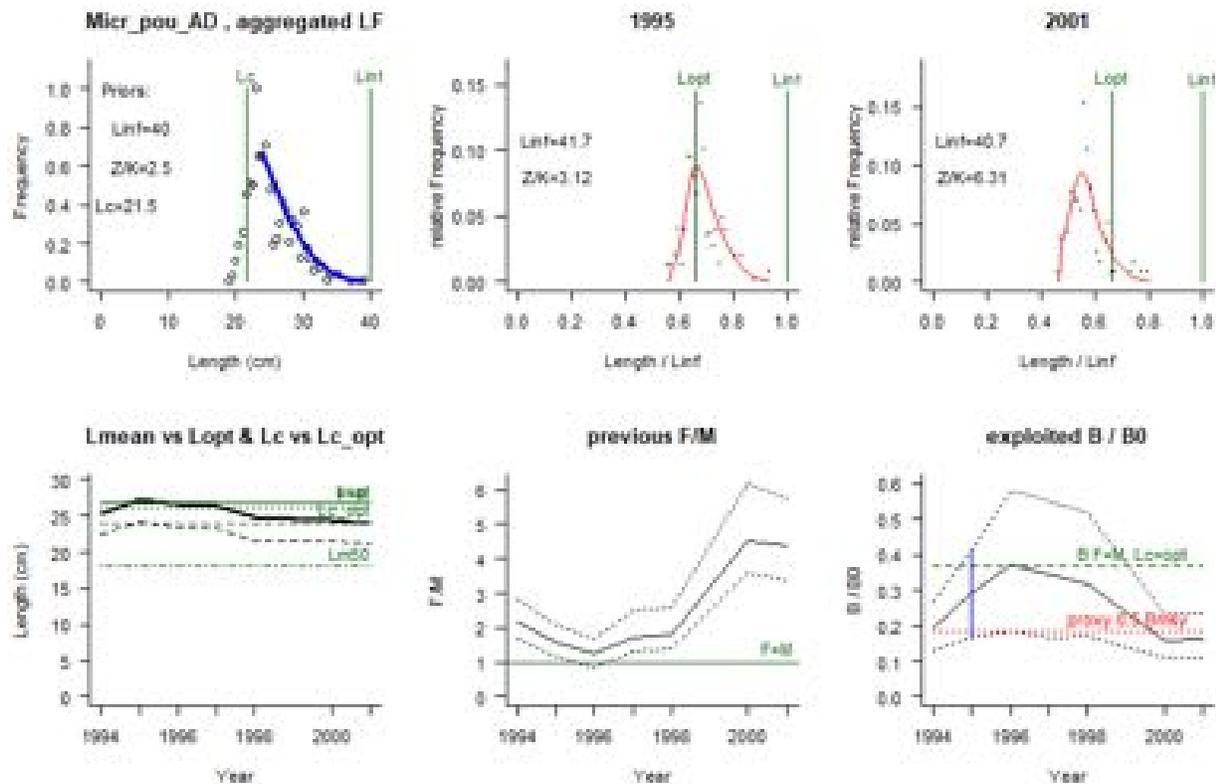
General reference points (median across years):

Linf = 40.3 (39.7-40.9) cm  
 Lopt = 27 cm, Lopt/Linf=0.66  
 Lc\_opt = 24 cm, Lc\_opt/Linf=0.59, Lmean if F=M 26.2 cm  
 M/K = 1.52 (1.25-1.81)  
 F/M = 2.19 (1.67-2.82), F/K=3.29 (2.94-3.84), Z/K=4.84 (4.52-5.35)  
 B/B0 = 0.19 (0.13-0.27), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.038 (0.017-0.056)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.045

Estimates for 2001 (mean of last 3 years with data):

Lc50 = 21.2 (21.1-21.3) cm, Lc/Linf=0.53 (0.53-0.53)  
 Lc95 = 23.4, alpha=1.31 (1.26-1.35)  
 Lmean/Lopt= 0.9, Lc/Lc\_opt=0.88, L95th=33 cm, L95th/Linf=0.82, Mature=100%  
 F/M = 4.4 (3.4-5.7), F/K=6.3 (5.5-7.1), Z/K=7.7 (7.1-8.5)  
 Y/R' = 0.027 (0.018-0.039)(reduced because B/B0 < 0.25)  
 B/B0 = 0.16 (0.11-0.23), best LF fit year 1996=0.37 (0.18-0.58)  
 B/Bmsy = 0.44 (0.3-0.64), **selected B/B0 1995 = 0.29 (0.17-0.41)**

RF: set Lcut to 18 cm to ignore distorting high catches of early juveniles;  
 excluded years with unsuitable LFs; set Linf to 40 cm, between median 36 and  
 max 44; note that Lc is overestimated, but F of adults and thus B/B0 seems  
 reasonable. selected 1995 for reasonable fit, CL, and B/B0.

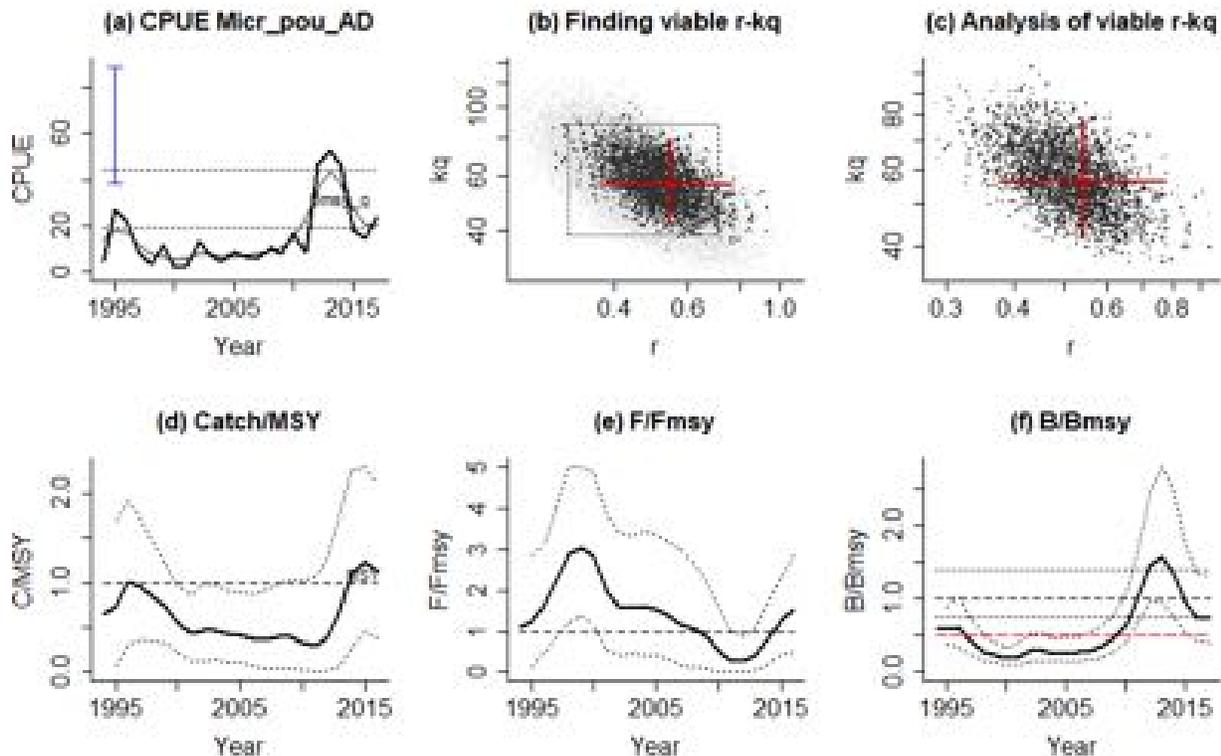


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AMSY Analysis, Fri Nov 01 16:38:14 2019  
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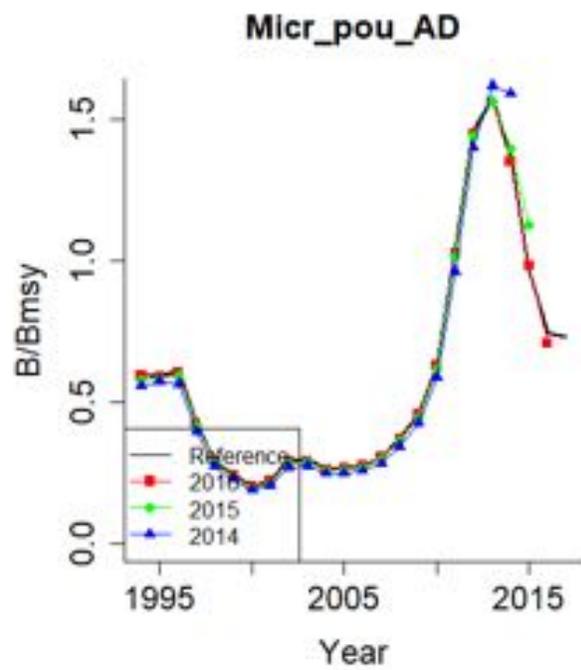
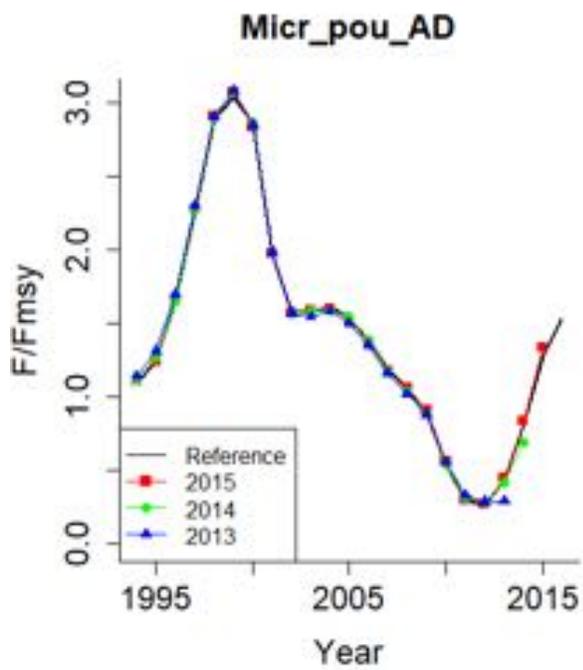
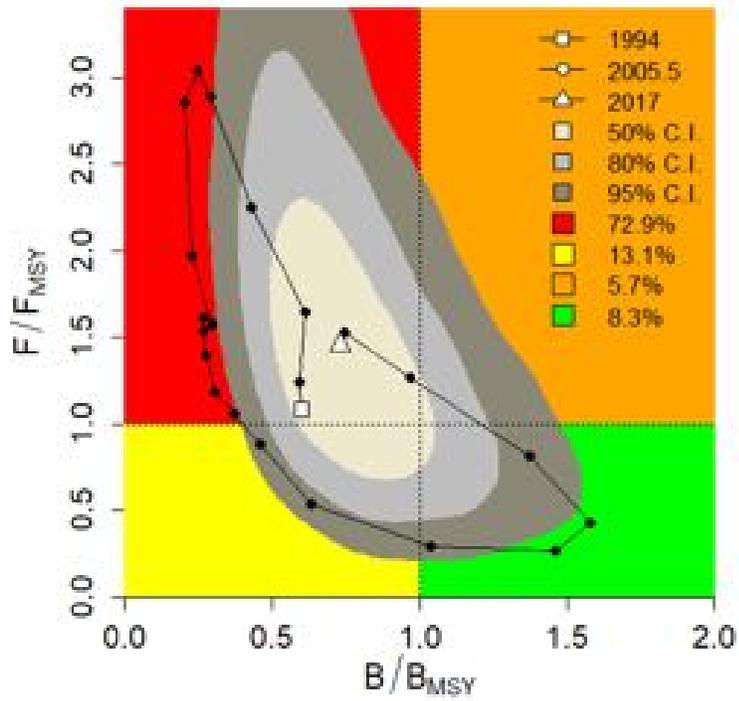
Stock **Micr\_pou\_AD**, *Micromesistius poutassou*, Blue whiting  
CPUE data for years 1994 - 2017, CPUE range 5.66 - 43.4, smooth = TRUE  
Prior for  $r$  = Medium, 0.31 - 0.71  
Used prior range for  $r$  = 0.29 - 0.761  
Prior for 1995 stock status = Small, 0.17 - 0.41  
Used 1995 prior B/B0 range = 0.17 - 0.41, prior B/Bmsy = 0.34 - 0.82  
Used prior range for  $kq$  = 38.3 - 88.5 [original range = 36.7 - 88.5]  
Comment: B/B0 prior from LBB. RF: OK  
Source:

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5000

Results:  
viable  $r$ - $kq$  pairs = 5000  
median  $kq$  = 56.1, 42.4 - 78.3  
median MSYq = 7.61, 5.46 - 10.8  
 $r$  (4 MSYq/ $kq$ ) = 0.543, 0.374 - 0.77  
Fmsy ( $r/2$ ) = 0.272, 0.187 - 0.385  
F/Fmsy = 1.53, 0.515 - 2.84 (2016)  
B/Bmsy = 0.731, 0.401 - 1.32 (2017)



AMSY Kobe plot and retrospective analysis for **Micr\_pou\_AD**, *Micromesistius poutassou*



LBB results for *Octopus vulgaris*, stock Octo\_vul\_AD, 2007-2017  
 Files:LBB4AMSY\_ID\_2.csv, Octo\_vul\_AD.csv

Linf prior= 19, SD=0.19 cm (user-defined), Lmax=27, median Lmax=15  
 Z/K prior = 3.2, SD=0.56, M/K prior=1.5, SD=0.15  
 F/K prior = 1.67 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 5.87, SD=0.59 cm, alpha prior=10.2, SD=1, Lm50=11 cm

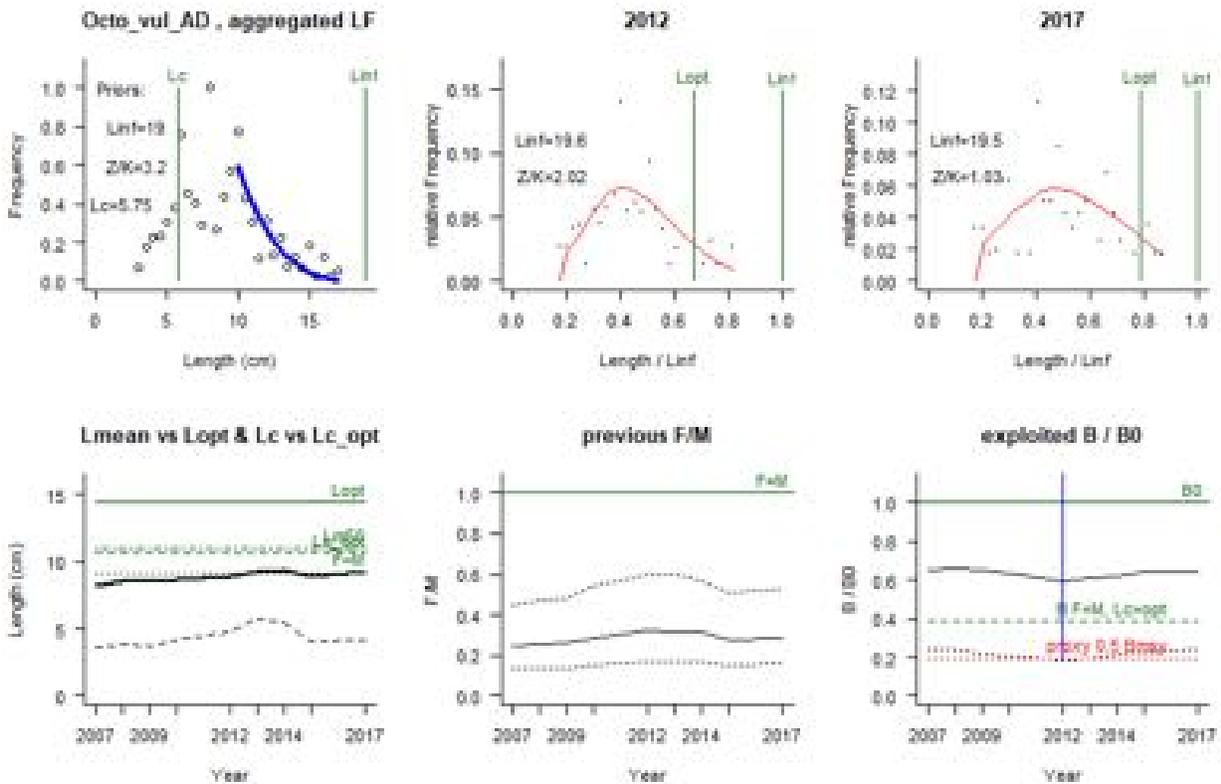
General reference points (median across years):

Linf = 19.4 (19.1-19.7) cm  
 Lopt = 14 cm, Lopt/Linf=0.74  
 Lc\_opt = 11 cm, Lc\_opt/Linf=0.55, Lmean if F=M 9.2 cm  
 M/K = 1.03 (0.81-1.17)  
 F/M = 0.276 (0.141-0.519), F/K=0.26 (0.164-0.445), Z/K=1.29 (1.14-1.43)  
 B/B0 = 0.64 (0.23-1.3), B/B0 F=M Lc=Lc\_opt 0.39  
 Y/R' = 0.045 (0.016-0.096), Y/R' F=M Lc=Lc\_opt 0.077

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 4.14 (3.9-4.4) cm, Lc/Linf=0.21 (0.2-0.23)  
 Lc95 = 7.81, alpha=0.804 (0.767-0.843)  
 Lmean/Lopt= 0.61, Lc/Lc\_opt=0.39, L95th=17 cm, L95th/Linf=0.88, Mature=32%  
 F/M = 0.29 (0.16-0.52), F/K=0.24 (0.14-0.37), Z/K=1.1 (0.98-1.2)  
 Y/R' = 0.055 (0.021-0.11)  
 B/B0 = 0.64 (0.24-1.3), best LF fit year 2009=0.647 (0.22-1.3)  
 B/Bmsy = 1.7 (0.63-3.4), **selected B/B0 2012 = 0.59 (0.19-1.2)**

RF: deleted outlier 75 cm in 2015; set Linf=19 cm, between median 15 and max 27 cm; merged LF to increase data per year; 2012 fit looked reasonable and is proposed for AMSY, albeit with high uncertainty.

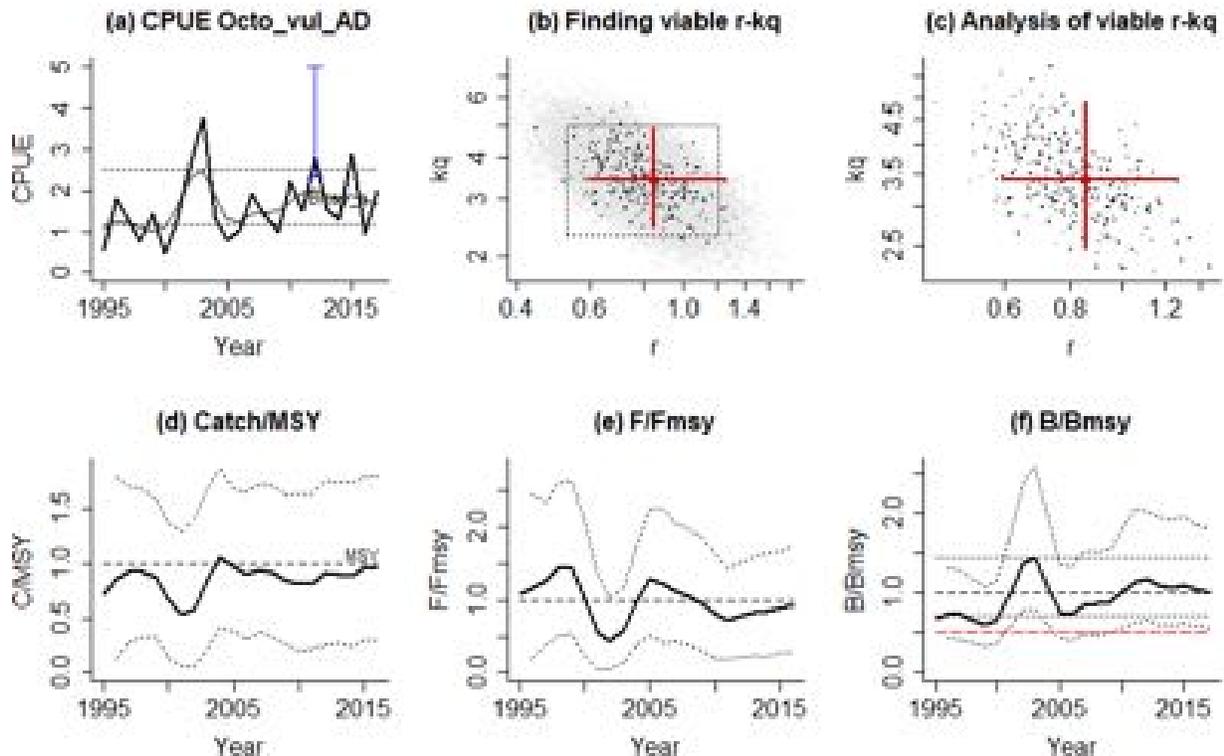


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AMSY Analysis, Fri Nov 01 16:43:40 2019  
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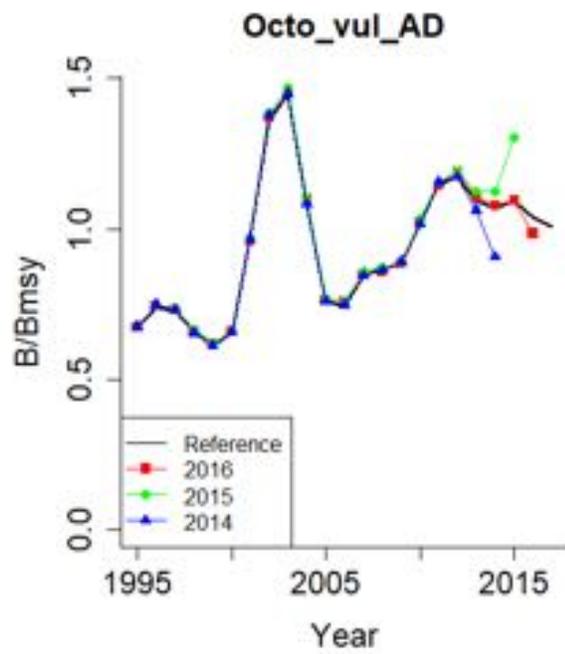
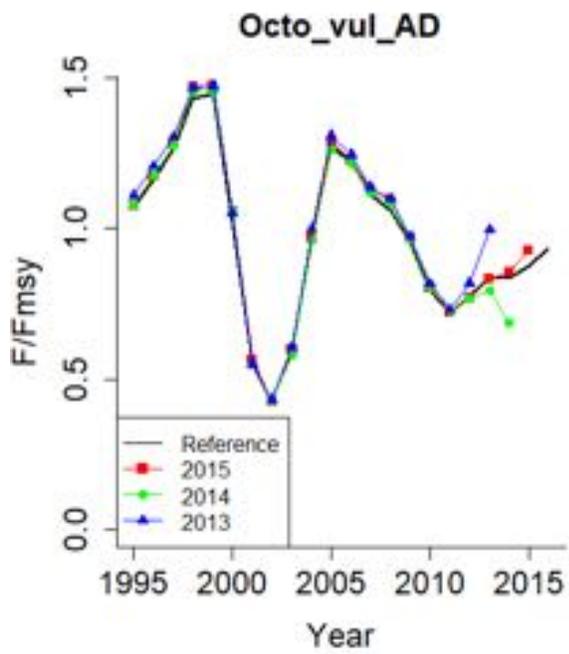
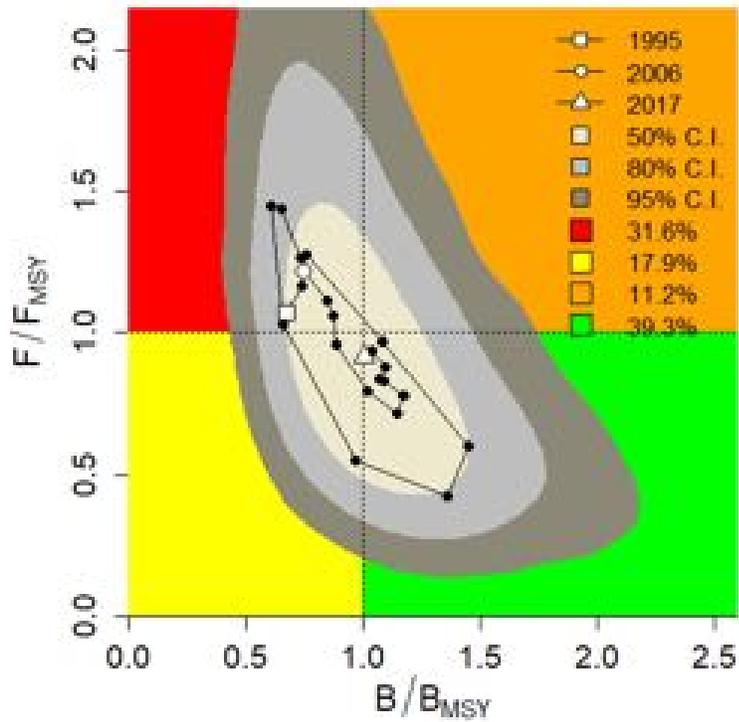
Stock **Octo\_vul\_AD**, *Octopus vulgaris*, Common octopus  
CPUE data for years 1995 - 2017, CPUE range 1.02 - 2.47, smooth = TRUE  
Prior for  $r$  = High, 0.53 - 1.21  
Used prior range for  $r$  = 0.493 - 1.29  
Prior for 2012 stock status = Small, 0.19 - 1.2  
Used 2012 prior B/B0 range = 0.19 - 1.2, prior B/Bmsy = 0.38 - 2.4  
Used prior range for  $kq$  = 2.31 - 5 [original range = 0.792 - 5]  
Comment: B/B0 prior from LBB. RF: OK  
Source:

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5013

Results:  
viable  $r$ - $kq$  pairs = 5013  
median  $kq$  = 3.38, 2.45 - 4.87  
median MSY $q$  = 0.72, 0.507 - 1.01  
 $r$  (4 MSY $q$ / $kq$ ) = 0.851, 0.595 - 1.26  
Fmsy ( $r/2$ ) = 0.425, 0.297 - 0.631  
F/Fmsy = 0.937, 0.289 - 1.74 (2016)  
B/Bmsy = 1.01, 0.557 - 1.81 (2017)



AMSY Kobe plot and retrospective analysis for *Octopus vulgaris* Octo\_vul\_AD



## Aegean Sea

LBB results for *Diplodus annularis*, stock ANN\_GSA22, 1994-2016  
Files:LBB4AMSY\_ID\_2.csv, ANN.csv

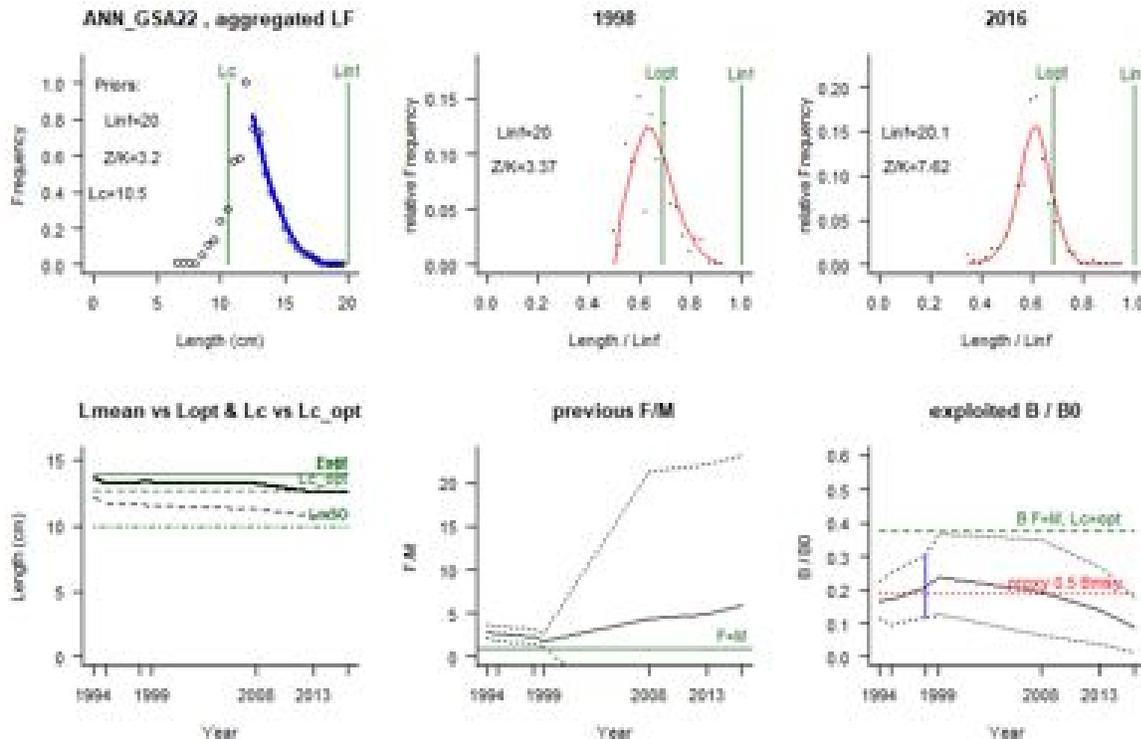
Linf prior= 20, SD=0.2 cm (user-defined), Lmax=19.5, median Lmax=18  
Z/K prior = 3.2, SD=0.13, M/K prior=1.5, SD=0.15  
F/K prior = 1.7 (wide range with tau=4 in log-normal distribution)  
Lc prior = 10.7, SD=1.1 cm, alpha prior=23.6, SD=2.4, Lm50=10 cm

General reference points (median across years):

Linf = 19.6 (19.3-19.9) cm  
Lopt = 14 cm, Lopt/Linf=0.71  
Lc\_opt = 13 cm, Lc\_opt/Linf=0.65, Lmean if F=M 14 cm  
M/K = 1.22 (0.97-1.6)  
F/M = 2.81 (1.43-3.62), F/K=2.94 (2.24-3.45), Z/K=4.16 (3.78-4.51)  
B/B0 = 0.17 (0.083-0.23), B/B0 F=M Lc=Lc\_opt 0.38  
Y/R' = 0.042 (0.024-0.079)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.062

Estimates for 2016 (mean of last 3 years with data):

Lc50 = 10.9 (10.8-10.9) cm, Lc/Linf=0.56 (0.56-0.56)  
Lc95 = 12.9, alpha=1.45 (1.41-1.49)  
Lmean/Lopt= 0.83, Lc/Lc\_opt=0.85, L95th=16.8 cm, L95th/Linf=0.87, Mature=91%  
F/M = 5.9 (-7.9-23), F/K=4 (3.5-4.4), Z/K=4.9 (4.5-5.2)  
Y/R' = 0.033 (-0.027-0.11)(reduced because B/B0 < 0.25)  
B/B0 = 0.086 (0.011-0.18), best LF fit year 1998=0.208 (0.12-0.3)  
B/Bmsy = 0.23 (0.029-0.47), **selected B/B0 1998 = 0.21 (0.12-0.3)**  
RF: Set Linf=20 to include Lmax=19.5. Removed years with unsuitable LF;  
accepted best-fit year 1998 (high B/B0 with narrow CV) as prior for AMSY.

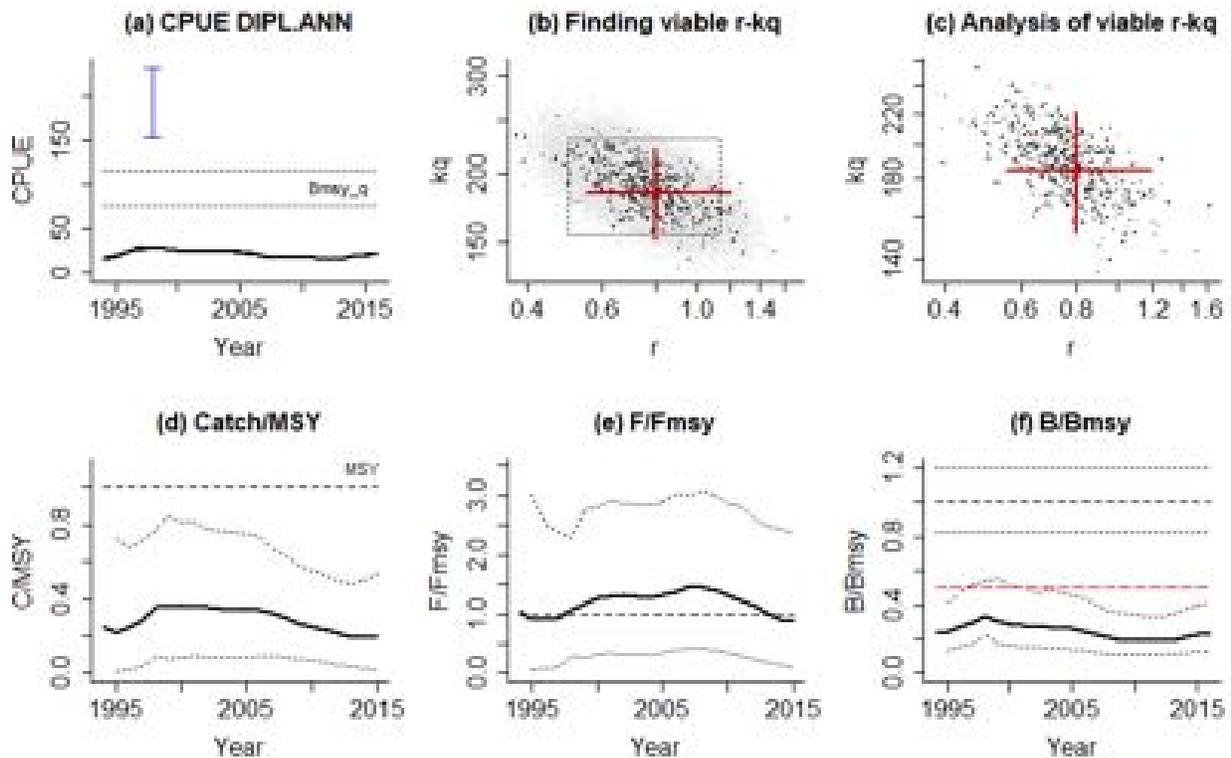


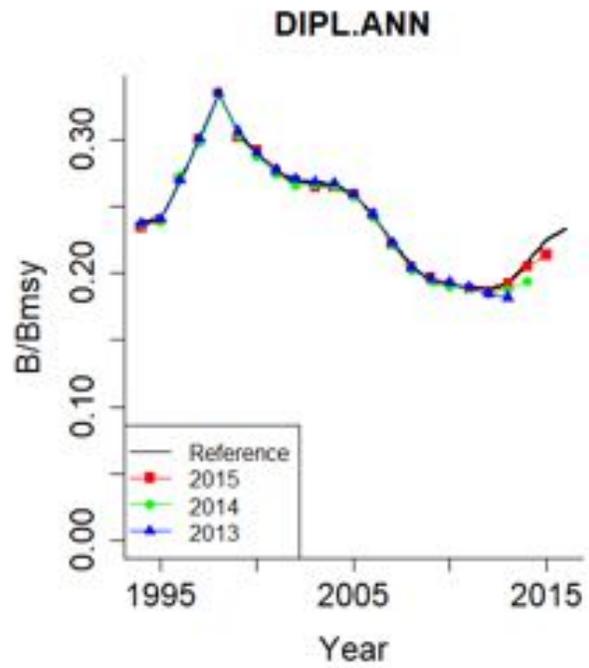
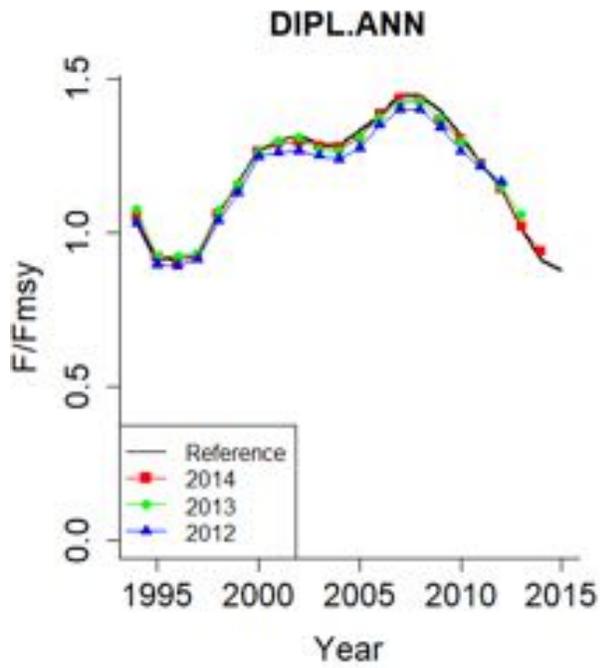
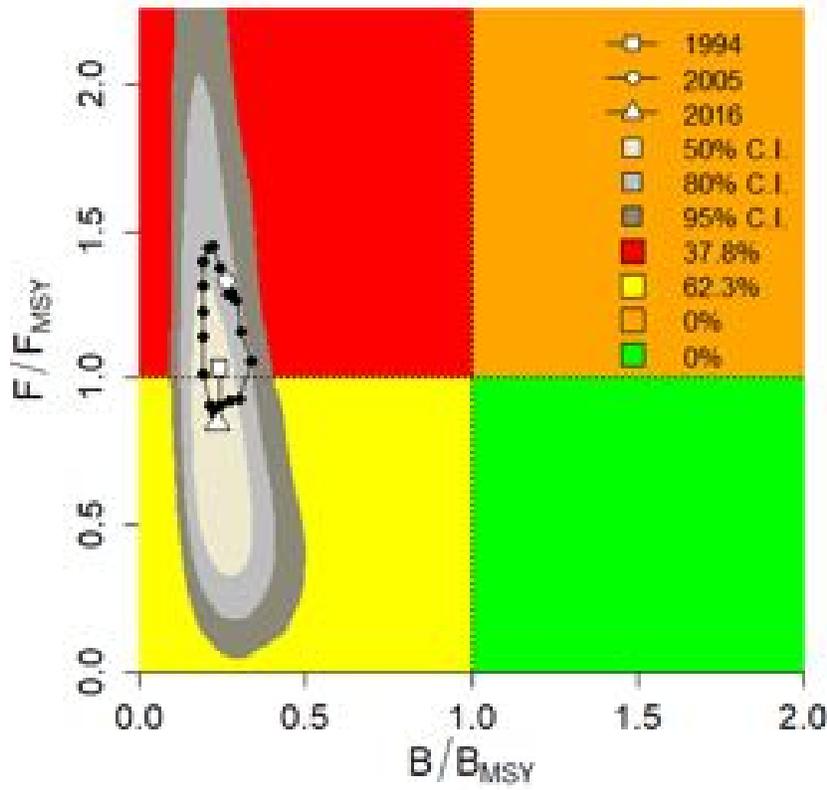
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AMSY Analysis, Fri Nov 01 16:48:36 2019  
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Stock **DIPL.ANN**, *Diplodus annularis*, Annular seabream  
CPUE data for years 1994 - 2016, CPUE range 17.1 - 28.4, smooth = TRUE  
Prior for  $r$  = High, 0.5 - 1.13  
Used prior range for  $r$  = 0.468 - 1.2  
Prior for 1998 stock status = Small, 0.12 - 0.3  
Used 1998 prior B/B0 range = 0.12 - 0.3, prior B/Bmsy = 0.24 - 0.6  
Used prior range for  $kq$  = 154 - 232 [original range = 77.2 - 193]  
Comment: B/B0 prior from LBB. RF: OK  
Source:

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5003

Results:  
viable  $r$ - $kq$  pairs = 5003  
median  $kq$  = 184, 152 - 221  
median MSY $q$  = 36.8, 27.2 - 51.4  
 $r$  (4 MSY $q$ / $kq$ ) = 0.8, 0.55 - 1.2  
Fmsy ( $r/2$ ) = 0.4, 0.275 - 0.599  
F/Fmsy = 0.877, 0.106 - 2.38 (2015)  
B/Bmsy = 0.234, 0.131 - 0.416 (2016)





-----  
 LBB results for *Capros aper*, stock BOC\_GSA22, 1999-2013  
 Files:LBB4AMSY\_ID\_2.csv, BOC.csv  
 -----

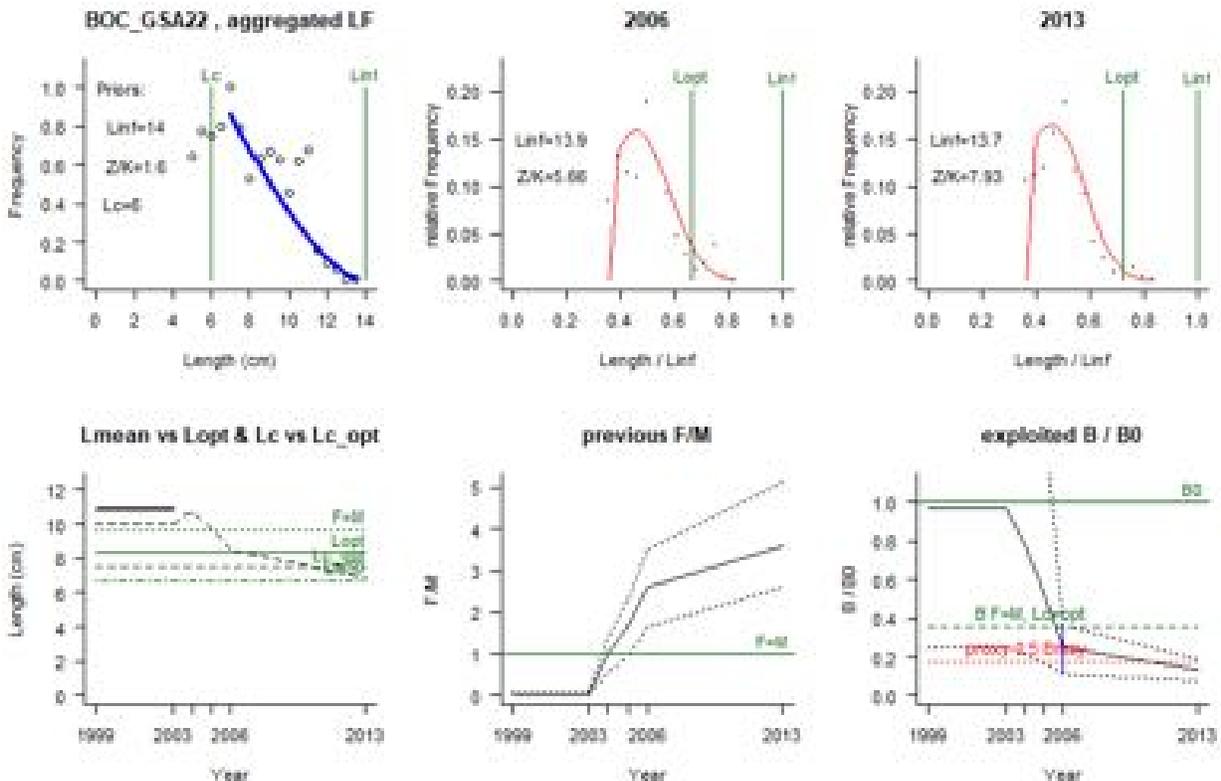
Linf prior= 14, SD=0.14 cm (user-defined), Lmax=13.5, median Lmax=11.2  
 Z/K prior = 1.6, SD=0.29, M/K prior=1.5, SD=0.15  
 F/K prior = 0.0745 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 6.12, SD=0.61 cm, alpha prior=7.97, SD=0.8, Lm50=6.7 cm

General reference points (median across years):

Linf = 13.7 (13.5-14) cm  
 Lopt = 8.3 cm, Lopt/Linf=0.61  
 Lc\_opt = 7.5 cm, Lc\_opt/Linf=0.54, Lmean if F=M 9.66 cm  
 M/K = 1.98 (1.71-2.22)  
 F/M = 2.43 (1.45-3.29), F/K=3.64 (2.91-4.28), Z/K=5.15 (4.55-5.76)  
 B/B0 = 0.31 (0.12-0.45), B/B0 F=M Lc=Lc\_opt 0.36  
 Y/R' = 0.013 (0.0064-0.02), Y/R' F=M Lc=Lc\_opt 0.028

Estimates for 2013 (mean of last 3 years with data):

Lc50 = 6.92 (6.58-7.28) cm, Lc/Linf=0.5 (0.48-0.53)  
 Lc95 = 11.7, alpha=0.62 (0.596-0.647)  
 Lmean/Lopt= 0.86, Lc/Lc\_opt=0.93, L95th=11.3 cm, L95th/Linf=0.82, Mature=51%  
 F/M = 3.6 (2.6-5.1), F/K=4.7 (4-5.4), Z/K=6.1 (5.5-6.7)  
 Y/R' = 0.025 (0.014-0.037)  
 B/B0 = 0.13 (0.075-0.2), best LF fit year 2005=0.526 (0.17-1.5)  
 B/Bmsy = 0.37 (0.21-0.55), **selected B/B0 2006 = 0.25 (0.11-0.36)**  
 RF: Set Linf=14 to include Lmax=13.5; merged LF to get more points per year;  
 set Lcut=4 to exclude early juveniles; set Lstart=7 to increase prior fit;  
 2006 seems least problematic.



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AMSY Analysis, Fri Nov 01 17:01:55 2019  
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Stock **CAPO.APE**, *Capros aper*, Boarfish

CPUE data for years 1994 - 2016, CPUE range 9.39 - 16.6, smooth = TRUE

Prior for  $r$  = Medium, 0.29 - 0.69

Used prior range for  $r$  = 0.272 - 0.735

Prior for 2006 stock status = Small, 0.1 - 0.4

Used 2006 prior B/B0 range = 0.1 - 0.4, prior B/Bmsy = 0.2 - 0.8

Used prior range for  $kq$  = 39.9 - 79.8 [original range = 19.9 - 79.8]

Comment: B/B0 prior from LBB. RF: OK

Source:

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5003

Results:

viable  $r$ - $kq$  pairs = 5003

median  $kq$  = 54.4, 38.7 - 75.4

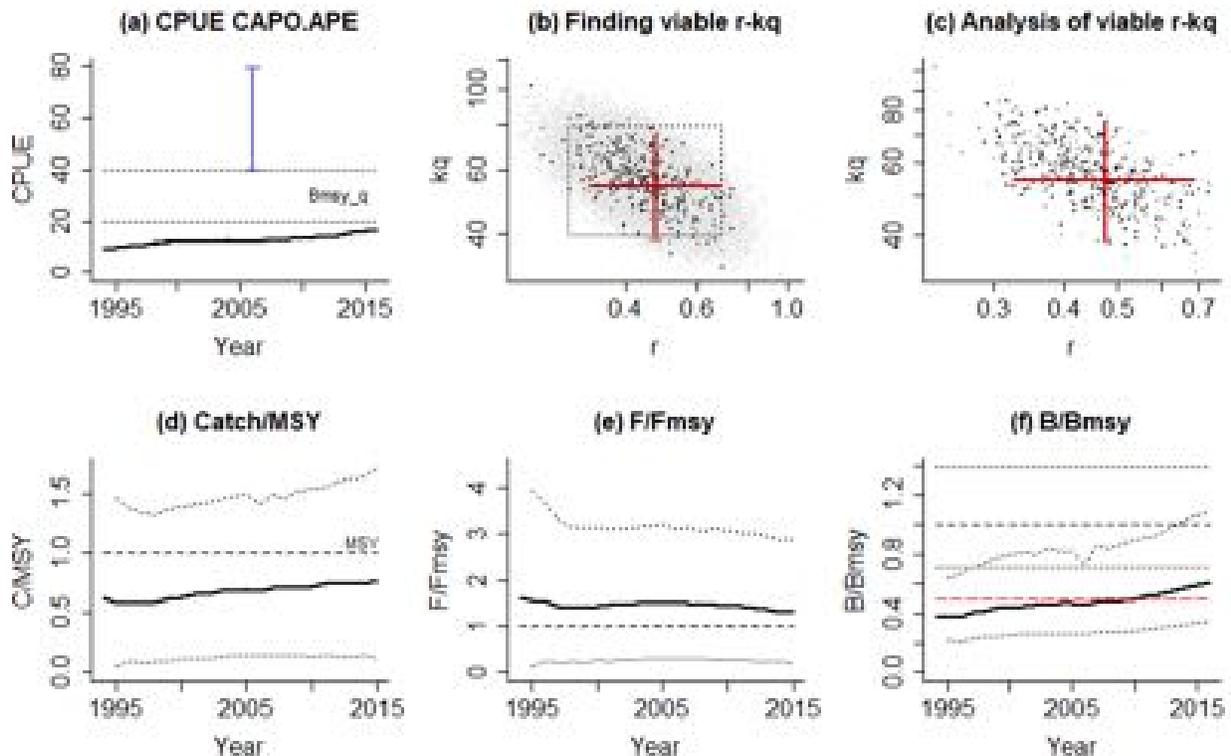
median MSY $q$  = 6.46, 4.45 - 9.18

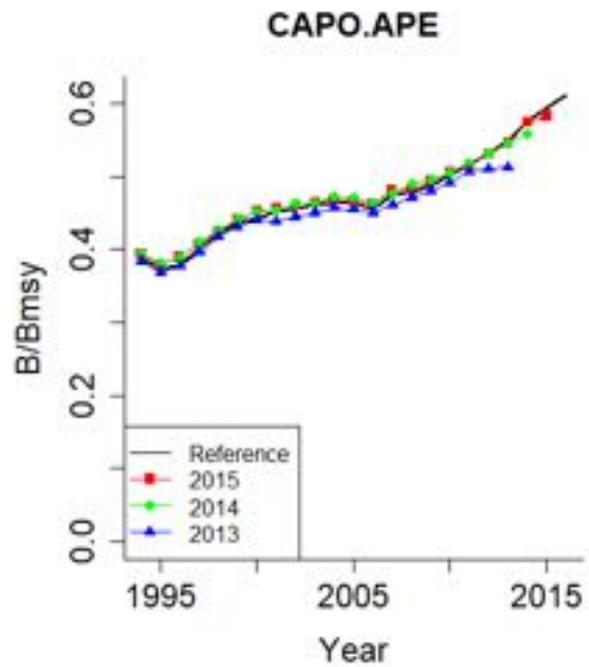
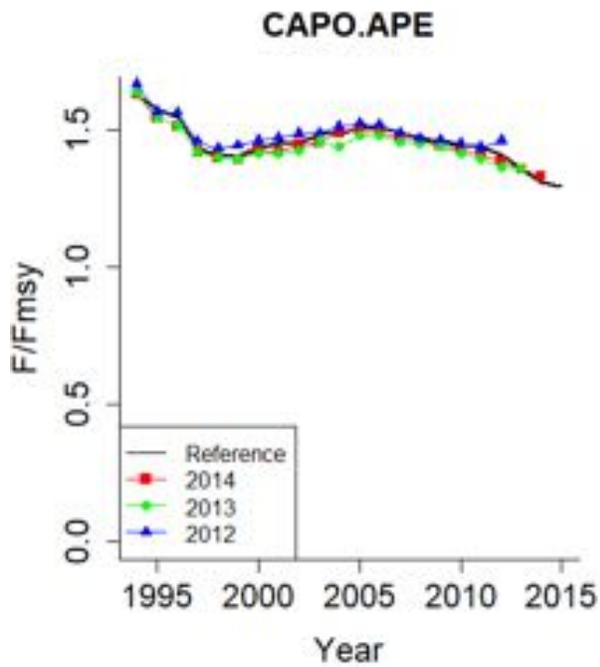
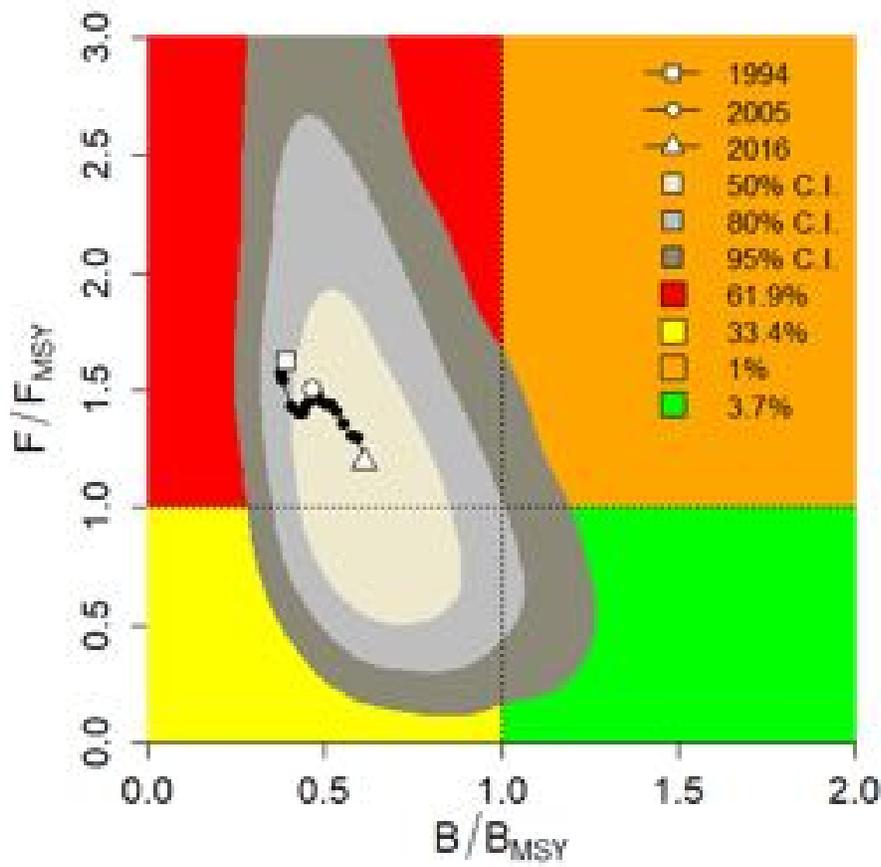
$r$  (4 MSY $q$ / $kq$ ) = 0.475, 0.323 - 0.688

Fmsy ( $r/2$ ) = 0.238, 0.162 - 0.344

F/Fmsy = 1.3, 0.21 - 2.89 (2015)

B/Bmsy = 0.612, 0.344 - 1.09 (2016)





-----  
 LBB results for *Helicolenus dactylopterus*, stock BRF\_GSA22, 1995-2016  
 Files:LBB4AMSY\_ID\_2.csv, BRF.csv  
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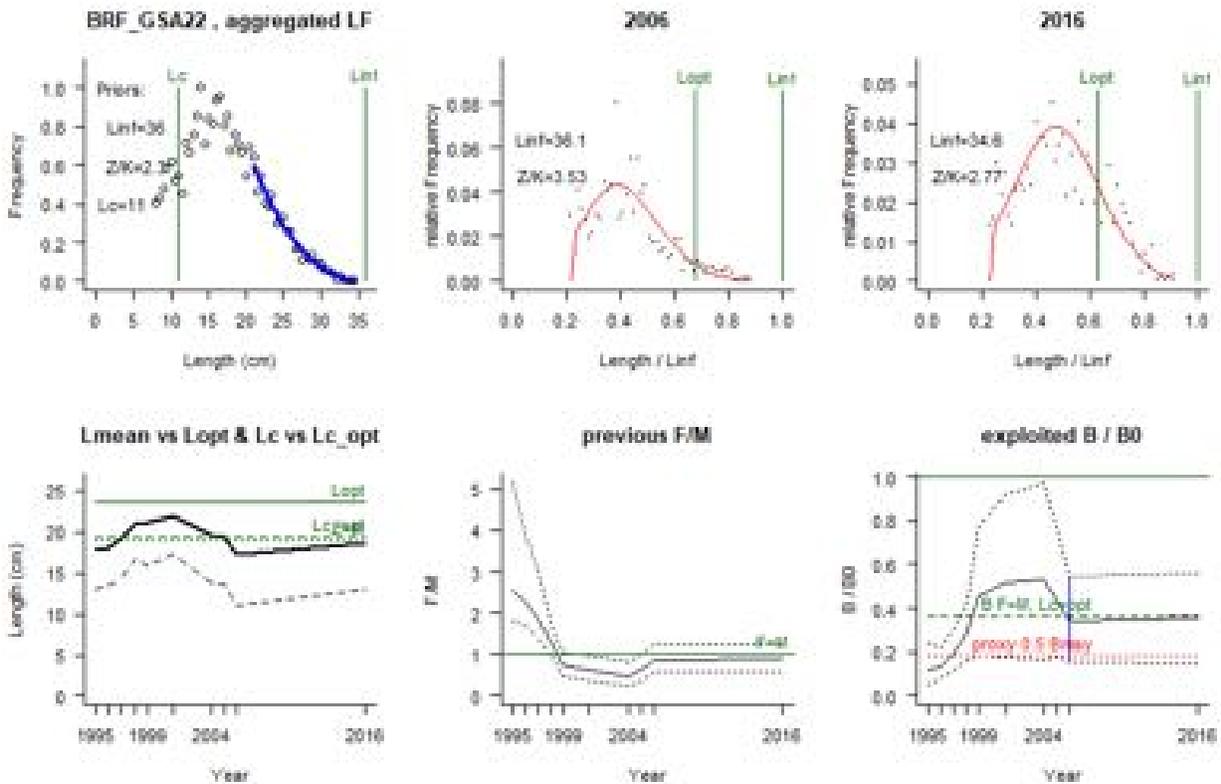
Linf prior= 36, SD=0.36 cm (user-defined), Lmax=57, median Lmax=32.8  
 Z/K prior = 2.3, SD=0.11, M/K prior=1.5, SD=0.15  
 F/K prior = 0.796 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 11.2, SD=1.1 cm, alpha prior=13.7, SD=1.4, Lm50=NA cm

General reference points (median across years):

Linf = 36 (35.4-36.7) cm  
 Lopt = 24 cm, Lopt/Linf=0.65  
 Lc\_opt = 19 cm, Lc\_opt/Linf=0.54, Lmean if F=M 18.9 cm  
 M/K = 1.58 (1.29-1.82)  
 F/M = 0.829 (0.502-1.22), F/K=1.38 (1.05-1.84), Z/K=2.75 (2.5-3.02)  
 B/B0 = 0.39 (0.16-0.6), B/B0 F=M Lc=Lc\_opt 0.36  
 Y/R' = 0.033 (0.014-0.052), Y/R' F=M Lc=Lc\_opt 0.04

Estimates for 2016 (mean of last 3 years with data):

Lc50 = 13 (12.4-13.5) cm, Lc/Linf=0.36 (0.35-0.38)  
 Lc95 = 21.4, alpha=0.347 (0.332-0.362)  
 Lmean/Lopt= 0.8, Lc/Lc\_opt=0.67, L95th=32 cm, L95th/Linf=0.9, Mature=NA%  
 F/M = 0.89 (0.58-1.3), F/K=1.4 (1-1.7), Z/K=3 (2.7-3.3)  
 Y/R' = 0.031 (0.015-0.048)  
 B/B0 = 0.36 (0.15-0.56), best LF fit year 2004=0.533 (0.16-0.97)  
 B/Bmsy = 0.99 (0.41-1.5), **selected B/B0 2006 = 0.34 (0.16-0.54)**  
 RF: Lmax=57 is probably an error, setting Linf=36 close to several annual  
 Lmax; Lm unknown for the area; set Lcut=8 to exclude early juveniles; excluded  
 years with unsuitable LF patterns; 2006 possible for AMSY.

