SEDAR 77 Assessment webinar II: Dynamic Factor Analysis (DFA) of Accepted Age-0 Scalloped Hammerhead Indices

PW08-RD11

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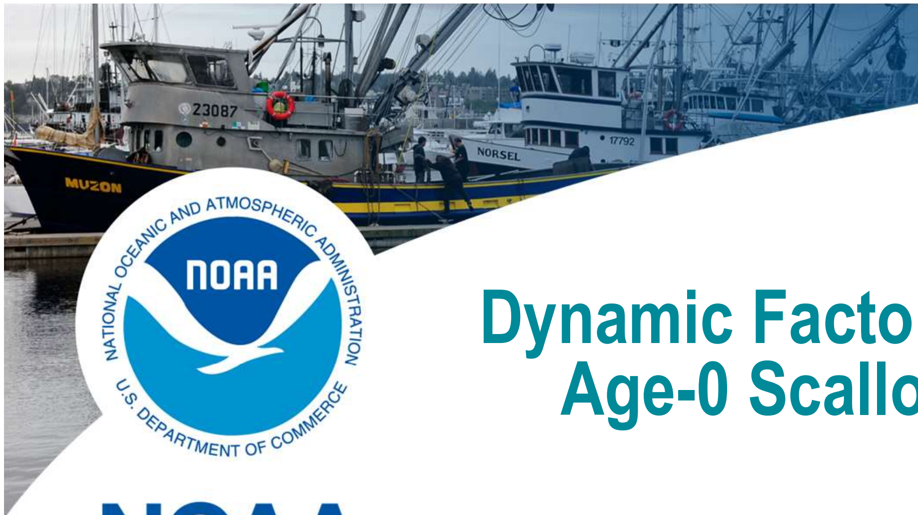

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Dynamic Factor Analysis (DFA) of Accepted Age-0 Scalloped Hammerhead Indices

SEDAR 77 (Assessment Webinar II)

July 15, 2022

Dynamic Factor Analysis (DFA) SEDAR 77

- https://sedarweb.org/sedar-77-hms-hammerhead-sharks-assessment-process-0

Reconciling age-0 indices of relative abundance of the U.S. Atlantic and Gulf of Mexico scalloped hammerhead (*Sphyrna lewini*)

Dean Courtney, Robert J. Latour, and Cassidy D. Peterson

SEDAR77-AW05

20 June 2022

DFA Methods Followed SEDAR 65

- https://sedarweb.org/sedar-65-assessment-process

Reconciling indices of relative abundance of the Atlantic blacktip shark (*Carcharhinus limbatus*)

Robert J. Latour and Cassidy D. Peterson

SEDAR65-AW03

6 March 2020

DFA Approach Simulation Tested

- Application of DFA to time-series of relative abundance simulation tested in Cassidy et al. 2021

ICES Journal of Marine Science

ICES CIEM International Council for the Exploration of the Sea / Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science (2021), 78(5), 1711–1729. doi:10.1093/icesjms/fsab051

Dynamic factor analysis to reconcile conflicting survey indices of abundance

Cassidy D. Peterson [1,*,†], Michael J. Wilberg [2], Enric Cortés[3], and Robert J. Latour[1]

[1]Virginia Institute of Marine Science, William & Mary, PO Box 1346, Gloucester Point, VA 23062, USA
[2]Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, PO Box 38, Solomons, MD 20688, USA
[3]Southeast Fisheries Science Center, National Marine Fisheries Service, 3500 Delwood Beach Rd, Panama City, FL 32408, USA

*Corresponding author: tel: +1 252 838 0885; e-mail: cassidy.peterson@noaa.gov.
†Present address: Southeast Fisheries Science Center, National Marine Fisheries Service, 101 Pivers Island Road, Beaufort, NC 28516, USA.

Peterson, C. D., Wilberg, M. J., Cortés, E., and Latour, R. J. Dynamic factor analysis to reconcile conflicting survey indices of abundance. – ICES Journal of Marine Science, 78: 1711–1729.

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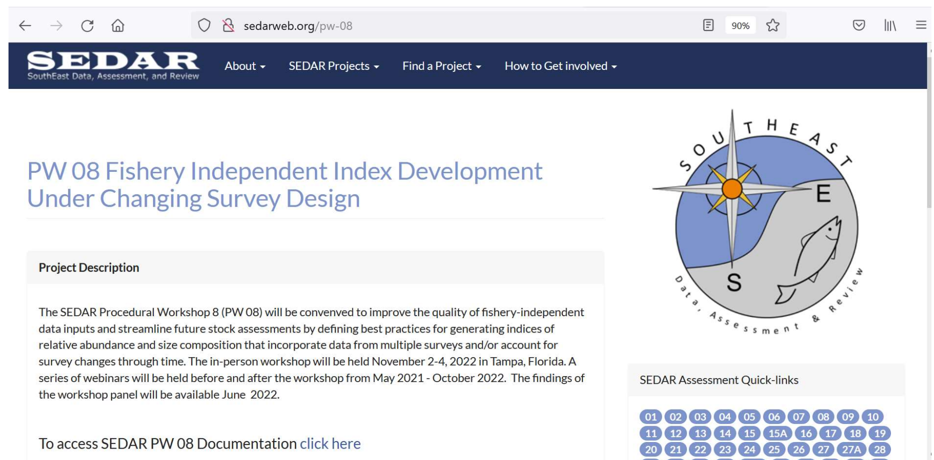
SEDAR Procedural Workshop 8

November 2-4, 2022 in Tampa, Florida



SEDAR Procedural Workshop 8

http://sedarweb.org/pw-08-sedar-fishery-independent-indices-terms-reference

TORS:

"2. Review past assessments and document types of issues that arose when indices of abundance were combined or due to changing survey design. Possible issues may include:

• Combining multiple surveys:

DFA Age-0 Scalloped Hammerhead

- Accepted age-0 scalloped hammerhead indices

Table 9. Recommended base indices of abundance for the Age 0 scalloped hammerhead including index name, the value of catch per unit effort, the area sampled and SEDAR document number (See Table 3 for the regions recommended for base model and sensitivity analysis with each index). CV is the coefficient of variation for the annual index value. Missing values in a given year correspond to zero catches (index value of 0 and no CV), where no sampling occurred (ns), or when the model did not converge (nc).

	TXPWD-Gillnet SEDAR77 DW-16 Stockwide/Gulf of Mexico sharks per net per hour		GULFSPAN SEDAR77 DW-17 Stockwide/Gulf of Mexico sharks per net per hour		COASTSPAN - LL SEDAR77-DW-30 Stockwide/Atlantic sharks per 100 hook hours		SCCOASTGN - LONG SEDAR77-DW-31 Stockwide/Atlantic sharks per net hour		SCCOASTGN - SHORT SEDAR77 DW-32 Stockwide/Atlantic sharks per net hour	
year	index	CV	index	CV	index	CV	index	CV	index	CV
1982	0.00033									
1983	0.00042	0.912								
1984	0.00000									
1985	0.00015									
1986	0.00035	0.732								
1987	0.00000									
1988	0.00050	0.618								
1989	0.00012									
1990	0.00090	0.603								
1991	0.00053	0.749								
1992	0.00000									
1993	0.00032	0.819								
1994	0.00027	0.848								
1995	0.00010	1.165								
1996	0.00093	0.536	0.009	0.294						
1997	0.00172	0.666	0.016	0.461						
1998	0.00031	0.842	0.002	0.548						
1999	0.00021	0.781	0.091	0.312						
2000	0.00048	0.589	0.156	0.253						
2001	0.00150	0.603	0.148	0.302			1.250	0.479		
2002	0.00033	0.822	0.15	0.166			0.788	0.518		
2003	0.00183	0.577	0.102	0.181			2.742	0.450		
2004	0.00075	0.689	0.07	0.227			0.541	1.432		
2005	0.00254	0.517	0.048	0.373	5.464	0.529	0.625	0.538		
2006	0.00069	0.630	0.079	0.22	8.119	0.416	0.981	1.018		
2007	0.00079	0.778	0.168	0.171	1.976	1.128	1.952	0.533	0.171	0.423
2008	0.00075	0.703	0.172	0.189	1.730	1.165	1.384	0.707	0.286	0.581
2009	0.00095	0.560	0.163	0.2	3.482	0.654	7.298	1.383	0.000	
2010	0.00213	0.598	0.208	0.211	9.376	0.327	2.297	0.854	0.114	0.581
2011	0.00091	0.563	0.159	0.201	3.876	0.372	1.487	0.540	0.113	0.307
2012	0.00124	0.540	0.093	0.217	1.907	0.469	8.180	0.527	0.116	0.307
2013	0.00484	0.428	0.129	0.215	2.052	0.427	4.058	0.451	0.090	0.423
2014	0.00198	0.477	0.141	0.207	2.443	0.548	2.204	0.695	0.000	
2015	0.00283	0.565	0.068	0.252	1.158	0.554	0.969	0.616	0.020	0.581
2016	0.00191	0.590	0.124	0.235	1.899	0.419	1.675	0.538	0.098	0.351
2017	0.00041	0.775	0.184	0.2	1.123	0.519	6.808	0.341	0.000	
2018	0.00482	0.499	0.21	0.225	0.738	0.565	3.725	0.547	0.000	
2019	0.00248	0.514	0.176	0.265	1.029	1.175	3.305	0.423	0.021	0.581

DFA Age-0 Scalloped Hammerhead

- Accepted age-0 scalloped hammerhead indices
  - **Decision**
  - Removed years with “zero” relative abundance

Scalloped HH Age 0
TXPWD-Gillnet
SEDAR77 DW-16
Gulf of Mexico
1984, 1987, 1992

Scalloped HH Age 0
SCCOASTGN - SHORT
SEDAR77 DW-32
Atlantic
sharks per net hour
2009, 2014, 2017, 2018

DFA Age-0 Scalloped Hammerhead

- DFA methods SEDAR65_DW03:

Methods

Dynamic Factor Analysis

The general form of a DFA model can be written as follows (Zuur et al. 2003a):

$$\boldsymbol{y}_t = \boldsymbol{\Gamma}\boldsymbol{\alpha}_t + \boldsymbol{\varepsilon}_t, \text{ where } \boldsymbol{\varepsilon}_t \sim MVN(0, \boldsymbol{R})$$
$$\boldsymbol{\alpha}_t = \boldsymbol{\alpha}_{t-1} + \boldsymbol{\eta}_t, \text{ where } \boldsymbol{\eta}_t \sim MVN(0, \boldsymbol{Q})$$

where $\boldsymbol{y}_t$ is the vector (*n* x 1) of estimated z-scored index values from all time-series of relative abundance in year *t*, $\boldsymbol{\alpha}_t$ is the vector (*m* x 1) of common trends ($m < n$), $\boldsymbol{\Gamma}$ is the matrix (*n* x *m*) of loadings on the trends which indicates the strength of each time-series in determining the resulting trend, and $\boldsymbol{R}$ and $\boldsymbol{Q}$ denote the variance-covariance matrices associated with the observation error vector $\boldsymbol{\varepsilon}_t$ (*n* x1) and process error vector $\boldsymbol{\eta}_t$ (*m* x 1), respectively. Both observation and process error terms assume a multivariate normal distribution. To ensure that the model is identifiable, $\boldsymbol{Q}$ is set to equal to the identity matrix while $\boldsymbol{R}$ is free to take on various forms. All factor loadings, common trends, and fitted values are unitless.

DFA Age-0 Scalloped Hammerhead

- DFA methods SEDAR65_DW03:

“Application of DFA to time-series of relative abundance requires some care to preserve the underlying error structure and the relative scale of the survey indices. Accordingly, the following analytical approach was adopted: **(1) all time-series of relative abundance were log-transformed, thereby normalizing the time-series error, (2) each time-series was centered and demeaned by subtracting and dividing each by its mean, (3) the global standard deviation (GSD) was calculated for all relative abundance time-series after being log-transformed and demeaned, (4) each time-series was then divided by the GSD,** (5) the DFA model was fitted, (6) the resulting DFA-predicted common trend was then multiplied by the GSD and back-transformed. Since the stock assessment model relies heavily on trend rather than magnitude of relative abundance indices, bias correcting will have little impact. However, standard errors estimated by the DFA model for the annual indices were multiplied by the GSD to preserve scale of uncertainty relative to the trend.”

DFA Age-0 Scalloped Hammerhead

- DFA methods SEDAR65_DW03:

"**The above approach does not work well in situations where the log-transformed relative abundance mean was close to zero or negative**, because the second step would essentially involve dividing by zero or a negative value, respectively. This was the case for a few of the Atlantic blacktip shark time-series of relative abundance. Simulation analyses have also shown that **DFA model fitting is fairly robust when the standard deviation of each time-series resulting from step four are approximately one (Peterson et al. 2021**). **Accordingly, the Atlantic blacktip time-series of relative abundance were first multiplied by a survey-specific constant, c, to ensure that the resulting time-series approximately achieved these two general criteria**. Multiplying indices by a constant is comparable to redefining effort such that the scale of the index changes. Best practices suggest that time-series be z-scored prior to DFA model fitting (Holmes et al. 2020), so in effect, the above analytical approach was developed in the spirit of maintaining consistency with that recommendation."

DFA Age-0 Scalloped Hammerhead

- DFA Implemented in R consistent with SEDAR Procedural Workshop 8

DFA TUTORIAL FROM ICES MANUSCRIPT: DOI: 10.1093/icesjms/fsab051

```
 # REQUIREMENTS FOR C -- change c vector
  y.bar # means must be >0 (otherwise demeaning will change sign/direction of index); means should be >1; ideally >~2 (which isn't always possible)
  gsd # gsd should be small! <~0.1
sd =  apply(dat.z, 1, sd, na.rm=T) # MOST IMPORTANT DIAGNOSTIC: sd should be 1.
  # this rescaling approach is to approximate a z-score.
  # if sd for an index is <1, then increase corresponding element in c matrix; vice versa || index specific c values
  # helpful to tune 1 at a time
  min(datL, na.rm=T) # ensure that minimum datL >0

  #### STOP ##########################################################
  # IF REQUIREMENTS FOR c ARE NOT MET, THEN ITERATIVELY MODIFY c VECTOR UNTIL REQUIREMENTS ARE MET!
```

DFA Age-0 Scalloped Hammerhead

- **Decisions**

1) DFA input CV obtained from average CV from each index (after removing zeros)

	TXPWD-Gillnet	GULFSPAN	COASTSPAN - LL	SCCOASTGN - LONG	SCCOASTGN - SHORT
	SEDAR77 DW-16	SEDAR77 DW-17	SEDAR77-DW-30	SEDAR77-DW-31	SEDAR77 DW-32
	Gulf of Mexico	Gulf of Mexico	Atlantic	Atlantic	Atlantic
	sharks per net per hour	sharks per net per hour	sharks per 100 hook hours	sharks per net hour	sharks per net hour
Average CV	0.665	0.255	0.618	0.663	0.460
Count	32.000	24.000	15.000	19.000	9.000

2) DFA input "z-score" scaler "c" obtained iteratively for each index following methods in SEDAR65_DW03 (after removing zeros)

	dat = dat.a * c # multiply dat.a by vector of constants (c)				
c	1042950.536	18596.21	60.94239372	108.564844	4126.117767
	TXPWD-Gillnet	GULFSPAN	COASTSPAN - LL	SCCOASTGN - LONG	SCCOASTGN - SHORT

DFA Age-0 Scalloped Hammerhead

- DFA obtained separately by region using the CVs and scalers “c” obtained above
  - DFA #1: Combined Gulf and Atlantic (5)

TXPWD-Gillnet	GULFSPAN	COASTSPAN - LL	SCCOASTGN - LONG	SCCOASTGN - SHORT
SEDAR77 DW-16	SEDAR77 DW-17	SEDAR77-DW-30	SEDAR77-DW-31	SEDAR77 DW-32
Gulf of Mexico	Gulf of Mexico	Atlantic	Atlantic	Atlantic
sharks per net per hour	sharks per net per hour	sharks per 100 hook hours	sharks per net hour	sharks per net hour

  - DFA #2: Gulf (2)

TXPWD-Gillnet	GULFSPAN
SEDAR77 DW-16	SEDAR77 DW-17
Gulf of Mexico	Gulf of Mexico
sharks per net per hour	sharks per net per hour

  - DFA#3: Atlantic (3)

COASTSPAN - LL	SCCOASTGN - LONG	SCCOASTGN - SHORT
SEDAR77-DW-30	SEDAR77-DW-31	SEDAR77 DW-32
Atlantic	Atlantic	Atlantic
sharks per 100 hook hours	sharks per net hour	sharks per net hour

DFA Age-0 Scalloped Hammerhead

- Diagnostics followed SEDAR65_DW03:

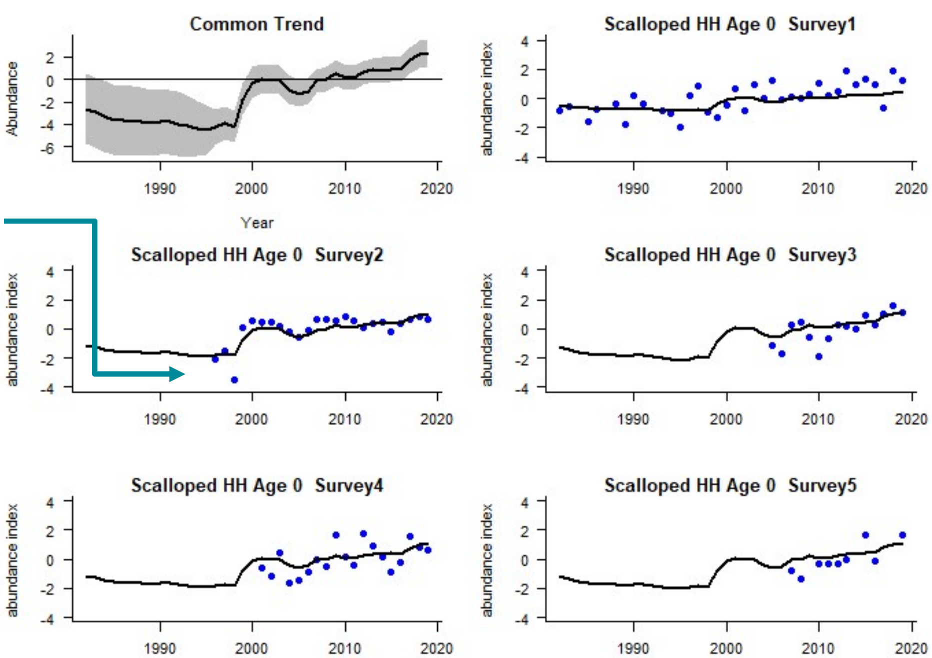
"The underlying assumptions of a DFA model are equivalent to those of a linear regression, which include normality, independence, and homogeneity of residuals (Zuur et al. 2003b). **Model validation was therefore based on standard diagnostic tools (QQ plots, analysis of residuals).** Additionally, 'fit ratio' statistics were calculated as $\Sigma_t y_{it}^2 / \Sigma_t \varepsilon_{it}^2$, where i denotes an individual time-series. **High fit ratios (i.e., $\gtrsim$ 0.6) suggest that the DFA model poorly fits the time series, or a few years in the time series** (Zuur et al. 2003b)."

