Hoki stock assessment (FNZ Project code HOK2019-03) Phase 1: Model development

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Report to Deepwater Working Group

25 May 2020

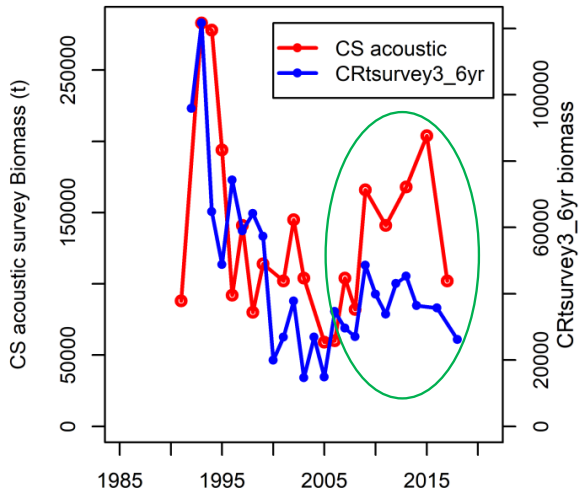
Introduction

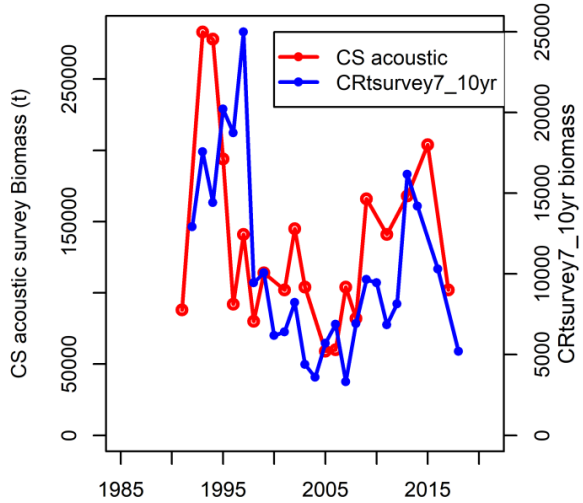
- Preliminary (= Exploratory) phase of HOK stock assessment project.
- Develop a final model structure (or structures) for stock assessment. Preliminary modelling due to be completed November 2020. Final assessment due to be completed in May 2021.
- Modelling – data included up to 2017/18 FY. Get the preliminary modelling “right” without emphasis on current stock status.
- Objective: develop a suite of plausible model options for HOK assessment.
- Today. Present result of initial modelling (and external analyses) to start to formulate the suite of plausible model options (“straw man” or “straw people”).
- Report to DW WG on progress to date, discuss next steps, identify additional model structures, etc.

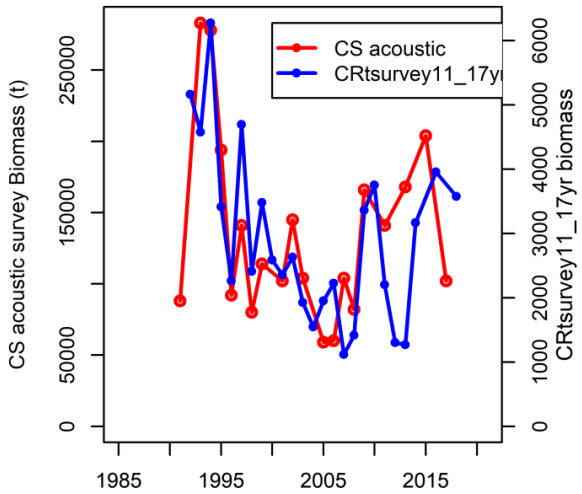
Overview

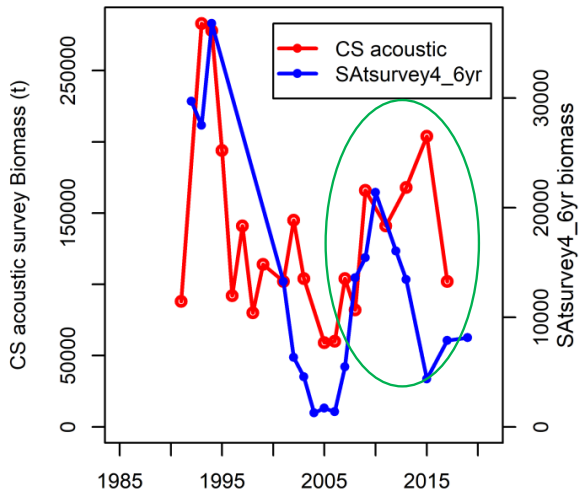
1. Comparative trends amongst key data sets – trawl survey indices, acoustic indices and age composition. Understanding data trends outside of the assessment model.
2. Fishery data sets – understanding previous model issues (poor fit, data conflict) defining selectivity functions to fit commercial age comps.
3. Exploratory modelling.
4. Model evaluation/selection.
5. Outstanding issues – further model development (next steps).

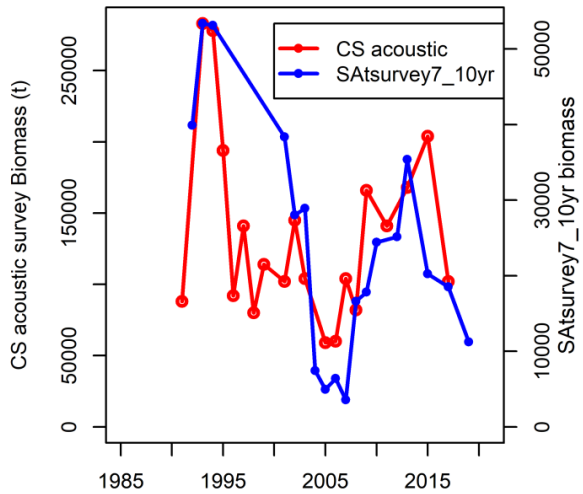
Data Summary – Cook Strait Acoustics Indices vs Trawl Survey Indices and WCSI Acoustics