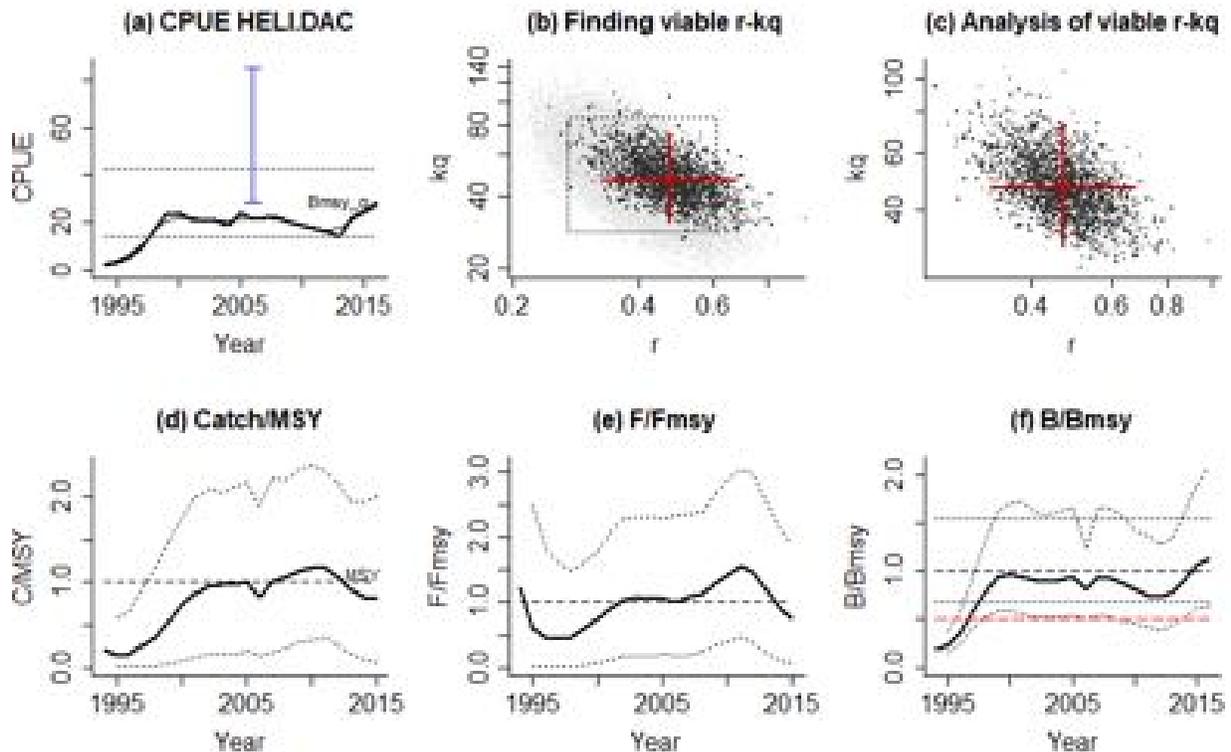


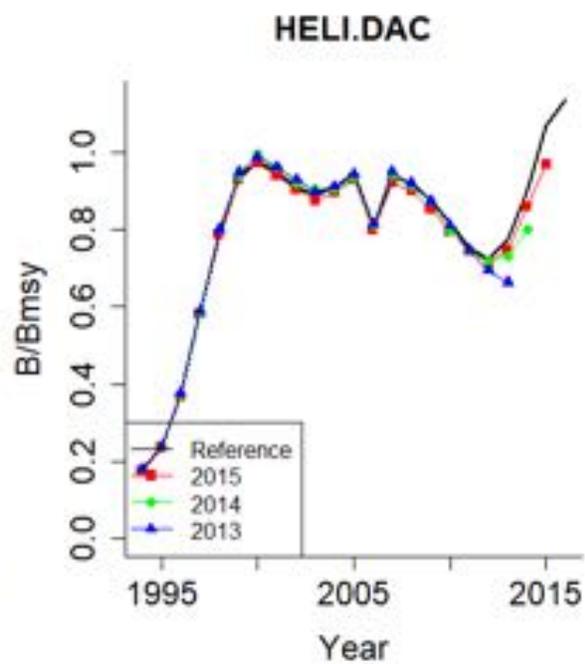
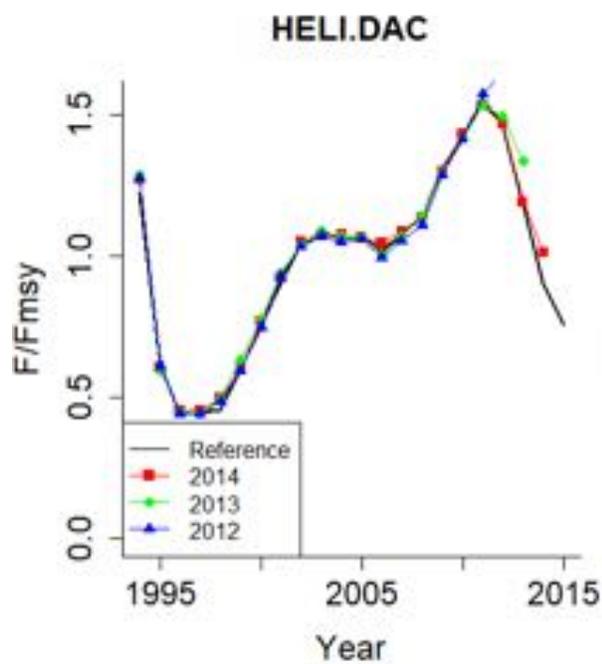
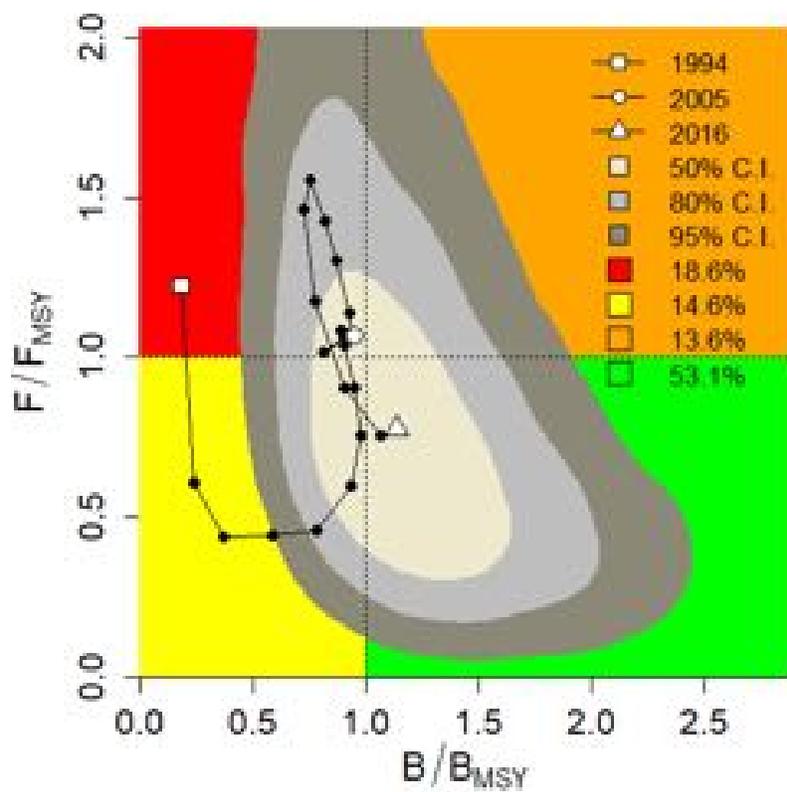
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AMSY Analysis, Fri Nov 01 17:14:11 2019  
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Stock HELI.DAC, *Helicolenus dactylopterus*, Blackbelly rosefish  
CPUE data for years 1994 - 2016, CPUE range 2.56 - 26.5, smooth = TRUE  
Prior for r = Medium, 0.27 - 0.61  
Used prior range for r = 0.253 - 0.652  
Prior for 2006 stock status = About half, 0.16 - 0.54  
Used 2006 prior B/B0 range = 0.16 - 0.54, prior B/Bmsy = 0.32 - 1.08  
Used prior range for kq = 28.6 - 85.7 [original range = 28.6 - 96.4]  
Comment: B/B0 prior from LBB. RF: OK  
Source:

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
Viable r-kq pairs = 2115

Results:  
viable r-kq pairs = 2115  
median kq = 46.9, 31.8 - 72.9  
median MSYq = 5.53, 3.89 - 8.2  
r (4 MSYq/kq) = 0.472, 0.324 - 0.676  
Fmsy (r/2) = 0.236, 0.162 - 0.338  
F/Fmsy = 0.757, 0.0695 - 1.88 (2015)  
B/Bmsy = 1.14, 0.633 - 2.1 (2016)





-----  
 LBB results for *Citharus linguatula*, stock CIL\_GSA22, 1994-2016  
 Files:Stock\_ID\_Greece2.csv, CIL.csv  
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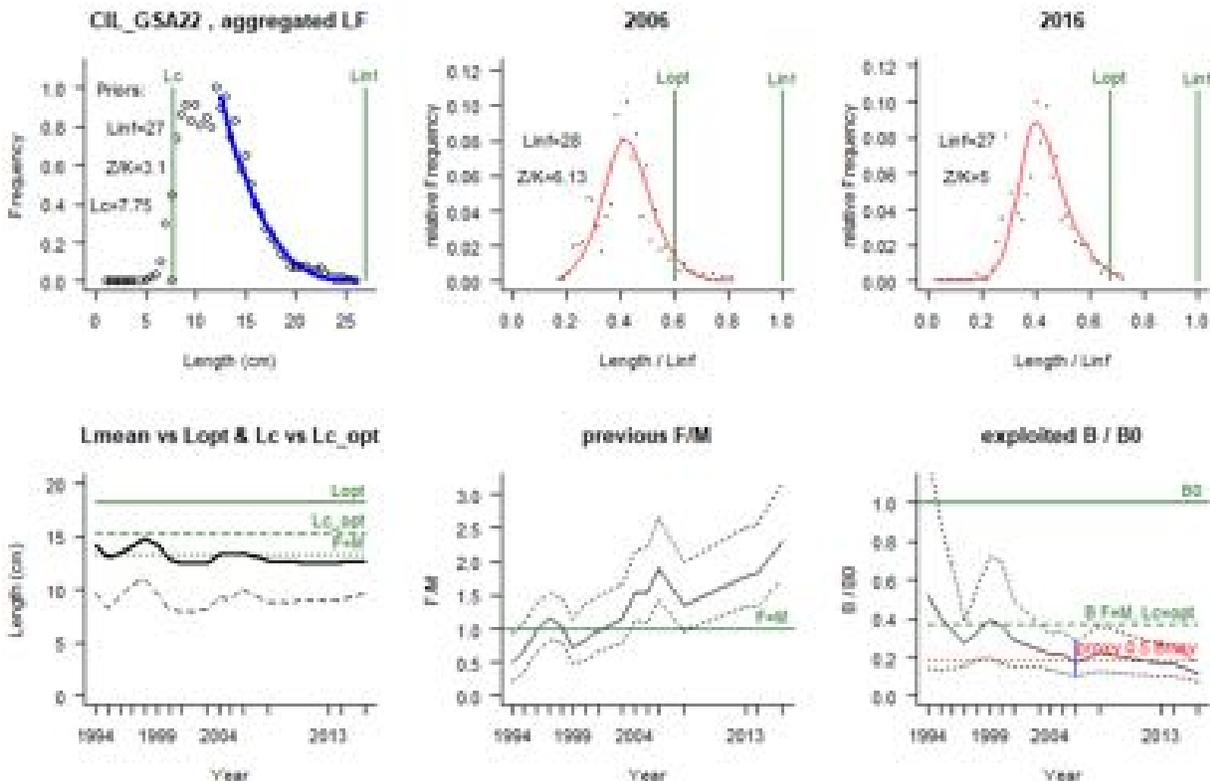
Linf prior= 27, SD=0.27 cm (user-defined), Lmax=33.5, median Lmax=25.2  
 Z/K prior = 3.1, SD=0.13, M/K prior=1.5, SD=0.15  
 F/K prior = 1.65 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 7.91, SD=0.79 cm, alpha prior=32.9, SD=3.3, Lm50=NA cm

General reference points (median across years):

Linf = 26.9 (26.5-27.4) cm  
 Lopt = 18 cm, Lopt/Linf=0.68  
 Lc\_opt = 15 cm, Lc\_opt/Linf=0.57, Lmean if F=M 13.3 cm  
 M/K = 1.42 (1.12-1.73)  
 F/M = 1.07 (0.768-1.58), F/K=1.59 (1.3-1.94), Z/K=3 (2.79-3.25)  
 B/B0 = 0.26 (0.14-0.4), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.036 (0.018-0.061), Y/R' F=M Lc=Lc\_opt 0.05

Estimates for 2016 (mean of last 3 years with data):

Lc50 = 9.55 (9.4-9.69) cm, Lc/Linf=0.35 (0.35-0.36)  
 Lc95 = 12.1, alpha=1.16 (1.13-1.2)  
 Lmean/Lopt= 0.7, Lc/Lc\_opt=0.62, L95th=20.3 cm, L95th/Linf=0.75, Mature=NA%  
 F/M = 2.3 (1.7-3.2), F/K=3.3 (2.9-3.8), Z/K=4.8 (4.5-5.1)  
 Y/R' = 0.019 (0.013-0.028)  
 B/B0 = 0.12 (0.077-0.17), best LF fit year 2016=0.118 (0.077-0.17)  
 B/Bmsy = 0.32 (0.21-0.46), **selected B/B0 2006 = 0.18 (0.1-0.28)**  
 RF: Set Linf=27 close to median=26 below max=33. Selected 2006 because of  
 reasonable LF fit and reasonable B/B0, compared to adjacent estimates.

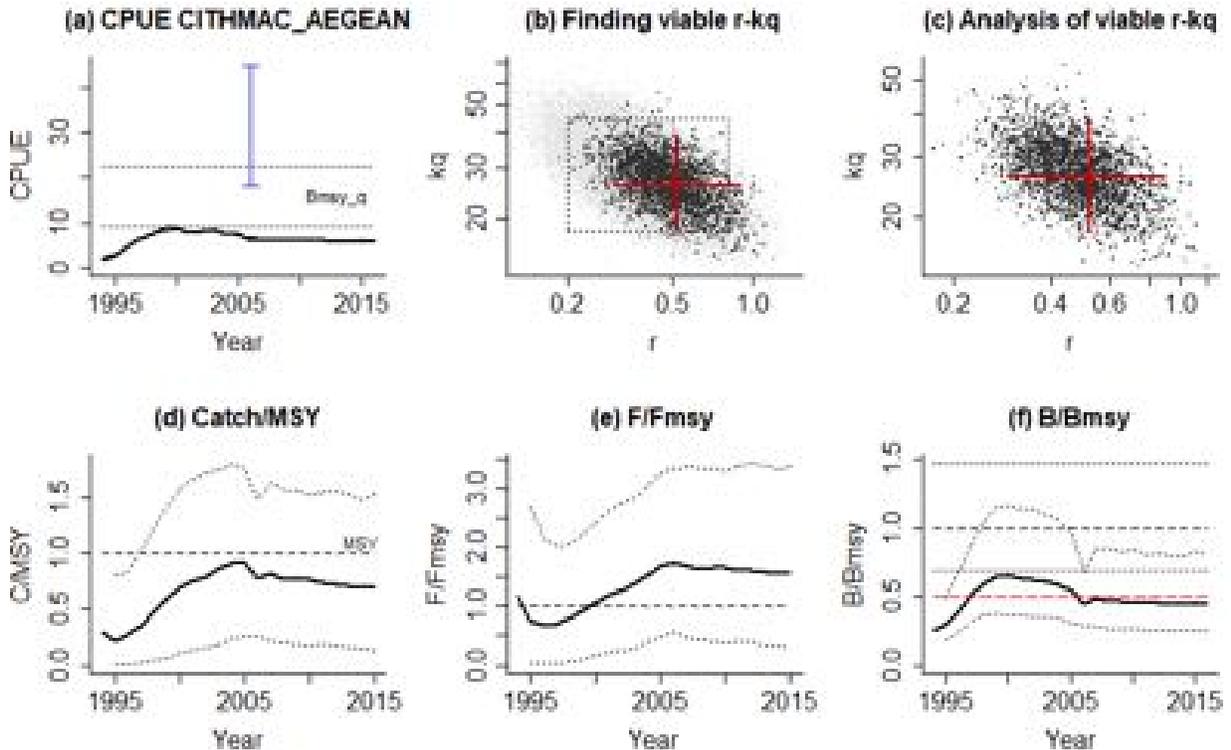


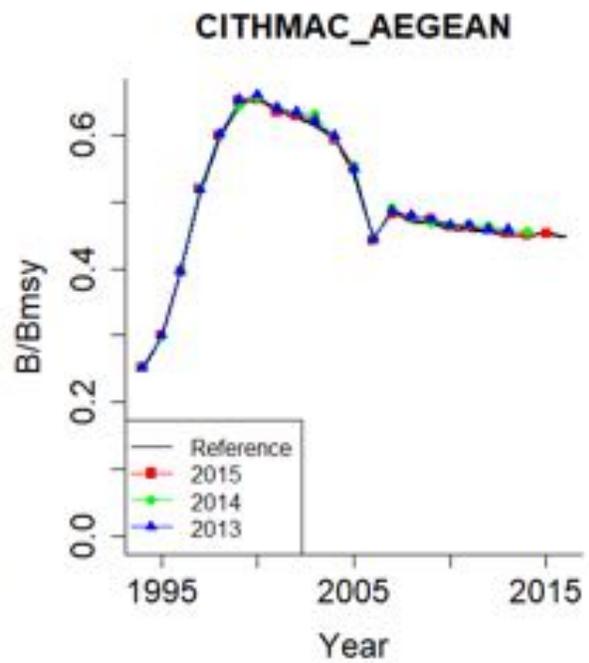
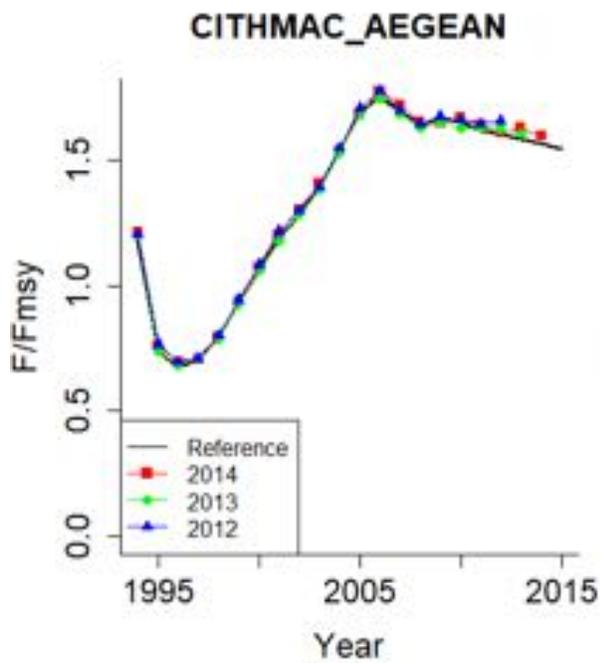
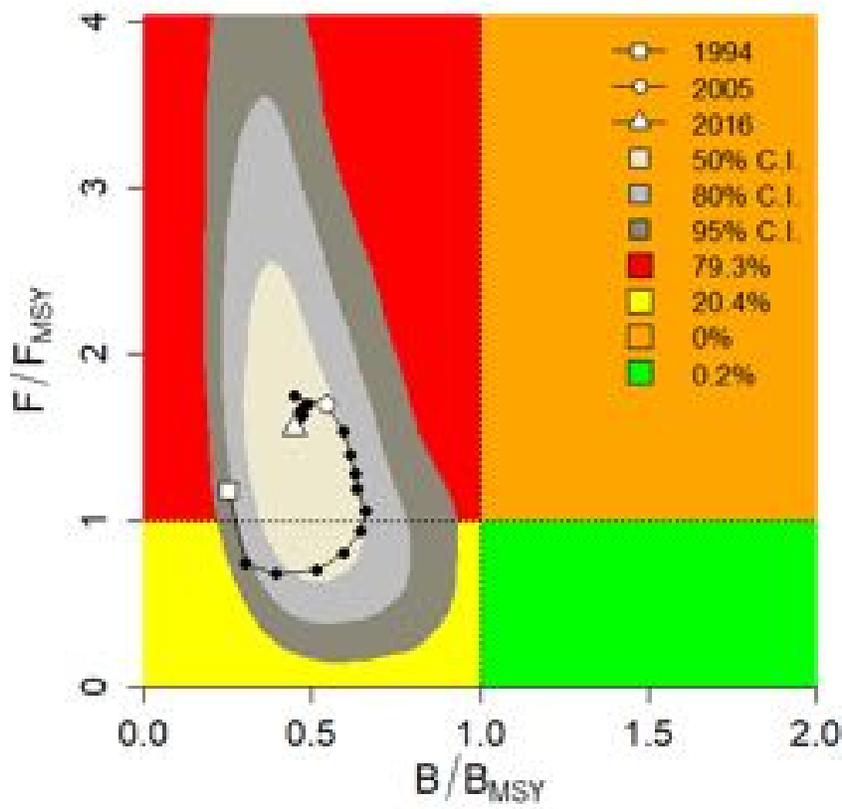
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 AMSY Analysis, Fri Nov 01 17:22:35 2019  
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Stock **CITHMAC\_AEGEAN**, *Citharus linguatula*, Spotted flounder  
 CPUE data for years 1994 - 2016, CPUE range 2.24 - 8.34, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 2006 stock status = Small, 0.12 - 0.3  
 Used 2006 prior B/B0 range = 0.12 - 0.3, prior B/Bmsy = 0.24 - 0.6  
 Used prior range for kq = 18 - 44.9 [original range = 18 - 44.9]  
 Comment: B/B0 prior from LBB. RF: OK  
 Source:

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5000

Results:  
 viable r-kq pairs = 5000  
 median kq = 26, 18 - 38.3  
 median MSYq = 3.39, 2.03 - 5.49  
 r (4 MSYq/kq) = 0.521, 0.295 - 0.887  
 Fmsy (r/2) = 0.26, 0.147 - 0.443  
 F/Fmsy = 1.55, 0.307 - 3.36 (2015)  
 B/Bmsy = 0.447, 0.251 - 0.803 (2016)





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 LBB results for *Hymenocephalus italicus*, stock HYS\_GSA22, 1999-2014  
 Files:Stock\_ID\_Greece2.csv, HYS.csv  
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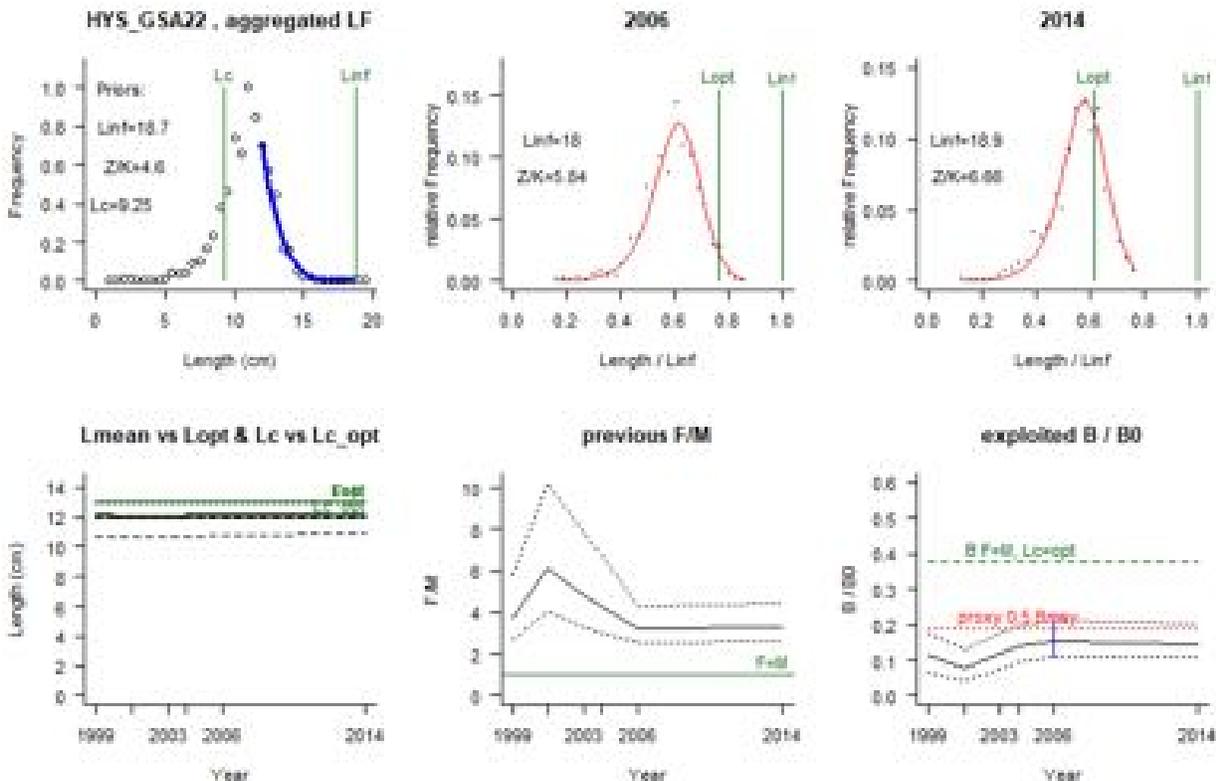
Linf prior= 18.7, SD=0.19 cm Lmax=21, median Lmax=18.8  
 Z/K prior = 4.6, SD=3.5, M/K prior=1.5, SD=0.15  
 F/K prior = 3.14 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 9.44, SD=0.94 cm, alpha prior=23.7, SD=2.4, Lm50=NA cm

General reference points (median across years):

Linf = 18.4 (18.1-18.7) cm  
 Lopt = 13 cm, Lopt/Linf=0.71  
 Lc\_opt = 12 cm, Lc\_opt/Linf=0.65, Lmean if F=M 12.9 cm  
 M/K = 1.26 (1.02-1.47)  
 F/M = 3.2 (2.47-4.61), F/K=4.41 (3.87-5.06), Z/K=5.61 (5.1-6.23)  
 B/B0 = 0.14 (0.098-0.2), B/B0 F=M Lc=Lc\_opt 0.38  
 Y/R' = 0.031 (0.021-0.05)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.059

Estimates for 2014 (mean of last 3 years with data):

Lc50 = 10.9 (10.7-11) cm, Lc/Linf=0.58 (0.58-0.59)  
 Lc95 = 13.6, alpha=1.08 (1.05-1.12)  
 Lmean/Lopt= 0.95, Lc/Lc\_opt=0.91, L95th=15.2 cm, L95th/Linf=0.82, Mature=NA%  
 F/M = 3.3 (2.7-4.4), F/K=4.4 (3.9-5), Z/K=5.8 (5.3-6.4)  
 Y/R' = 0.032 (0.023-0.045)(reduced because B/B0 < 0.25)  
 B/B0 = 0.15 (0.11-0.2), best LF fit year 2004=0.141 (0.098-0.2)  
 B/Bmsy = 0.39 (0.29-0.54), **selected B/B0 2006 = 0.15 (0.11-0.21)**  
 RF: Set Linf=Lmax=21, close to median=18.5. Excluded years with unrealistic LF fits. Selected 2006 because of good LF fit and reasonable B/B0 compared to adjacent estimates.



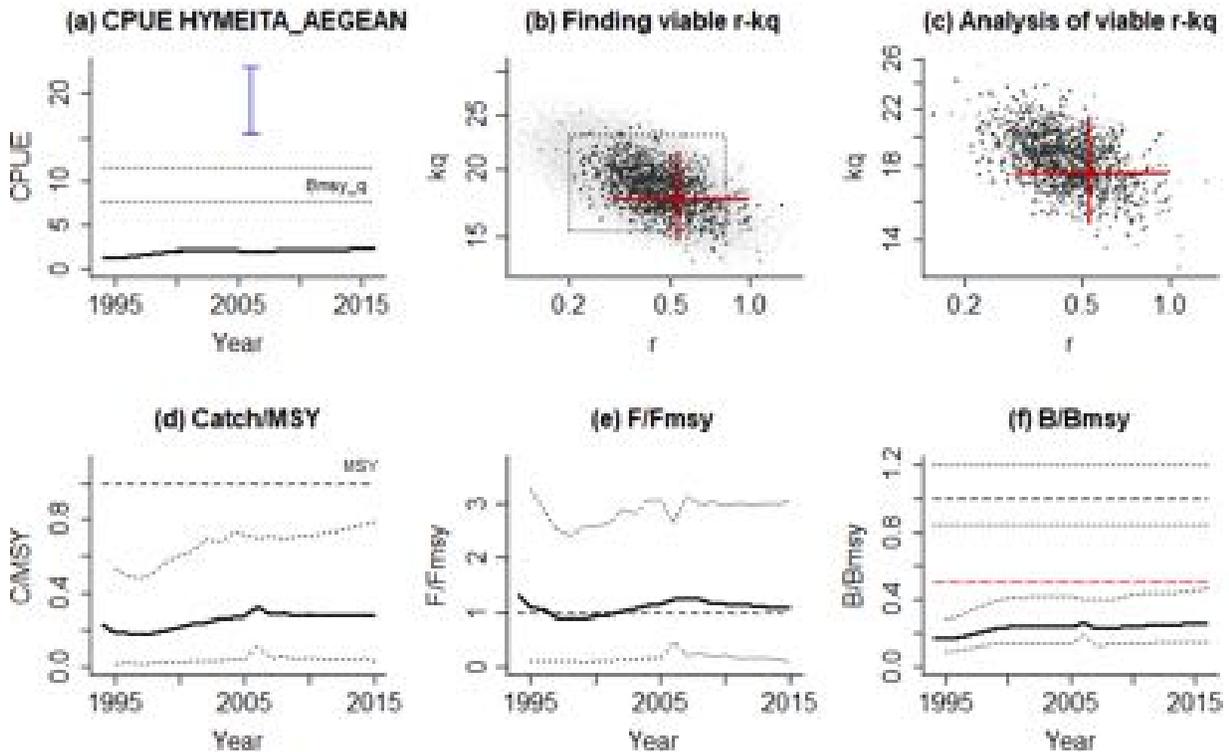
File FirstAss\_ID\_4.csv read successfully

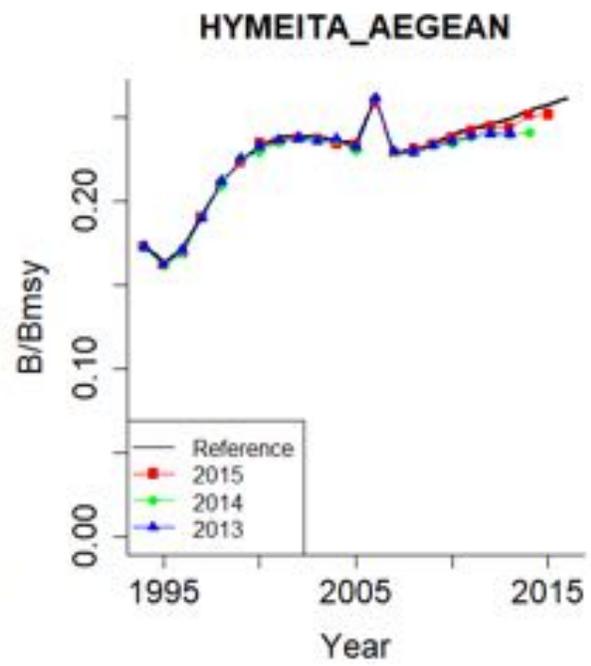
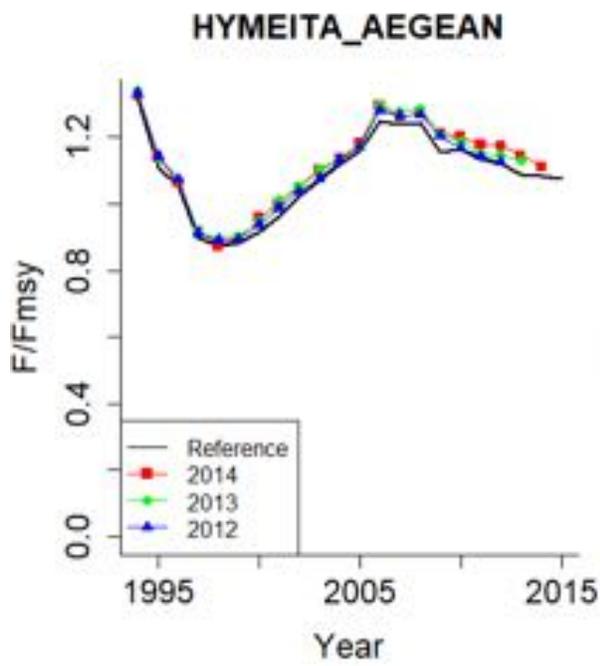
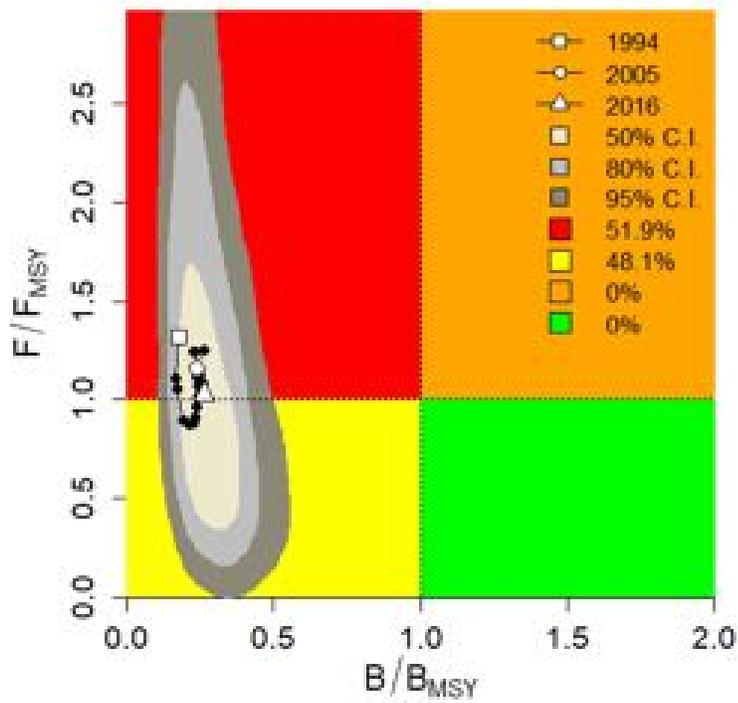
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AMSY Analysis, Fri Nov 01 17:30:01 2019  
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Stock **HYMEITA\_AEGEAN**, *Hymenocephalus italicus*, Glasshead grenadier  
CPUE data for years 1994 - 2016, CPUE range 1.22 - 2.3, smooth = TRUE  
Prior for  $r$  = Medium, NA - NA  
Used prior range for  $r$  = 0.2 - 0.8  
Prior for 2006 stock status = Very small, 0.1 - 0.22  
Used 2006 prior B/B0 range = 0.1 - 0.22, prior B/Bmsy = 0.2 - 0.44  
Used prior range for  $kq$  = 15.4 - 23.1 [original range = 7.7 - 16.9]  
Comment: B/B0 prior from LBB. RF: OK  
Source:

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5000

Results:  
viable  $r$ - $kq$  pairs = 5000  
median  $kq$  = 17.6, 14.8 - 21.2  
median MSYq = 2.34, 1.39 - 3.91  
 $r$  (4 MSYq/ $kq$ ) = 0.533, 0.294 - 0.975  
 $F_{msy}$  ( $r/2$ ) = 0.267, 0.147 - 0.488  
 $F/F_{msy}$  = 1.07, 0.111 - 3.05 (2015)  
 $B/B_{msy}$  = 0.262, 0.147 - 0.471 (2016)





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 LBB results for *Scorpaena notata*, stock SNQ\_GSA22, 1996-2014  
 Files:Stock\_ID\_Greece2.csv, SNQ.csv  
 -----

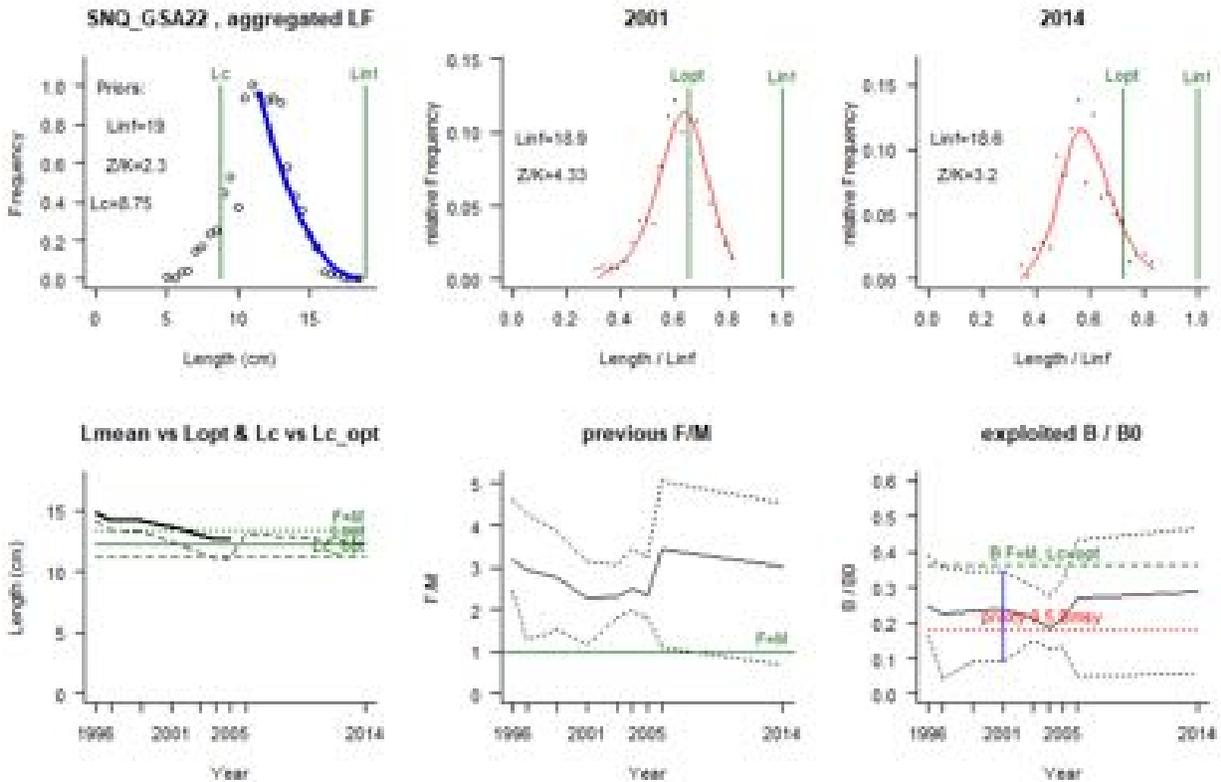
Linf prior= 19, SD=0.19 cm (user-defined), Lmax=20, median Lmax=17.5  
 Z/K prior = 2.3, SD=0.22, M/K prior=1.5, SD=0.15  
 F/K prior = 0.763 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 8.93, SD=0.89 cm, alpha prior=19.6, SD=2, Lm50=NA cm

General reference points (median across years):

Linf = 18.8 (18.5-19.1) cm  
 Lopt = 12 cm, Lopt/Linf=0.66  
 Lc\_opt = 11 cm, Lc\_opt/Linf=0.6, Lmean if F=M 13.4 cm  
 M/K = 1.57 (1.32-1.86)  
 F/M = 2.69 (1.33-3.69), F/K=4.35 (2.3-4.99), Z/K=5.81 (3.93-6.42)  
 B/B0 = 0.24 (0.13-0.33), B/B0 F=M Lc=Lc\_opt 0.36  
 Y/R' = 0.035 (0.024-0.049)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.041

Estimates for 2014 (mean of last 3 years with data):

Lc50 = 12.4 (12.2-12.9) cm, Lc/Linf=0.68 (0.67-0.7)  
 Lc95 = 15.5, alpha=0.953 (0.888-0.986)  
 Lmean/Lopt= NA, Lc/Lc\_opt=1.1, L95th=16.2 cm, L95th/Linf=0.88, Mature=NA%  
 F/M = 3 (0.71-4.5), F/K=7.2 (1-10), Z/K=9 (2.6-12)  
 Y/R' = 0.041 (0.021-0.065)(reduced because B/B0 < 0.25)  
 B/B0 = 0.29 (0.055-0.47), best LF fit year 2001=0.236 (0.093-0.35)  
 B/Bmsy = 0.79 (0.15-1.3), **selected B/B0 2001 = 0.24 (0.093-0.35)**  
 RF: Set Linf=19 between median18 and max 20. Excluded years with unreasonable LF fits. Selected 2001 because of good fit and reasonable B/B0 compared to adjacent estimates.

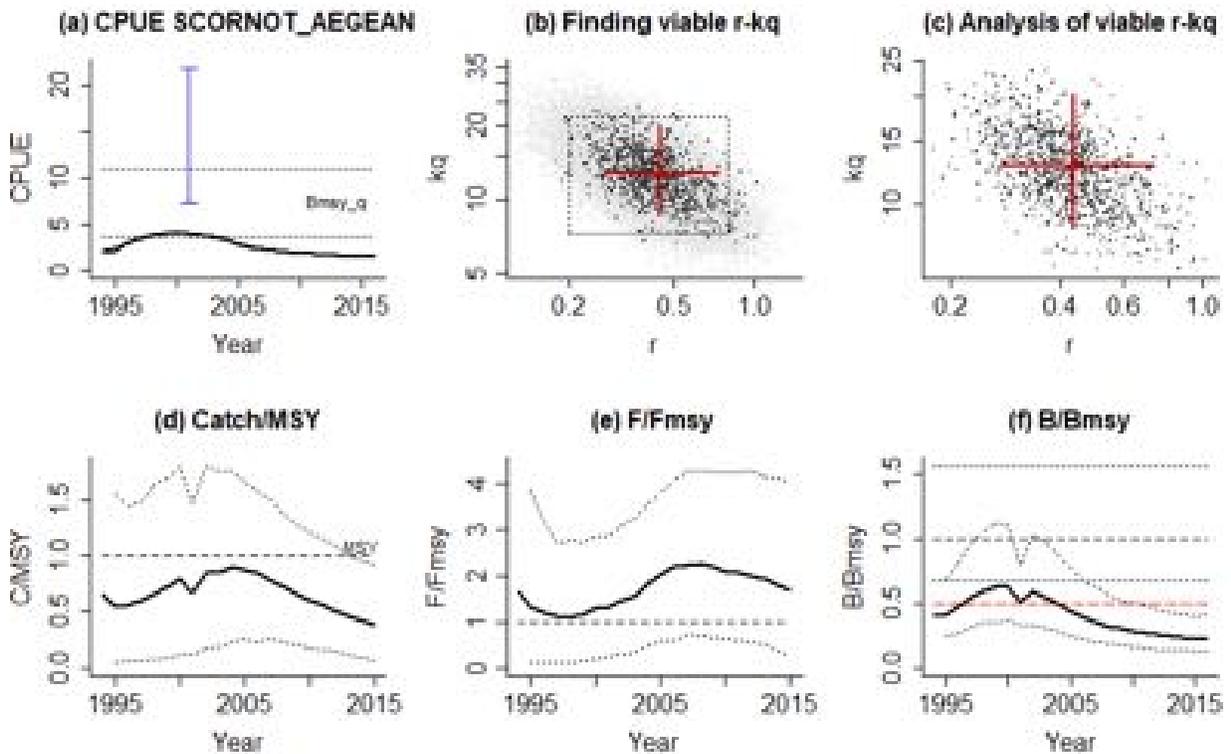


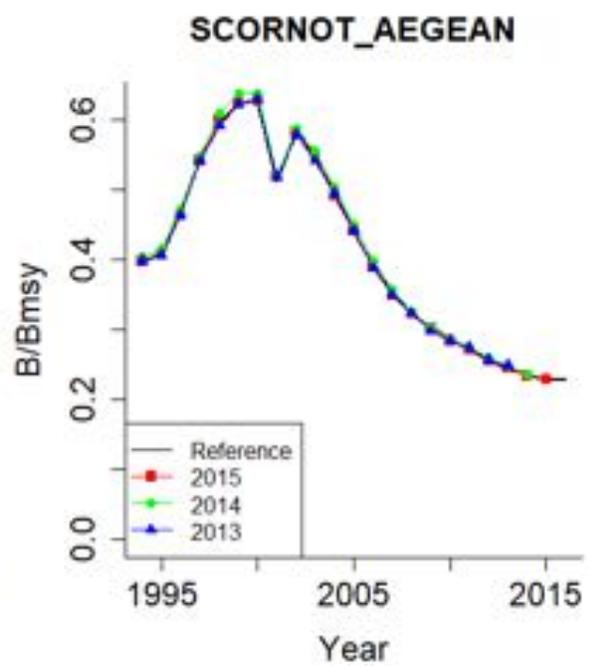
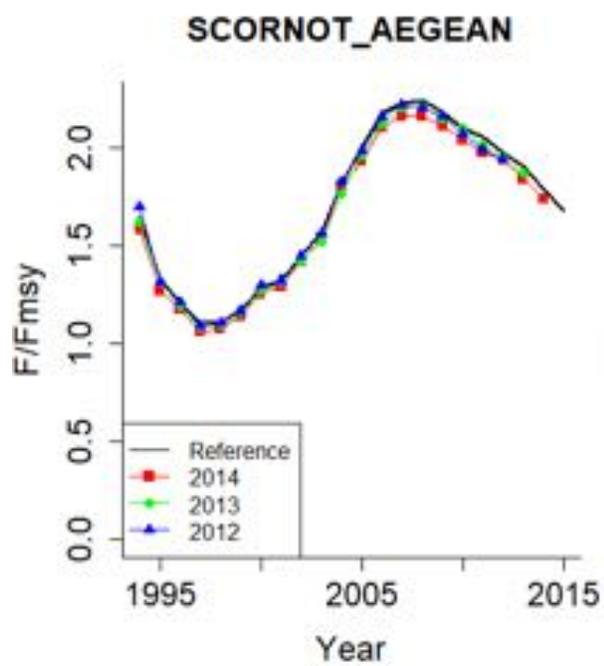
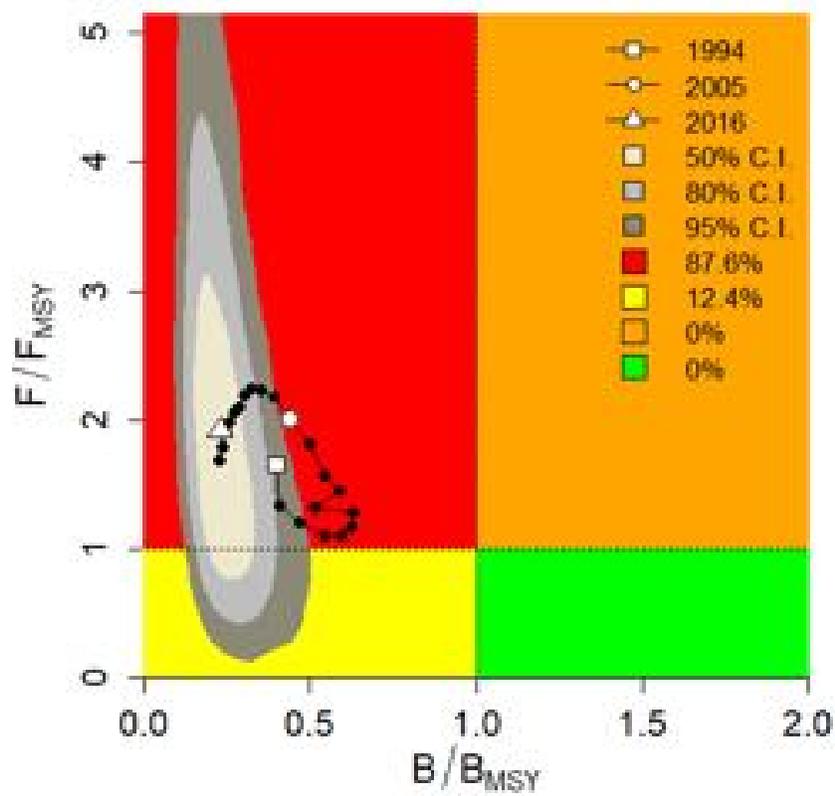
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 AMSY Analysis, Fri Nov 01 17:33:46 2019  
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Stock **SCORNOT\_AEGEAN**, *Scorpaena notata*, Small red scorpionfish  
 CPUE data for years 1994 - 2016, CPUE range 1.46 - 4, smooth = TRUE  
 Prior for  $r$  = Medium, NA - NA  
 Used prior range for  $r$  = 0.2 - 0.8  
 Prior for 2001 stock status = Small, 0.09 - 0.35  
 Used 2001 prior B/B0 range = 0.09 - 0.35, prior B/Bmsy = 0.18 - 0.7  
 Used prior range for  $kq$  = 7.28 - 21.8 [original range = 7.28 - 28.3]  
 Comment: B/B0 prior from LBB. RF: OK  
 Source:

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
 Viable  $r$ - $kq$  pairs = 5001

Results:  
 viable  $r$ - $kq$  pairs = 5001  
 median  $kq$  = 12.8, 8.64 - 20  
 median MSY $q$  = 1.41, 0.879 - 2.25  
 $r$  (4 MSY $q$ / $kq$ ) = 0.441, 0.269 - 0.734  
 Fmsy ( $r/2$ ) = 0.22, 0.135 - 0.367  
 F/Fmsy = 1.68, 0.264 - 4.03 (2015)  
 B/Bmsy = 0.229, 0.127 - 0.409 (2016)





## Cyprus

LBB results for *Merluccius merluccius*, stock Merl\_mer\_CY, 2012-2017  
Files:LBB4AMSY\_ID\_2.csv, Merl\_mer\_CY.csv

Linf prior= 55, SD=0.55 cm (user-defined), Lmax=54, median Lmax=50  
Z/K prior = 5.3, SD=0.71, M/K prior=1.5, SD=0.15  
F/K prior = 3.81 (wide range with tau=4 in log-normal distribution)  
Lc prior = 19.6, SD=2 cm, alpha prior=14.9, SD=1.5, Lm50=27 cm

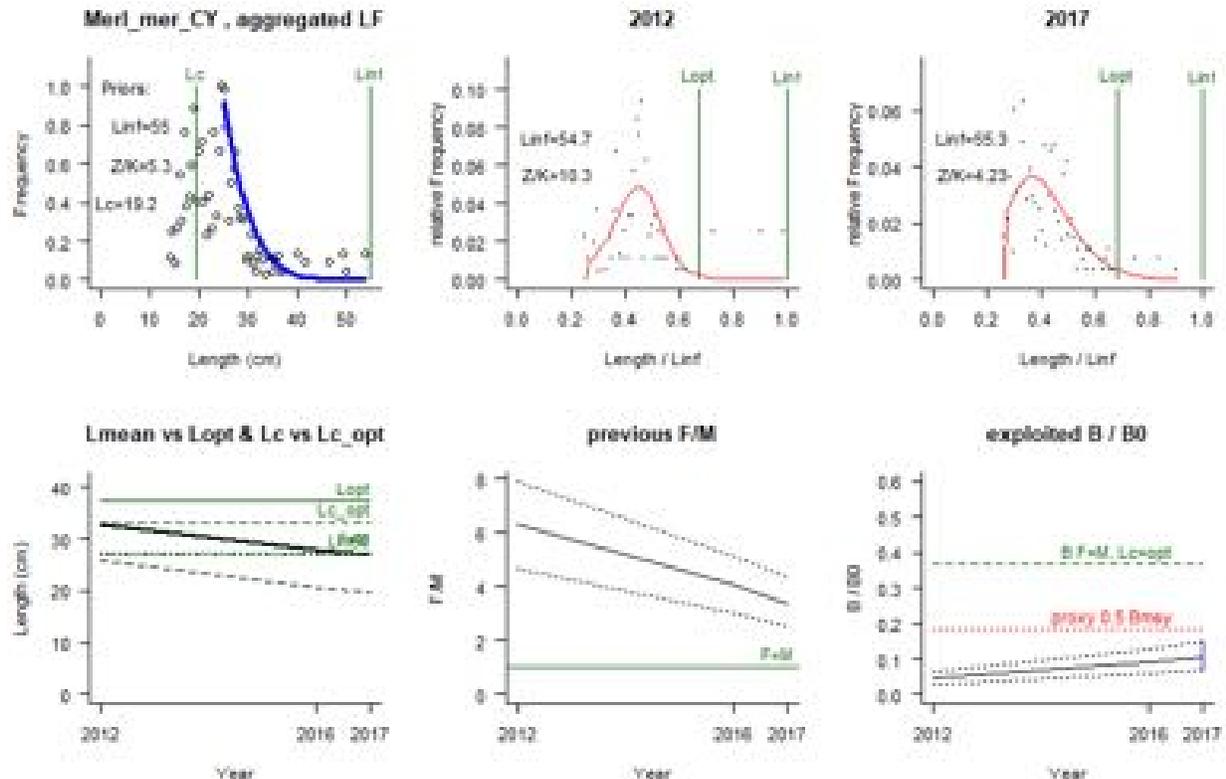
General reference points (median across years):

Linf = 55.3 (54.4-56.4) cm  
Lopt = 37 cm, Lopt/Linf=0.68  
Lc\_opt = 33 cm, Lc\_opt/Linf=0.6, Lmean if F=M 27.4 cm  
M/K = 1.44 (1.16-1.68)  
F/M = 2.02 (1.57-2.87), F/K=2.83 (2.48-3.29), Z/K=4.24 (3.96-4.57)  
B/B0 = 0.13 (0.087-0.19), B/B0 F=M Lc=Lc\_opt 0.37  
Y/R' = 0.022 (0.015-0.029)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.047

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 19.7 (19.2-20.1) cm, Lc/Linf=0.36 (0.35-0.36)  
Lc95 = 28.7, alpha=0.327 (0.313-0.338)  
Lmean/Lopt= 0.72, Lc/Lc\_opt=0.59, L95th=52.7 cm, L95th/Linf=0.96, Mature=21%  
F/M = 3.4 (2.5-4.4), F/K=4.8 (4.1-5.5), Z/K=6.2 (5.6-6.9)  
Y/R' = 0.018 (0.012-0.025)(reduced because B/B0 < 0.25)  
B/B0 = 0.11 (0.071-0.15), best LF fit year 2017=0.107 (0.071-0.15)  
B/Bmsy = 0.29 (0.19-0.41), **selected B/B0 2017 = 0.11 (0.071-0.15)**

RF: set Linf to 55, between median 50.2 and max 59.5. Set Lcut=14 to exclude early juveniles. Set Lstart=25 to improve fit to aggregated data. Merged LF to increase data per year. 2017 selected for AMSY.



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AMSY Analysis, Fri Nov 01 17:37:03 2019

Warning: Retrospective analysis not meaningful and omitted if B/k prior is in the final year(s)

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Stock **MERL\_MER\_CY**, *Merluccius merluccius*, European hake

CPUE data for years 2005 - 2017, CPUE range 2.94 - 15.1, smooth = TRUE

Prior for  $r$  = Medium, 0.35 - 0.8

Used prior range for  $r$  = 0.327 - 0.851

Prior for 2017 stock status = Very small, 0.07 - 0.15

Used 2017 prior B/B<sub>0</sub> range = 0.07 - 0.15, prior B/B<sub>msy</sub> = 0.14 - 0.3

Used prior range for  $kq$  = 84.9 - 182 [original range = 84.9 - 182]

Comment: B/B<sub>0</sub> prior from LBB. RF: OK

Source:

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5000

Results:

viable  $r$ - $kq$  pairs = 5000

median  $kq$  = 117, 85.2 - 164

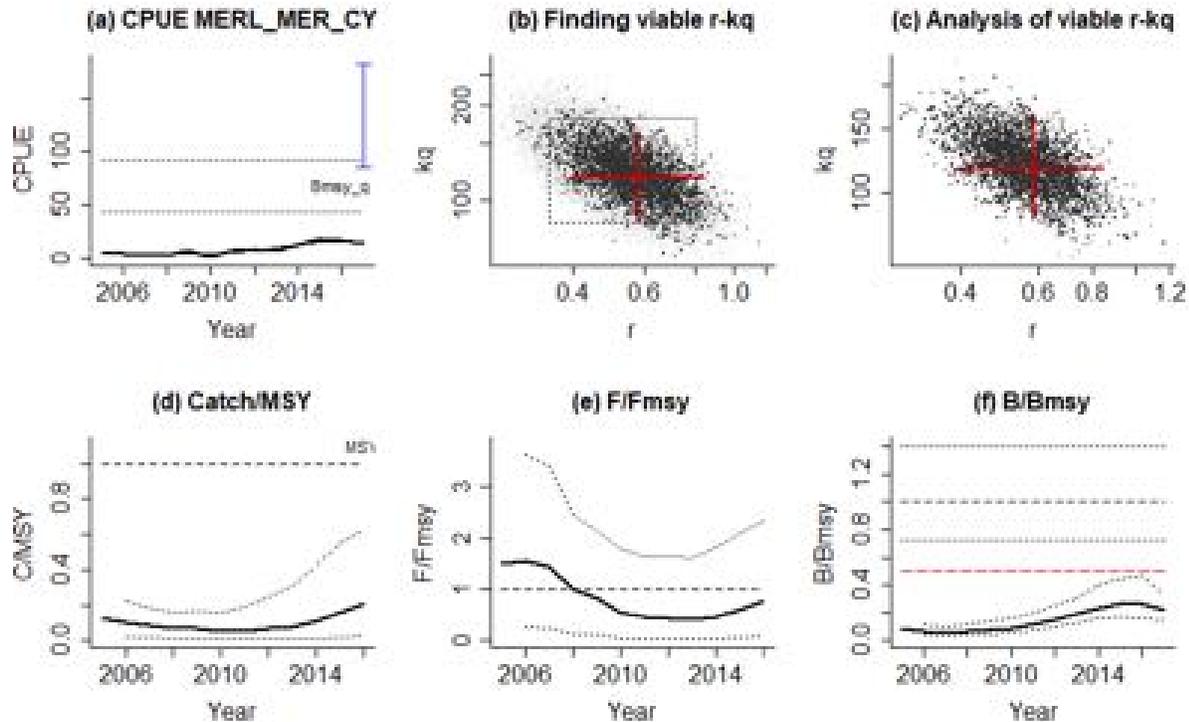
median MSY $q$  = 17.1, 12.2 - 23.9

$r$  (4 MSY $q$ / $kq$ ) = 0.584, 0.39 - 0.842

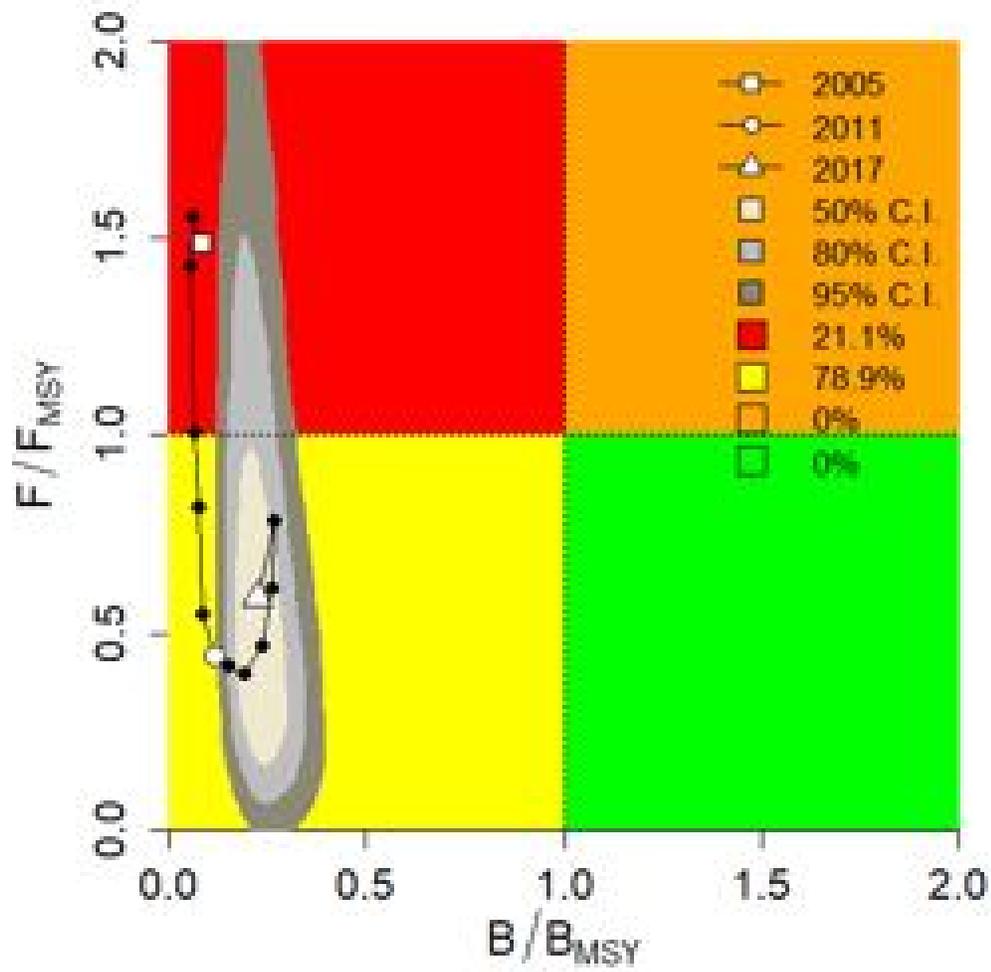
F<sub>msy</sub> ( $r/2$ ) = 0.292, 0.195 - 0.421

F/F<sub>msy</sub> = 0.785, 0.07 - 2.35 (2016)

B/B<sub>msy</sub> = 0.224, 0.146 - 0.333 (2017)



AMSY Kobe plot for MERL\_MERL\_CY, *Merluccius merluccius* in Cyprus



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 LBB results for *sepia officinalis*, stock SEPIOFF\_CY, 2005-2017  
 Files:LBB4AMSY\_ID\_2.csv, SEPIOFF\_CY.csv  
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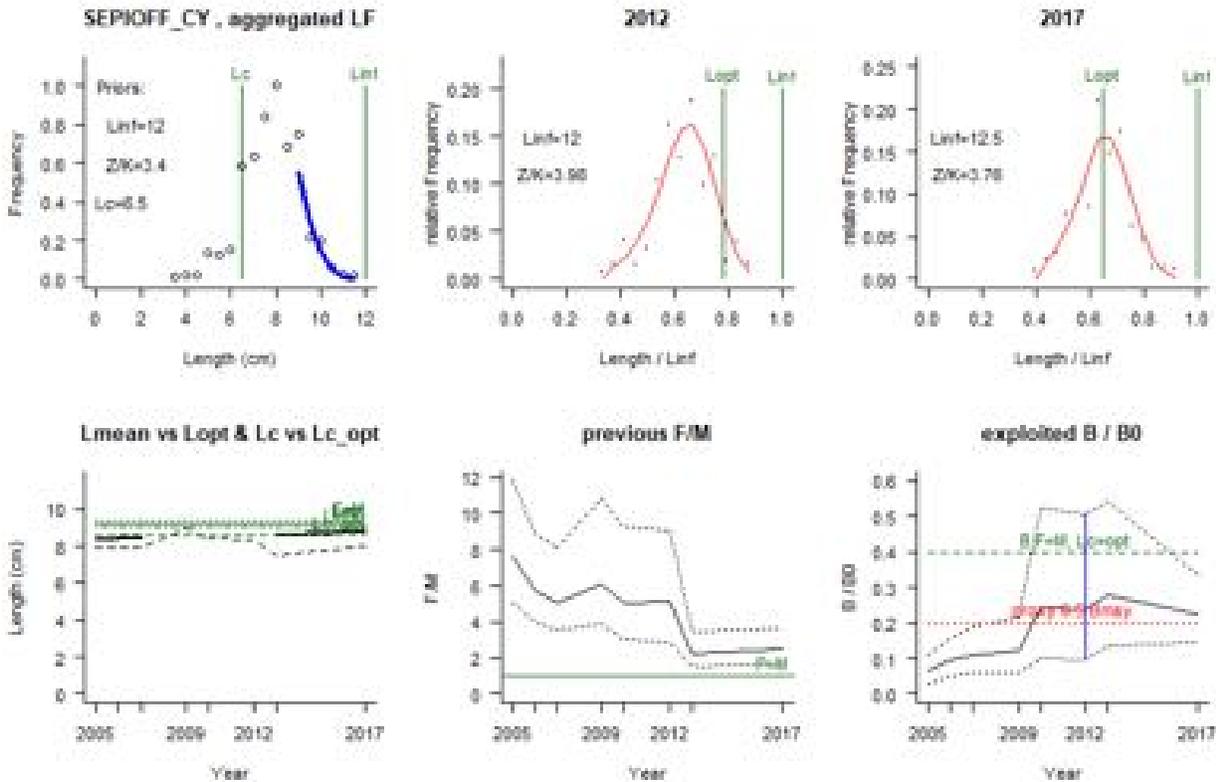
Linf prior= 12, SD=0.12 cm (user-defined), Lmax=12, median Lmax=10.2  
 Z/K prior = 3.4, SD=0.65, M/K prior=1.5, SD=0.15  
 F/K prior = 1.86 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 6.63, SD=0.66 cm, alpha prior=17.4, SD=1.7, Lm50=9 cm

General reference points (median across years):

Linf = 11.9 (11.8-12.1) cm  
 Lopt = 9.2 cm, Lopt/Linf=0.77  
 Lc\_opt = 8.6 cm, Lc\_opt/Linf=0.72, Lmean if F=M 9.35 cm  
 M/K = 0.877 (0.591-1.15)  
 F/M = 3.77 (2.58-6), F/K=3.12 (2.57-3.58), Z/K=3.95 (3.55-4.39)  
 B/B0 = 0.13 (0.076-0.23), B/B0 F=M Lc=Lc\_opt 0.4  
 Y/R' = 0.057 (0.025-0.092)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.093

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 7.98 (7.82-8.11) cm, Lc/Linf=0.65 (0.64-0.66)  
 Lc95 = 10.4, alpha=1.2 (1.16-1.23)  
 Lmean/Lopt= 1, Lc/Lc\_opt=0.93, L95th=11.2 cm, L95th/Linf=0.91, Mature=15%  
 F/M = 2.5 (1.7-3.6), F/K=2.7 (2.2-3.1), Z/K=3.9 (3.5-4.3)  
 Y/R' = 0.053 (0.032-0.08)(reduced because B/B0 < 0.25)  
 B/B0 = 0.23 (0.14-0.34), best LF fit year 2010=0.245 (0.1-0.52)  
 B/Bmsy = 0.57 (0.36-0.85), **selected B/B0 2012 = 0.24 (0.094-0.5)**  
 RF: Set Linf=12 with median 10.5 and Lmax 12. Merged LF to get more data per year. Discarded years with unsuitable LFs. Chose 2012 for AMSY prior because of good fit with reasonable CL.