DFA #1: Combined Gulf and Atlantic

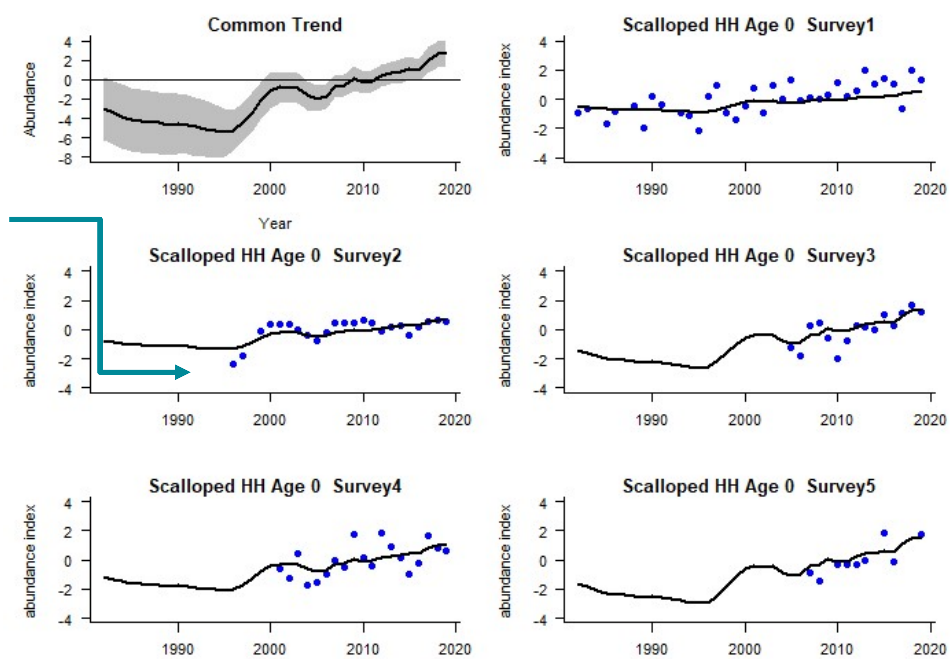
- Results

TXPWD-Gillnet	GULFSPAN	COASTSPAN - LL	SCCOASTGN - LONG	SCCOASTGN - SHORT
SEDAR77 DW-16	SEDAR77 DW-17	SEDAR77-DW-30	SEDAR77-DW-31	SEDAR77 DW-32
Gulf of Mexico	Gulf of Mexico	Atlantic	Atlantic	Atlantic
sharks per net per hour	sharks per net per hour	sharks per 100 hook hours	sharks per net hour	sharks per net hour

V1



V2

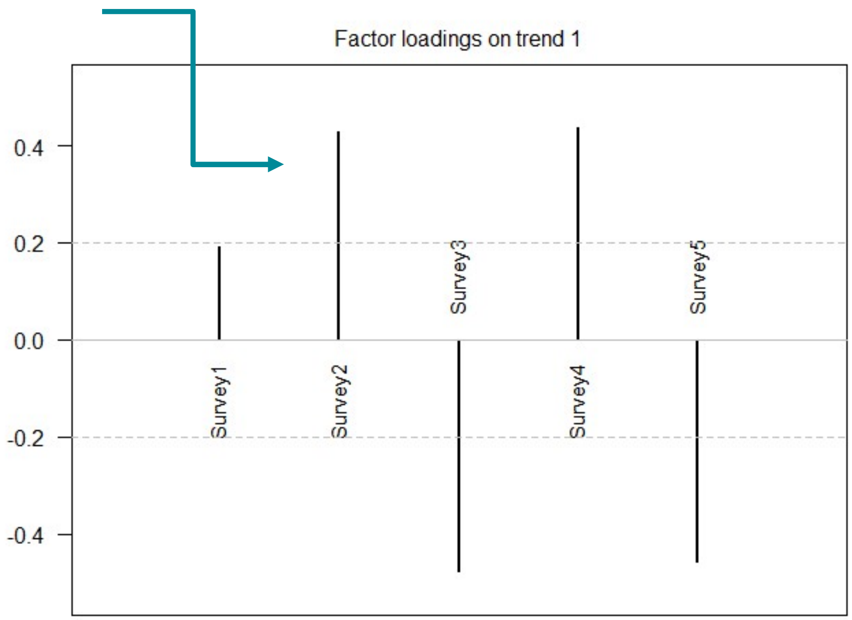


DFA #1: Combined Gulf and Atlantic

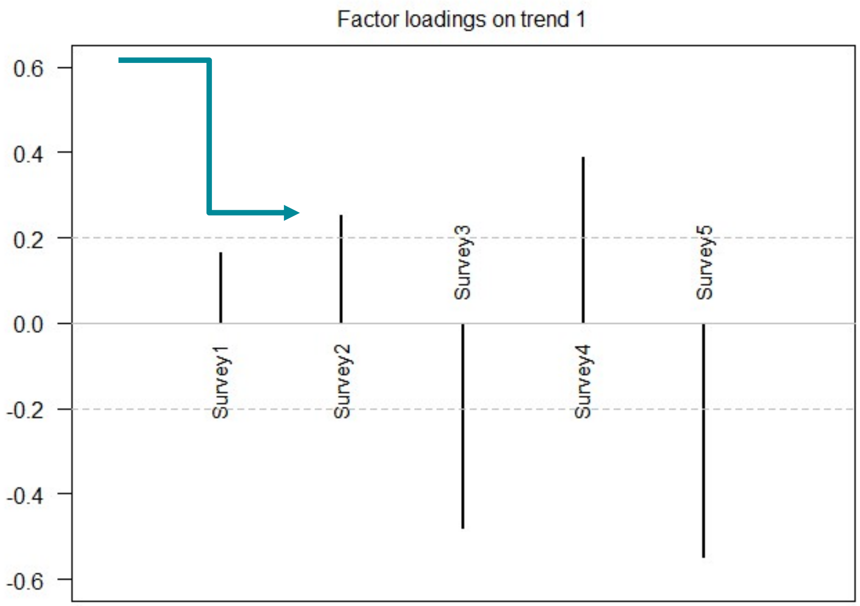
- Results

TXPWD-Gillnet	GULFSPAN	COASTSPAN - LL	SCCOASTGN - LONG	SCCOASTGN - SHORT
SEDAR77 DW-16	SEDAR77 DW-17	SEDAR77-DW-30	SEDAR77-DW-31	SEDAR77 DW-32
Gulf of Mexico	Gulf of Mexico	Atlantic	Atlantic	Atlantic
sharks per net per hour	sharks per net per hour	sharks per 100 hook hours	sharks per net hour	sharks per net hour

V1



V2



DFA #1: Combined Gulf and Atlantic

- Results

TXPWD-Gillnet	GULFSPAN	COASTSPAN - LL	SCCOASTGN - LONG	SCCOASTGN - SHORT
SEDAR77 DW-16	SEDAR77 DW-17	SEDAR77-DW-30	SEDAR77-DW-31	SEDAR77 DW-32
Gulf of Mexico	Gulf of Mexico	Atlantic	Atlantic	Atlantic
sharks per net per hour	sharks per net per hour	sharks per 100 hook hours	sharks per net hour	sharks per net hour

- Fit ratios (Fit ratio >=0.6 suggest poor fit)
- V1

```
>  FitRatio
  Survey1   Survey2   Survey3   Survey4   Survey5
0.6907538 0.2845292 0.5466649 0.6591031 0.6637722
>  mean(FitRatio)
[1] 0.5689646
```

  - Survey 2, Good fit; but Survey 1, 4, 5 poor fit;
- V2

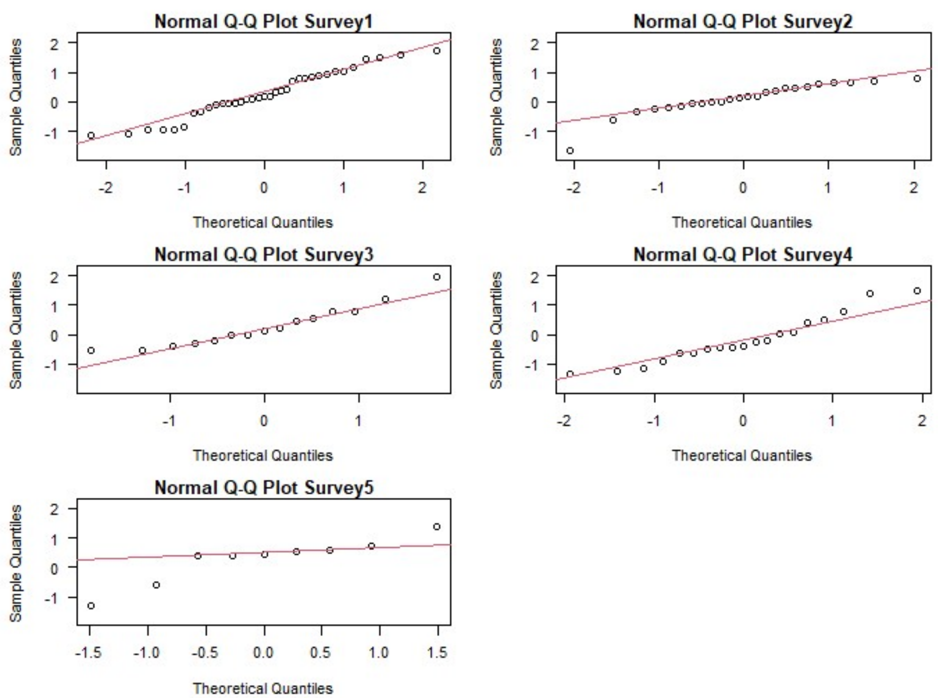
```
>  FitRatio
  Survey1   Survey2   Survey3   Survey4   Survey5
0.7185246 0.4142706 0.4177663 0.6360371 0.4331884
>  mean(FitRatio)
[1] 0.5239574
```

- Survey 1 and 4 similar poor fit as in V1
- Survey 2 reduced fit compared to V1
- Survey 3 and 4 improved fit compared to V1
  - Overall fit ratio improved

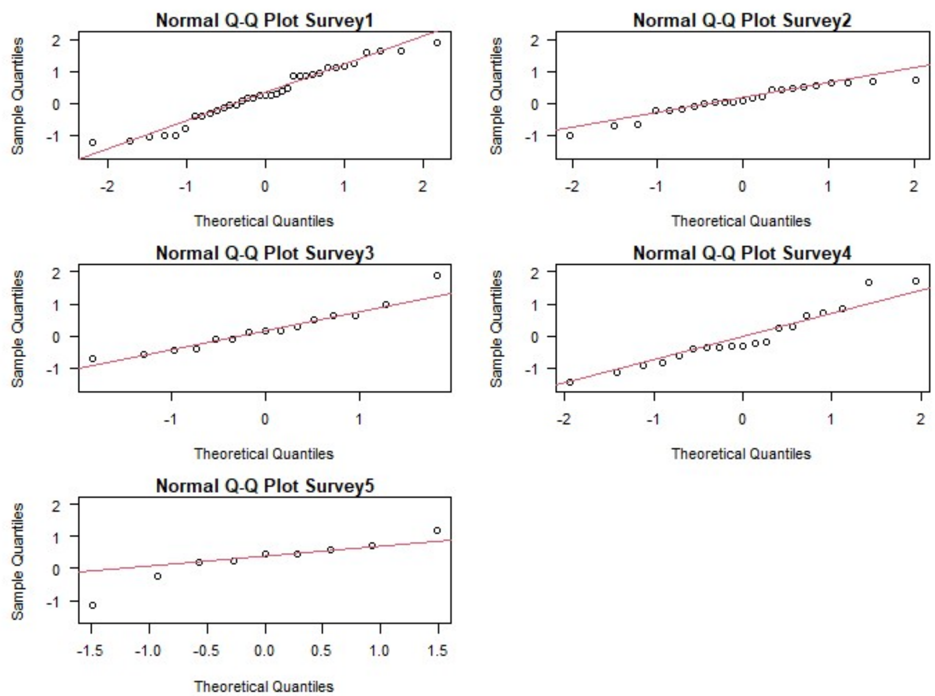
DFA #1: Combined Gulf and Atlantic

- Manual QQ plots “raw residuals” from fit (dat.z-fit.b)
- Survey 2 skewed in both V1 and V2
- Survey 5 has low sample size

V1



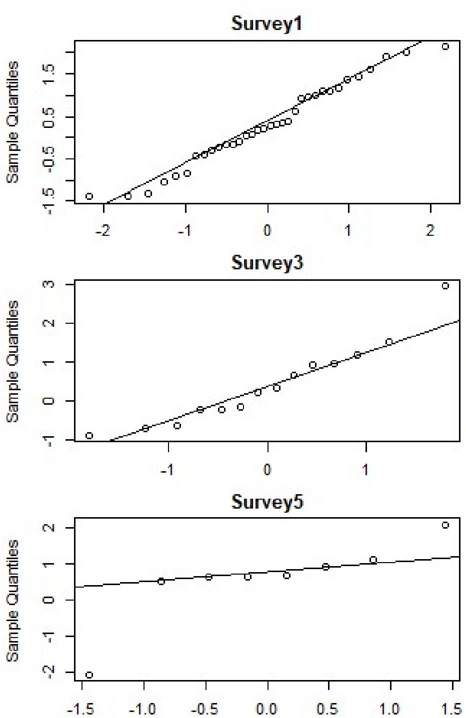
V2



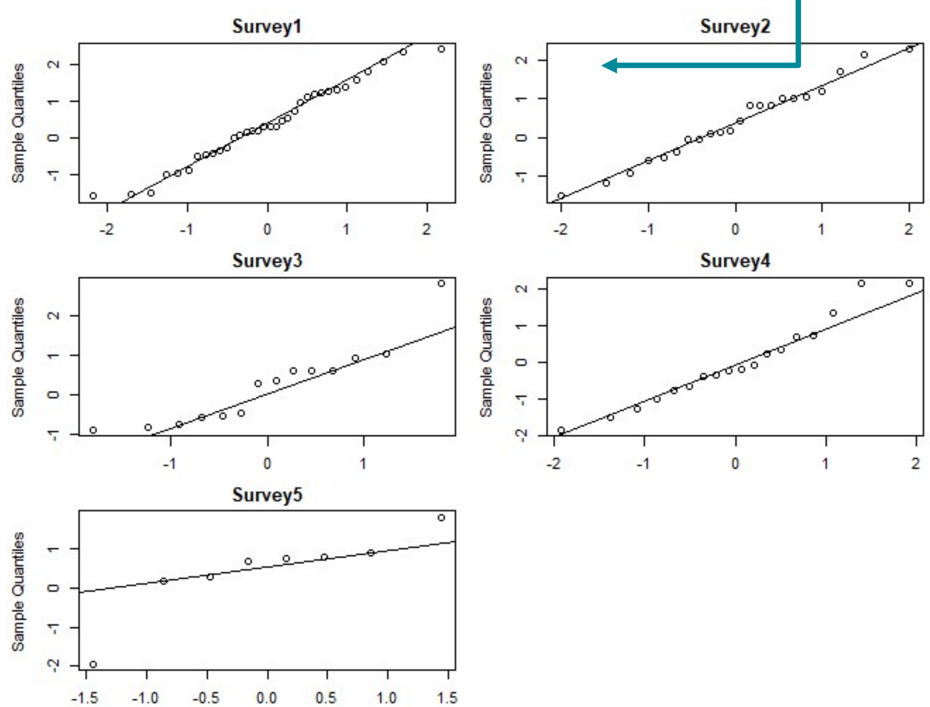
DFA #1: Combined Gulf and Atlantic

- QQ plots “standardized residuals”
- Survey 2 still has some skew in V1 but reduced in V2