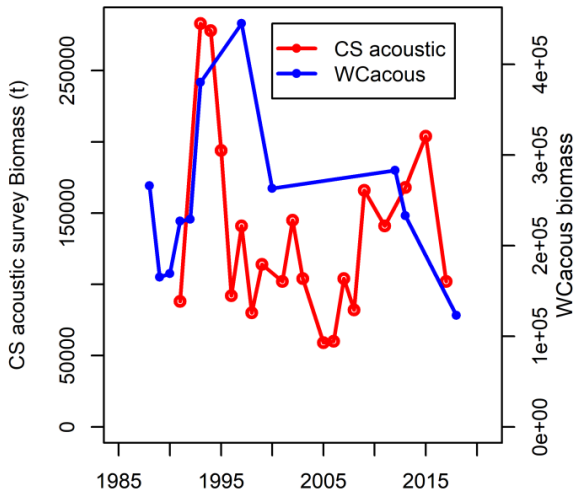




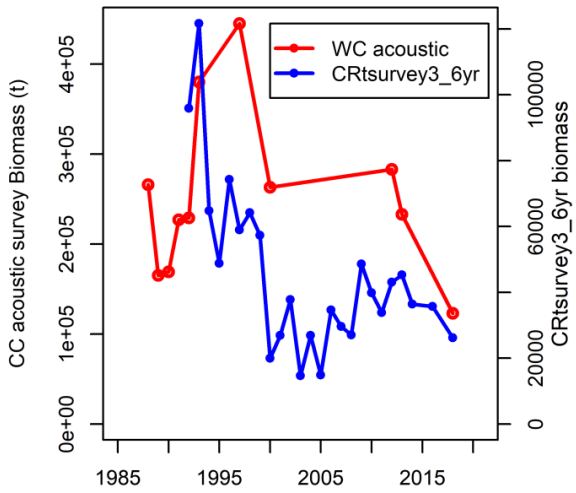


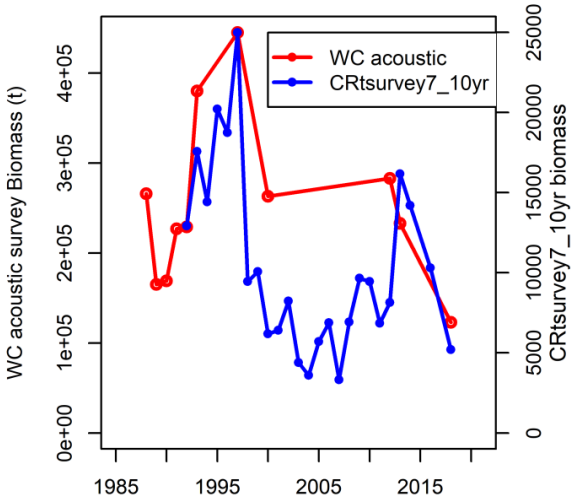


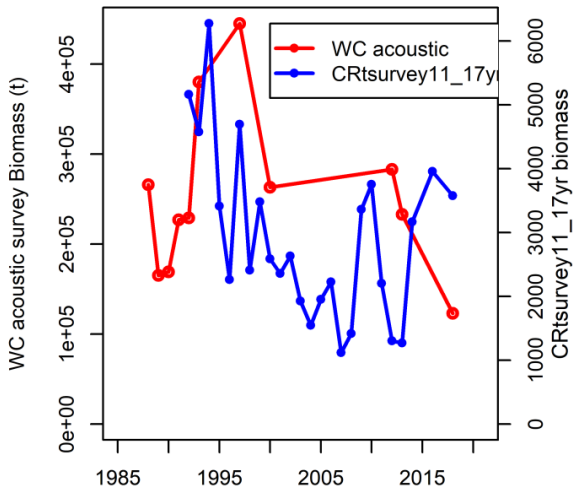


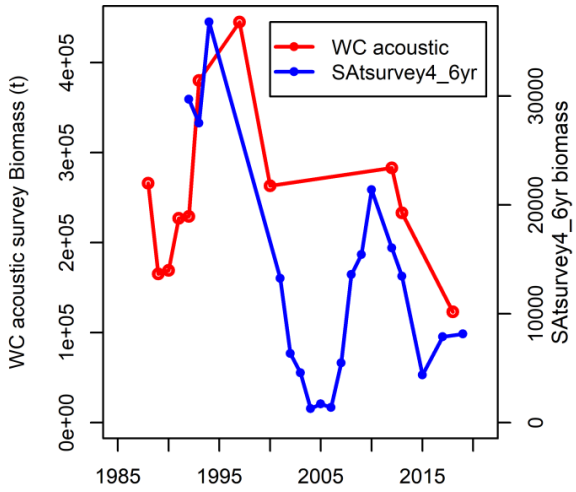


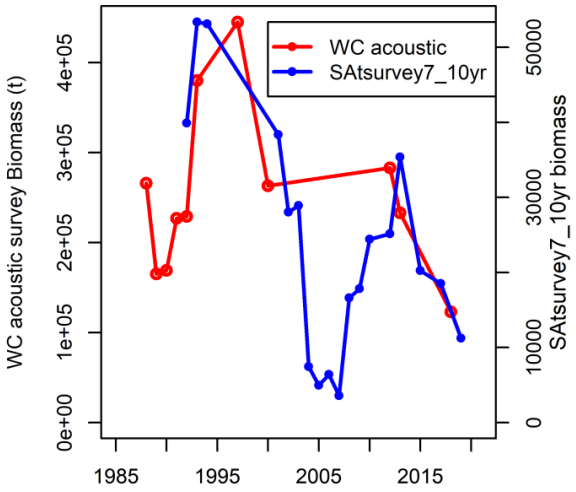
Data Summary – WCSI Acoustics Indices vs Trawl Survey Indices and Cook Strait Acoustics