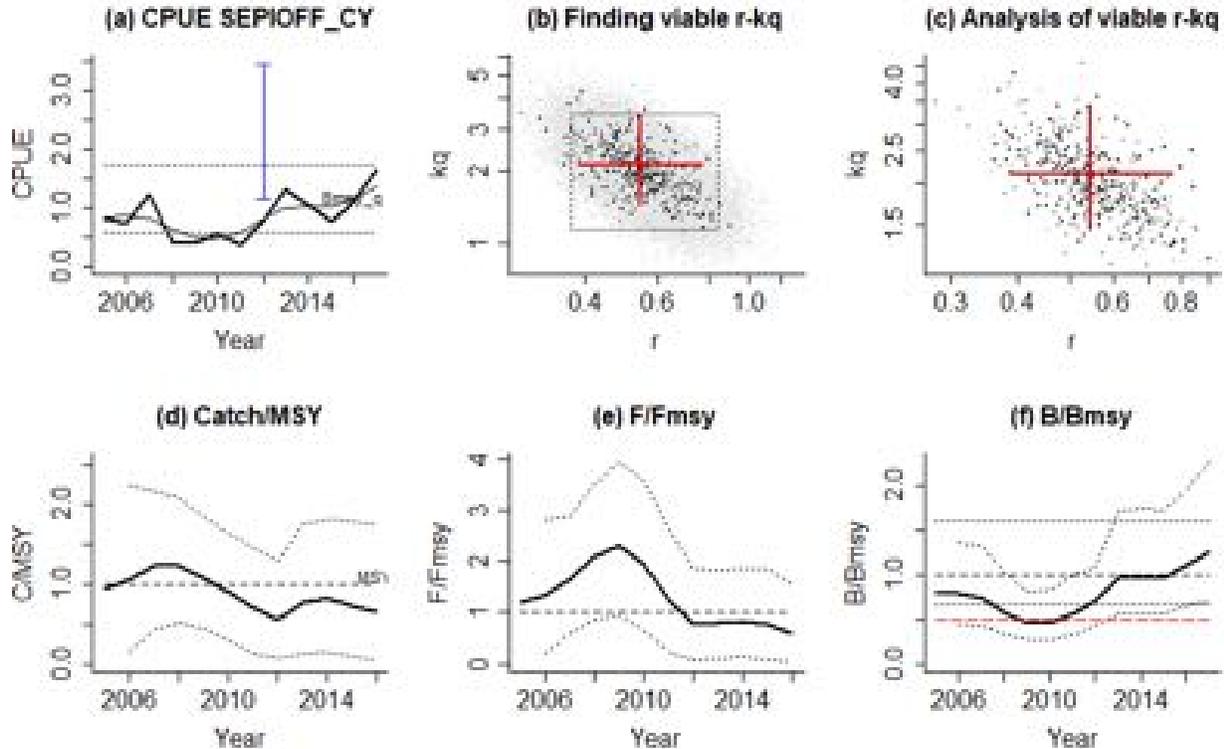


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AMSY Analysis, Fri Nov 01 17:42:28 2019  
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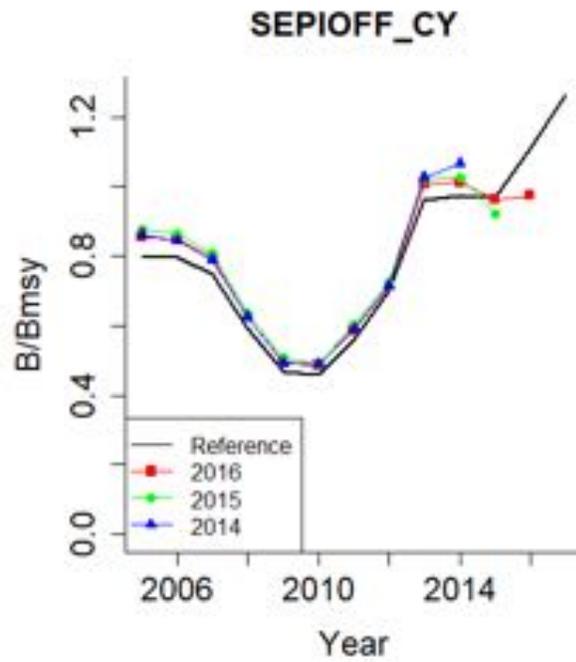
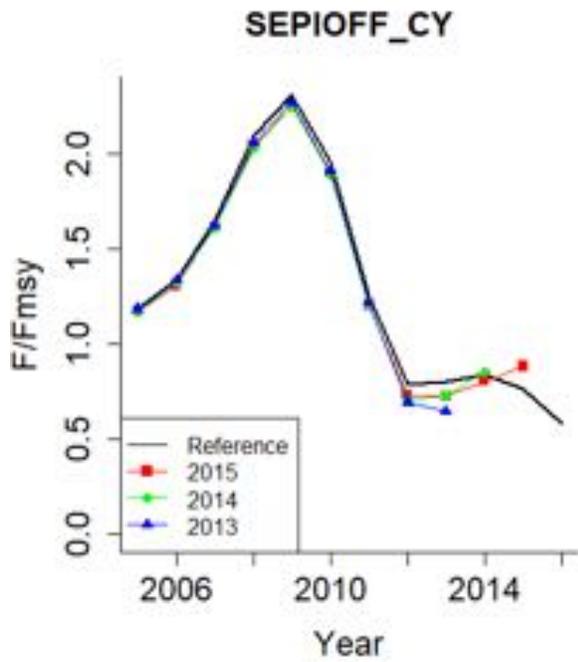
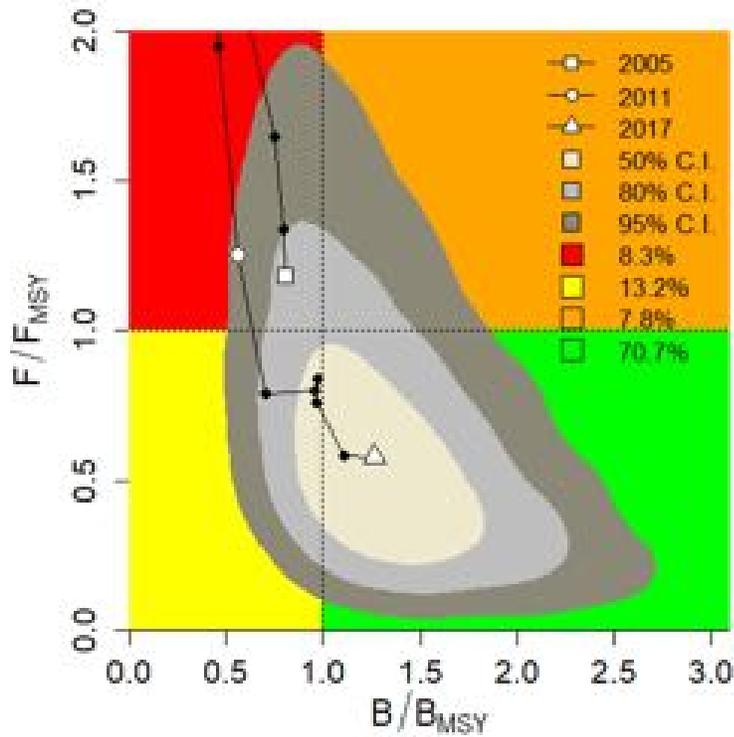
Stock **SEPIOFF\_CY**, *Sepia officinalis*, common cuttlefish  
CPUE data for years 2005 - 2017, CPUE range 0.477 - 1.35, smooth = TRUE  
Prior for  $r$  = Medium, 0.37 - 0.84  
Used prior range for  $r$  = 0.346 - 0.897  
Prior for 2012 stock status = Small, 0.09 - 0.5  
Used 2012 prior B/B0 range = 0.09 - 0.5, prior B/Bmsy = 0.18 - 1  
Used prior range for  $kq$  = 1.15 - 3.45 [original range = 0.829 - 4.6]  
Comment: B/B0 prior from LBB. RF: OK  
Source:

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5010

Results:  
viable  $r$ - $kq$  pairs = 5010  
median  $kq$  = 2.13, 1.44 - 3.42  
median MSYq = 0.29, 0.204 - 0.448  
 $r$  (4 MSYq/ $kq$ ) = 0.544, 0.385 - 0.768  
 $F_{msy}$  ( $r/2$ ) = 0.272, 0.193 - 0.384  
 $F/F_{msy}$  = 0.583, 0.0444 - 1.57 (2016)  
 $B/B_{msy}$  = 1.26, 0.708 - 2.27 (2017)



AMSY Kobe plot and retrospective analysis for *Sepia officinalis* in Cyprus



# North Sea

LBB results for *Agonus cataphractus*, stock *Agonus cataphractus*, 1983-2017  
 Files: LBB4AMSY\_ID\_3.csv, LBB\_June042019\_Agonus cataphractus.csv

Linf prior = 18, SD=0.18 cm (user-defined), Lmax=22, median Lmax=15  
 Z/K prior = 3.6, SD=0.056, M/K prior=1.5, SD=0.15  
 F/K prior = 2.12 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 8.67, SD=0.87 cm, alpha prior=18.9, SD=1.9, Lm50=NA cm

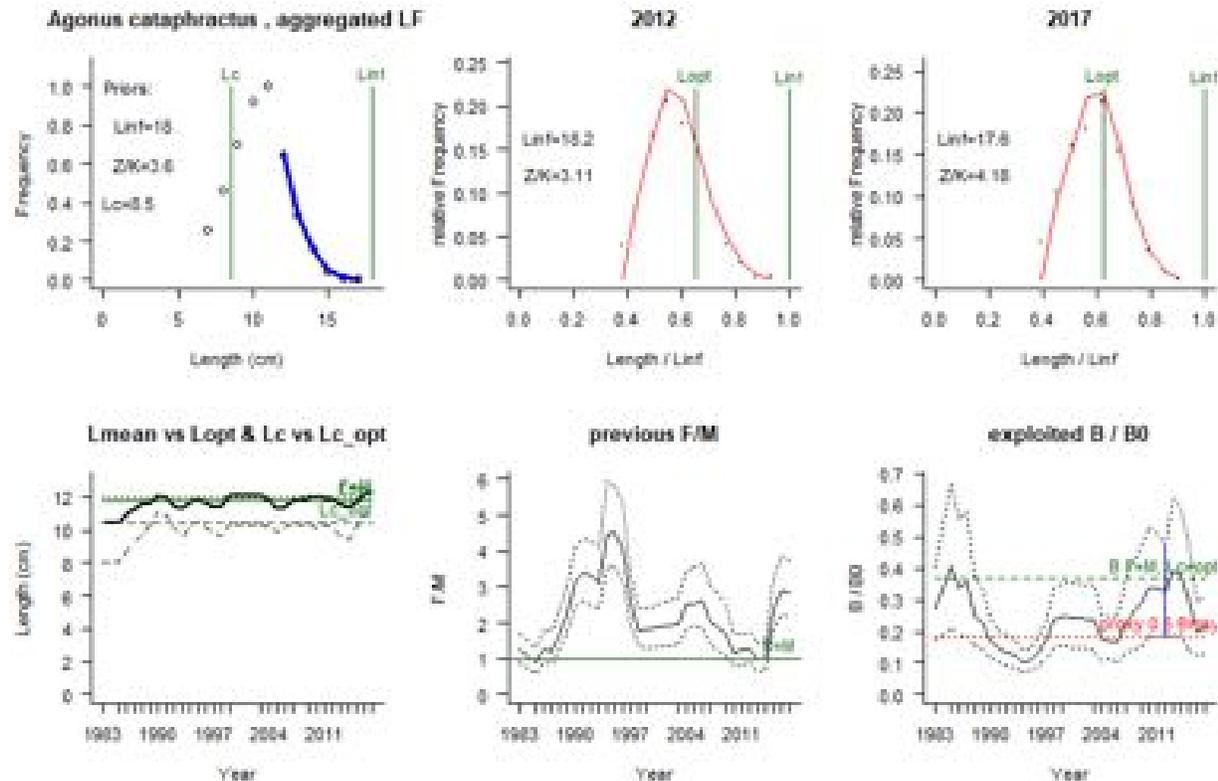
General reference points (median across years):

Linf = 18 (17.6-18.3) cm  
 Lopt = 12 cm, Lopt/Linf=0.66  
 Lc\_opt = 10 cm, Lc\_opt/Linf=0.58, Lmean if F=M 12 cm  
 M/K = 1.57 (1.28-1.82)  
 F/M = 1.99 (1.46-2.69), F/K=3.08 (2.6-3.63), Z/K=4.6 (4.15-5.06)  
 B/B0 = 0.21 (0.14-0.31), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.036 (0.022-0.053) (reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.041

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 10.9 (10.6-11.3) cm, Lc/Linf=0.62 (0.6-0.64)  
 Lc95 = 15.3, alpha=0.681 (0.654-0.712)  
 Lmean/Lopt = 1.1, Lc/Lc\_opt=1, L95th=15.7 cm, L95th/Linf=0.88, Mature=NA%  
 F/M = 2.8 (2.2-3.7), F/K=4.2 (3.5-5.1), Z/K=5.9 (5.2-6.7)  
 Y/R' = 0.031 (0.019-0.045) (reduced because B/B0 < 0.25)  
 B/B0 = 0.21 (0.13-0.31), best LF fit year 1996=0.132 (0.088-0.18)  
 B/Bmsy = 0.58 (0.35-0.84), **selected B/B0 2012 = 0.32 (0.19-0.47)**

RF: Uses SMFS 2017 data. Set Lcut to 7 cm to avoid early juveniles. Set Linf to 18 cm between median=15 and max=22. Merged LFs of subsequent years to reduce variability.

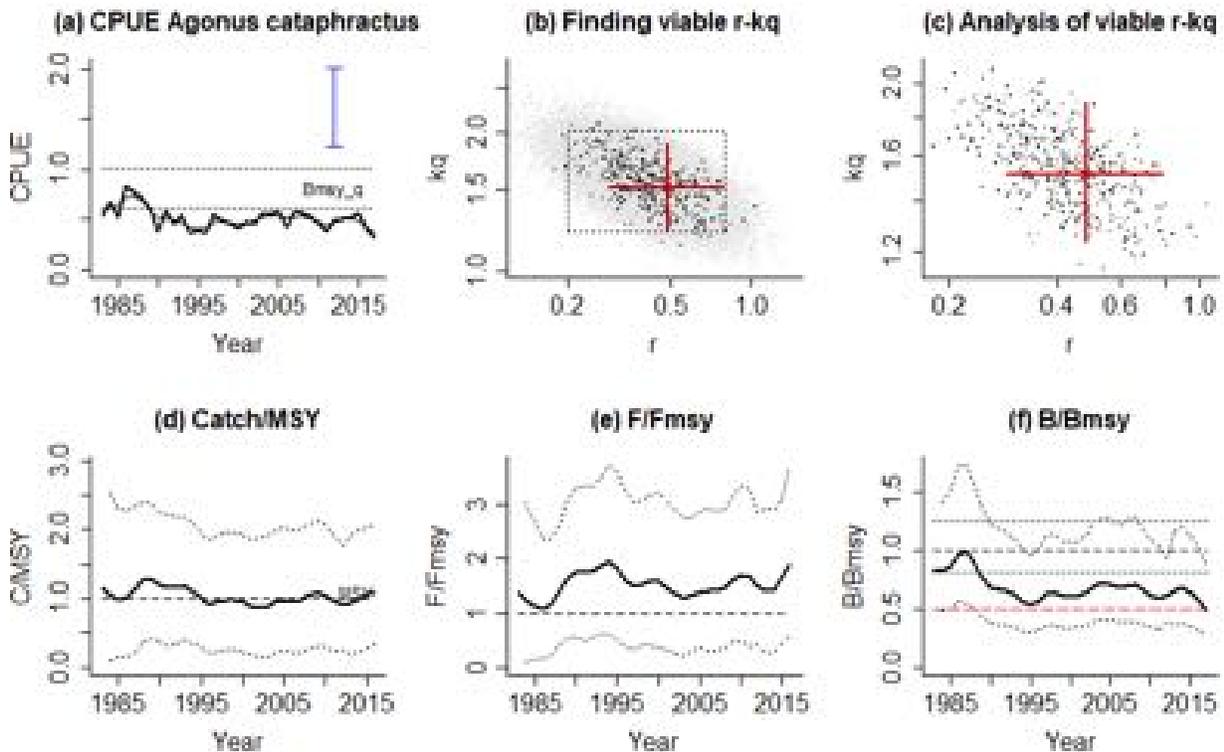


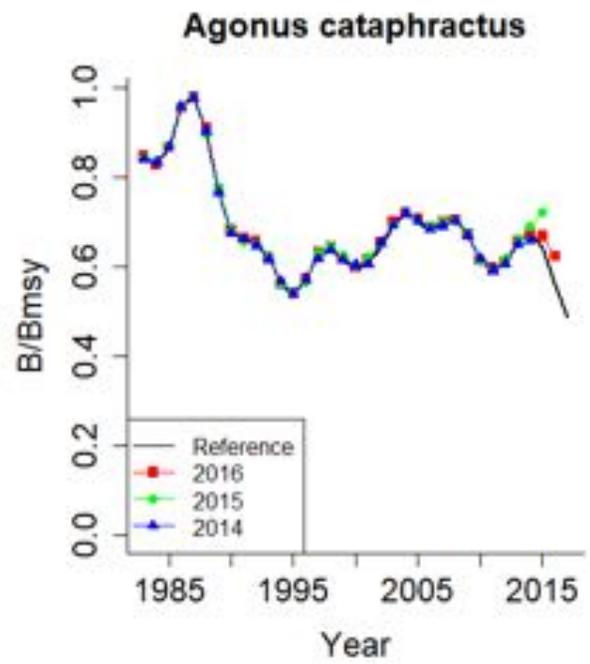
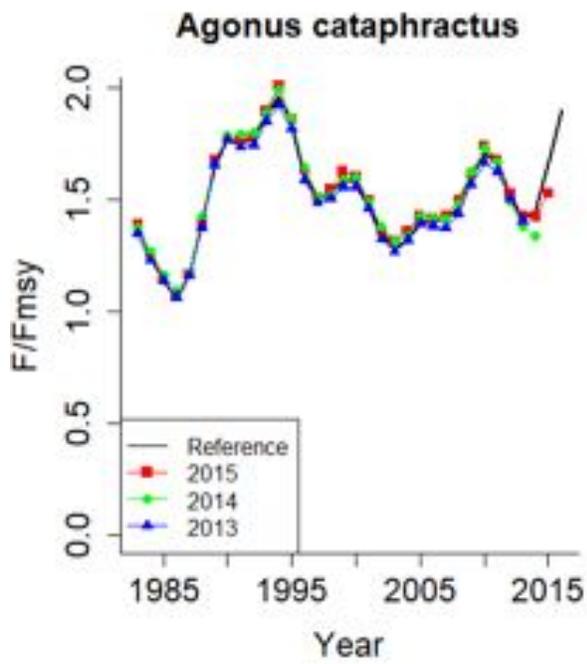
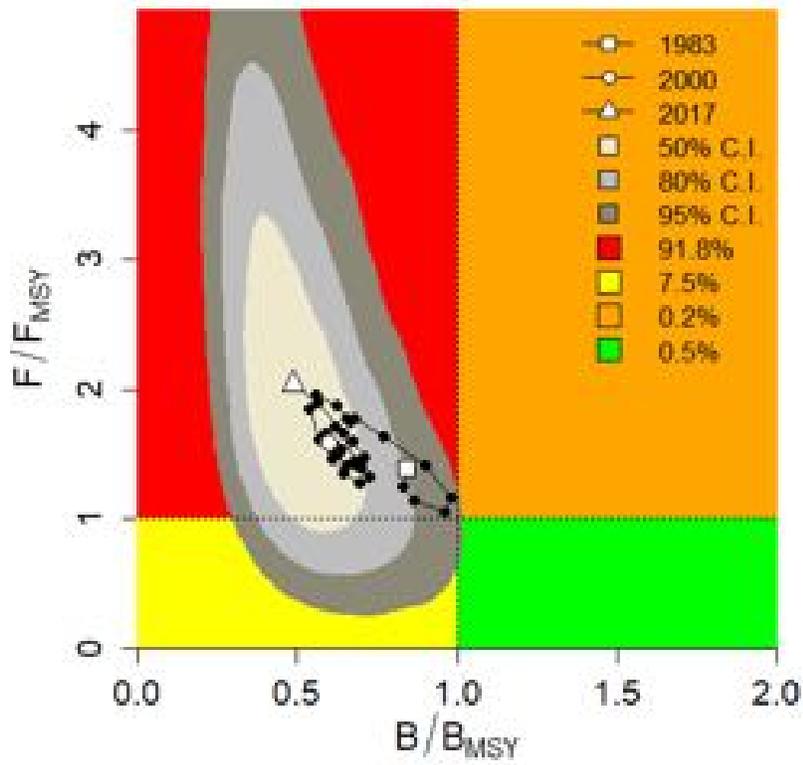
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AMSY Analysis, Fri Nov 01 17:46:47 2019  
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Stock **Agonus cataphractus**, *Agonus cataphractus*, Hooknose  
CPUE data for years 1983 - 2017, CPUE range 0.37 - 0.739, smooth = TRUE  
Prior for  $r$  = Medium, NA - NA  
Used prior range for  $r$  = 0.2 - 0.8  
Prior for 2012 stock status = About half, 0.19 - 0.47  
Used 2012 prior B/B0 range = 0.19 - 0.47, prior B/Bmsy = 0.38 - 0.94  
Used prior range for  $kq$  = 1.22 - 2.02 [original range = 0.815 - 2.02]  
Comment: B/B0 prior from LBB. RF: OK  
Source: SMFS 2017

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5001

Results:  
viable  $r$ - $kq$  pairs = 5001  
median  $kq$  = 1.52, 1.23 - 1.88  
median MSYq = 0.184, 0.12 - 0.278  
 $r$  (4 MSYq/ $kq$ ) = 0.485, 0.287 - 0.783  
 $F_{msy}$  ( $r/2$ ) = 0.243, 0.143 - 0.391  
 $F/F_{msy}$  = 1.9, 0.585 - 3.68 (2016)  
 $B/B_{msy}$  = 0.487, 0.272 - 0.858 (2017)





LBB results for *Amblyraja radiata*, stock *Amblyraja radiata*, 1983-2017  
 Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Amblyraja radiata.csv

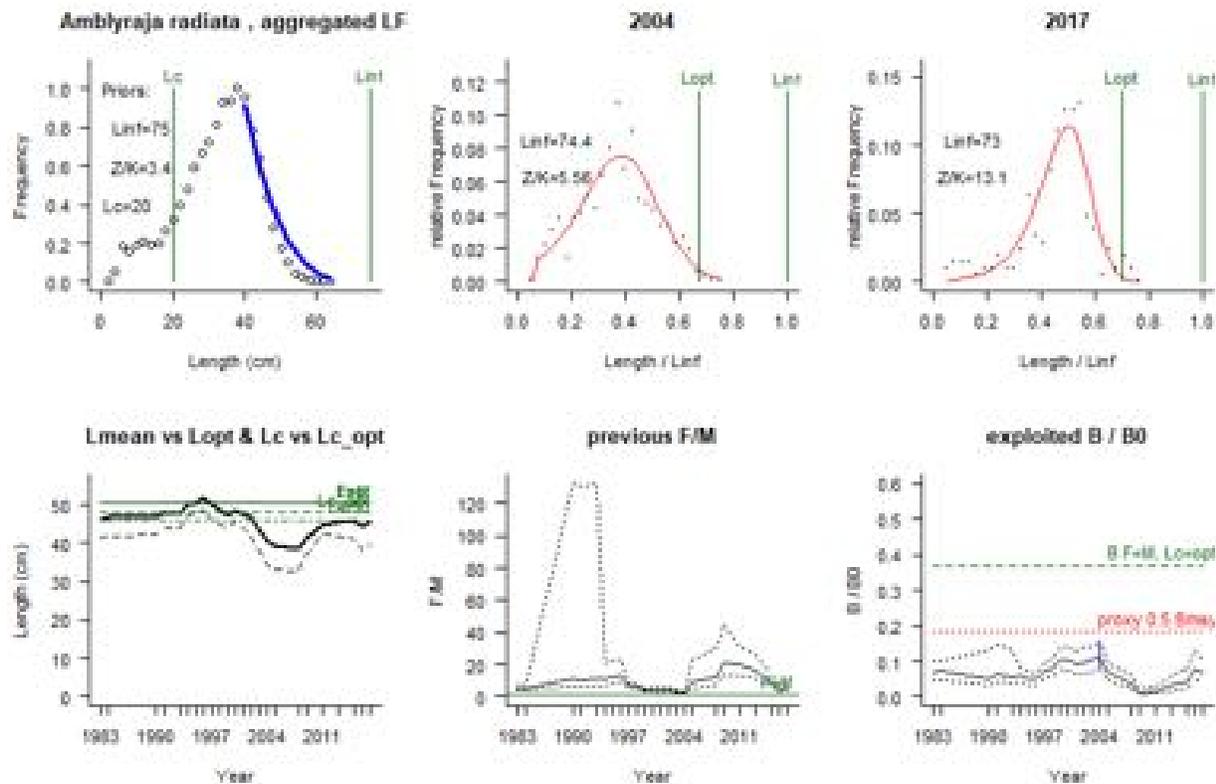
Linf prior= 75, SD=0.75 cm (user-defined), Lmax=82, median Lmax=58  
 Z/K prior = 3.4, SD=0.46, M/K prior=1.5, SD=0.15  
 F/K prior = 1.9 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 20.4, SD=2 cm, alpha prior=11.8, SD=1.2, Lm50=46 cm

General reference points (median across years):

Linf = 73.8 (72.6-75.1) cm  
 Lopt = 50 cm, Lopt/Linf=0.68  
 Lc\_opt = 48 cm, Lc\_opt/Linf=0.65, Lmean if F=M 50.4 cm  
 M/K = 1.39 (1.14-1.64)  
 F/M = 5.74 (4.36-8.33), F/K=8.23 (7.14-9.33), Z/K=9.25 (8.36-10.4)  
 B/B0 = 0.066 (0.042-0.1), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.012 (0.0083-0.016)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.048

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 40 (38.9-41) cm, Lc/Linf=0.54 (0.53-0.56)  
 Lc95 = 58.8, alpha=0.156 (0.152-0.161)  
 Lmean/Lopt= 0.86, Lc/Lc\_opt=0.83, L95th=57.3 cm, L95th/Linf=0.78, Mature=6.3%  
 F/M = 6.4 (4.7-8.9), F/K=7.2 (6.2-8.4), Z/K=8.4 (7.4-9.5)  
 Y/R' = 0.015 (0.0098-0.024)(reduced because B/B0 < 0.25)  
 B/B0 = 0.071 (0.046-0.11), best LF fit year 1983=0.0695 (0.046-0.1)  
 B/Bmsy = 0.19 (0.12-0.29), **selected B/B0 2004 = 0.11 (0.078-0.16)**  
 RF: Set Lstart=40 to avoid error in prior fit. Set Linf=75 between Lmax=82 and Lmedian=58. Selected 2004 for reasonable fit and CLs.

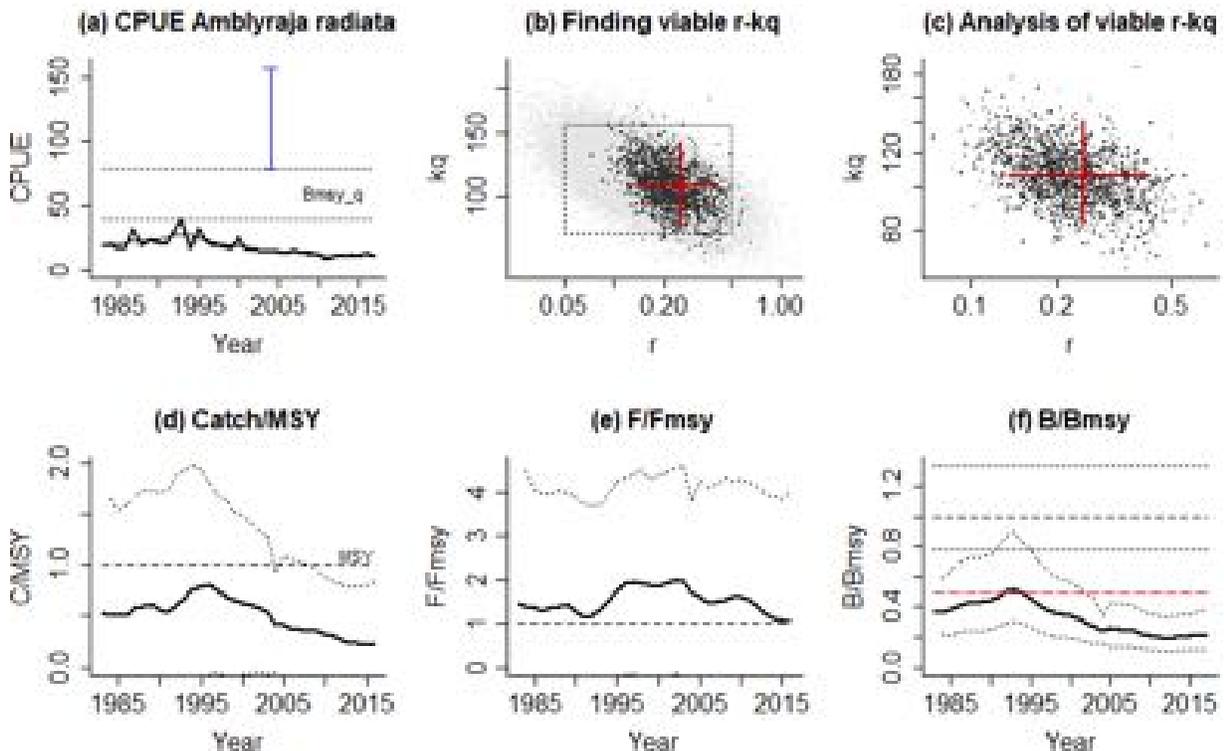


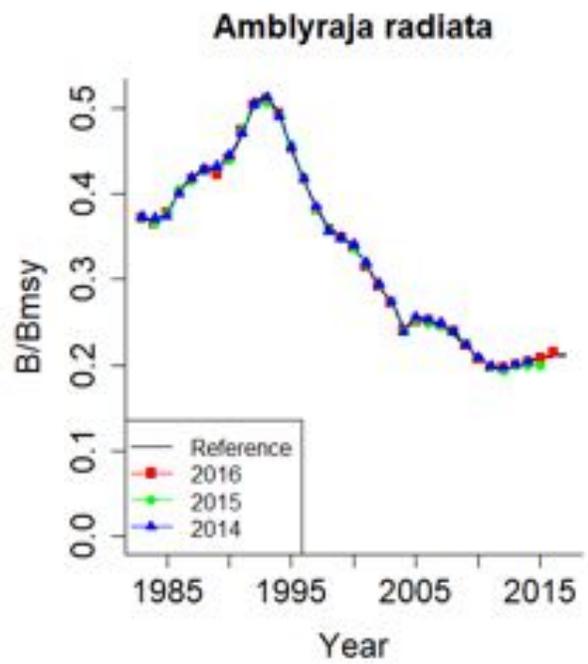
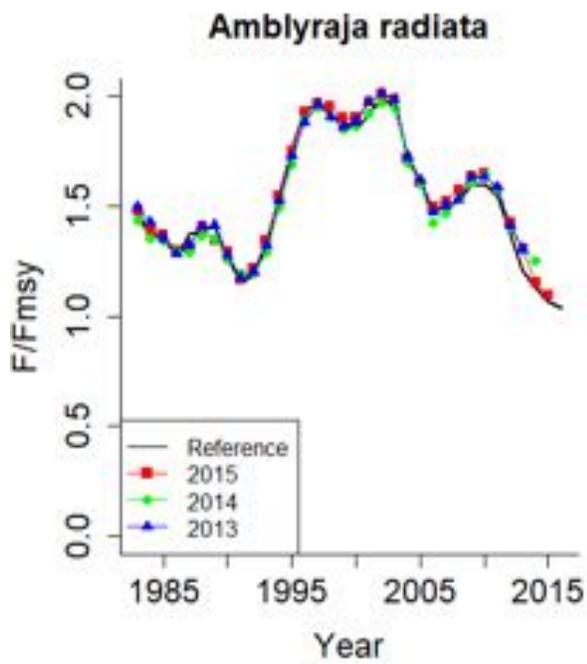
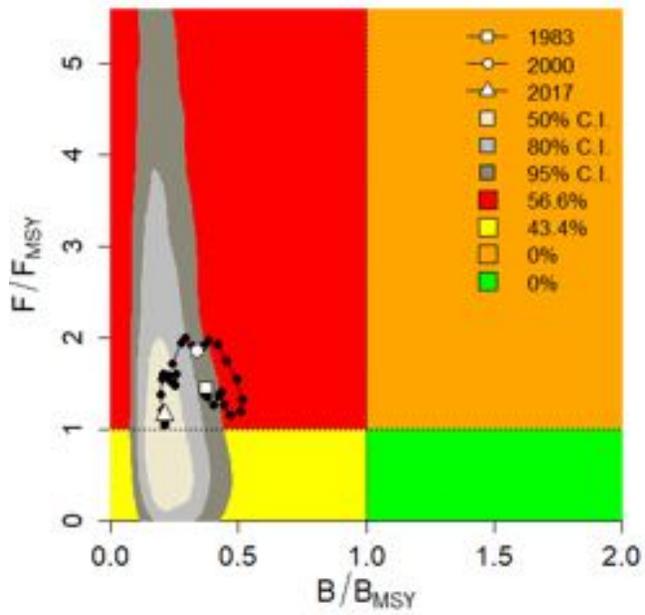
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AMSY Analysis, Fri Nov 01 17:50:42 2019  
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Stock *Amblyraja radiata*, *Amblyraja radiata*, Starry ray  
CPUE data for years 1983 - 2017, CPUE range 10.5 - 27.6, smooth = TRUE  
Prior for  $r$  = Low, NA - NA  
Used prior range for  $r$  = 0.05 - 0.5  
Prior for 2004 stock status = Very small, 0.08 - 0.16  
Used 2004 prior B/B0 range = 0.08 - 0.16, prior B/Bmsy = 0.16 - 0.32  
Used prior range for  $kq$  = 78.6 - 157 [original range = 78.6 - 157]  
Comment: B/B0 prior from LBB. RF: OK  
Source: SMFS 2017

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5000

Results:  
viable  $r$ - $kq$  pairs = 5000  
median  $kq$  = 106, 82.7 - 142  
median MSY $q$  = 6.59, 3.79 - 10.8  
 $r$  (4 MSY $q$ / $kq$ ) = 0.248, 0.134 - 0.418  
Fmsy ( $r/2$ ) = 0.124, 0.0671 - 0.209  
F/Fmsy = 1.04, -0.84 - 3.99 (2016)  
B/Bmsy = 0.211, 0.119 - 0.385 (2017)





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 LBB results for *Buglossidium luteum*, stock *Buglossidium luteum*, 1983-2017  
 Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Buglossidium luteum.csv  
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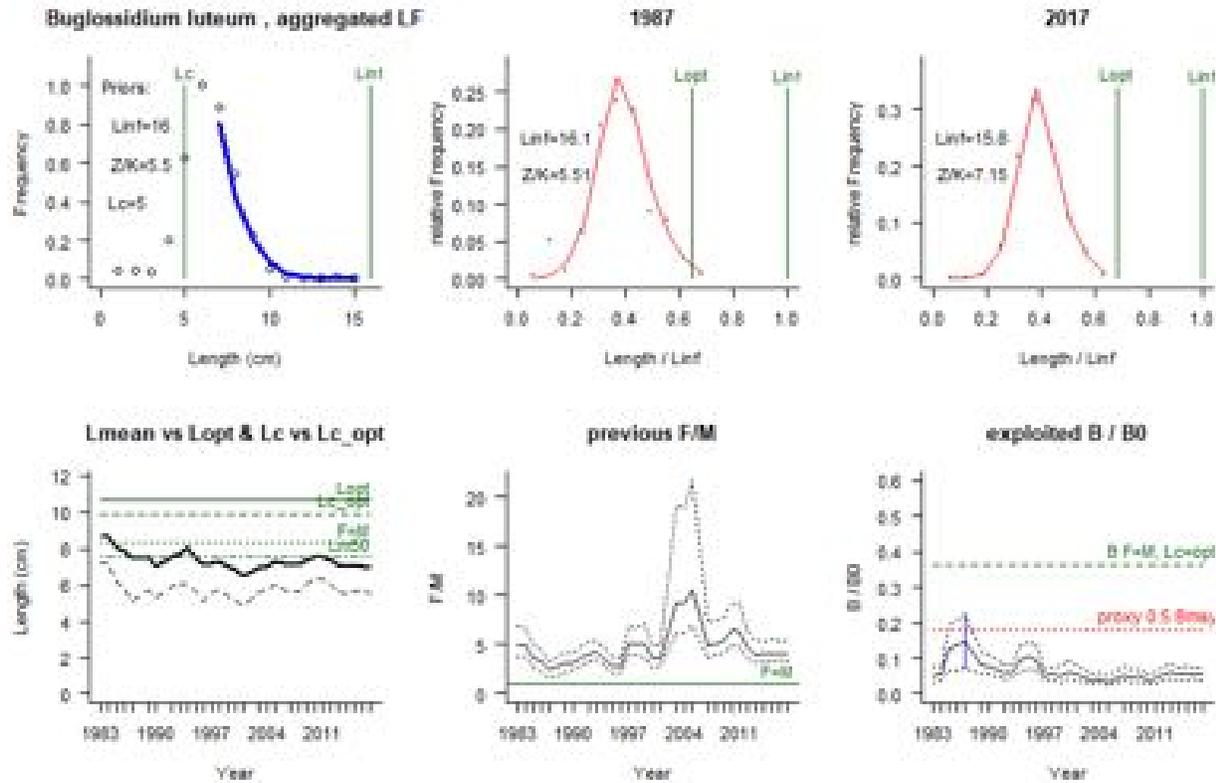
Linf prior= 16, SD=0.16 cm (user-defined), Lmax=20, median Lmax=13  
 Z/K prior = 5.5, SD=0.3, M/K prior=1.5, SD=0.15  
 F/K prior = 3.97 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 5.1, SD=0.51 cm, alpha prior=27.3, SD=2.7, Lm50=7.5 cm

General reference points (median across years):

Linf = 16 (15.8-16.3) cm  
 Lopt = 11 cm, Lopt/Linf=0.66  
 Lc\_opt = 9.9 cm, Lc\_opt/Linf=0.62, Lmean if F=M 8.28 cm  
 M/K = 1.51 (1.24-1.8)  
 F/M = 3.79 (3.01-5.12), F/K=6.03 (5.48-6.71), Z/K=7.77 (7.3-8.38)  
 B/B0 = 0.058 (0.042-0.082), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.0073 (0.0055-0.0099)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.045

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 5.52 (5.44-5.61) cm, Lc/Linf=0.34 (0.34-0.35)  
 Lc95 = 7.2, alpha=1.75 (1.69-1.82)  
 Lmean/Lopt= 0.66, Lc/Lc\_opt=0.56, L95th=10.3 cm, L95th/Linf=0.64, Mature=17%  
 F/M = 4.1 (3.4-5.4), F/K=6.4 (5.9-7), Z/K=8 (7.5-8.4)  
 Y/R' = 0.0068 (0.005-0.0094)(reduced because B/B0 < 0.25)  
 B/B0 = 0.055 (0.04-0.076), best LF fit year 1995=0.103 (0.071-0.15)  
 B/Bmsy = 0.15 (0.11-0.21), **selected B/B0 1987 = 0.15 (0.073-0.23)**  
 RF: Set Linf=15cm above median=14. Selected 1987 because of reasonable fit and CL with not too low B/B0.



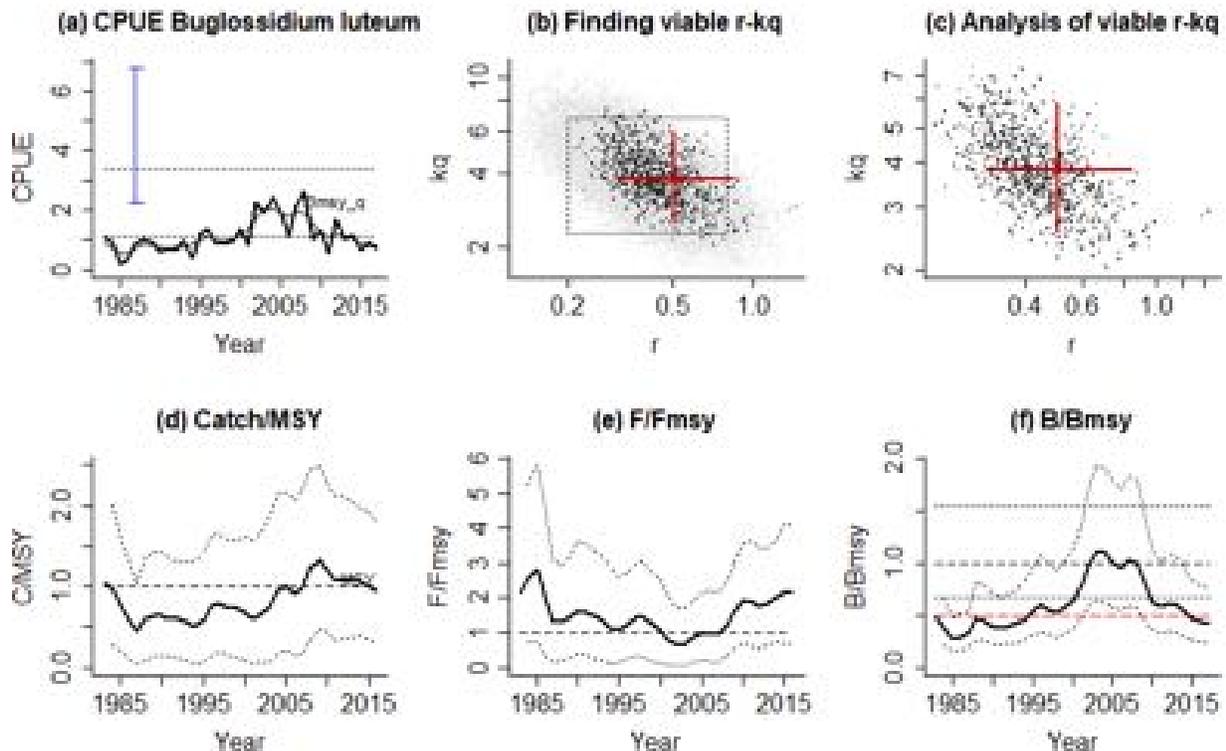
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AMSY Analysis, Fri Nov 01 17:55:47 2019  
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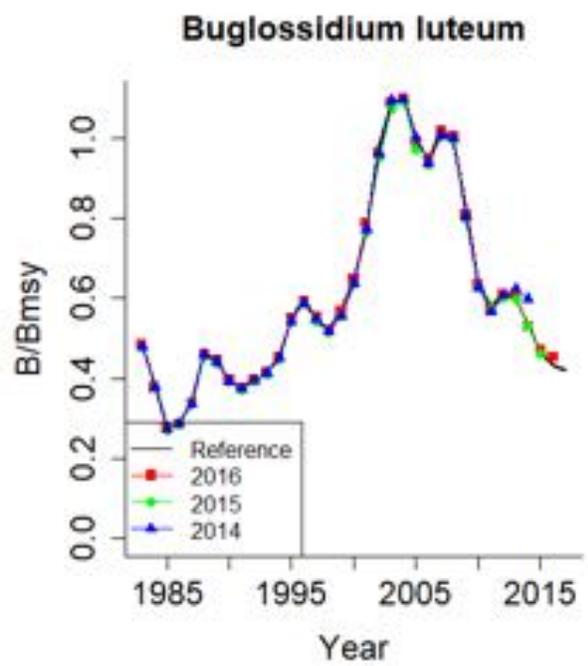
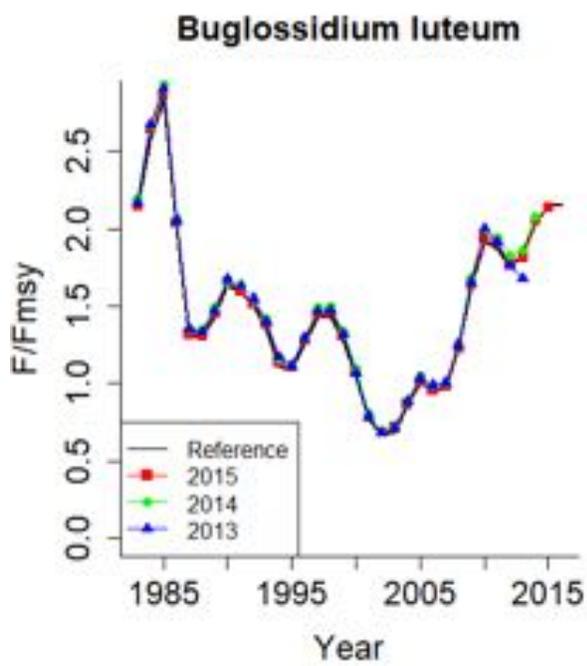
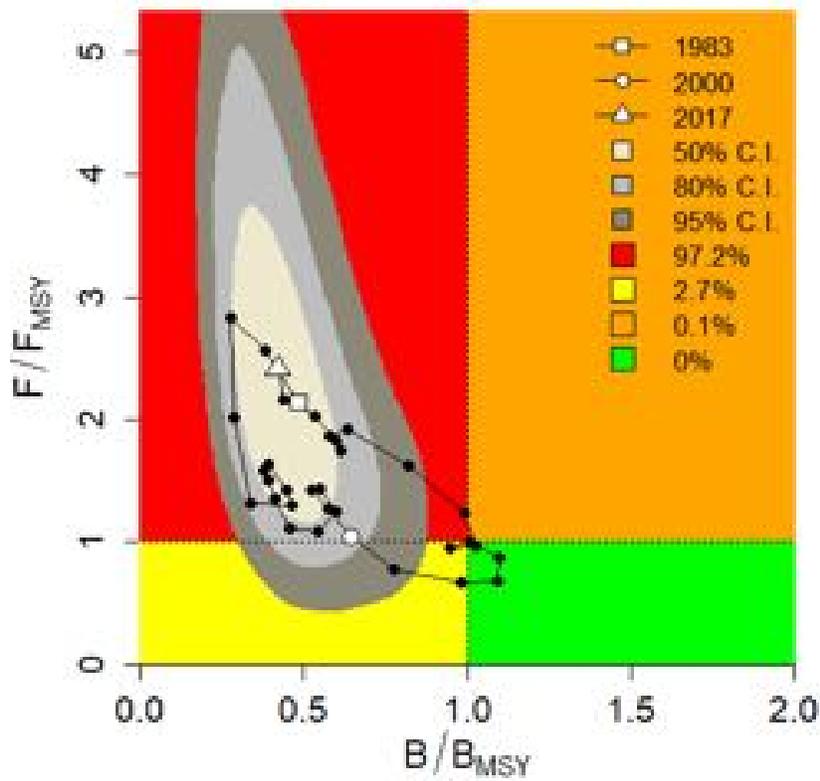
Stock *Buglossidium luteum*, *Buglossidium luteum*, Solonette

CPUE data for years 1983 - 2017, CPUE range 0.527 - 2.07, smooth = TRUE  
Prior for  $r$  = Medium, NA - NA  
Used prior range for  $r$  = 0.2 - 0.8  
Prior for 1987 stock status = Very small, 0.07 - 0.23  
Used 1987 prior B/B0 range = 0.07 - 0.23, prior B/Bmsy = 0.14 - 0.46  
Used prior range for  $kq$  = 2.26 - 6.79 [original range = 2.26 - 7.44]  
Comment: B/B0 prior from LBB. RF: OK  
Source: SMFS 2017

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5003

Results:  
viable  $r$ - $kq$  pairs = 5003  
median  $kq$  = 3.8, 2.56 - 5.86  
median MSY $q$  = 0.48, 0.301 - 0.805  
 $r$  (4 MSY $q$ / $kq$ ) = 0.505, 0.304 - 0.844  
Fmsy ( $r/2$ ) = 0.252, 0.152 - 0.422  
F/Fmsy = 2.16, 0.686 - 4.09 (2016)  
B/Bmsy = 0.42, 0.233 - 0.759 (2017)





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 LBB results for *Callionymus lyra*, stock *Callionymus lyra*, 1993-2017  
 Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Callionymus lyra.csv  
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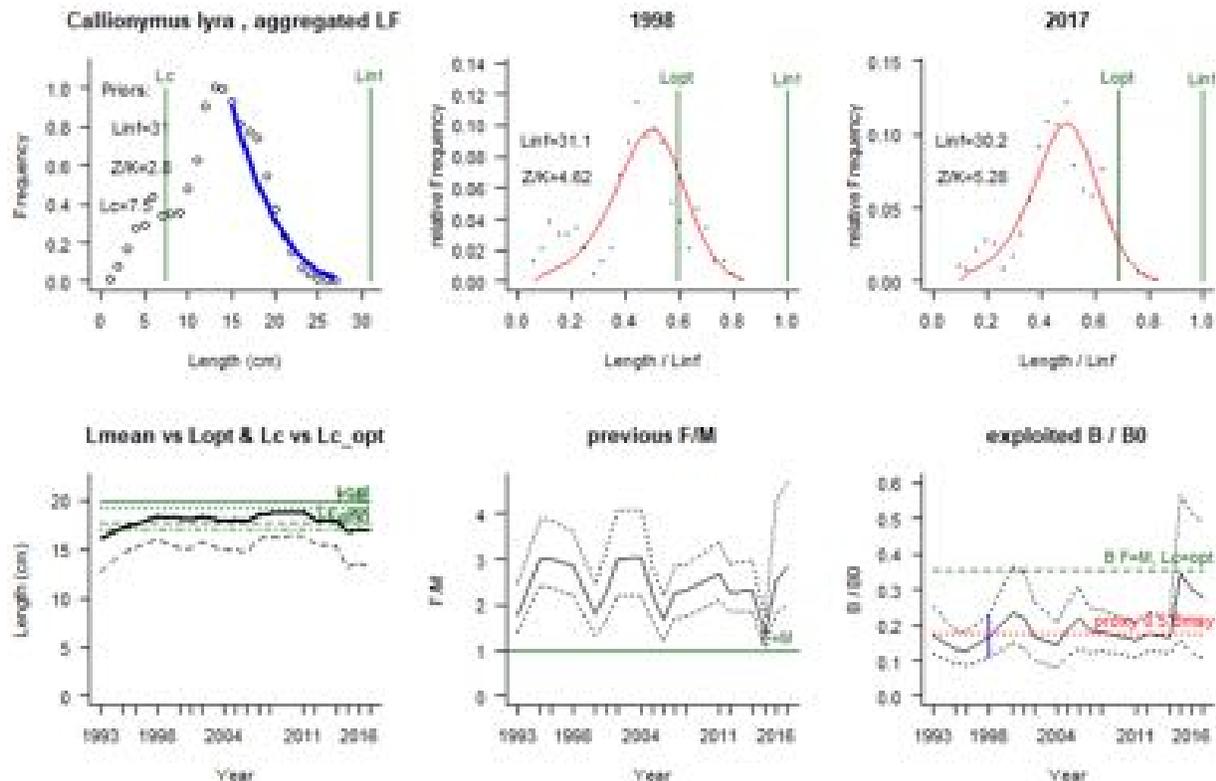
Linf prior= 31, SD=0.31 cm (user-defined), Lmax=37, median Lmax=25  
 Z/K prior = 2.8, SD=0.25, M/K prior=1.5, SD=0.15  
 F/K prior = 1.34 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 7.65, SD=0.77 cm, alpha prior=12, SD=1.2, Lm50=17 cm

General reference points (median across years):

Linf = 31.1 (30.4-31.7) cm  
 Lopt = 20 cm, Lopt/Linf=0.64  
 Lc\_opt = 18 cm, Lc\_opt/Linf=0.57, Lmean if F=M 19.1 cm  
 M/K = 1.71 (1.45-1.97)  
 F/M = 2.04 (1.61-2.54), F/K=4.11 (3.46-4.83), Z/K=5.48 (5.05-6.15)  
 B/B0 = 0.17 (0.12-0.24), B/B0 F=M Lc=Lc\_opt 0.36  
 Y/R' = 0.02 (0.014-0.033)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.034

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 13.2 (12.7-13.8) cm, Lc/Linf=0.43 (0.42-0.45)  
 Lc95 = 21.2, alpha=0.365 (0.352-0.378)  
 Lmean/Lopt= 0.78, Lc/Lc\_opt=0.75, L95th=24.3 cm, L95th/Linf=0.8, Mature=22%  
 F/M = 2.8 (2-4.7), F/K=2.7 (2.3-3.2), Z/K=4 (3.6-4.4)  
 Y/R' = 0.021 (0.011-0.035)(reduced because B/B0 < 0.25)  
 B/B0 = 0.28 (0.1-0.49), best LF fit year 2017=0.278 (0.1-0.49)  
 B/Bmsy = 0.78 (0.29-1.4), **selected B/B0 1998 = 0.17 (0.11-0.23)**  
 RF: Set Linf=31 between median and max. Deleted unrealistic LF years. Selected 1998 because of reasonable fit and LC.