V1



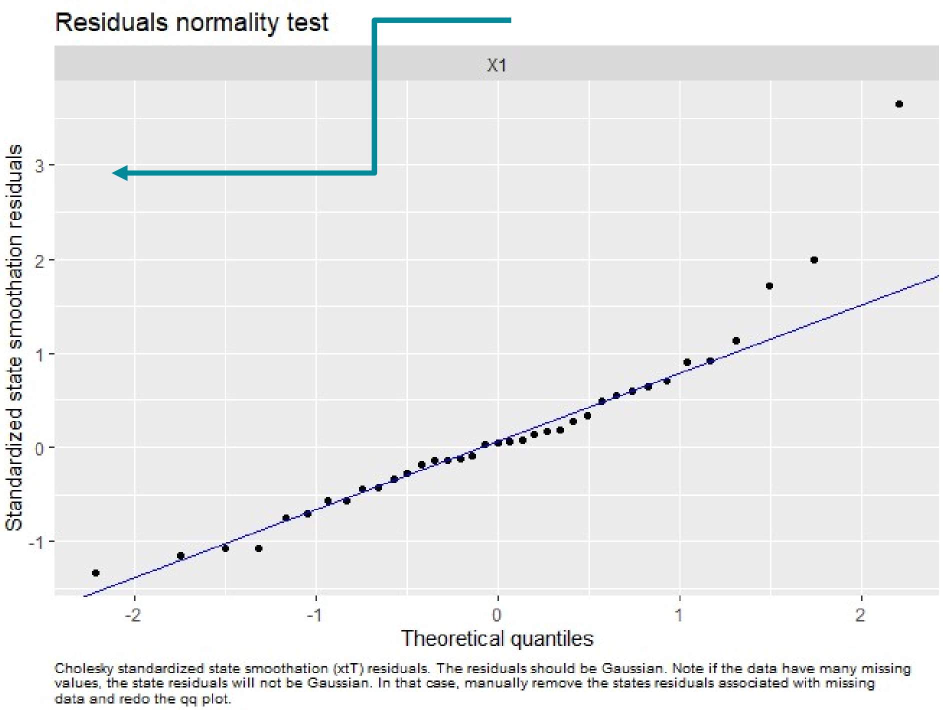
V2



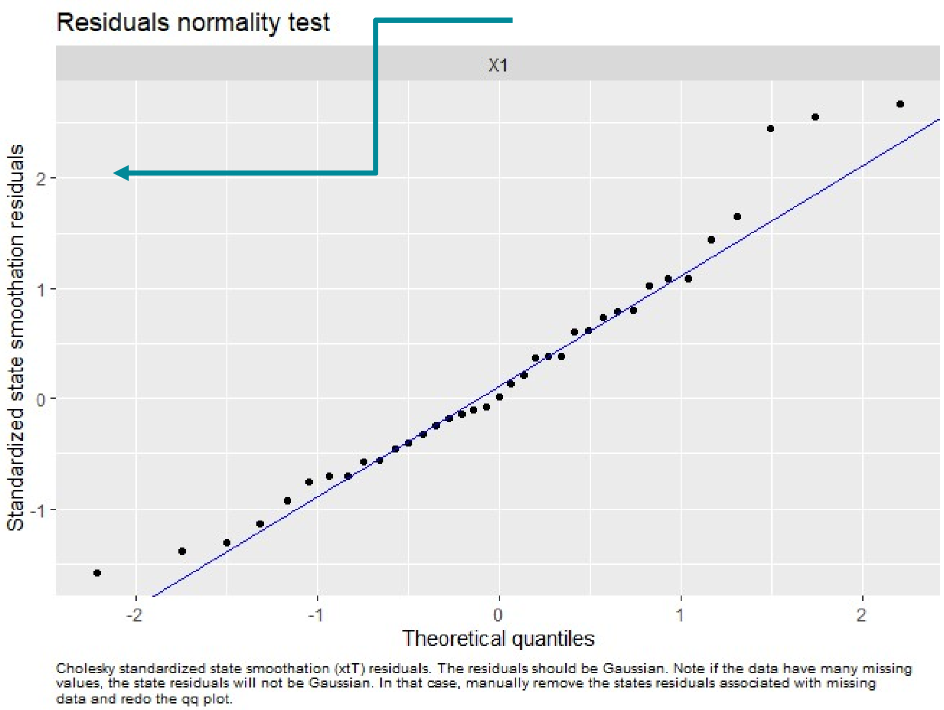
DFA #1: Combined Gulf and Atlantic

- QQ plots State Vector “standardized residuals”
- Some skew, but reduced in V2

V1



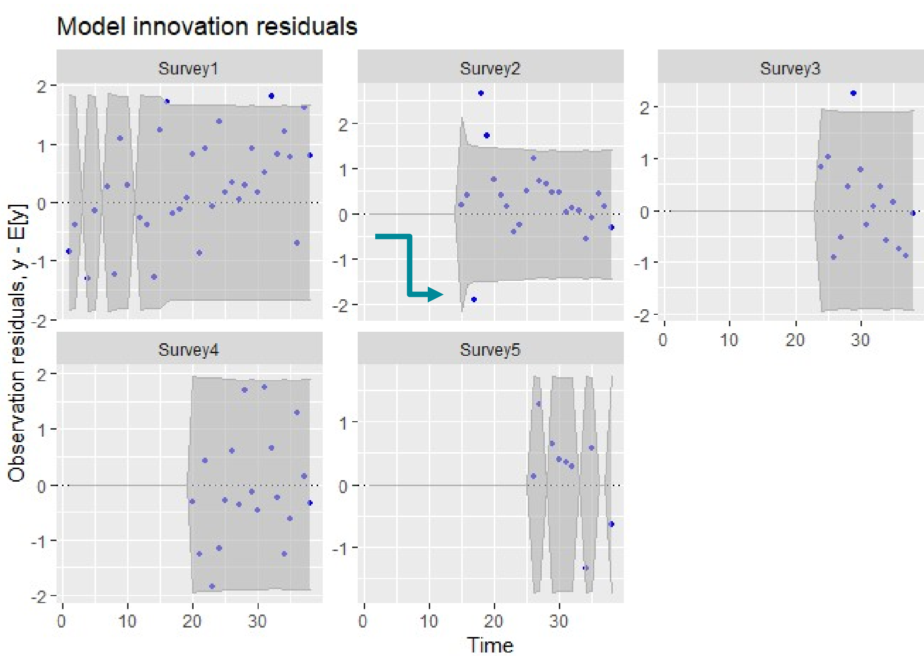
V2



DFA #1: Combined Gulf and Atlantic

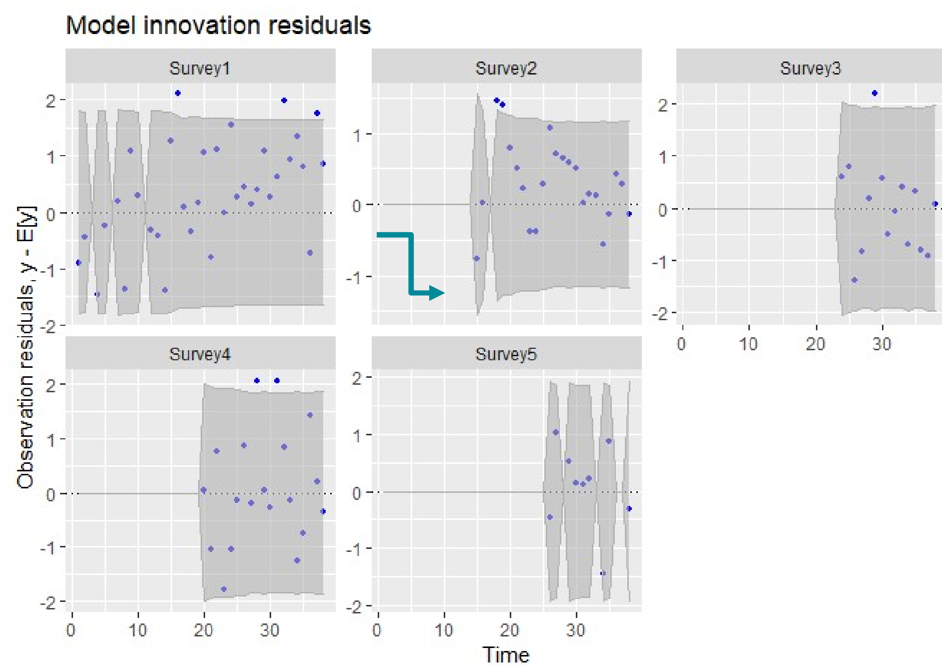
- Analysis of survey residuals to fit
- Survey 2 residual pattern reduced in V2

V1



Innovations (one-step ahead) residuals. These residuals should not have a temporal trend and 95% of residuals should fall within the CIs. A violation of this indicates that the model cannot fit the data.

V2

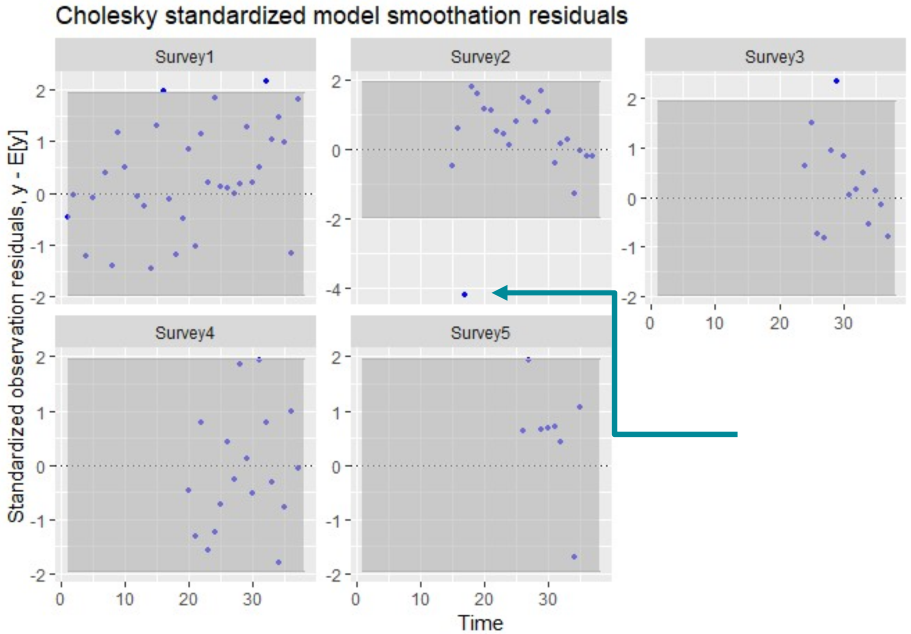


Innovations (one-step ahead) residuals. These residuals should not have a temporal trend and 95% of residuals should fall within the CIs. A violation of this indicates that the model cannot fit the data.

DFA #1: Combined Gulf and Atlantic

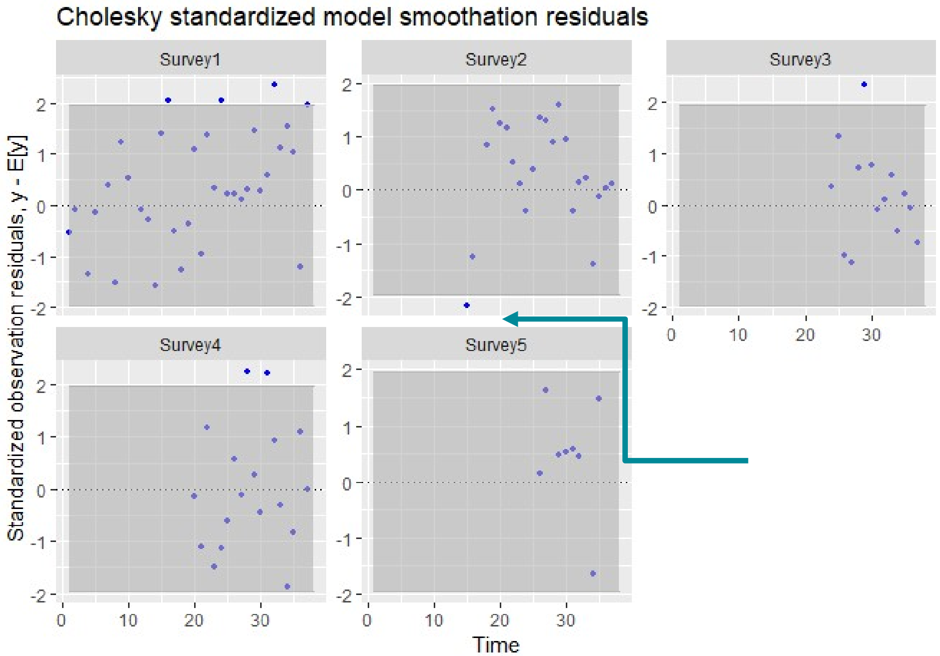
- Analysis of survey standardized residuals
- Scale (influence) of Survey 2 outliers reduced in V2

V1



Cholesky standardized model smoothation (ytT) residuals. These residuals should not have a temporal trend. Residuals outside the +/- 2 limits are potential outliers.

V2

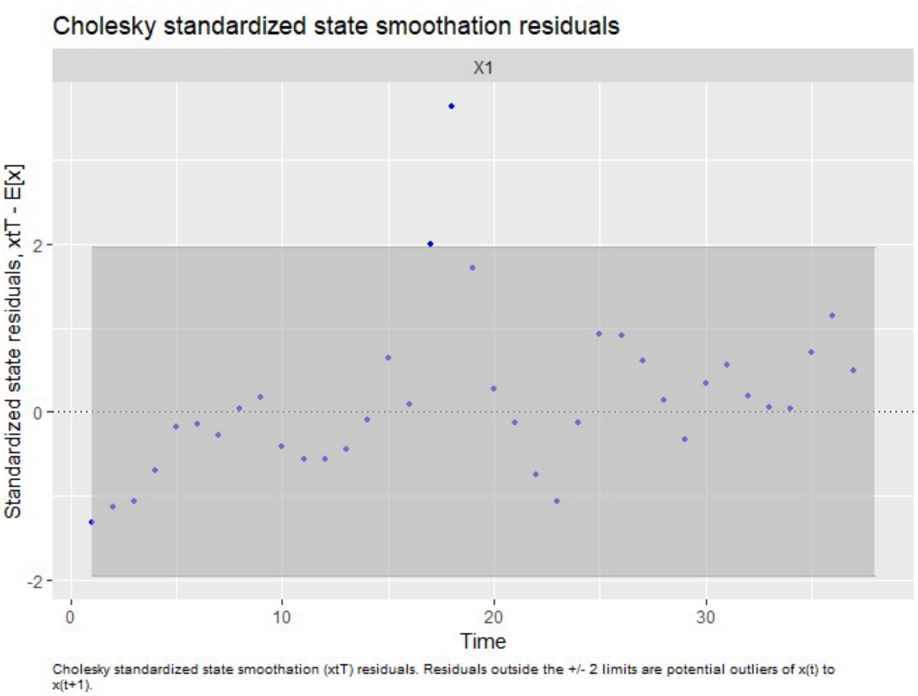


Cholesky standardized model smoothation (ytT) residuals. These residuals should not have a temporal trend. Residuals outside the +/- 2 limits are potential outliers.