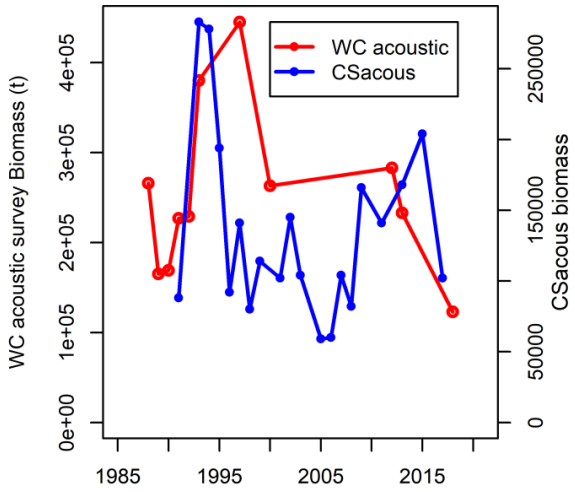






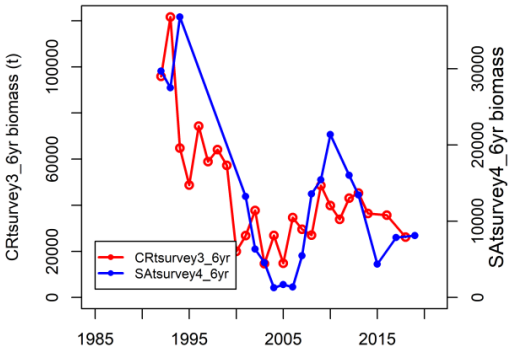




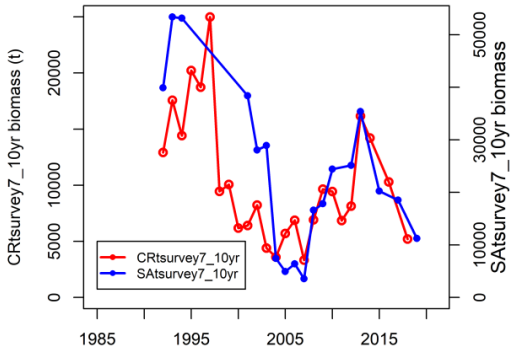


Data Summary – Chatham Rise vs Sub Antarctic Trawl Survey Indices

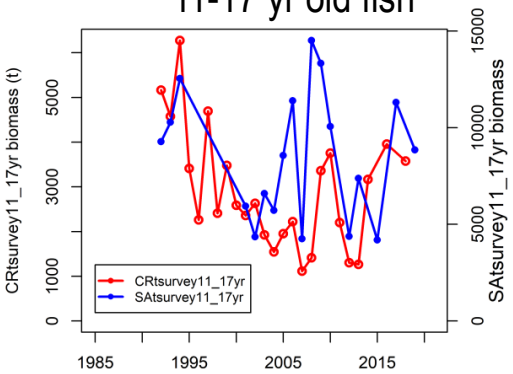
4-6 yr old fish

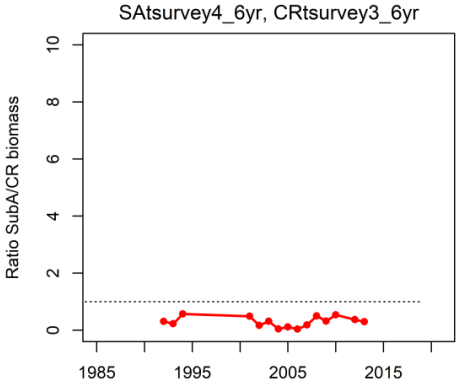


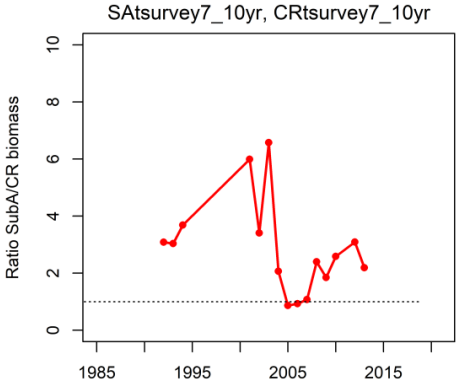
7-10 yr old fish

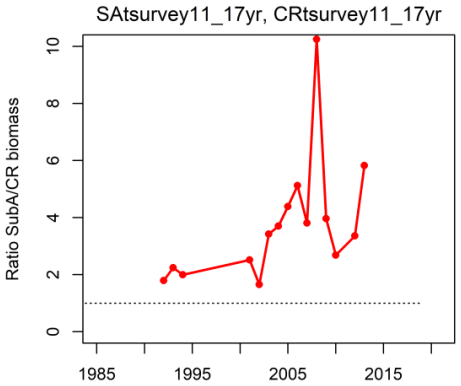


11-17 yr old fish









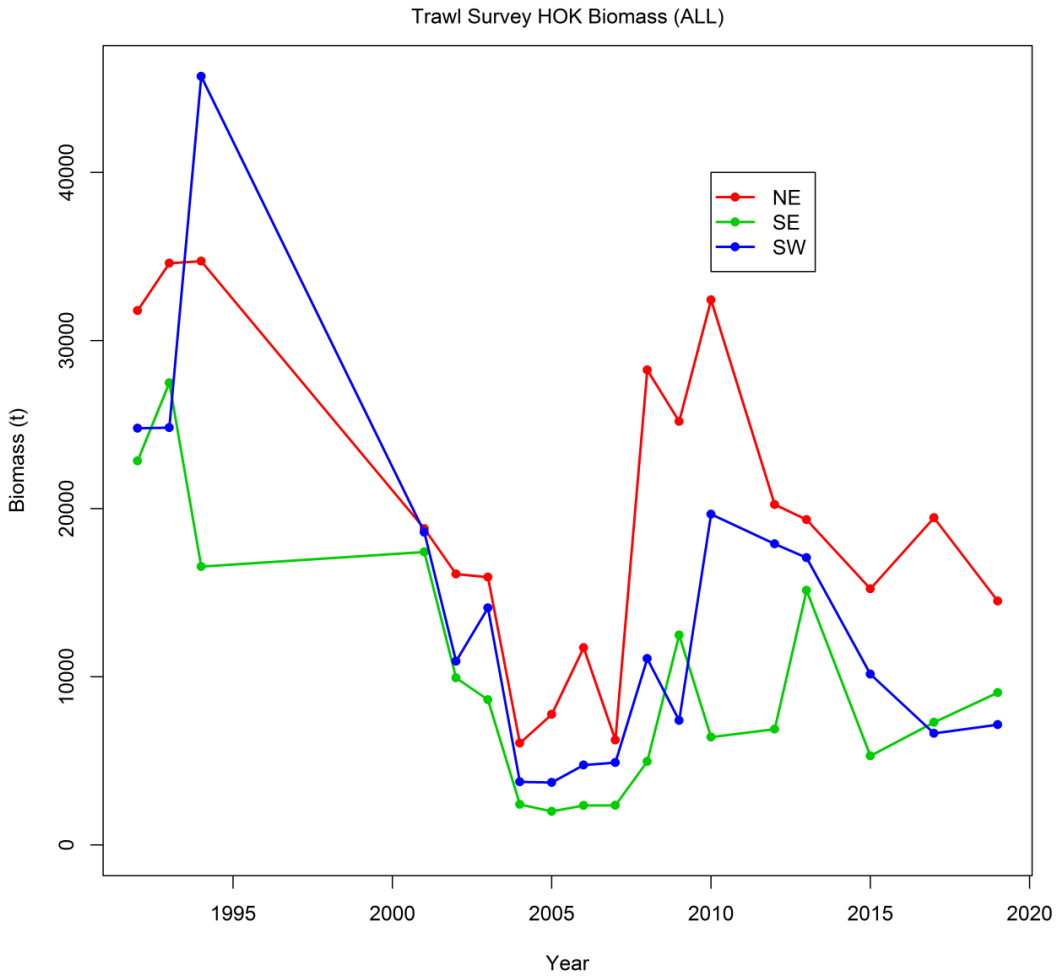
Ratio SubA/CR trawl survey biomass

Older fish observed in SubA and CR trawl surveys around 2005 and 2010.

Data Summary – Sub Antarctic Trawl Survey Indices by Area

Sub Antarctic trawl survey

Biomass trend differs between areas (strata groupings) of the survey. Related to the age composition of the population in each area.