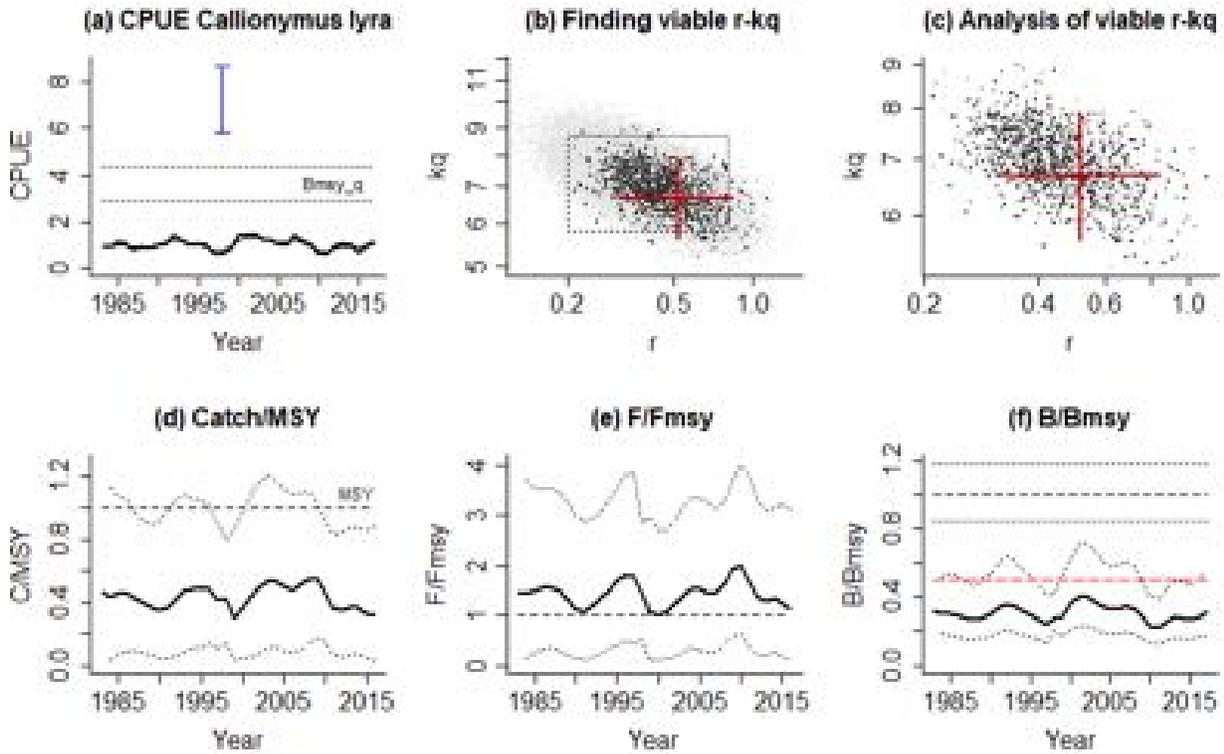


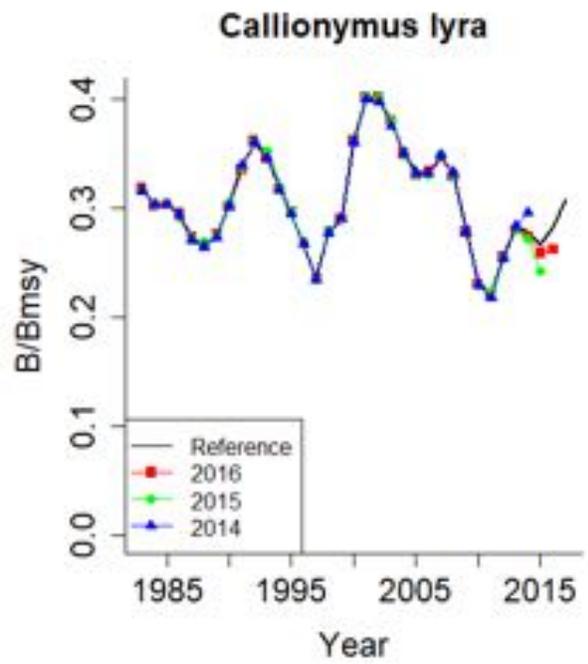
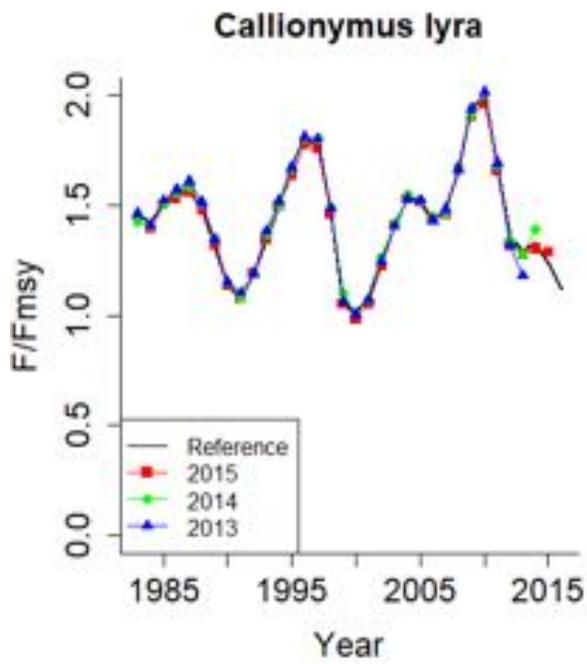
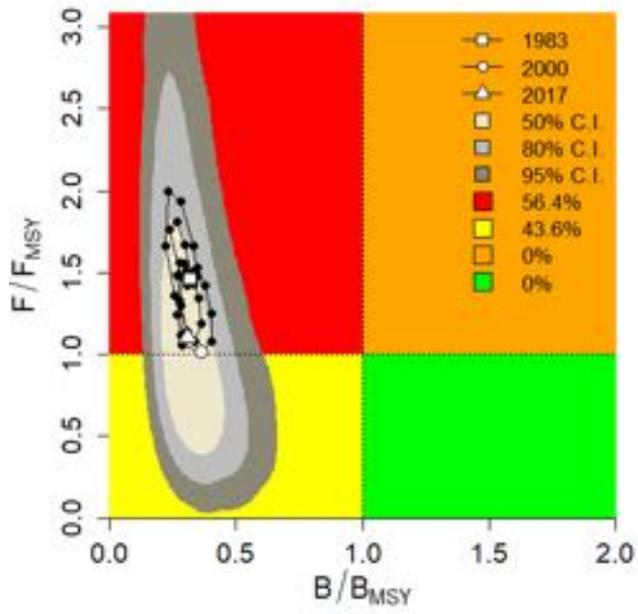
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AMSY Analysis, Fri Nov 01 17:59:19 2019  
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Stock *Callionymus lyra*, *Callionymus lyra*, Dragonet  
CPUE data for years 1983 - 2017, CPUE range 0.729 - 1.32, smooth = TRUE  
Prior for  $r$  = Medium, NA - NA  
Used prior range for  $r$  = 0.2 - 0.8  
Prior for 1998 stock status = Very small, 0.11 - 0.23  
Used 1998 prior B/B0 range = 0.11 - 0.23, prior B/Bmsy = 0.22 - 0.46  
Used prior range for  $kq$  = 5.81 - 8.71 [original range = 2.9 - 6.07]  
Comment: B/B0 prior from LBB. RF: OK  
Source: SMFS 2017

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5000

Results:  
viable  $r$ - $kq$  pairs = 5000  
median  $kq$  = 6.66, 5.61 - 7.87  
median MSY $q$  = 0.866, 0.547 - 1.39  
 $r$  (4 MSY $q$ / $kq$ ) = 0.52, 0.308 - 0.835  
Fmsy ( $r/2$ ) = 0.26, 0.154 - 0.418  
F/Fmsy = 1.12, 0.12 - 3.15 (2016)  
B/Bmsy = 0.308, 0.172 - 0.555 (2017)





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 LBB results for *Callionymus maculatus*, stock *Callionymus maculatus*, 1983-2016  
 Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Callionymus maculatus.csv  
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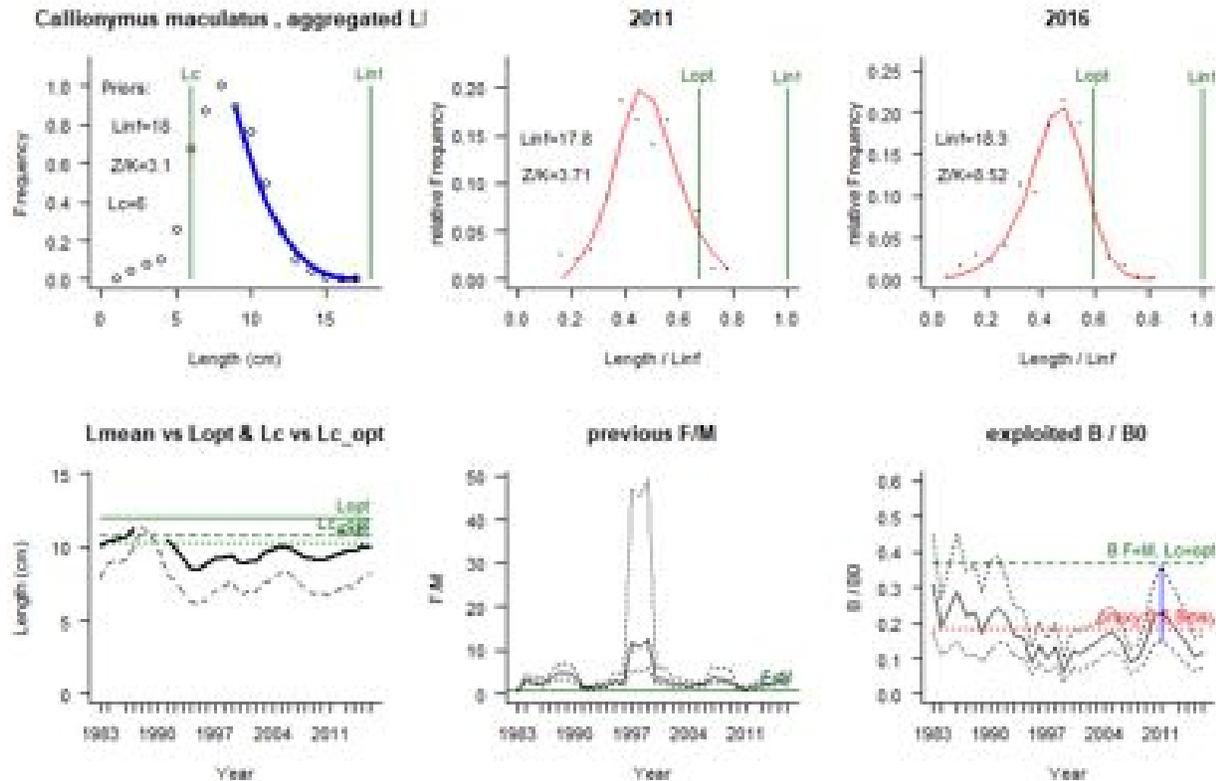
Linf prior= 18, SD=0.18 cm (user-defined), Lmax=21, median Lmax=15  
 Z/K prior = 3.1, SD=0.25, M/K prior=1.5, SD=0.15  
 F/K prior = 1.63 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 6.12, SD=0.61 cm, alpha prior=17.8, SD=1.8, Lm50=NA cm

General reference points (median across years):

Linf = 17.7 (17.3-18) cm  
 Lopt = 12 cm, Lopt/Linf=0.68  
 Lc\_opt = 11 cm, Lc\_opt/Linf=0.61, Lmean if F=M 10.3 cm  
 M/K = 1.41 (1.15-1.64)  
 F/M = 2.35 (1.76-3.03), F/K=3.18 (2.83-3.7), Z/K=4.31 (3.96-4.66)  
 B/B0 = 0.13 (0.087-0.18), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.022 (0.013-0.032)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.049

Estimates for 2016 (mean of last 3 years with data):

Lc50 = 8.2 (7.97-8.4) cm, Lc/Linf=0.45 (0.44-0.46)  
 Lc95 = 11.8, alpha=0.823 (0.796-0.85)  
 Lmean/Lopt= 0.84, Lc/Lc\_opt=0.76, L95th=15 cm, L95th/Linf=0.83, Mature=NA%  
 F/M = 2.9 (2.2-3.7), F/K=4.8 (4.2-5.5), Z/K=6.5 (5.8-7.1)  
 Y/R' = 0.02 (0.013-0.028)(reduced because B/B0 < 0.25)  
 B/B0 = 0.12 (0.08-0.17), best LF fit year 2003=0.143 (0.092-0.2)  
 B/Bmsy = 0.32 (0.22-0.46), **selected B/B0 2011 = 0.24 (0.15-0.36)**  
 RF: Set Linf=18cm between median and max. Selected 2011 because of reasonable fit and CL and not too low B/B0.

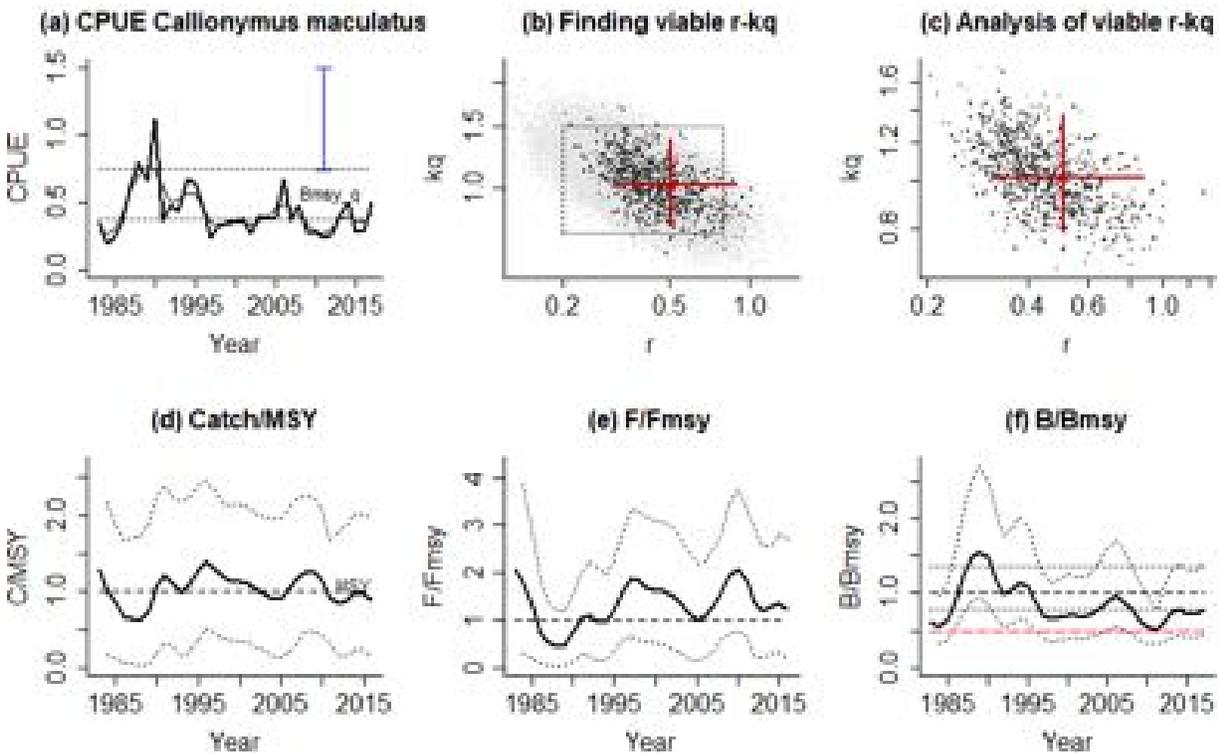


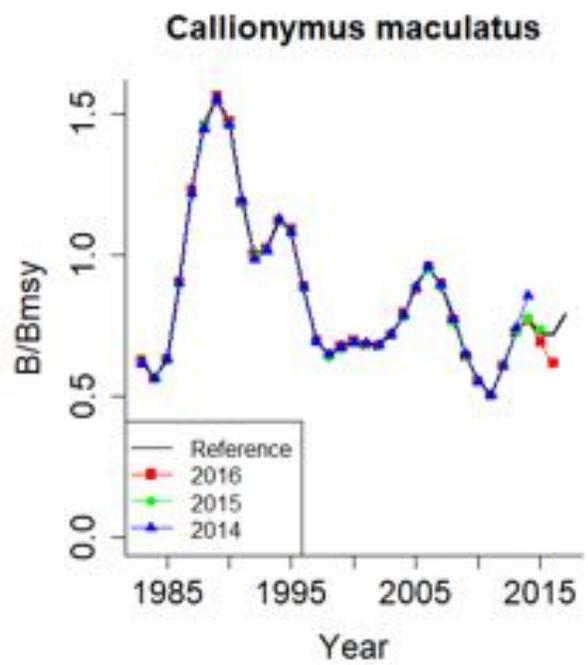
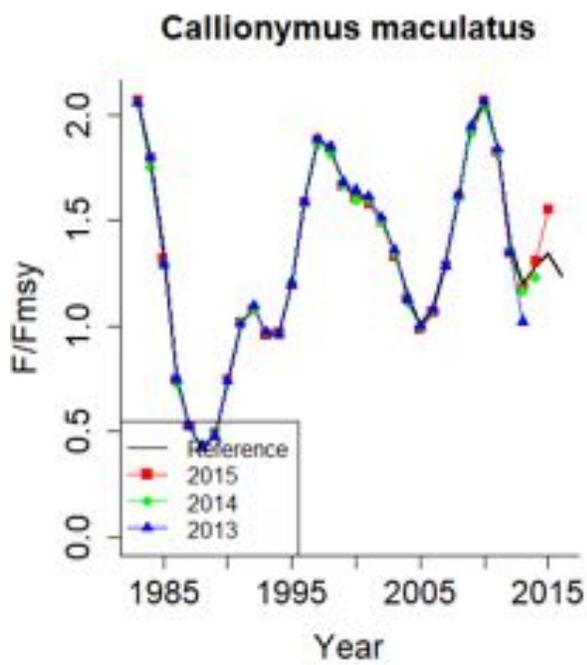
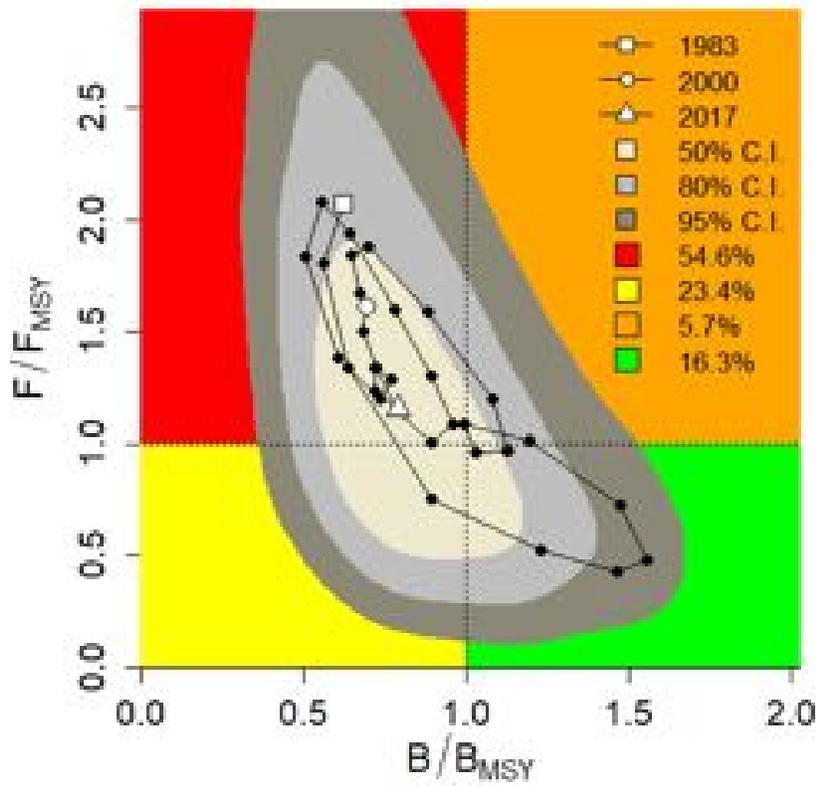
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AMSY Analysis, Fri Nov 01 18:03:38 2019  
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Stock *Callionymus maculatus*, *Callionymus maculatus*, Spotted dragonet  
CPUE data for years 1983 - 2017, CPUE range 0.265 - 0.771, smooth = TRUE  
Prior for  $r$  = Medium, NA - NA  
Used prior range for  $r$  = 0.2 - 0.8  
Prior for 2011 stock status = Small, 0.15 - 0.36  
Used 2011 prior B/B0 range = 0.15 - 0.36, prior B/Bmsy = 0.3 - 0.72  
Used prior range for  $kq$  = 0.745 - 1.5 [original range = 0.625 - 1.5]  
Comment: B/B0 prior from LBB. RF: OK  
Source: SMFS 2017

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5000

Results:  
viable  $r$ - $kq$  pairs = 5000  
median  $kq$  = 1.02, 0.787 - 1.38  
median MSY $q$  = 0.129, 0.0829 - 0.205  
 $r$  (4 MSY $q$ / $kq$ ) = 0.509, 0.314 - 0.884  
Fmsy ( $r/2$ ) = 0.254, 0.157 - 0.442  
F/Fmsy = 1.23, 0.191 - 2.71 (2016)  
B/Bmsy = 0.79, 0.438 - 1.43 (2017)





LBB results for *Chelidonichthys cuculus*, stock *Chelidonichthys cuculus*, 2001-2013

Files: LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Chelidonichthys cuculus.csv

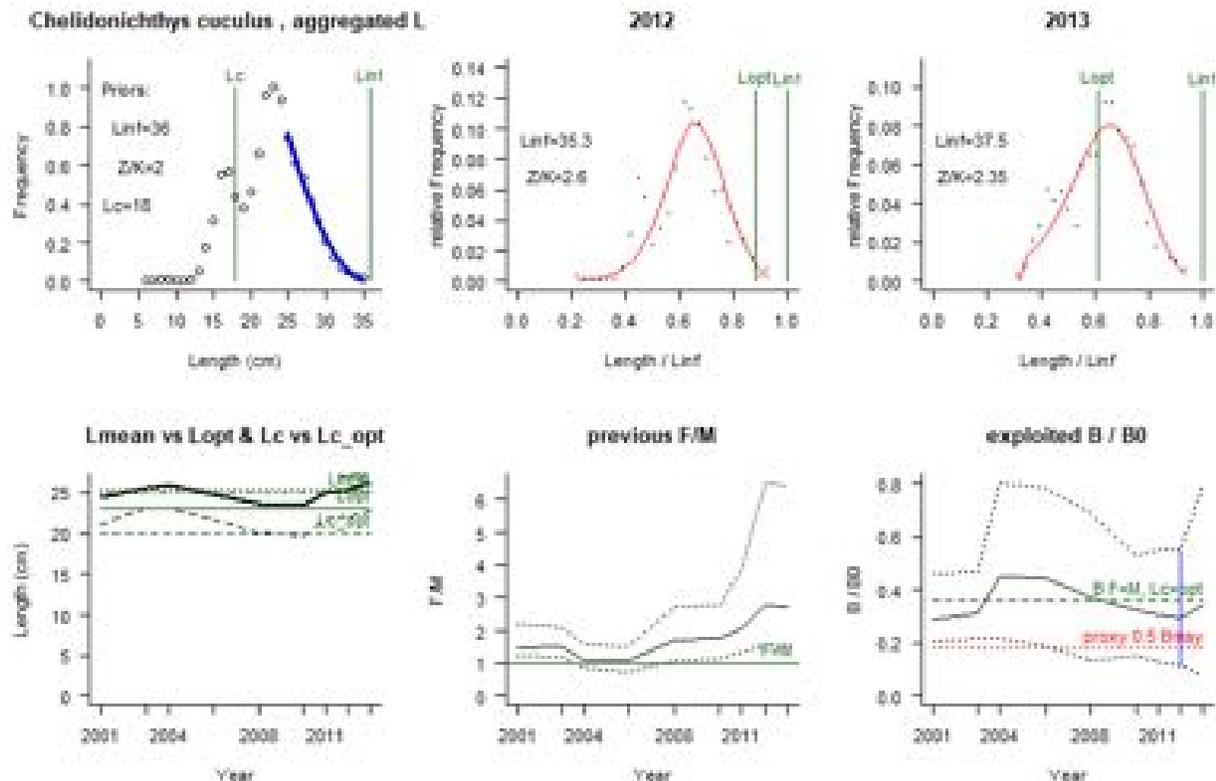
Linf prior = 36, SD=0.36 cm (user-defined), Lmax=40, median Lmax=35  
 Z/K prior = 2, SD=0.066, M/K prior=1.5, SD=0.15  
 F/K prior = 0.544 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 18.4, SD=1.8 cm, alpha prior=13.4, SD=1.3, Lm50=25 cm

General reference points (median across years):

Linf = 35.8 (35.2-36.4) cm  
 Lopt = 23 cm, Lopt/Linf=0.64  
 Lc\_opt = 20 cm, Lc\_opt/Linf=0.56, Lmean if F=M 25.4 cm  
 M/K = 1.67 (1.43-1.83)  
 F/M = 1.49 (1.2-2.03), F/K=2.01 (1.43-2.57), Z/K=2.89 (2.63-3.23)  
 B/B0 = 0.29 (0.14-0.47), B/B0 F=M Lc=Lc\_opt 0.36  
 Y/R' = 0.03 (0.021-0.048), Y/R' F=M Lc=Lc\_opt 0.037

Estimates for 2013 (mean of last 3 years with data):

Lc50 = 22.7 (22.2-23.2) cm, Lc/Linf=0.63 (0.62-0.64)  
 Lc95 = 30, alpha=0.402 (0.389-0.413)  
 Lmean/Lopt = 0.95, Lc/Lc\_opt=1.1, L95th=33.3 cm, L95th/Linf=0.93, Mature=37%  
 F/M = 2.7 (1.5-6.4), F/K=1.5 (1.2-1.9), Z/K=2.5 (2.2-2.8)  
 Y/R' = 0.059 (0.018-0.14)  
 B/B0 = 0.35 (0.076-0.79), best LF fit year 2010=0.328 (0.15-0.53)  
 B/Bmsy = 0.96 (0.21-2.2), **selected B/B0 2012 = 0.29 (0.12-0.55)**  
 RF: Set Linf=36 between median and max. Used 2012 because of good fit and CL.

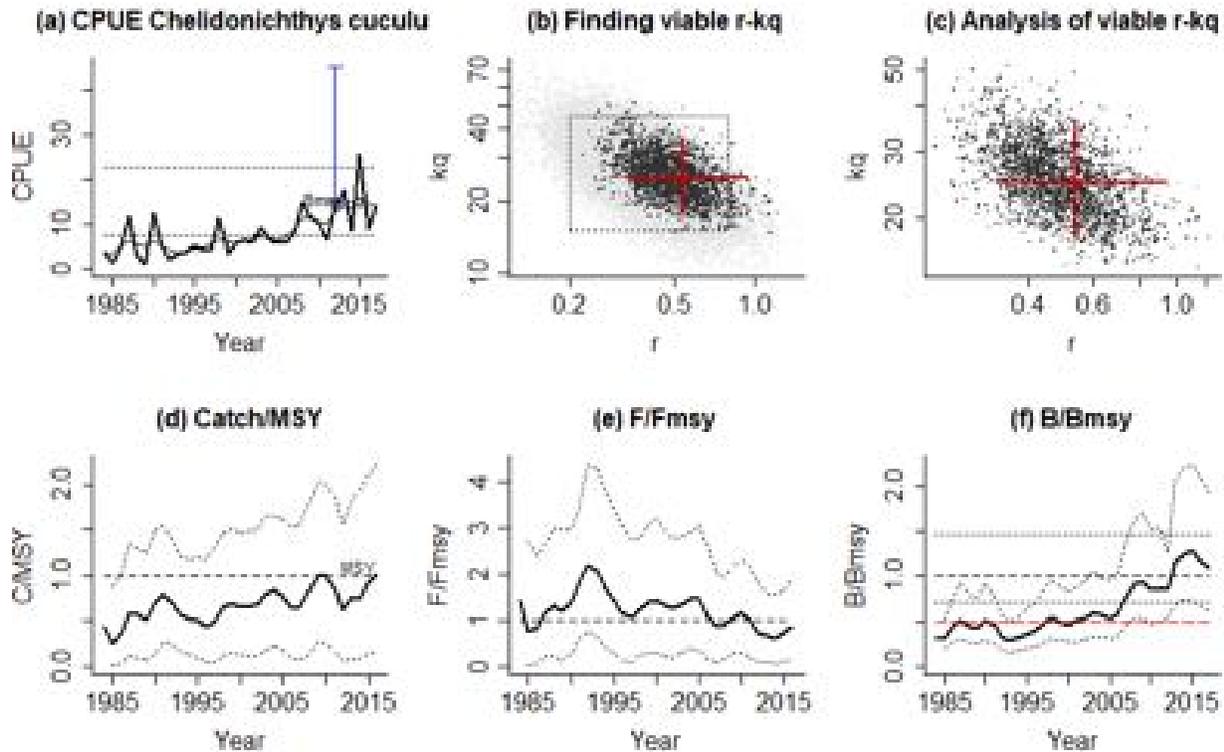


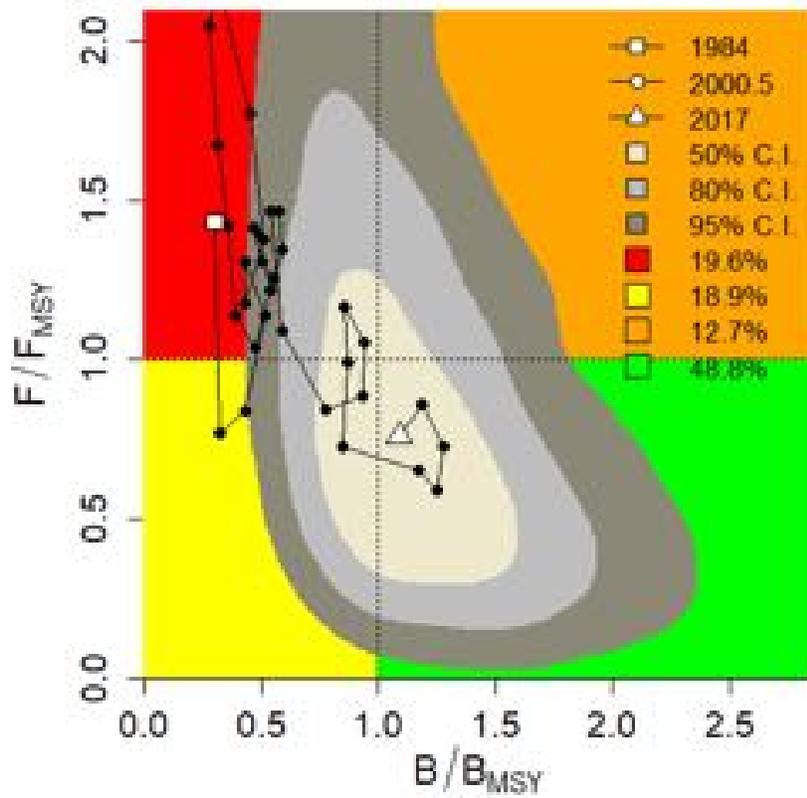
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AMSY Analysis, Fri Nov 01 18:08:05 2019  
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Stock *Chelidonichthys cuculus*, *Chelidonichthys cuculus*, Red gurnard  
CPUE data for years 1984 - 2017, CPUE range 2.86 - 15.7, smooth = TRUE  
Prior for r = Medium, NA - NA  
Used prior range for r = 0.2 - 0.8  
Prior for 2012 stock status = Small, 0.12 - 0.55  
Used 2012 prior B/B0 range = 0.12 - 0.55, prior B/Bmsy = 0.24 - 1.1  
Used prior range for kq = 15 - 45.1 [original range = 13.1 - 60.2]  
Comment: B/B0 prior from LBB. RF: OK  
Source: SMFS 2017

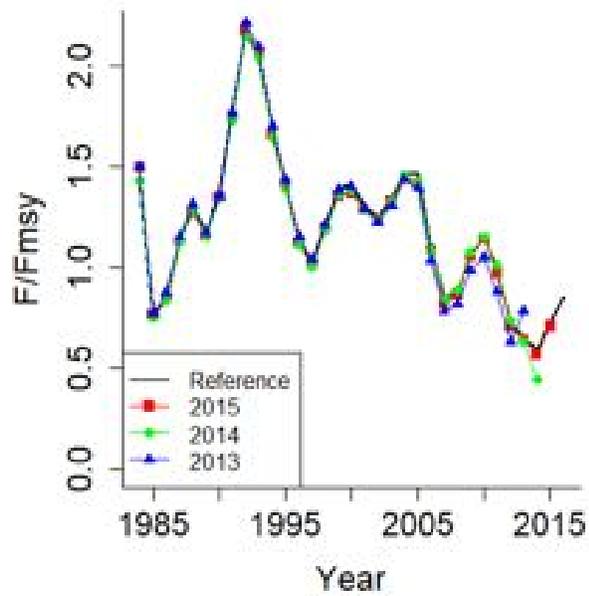
Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
Viable r-kq pairs = 5000

Results:  
viable r-kq pairs = 5000  
median kq = 24.8, 17.6 - 36.5  
median MSYq = 3.33, 2.11 - 5.62  
r (4 MSYq/kq) = 0.537, 0.325 - 0.94  
Fmsy (r/2) = 0.269, 0.163 - 0.47  
F/Fmsy = 0.859, 0.13 - 1.88 (2016)  
B/Bmsy = 1.09, 0.607 - 1.94 (2017)

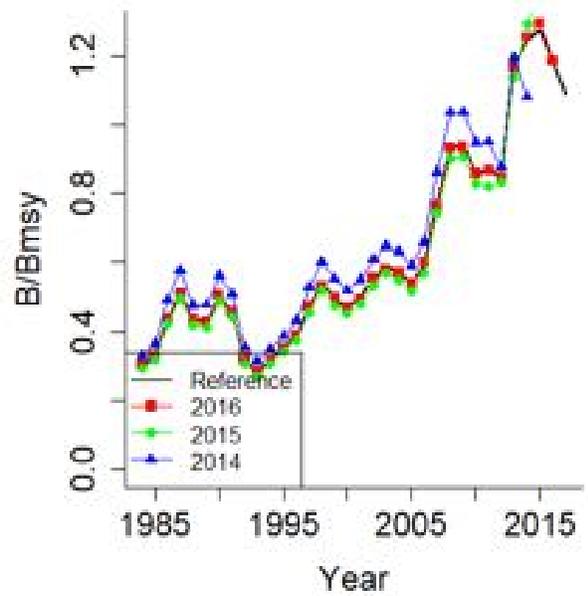




**Chelidonichthys cuculus**



**Chelidonichthys cuculus**



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 LBB results for *Echiichthys vipera*, stock *Echiichthys vipera*, 1998-2017  
 Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Echiichthys vipera.csv  
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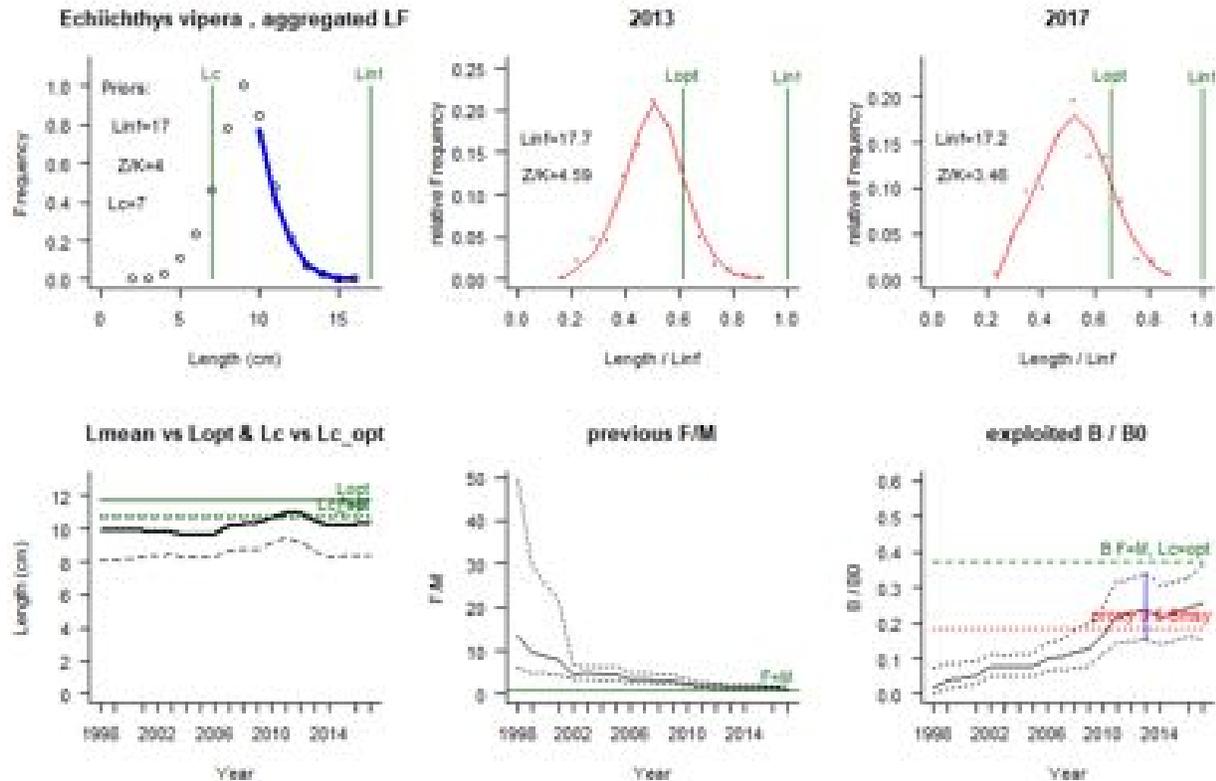
Linf prior= 17, SD=0.17 cm (user-defined), Lmax=19, median Lmax=15  
 Z/K prior = 4, SD=0.091, M/K prior=1.5, SD=0.15  
 F/K prior = 2.55 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 7.14, SD=0.71 cm, alpha prior=12.6, SD=1.3, Lm50=NA cm

General reference points (median across years):

Linf = 16.9 (16.7-17.3) cm  
 Lopt = 12 cm, Lopt/Linf=0.69  
 Lc\_opt = 11 cm, Lc\_opt/Linf=0.63, Lmean if F=M 10.8 cm  
 M/K = 1.33 (1.09-1.6)  
 F/M = 2.84 (2.12-4.1), F/K=3.88 (3.36-4.45), Z/K=4.88 (4.5-5.36)  
 B/B0 = 0.13 (0.081-0.19), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.029 (0.019-0.041)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.053

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 8.41 (8.22-8.63) cm, Lc/Linf=0.48 (0.47-0.5)  
 Lc95 = 12.1, alpha=0.808 (0.778-0.841)  
 Lmean/Lopt= 0.94, Lc/Lc\_opt=0.78, L95th=15.7 cm, L95th/Linf=0.9, Mature=NA%  
 F/M = 1.4 (0.99-1.8), F/K=2.5 (2-2.9), Z/K=4.2 (3.9-4.6)  
 Y/R' = 0.036 (0.022-0.051)(reduced because B/B0 < 0.25)  
 B/B0 = 0.25 (0.15-0.36), best LF fit year 2005=0.0774 (0.05-0.11)  
 B/Bmsy = 0.68 (0.42-0.97), **selected B/B0 2013 = 0.24 (0.15-0.34)**  
 RF: Set Linf=17 between median and max. Exluded years with unrealistic LF fits. Selected 2013 for reasonable fit and CL.

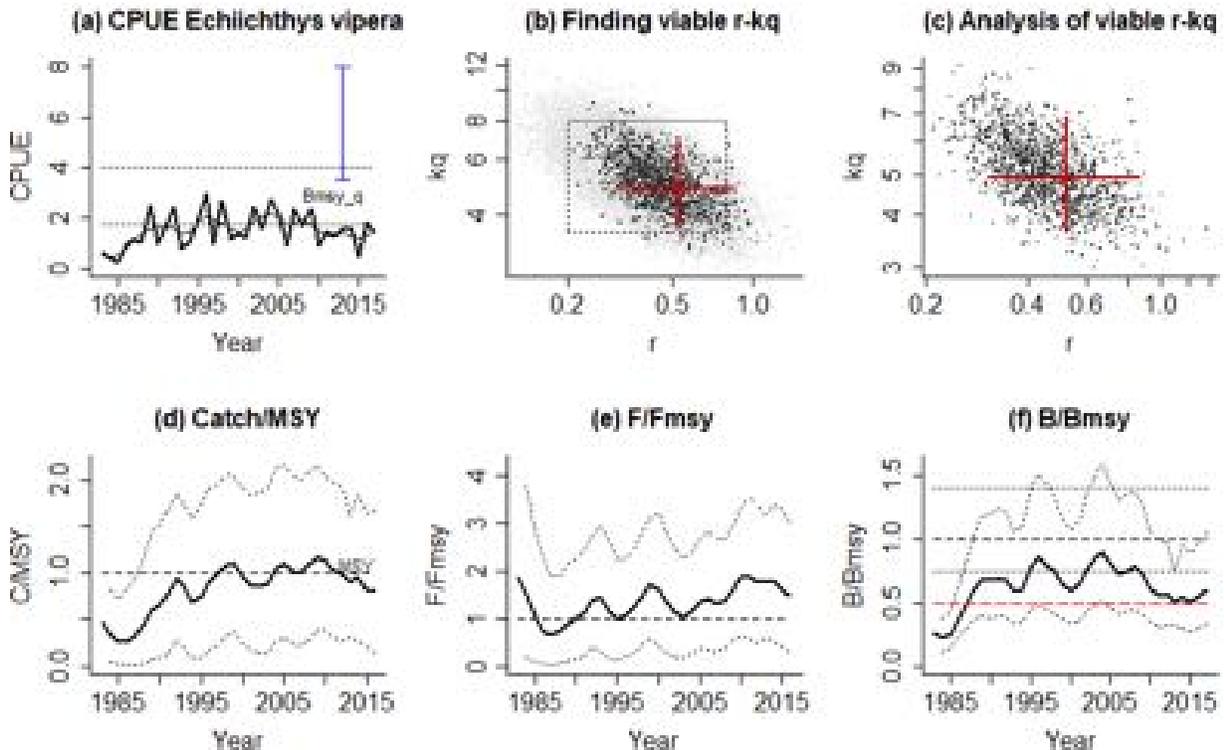


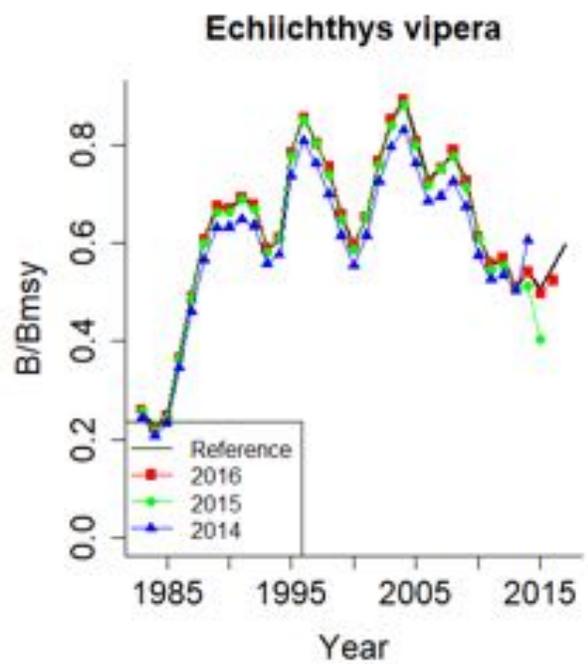
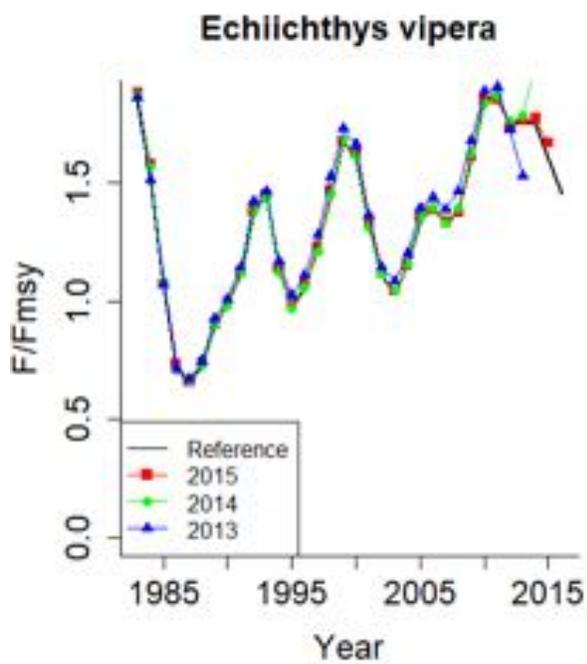
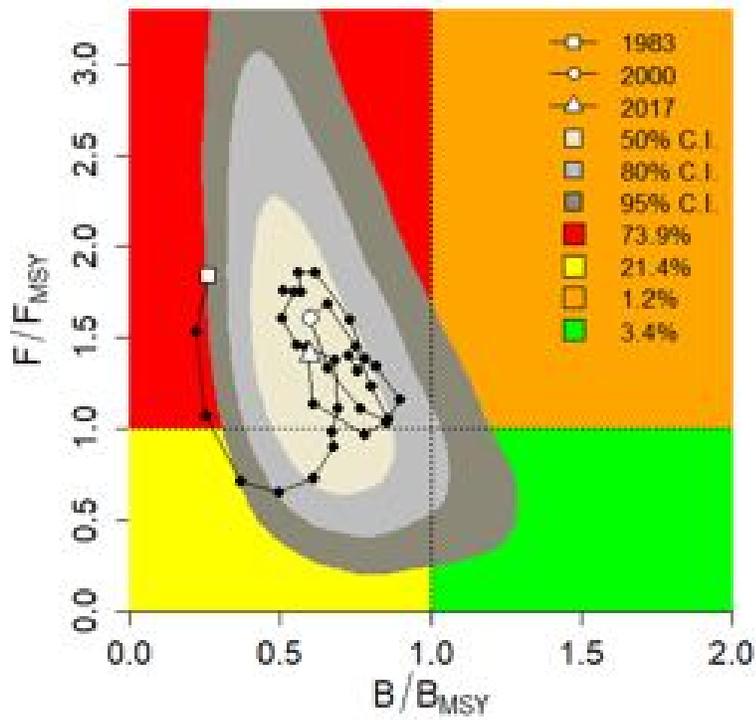
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AMSY Analysis, Fri Nov 01 18:12:40 2019  
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Stock *Echiichthys vipera*, *Echiichthys vipera*, Lesser weever  
CPUE data for years 1983 - 2017, CPUE range 0.489 - 2.16, smooth = TRUE  
Prior for r = Medium, NA - NA  
Used prior range for r = 0.2 - 0.8  
Prior for 2013 stock status = Small, 0.15 - 0.34  
Used 2013 prior B/B0 range = 0.15 - 0.34, prior B/Bmsy = 0.3 - 0.68  
Used prior range for kq = 3.54 - 8.02 [original range = 3.54 - 8.02]  
Comment: B/B0 prior from LBB. RF: OK  
Source: SMFS 2017

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
Viable r-kq pairs = 5004

Results:  
viable r-kq pairs = 5004  
median kq = 4.89, 3.64 - 6.86  
median MSYq = 0.641, 0.404 - 1.01  
r (4 MSYq/kq) = 0.524, 0.306 - 0.859  
Fmsy (r/2) = 0.262, 0.153 - 0.43  
F/Fmsy = 1.46, 0.266 - 3.03 (2016)  
B/Bmsy = 0.599, 0.331 - 1.06 (2017)





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 LBB results for *Enchelyopus cimbrius*, stock *Enchelyopus cimbrius*, 1983-2017  
 Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Enchelyopus cimbrius.csv  
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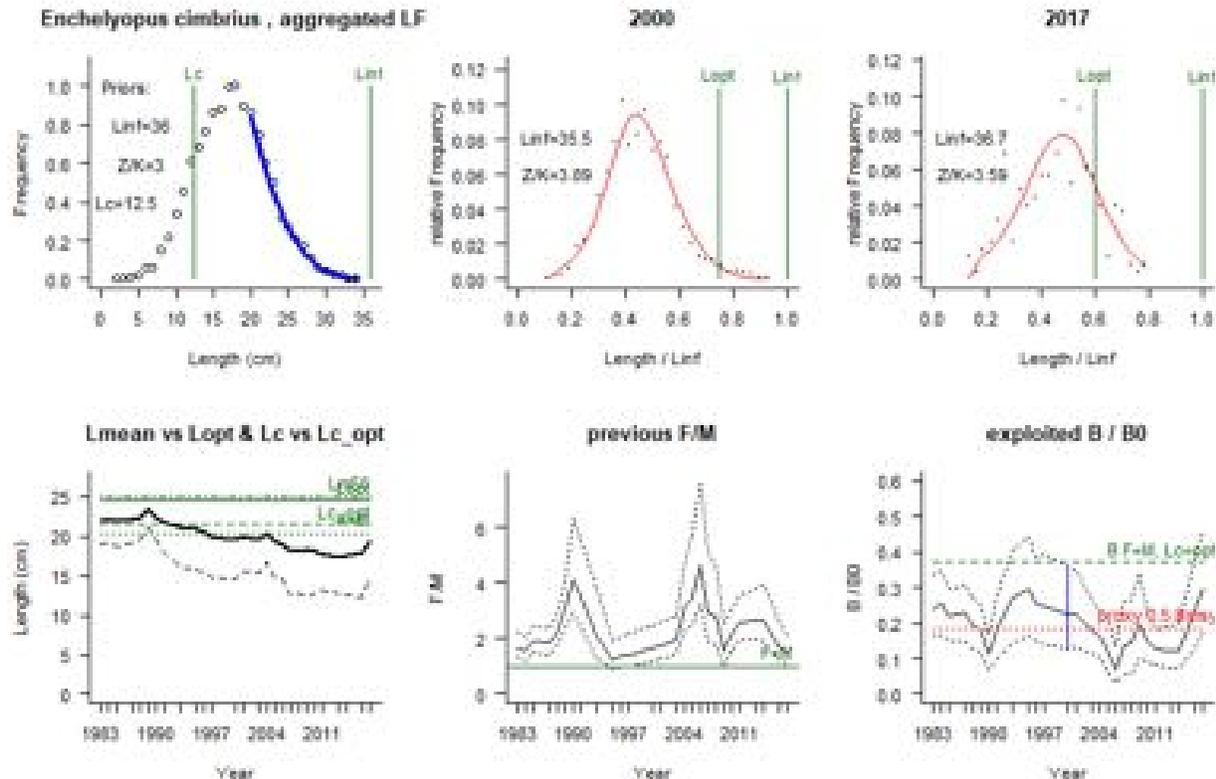
Linf prior= 36, SD=0.36 cm (user-defined), Lmax=44, median Lmax=32  
 Z/K prior = 3, SD=0.076, M/K prior=1.5, SD=0.15  
 F/K prior = 1.52 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 12.8, SD=1.3 cm, alpha prior=16.6, SD=1.7, Lm50=25 cm

General reference points (median across years):

Linf = 35.6 (35-36.2) cm  
 Lopt = 25 cm, Lopt/Linf=0.69  
 Lc\_opt = 21 cm, Lc\_opt/Linf=0.6, Lmean if F=M 20.4 cm  
 M/K = 1.36 (1.16-1.59)  
 F/M = 1.65 (1.3-2.42), F/K=2.32 (1.94-2.73), Z/K=3.83 (3.5-4.11)  
 B/B0 = 0.2 (0.11-0.31), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.036 (0.02-0.051)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.052

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 14.2 (13.9-14.7) cm, Lc/Linf=0.4 (0.39-0.42)  
 Lc95 = 20.6, alpha=0.459 (0.444-0.474)  
 Lmean/Lopt= 0.81, Lc/Lc\_opt=0.66, L95th=29.3 cm, L95th/Linf=0.83, Mature=5.7%  
 F/M = 1.5 (1.1-2.2), F/K=1.9 (1.5-2.3), Z/K=3.4 (3.1-3.7)  
 Y/R' = 0.029 (0.017-0.045)(reduced because B/B0 < 0.25)  
 B/B0 = 0.3 (0.17-0.46), best LF fit year 1985=0.22 (0.15-0.3)  
 B/Bmsy = 0.8 (0.46-1.2), **selected B/B0 2000 = 0.23 (0.13-0.36)**  
 RF: Set Linf between median and max. Excluded years with unrealistic LF fits.  
 Selected 2000 because of reasonable fit and CL

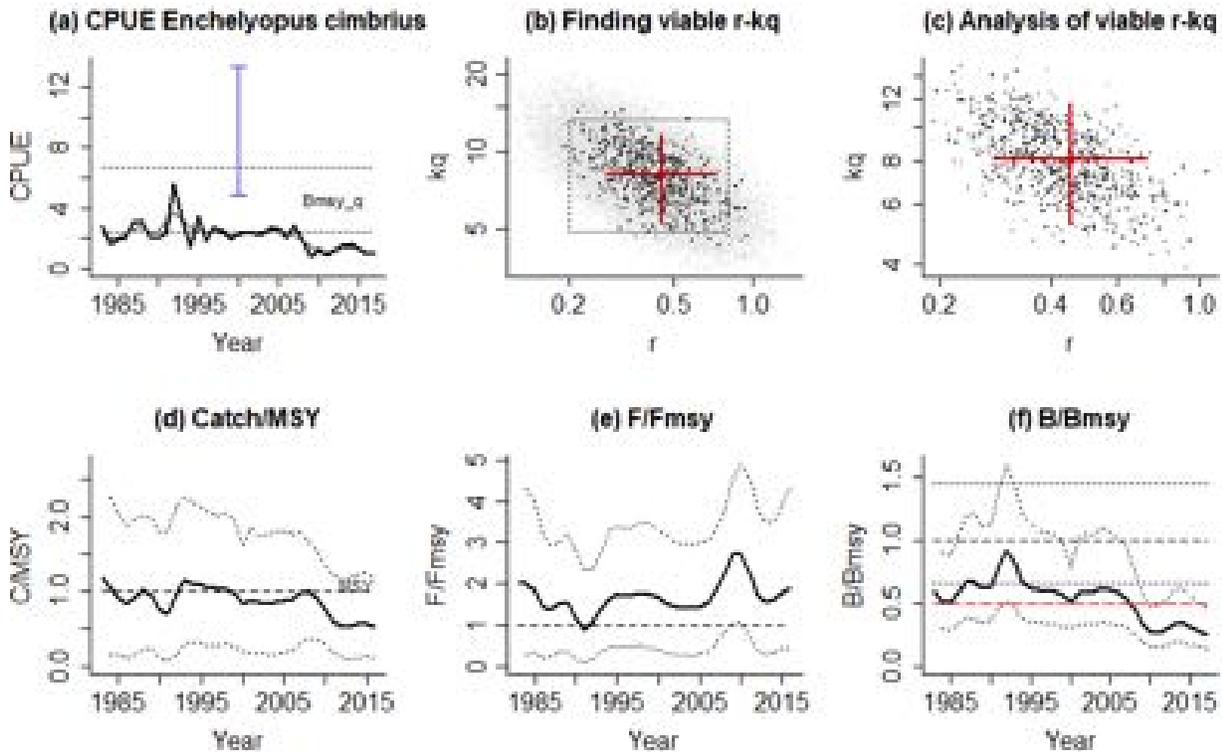


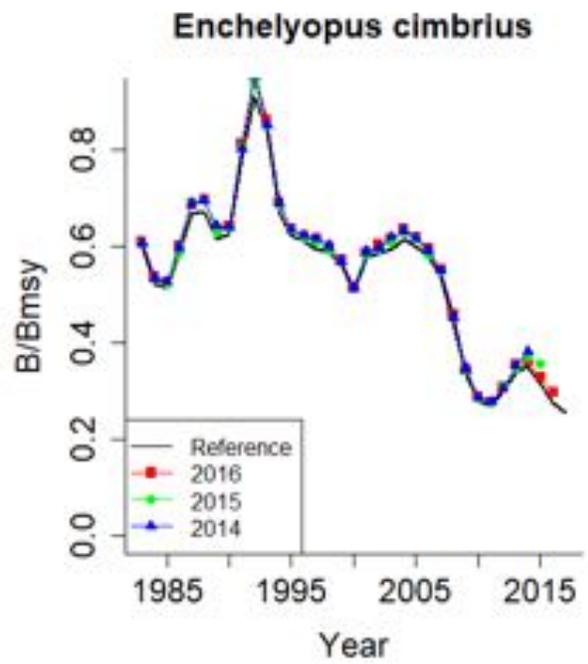
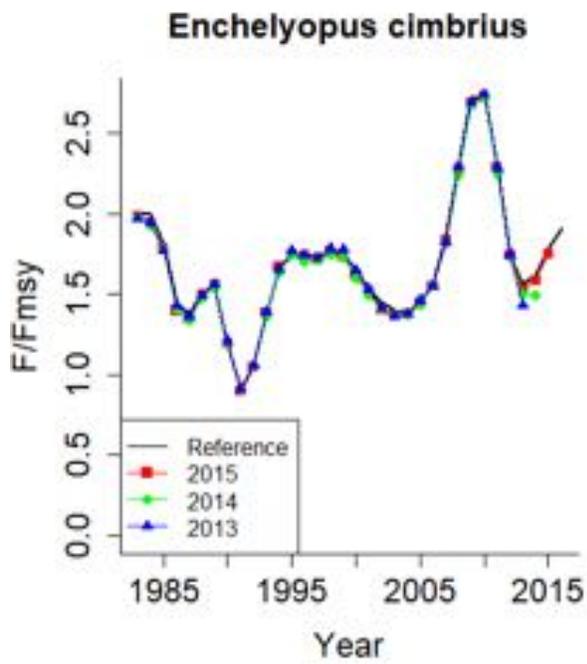
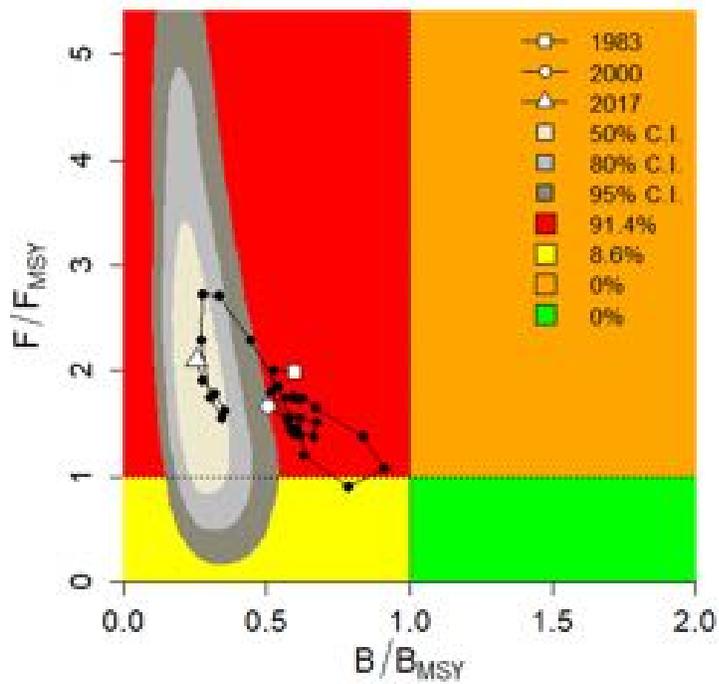
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AMSY Analysis, Fri Nov 01 18:16:36 2019  
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Stock *Enchelyopus cimbrius*, *Enchelyopus cimbrius*, Fourbeard rockling  
CPUE data for years 1983 - 2017, CPUE range 1.02 - 3.68, smooth = TRUE  
Prior for r = Medium, NA - NA  
Used prior range for r = 0.2 - 0.8  
Prior for 2000 stock status = Small, 0.13 - 0.36  
Used 2000 prior B/B0 range = 0.13 - 0.36, prior B/Bmsy = 0.26 - 0.72  
Used prior range for kq = 4.84 - 13.4 [original range = 4.84 - 13.4]  
Comment: B/B0 prior from LBB. RF: OK  
Source: SMFS 2017

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
Viable r-kq pairs = 5007

Results:  
viable r-kq pairs = 5007  
median kq = 8.07, 5.26 - 11.7  
median MSYq = 0.912, 0.562 - 1.41  
r (4 MSYq/kq) = 0.452, 0.277 - 0.724  
Fmsy (r/2) = 0.226, 0.138 - 0.362  
F/Fmsy = 1.91, 0.447 - 4.29 (2016)  
B/Bmsy = 0.254, 0.142 - 0.455 (2017)





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 LBB results for *Lumpenus lampretaeformis*, *Lumpenus lampretaeformis*, 1999-2017  
 Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Lumpenus lampretaeformis.csv  
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Lin<sub>f</sub> prior= 33, SD=0.33 cm (user-defined), L<sub>max</sub>=36, median L<sub>max</sub>=31.5  
 Z/K prior = 2.8, SD=0.12, M/K prior=1.5, SD=0.15  
 F/K prior = 1.28 (wide range with tau=4 in log-normal distribution)  
 L<sub>c</sub> prior = 16.3, SD=1.6 cm, alpha prior=19.9, SD=2, L<sub>m50</sub>=20 cm

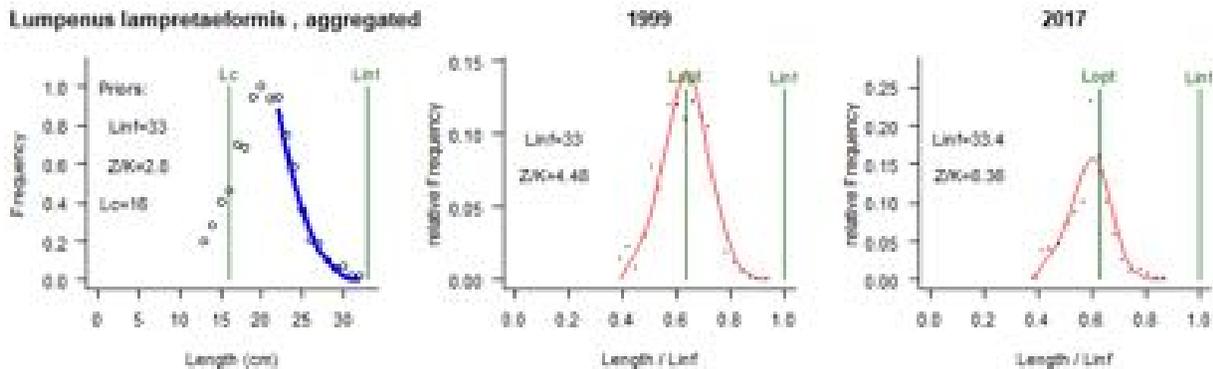
General reference points (median across years):

Lin<sub>f</sub> = 33 (32.5-33.6) cm  
 L<sub>opt</sub> = 21 cm, L<sub>opt</sub>/Lin<sub>f</sub>=0.65  
 L<sub>c</sub><sub>opt</sub> = 19 cm, L<sub>c</sub><sub>opt</sub>/Lin<sub>f</sub>=0.56, L<sub>mean</sub> if F=M 23 cm  
 M/K = 1.62 (1.36-1.9)  
 F/M = 1.49 (1.05-2.04), F/K=2.35 (1.82-2.87), Z/K=3.93 (3.52-4.37)  
 B/B<sub>0</sub> = 0.3 (0.18-0.45), B/B<sub>0</sub> F=M L<sub>c</sub>=L<sub>c</sub><sub>opt</sub> 0.36  
 Y/R' = 0.032 (0.019-0.052), Y/R' F=M L<sub>c</sub>=L<sub>c</sub><sub>opt</sub> 0.039

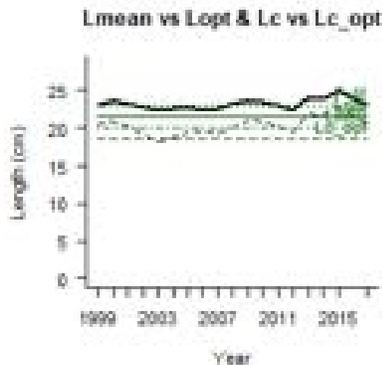
Estimates for 2017 (mean of last 3 years with data):

L<sub>c50</sub> = 20.6 (20.2-21) cm, L<sub>c</sub>/Lin<sub>f</sub>=0.63 (0.61-0.64)  
 L<sub>c95</sub> = 26.8, alpha=0.482 (0.466-0.497)  
 L<sub>mean</sub>/L<sub>opt</sub>= 1.1, L<sub>c</sub>/L<sub>c</sub><sub>opt</sub>=1.1, L<sub>95th</sub>=28.3 cm, L<sub>95th</sub>/Lin<sub>f</sub>=0.86, Mature=38%  
 F/M = 6.5 (5.1-8), F/K=10 (8.5-11), Z/K=12 (10-13)  
 Y/R' = 0.02 (0.013-0.028)  
 B/B<sub>0</sub> = 0.11 (0.072-0.15), best LF fit year 2014=0.097 (0.048-0.19)  
 B/B<sub>msy</sub> = 0.29 (0.2-0.41), **selected B/B<sub>0</sub> 1999 = 0.28 (0.19-0.45)**  
 RF: Set Lin<sub>f</sub> between median and max. Set L<sub>cut</sub>=13 to exclude early juveniles.  
 Selected 1999 because of reasonable fit and CL.