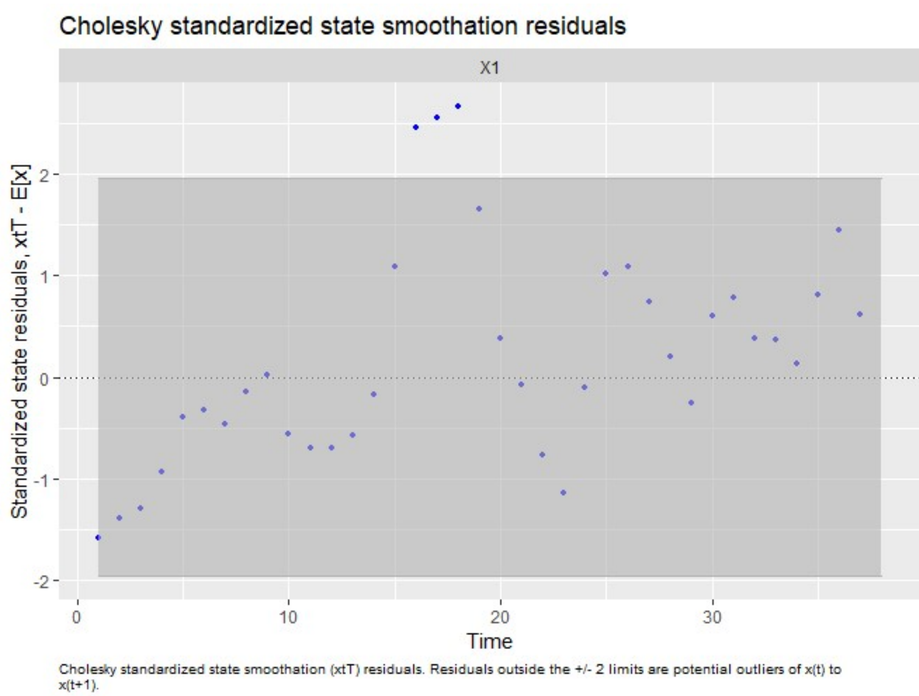
DFA #1: Combined Gulf and Atlantic

- Analysis of state vector standardized residuals
- Scale (influence) of outliers reduced but trend remains V2

V1



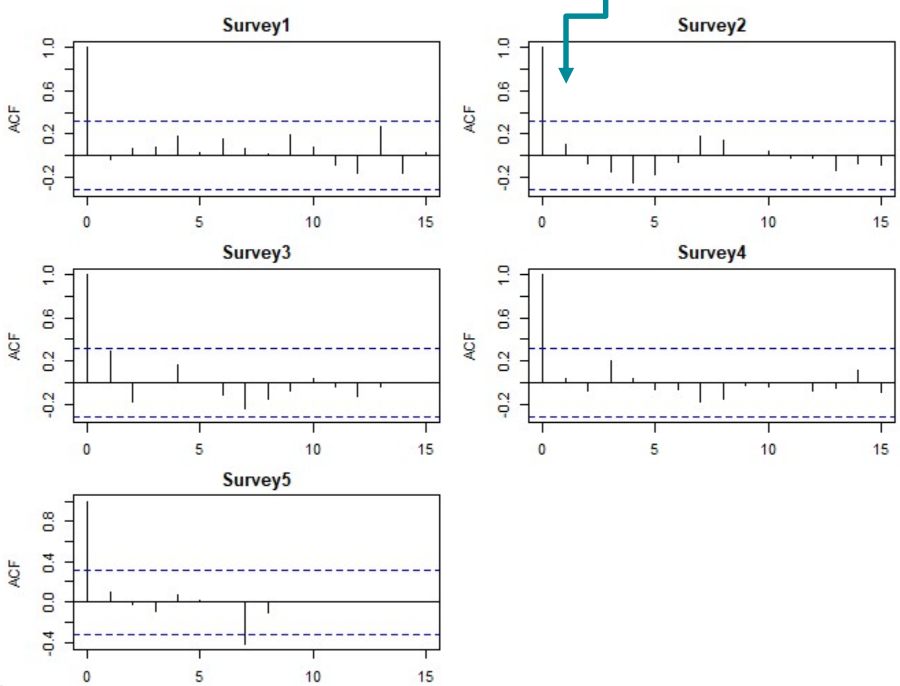
V2



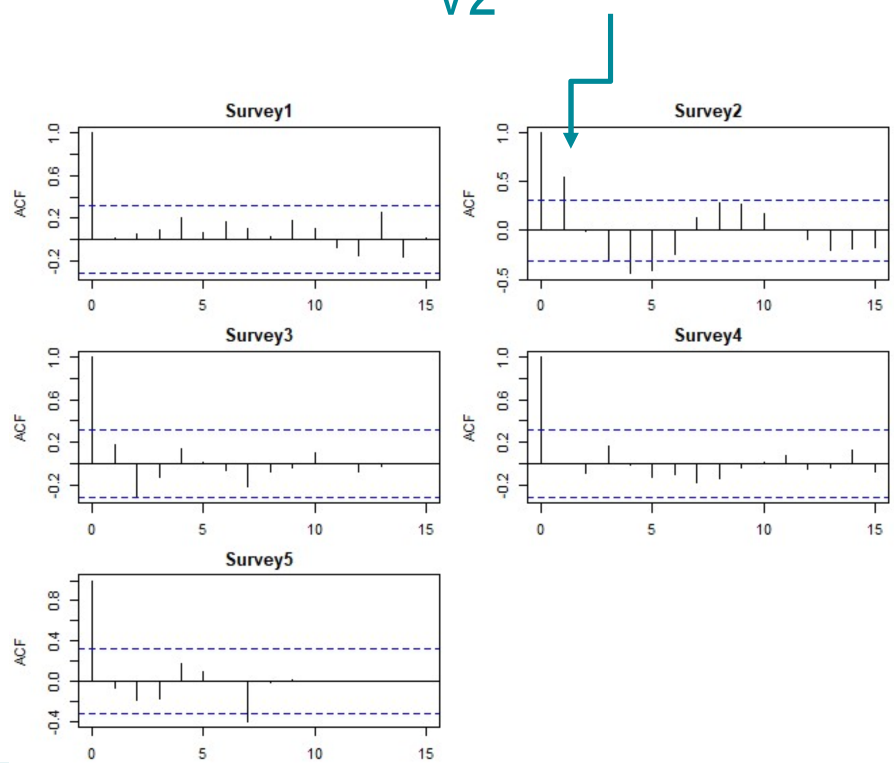
DFA #1: Combined Gulf and Atlantic

- Analysis of standardized residuals autocorrelation (acf)
- Survey 2 has autocorrelation (significant at lag 1 in V2)

V1



V2



DFA #1: Combined Gulf and Atlantic (V2)

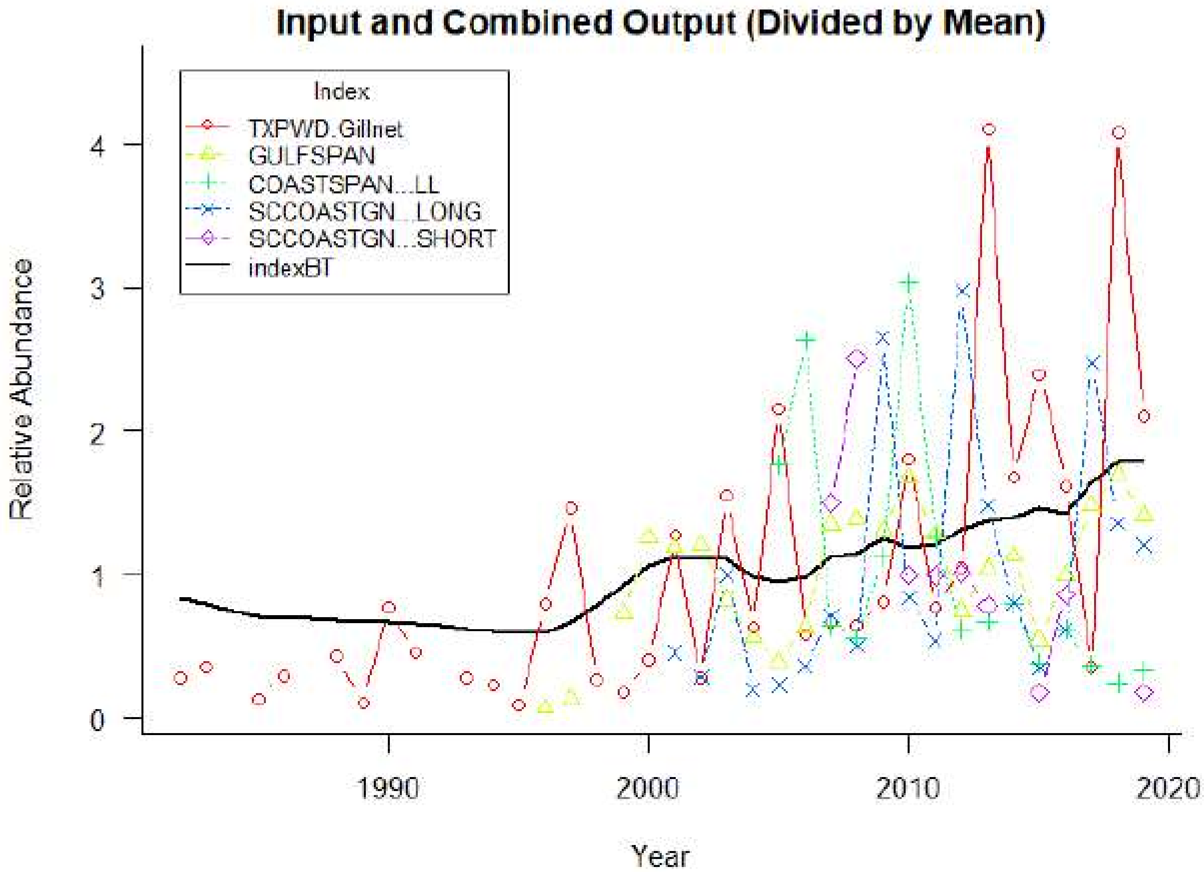


Figure 1. Raw time-series of relative abundance indices for age-0 individuals for combined Gulf of Mexico and Atlantic indices (Table 1) along with back-transformed common trend resulting from the DFA model fitted to the age-0 time-series of relative abundance (Table 3). All indices are divided by their mean for plotting.

DFA #1: Combined Gulf and Atlantic (V2)

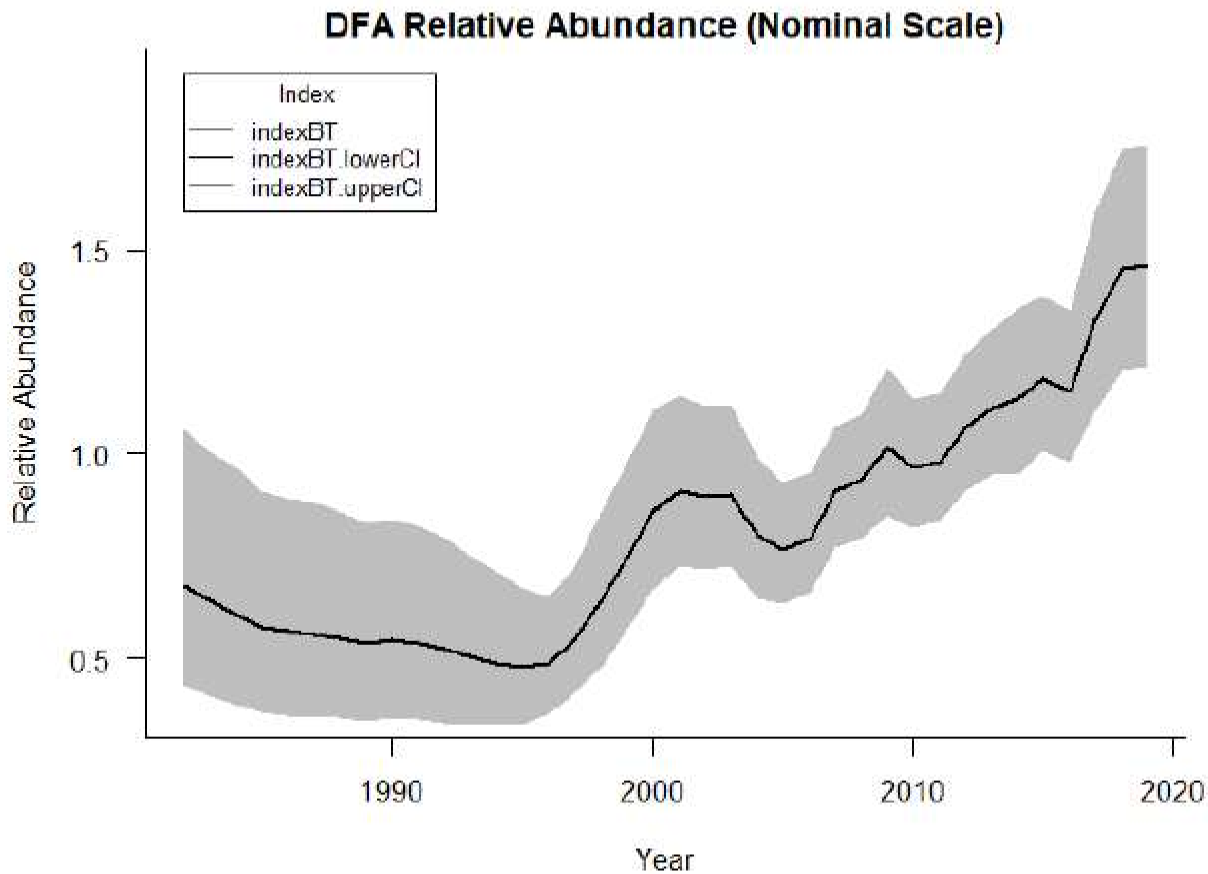


Figure 4. Back-transformed common trend resulting from the DFA model fitted to the age-0 time-series of relative abundance for combined Gulf of Mexico and Atlantic (Table 3). The shaded interval denotes the approximate 95% confidence interval.

DFA #1: Combined Gulf and Atlantic (V2)

- **Decision**
- **Recommend V2 for use in Sensitivity Analysis**
- Remove outlier survey 2 (1998)

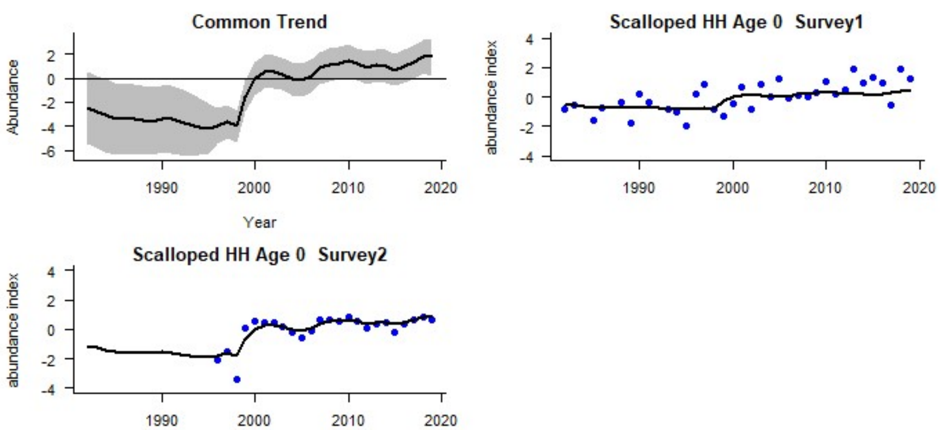
TXPWD-Gillnet	GULFSPAN		COASTSPAN - LL	SCCOASTGN - LONG	SCCOASTGN - SHORT
SEDAR77 DW-16	SEDAR77 DW-17		SEDAR77-DW-30	SEDAR77-DW-31	SEDAR77 DW-32
Gulf of Mexico	Gulf of Mexico		Atlantic	Atlantic	Atlantic
sharks per net per hour	sharks per net per hour		sharks per 100 hook hours	sharks per net hour	sharks per net hour
	index	CV			
	0.009	0.294			
	0.016	0.461			
	0.002	0.548			

DFA #2: Gulf

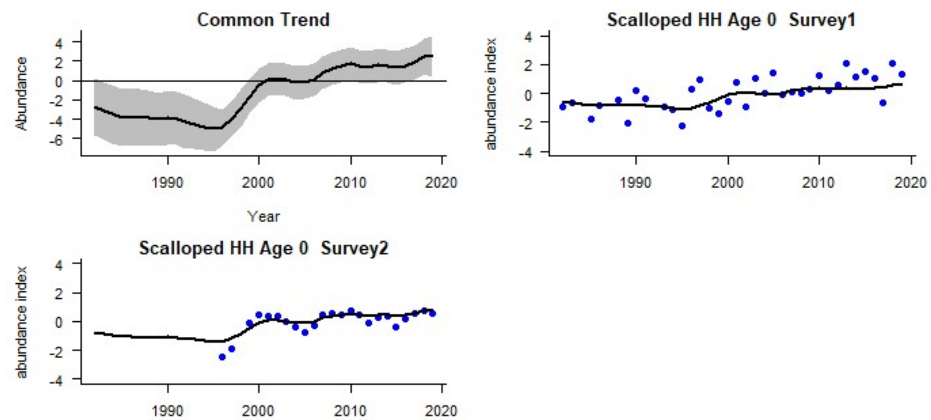
- Results

TXPWD-Gillnet	GULFSPAN
SEDAR77 DW-16	SEDAR77 DW-17
Gulf of Mexico	Gulf of Mexico
sharks per net per hour	sharks per net per hour