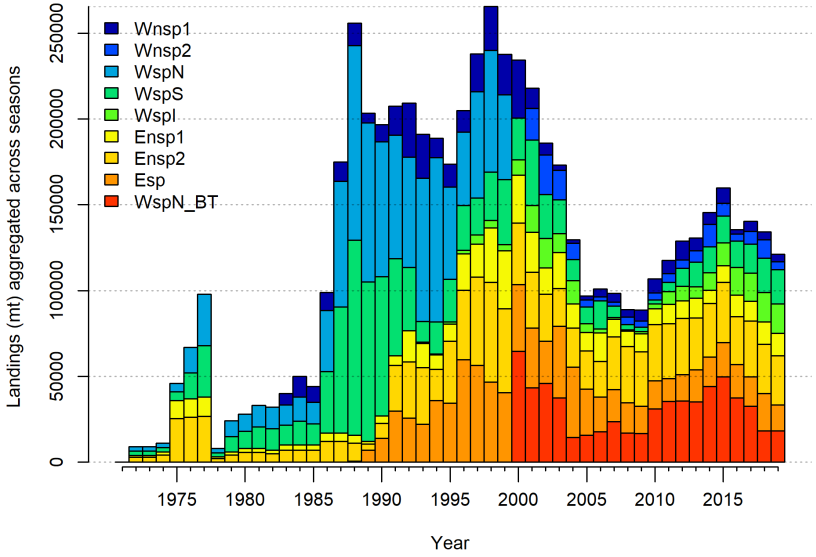
Main observations – abundance indices

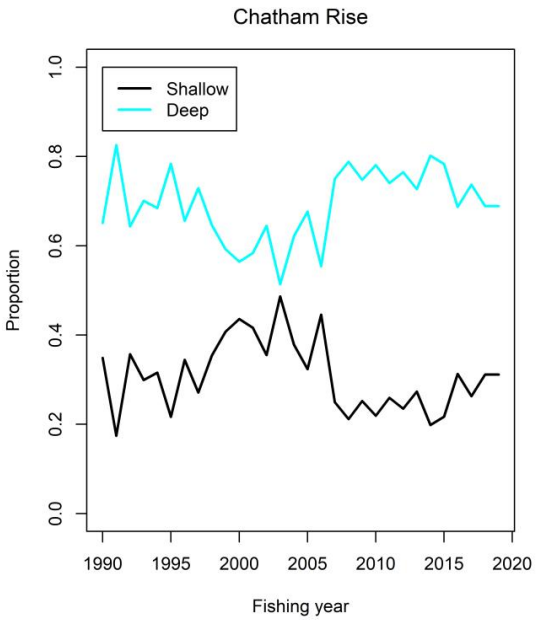
- Similar trends in abundance from a range of indices.
- Trend in CR trawl survey sub adult (3-6 yr) biomass indices diverge from CS acoustic indices from late 2000s.
- Also divergence between CR + SA trawl survey sub adult (3-6 yr) biomass indices around the same time.
- Magnitude of CS and WCSI acoustic biomass indices is similar.
- CR and SA trawl survey “old fish” indices also show similar trends with variation in biomass.
- Shift in relative trawl survey biomass from CR to SA with increasing age. Variable abundance trends from the SA survey by area. Useful to undertake a similar analysis of the CR trawl survey (area/size class).

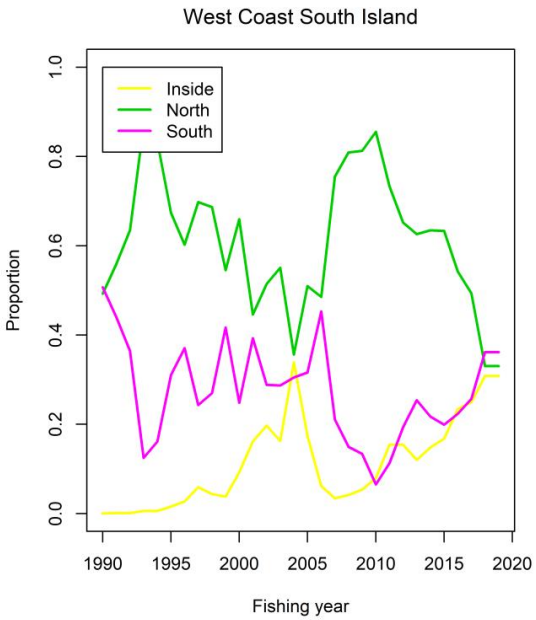
Data Summary – Catch Distribution by Fishery

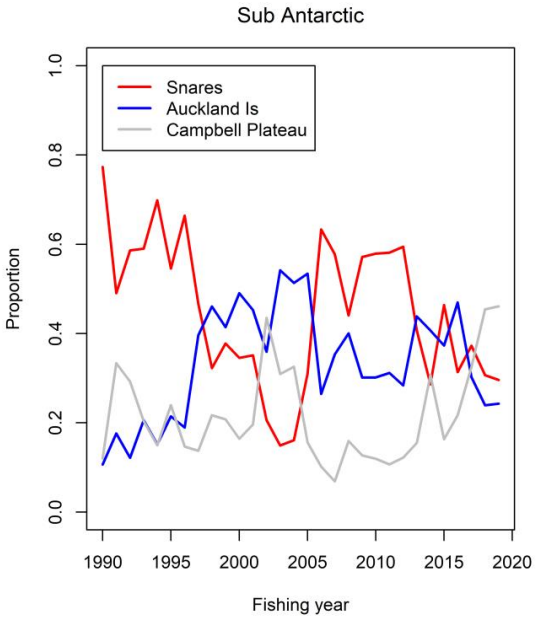
Shift in WCSI pattern of exploitation towards the Northern fishery = younger fish.

Variable proportion of the Sub Antarctic catch taken from the Snares fishery (younger fish).