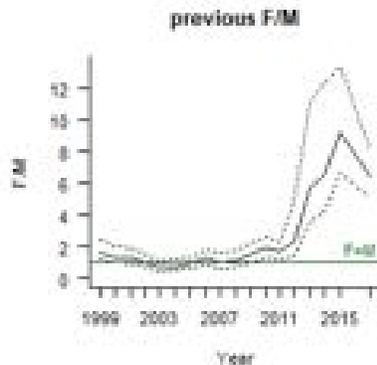
Lumpenus lampretaeformis , aggregated



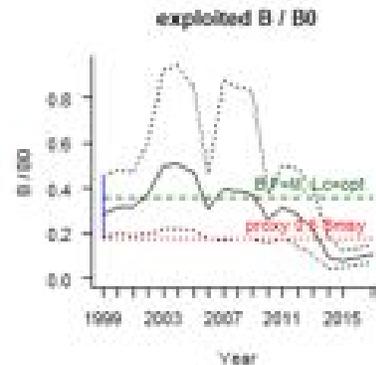
L<sub>mean</sub> vs L<sub>opt</sub> & L<sub>c</sub> vs L<sub>c</sub><sub>opt</sub>



previous F/M



exploited B / B<sub>0</sub>

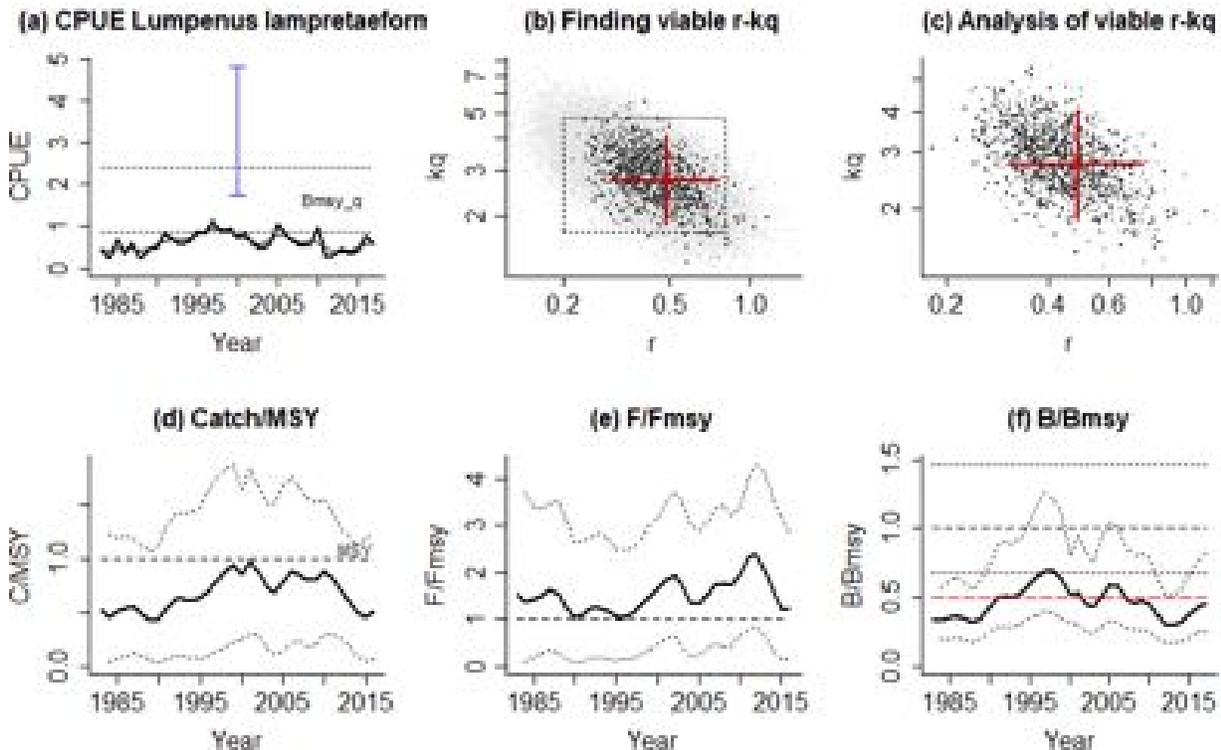


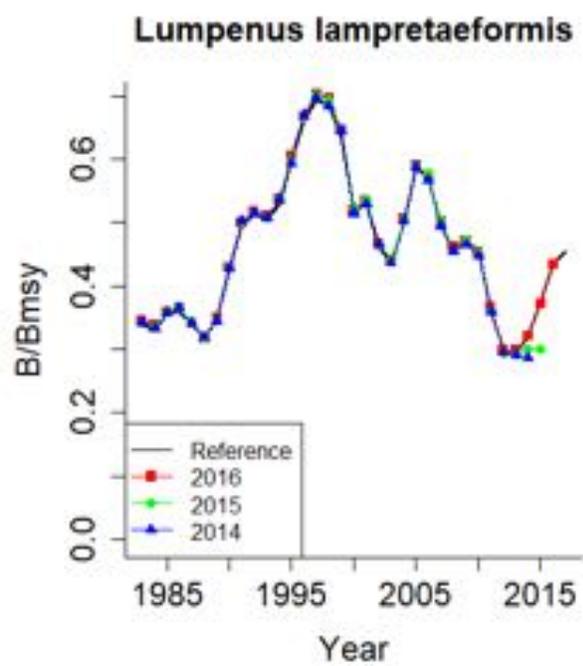
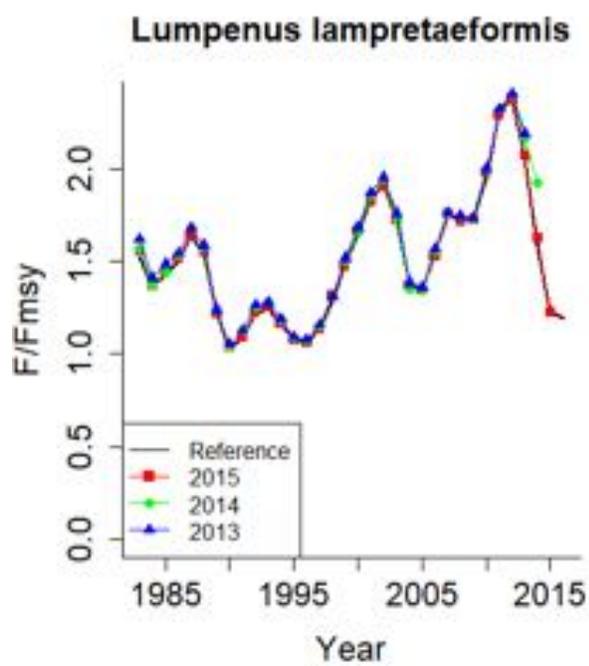
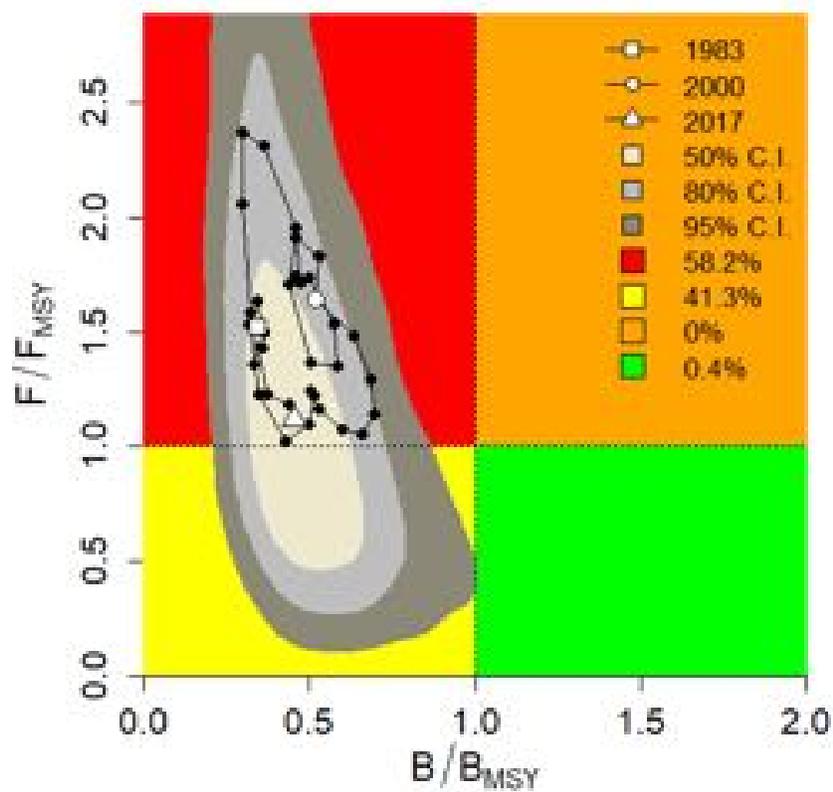
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 AMSY Analysis, Fri Nov 01 18:20:05 2019  
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Stock *Lumpenus lampretaeformis*, *Lumpenus lampretaeformis*, Snake blenny  
 CPUE data for years 1983 - 2017, CPUE range 0.401 - 0.948, smooth = TRUE  
 Prior for  $r$  = Medium, NA - NA  
 Used prior range for  $r$  = 0.2 - 0.8  
 Prior for 2000 stock status = Small, 0.13 - 0.36  
 Used 2000 prior B/B0 range = 0.13 - 0.36, prior B/Bmsy = 0.26 - 0.72  
 Used prior range for  $kq$  = 1.74 - 4.82 [original range = 1.74 - 4.82]  
 Comment: B/B0 prior from LBB. RF: OK  
 Source: SMFS 2017

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
 Viable  $r$ - $kq$  pairs = 5000

Results:  
 viable  $r$ - $kq$  pairs = 5000  
 median  $kq$  = 2.75, 1.86 - 4.04  
 median MSYq = 0.335, 0.208 - 0.533  
 $r$  (4 MSYq/ $kq$ ) = 0.486, 0.302 - 0.755  
 Fmsy ( $r/2$ ) = 0.243, 0.151 - 0.377  
 F/Fmsy = 1.19, 0.138 - 2.88 (2016)  
 B/Bmsy = 0.454, 0.252 - 0.824 (2017)





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 LBB results for *Lycodes vahlii*, stock *Lycodes vahlii*, 1994-2013  
 Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Lycodes vahlii.csv  
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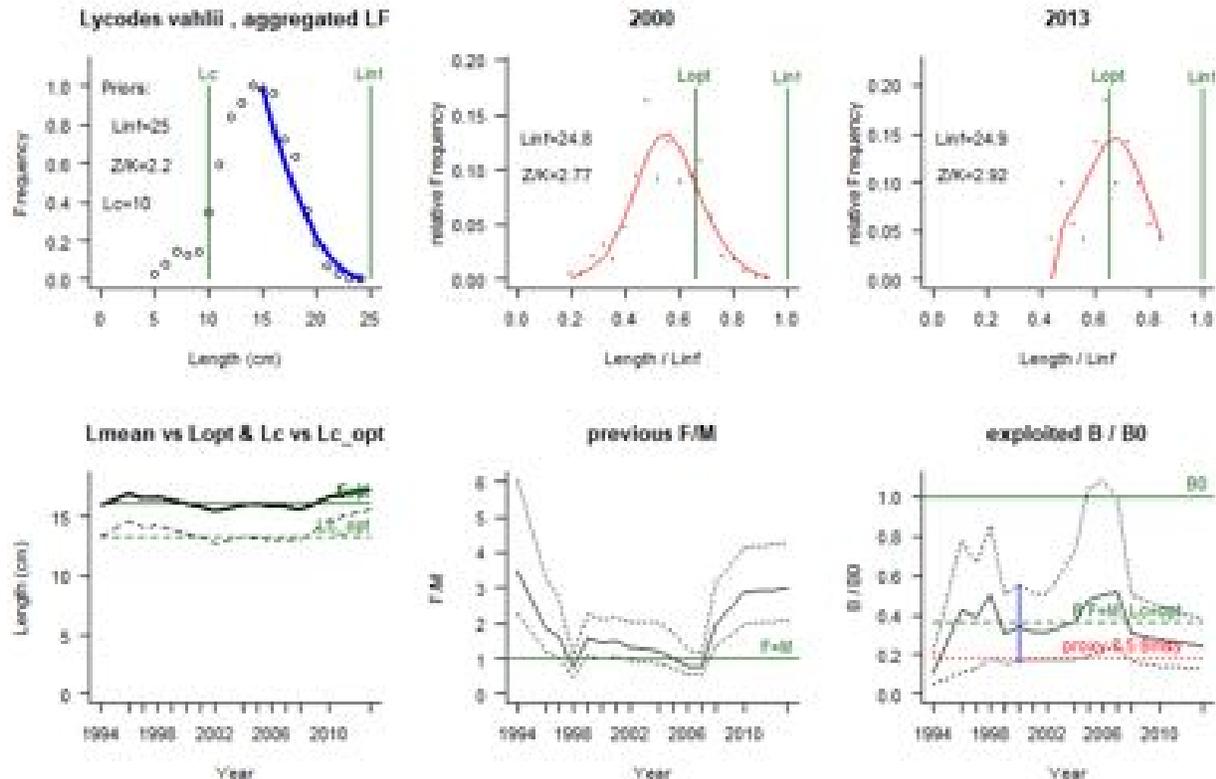
Linf prior= 25, SD=0.25 cm (user-defined), Lmax=32, median Lmax=22  
 Z/K prior = 2.2, SD=0.21, M/K prior=1.5, SD=0.15  
 F/K prior = 0.679 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 10.2, SD=1 cm, alpha prior=12.2, SD=1.2, Lm50=NA cm

General reference points (median across years):

Linf = 24.3 (23.8-24.7) cm  
 Lopt = 16 cm, Lopt/Linf=0.66  
 Lc\_opt = 13 cm, Lc\_opt/Linf=0.55, Lmean if F=M 16.1 cm  
 M/K = 1.54 (1.24-1.75)  
 F/M = 0.921 (0.601-1.45), F/K=1.44 (1.09-1.88), Z/K=3.01 (2.73-3.36)  
 B/B0 = 0.37 (0.18-0.62), B/B0 F=M Lc=Lc\_opt 0.36  
 Y/R' = 0.033 (0.019-0.069), Y/R' F=M Lc=Lc\_opt 0.042

Estimates for 2013 (mean of last 3 years with data):

Lc50 = 15.6 (15.2-15.9) cm, Lc/Linf=0.64 (0.62-0.65)  
 Lc95 = 20.1, alpha=0.66 (0.636-0.678)  
 Lmean/Lopt= 1, Lc/Lc\_opt=1.2, L95th=20.3 cm, L95th/Linf=0.83, Mature=NA%  
 F/M = 3 (2.1-4.3), F/K=4.1 (3.1-4.7), Z/K=5.5 (4.6-6.2)  
 Y/R' = 0.032 (0.017-0.052)  
 B/B0 = 0.24 (0.13-0.38), best LF fit year 2001=0.313 (0.17-0.51)  
 B/Bmsy = 0.67 (0.35-1), **selected B/B0 2000 = 0.34 (0.16-0.56)**  
 RF: Set Linf=26cm between median and max. Excluded years with unrealistic LF fits. Selected 2000 for reasonable fit, CL and B/B0

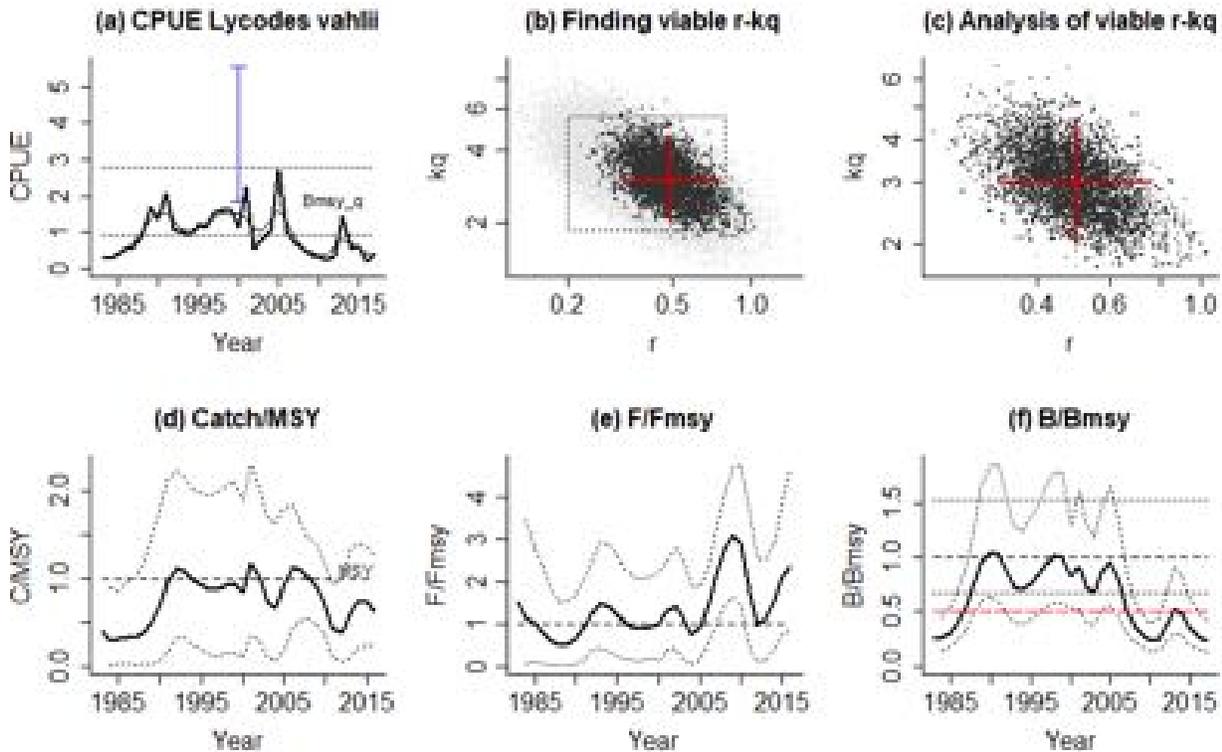


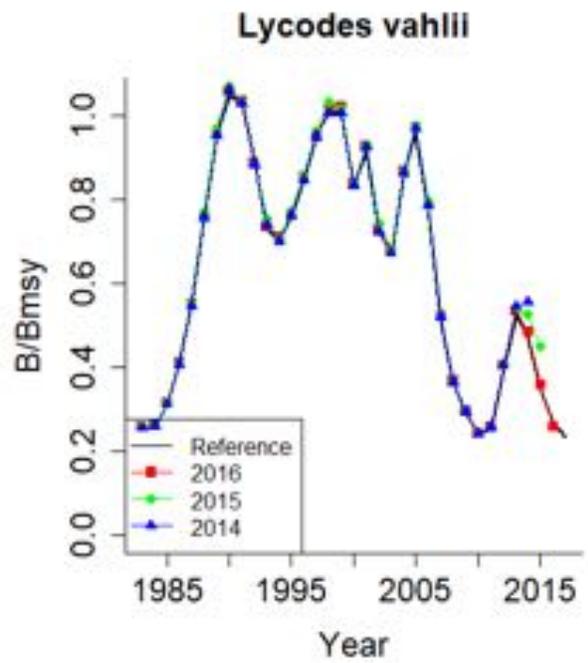
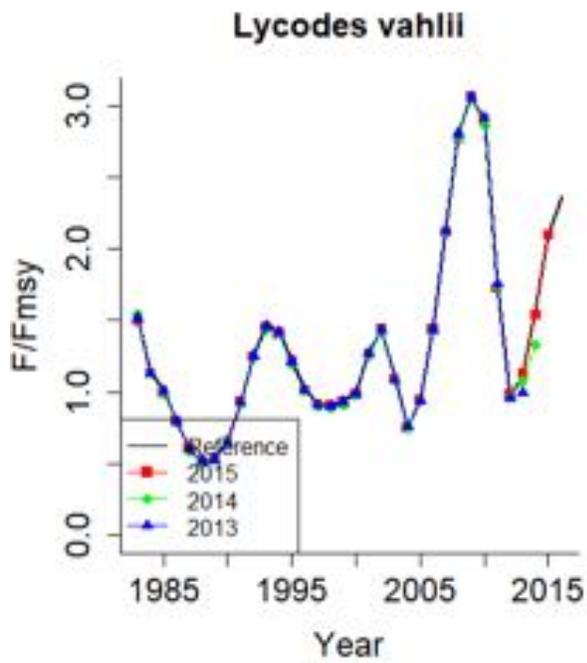
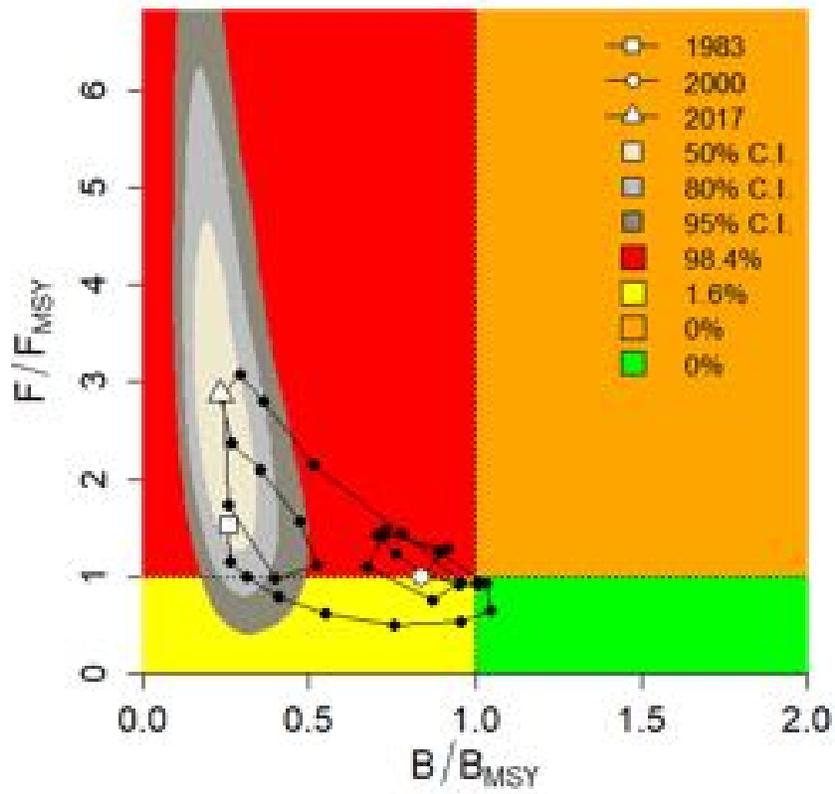
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AMSY Analysis, Fri Nov 01 18:23:28 2019  
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Stock *Lycodes vahlii*, *Lycodes vahlii*, Vahl's eelpout  
CPUE data for years 1983 - 2017, CPUE range 0.295 - 1.59, smooth = TRUE  
Prior for r = Medium, NA - NA  
Used prior range for r = 0.2 - 0.8  
Prior for 2000 stock status = About half, 0.16 - 0.56  
Used 2000 prior B/B0 range = 0.16 - 0.56, prior B/Bmsy = 0.32 - 1.12  
Used prior range for kq = 1.85 - 5.56 [original range = 1.85 - 6.49]  
Comment: B/B0 prior from LBB. RF: OK  
Source: SMFS 2017

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
Viable r-kq pairs = 5000

Results:  
viable r-kq pairs = 5000  
median kq = 3, 2.04 - 4.58  
median MSYq = 0.37, 0.243 - 0.562  
r (4 MSYq/kq) = 0.493, 0.319 - 0.756  
Fmsy (r/2) = 0.247, 0.159 - 0.378  
F/Fmsy = 2.36, 0.812 - 4.64 (2016)  
B/Bmsy = 0.232, 0.13 - 0.425 (2017)





LBB results for *Myoxocephalus scorpius*, stock *Myoxocephalus scorpius*, 1983-2016

Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Myoxocephalus scorpius.csv

Linf prior= 31, SD=0.31 cm (user-defined), Lmax=34, median Lmax=29  
 Z/K prior = 2.1, SD=0.079, M/K prior=1.5, SD=0.15  
 F/K prior = 0.563 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 12.2, SD=1.2 cm, alpha prior=17.3, SD=1.7, Lm50=16 cm

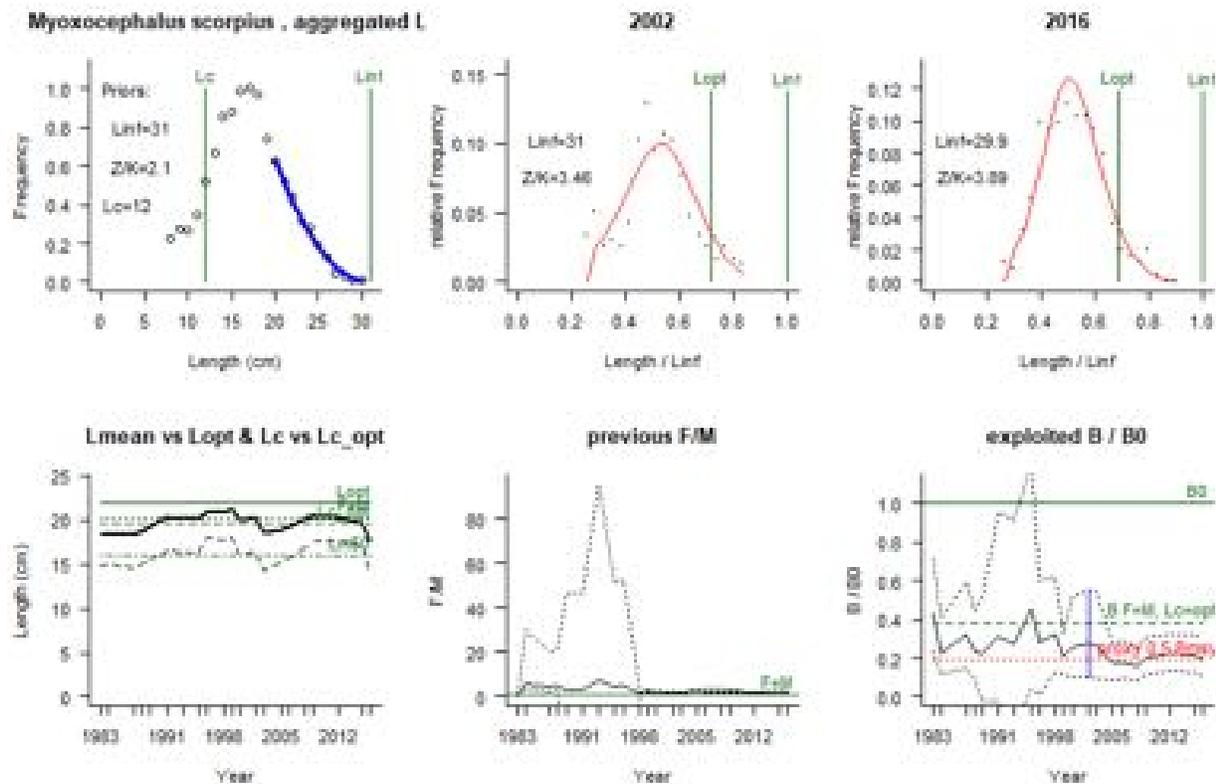
General reference points (median across years):

Linf = 30.2 (29.8-30.7) cm  
 Lopt = 22 cm, Lopt/Linf=0.72  
 Lc\_opt = 20 cm, Lc\_opt/Linf=0.65, Lmean if F=M 20.2 cm  
 M/K = 1.14 (0.9-1.33)  
 F/M = 2.09 (1.23-3.04), F/K=2.21 (1.53-2.53), Z/K=3.21 (2.99-3.51)  
 B/B0 = 0.19 (0.11-0.31), B/B0 F=M Lc=Lc\_opt 0.38  
 Y/R' = 0.04 (0.021-0.08)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.066

Estimates for 2016 (mean of last 3 years with data):

Lc50 = 14.3 (13.9-14.6) cm, Lc/Linf=0.47 (0.46-0.48)  
 Lc95 = 20.5, alpha=0.472 (0.454-0.486)  
 Lmean/Lopt= 0.84, Lc/Lc\_opt=0.73, L95th=26.3 cm, L95th/Linf=0.86, Mature=39%  
 F/M = 1.9 (1.3-2.8), F/K=2.5 (2-3), Z/K=3.9 (3.5-4.3)  
 Y/R' = 0.038 (0.021-0.059)(reduced because B/B0 < 0.25)  
 B/B0 = 0.19 (0.11-0.3), best LF fit year 2012=0.224 (0.14-0.32)  
 B/Bmsy = 0.51 (0.29-0.77), **selected B/B0 2002 = 0.28 (0.1-0.55)**

RF: Set Linf=31 between median and max. Set Lcut=8cm to exclude peaks of early juveniles. Excluded years with unrealistic LF patterns. Selected 2002 because of reasonable fit, CL and B/B0 compared to other years.

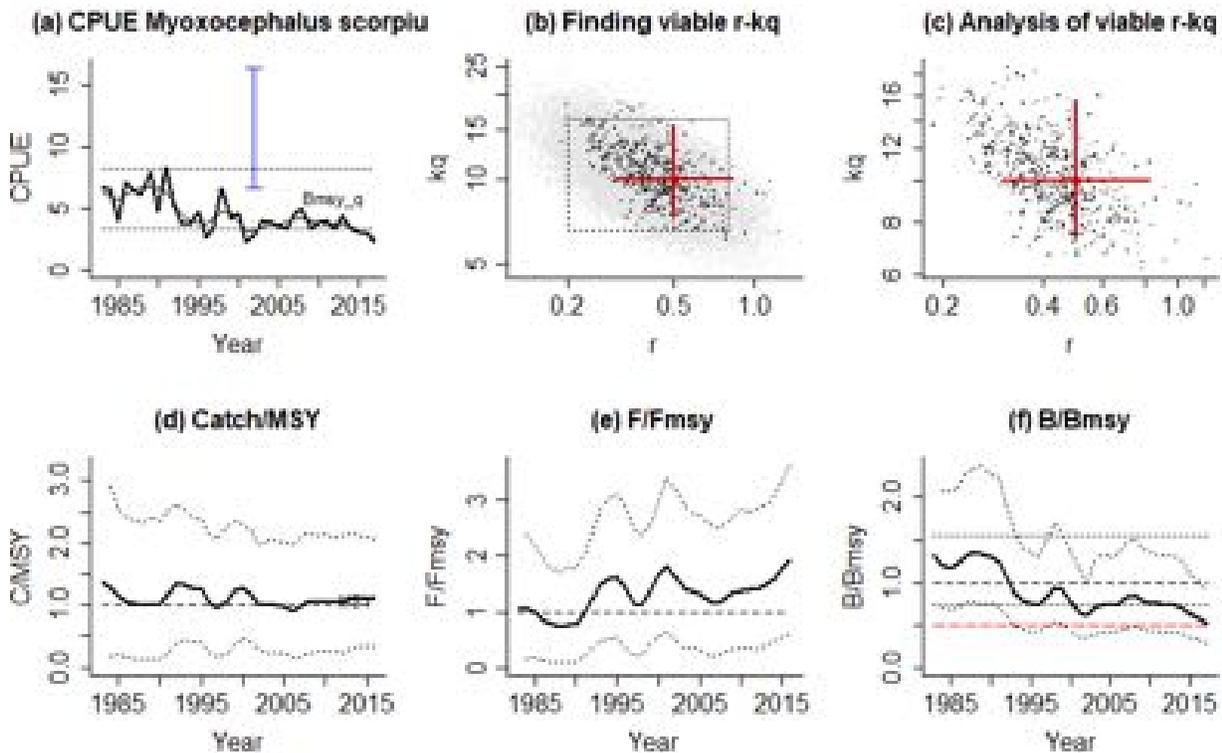


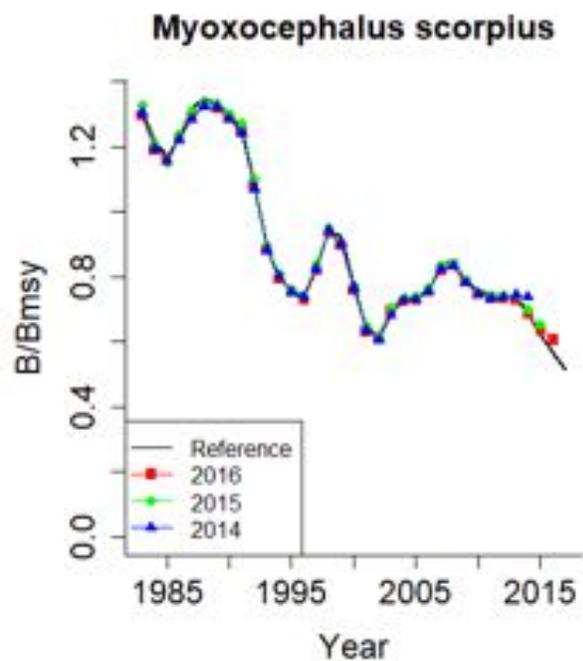
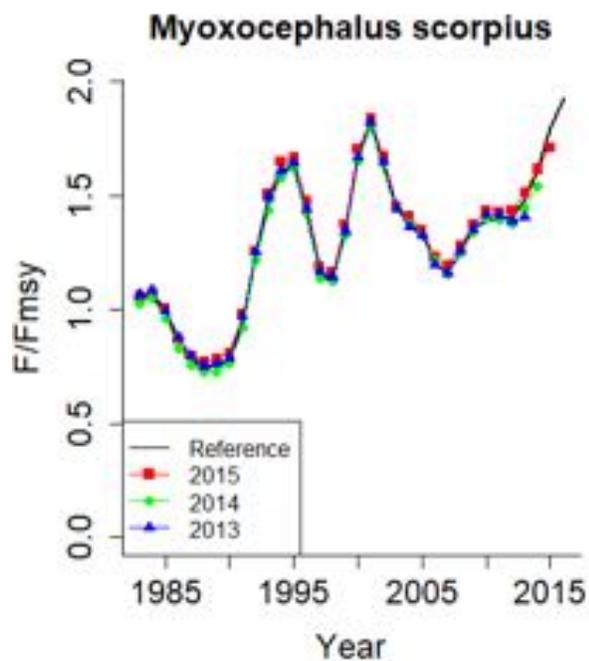
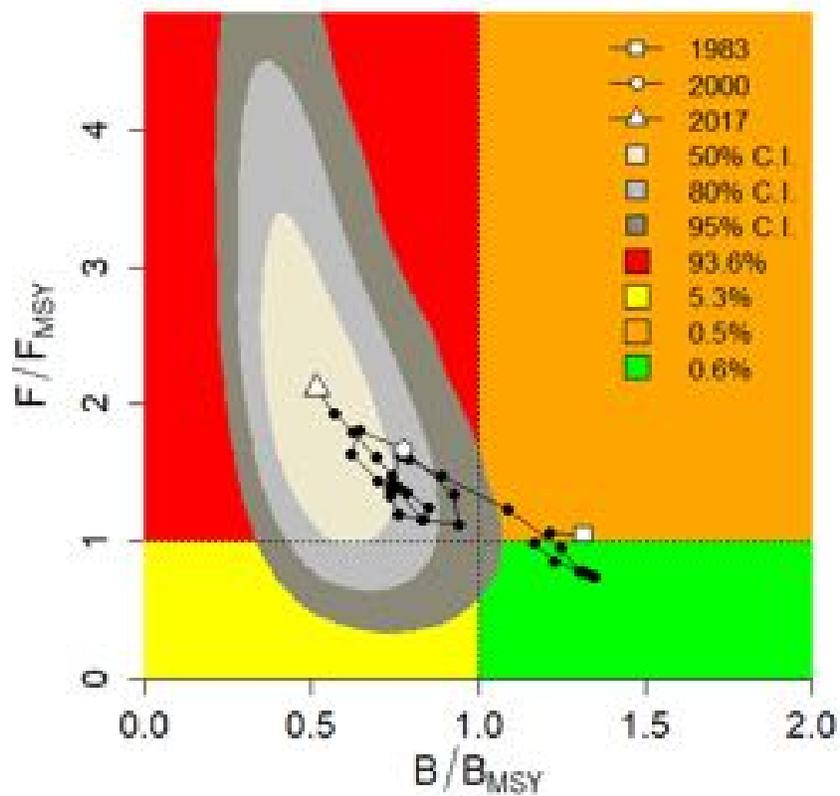
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 AMSY Analysis, Fri Nov 01 18:29:22 2019  
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Stock *Myoxocephalus scorpius*, *Myoxocephalus scorpius*, Shorthorn sculpin  
 CPUE data for years 1983 - 2017, CPUE range 2.59 - 6.64, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 2002 stock status = About half, 0.1 - 0.55  
 Used 2002 prior B/B0 range = 0.1 - 0.55, prior B/Bmsy = 0.2 - 1.1  
 Used prior range for kq = 6.62 - 16.4 [original range = 2.97 - 16.4]  
 Comment: B/B0 prior from LBB. RF: OK  
 Source: SMFS 2017

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5001

Results:  
 viable r-kq pairs = 5001  
 median kq = 10, 7.42 - 15.6  
 median MSYq = 1.26, 0.836 - 2  
 r (4 MSYq/kq) = 0.5, 0.299 - 0.832  
 Fmsy (r/2) = 0.25, 0.15 - 0.416  
 F/Fmsy = 1.93, 0.611 - 3.63 (2016)  
 B/Bmsy = 0.515, 0.287 - 0.906 (2017)





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 LBB results for *Myxine glutinosa*, stock *Myxine glutinosa*, 1995-2017  
 Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Myxine glutinosa.csv  
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Linf prior= 40, SD=0.4 cm (user-defined), Lmax=76, median Lmax=36  
 Z/K prior = 3.1, SD=0.082, M/K prior=1.5, SD=0.15  
 F/K prior = 1.56 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 17.3, SD=1.7 cm, alpha prior=16.7, SD=1.7, Lm50=30 cm

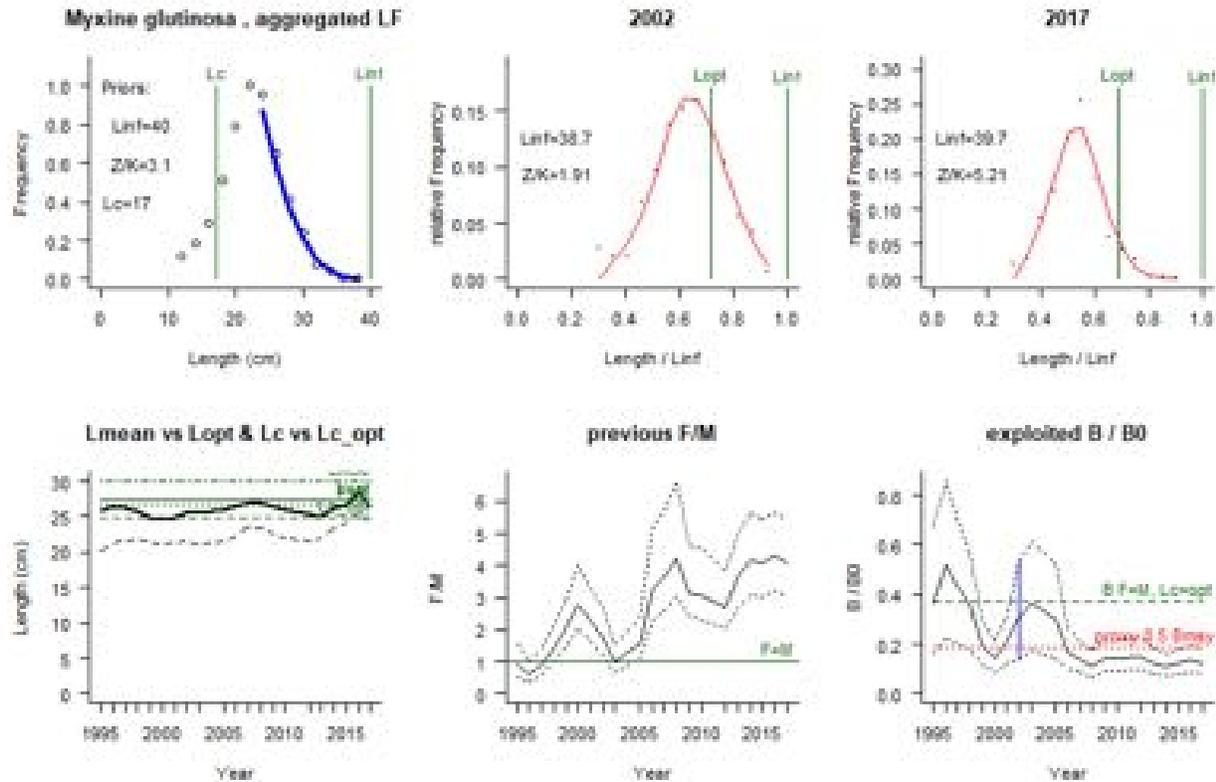
General reference points (median across years):

Linf = 39.7 (39-40.4) cm  
 Lopt = 27 cm, Lopt/Linf=0.69  
 Lc\_opt = 25 cm, Lc\_opt/Linf=0.62, Lmean if F=M 26.7 cm  
 M/K = 1.36 (1.07-1.63)  
 F/M = 2.6 (2.03-3.73), F/K=3.26 (2.85-3.97), Z/K=4.57 (4.21-5.11)  
 B/B0 = 0.15 (0.1-0.23), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.034 (0.02-0.053)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.051

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 23.7 (23.1-24.2) cm, Lc/Linf=0.6 (0.58-0.61)  
 Lc95 = 31.2, alpha=0.392 (0.379-0.405)  
 Lmean/Lopt= 1, Lc/Lc\_opt=0.96, L95th=33.3 cm, L95th/Linf=0.84, Mature=0.63%  
 F/M = 4 (3-5.4), F/K=6.8 (5.5-7.9), Z/K=8.4 (7.1-9.4)  
 Y/R' = 0.025 (0.016-0.036)(reduced because B/B0 < 0.25)  
 B/B0 = 0.13 (0.083-0.19), best LF fit year 2005=0.305 (0.14-0.53)  
 B/Bmsy = 0.34 (0.22-0.5), **selected B/B0 2002 = 0.31 (0.14-0.53)**

RF: Set Linf=40. Set Lcut to 12 to exclude early juveniles. Excluded years with unrealistic LF fits. Selected 2002 because of reasonable LF fit and B/B0 compatible with adjacent estimates.

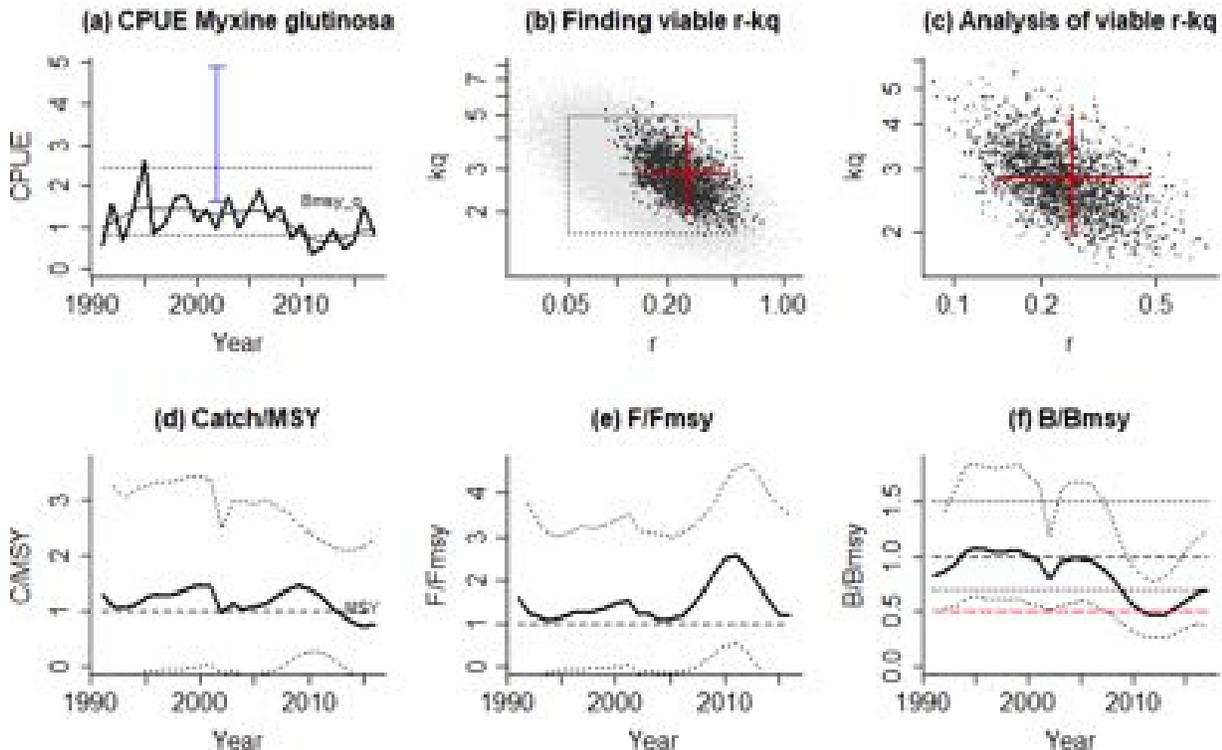


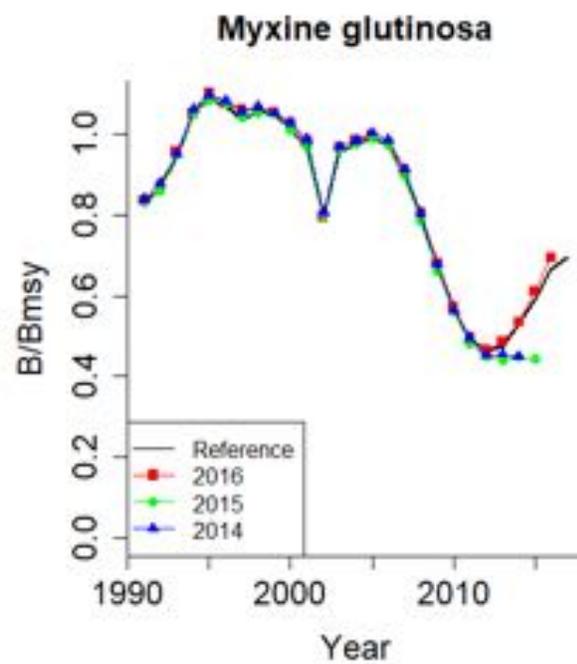
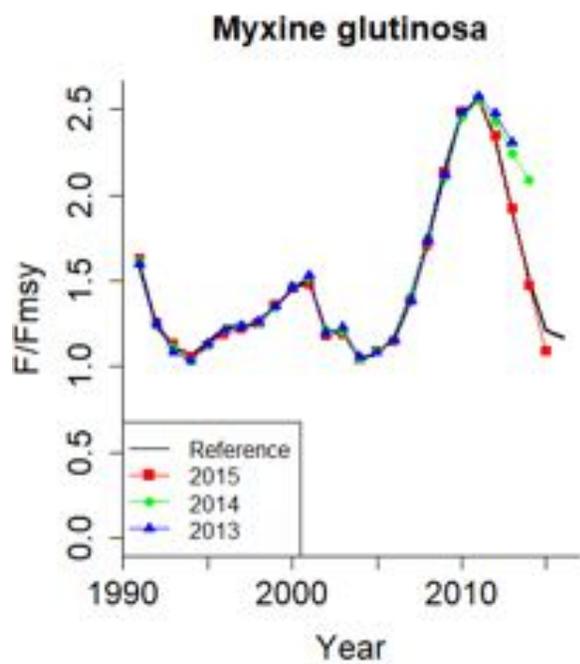
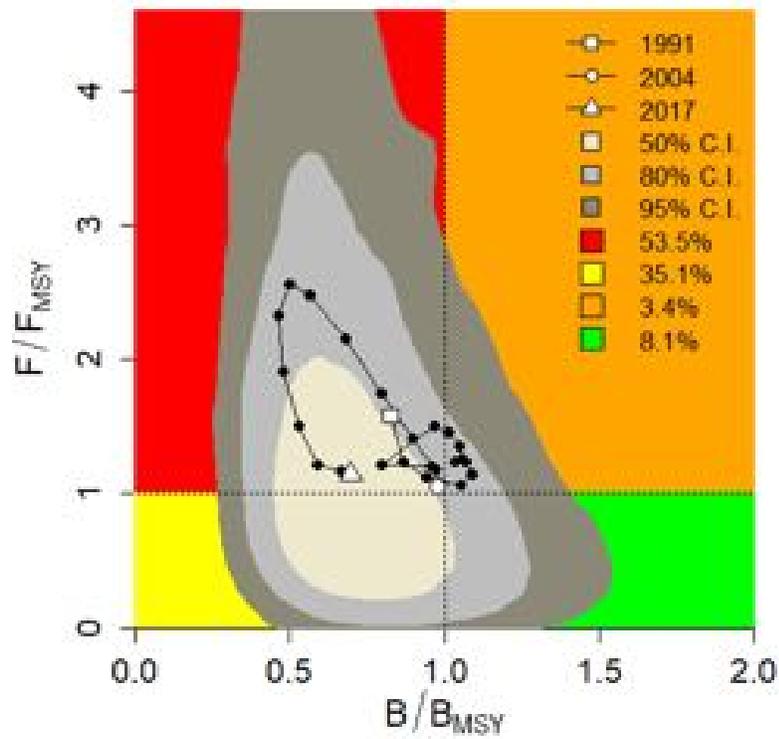
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AMSY Analysis, Fri Nov 01 18:33:43 2019  
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Stock *Myxine glutinosa*, *Myxine glutinosa*, Atlantic hagfish  
CPUE data for years 1991 - 2017, CPUE range 0.66 - 1.48, smooth = TRUE  
Prior for  $r$  = Low, NA - NA  
Used prior range for  $r$  = 0.05 - 0.5  
Prior for 2002 stock status = About half, 0.14 - 0.53  
Used 2002 prior B/B0 range = 0.14 - 0.53, prior B/Bmsy = 0.28 - 1.06  
Used prior range for  $kq$  = 1.64 - 4.91 [original range = 1.64 - 6.19]  
Comment: B/B0 prior from LBB. RF: OK  
Source: SMFS 2017

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5001

Results:  
viable  $r$ - $kq$  pairs = 5001  
median  $kq$  = 2.83, 1.98 - 4.25  
median MSYq = 0.183, 0.107 - 0.317  
 $r$  (4 MSYq/ $kq$ ) = 0.258, 0.14 - 0.467  
Fmsy ( $r/2$ ) = 0.129, 0.0698 - 0.233  
F/Fmsy = 1.16, -0.322 - 3.5 (2016)  
B/Bmsy = 0.696, 0.379 - 1.25 (2017)





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 LBB results for *Raja clavata*, stock **rjc.27.3a47d**, 1983-2015  
 Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Raja clavata.csv  
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Linf prior= 90, SD=0.9 cm (user-defined), Lmax=95, median Lmax=85  
 Z/K prior = 2.9, SD=0.3, M/K prior=1.5, SD=0.15  
 F/K prior = 1.43 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 22.9, SD=2.3 cm, alpha prior=15.7, SD=1.6, Lm50=40 cm

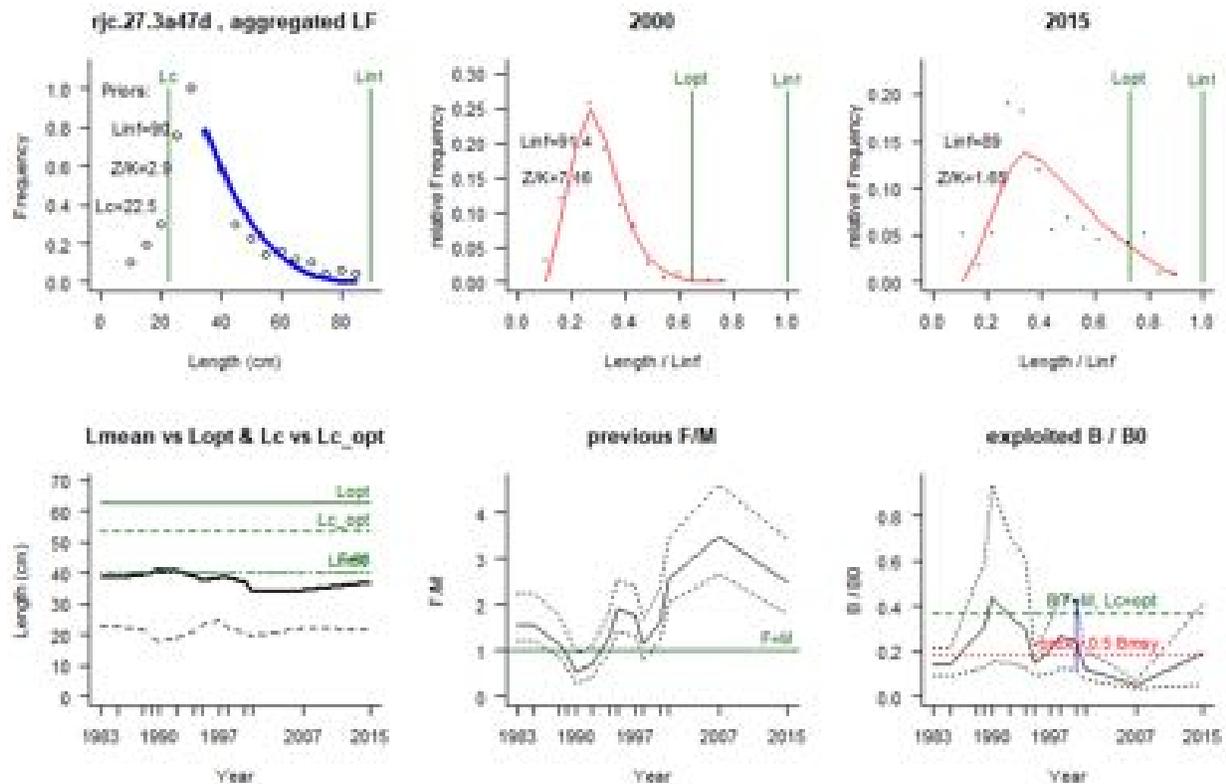
General reference points (median across years):

Linf = 92.6 (91.2-94.2) cm  
 Lopt = 63 cm, Lopt/Linf=0.68  
 Lc\_opt = 53 cm, Lc\_opt/Linf=0.58, Lmean if F=M 40.2 cm  
 M/K = 1.43 (1.17-1.67)  
 F/M = 1.23 (0.921-1.91), F/K=1.89 (1.62-2.35), Z/K=3.45 (3.26-3.67)  
 B/B0 = 0.2 (0.096-0.31), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.025 (0.012-0.041)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.048

Estimates for 2015 (mean of last 3 years with data):

Lc50 = 21.9 (20.1-23.7) cm, Lc/Linf=0.24 (0.22-0.26)  
 Lc95 = 35.1, alpha=0.223 (0.217-0.228)  
 Lmean/Lopt= 0.59, Lc/Lc\_opt=0.41, L95th=81.7 cm, L95th/Linf=0.91, Mature=33%  
 F/M = 2.5 (1.8-3.4), F/K=3.5 (3.1-3.9), Z/K=4.8 (4.5-5)  
 Y/R' = 0.021 (0.0055-0.043)(reduced because B/B0 < 0.25)  
 B/B0 = 0.19 (0.053-0.41), best LF fit year 2001=0.122 (0.074-0.21)  
 B/Bmsy = 0.53 (0.14-1.1), **selected B/B0 2000 = 0.25 (0.11-0.42)**

RF: Set Linf between median and max. Set Lcut=10 to remove peaks of early juveniles. Set Lstart=34 to have better fit of aggregated prior Z/K. Used MergeLF to increase numbers. Excluded years with unrealistic LF fits. Selected 2000 because of intermediate B/B0 and reasonable LF fit.