V1



V2

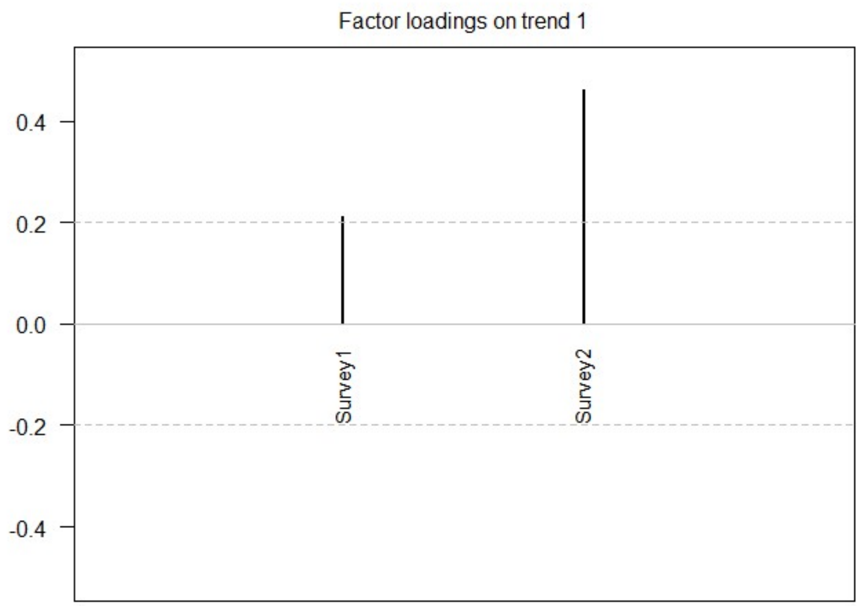


DFA #2: Gulf

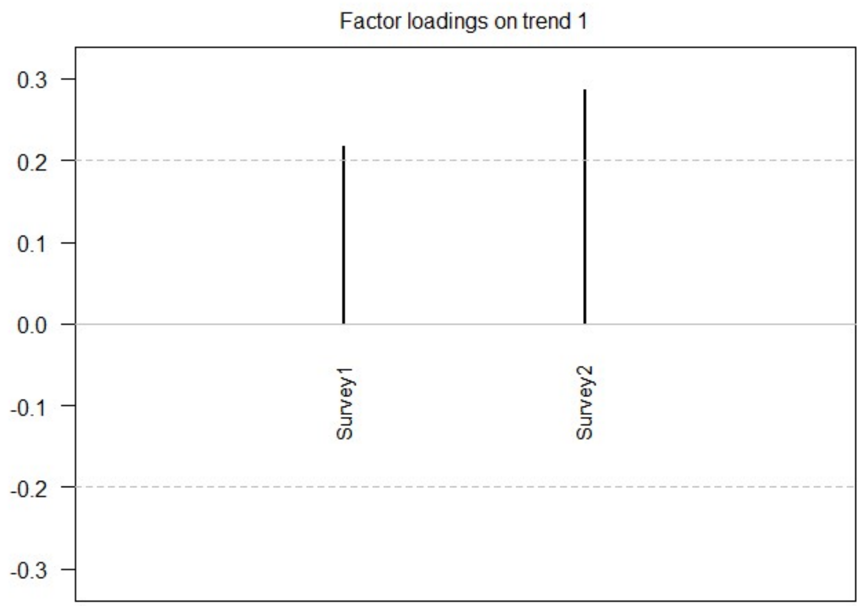
- Results

TXPWD-Gillnet	GULFSPAN
SEDAR77 DW-16	SEDAR77 DW-17
Gulf of Mexico	Gulf of Mexico
sharks per net per hour	sharks per net per hour

V1



V2



DFA #2: Gulf

- Results

TXPWD-Gillnet	GULFSPAN
SEDAR77 DW-16	SEDAR77 DW-17
Gulf of Mexico	Gulf of Mexico
sharks per net per hour	sharks per net per hour

- Fit ratios (Fit ratio >=0.6 suggest poor fit)
- V1

```
>   FitRatio
  Survey1   Survey2
0.6521836 0.1869621
>   mean(FitRatio)
[1] 0.4195729
```

  - Survey 2, Good fit; but Survey 1, 4, 5 poor fit;
- V2

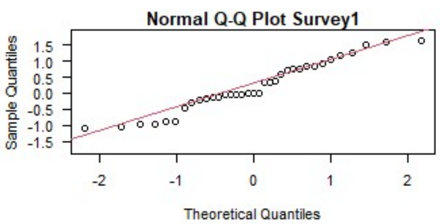
```
>   FitRatio
  Survey1   Survey2
0.6227688 0.3028268
>   mean(FitRatio)
[1] 0.4627978
```

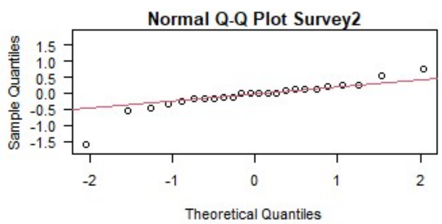
- Survey 1 similar poor fit as in V1
- Survey 2 reduced fit compared to V1
  - Overall fit ratio slightly worse than V1

DFA #2: Gulf

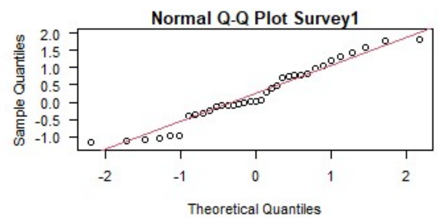
- Manual QQ plots “raw residuals” from fit (dat.z-fit.b)
- Survey 2 skewed in both V1 and V2