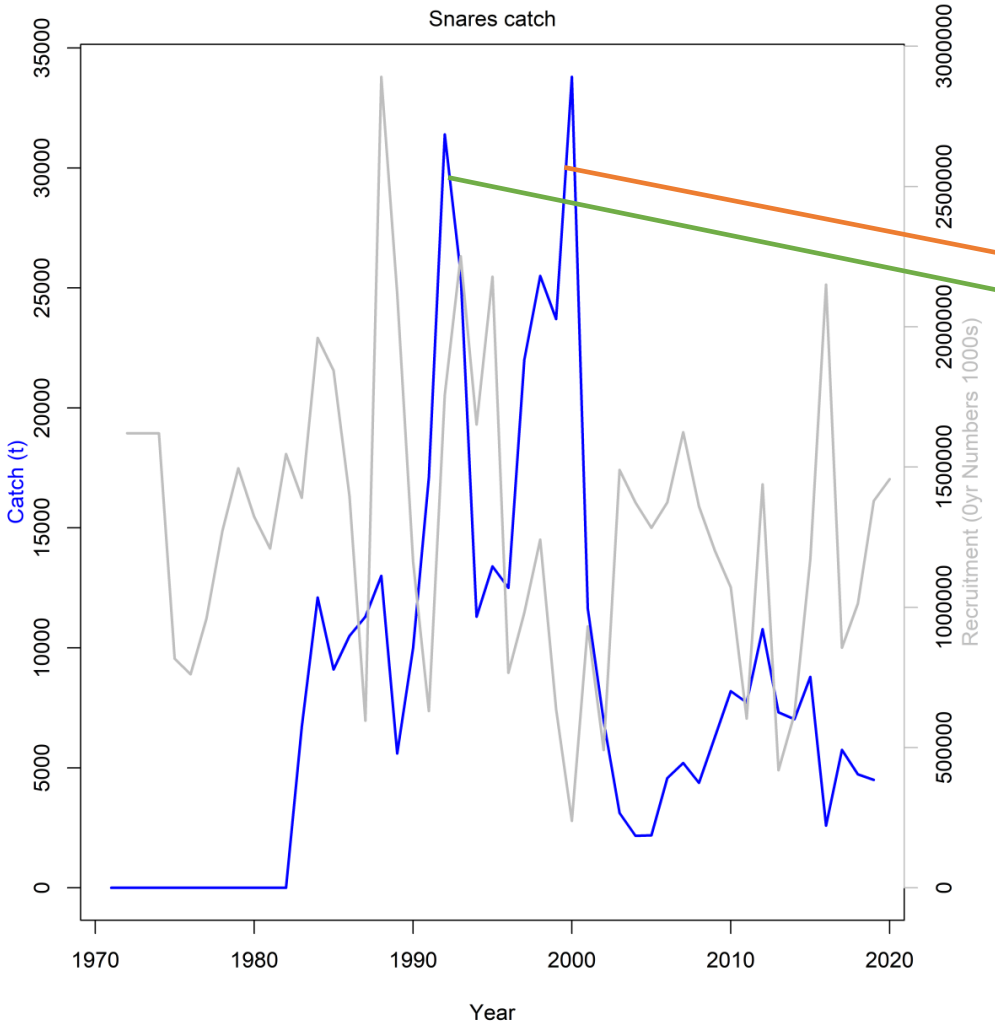


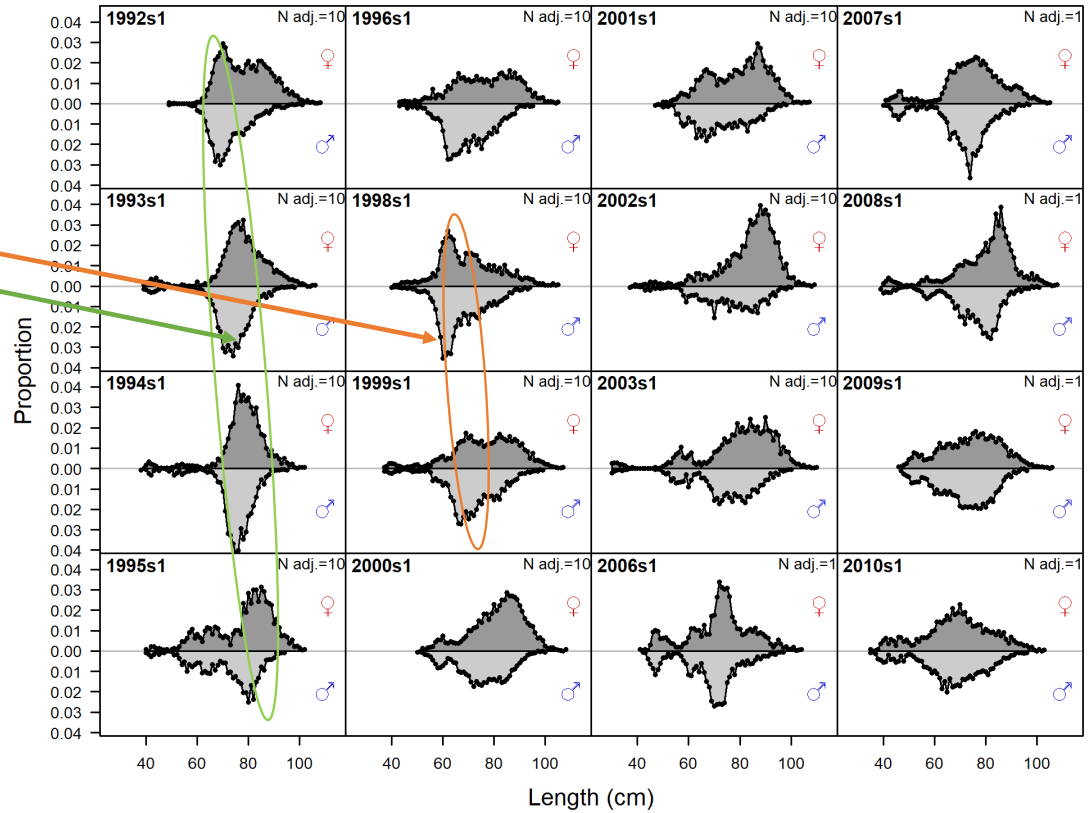




Data Summary – Snares Fishery

Snares LF data from 1990s and 2000s.