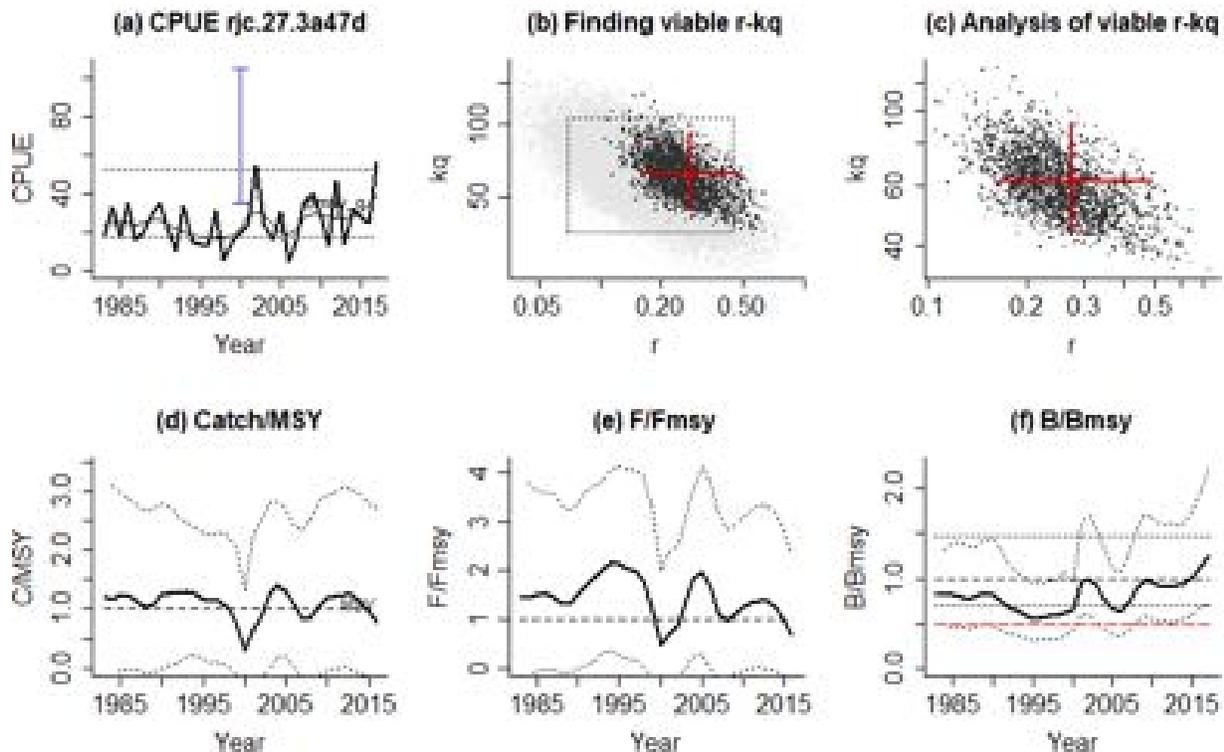


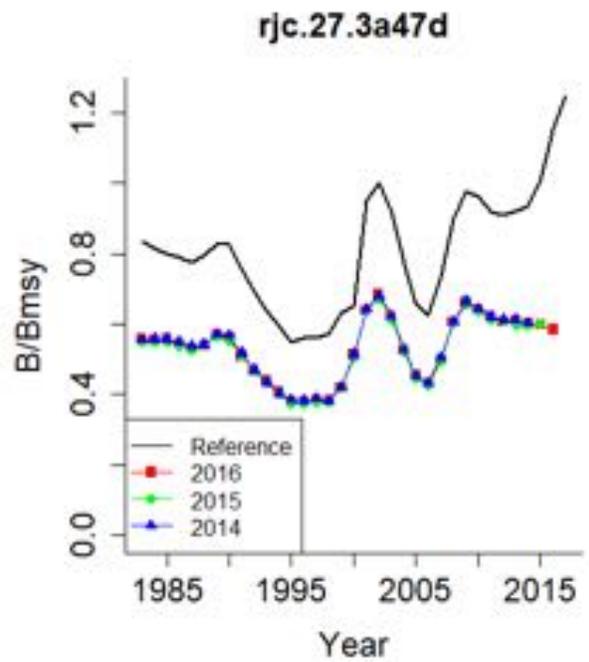
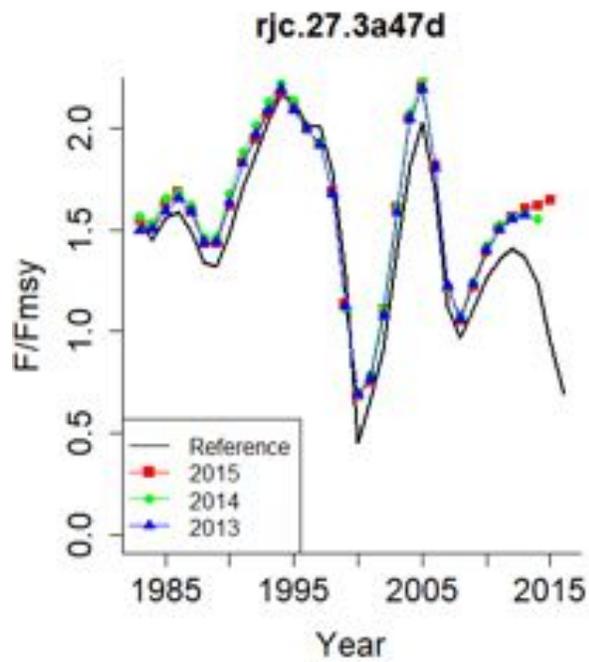
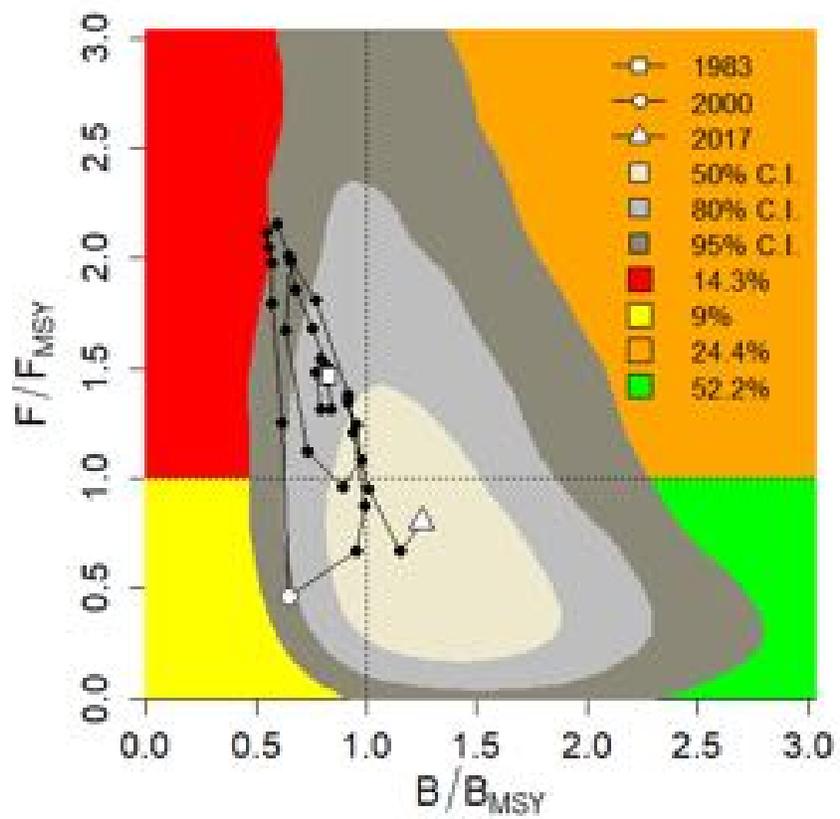
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AMSY Analysis, Fri Nov 01 18:41:58 2019  
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Stock **rjc.27.3a47d**, *Raja clavata*, Thornback ray  
CPUE data for years 1983 - 2017, CPUE range 16.7 - 39, smooth = TRUE  
Prior for  $r$  = Low, 0.07 - 0.45  
Used prior range for  $r$  = 0.0606 - 0.522  
Prior for 2000 stock status = Small, 0.11 - 0.42  
Used 2000 prior B/B0 range = 0.11 - 0.42, prior B/Bmsy = 0.22 - 0.84  
Used prior range for  $kq$  = 35.1 - 105 [original range = 35.1 - 134]  
Comment: B/B0 prior from LBB. RF: Note that the steep increase in cpue in the last year changes the whole assessment, as nicely shown by the retrospective analysis. Thus, for management, the analysis should be restricted to 2016 until new data come in to evaluate the peak in 2017.  
Source: SMFS 2017 for length and CPUE

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5000

Results:  
viable  $r$ - $kq$  pairs = 5000  
median  $kq$  = 62, 43.3 - 91.6  
median MSY $q$  = 4.28, 2.62 - 7.01  
 $r$  (4 MSY $q$ / $kq$ ) = 0.277, 0.162 - 0.488  
Fmsy ( $r/2$ ) = 0.138, 0.0812 - 0.244  
F/Fmsy = 0.675, -0.197 - 2.36 (2016)  
B/Bmsy = 1.25, 0.702 - 2.25 (2017)





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 LBB results for *Raja montagui*, stock rjm.27.3a47d, 1983-2016  
 Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Raja montagui.csv  
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Linf prior= 75, SD=0.75 cm (user-defined), Lmax=95, median Lmax=60  
 Z/K prior = 2.7, SD=0.38, M/K prior=1.5, SD=0.15  
 F/K prior = 1.24 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 30.6, SD=3.1 cm, alpha prior=9.04, SD=0.9, Lm50=59 cm

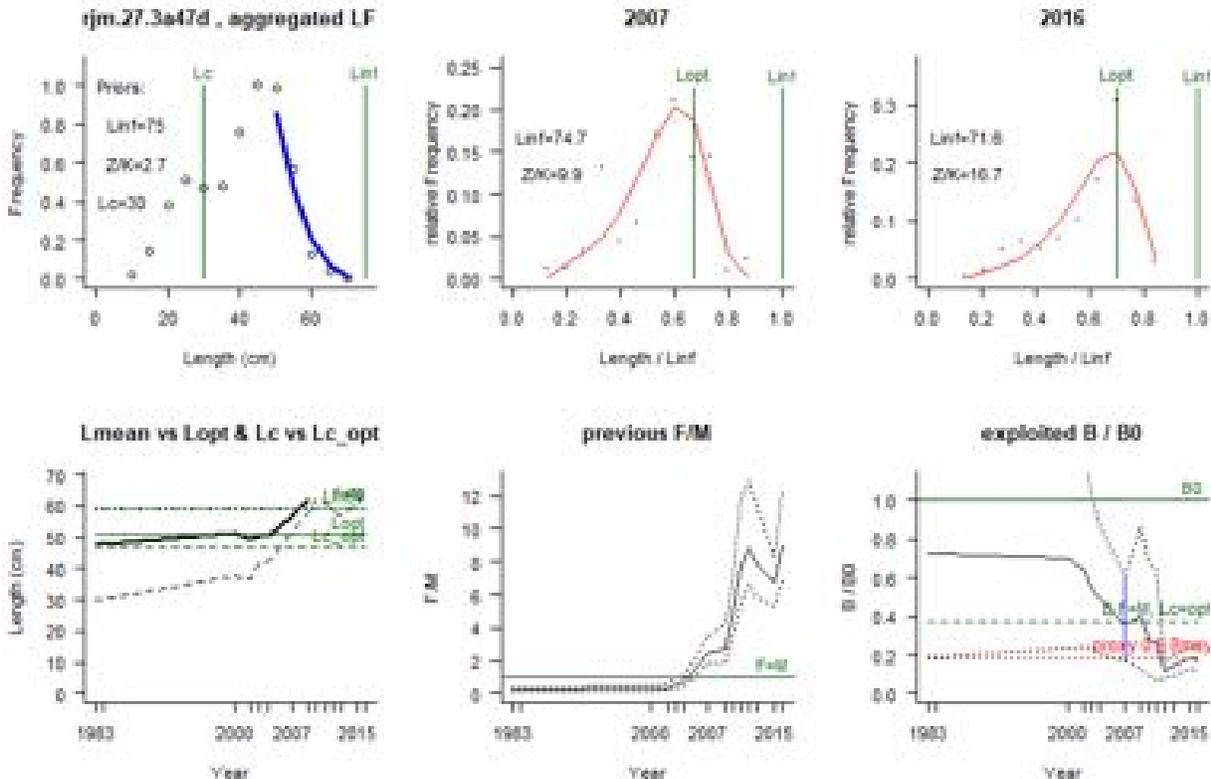
General reference points (median across years):

Linf = 73.9 (72.4-75.2) cm  
 Lopt = 51 cm, Lopt/Linf=0.69  
 Lc\_opt = 47 cm, Lc\_opt/Linf=0.63, Lmean if F=M 59.6 cm  
 M/K = 1.37 (1.17-1.56)  
 F/M = 3.04 (2.1-4.63), F/K=5.41 (3.8-8.77), Z/K=6.96 (5.36-10.3)  
 B/B0 = 0.34 (0.15-0.58), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.024 (0.014-0.039), Y/R' F=M Lc=Lc\_opt 0.048

Estimates for 2016 (mean of last 3 years with data):

Lc50 = 64.6 (62.9-66.7) cm, Lc/Linf=0.89 (0.87-0.92)  
 Lc95 = 87.5, alpha=0.129 (0.124-0.133)  
 Lmean/Lopt= NA, Lc/Lc\_opt=1.4, L95th=60 cm, L95th/Linf=0.83, Mature=3%  
 F/M = 9 (6.9-12), F/K=15 (12-19), Z/K=17 (14-21)  
 Y/R' = 0.023 (0.015-0.034)  
 B/B0 = 0.17 (0.12-0.24), best LF fit year 2012=0.118 (0.08-0.17)  
 B/Bmsy = 0.47 (0.32-0.65), **selected B/B0 2007 = 0.36 (0.17-0.61)**

RF: Set Lstart to 50cm to avoid error in aggregated fit. Set Lcut=10cm to avoid peaks of early juveniles. Used MergeLF to increase numbers per year. Set Linf between median and max. All fits are close to unsatisfactory. Selected 2007 for intermediate B/B0 and reasonable fit.

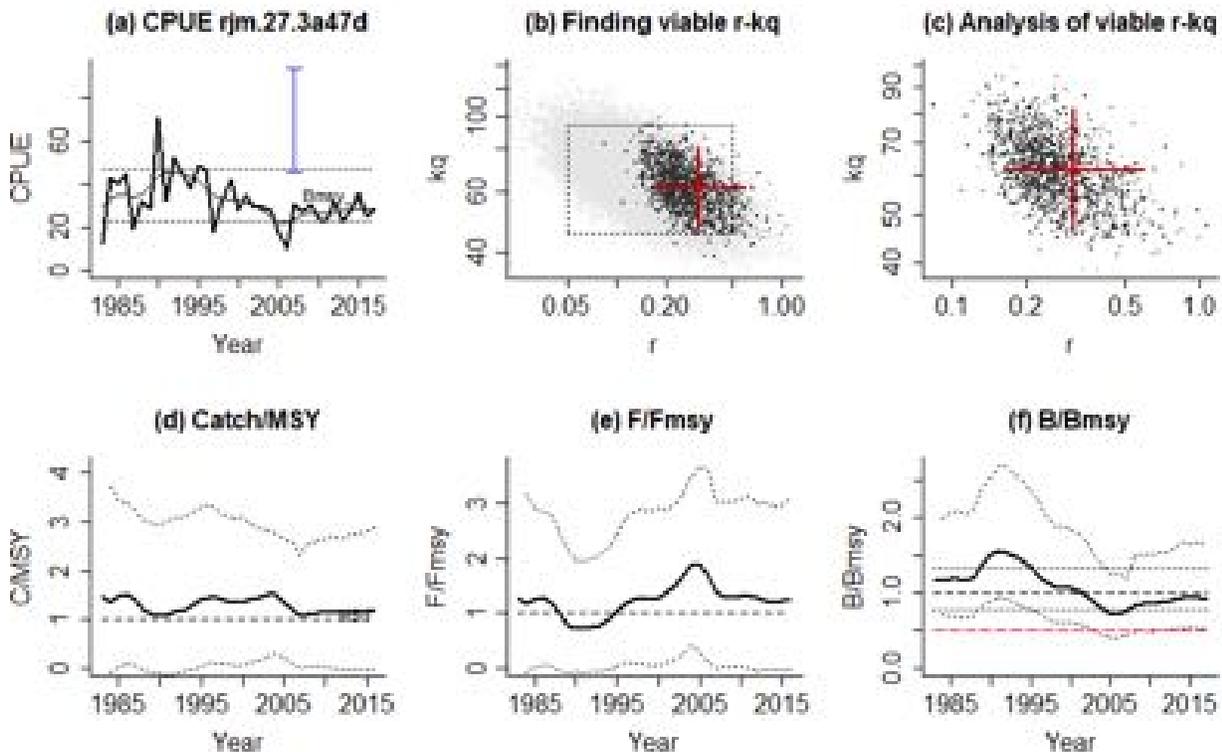


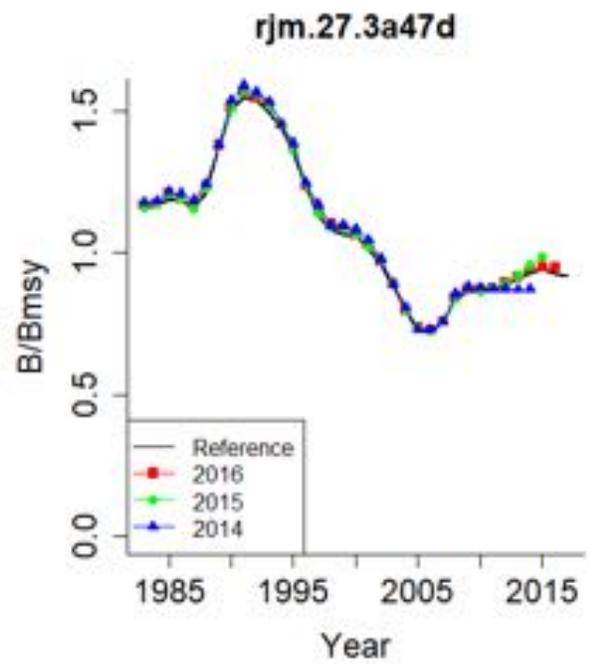
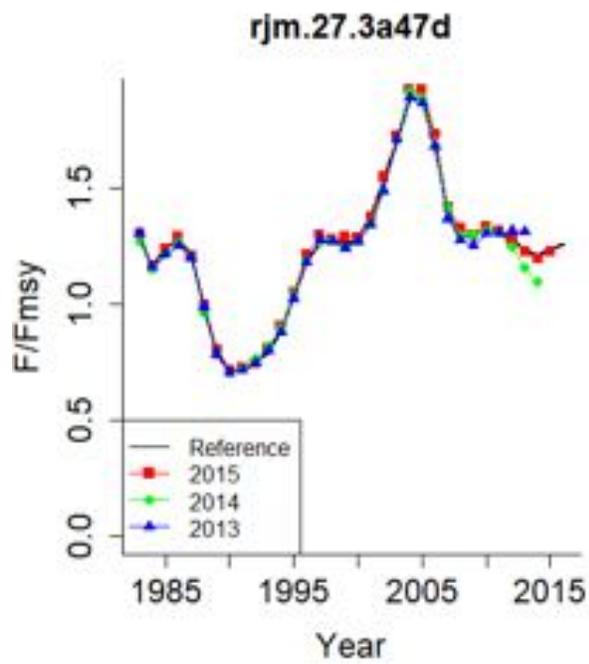
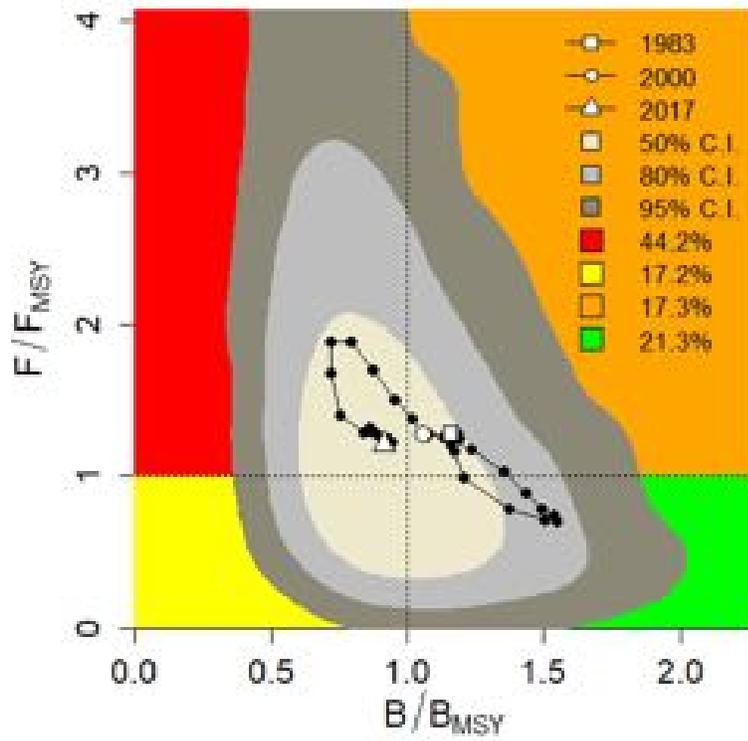
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 AMSY Analysis, Fri Nov 01 19:21:23 2019  
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Stock **rjm.27.3a47d**, *Raja montagui*, Spotted ray  
 CPUE data for years 1983 - 2017, CPUE range 21.8 - 45.4, smooth = TRUE  
 Prior for  $r$  = Low, NA - NA  
 Used prior range for  $r$  = 0.05 - 0.5  
 Prior for 2007 stock status = About half, 0.17 - 0.61  
 Used 2007 prior B/B0 range = 0.17 - 0.61, prior B/Bmsy = 0.34 - 1.22  
 Used prior range for  $kq$  = 45.3 - 93.8 [original range = 26.1 - 93.8]  
 Comment: B/B0 prior from LBB. RF: OK  
 Source: SMFS 2017 for length and CPUE.

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
 Viable  $r$ - $kq$  pairs = 5003

Results:  
 viable  $r$ - $kq$  pairs = 5003  
 median  $kq$  = 61.3, 46.8 - 81.6  
 median MSYq = 4.8, 2.78 - 8.18  
 $r$  (4 MSYq/ $kq$ ) = 0.313, 0.169 - 0.601  
 Fmsy ( $r/2$ ) = 0.157, 0.0846 - 0.3  
 F/Fmsy = 1.26, -0.0468 - 3.1 (2016)  
 B/Bmsy = 0.915, 0.505 - 1.62 (2017)





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 LBB results for *scyliorhinus canicula*, stock **syc.27.3a47d**, 1984-2017  
 Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Scyliorhinus canicula.csv  
 -----

Linf prior= 85, SD=0.85 cm (user-defined), Lmax=112, median Lmax=72  
 Z/K prior = 2.4, SD=0.32, M/K prior=1.5, SD=0.15  
 F/K prior = 0.933 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 39.8, SD=4 cm, alpha prior=8.9, SD=0.89, Lm50=57 cm

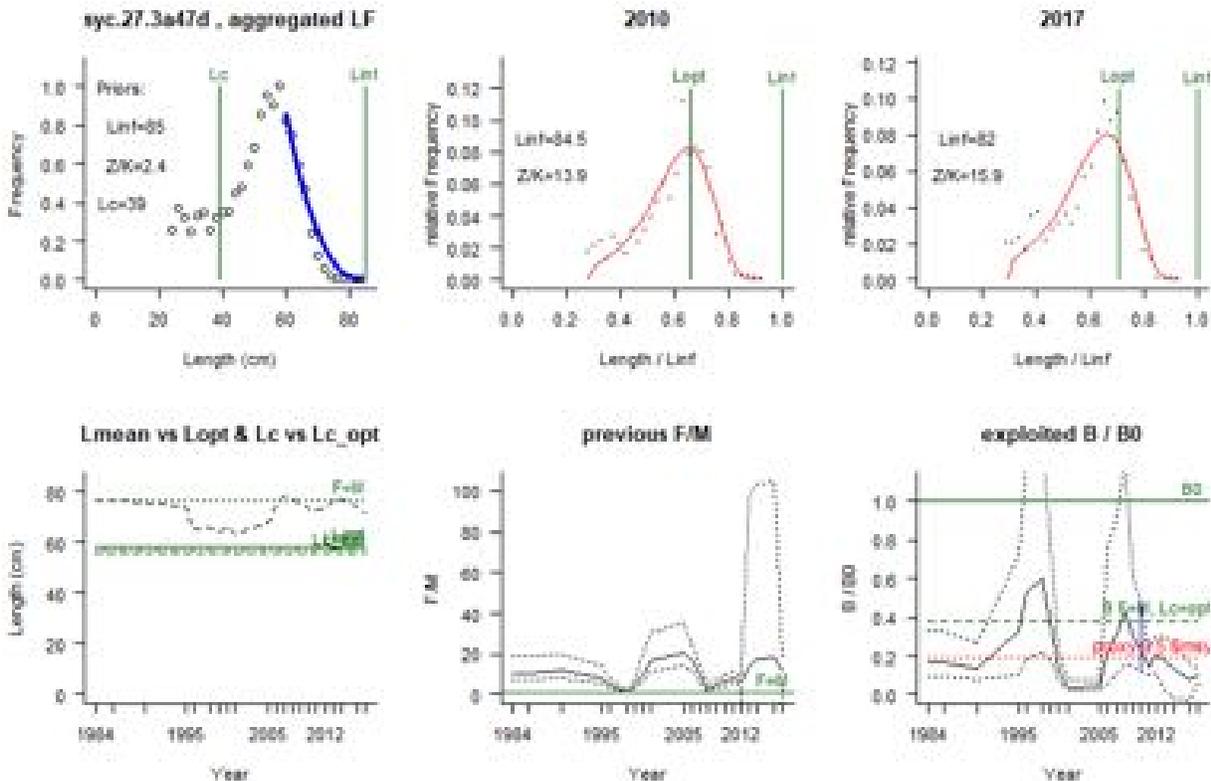
General reference points (median across years):

Linf = 81.2 (79.8-82.9) cm  
 Lopt = 58 cm, Lopt/Linf=0.72  
 Lc\_opt = 56 cm, Lc\_opt/Linf=0.69, Lmean if F=M 76.4 cm  
 M/K = 1.19 (0.959-1.42)  
 F/M = 8.43 (6.16-12.6), F/K=8.92 (7.26-10.3), Z/K=10.6 (8.16-12.1)  
 B/B0 = 0.16 (0.09-0.22), B/B0 F=M Lc=Lc\_opt 0.38  
 Y/R' = 0.032 (0.018-0.056)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.06

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 71.5 (69.1-73.8) cm, Lc/Linf=0.87 (0.85-0.9)  
 Lc95 = 100, alpha=0.103 (0.099-0.106)  
 Lmean/Lopt= NA, Lc/Lc\_opt=1.3, L95th=74.7 cm, L95th/Linf=0.91, Mature=27%  
 F/M = 12 (8.1-17), F/K=11 (9-14), Z/K=13 (10-15)  
 Y/R' = 0.028 (0.016-0.041)(reduced because B/B0 < 0.25)  
 B/B0 = 0.1 (0.064-0.14), best LF fit year 2009=0.301 (0.15-0.6)  
 B/Bmsy = 0.26 (0.17-0.36), **selected B/B0 2010 = 0.23 (0.12-0.48)**

RF: Set Linf between median and max. Set Lcut to avoid peaks of early juveniles. Set Lstart=60 to avoid error message. Excluded years with unrealistic LF fits. Selected 2010 because of intermediate B/B0 and reasonable LF fit.201



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AMSY Analysis, Fri Nov 01 19:25:55 2019  
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Stock **syc.27.3a47d**, *Scyliorhinus canicula*, Lesser spotted dogfish  
CPUE data for years 1983 - 2017, CPUE range 10.6 - 22, smooth = TRUE

Prior for  $r$  = Low, 0.23 - 0.53  
Used prior range for  $r$  = 0.215 - 0.564  
Prior for 2010 stock status = Small, 0.12 - 0.48  
Used 2010 prior B/B<sub>0</sub> range = 0.12 - 0.48, prior B/B<sub>msy</sub> = 0.24 - 0.96  
Used prior range for  $kq$  = 21.1 - 63.4 [original range = 19.4 - 77.8]

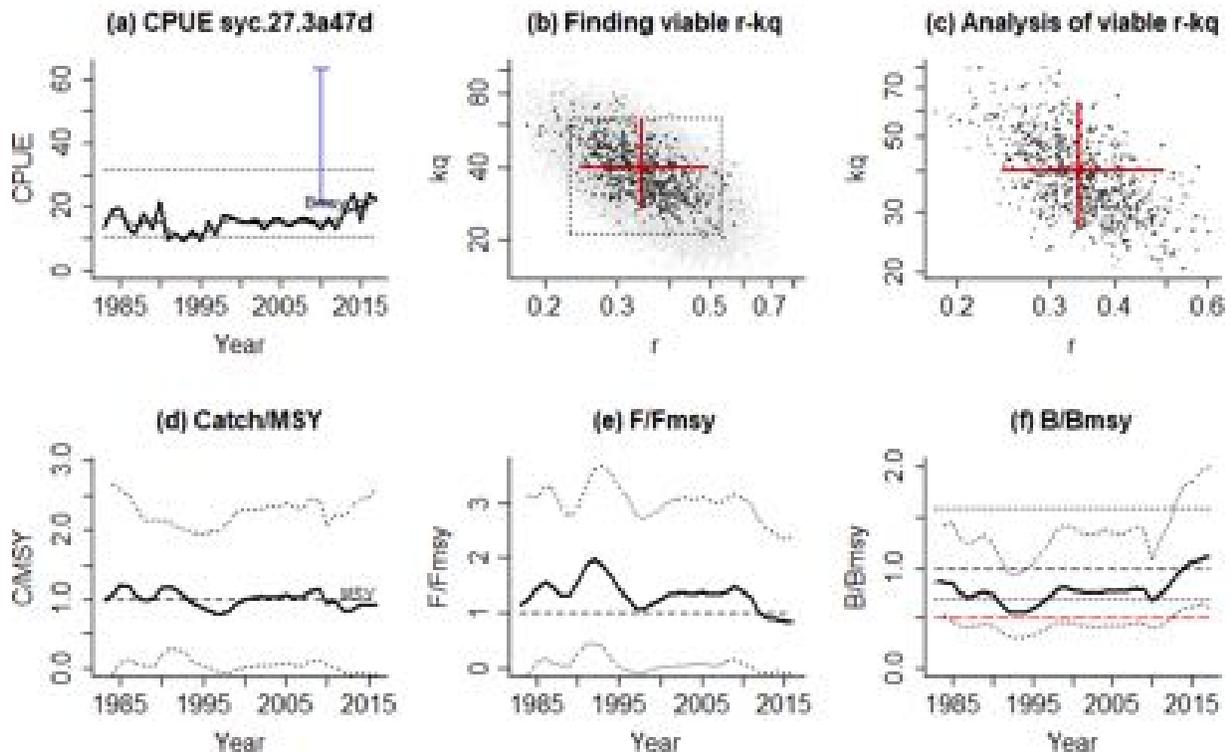
Comment: B/B<sub>0</sub> prior from LBB. RF: the last year sets a new max CPUE and thus changes the setting of prior  $kq$ . This is nicely shown in the retrospective analysis. For management, the last year should be excluded until confirmed by more data.

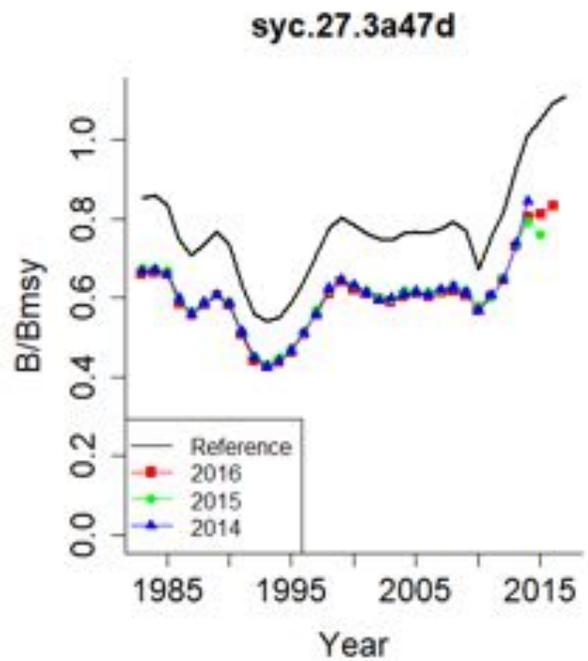
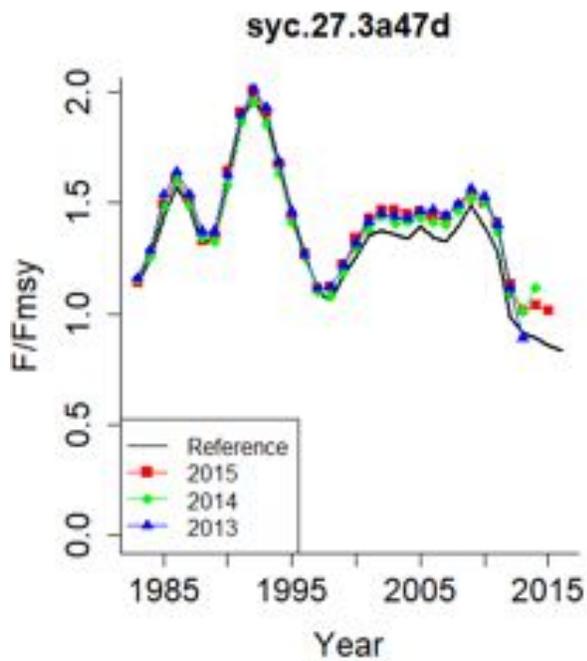
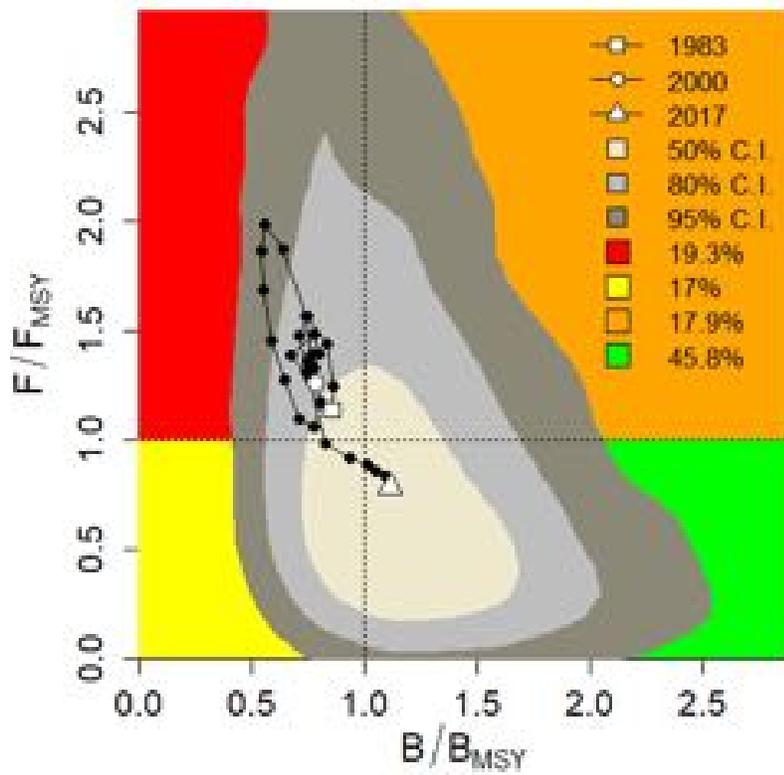
Source: SMFS 2017 for length and CPUE.

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5003

Results:

viable  $r$ - $kq$  pairs = 5003  
median  $kq$  = 39.7, 27.2 - 63  
median MSY $q$  = 3.4, 2.37 - 5.19  
 $r$  (4 MSY $q$ / $kq$ ) = 0.342, 0.242 - 0.492  
F<sub>msy</sub> ( $r/2$ ) = 0.171, 0.121 - 0.246  
F/F<sub>msy</sub> = 0.834, -0.0937 - 2.41 (2016)  
B/B<sub>msy</sub> = 1.11, 0.601 - 2.01 (2017)



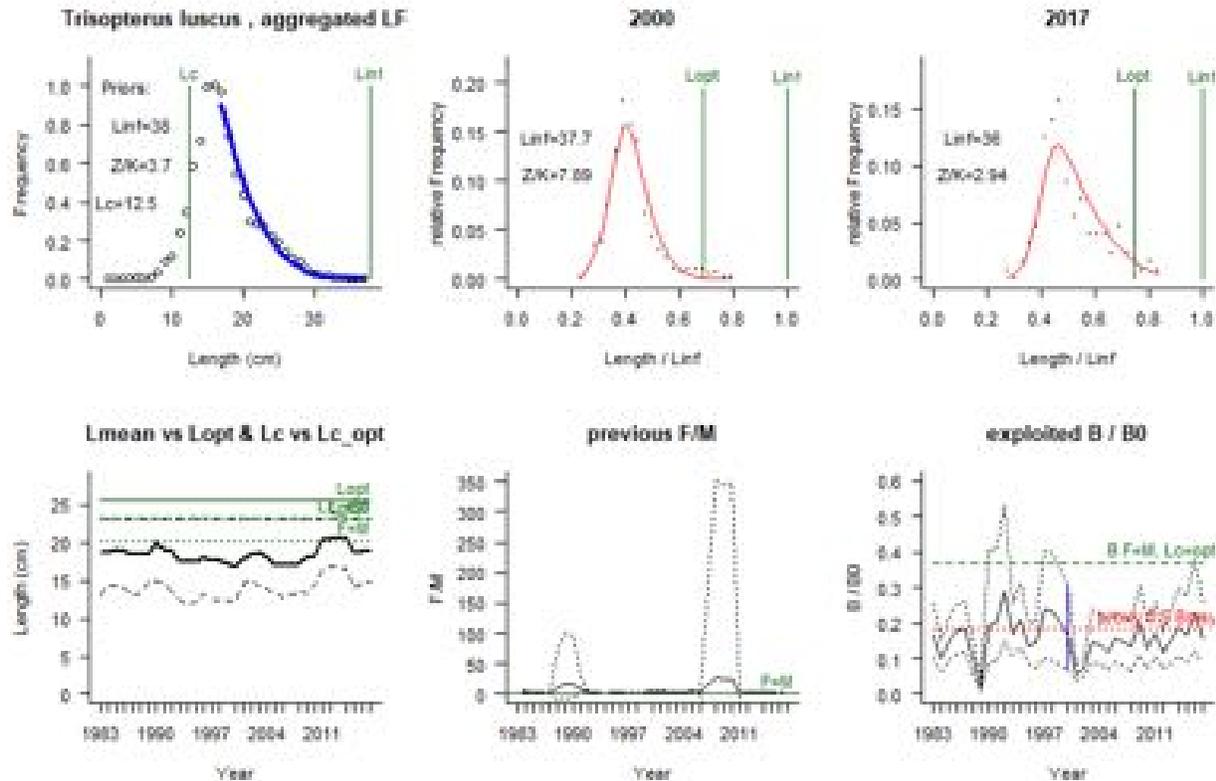


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 LBB results for *Trisopterus luscus*, stock *Trisopterus luscus*, 1983-2017  
 Files:LBB4AMSY\_ID\_3.csv, LBB\_June052019\_Trисopterus luscus.csv  
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Linf prior= 38, SD=0.38 cm (user-defined), Lmax=44, median Lmax=33  
 Z/K prior = 3.7, SD=0.18, M/K prior=1.5, SD=0.15  
 F/K prior = 2.19 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 12.8, SD=1.3 cm, alpha prior=24.5, SD=2.4, Lm50=23 cm

General reference points (median across years):  
 Linf = 37.6 (36.9-38.2) cm  
 Lopt = 26 cm, Lopt/Linf=0.68  
 Lc\_opt = 23 cm, Lc\_opt/Linf=0.62, Lmean if F=M 20.2 cm  
 M/K = 1.41 (1.11-1.66)  
 F/M = 2.66 (1.24-3.74), F/K=3.4 (3-3.92), Z/K=4.54 (4.26-4.92)  
 B/B0 = 0.14 (0.08-0.2), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.027 (0.016-0.04)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.05

Estimates for 2017 (mean of last 3 years with data):  
 Lc50 = 14.7 (14.6-14.8) cm, Lc/Linf=0.4 (0.4-0.41)  
 Lc95 = 17.9, alpha=0.898 (0.874-0.92)  
 Lmean/Lopt= 0.75, Lc/Lc\_opt=0.63, L95th=28.3 cm, L95th/Linf=0.78, Mature=14%  
 F/M = 2.4 (1.7-3.7), F/K=3.2 (2.9-3.7), Z/K=4.5 (4.2-4.8)  
 Y/R' = 0.036 (0.019-0.059)(reduced because B/B0 < 0.25)  
 B/B0 = 0.16 (0.086-0.26), best LF fit year 2015=0.168 (0.091-0.27)  
 B/Bmsy = 0.43 (0.23-0.71), **selected B/B0 2000 = 0.17 (0.071-0.31)**  
 RF: Set Linf between median and max. Excluded years with unrealistic LF fits.  
 Selected 2000 for intermediate B/B0 and reasonable LF fit.

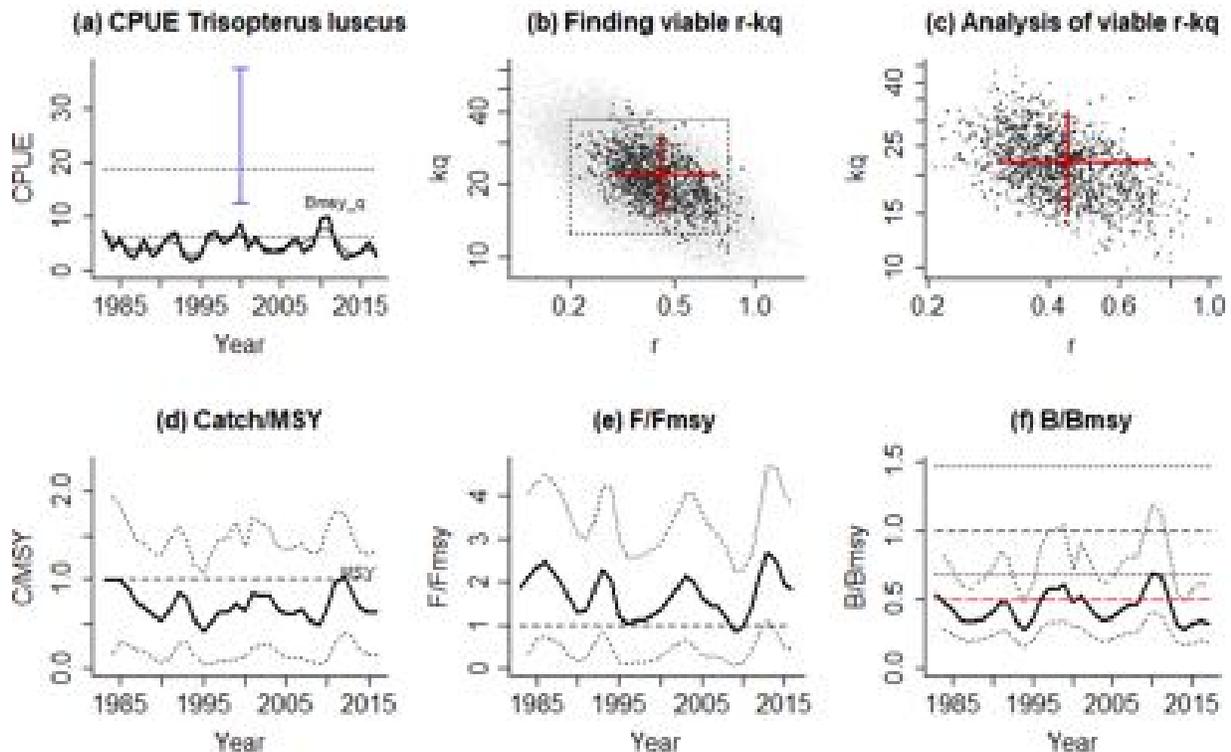


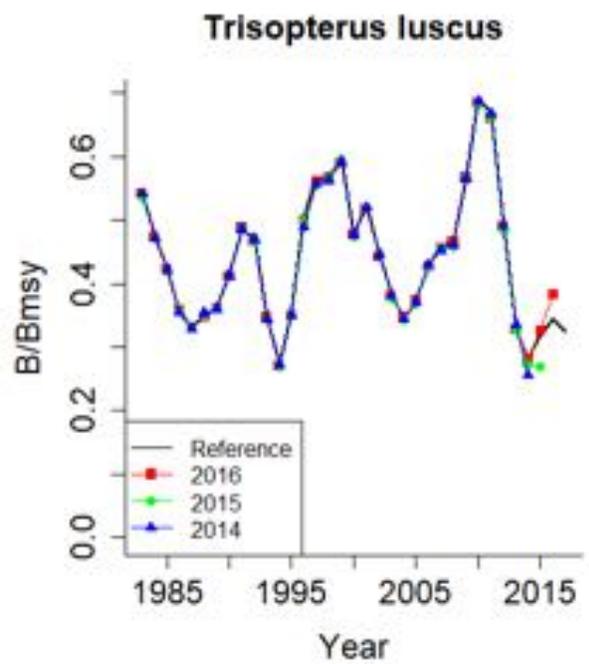
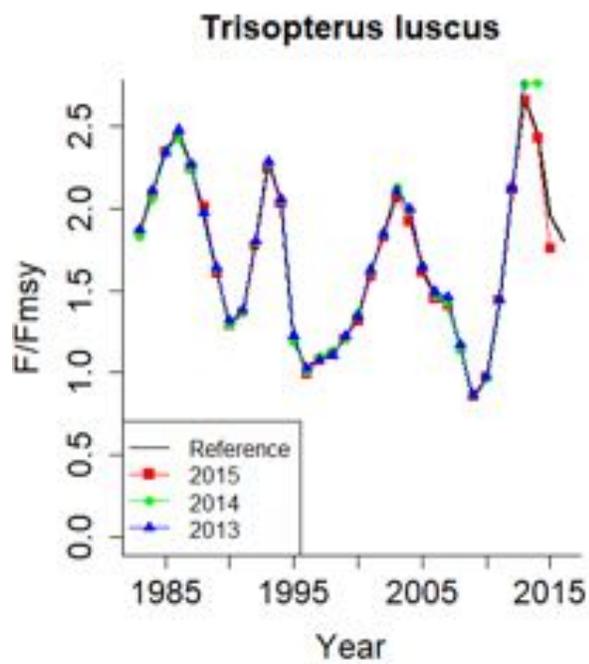
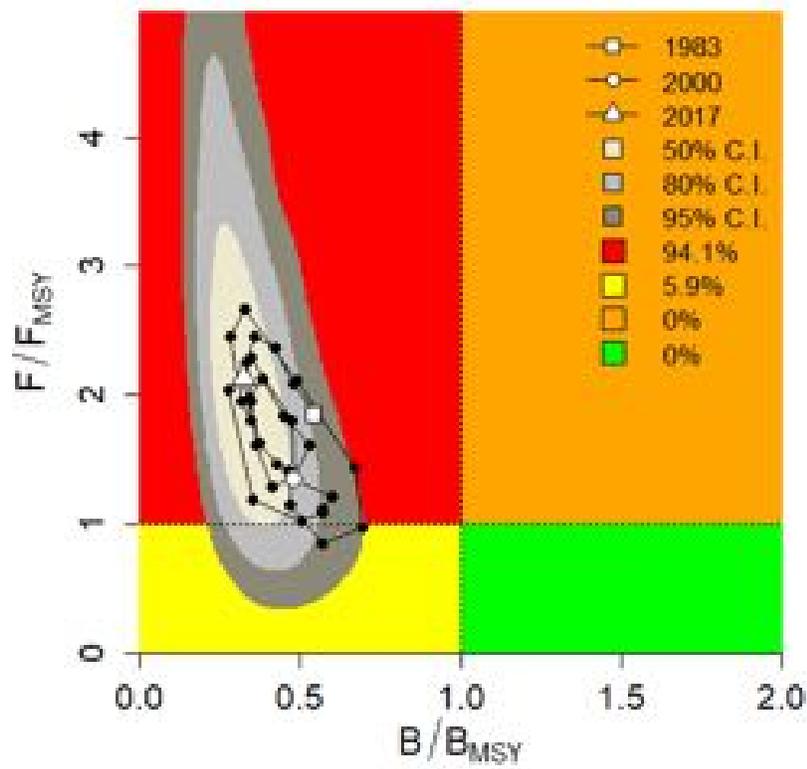
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AMSY Analysis, Fri Nov 01 19:33:23 2019  
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Stock *Trisopterus luscus*, *Trisopterus luscus*, Pouting  
CPUE data for years 1983 - 2017, CPUE range 2.89 - 7.57, smooth = TRUE  
Prior for  $r$  = Medium, NA - NA  
Used prior range for  $r$  = 0.2 - 0.8  
Prior for 2000 stock status = Very small, 0.07 - 0.31  
Used 2000 prior B/B0 range = 0.07 - 0.31, prior B/Bmsy = 0.14 - 0.62  
Used prior range for  $kq$  = 12.5 - 37.4 [original range = 12.5 - 55.2]  
Comment: B/B0 prior from LBB. RF: OK  
Source: SMFS 2017

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5003

Results:  
viable  $r$ - $kq$  pairs = 5003  
median  $kq$  = 21.8, 14.8 - 32.2  
median MSY $q$  = 2.45, 1.53 - 3.68  
 $r$  (4 MSY $q$ / $kq$ ) = 0.449, 0.295 - 0.707  
Fmsy ( $r/2$ ) = 0.224, 0.147 - 0.354  
F/Fmsy = 1.8, 0.46 - 3.83 (2016)  
B/Bmsy = 0.324, 0.183 - 0.583 (2017)





## Baltic Sea

LBB results for *Enchelyopus cimbrius*, stock **Ench\_cim22-24**, 1993-2018  
 Files: LBB4AMSY\_ID\_4.csv, LBB\_June102019\_Enchelyopus cimbrius.csv

Linf prior = 37, SD=0.37 cm (user-defined), Lmax=37, median Lmax=34  
 Z/K prior = 1.7, SD=0.16, M/K prior=1.5, SD=0.15  
 F/K prior = 0.209 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 16.8, SD=1.7 cm, alpha prior=15.3, SD=1.5, Lm50=25 cm

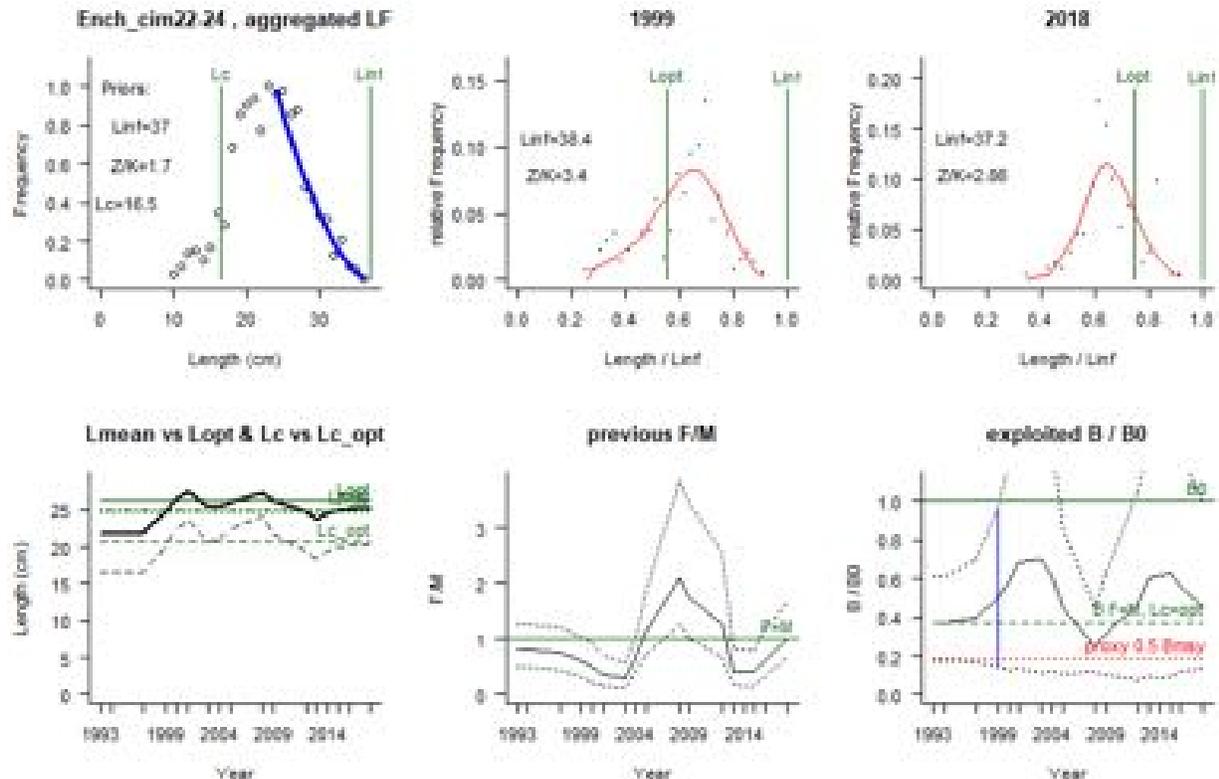
General reference points (median across years):

Linf = 37.5 (36.9-38) cm  
 Lopt = 26 cm, Lopt/Linf=0.7  
 Lc\_opt = 21 cm, Lc\_opt/Linf=0.55, Lmean if F=M 24.8 cm  
 M/K = 1.29 (1.05-1.61)  
 F/M = 0.545 (0.246-1.01), F/K=0.797 (0.414-1.3), Z/K=2.2 (1.97-2.35)  
 B/B0 = 0.51 (0.13-1), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.045 (0.012-0.093), Y/R' F=M Lc=Lc\_opt 0.056

Estimates for 2018 (mean of last 3 years with data):

Lc50 = 20.3 (20-20.6) cm, Lc/Linf=0.54 (0.53-0.55)  
 Lc95 = 26.7, alpha=0.459 (0.444-0.476)  
 Lmean/Lopt = 0.94, Lc/Lc\_opt=0.99, L95th=34.7 cm, L95th/Linf=0.92, Mature=32%  
 F/M = 1 (0.7-1.7), F/K=1.1 (0.87-1.5), Z/K=2.4 (2.2-2.6)  
 Y/R' = 0.059 (0.03-0.1)  
 B/B0 = 0.45 (0.13-0.99), best LF fit year 2001=0.683 (0.13-1.5)  
 B/Bmsy = 1.2 (0.36-2.6), **selected B/B0 1999 = 0.51 (0.15-0.97)**

RF: Set Linf = Lmax because of relatively undisturbed population. Merged LFs of adjacent years. Excluded years with unrealistic fits. Selected 1999 because of reasonable LF and B/B0 fit.

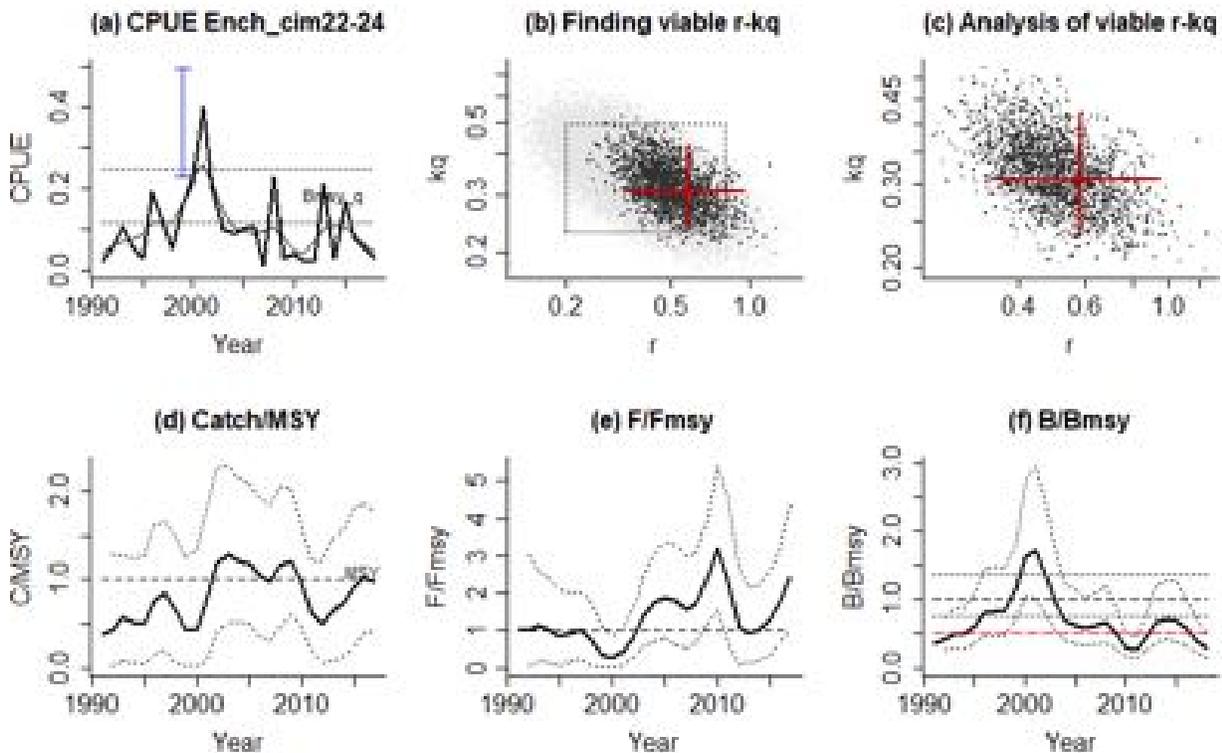


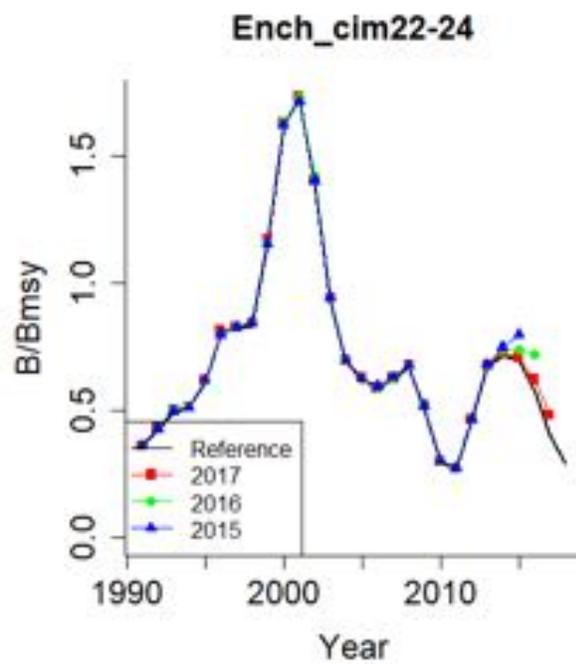
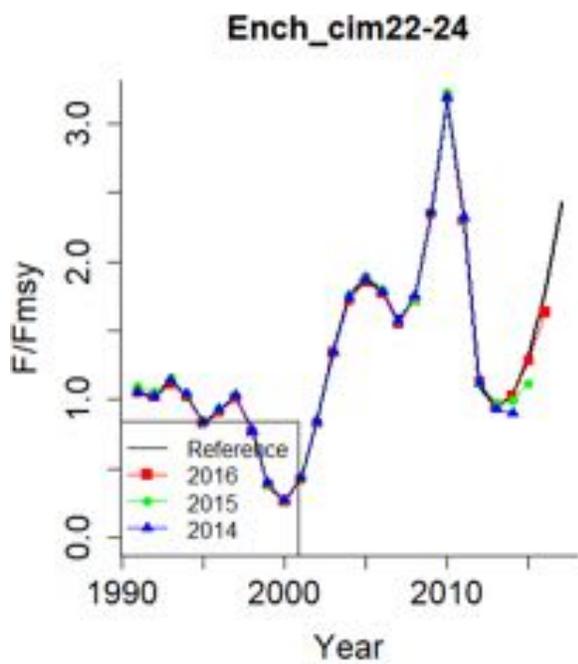
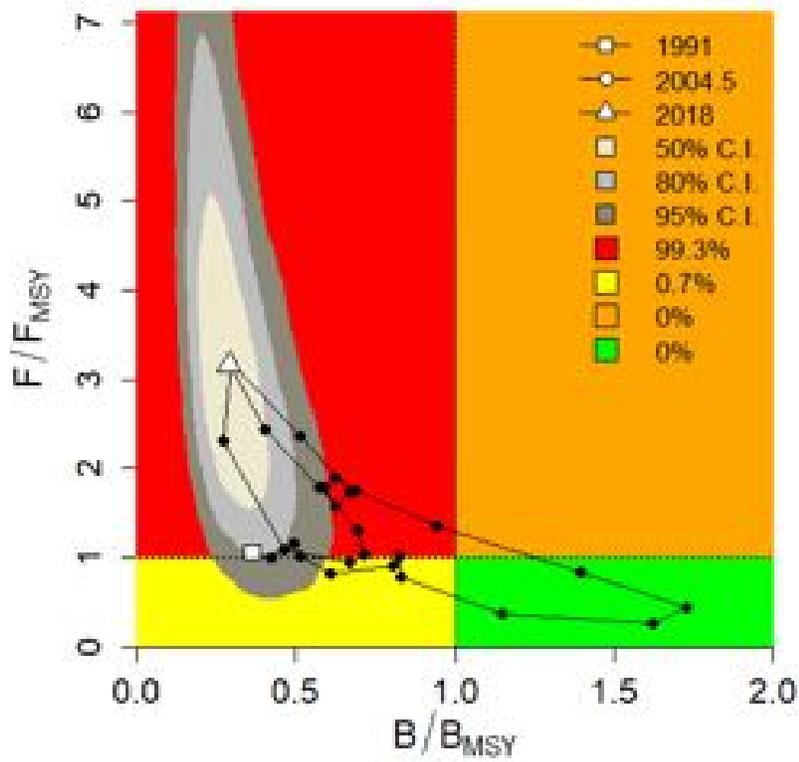
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AMSY Analysis, Fri Nov 01 19:37:40 2019  
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Stock **Ench\_cim22-24**, *Enchelyopus cimbrius*, Fourbeard rockling  
CPUE data for years 1991 - 2018, CPUE range 0.0406 - 0.262, smooth = TRUE  
Prior for  $r$  = Medium, NA - NA  
Used prior range for  $r$  = 0.2 - 0.8  
Prior for 1999 stock status = About half, 0.15 - 0.97  
Used 1999 prior B/B0 range = 0.15 - 0.97, prior B/Bmsy = 0.3 - 1.94  
Used prior range for  $kq$  = 0.229 - 0.496 [original range = 0.0767 - 0.496]  
Comment: B/B0 prior from LBB. RF: OK  
Source: SMFS 2017

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5000

Results:  
viable  $r$ - $kq$  pairs = 5000  
median  $kq$  = 0.307, 0.236 - 0.423  
median MSYq = 0.0446, 0.0282 - 0.0702  
 $r$  (4 MSYq/ $kq$ ) = 0.581, 0.343 - 0.943  
Fmsy ( $r/2$ ) = 0.291, 0.172 - 0.471  
F/Fmsy = 2.43, 1.01 - 4.38 (2017)  
B/Bmsy = 0.289, 0.161 - 0.518 (2018)





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 LBB results for *Eutrigla gurnardus*, stock **Eut\_gurn\_Balt**, 2004-2018  
 Files:LBB4AMSY\_ID\_4.csv, LBB\_June182019\_Eutrigla gurnardus.csv  
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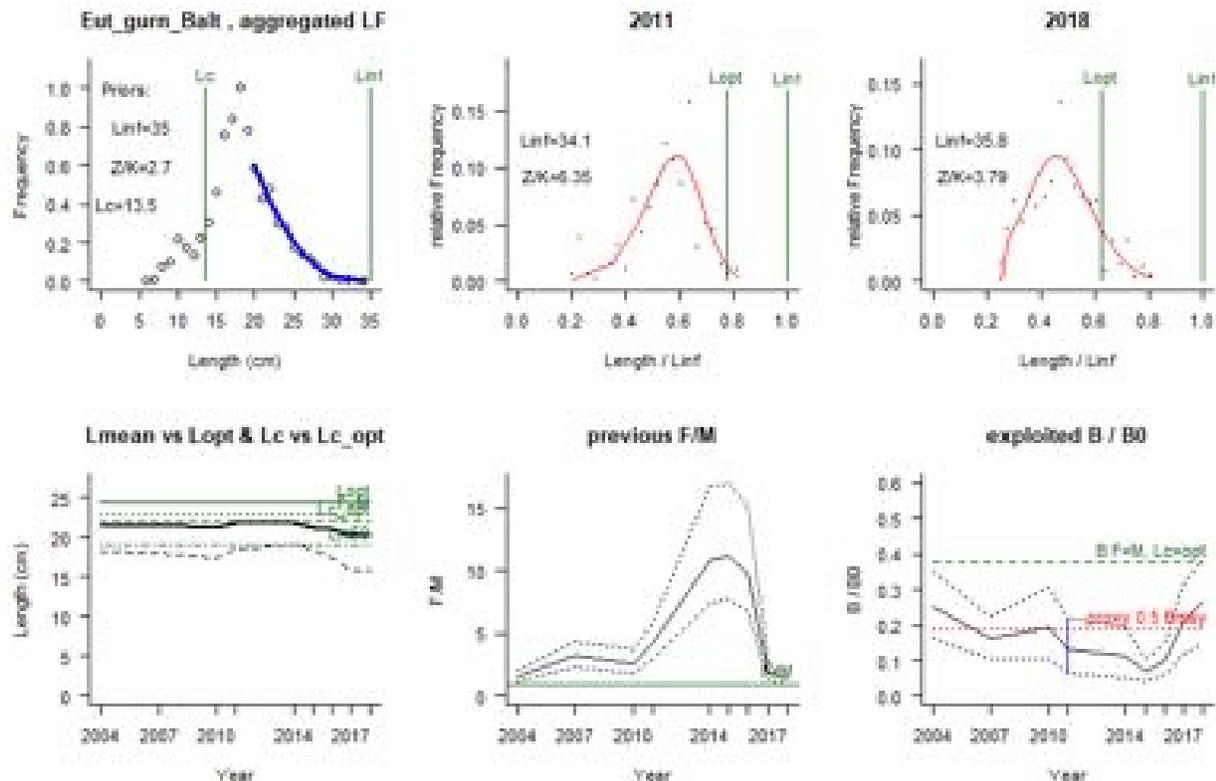
Linf prior= 35, SD=0.35 cm (user-defined), Lmax=39, median Lmax=29  
 Z/K prior = 2.7, SD=0.16, M/K prior=1.5, SD=0.15  
 F/K prior = 1.16 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 13.8, SD=1.4 cm, alpha prior=17.8, SD=1.8, Lm50=19 cm

General reference points (median across years):

Linf = 34.8 (34.1-35.3) cm  
 Lopt = 24 cm, Lopt/Linf=0.7  
 Lc\_opt = 22 cm, Lc\_opt/Linf=0.63, Lmean if F=M 22.9 cm  
 M/K = 1.26 (0.991-1.5)  
 F/M = 2.31 (1.65-3.21), F/K=2.74 (2.3-3.22), Z/K=3.93 (3.64-4.22)  
 B/B0 = 0.16 (0.095-0.23), B/B0 F=M Lc=Lc\_opt 0.38  
 Y/R' = 0.031 (0.02-0.046)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.058

Estimates for 2018 (mean of last 3 years with data):

Lc50 = 16 (15.6-16.3) cm, Lc/Linf=0.45 (0.44-0.46)  
 Lc95 = 22.5, alpha=0.454 (0.438-0.469)  
 Lmean/Lopt= 0.87, Lc/Lc\_opt=0.73, L95th=30.3 cm, L95th/Linf=0.85, Mature=28%  
 F/M = 1.4 (1-2), F/K=2.2 (1.8-2.6), Z/K=3.8 (3.5-4.1)  
 Y/R' = 0.034 (0.02-0.05)(reduced because B/B0 < 0.25)  
 B/B0 = 0.26 (0.15-0.38), best LF fit year 2004=0.25 (0.16-0.35)  
 B/Bmsy = 0.7 (0.39-1), **selected B/B0 2011 = 0.13 (0.062-0.22)**  
 RF: Set Linf between median and max. Excluded years with unrealistic LF fits.  
 Selected 2011 because of good fit and similar B/B0 as preceding years.