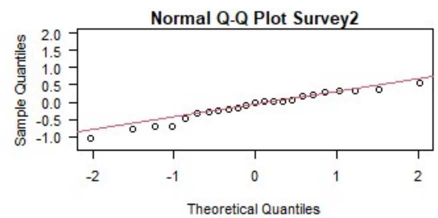
V1





V2

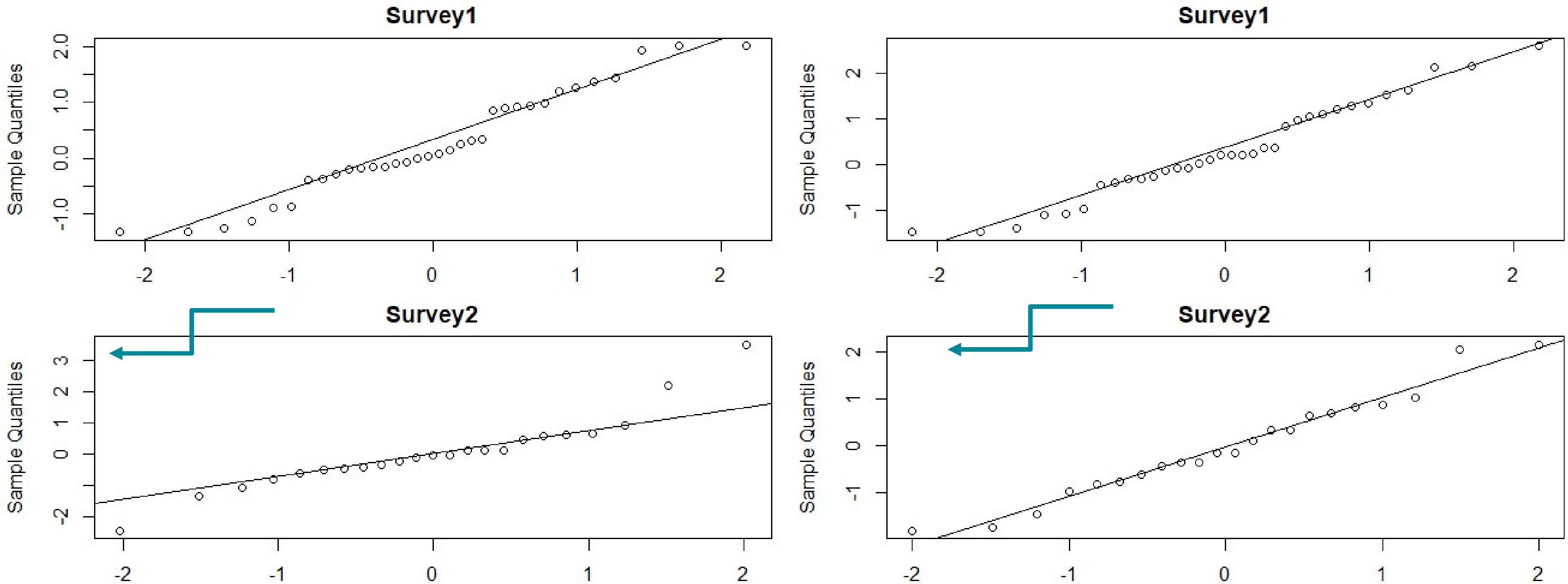




DFA #2: Gulf

- QQ plots “standardized residuals”
- Survey 2 skew in V1 reduced in V2

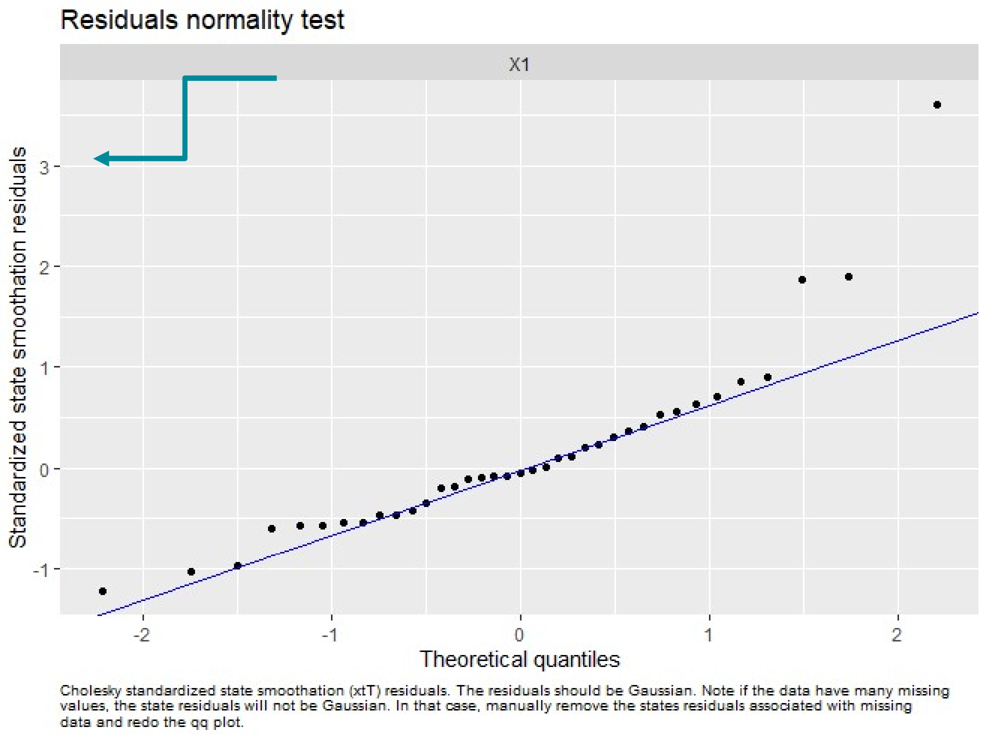
V1 V2



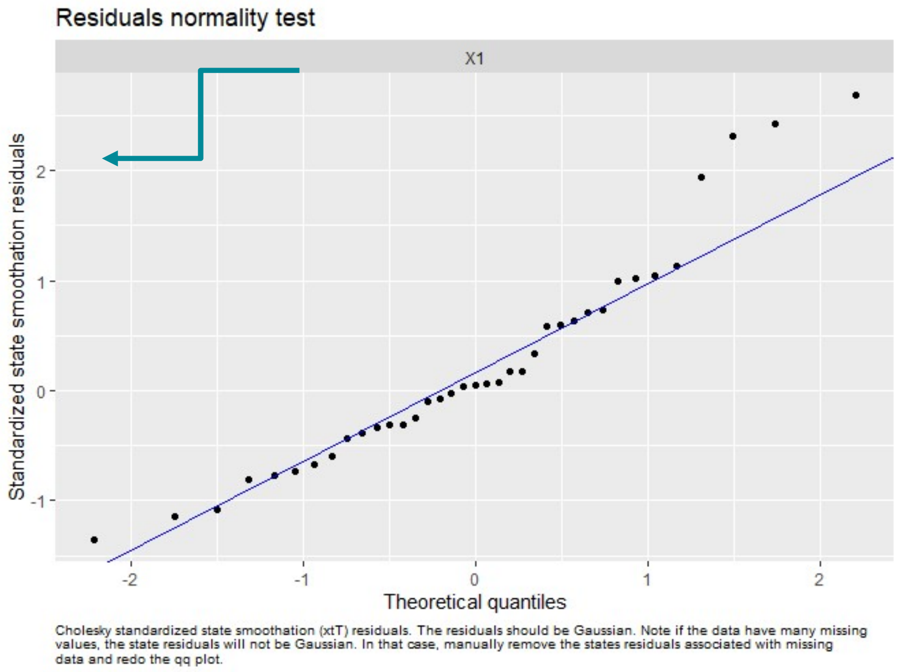
DFA #2: Gulf

- QQ plots state vector “standardized residuals”
- Some skew, but reduced in V2

V1



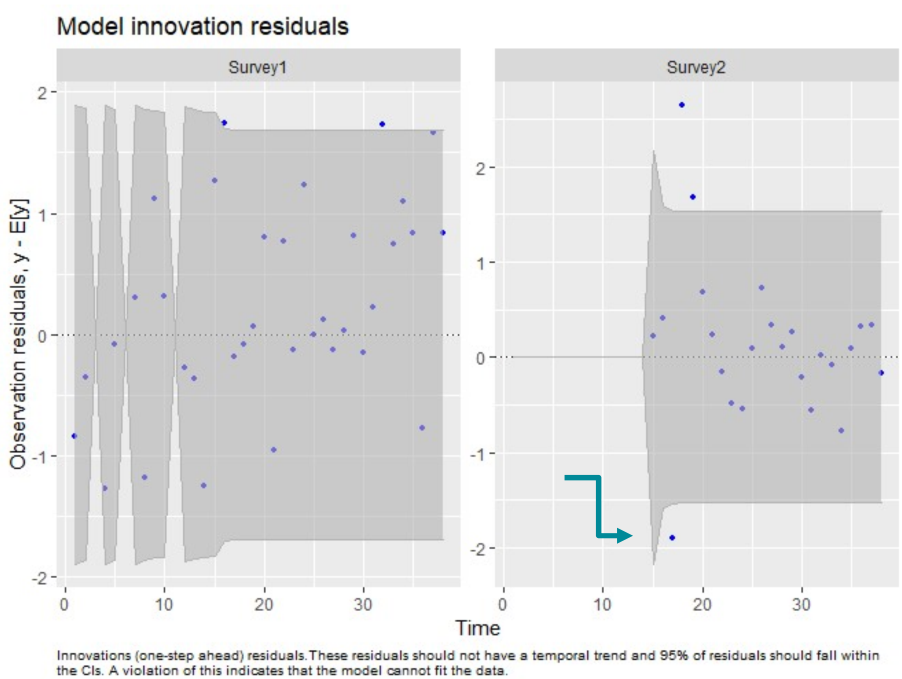
V2



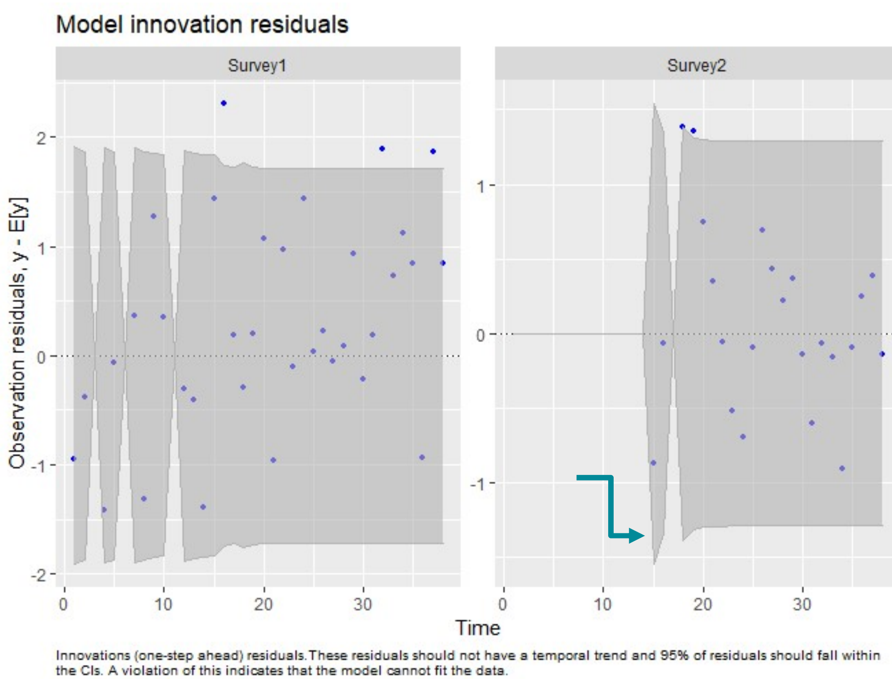
DFA #2: Gulf

- Analysis of survey residuals to fit
- Survey 2 outlier pattern reduced in V2

V1



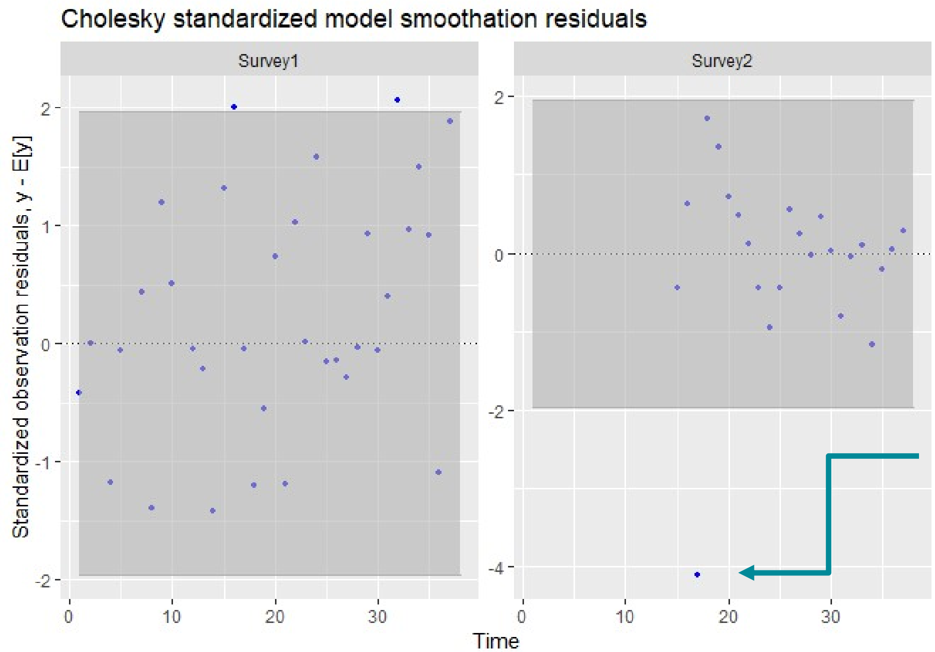
V2



DFA #2: Gulf

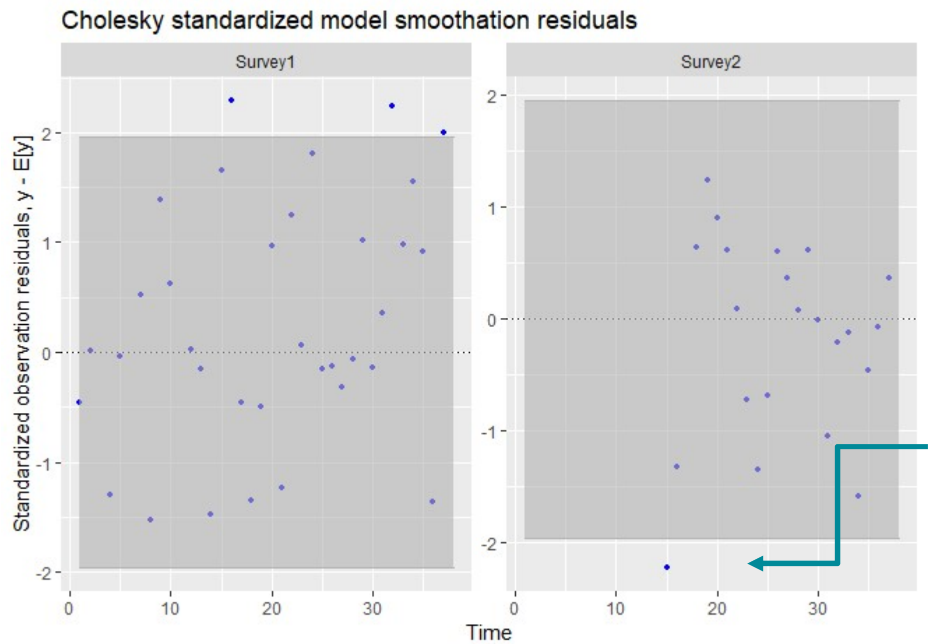
- Analysis of survey standardized residuals
- Scale (influence) of Survey 2 outliers reduced in V2

V1



Cholesky standardized model smoothation (ytT) residuals. These residuals should not have a temporal trend. Residuals outside the +/- 2 limits are potential outliers.

V2

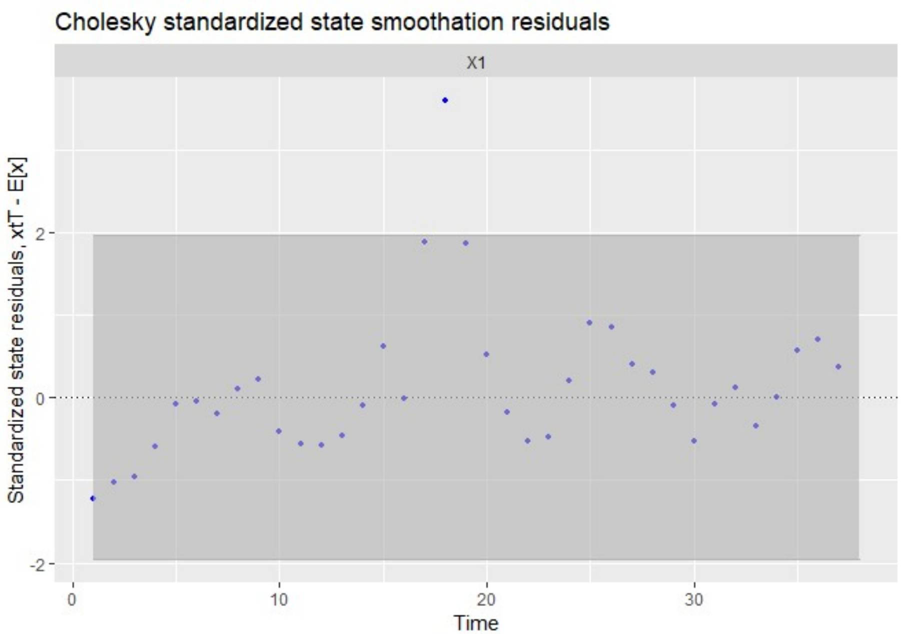


Cholesky standardized model smoothation (ytT) residuals. These residuals should not have a temporal trend. Residuals outside the +/- 2 limits are potential outliers.

DFA #2: Gulf

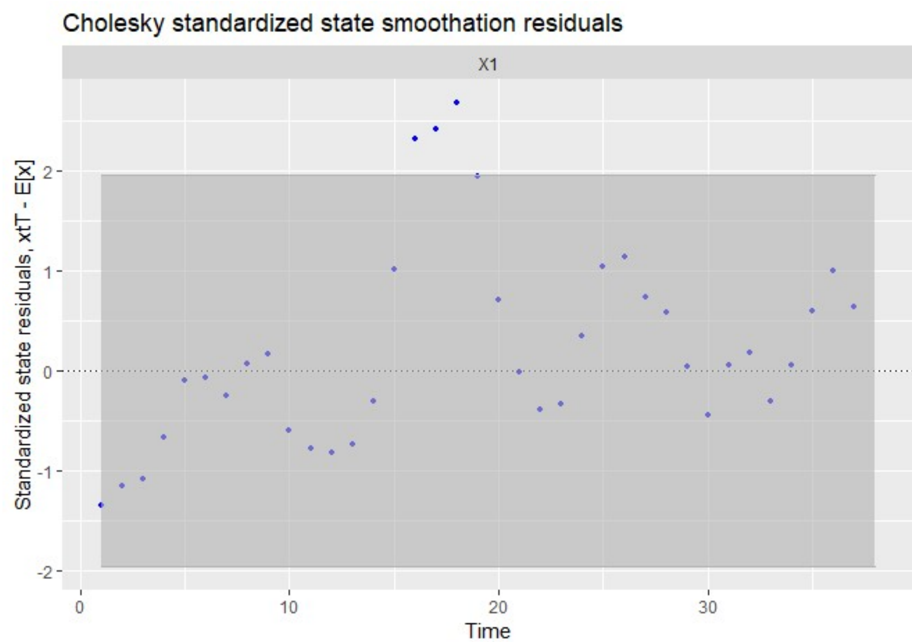
- Analysis of state vector standardized residuals
- Scale (influence) of outliers reduced but trend remains V2

V1



Cholesky standardized state smoothation (xtT) residuals. Residuals outside the +/- 2 limits are potential outliers of x(t) to x(t+1).

V2

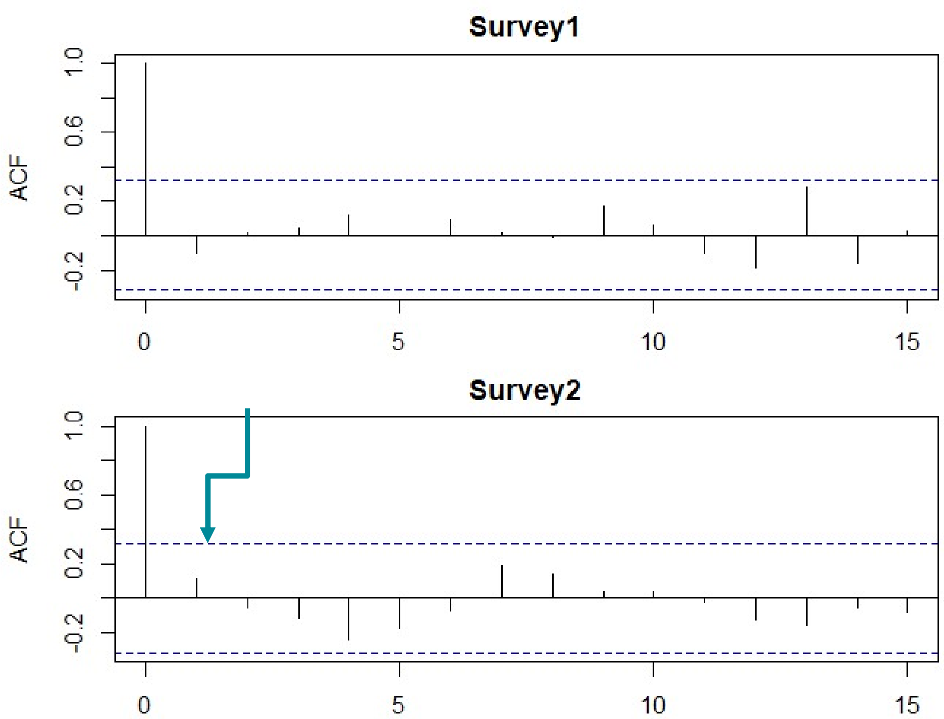


Cholesky standardized state smoothation (xtT) residuals. Residuals outside the +/- 2 limits are potential outliers of x(t) to x(t+1).

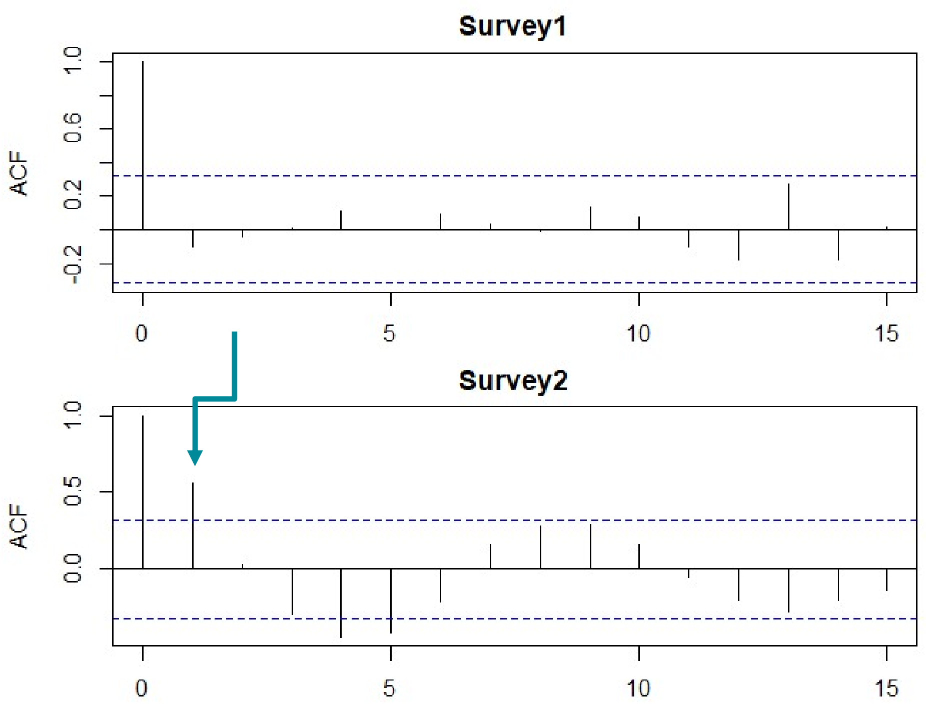
DFA #2: Gulf

- Analysis of standardized residuals autocorrelation (acf)
- Survey 2 has autocorrelation (significant at lag 1 in V2)

V1



V2



DFA #2: Gulf (V2)

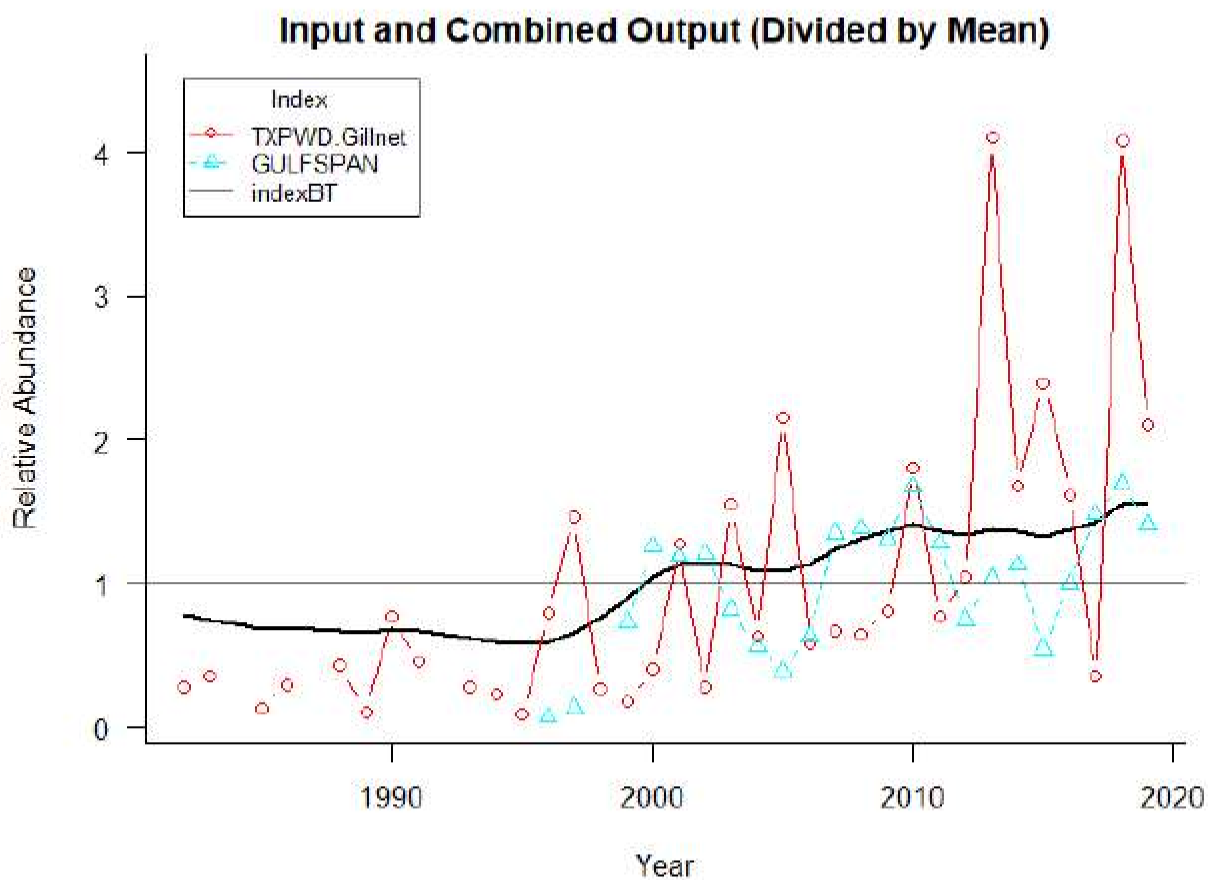


Figure 5. Raw time-series of relative abundance indices for age-0 individuals for Gulf of Mexico indices (Table 1) along with back-transformed common trend resulting from the DFA model fitted to the age-0 time-series of relative abundance (Table 3). All indices are divided by their mean for plotting.