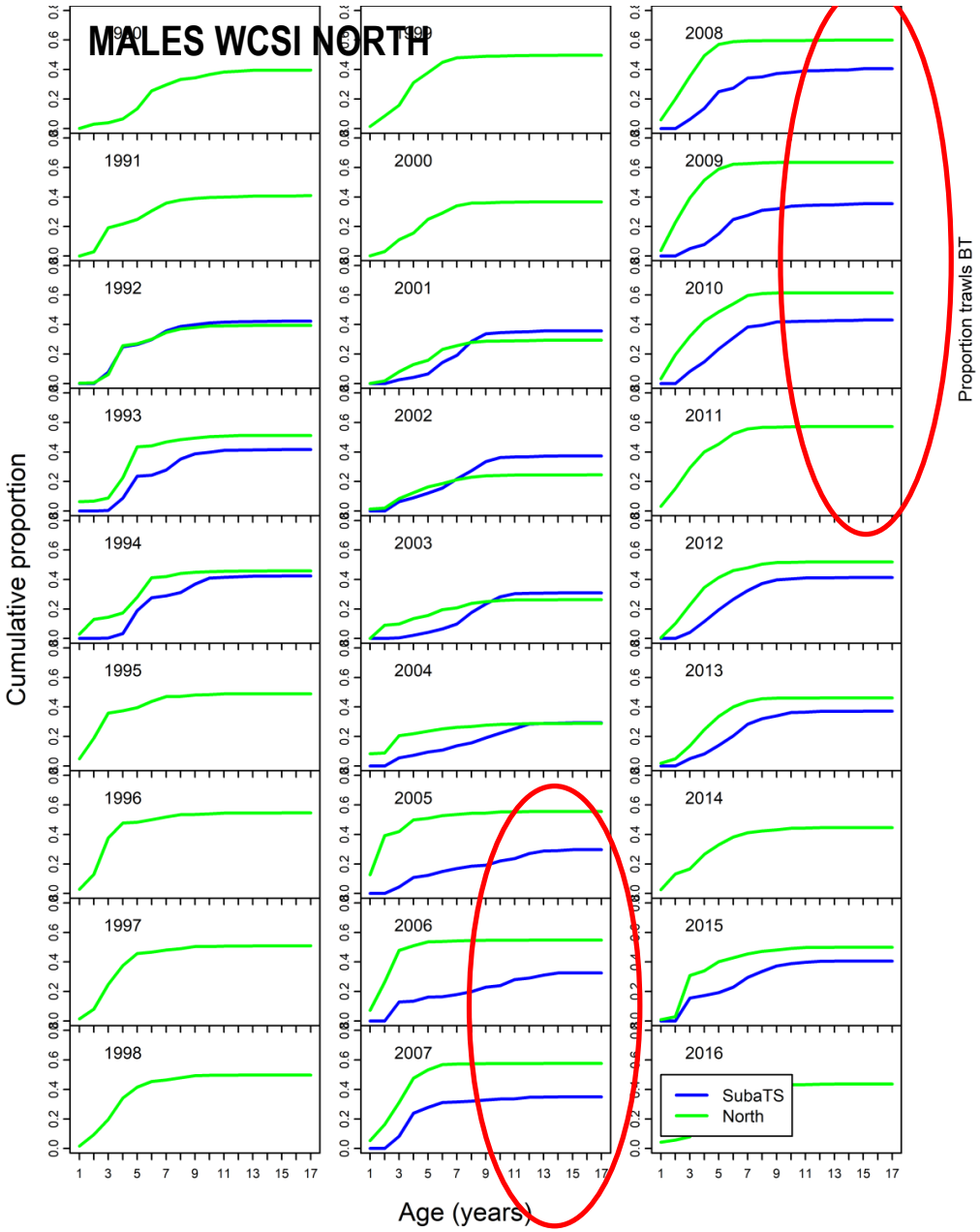


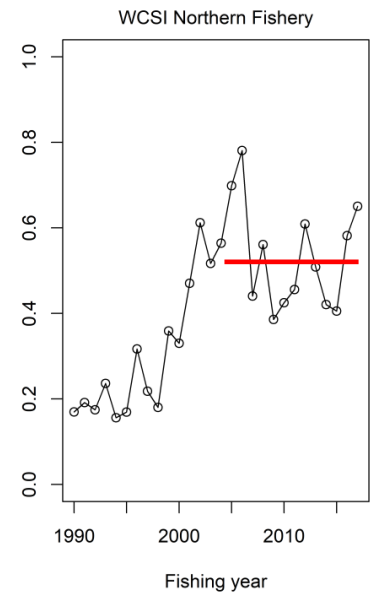


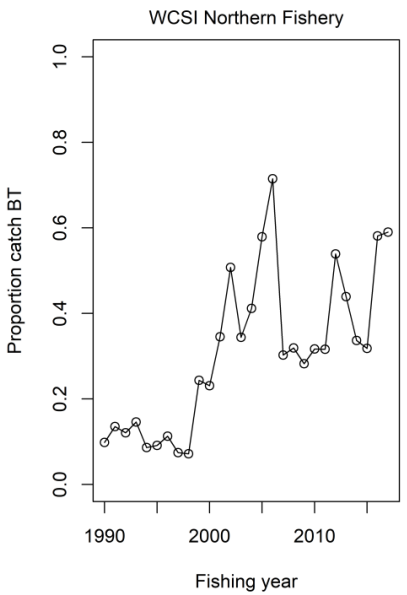
Snares catches in the 1990s follow two periods of strong (estimated) recruitment. Also evident in the LF data from the Snares fishery.

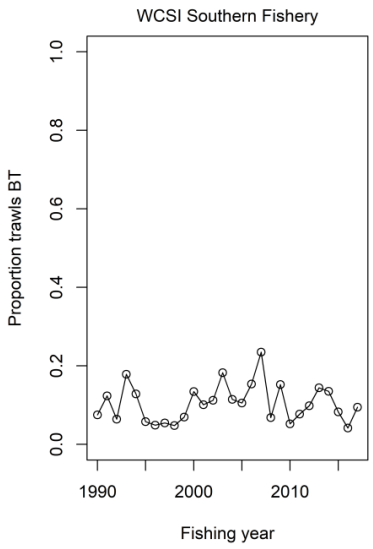
Fishery age comp data

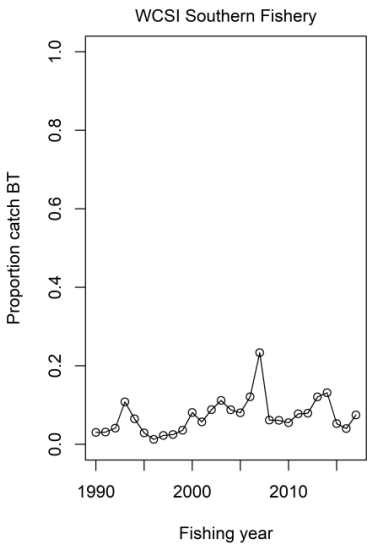
- Previous assessment had a poor fit to WCSI age comp. Limited scope to evaluate as considered single (homogeneous) fishery. Limited attempts to address via selectivity time blocks.
- Initial model options indicated lack of fit was primarily related to WCSI Northern area of fishery. Shift to high proportion of younger male fish in about 2005.
- Similar trend in WCSI Southern area, although somewhat less pronounced.
- Cook Strait fishery. Shift to higher proportion of younger male fish in catch in about 2006.
- Do changes relate to recruitment of stronger year classes (males first) or a change in fishery selectivity or (probably) both. Compare to age structures from the trawl surveys – understand conflict in the data sets.
- [linkage between WCSI North and Cook Strait fishery??]