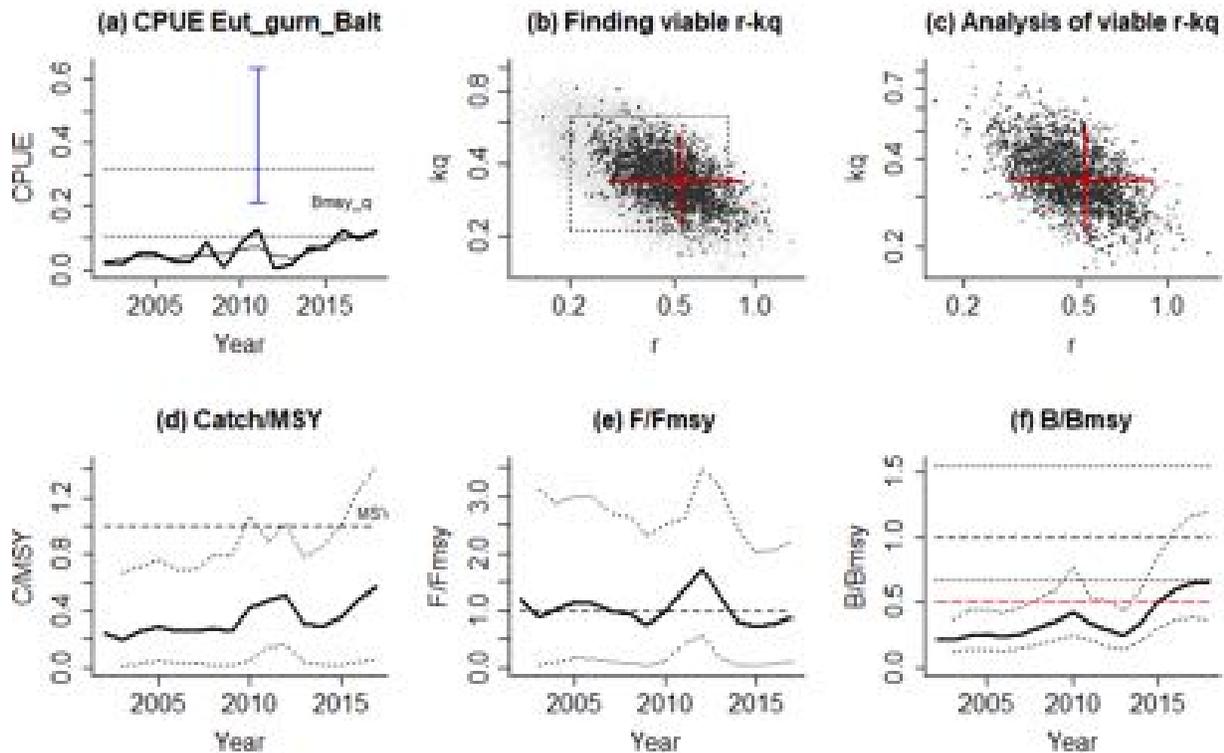


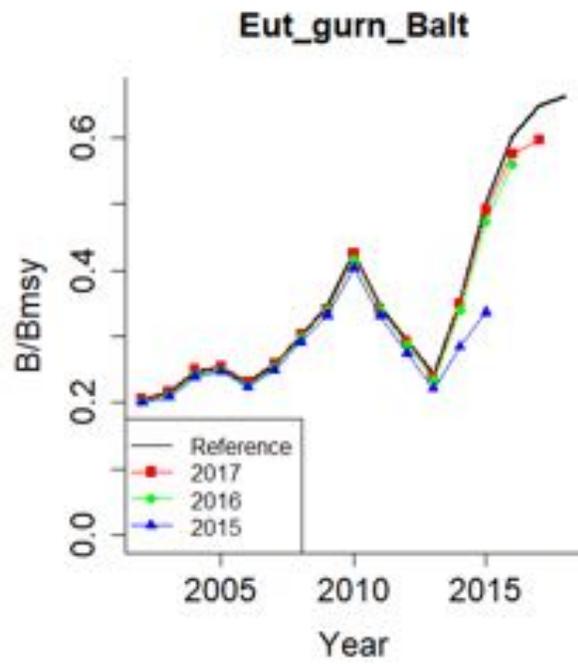
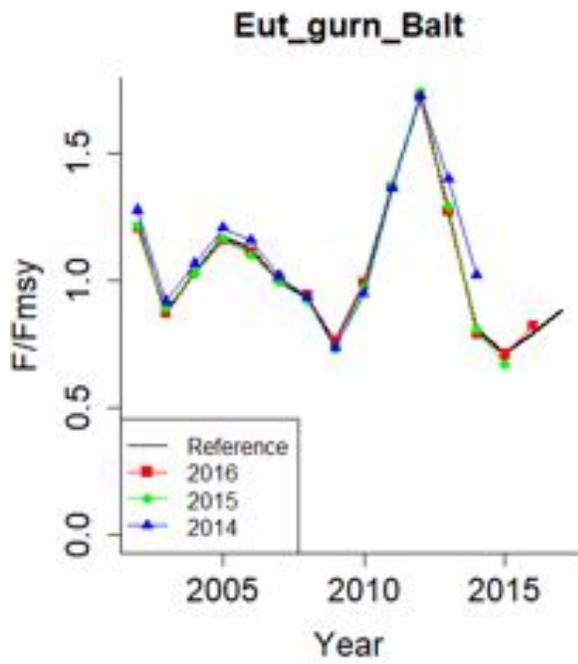
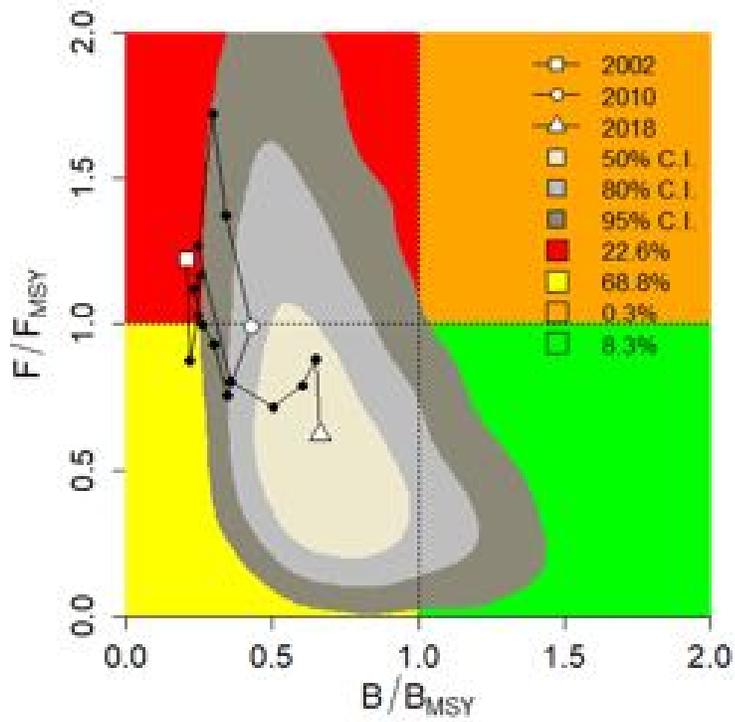
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AMSY Analysis, Fri Nov 01 19:41:14 2019  
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Stock **Eut\_gurn\_Balt**, *Eutrigla gurnardus*, Grey gurnard  
CPUE data for years 2002 - 2018, CPUE range 0.0262 - 0.113, smooth = TRUE  
Prior for  $r$  = Medium, NA - NA  
Used prior range for  $r$  = 0.2 - 0.8  
Prior for 2011 stock status = Very small, 0.06 - 0.22  
Used 2011 prior B/B0 range = 0.06 - 0.22, prior B/Bmsy = 0.12 - 0.44  
Used prior range for  $kq$  = 0.212 - 0.636 [original range = 0.212 - 0.777]  
Comment: B/B0 prior from LBB. RF: OK  
Source: DATRAS IBTS

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5001

Results:  
viable  $r$ - $kq$  pairs = 5001  
median  $kq$  = 0.338, 0.225 - 0.517  
median MSY $q$  = 0.0434, 0.0261 - 0.074  
 $r$  (4 MSY $q$ / $kq$ ) = 0.513, 0.29 - 0.89  
Fmsy ( $r/2$ ) = 0.256, 0.145 - 0.445  
F/Fmsy = 0.876, 0.0965 - 2.25 (2017)  
B/Bmsy = 0.669, 0.37 - 1.22 (2018)





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 LBB results for *Myoxocephalus scorpius*, stock **Myox\_scor\_22-24**, 2000-2017  
 Files:LBB4AMSY\_ID\_4.csv, LBB\_June102019\_Myoxocephalus scorpius.csv  
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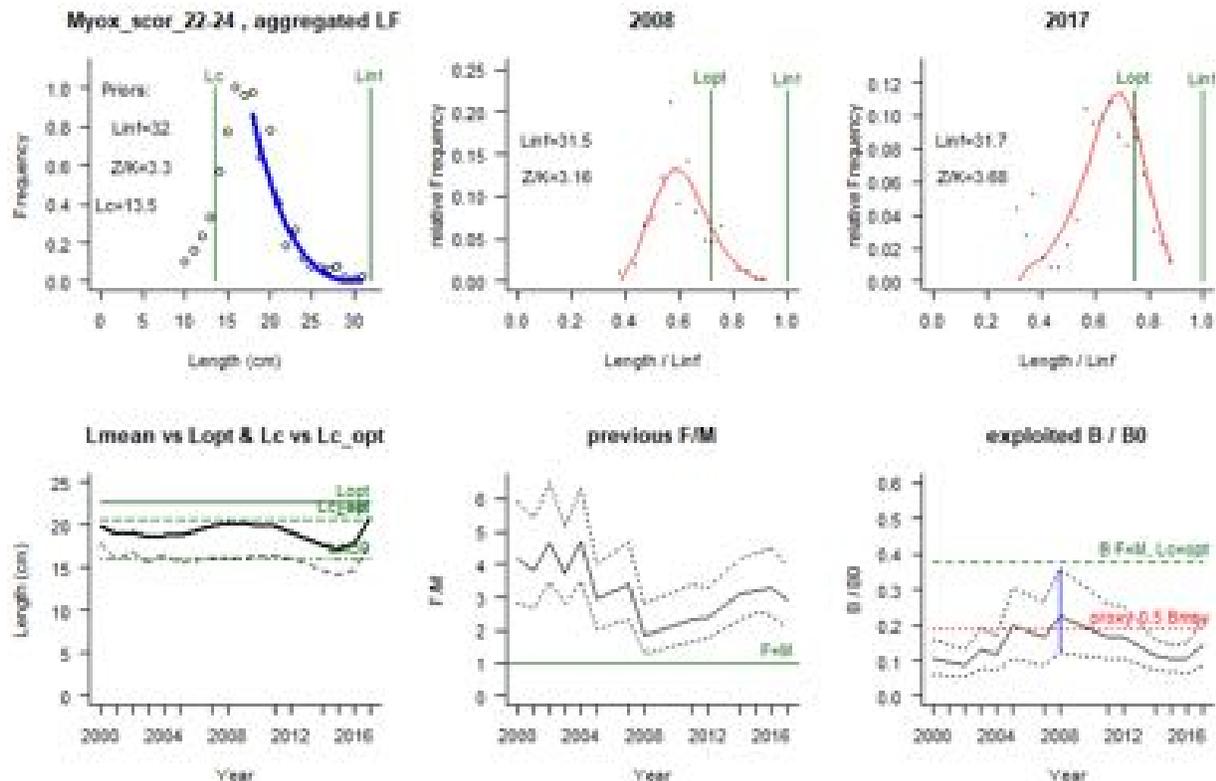
Linf prior= 32, SD=0.32 cm (user-defined), Lmax=33, median Lmax=29  
 Z/K prior = 3.3, SD=0.32, M/K prior=1.5, SD=0.15  
 F/K prior = 1.76 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 13.8, SD=1.4 cm, alpha prior=11.5, SD=1.2, Lm50=16 cm

General reference points (median across years):

Linf = 32 (31.5-32.6) cm  
 Lopt = 23 cm, Lopt/Linf=0.71  
 Lc\_opt = 21 cm, Lc\_opt/Linf=0.65, Lmean if F=M 20.6 cm  
 M/K = 1.24 (1.01-1.55)  
 F/M = 2.85 (2.13-3.94), F/K=3.73 (3.21-4.26), Z/K=4.92 (4.46-5.34)  
 B/B0 = 0.13 (0.079-0.18), B/B0 F=M Lc=Lc\_opt 0.38  
 Y/R' = 0.035 (0.02-0.052)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.06

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 17.9 (17.6-18.2) cm, Lc/Linf=0.56 (0.55-0.57)  
 Lc95 = 22.5, alpha=0.632 (0.613-0.655)  
 Lmean/Lopt= 0.91, Lc/Lc\_opt=0.86, L95th=29 cm, L95th/Linf=0.91, Mature=83%  
 F/M = 2.9 (2.1-4), F/K=3.4 (2.9-4), Z/K=4.6 (4.2-5.1)  
 Y/R' = 0.044 (0.025-0.066)(reduced because B/B0 < 0.25)  
 B/B0 = 0.15 (0.087-0.22), best LF fit year 2002=0.0873 (0.055-0.13)  
 B/Bmsy = 0.39 (0.23-0.58), **selected B/B0 2008 = 0.22 (0.12-0.36)**  
 RF: Set Linf between median and max. Excluded years with unrealistic fit.  
 Selected 2008 because of reasonable LF and B/B0.

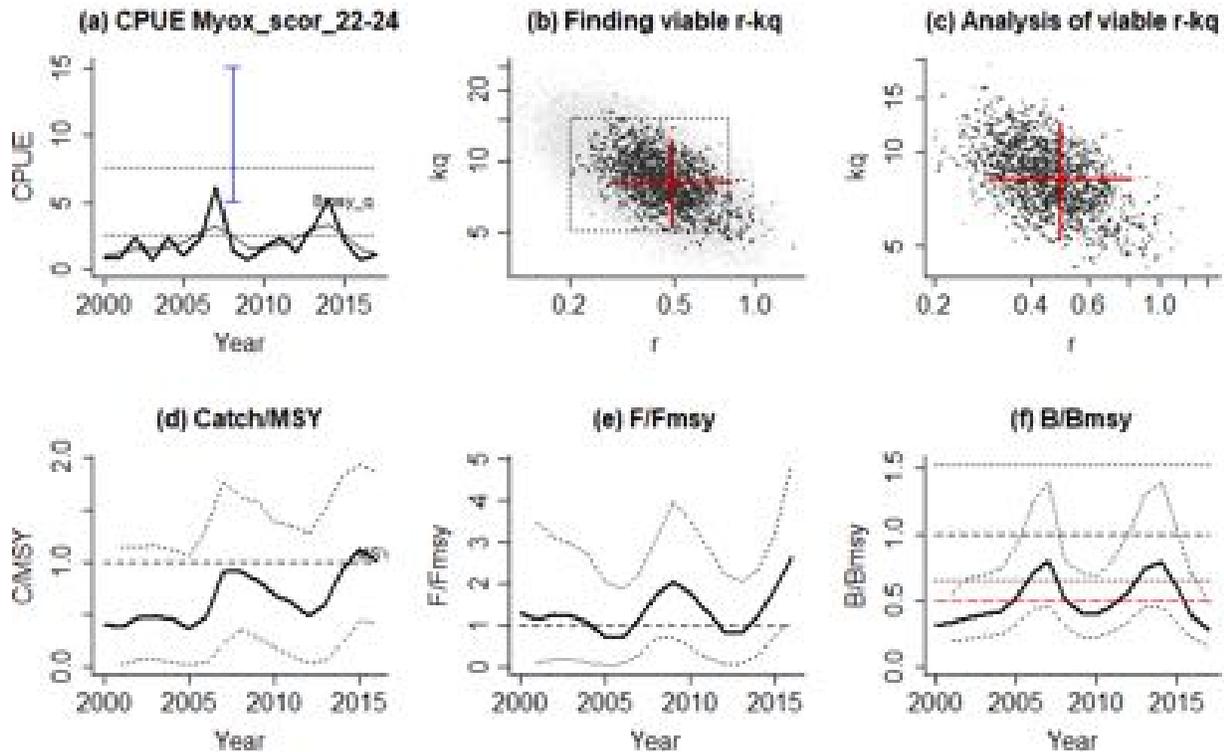


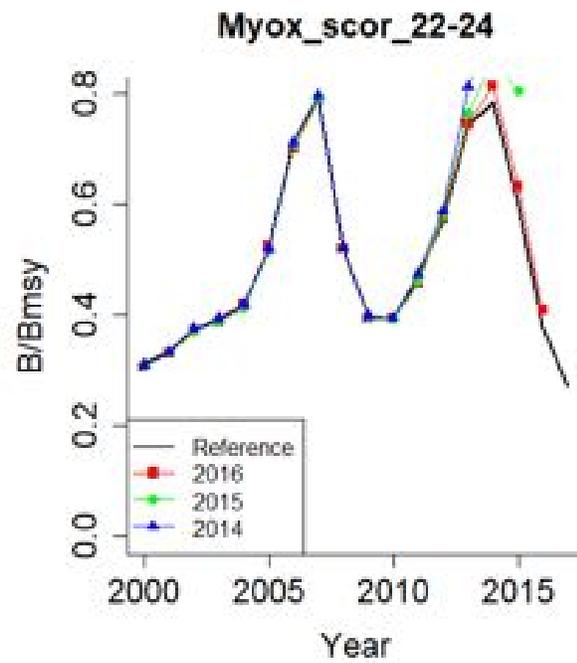
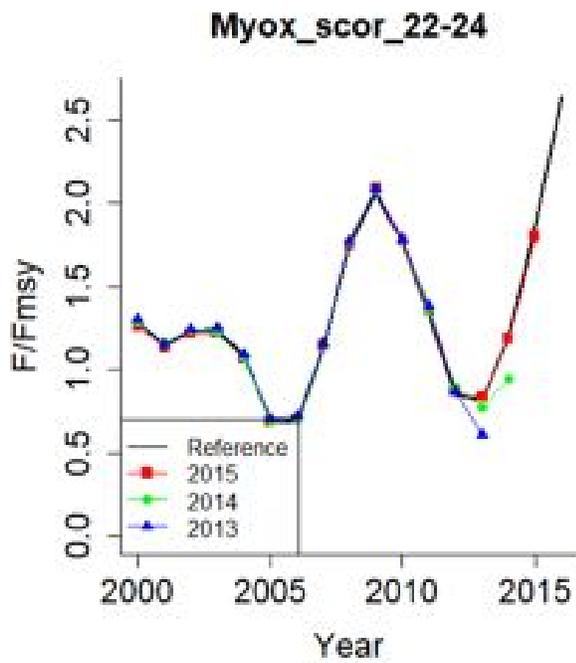
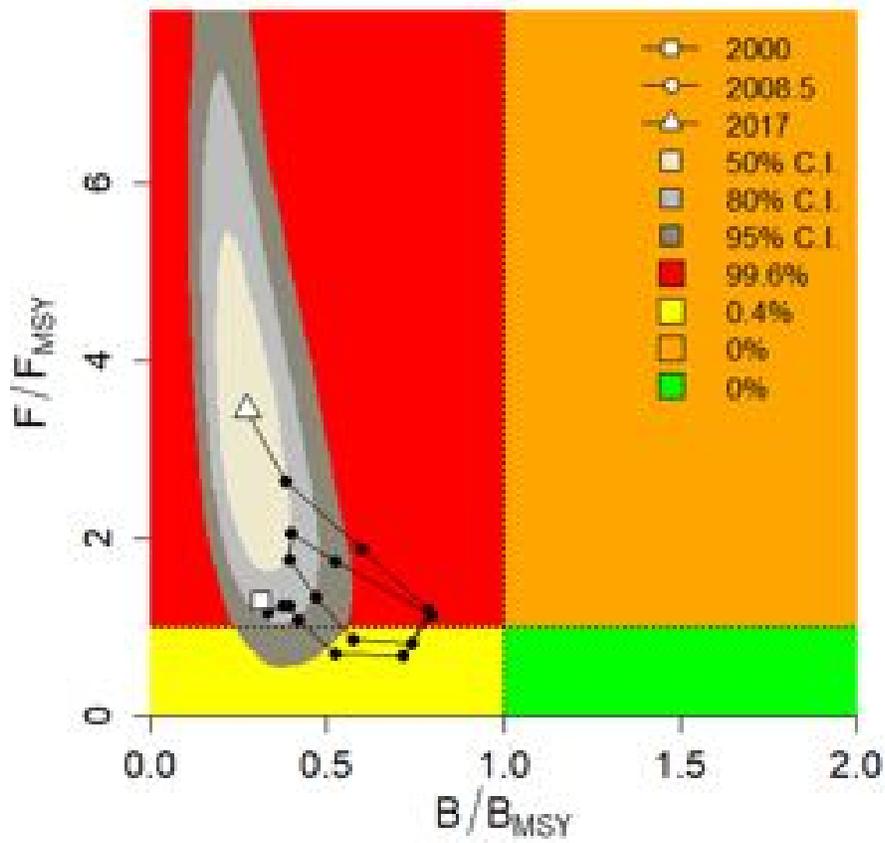
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AMSY Analysis, Fri Nov 01 19:45:13 2019  
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Stock **Myox\_scor\_22-24**, *Myoxocephalus scorpius*, Shorthorn sculpin  
CPUE data for years 2000 - 2017, CPUE range 0.974 - 3.28, smooth = TRUE  
Prior for r = Medium, NA - NA  
Used prior range for r = 0.2 - 0.8  
Prior for 2008 stock status = Small, 0.12 - 0.36  
Used 2008 prior B/B0 range = 0.12 - 0.36, prior B/Bmsy = 0.24 - 0.72  
Used prior range for kq = 5.06 - 15.2 [original range = 5.06 - 15.2]  
Comment: B/B0 prior from LBB. RF: OK  
Source: SMFS 2017

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
Viable r-kq pairs = 5000

Results:  
viable r-kq pairs = 5000  
median kq = 8.12, 5.22 - 12.4  
median MSYq = 1.01, 0.606 - 1.57  
r (4 MSYq/kq) = 0.496, 0.298 - 0.824  
Fmsy (r/2) = 0.248, 0.149 - 0.412  
F/Fmsy = 2.64, 1.1 - 4.87 (2016)  
B/Bmsy = 0.272, 0.151 - 0.482 (2017)





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 LBB results for *Zoarces viviparus*, stock Zoar\_vivi\_Balt, 2000-2017  
 Files:LBB4AMSY\_ID\_4.csv, LBB\_June182019\_Zoar\_vivi\_Balt.csv  
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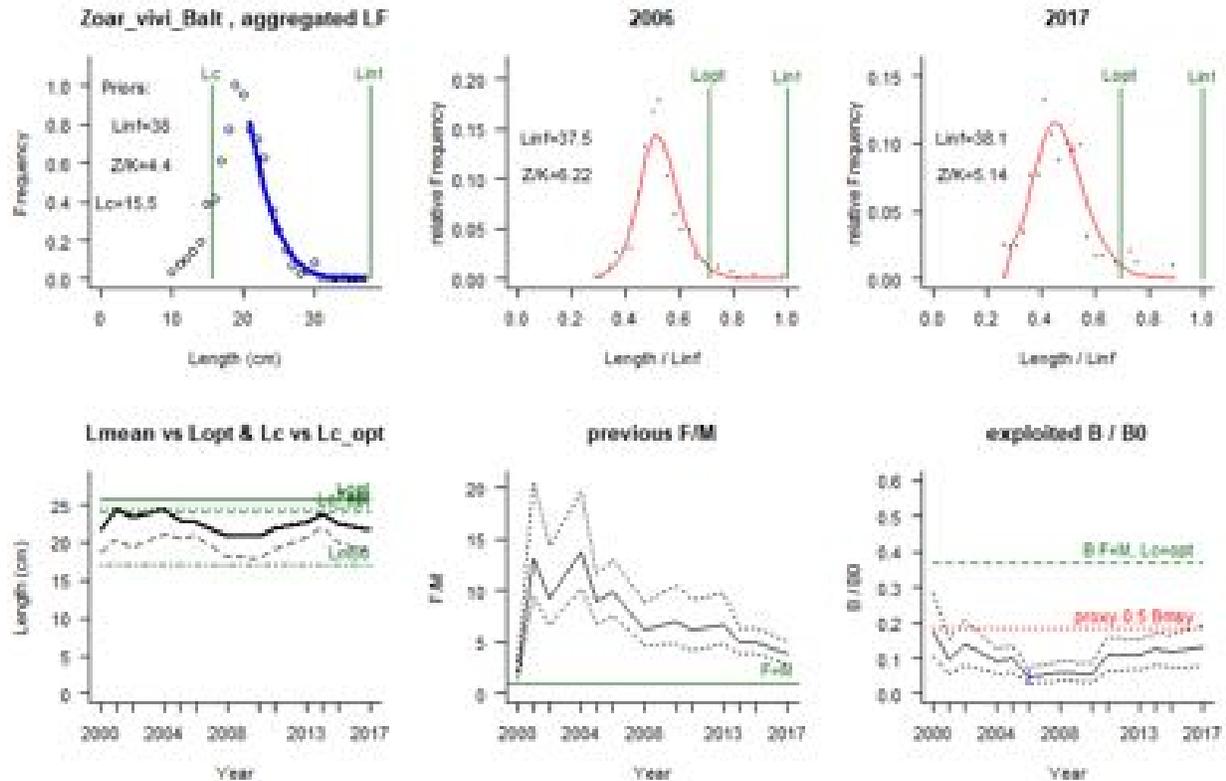
Linf prior= 38, SD=0.38 cm (user-defined), Lmax=38, median Lmax=34  
 Z/K prior = 4.4, SD=0.29, M/K prior=1.5, SD=0.15  
 F/K prior = 2.88 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 15.8, SD=1.6 cm, alpha prior=17.7, SD=1.8, Lm50=17 cm

General reference points (median across years):

Linf = 37.8 (37.2-38.5) cm  
 Lopt = 25 cm, Lopt/Linf=0.67  
 Lc\_opt = 24 cm, Lc\_opt/Linf=0.63, Lmean if F=M 24.5 cm  
 M/K = 1.46 (1.18-1.7)  
 F/M = 4.34 (3.4-5.58), F/K=5.44 (5.01-6.81), Z/K=7.48 (6.48-9.02)  
 B/B0 = 0.07 (0.044-0.099), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.012 (0.0085-0.016)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.047

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 18.8 (18.2-19.2) cm, Lc/Linf=0.49 (0.48-0.5)  
 Lc95 = 24.2, alpha=0.547 (0.527-0.563)  
 Lmean/Lopt= 0.87, Lc/Lc\_opt=0.79, L95th=33 cm, L95th/Linf=0.87, Mature=50%  
 F/M = 4 (2.9-5.3), F/K=6.9 (5.2-8.5), Z/K=8.4 (6.8-10)  
 Y/R' = 0.024 (0.015-0.037)(reduced because B/B0 < 0.25)  
 B/B0 = 0.13 (0.082-0.2), best LF fit year 2004=0.0943 (0.061-0.13)  
 B/Bmsy = 0.36 (0.22-0.54), **selected B/B0 2002 = 0.15 (0.095-0.21)**  
 RF: Set Linf between median and max. Set Lcut=10 to exclude peaks of early juveniles. Excluded years with unrealistic fits. Selected 2002 because of reasonable B/B0.

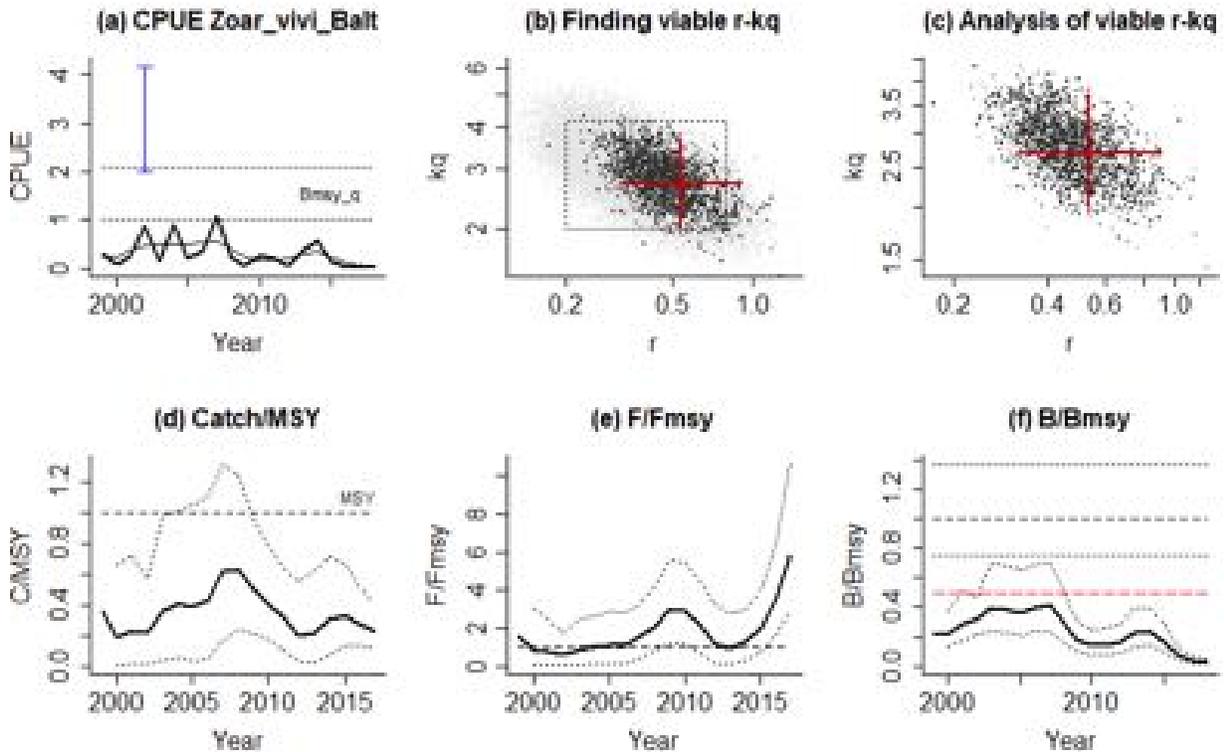


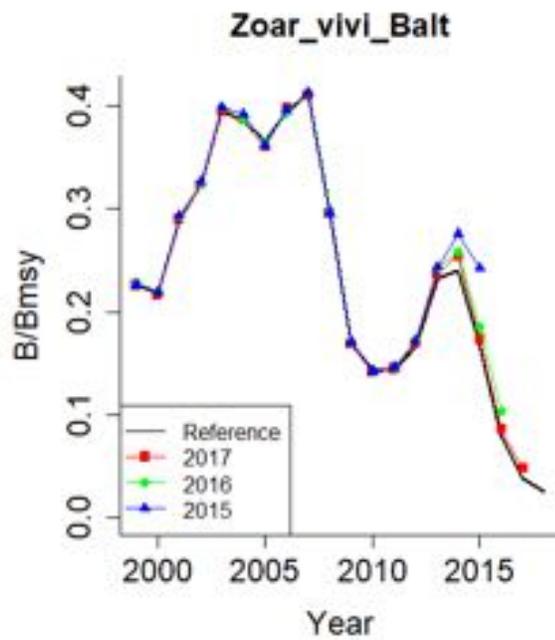
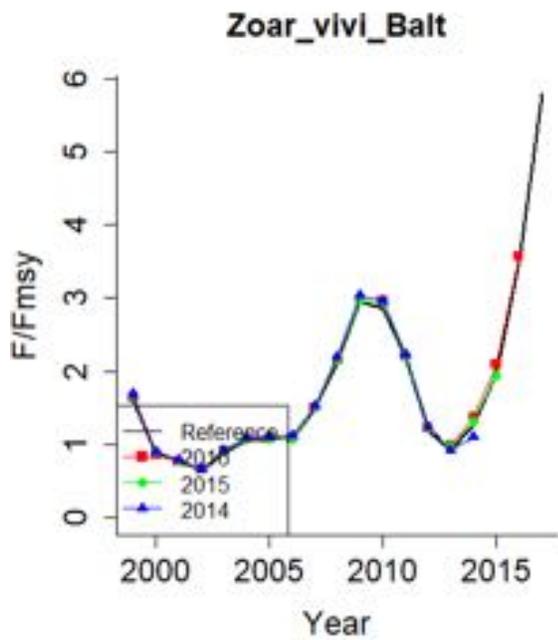
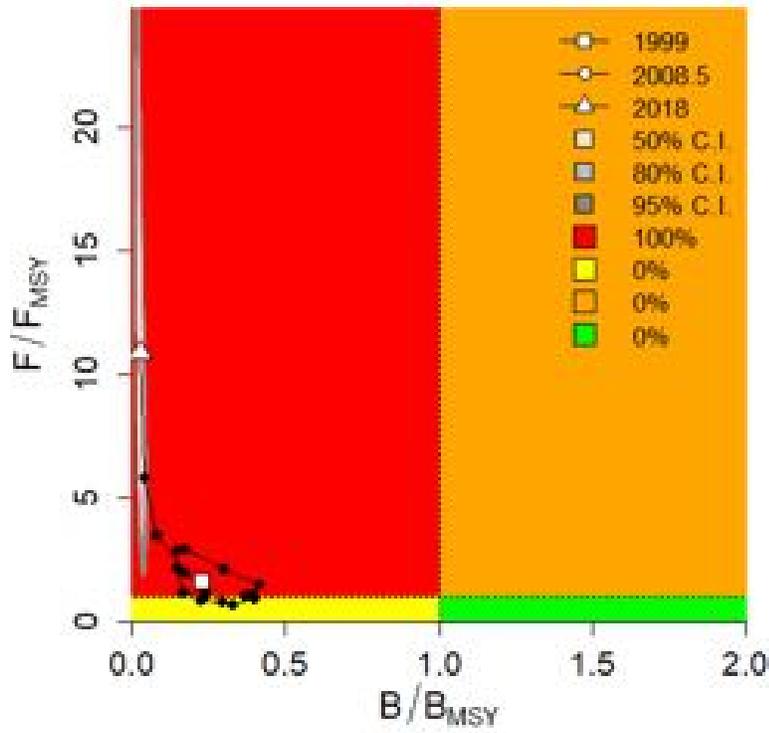
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AMSY Analysis, Fri Nov 01 19:48:23 2019  
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Stock **Zoar\_vivi\_Balt**, *Zoarces viviparus*, Eelpout  
CPUE data for years 1999 - 2018, CPUE range 0.0339 - 0.568, smooth = TRUE  
Prior for  $r$  = Medium, NA - NA  
Used prior range for  $r$  = 0.2 - 0.8  
Prior for 2002 stock status = Very small, 0.1 - 0.21  
Used 2002 prior B/B0 range = 0.1 - 0.21, prior B/Bmsy = 0.2 - 0.42  
Used prior range for  $kq$  = 1.99 - 4.18 [original range = 1.99 - 4.18]  
Comment: B/B0 prior from LBB. RF: OK  
Source: DATRAS IBTS

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5002

Results:  
viable  $r$ - $kq$  pairs = 5002  
median  $kq$  = 2.7, 2.02 - 3.7  
median MSYq = 0.361, 0.23 - 0.586  
 $r$  (4 MSYq/ $kq$ ) = 0.535, 0.32 - 0.901  
 $F_{msy}$  ( $r/2$ ) = 0.267, 0.16 - 0.45  
 $F/F_{msy}$  = 5.8, 2.89 - 10.6 (2017)  
 $B/B_{msy}$  = 0.0252, 0.014 - 0.0453 (2018)





## Northwest Atlantic

LBB results for *Leucoraja erinacea*, Little skate Eastern Canada, 2007-2018

Linf prior= 65, SD=0.65 cm (user-defined), Lmax=76, median Lmax=62.5

Z/K prior = 5.1, SD=0.37, M/K prior=1.5, SD=0.15

F/K prior = 3.64 (wide range with tau=4 in log-normal distribution)

Lc prior = 44.4, SD=4.4 cm, alpha prior=23.2, SD=2.3, Lm50=47.4 cm

General reference points (median across years):

Linf = 65.3 (64.2-66.4) cm

Lopt = 43 cm, Lopt/Linf=0.66

Lc\_opt = 40 cm, Lc\_opt/Linf=0.61, Lmean if F=M 51.2 cm

M/K = 1.54 (1.25-1.83)

F/M = 3.16 (2.49-4.21), F/K=5 (4.21-5.85), Z/K=6.44 (5.68-7.29)

B/B0 = 0.18 (0.12-0.25), B/B0 F=M Lc=Lc\_opt 0.39

Y/R' = 0.034 (0.022-0.047)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.042

Estimates for 2018 (mean of last 3 years with data):

Lc50 = 45.9 (45.5-46.4) cm, Lc/Linf=0.71 (0.7-0.72)

Lc95 = 53, alpha=0.417 (0.399-0.432)

Lmean/Lopt= 1.1, Lc/Lc\_opt=1.2, L95th=57.3 cm, L95th/Linf=0.88, Mature=30%

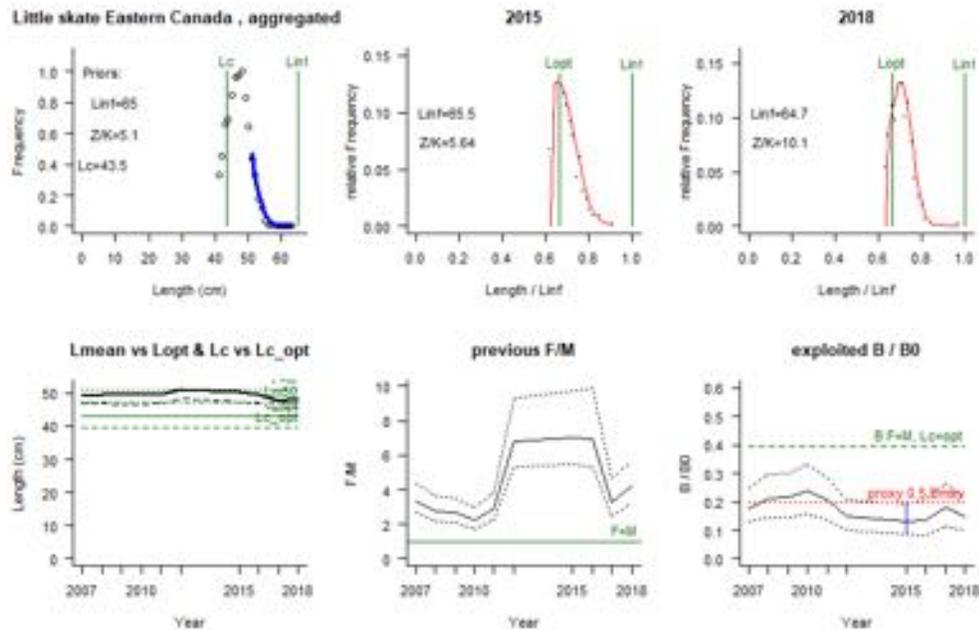
F/M = 4.3 (3.2-5.7), F/K=6.2 (5.3-7.3), Z/K=7.6 (6.8-8.7)

Y/R' = 0.032 (0.021-0.047)(reduced because B/B0 < 0.25)

B/B0 = 0.15 (0.098-0.22), best LF fit year 2011=0.205 (0.14-0.28)

B/Bmsy = 0.38 (0.25-0.55), **selected B/B0 2015 = 0.13 (0.085-0.2)**

LF data from scientific research surveys provided by Fisheries and Oceans Canada (DFO); Lm50 average of male and female taken from McPhie, R.P. and Campana, S.E., 2009. Reproductive characteristics and population decline of four species of skate (Rajidae) off the eastern coast of Canada. Journal of Fish Biology, 75(1), pp.223-246.; specimens under 40 cm not considered because of confusion with winter skate. RF: set Linf to 65 cm slightly above median. Excluded years with unreasonable fits. Selected 2015 because of good fit and reasonable B/B0 compared with adjacent estimates.

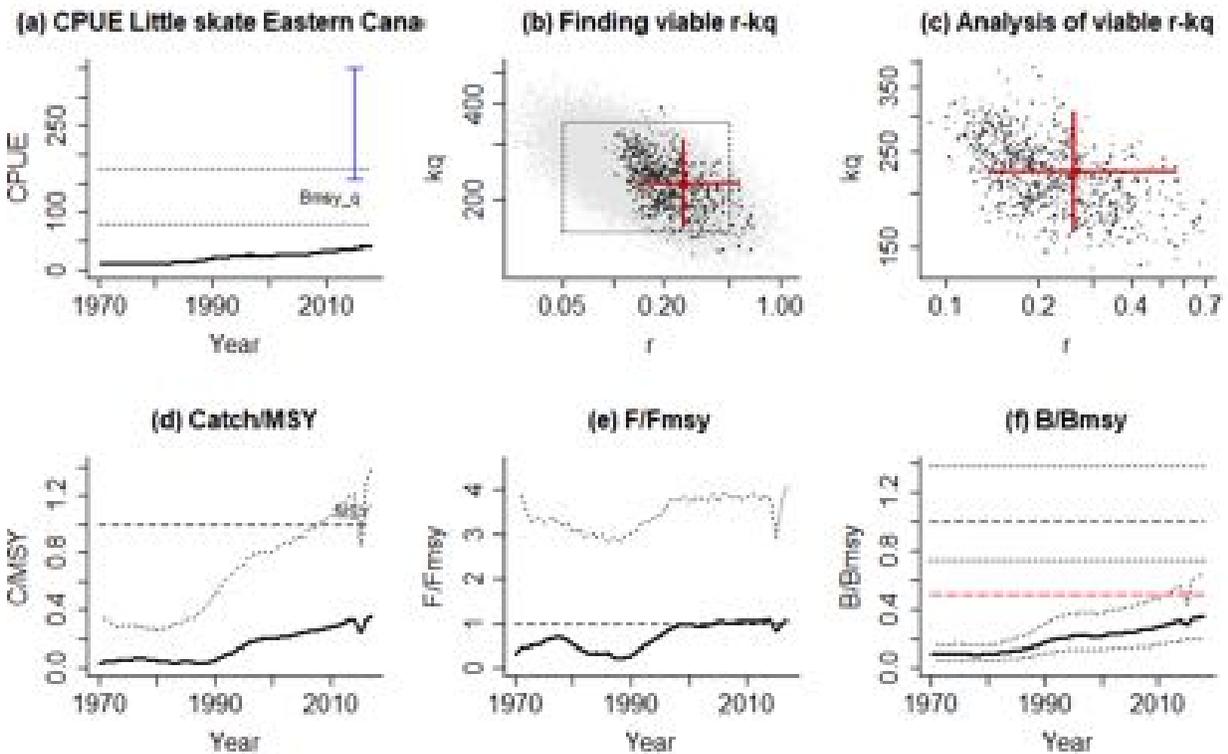


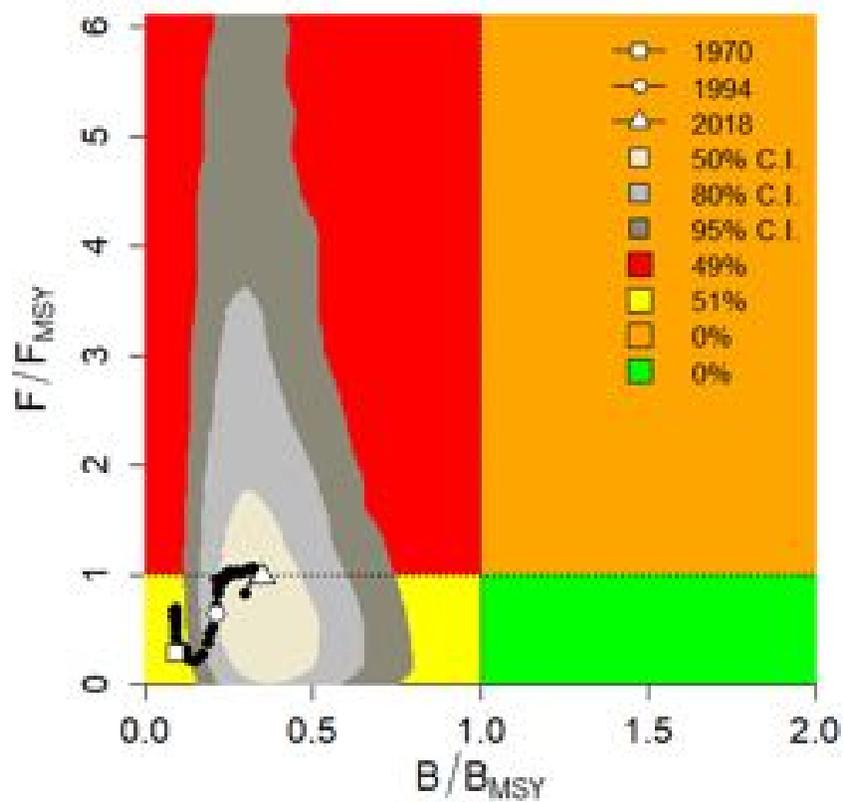
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AMSY Analysis, Fri Nov 01 19:53:16 2019  
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Stock **Little skate Eastern Canada, *Leucoraja erinacea***, Little skate  
CPUE data for years 1970 - 2018, CPUE range 9.57 - 38.7, smooth = TRUE  
Prior for  $r$  = Low, NA - NA  
Used prior range for  $r$  = 0.05 - 0.5  
Prior for 2015 stock status = Very small, 0.09 - 0.2  
Used 2015 prior B/B0 range = 0.09 - 0.2, prior B/Bmsy = 0.18 - 0.4  
Used prior range for  $kq$  = 158 - 351 [original range = 158 - 351]  
Comment: CPUE from research surveys provided by Fisheries and Oceans Canada (DFO); Bk priors from LBB; Correspondence with Dave Kulka suggests 0.5 to 0.85 in 2018

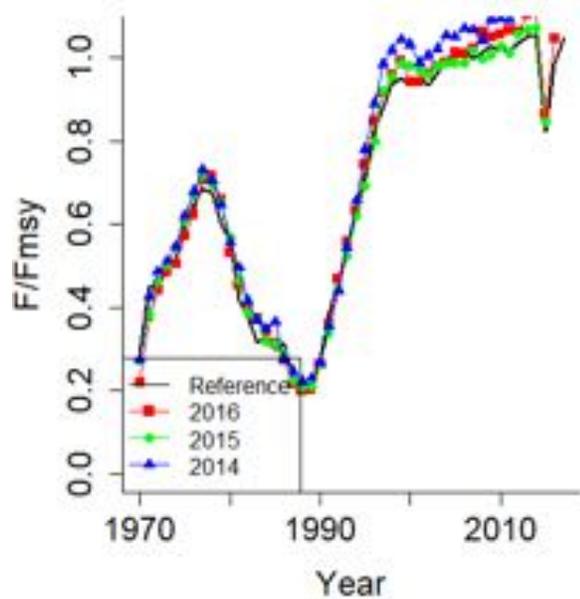
Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5008

Results:  
viable  $r$ - $kq$  pairs = 5008  
median  $kq$  = 223, 164 - 308  
median MSYq = 14.6, 8.27 - 28  
 $r$  (4 MSYq/ $kq$ ) = 0.262, 0.139 - 0.565  
Fmsy ( $r/2$ ) = 0.131, 0.0696 - 0.282  
F/Fmsy = 1.05, -0.619 - 4.05 (2017)  
B/Bmsy = 0.348, 0.191 - 0.622 (2018)  
)

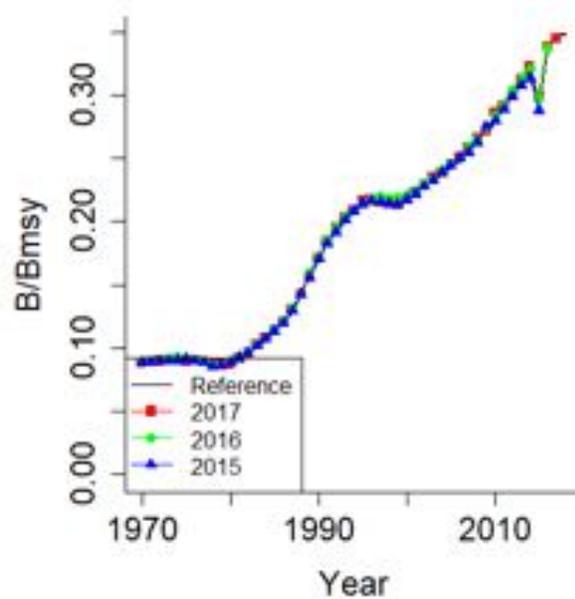




Little skate Eastern Canada



Little skate Eastern Canada



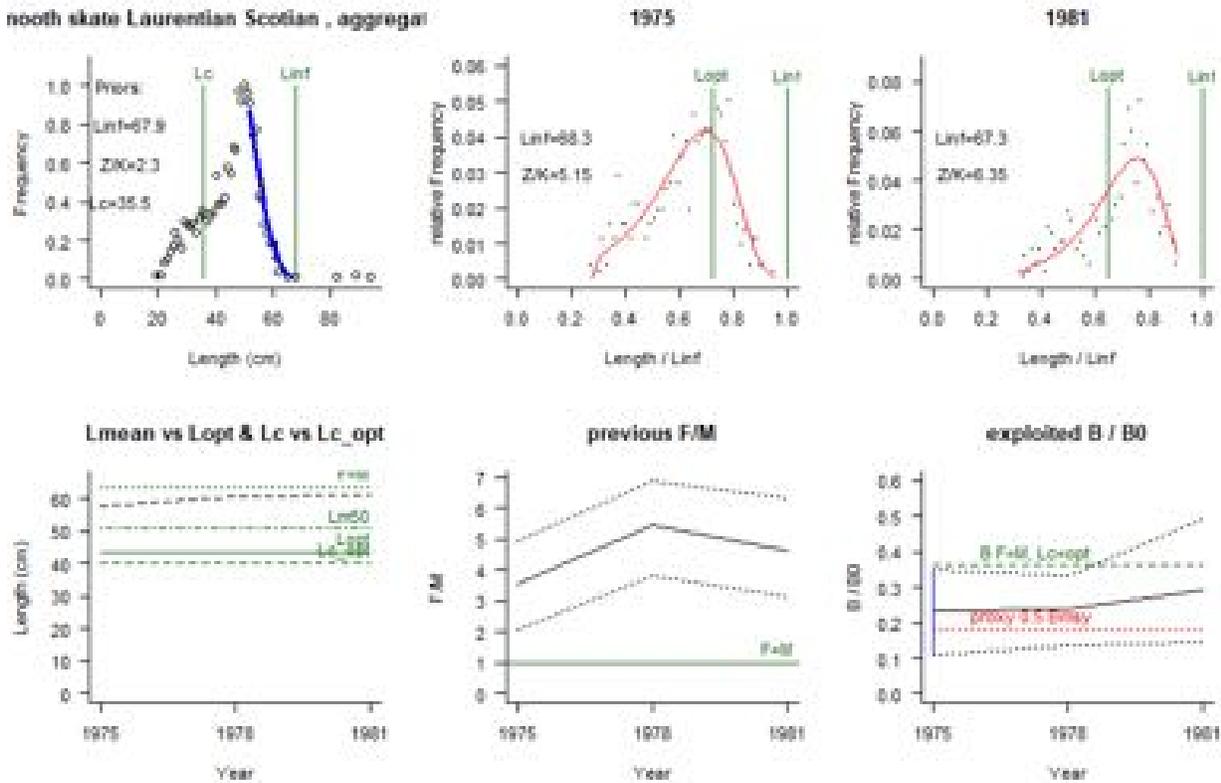
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 LBB results for *Malacoraja senta*, Smooth skate Laurentian Scotian, 1975-1981  
 Files:Little\_smooth\_skate\_LBB\_ID.csv, LBB\_smooth\_skate.csv  
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Linf prior= 67.9, SD=0.68 cm Lmax=94, median Lmax=68  
 Z/K prior = 2.3, SD=1.6, M/K prior=1.5, SD=0.15  
 F/K prior = 0.761 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 36.2, SD=3.6 cm, alpha prior=11.3, SD=1.1, Lm50=50.8 cm

General reference points (median across years):  
 Linf = 67.3 (66-68.7) cm  
 Lopt = 44 cm, Lopt/Linf=0.65  
 Lc\_opt = 40 cm, Lc\_opt/Linf=0.6, Lmean if F=M 63.8 cm  
 M/K = 1.62 (1.42-1.79)  
 F/M = 3.54 (2.07-5.18), F/K=4.73 (2.82-7.88), Z/K=6.27 (4.42-9.37)  
 B/B0 = 0.24 (0.16-0.35), B/B0 F=M Lc=Lc\_opt 0.36  
 Y/R' = 0.03 (0.02-0.057)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.038

Estimates for 1981 (mean of last 3 years with data):  
 Lc50 = 61.4 (59.7-63.4) cm, Lc/Linf=0.91 (0.88-0.94)  
 Lc95 = 80.9, alpha=0.151 (0.146-0.157)  
 Lmean/Lopt= NA, Lc/Lc\_opt=1.5, L95th=62.7 cm, L95th/Linf=0.93, Mature=36%  
 F/M = 4.6 (3.1-6.3), F/K=7.1 (5.2-9.4), Z/K=8.6 (6.8-11)  
 Y/R' = 0.042 (0.021-0.066)(reduced because B/B0 < 0.25)  
 B/B0 = 0.29 (0.15-0.49), best LF fit year 1975=0.233 (0.11-0.35)  
 B/Bmsy = 0.8 (0.4-1.4), **selected B/B0 1975 = 0.23 (0.11-0.35)**  
 LF data (average over 3 years) from scientific research surveys provided by Fisheries and Oceans Canada (DFO); Lm50 average of male and female and different studies taken from COSEWIC assessment and status report on the Smooth skate *Malacoraja senta*, 2012. RF: selected 2015 because of best LF fit.