DFA #2: Gulf (V2)

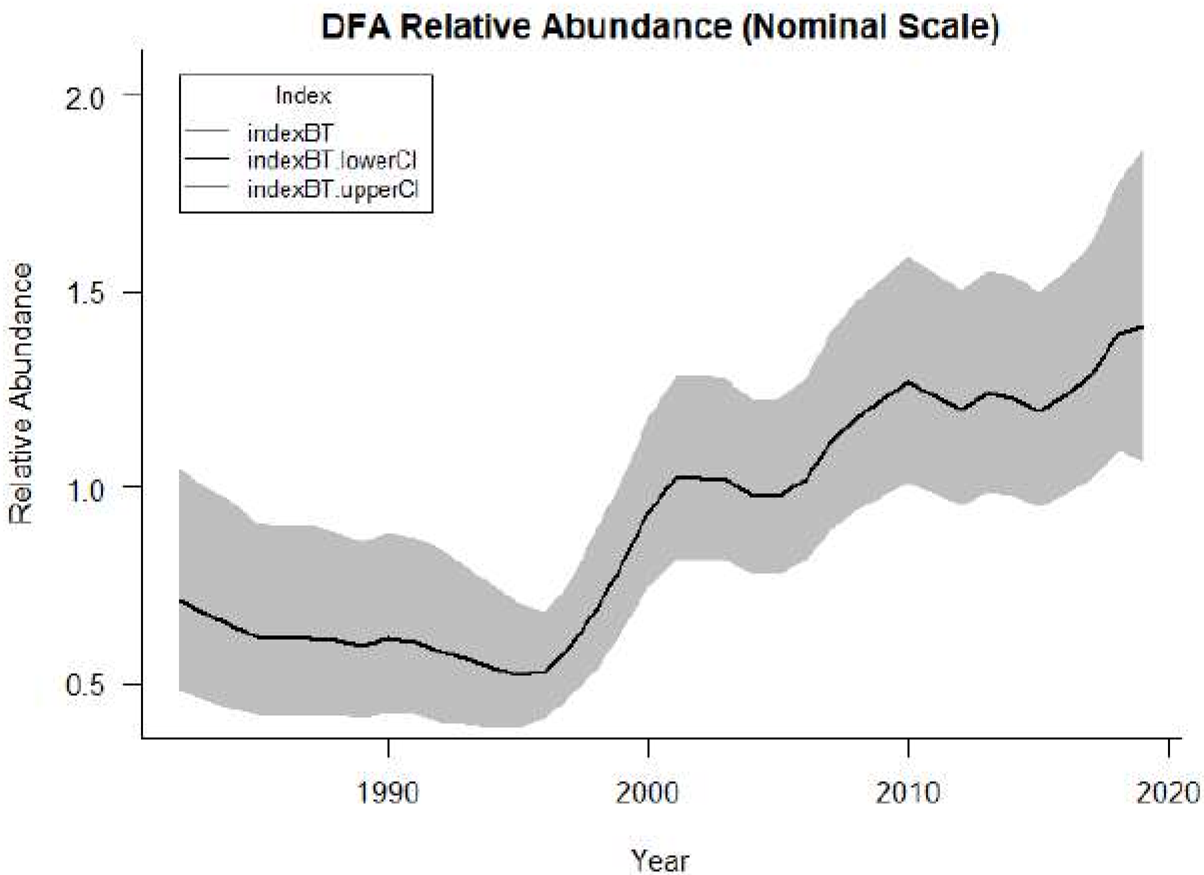


Figure 8. Back-transformed common trend resulting from the DFA model fitted to the age-0 time-series of relative abundance for Gulf of Mexico (Table 3). The shaded interval denotes the approximate 95% confidence interval.

DFA #2: Gulf (V2)

- **Decision**
- **Recommend V2 for use in Sensitivity Analysis**
- Remove outlier survey 2 (1998)

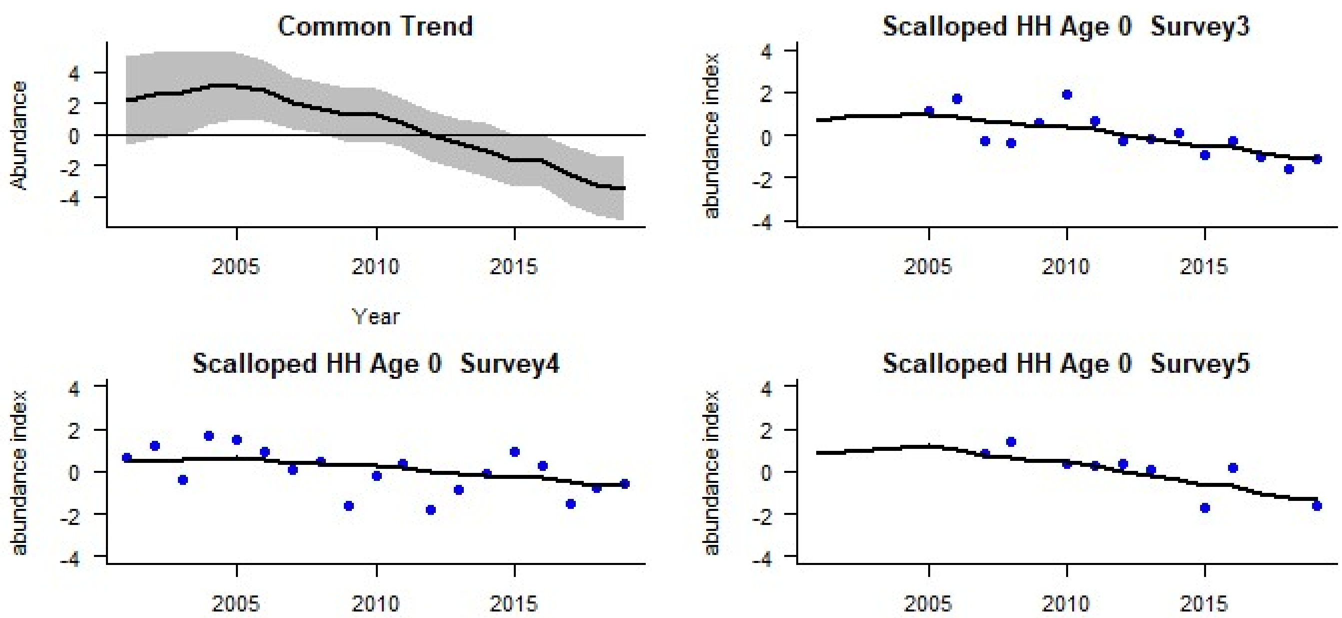
TXPWD-Gillnet
SEDAR77 DW-16
Gulf of Mexico
sharks per net per hour

GULFSPAN	
SEDAR77 DW-17	
Gulf of Mexico	
sharks per net per hour	
index	CV
0.009	0.294
0.016	0.461
0.002	0.548

DFA #3: Atlantic

- Results

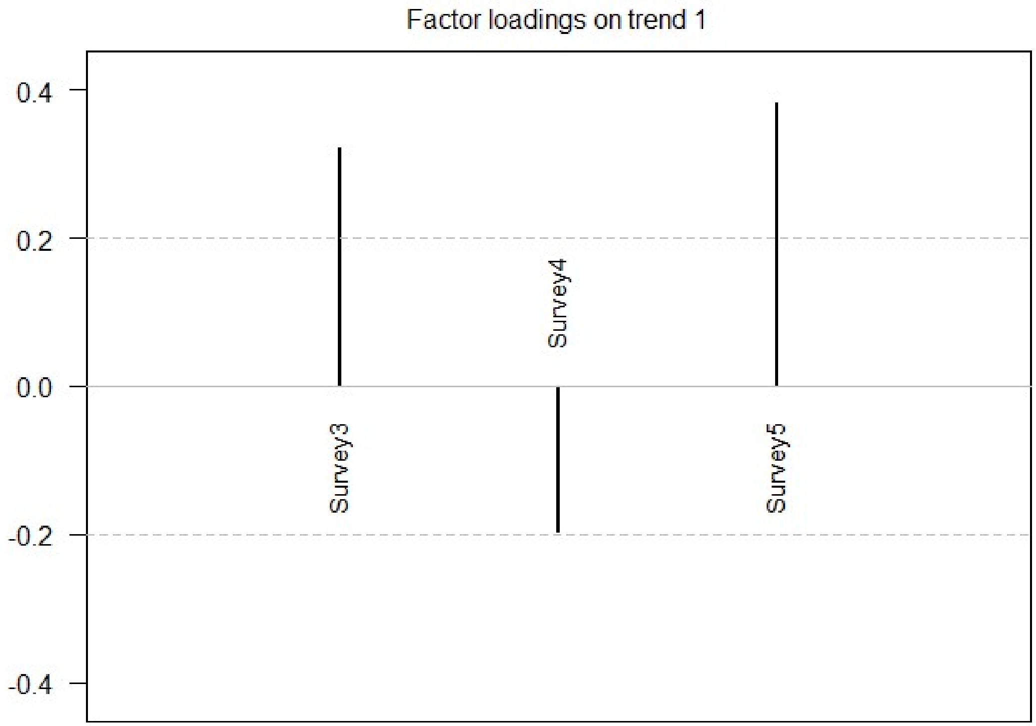
COASTSPAN - LL	SCCOASTGN - LONG	SCCOASTGN - SHORT
SEDAR77-DW-30	SEDAR77-DW-31	SEDAR77 DW-32
Atlantic	Atlantic	Atlantic
sharks per 100 hook hours	sharks per net hour	sharks per net hour



DFA #3: Atlantic

- Results

COASTSPAN - LL	SCCOASTGN - LONG	SCCOASTGN - SHORT
SEDAR77-DW-30	SEDAR77-DW-31	SEDAR77 DW-32
Atlantic	Atlantic	Atlantic
sharks per 100 hook hours	sharks per net hour	sharks per net hour



DFA #3: Atlantic

- Results

COASTSPAN - LL	SCCOASTGN - LONG	SCCOASTGN - SHORT
SEDAR77-DW-30	SEDAR77-DW-31	SEDAR77 DW-32
Atlantic	Atlantic	Atlantic
sharks per 100 hook hours	sharks per net hour	sharks per net hour

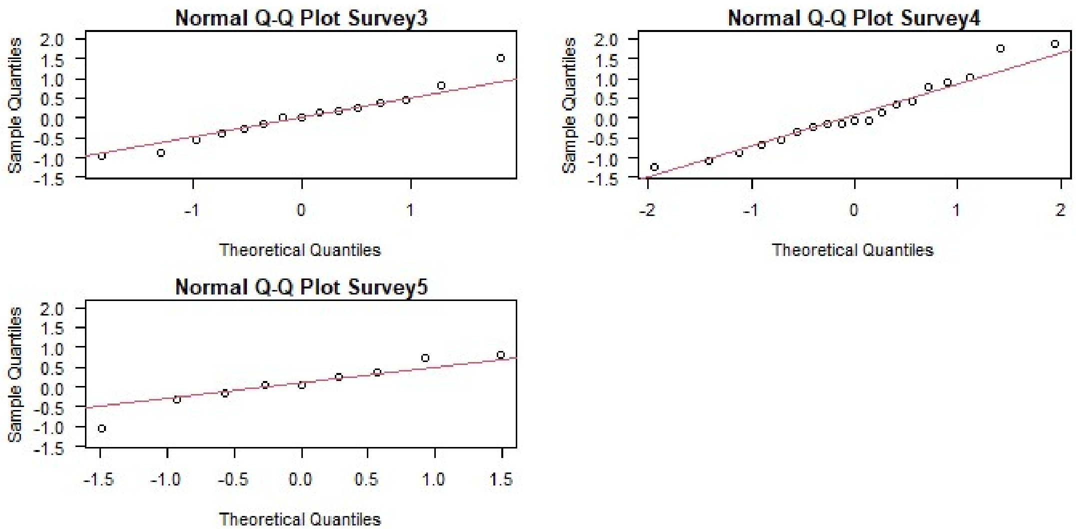
- Fit ratios (Fit ratio >=0.6 suggest poor fit)

```
>   FitRatio
  Survey3   Survey4   Survey5
0.3782546 0.7334609 0.3071547
>   mean(FitRatio)
[1] 0.4729567
```

- Fit to Survey 4 is poor (Fit ratio >=0.6)

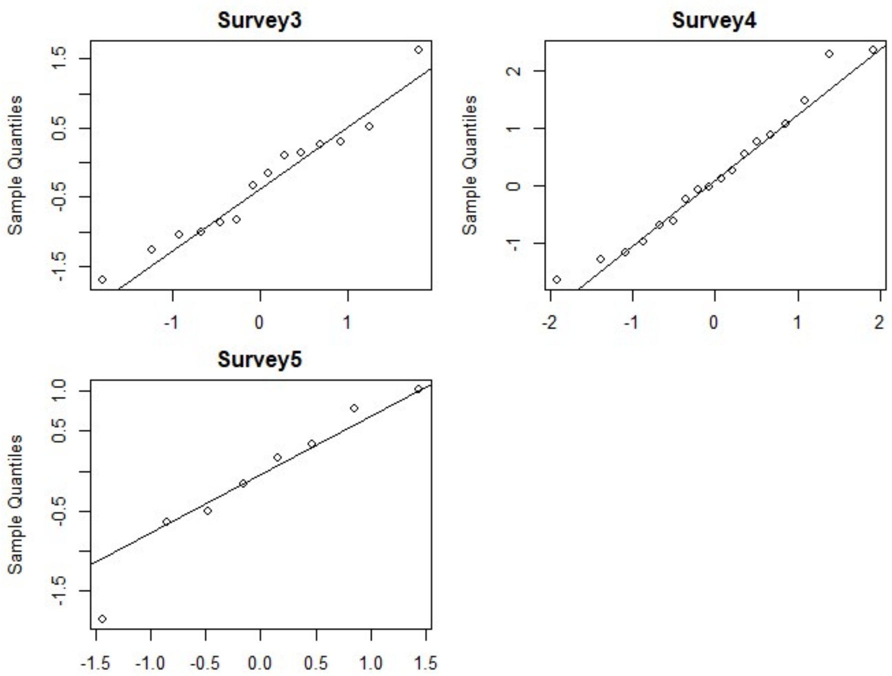
DFA #3: Atlantic

- Manual QQ plots “raw residuals” from fit (dat.z-fit.b)
- Survey 3 and 4 reasonable
- Survey 5 has low sample size



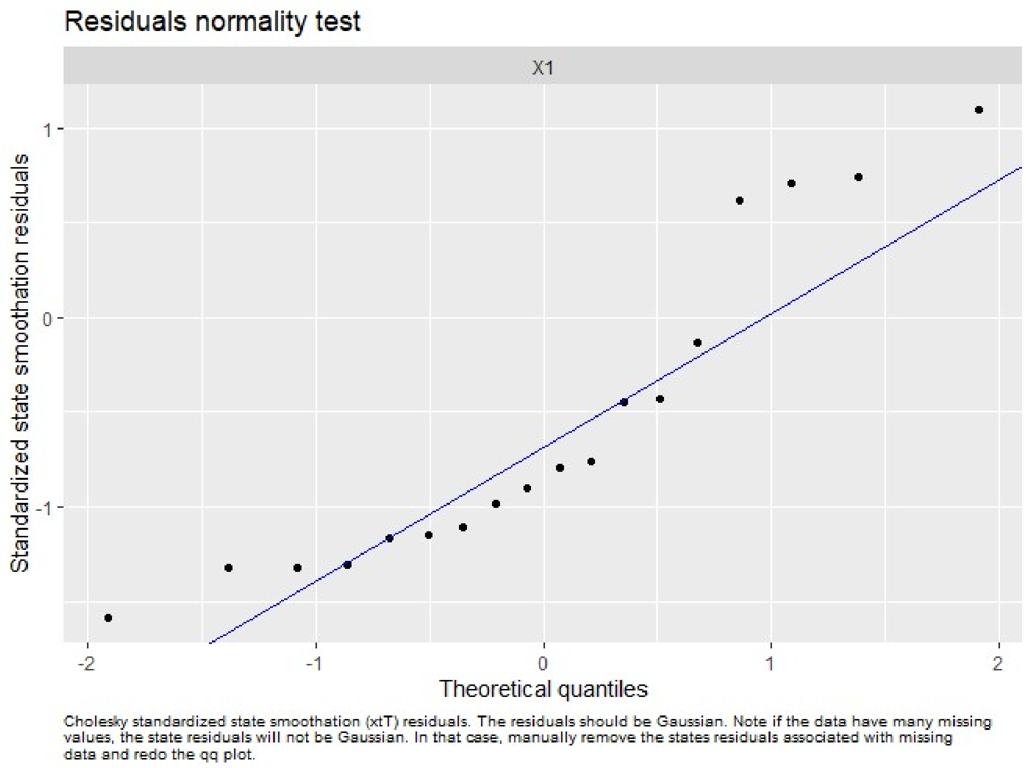
DFA #3: Atlantic

- QQ plots “standardized residuals”
- Survey 3 and 4 reasonable
- Survey 5 has low sample size