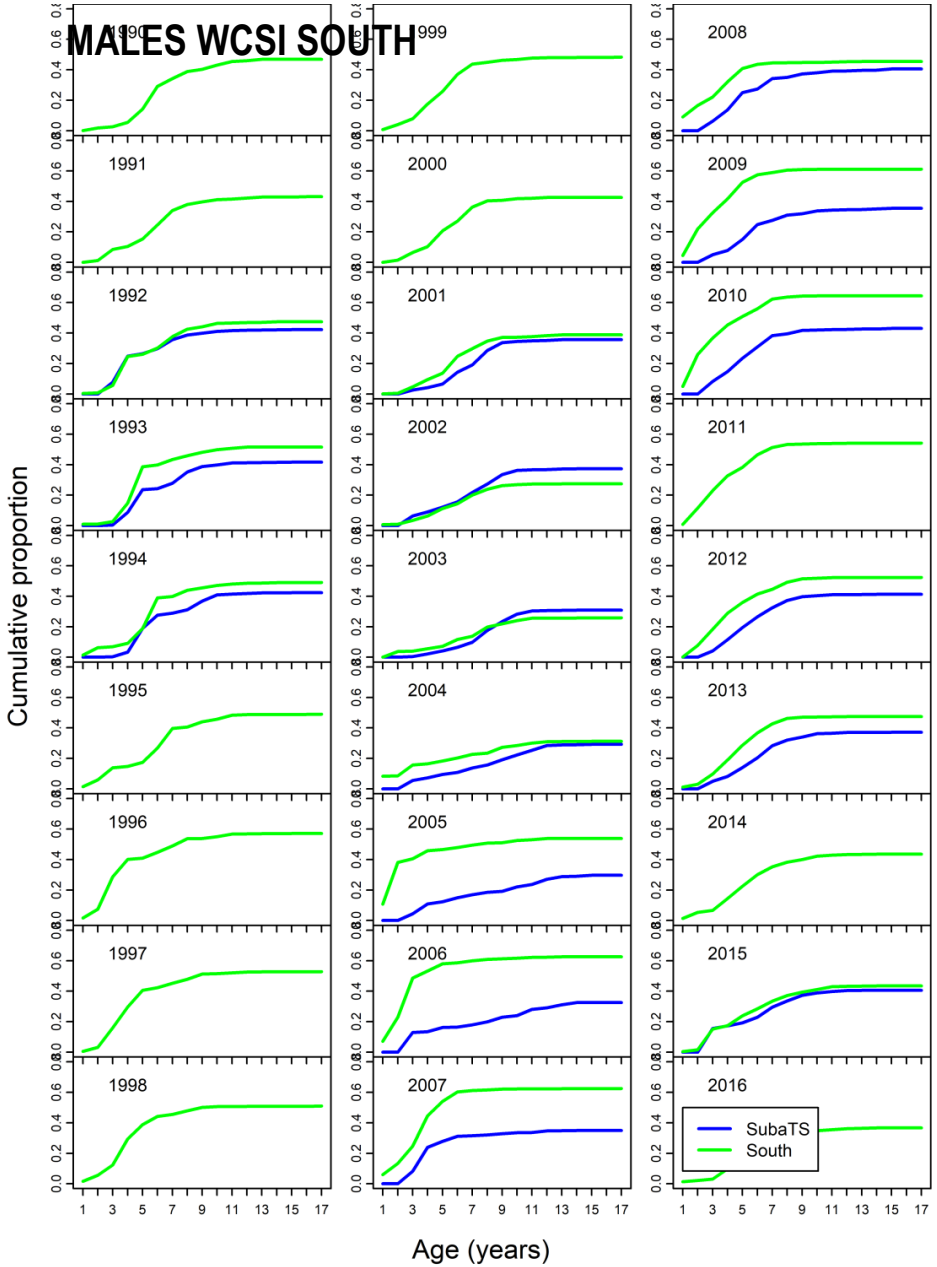


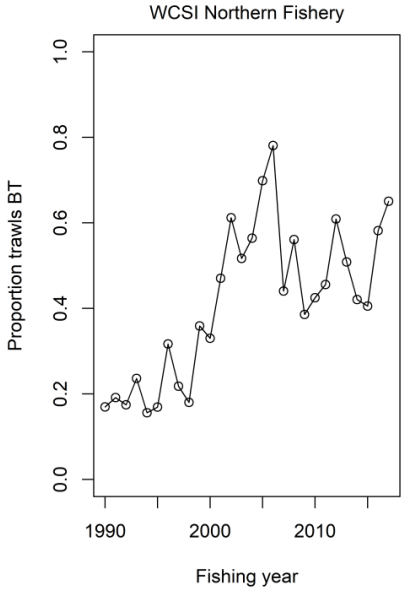


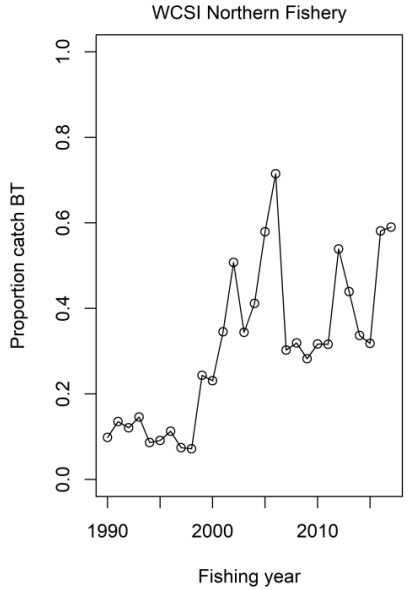
Change in operation of the fishery around 2005, partly reflected in an increase proportion BT catch in the north.

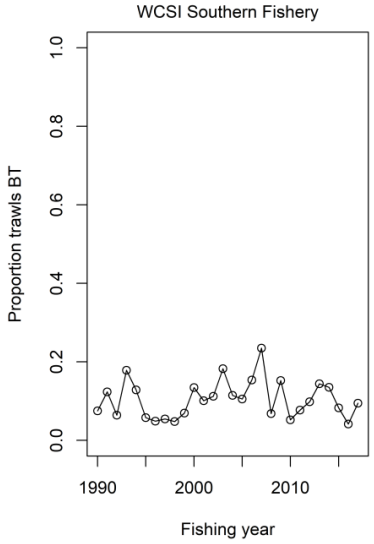
Potential change in fishery selectivity towards male fish.