Smooth skate Laurentian Scotian , aggregated



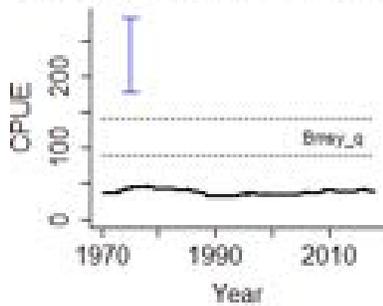
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AMSY Analysis, Fri Nov 01 19:57:42 2019  
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Stock **Smooth skate Laurentian Scotian, *Malacoraja senta***, Smooth skate  
CPUE data for years 1970 - 2018, CPUE range 32.1 - 44.6, smooth = TRUE  
Prior for  $r$  = Low, NA - NA  
Used prior range for  $r$  = 0.05 - 0.5  
Prior for 1975 stock status = Small, 0.11 - 0.35  
Used 1975 prior  $B/B_0$  range = 0.11 - 0.35, prior  $B/B_{msy}$  = 0.22 - 0.7  
Used prior range for  $kq$  = 178 - 282 [original range = 88.8 - 282]  
Comment: CPUE from research surveys provided by Fisheries and Oceans Canada (DFO); Bk priors from LBB; Correspondence with Dave Kulka suggests 0.25 to 0.85 in 2018

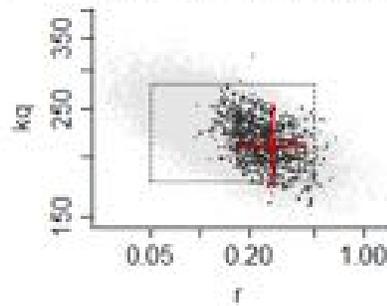
Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5000

Results:  
viable  $r$ - $kq$  pairs = 5000  
median  $kq$  = 211, 174 - 255  
median  $MSYq$  = 14.6, 8.69 - 23.5  
 $r$  (4  $MSYq/kq$ ) = 0.276, 0.162 - 0.451  
 $F_{msy}$  ( $r/2$ ) = 0.138, 0.0809 - 0.225  
 $F/F_{msy}$  = 1.51, -0.323 - 4.2 (2017)  
 $B/B_{msy}$  = 0.374, 0.209 - 0.676 (2018)

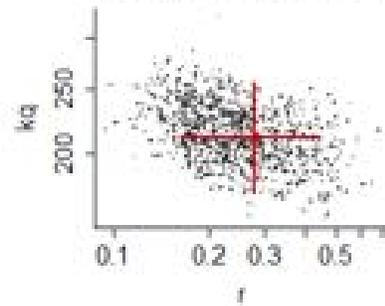
(a) CPUE Smooth skate Laurentian Sc



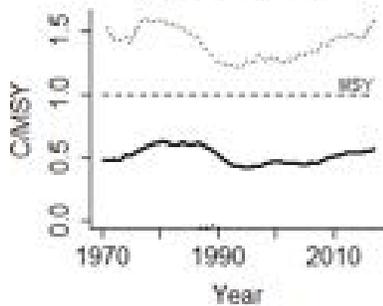
(b) Finding viable r-kq



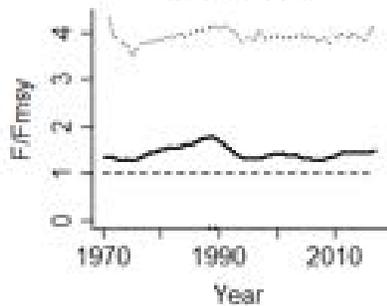
(c) Analysis of viable r-kq



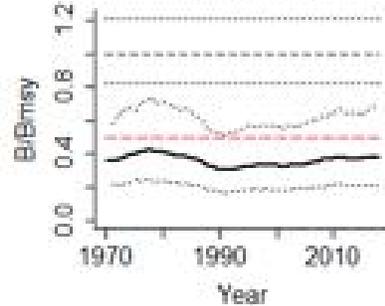
(d) Catch/MSY

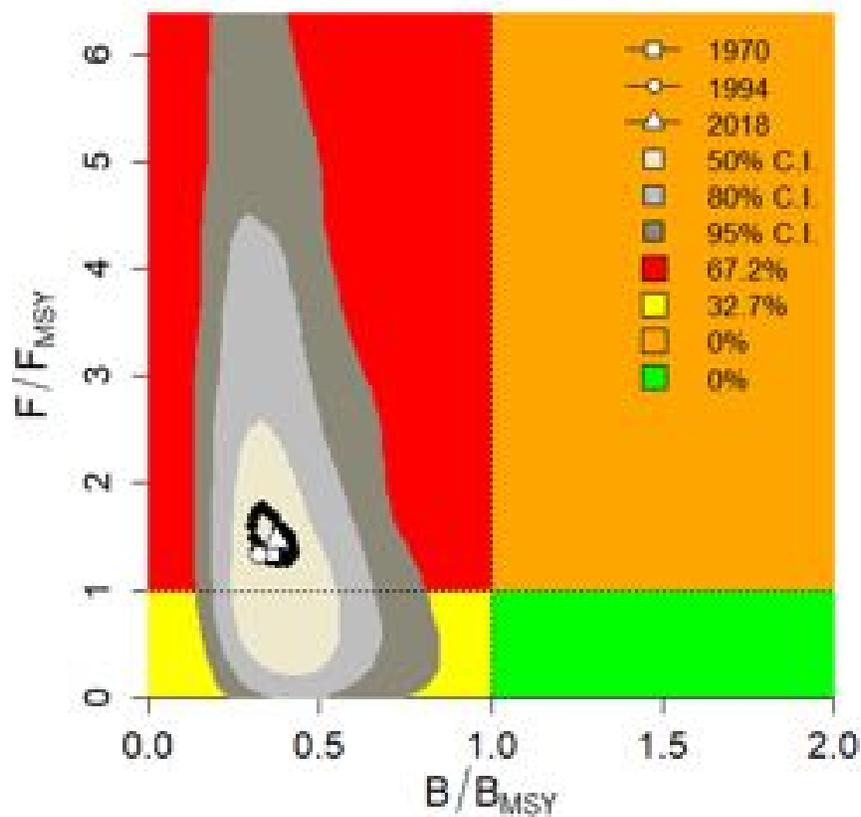


(e) F/Fmsy

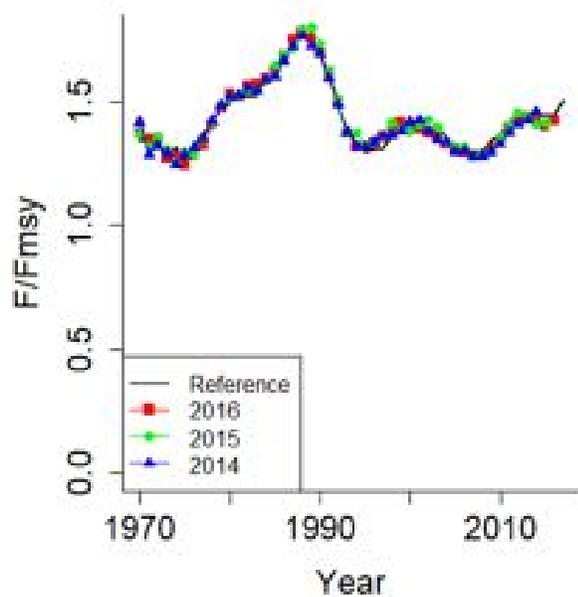


(f) B/Bmsy

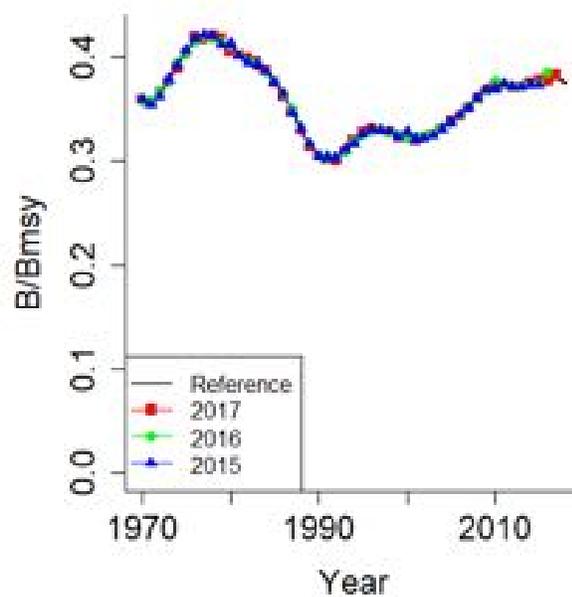




Smooth skate Laurentian Scotian



Smooth skate Laurentian Scotian



## South Africa

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 LBB results for *Helicolenus dactylopterus*, stock HELDAC, 1993-2017  
 Files: LBB4AMSY\_ID\_ZAdem\_AMSY.csv, LBBdatZAdem\_AMSY.csv  
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Linf prior = 50, SD = 0.5 cm Lmax = 84, median Lmax = 50  
 Z/K prior = 5.3, SD = 2.5, M/K prior = 1.5, SD = 0.075 (user-defined)  
 F/K prior = 3.78 (wide range with tau = 4 in log-normal distribution)  
 Lc prior = 11.2, SD = 1.1 cm, alpha prior = 12.8, SD = 1.3, Lm50 = 32 cm

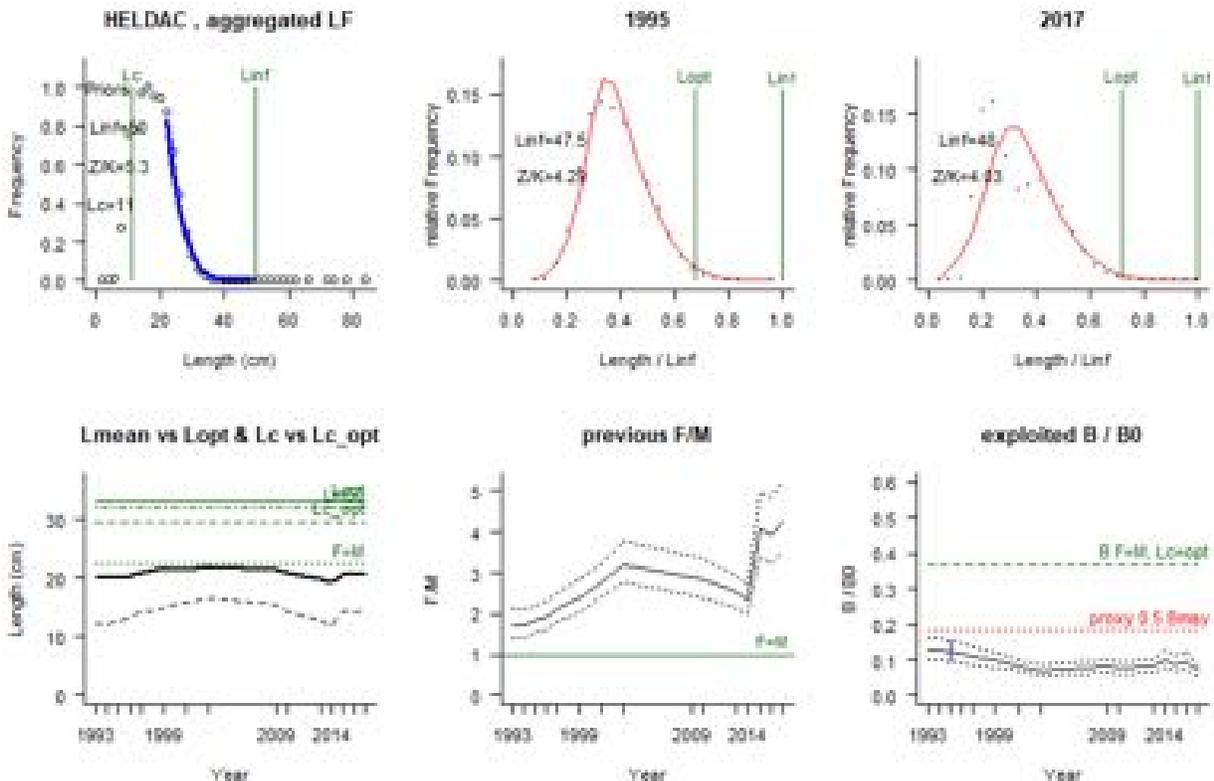
General reference points (median across years):

Linf = 48.4 (48-49.1) cm  
 Lopt = 33 cm, Lopt/Linf = 0.68  
 Lc\_opt = 30 cm, Lc\_opt/Linf = 0.61, Lmean if F=M 22.3 cm  
 M/K = 1.41 (1.27-1.55)  
 F/M = 2.27 (1.97-2.68), F/K = 2.99 (2.72-3.24), Z/K = 4.38 (4.2-4.6)  
 B/B0 = 0.097 (0.076-0.12), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.013 (0.01-0.017) (reduced: B/B0 < 0.25), Y/R' F=M Lc=Lc\_opt 0.05

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 14.4 (14.1-14.7) cm, Lc/Linf = 0.3 (0.3-0.31)  
 Lc95 = 22.3, alpha = 0.371 (0.362-0.381)  
 Lmean/Lopt = 0.59, Lc/Lc\_opt = 0.49, L95th = 47.3 cm, L95th/Linf = 0.99, Mature = 0.7%  
 F/M = 4.3 (3.5-5.2), F/K = 4.2 (3.9-4.6), Z/K = 5.4 (5.1-5.6)  
 Y/R' = 0.01 (0.0081-0.013) (reduced because B/B0 < 0.25)  
 B/B0 = 0.067 (0.053-0.084), best LF fit year 1997 = 0.111 (0.087-0.14)  
 B/Bmsy = 0.18 (0.14-0.23), **selected B/B0 1995 = 0.12 (0.095-0.15)**

Trawl survey data; RF set MK.user = 1.5 to avoid negative M/K; excluded years with unreasonable LFs; selected 1995 because of good fit and reasonable B/B0 compared with adjacent years.

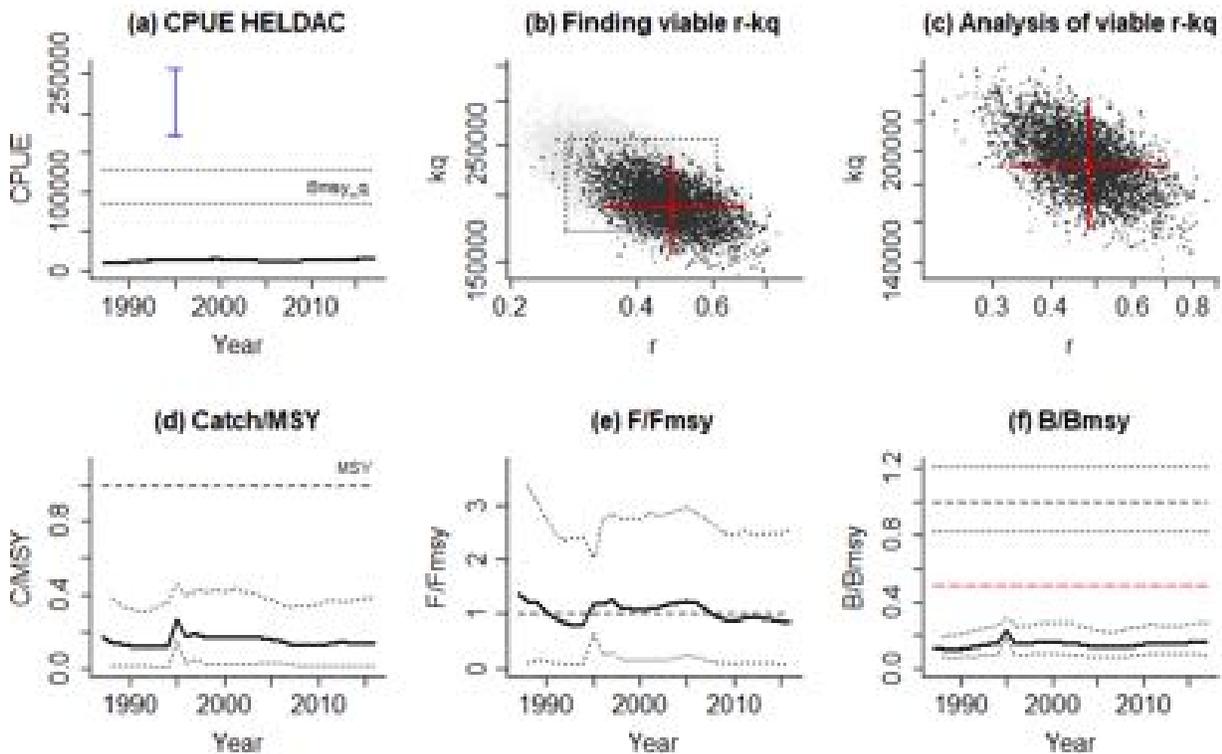


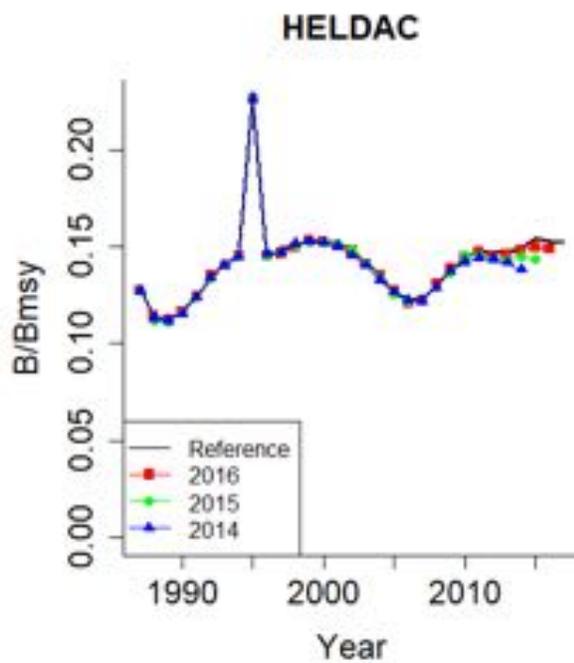
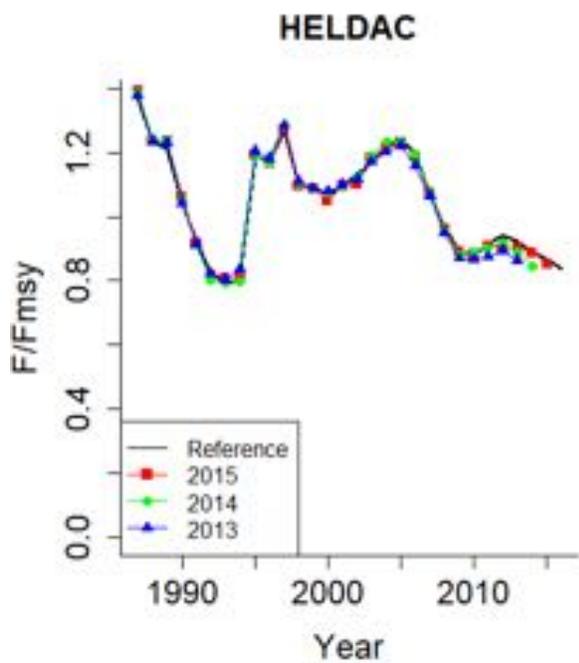
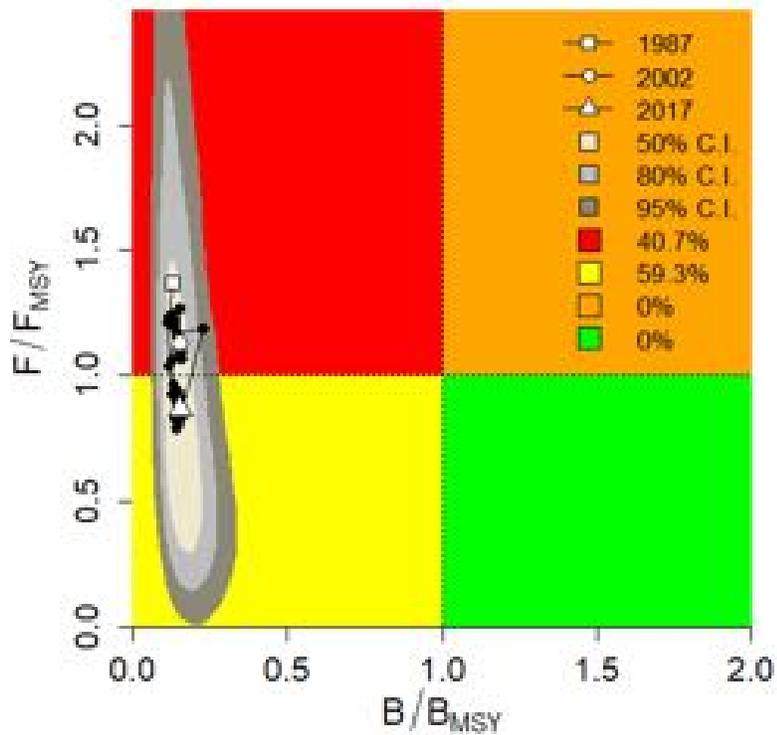
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AMSY Analysis, Fri Nov 01 20:01:47 2019  
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Stock HELDAC, *Helicolenus dactylopterus*, Blackbelly rosefish  
CPUE data for years 1987 - 2017, CPUE range 9705 - 14521, smooth = TRUE  
Prior for r = Medium, 0.27 - 0.61  
Used prior range for r = 0.254 - 0.652  
Prior for 1995 stock status = Very small, 0.1 - 0.15  
Used 1995 prior B/B0 range = 0.1 - 0.15, prior B/Bmsy = 0.2 - 0.3  
Used prior range for kq = 171295 - 256942 [original range = 85647 - 128471]  
Comment: B/B0 prior from LBB. RF: OK  
Source:

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
Viable r-kq pairs = 5000

Results:  
viable r-kq pairs = 5000  
median kq = 190329, 155676 - 231260  
median MSYq = 22964, 16864 - 31517  
r (4 MSYq/kq) = 0.483, 0.328 - 0.711  
Fmsy (r/2) = 0.241, 0.164 - 0.355  
F/Fmsy = 0.836, 0.0679 - 2.53 (2016)  
B/Bmsy = 0.153, 0.0838 - 0.274 (2017)





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 LBB results for *Cymatoceps nasutus*, stock PNSK, 2009-2009  
 Files:LBB4AMSY\_ID\_2.csv, LBBdatZA.csv  
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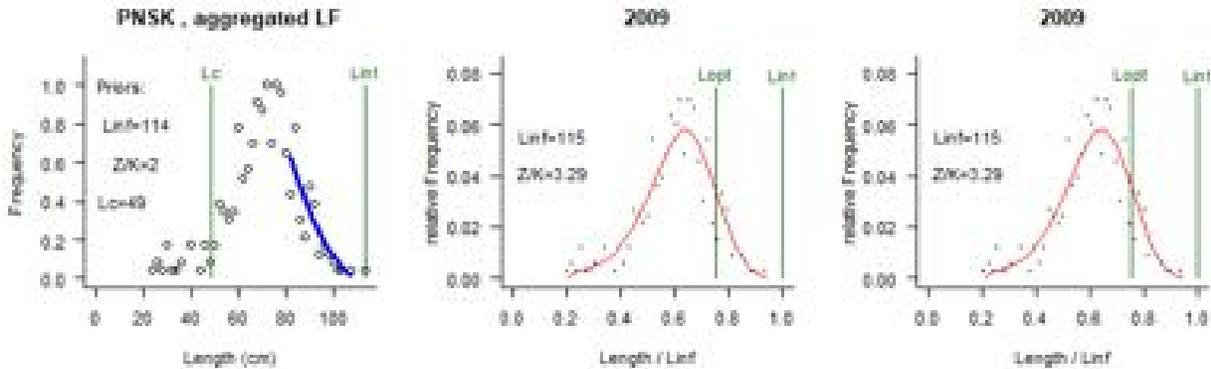
Linf prior= 114, SD=1.1 cm Lmax=114, median Lmax=114  
 Z/K prior = 2, SD=3, M/K prior=1.5, SD=0.15  
 F/K prior = 0.517 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 50, SD=5 cm, alpha prior=10.5, SD=1, Lm50=53 cm

General reference points (median across years):

Linf = 115 (113-116) cm  
 Lopt = 86 cm, Lopt/Linf=0.75  
 Lc\_opt = 78 cm, Lc\_opt/Linf=0.68, Lmean if F=M 86.8 cm  
 M/K = 0.985 (0.763-1.25)  
 F/M = 2.35 (1.58-3.55), F/K=2.31 (1.98-2.9), Z/K=3.32 (2.97-3.82)  
 B/B0 = 0.2 (0.11-0.32), B/B0 F=M Lc=Lc\_opt 0.39  
 Y/R' = 0.072 (0.042-0.12)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.079

Estimates for 2009 (mean of last 3 years with data):

Lc50 = 72.8 (71.4-74.3) cm, Lc/Linf=0.63 (0.62-0.65)  
 Lc95 = 100, alpha=0.107 (0.103-0.109)  
 Lmean/Lopt= 0.96, Lc/Lc\_opt=0.94, L95th=108 cm, L95th/Linf=0.94, Mature=89%  
 F/M = 2.4 (1.6-3.6), F/K=2.3 (2-2.9), Z/K=3.3 (3-3.8)  
 Y/R' = 0.072 (0.042-0.12)(reduced because B/B0 < 0.25)  
 B/B0 = 0.2 (0.11-0.32), best LF fit year 2009=0.196 (0.11-0.32)  
 B/Bmsy = 0.5 (0.29-0.82)

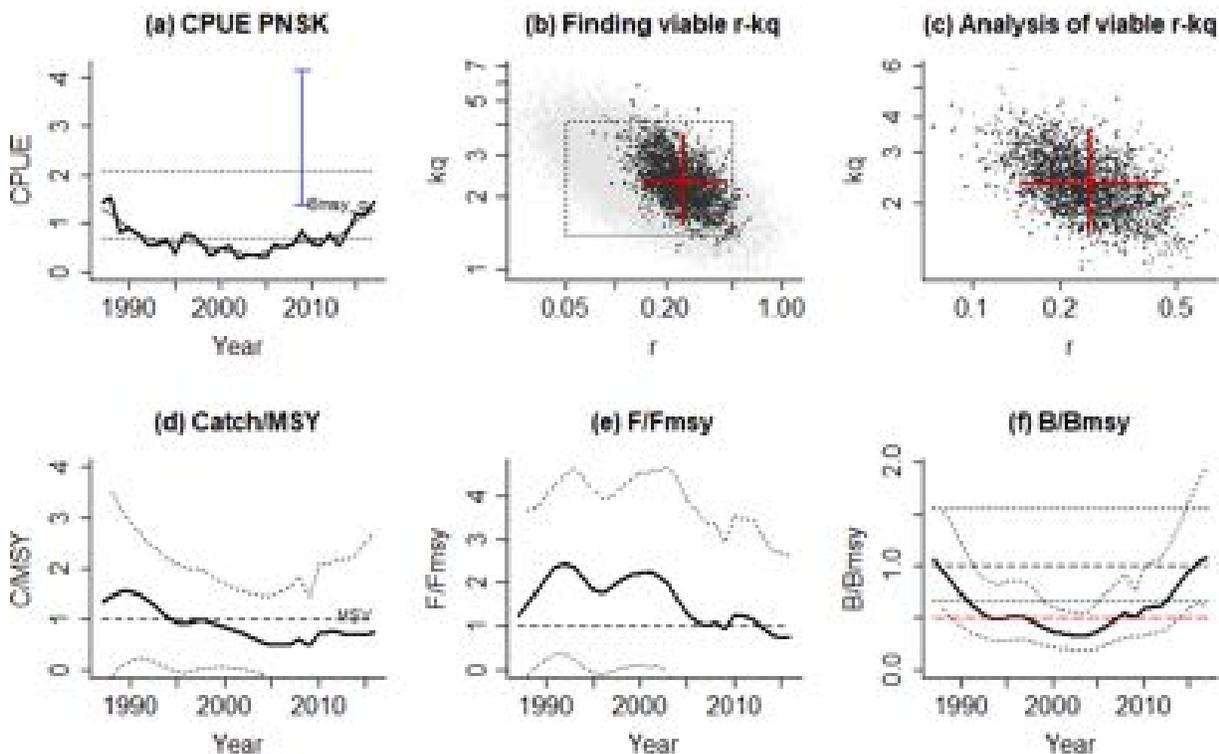


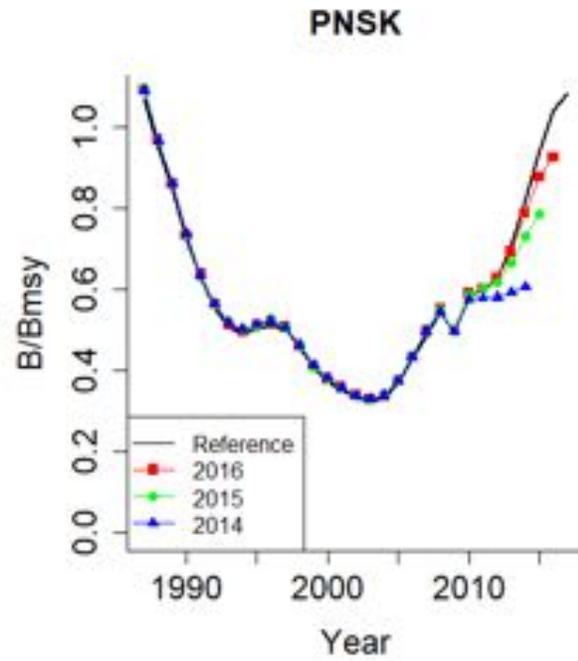
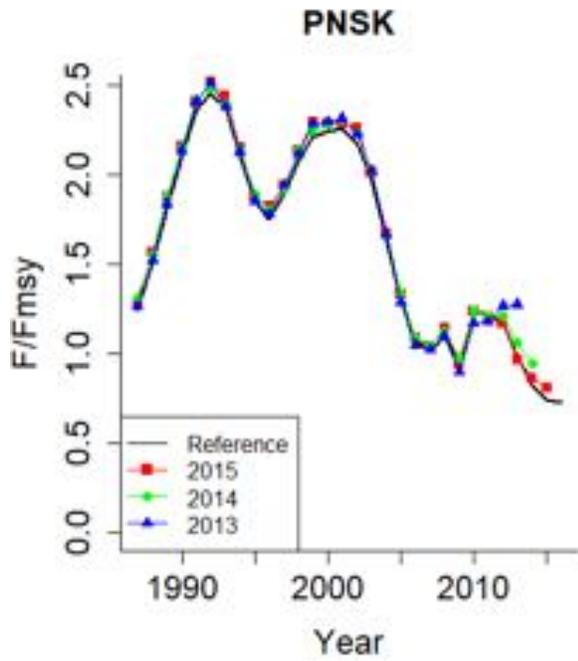
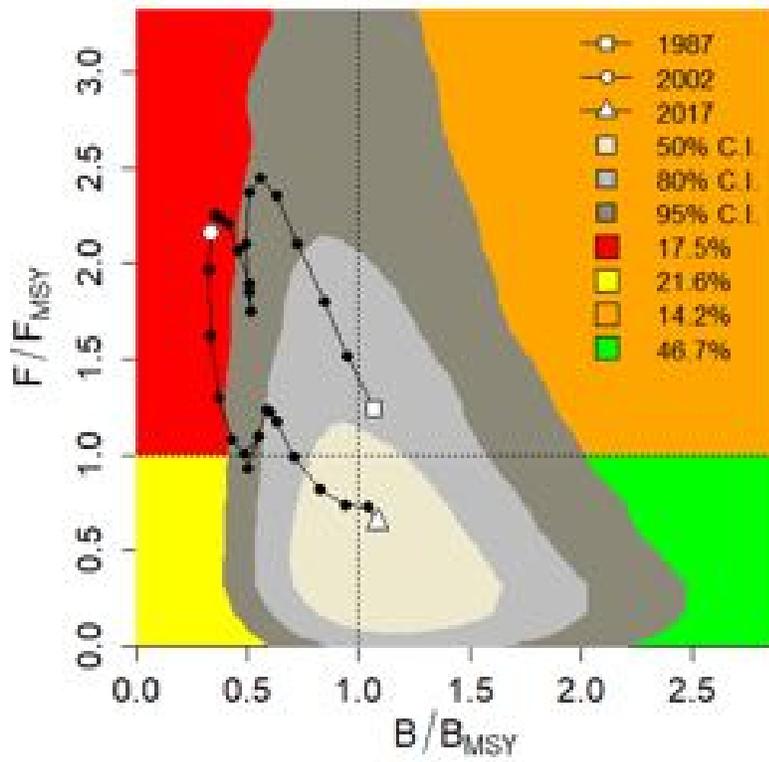
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 AMSY Analysis, Fri Nov 01 20:09:39 2019  
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Stock **PNSK**, *Cyματοceps nasutus*, Black musselcracker  
 CPUE data for years 1987 - 2017, CPUE range 0.374 - 1.29, smooth = TRUE  
 Prior for r = Low, NA - NA  
 Used prior range for r = 0.05 - 0.5  
 Prior for 2009 stock status = Small, 0.11 - 0.34  
 Used 2009 prior B/B0 range = 0.11 - 0.34, prior B/Bmsy = 0.22 - 0.68  
 Used prior range for kq = 1.38 - 4.15 [original range = 1.38 - 4.28]  
 Comment: B/B0 prior from LBB for 2009 (landing observer programm)  
 Source:

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5000

Results:  
 viable r-kq pairs = 5000  
 median kq = 2.33, 1.56 - 3.61  
 median MSYq = 0.148, 0.0889 - 0.247  
 r (4 MSYq/kq) = 0.254, 0.144 - 0.438  
 Fmsy (r/2) = 0.127, 0.0719 - 0.219  
 F/Fmsy = 0.727, -0.246 - 2.62 (2016)  
 B/Bmsy = 1.08, 0.598 - 1.95 (2017)





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 LBB results for *Argyrosomus thorpei*, stock STKB1, 2008-2008  
 Files:LBB4AMSY\_ID\_2.csv, LBBdatZA.csv  
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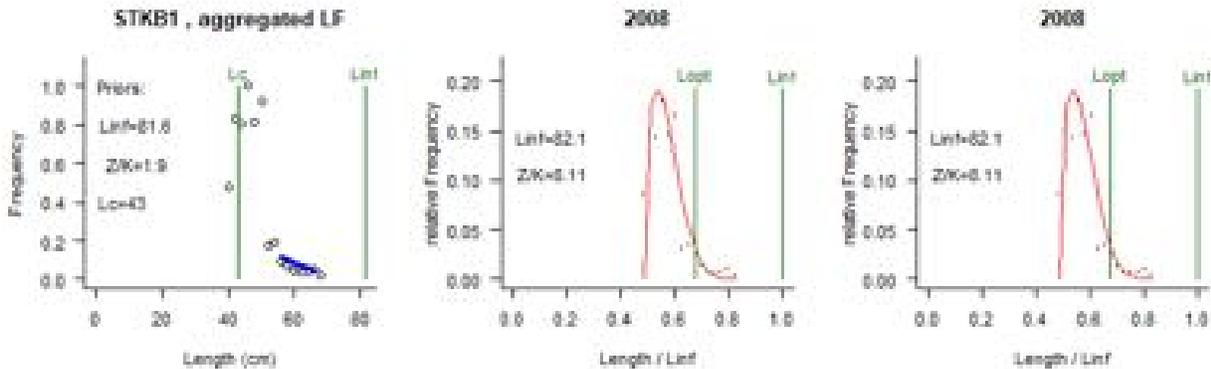
Linf prior= 81.6, SD=0.82 cm Lmax=106, median Lmax=68  
 Z/K prior = 1.9, SD=11, M/K prior=1.5, SD=0.15  
 F/K prior = 0.401 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 43.9, SD=4.4 cm, alpha prior=20.1, SD=2, Lm50=33 cm

General reference points (median across years):

Linf = 82.1 (80.3-83.6) cm  
 Lopt = 55 cm, Lopt/Linf=0.68  
 Lc\_opt = 52 cm, Lc\_opt/Linf=0.64, Lmean if F=M 53.4 cm  
 M/K = 1.44 (1.12-1.74)  
 F/M = 4.67 (3.63-6.18), F/K=6.67 (5.99-7.49), Z/K=8.09 (7.36-8.99)  
 B/B0 = 0.083 (0.055-0.12), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.017 (0.011-0.024)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.048

Estimates for 2008 (mean of last 3 years with data):

Lc50 = 43.5 (42.9-43.9) cm, Lc/Linf=0.53 (0.52-0.54)  
 Lc95 = 54.5, alpha=0.268 (0.259-0.278)  
 Lmean/Lopt= 0.88, Lc/Lc\_opt=0.83, L95th=68 cm, L95th/Linf=0.83, Mature=100%  
 F/M = 4.7 (3.6-6.2), F/K=6.7 (6-7.5), Z/K=8.1 (7.4-9)  
 Y/R' = 0.017 (0.011-0.024)(reduced because B/B0 < 0.25)  
 B/B0 = 0.083 (0.055-0.12), best LF fit year 2008=0.0826 (0.055-0.12)  
 B/Bmsy = 0.22 (0.15-0.32)  
 Fixed Linf to mean between Linf (too low) and Lmax

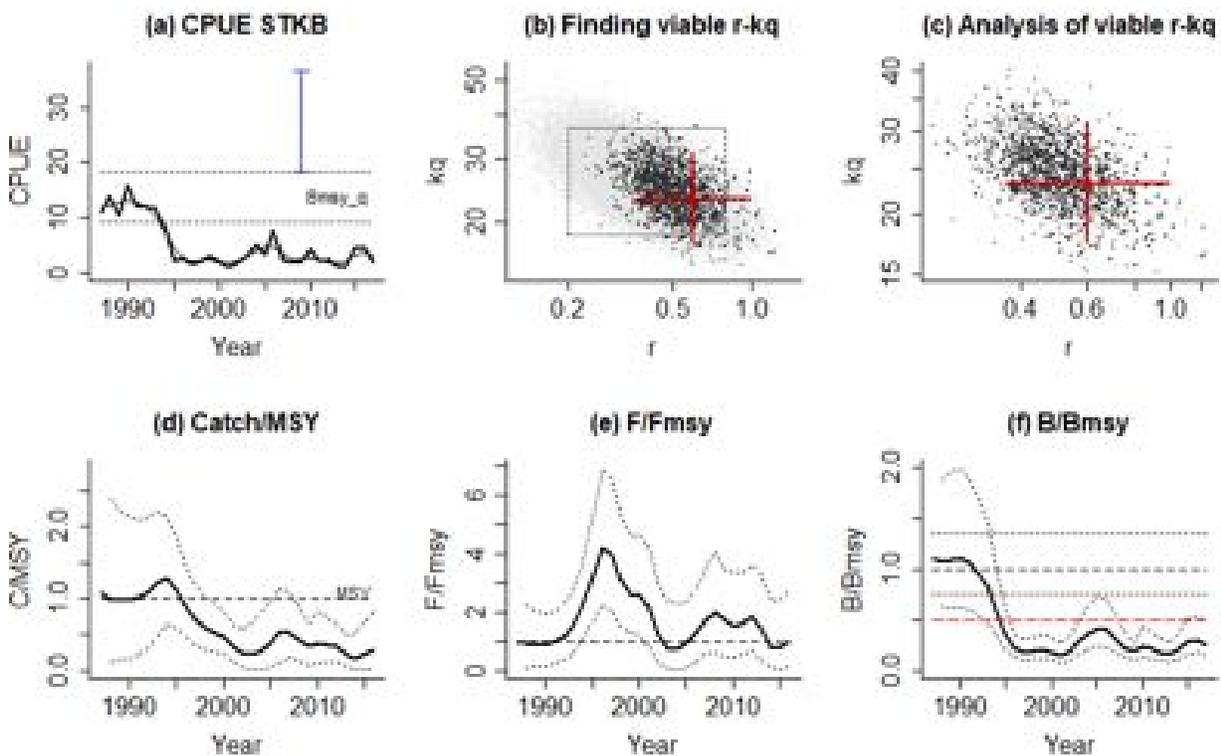


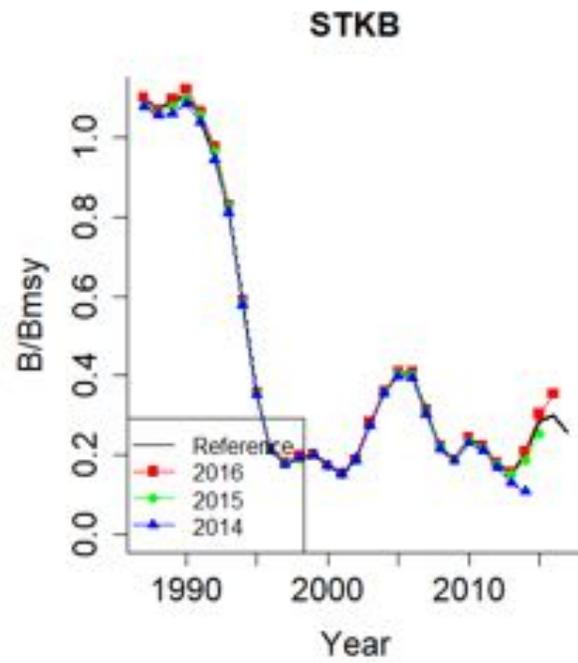
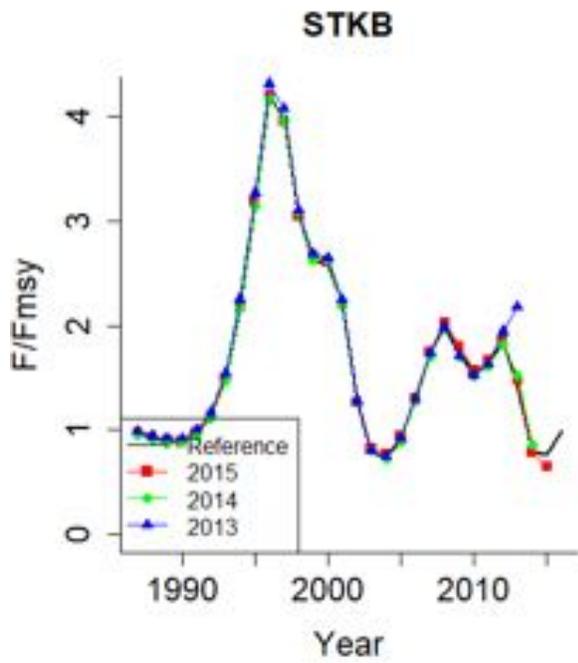
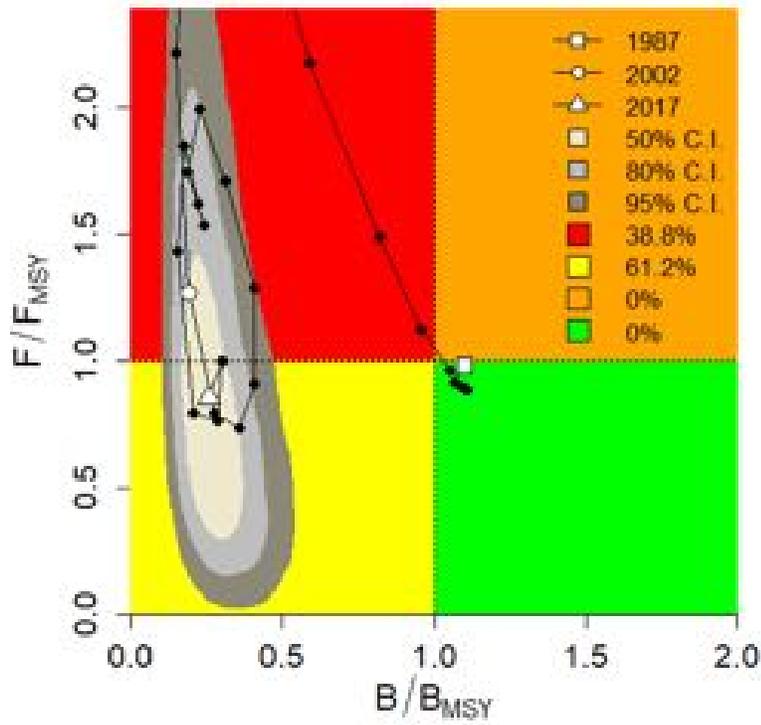
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 AMSY Analysis, Fri Nov 01 20:14:58 2019  
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Stock **STKB**, *Argyrosomus thorpei*, Squairetail kob  
 CPUE data for years 1987 - 2017, CPUE range 1.73 - 13.2, smooth = TRUE  
 Prior for r = Medium, NA - NA  
 Used prior range for r = 0.2 - 0.8  
 Prior for 2009 stock status = Very small, 0.06 - 0.12  
 Used 2009 prior B/B0 range = 0.06 - 0.12, prior B/Bmsy = 0.12 - 0.24  
 Used prior range for kq = 18.4 - 36.7 [original range = 18.4 - 36.7]  
 Comment: B/B0 prior from LBB for 2009 (landing observer programm)  
 Source:

Monte Carlo filtering of r-kq space with 50000 points and 30 error patterns.  
 Viable r-kq pairs = 5000

Results:  
 viable r-kq pairs = 5000  
 median kq = 23.2, 17.5 - 31.2  
 median MSYq = 3.48, 2.22 - 5.66  
 r (4 MSYq/kq) = 0.601, 0.363 - 0.988  
 Fmsy (r/2) = 0.301, 0.182 - 0.494  
 F/Fmsy = 0.996, 0.122 - 2.7 (2016)  
 B/Bmsy = 0.258, 0.146 - 0.465 (2017)





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 LBB results for *Raja straeleni*, stock TBSK, 2007-2017  
 Files:LBB4AMSY\_ID\_ZAdem\_AMSY.csv, LBBdatZAdem\_AMSY.csv  
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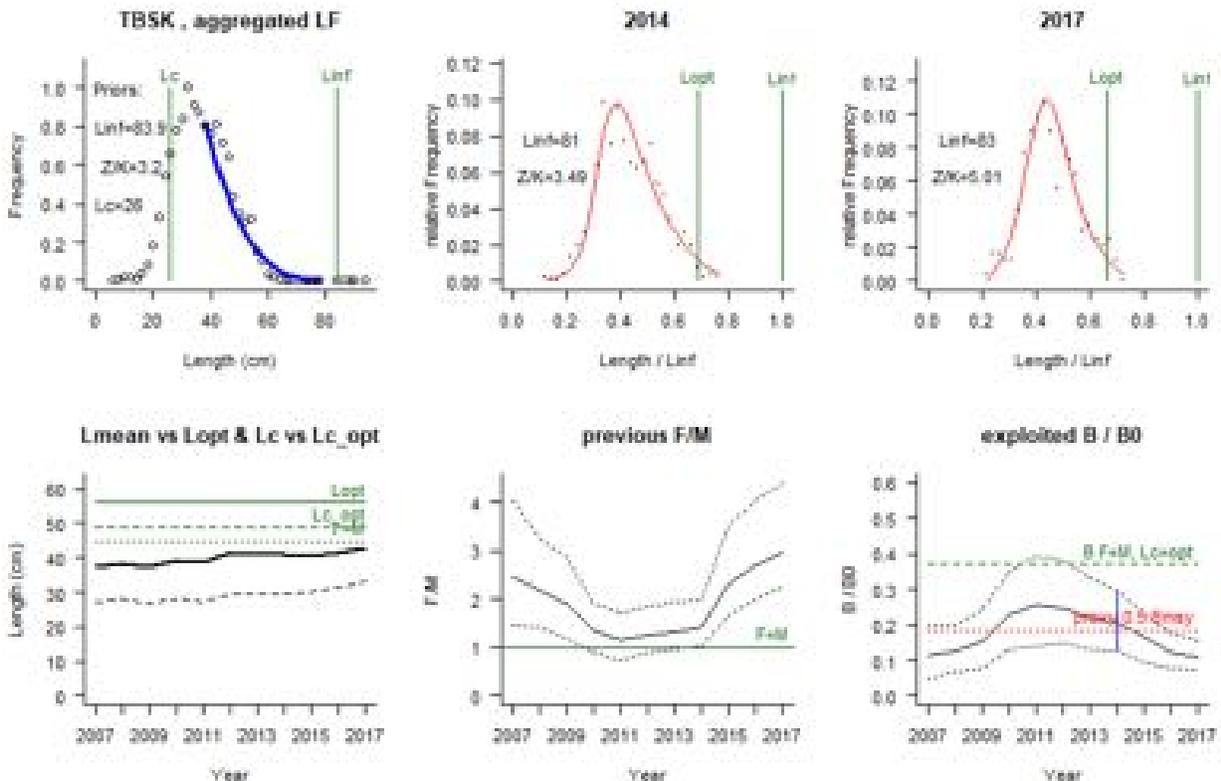
Linf prior= 83.9, SD=0.84 cm Lmax=94, median Lmax=84  
 Z/K prior = 3.2, SD=1.9, M/K prior=1.5, SD=0.15  
 F/K prior = 1.73 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 26.5, SD=2.7 cm, alpha prior=25.6, SD=2.6, Lm50=NA cm

General reference points (median across years):

Linf = 81.6 (80-83.1) cm  
 Lopt = 56 cm, Lopt/Linf=0.69  
 Lc\_opt = 49 cm, Lc\_opt/Linf=0.6, Lmean if F=M 44.9 cm  
 M/K = 1.36 (1.14-1.72)  
 F/M = 1.62 (1.26-2.46), F/K=2.13 (1.76-2.45), Z/K=3.46 (3.22-3.67)  
 B/B0 = 0.17 (0.094-0.24), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.031 (0.017-0.042)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.053

Estimates for 2017 (mean of last 3 years with data):

Lc50 = 33.3 (32.8-33.9) cm, Lc/Linf=0.41 (0.4-0.41)  
 Lc95 = 45.6, alpha=0.239 (0.231-0.249)  
 Lmean/Lopt= 0.75, Lc/Lc\_opt=0.68, L95th=62.7 cm, L95th/Linf=0.77, Mature=NA%  
 F/M = 3 (2.2-4.4), F/K=3.8 (3.3-4.2), Z/K=5.1 (4.7-5.5)  
 Y/R' = 0.019 (0.013-0.029)(reduced because B/B0 < 0.25)  
 B/B0 = 0.11 (0.073-0.16), best LF fit year 2017=0.108 (0.073-0.16)  
 B/Bmsy = 0.29 (0.2-0.42), **selected B/B0 2014 = 0.21 (0.12-0.3)**  
 Trawl survey data; sharks and rays more consistently measured in chosen recent period from 2007 onward. RF selected 2014 because of good fit and reasonable B/B0 compared to adjacent estimates.



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AMSY Analysis, Fri Nov 01 20:18:57 2019  
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Stock **TBSK**, *Raja straeleni*, Biscuit skate

CPUE data for years 1991 - 2017, CPUE range 15383 - 21126, smooth = TRUE

Prior for  $r$  = Low, NA - NA

Used prior range for  $r$  = 0.05 - 0.5

Prior for 2014 stock status = Small, 0.12 - 0.3

Used 2014 prior B/B0 range = 0.12 - 0.3, prior B/Bmsy = 0.24 - 0.6

Used prior range for  $kq$  = 86428 - 129642 [original range = 43214 - 108035]

Comment: B/B0 prior from LBB. RF: OK

Source:

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5003

Results:

viable  $r$ - $kq$  pairs = 5003

median  $kq$  = 101005, 86440 - 118314

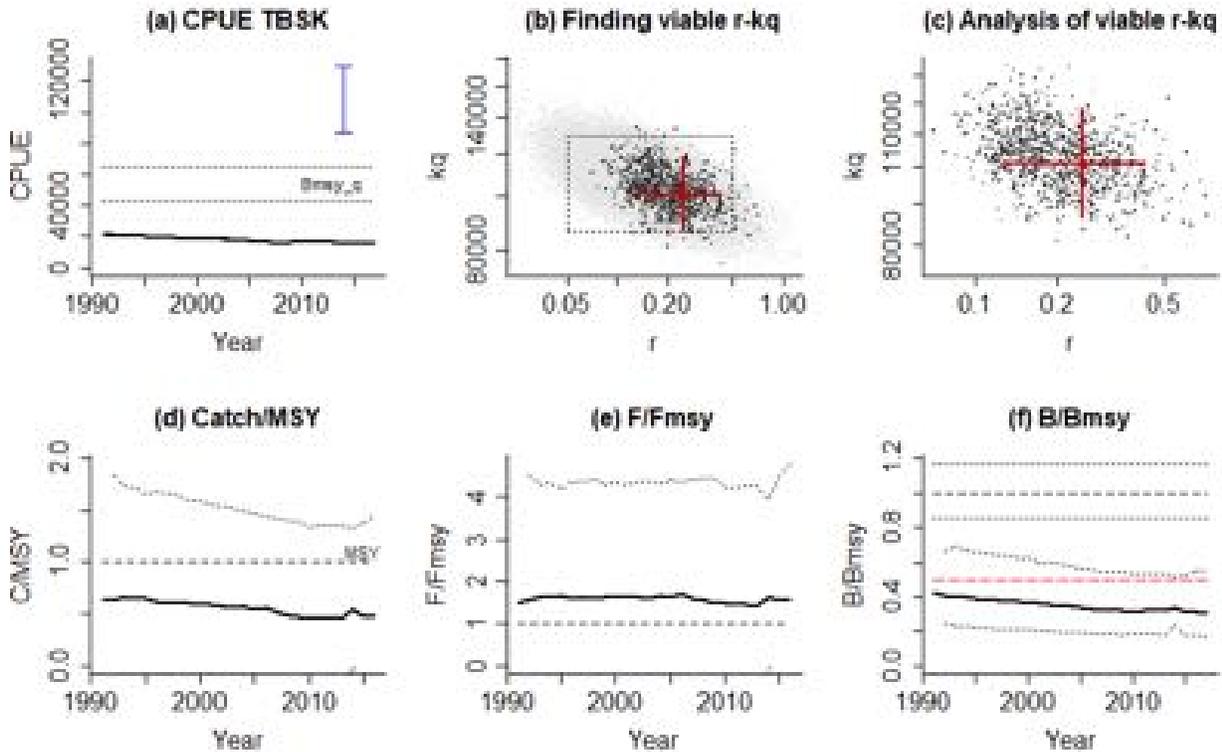
median MSYq = 6243, 3326 - 10390

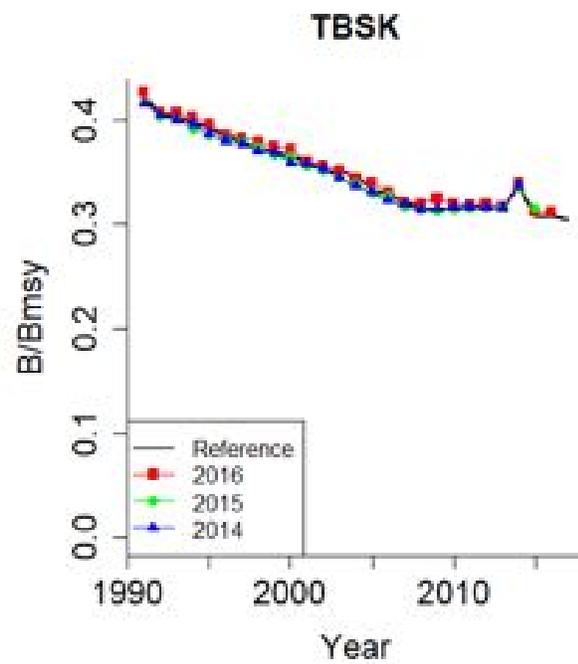
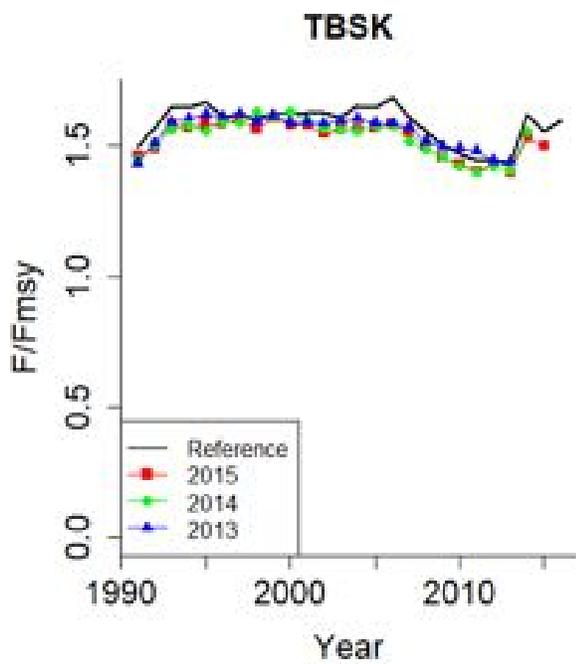
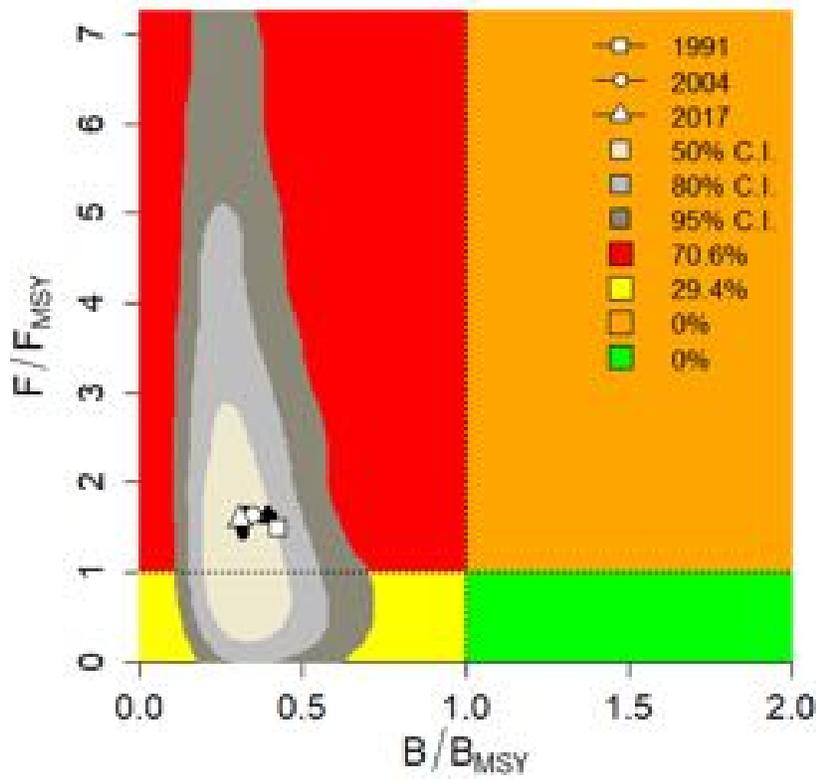
$r$  (4 MSYq/ $kq$ ) = 0.247, 0.126 - 0.424

Fmsy ( $r/2$ ) = 0.124, 0.0628 - 0.212

F/Fmsy = 1.6, -0.409 - 4.78 (2016)

B/Bmsy = 0.305, 0.168 - 0.555 (2017)





LBB results for *Rhabdosargus globiceps*, stock WSTM, 1987-2007  
 Files:LBB4AMSY\_ID\_ZAdem\_AMSY.csv, LBBdatZAdem\_AMSY.csv

Linf prior= 51, SD=0.51 cm Lmax=58, median Lmax=48  
 Z/K prior = 3, SD=0.68, M/K prior=1.45, SD=0.075(user-defined)  
 F/K prior = 1.58 (wide range with tau=4 in log-normal distribution)  
 Lc prior = 25.5, SD=2.6 cm, alpha prior=22.8, SD=2.3, Lm50=NA cm

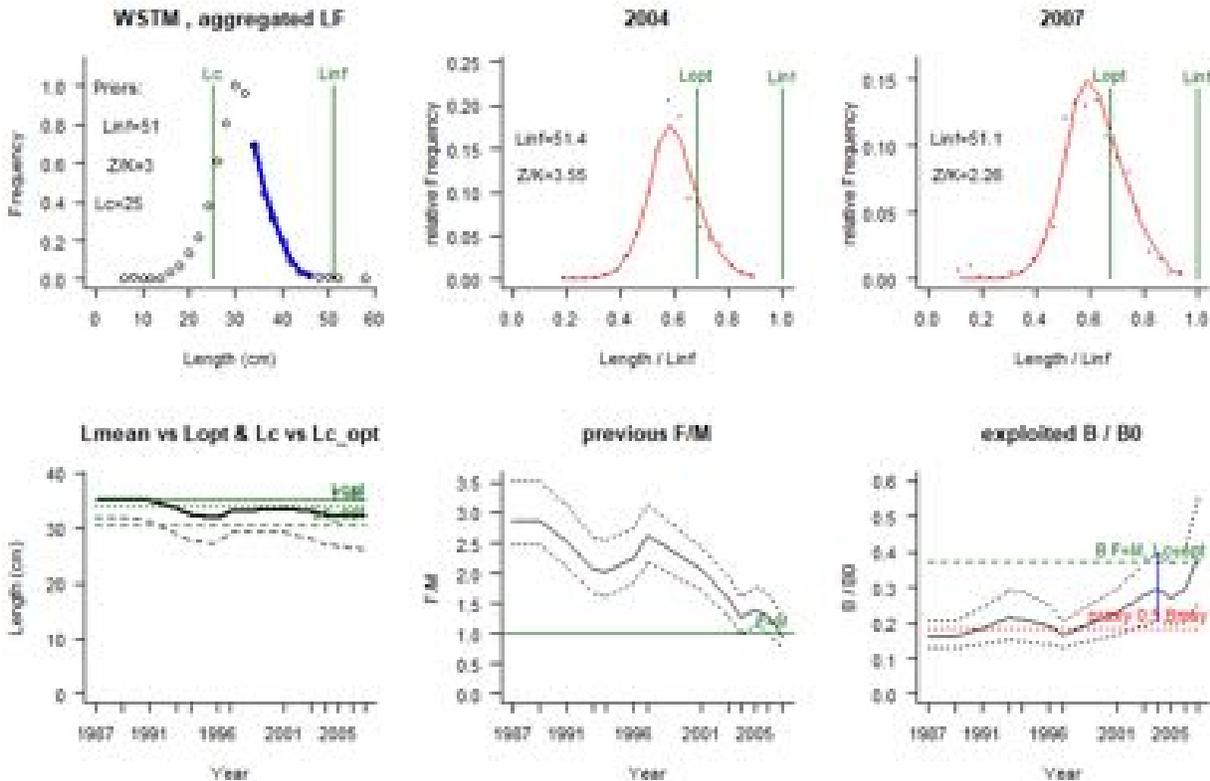
General reference points (median across years):

Linf = 51 (50.3-51.6) cm  
 Lopt = 35 cm, Lopt/Linf=0.69  
 Lc\_opt = 30 cm, Lc\_opt/Linf=0.6, Lmean if F=M 33.8 cm  
 M/K = 1.37 (1.21-1.49)  
 F/M = 1.58 (1.3-1.96), F/K=2.18 (1.86-2.47), Z/K=3.55 (3.26-3.83)  
 B/B0 = 0.24 (0.18-0.31), B/B0 F=M Lc=Lc\_opt 0.37  
 Y/R' = 0.049 (0.035-0.062)(reduced: B/B0<0.25), Y/R' F=M Lc=Lc\_opt 0.052

Estimates for 2007 (mean of last 3 years with data):

Lc50 = 26.2 (25.9-26.5) cm, Lc/Linf=0.52 (0.52-0.53)  
 Lc95 = 33.1, alpha=0.426 (0.416-0.438)  
 Lmean/Lopt= 0.92, Lc/Lc\_opt=0.86, L95th=46.7 cm, L95th/Linf=0.93, Mature=NA%  
 F/M = 0.97 (0.75-1.3), F/K=1.3 (1-1.5), Z/K=2.5 (2.3-2.8)  
 Y/R' = 0.055 (0.037-0.078)(reduced because B/B0 < 0.25)  
 B/B0 = 0.38 (0.25-0.55), best LF fit year 2007=0.382 (0.25-0.55)  
 B/Bmsy = 1 (0.68-1.5), **selected B/B0 2004 = 0.3 (0.21-0.4)**

Trawl Survey data; excluded unsuitable LF data; only first period covered. RF selected 2004 because of good fit and reasonable B/B0 compared to adjacent estimates.



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AMSY Analysis, Fri Nov 01 20:22:08 2019  
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Stock **WSTM**, *Rhabdosargus globiceps*, white stumpnose

CPUE data for years 1987 - 2016, CPUE range 1500 - 3844, smooth = TRUE

Prior for  $r$  = Medium, NA - NA

Used prior range for  $r$  = 0.2 - 0.8

Prior for 2004 stock status = Small, 0.21 - 0.4

Used 2004 prior B/B<sub>0</sub> range = 0.21 - 0.4, prior B/B<sub>msy</sub> = 0.42 - 0.8

Used prior range for  $kq$  = 5603 - 10672 [original range = 5603 - 10672]

Comment: B/B<sub>0</sub> prior from LBB. RF: OK

Source:

Monte Carlo filtering of  $r$ - $kq$  space with 50000 points and 30 error patterns.  
Viable  $r$ - $kq$  pairs = 5009

Results:

viable  $r$ - $kq$  pairs = 5009

median  $kq$  = 7437, 5532 - 9572

median MSY $q$  = 899, 572 - 1419

$r$  (4 MSY $q$ / $kq$ ) = 0.484, 0.293 - 0.806

F<sub>msy</sub> ( $r/2$ ) = 0.242, 0.146 - 0.403

F/F<sub>msy</sub> = 0.887, 0.106 - 2.03 (2015)

B/B<sub>msy</sub> = 1.03, 0.572 - 1.85 (2016)