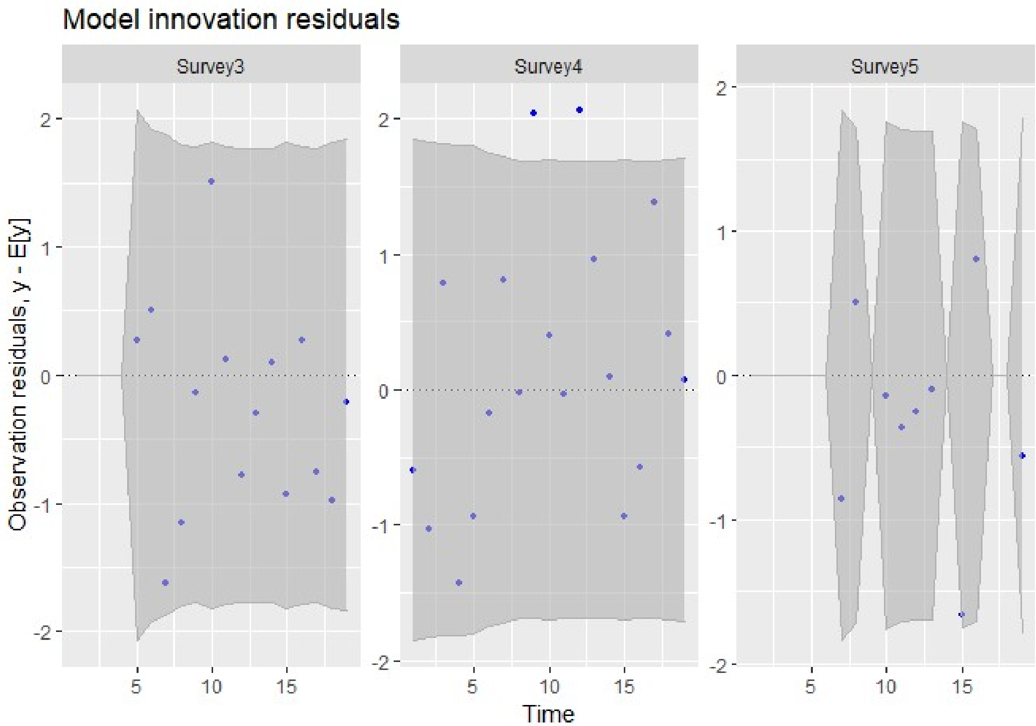
DFA #3: Atlantic

- QQ plots state vector “standardized residuals”
- Some skew but reasonable



DFA #3: Atlantic

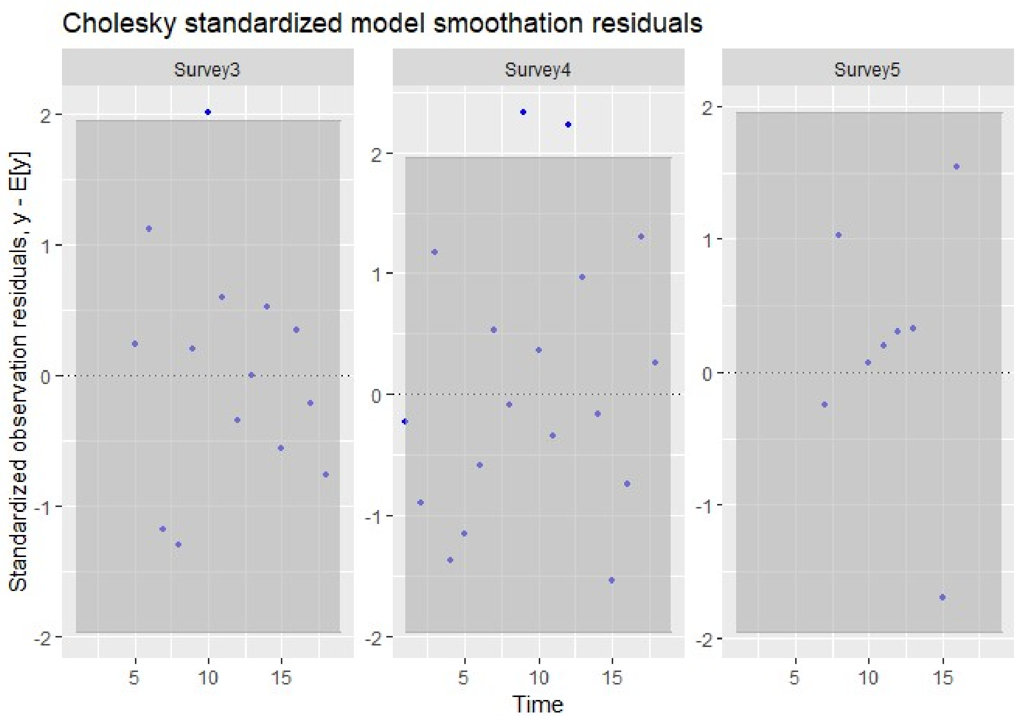
- Analysis of survey residuals to fit
- Some outlier pattern similar to DFA #1 and #2 V2 above



Innovations (one-step ahead) residuals. These residuals should not have a temporal trend and 95% of residuals should fall within the CIs. A violation of this indicates that the model cannot fit the data.

DFA #3: Atlantic

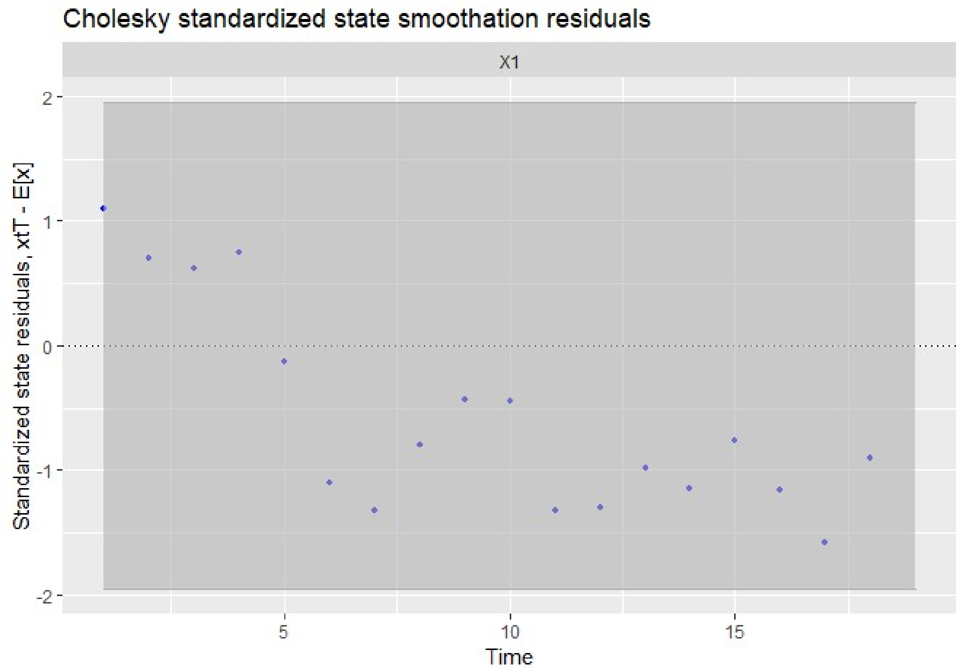
- Analysis of survey standardized residuals
- Scale (influence) of outliers similar to DFA #1 and #2 V2



Cholesky standardized model smoothation (ytT) residuals. These residuals should not have a temporal trend. Residuals outside the +/- 2 limits are potential outliers.

DFA #3: Atlantic

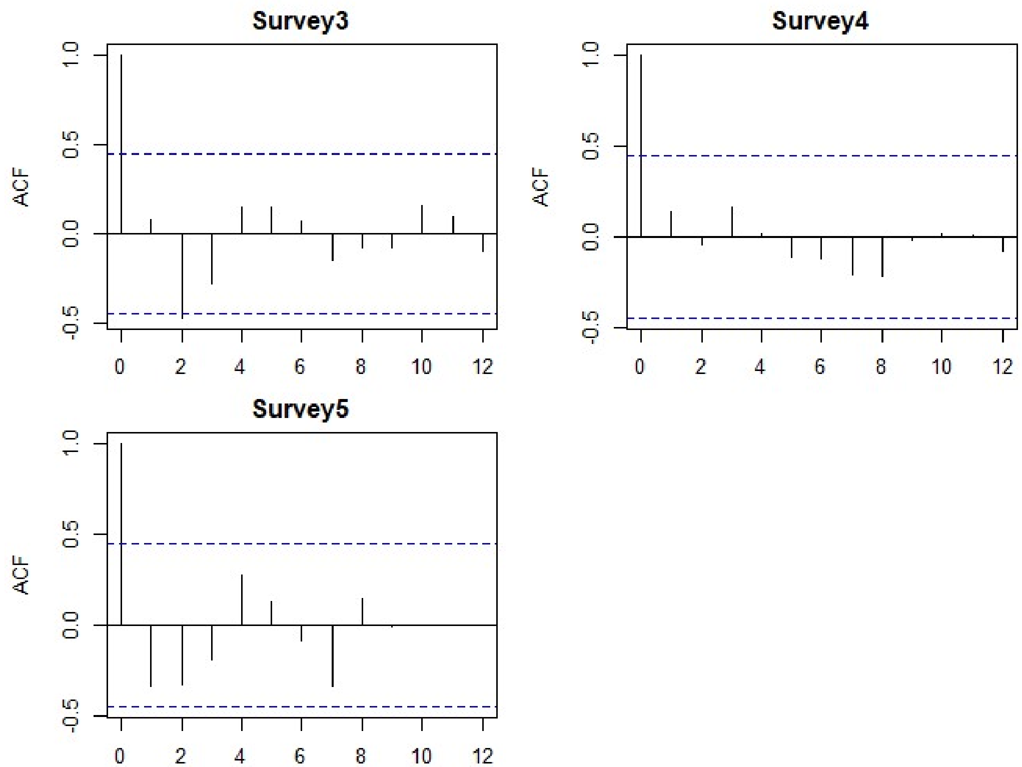
- Analysis of state vector standardized residuals
- Scale (influence) of outliers reduced relative to survey,
  - but there is some pattern in residuals



Cholesky standardized state smoothation (xtT) residuals. Residuals outside the +/- 2 limits are potential outliers of x(t) to x(t+1).

DFA #3: Atlantic

- Analysis of standardized residuals autocorrelation (acf)
- Survey 3 has some autocorrelation (significant at lag 2)



DFA #3: Atlantic

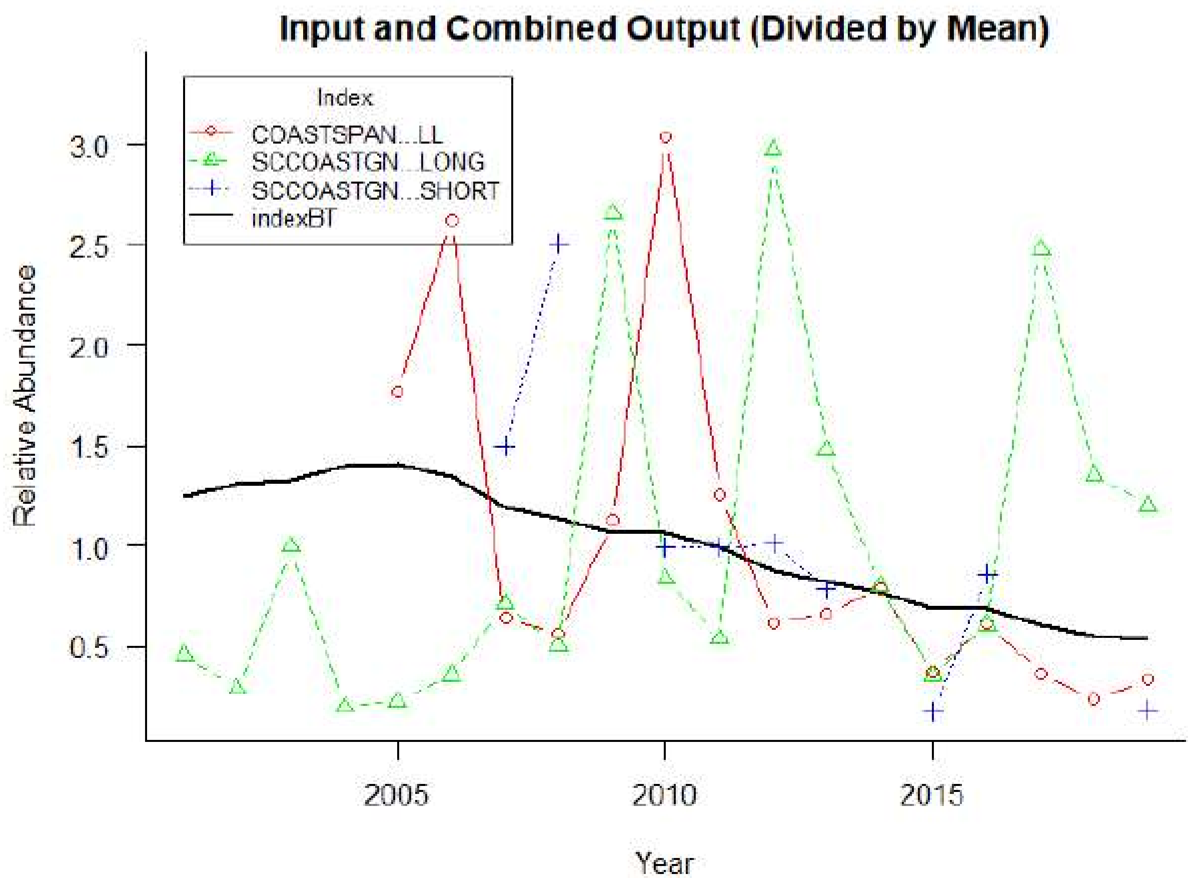


Figure 9. Raw time-series of relative abundance indices for age-0 individuals for Atlantic indices (Table 1) along with back-transformed common trend resulting from the DFA model fitted to the age-0 time-series of relative abundance (Table 3). All indices are divided by their mean for plotting.

DFA #3: Atlantic

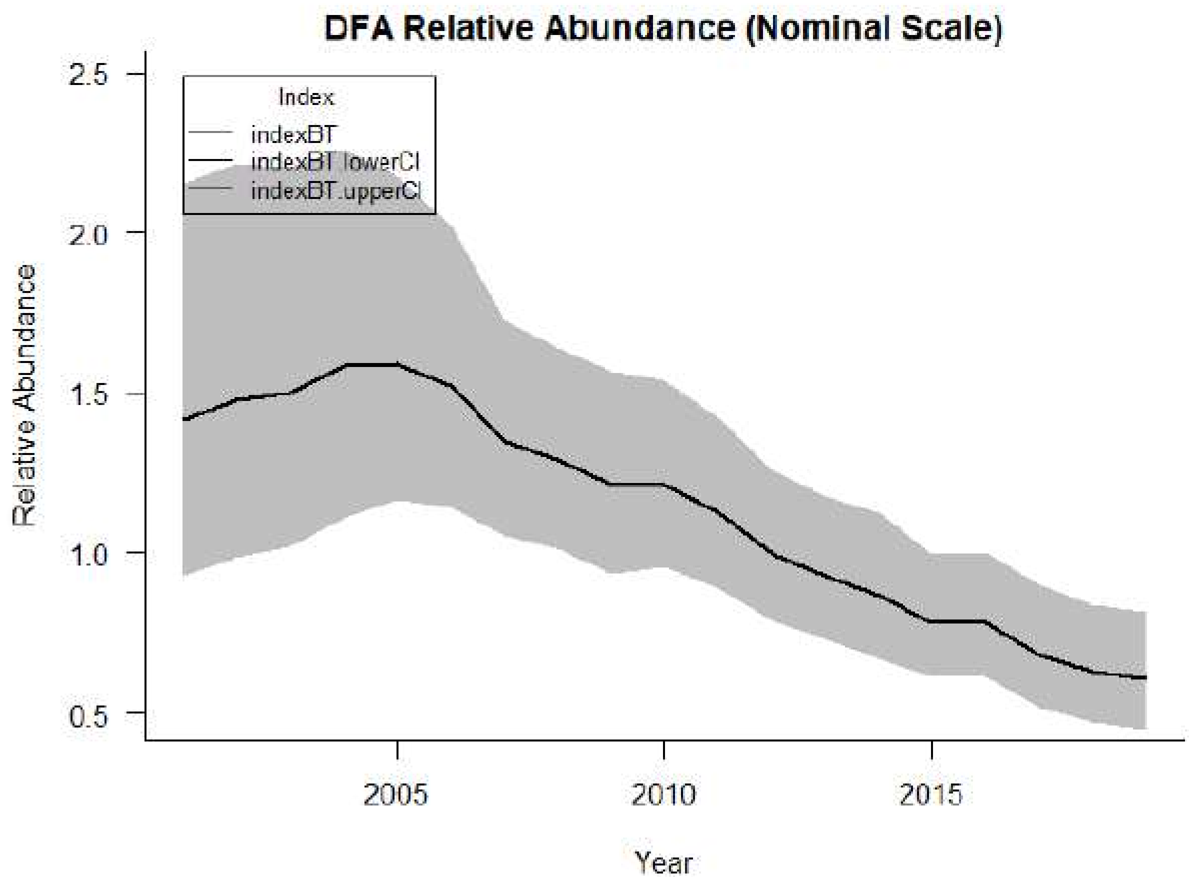


Figure 12. Back-transformed common trend resulting from the DFA model fitted to the age-0 time-series of relative abundance for Atlantic (Table 3). The shaded interval denotes the approximate 95% confidence interval.

DFA #3: Atlantic

- Decision
- Recommend for use in Sensitivity Analysis