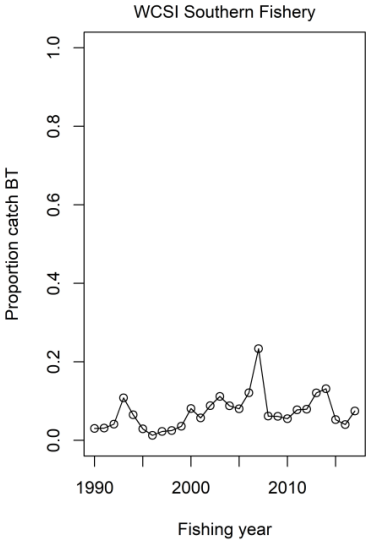
MALES WCSI SOUTH

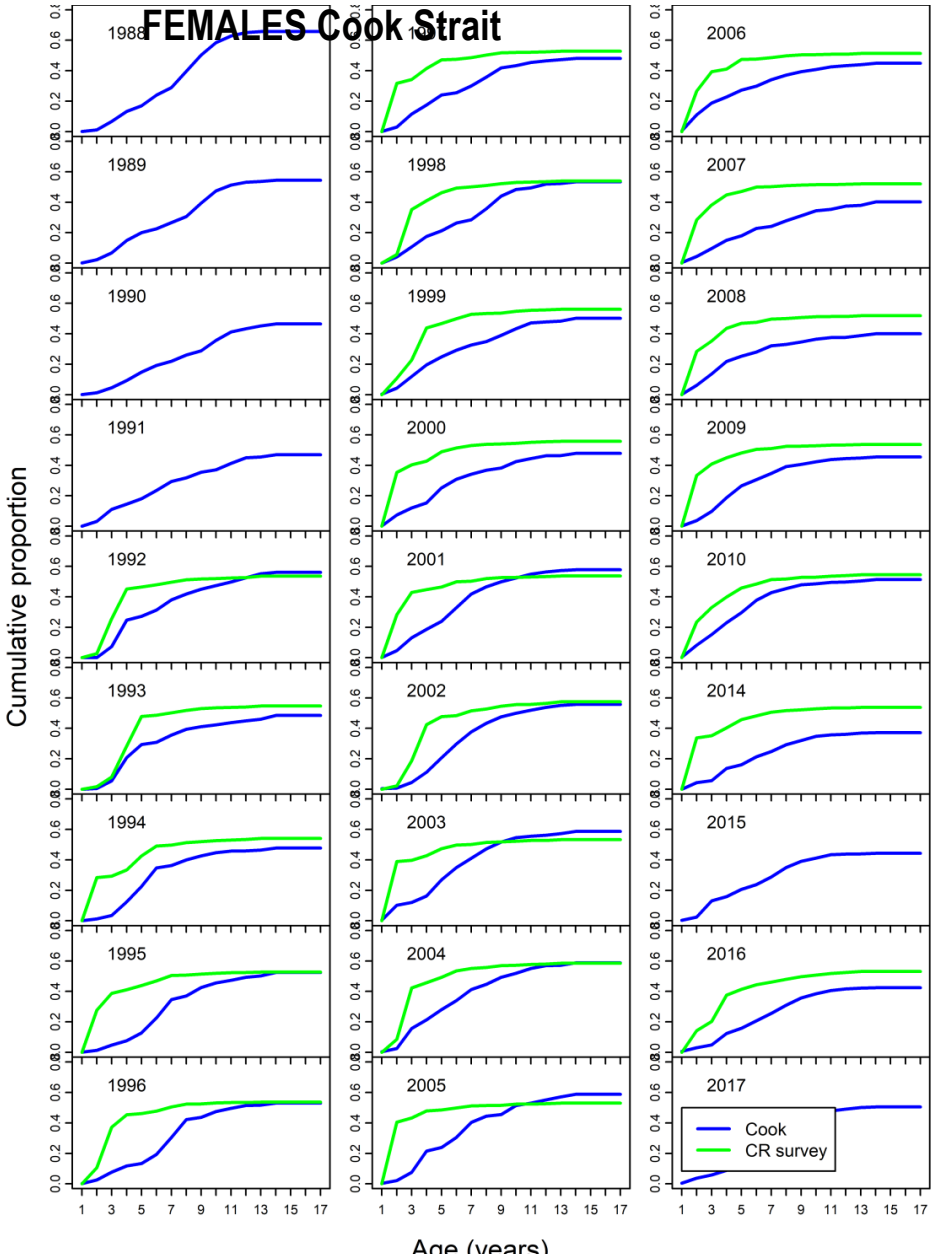


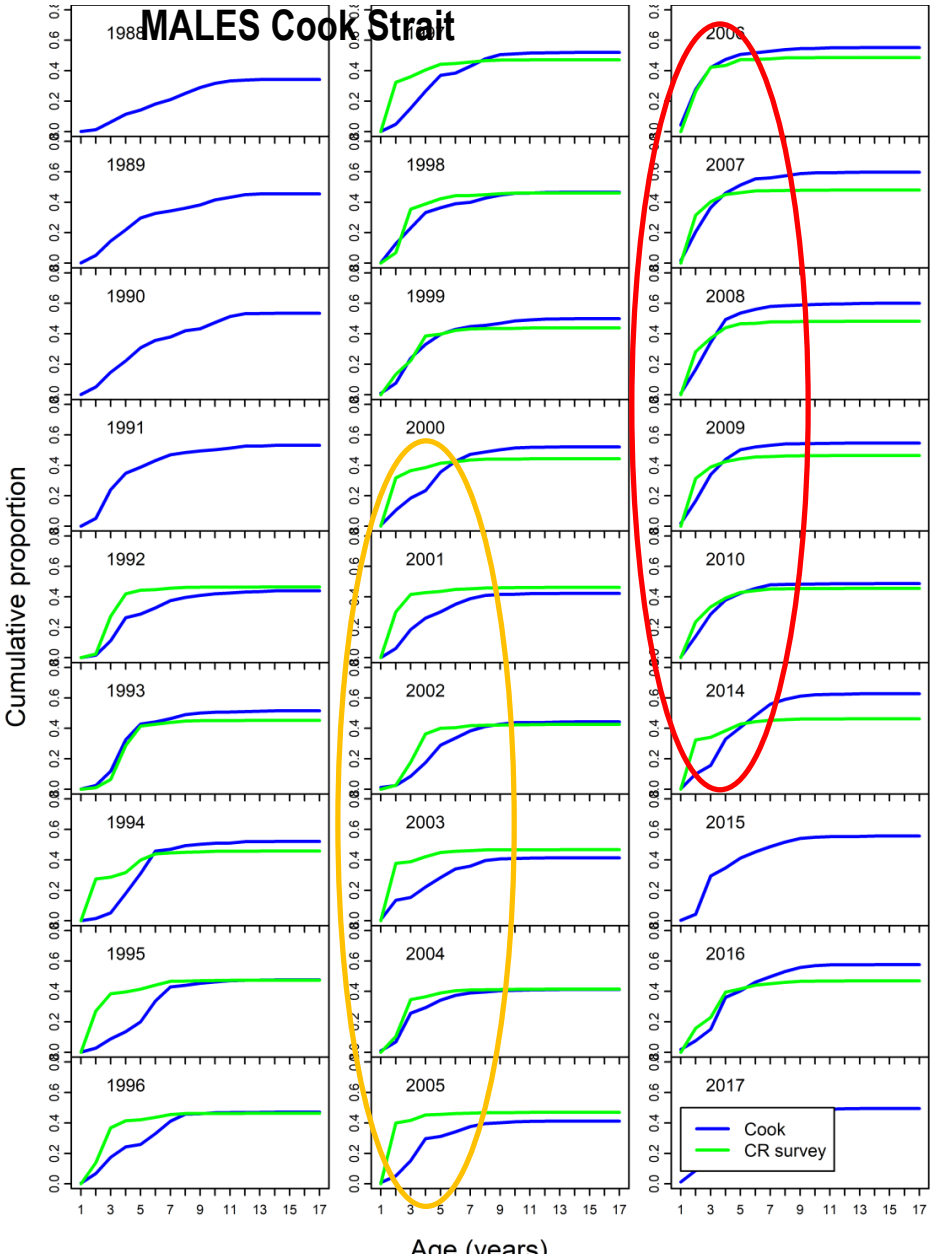












Cook Fishery

Shift to higher proportion males in about 2006

Fishery age comps – model configuration (selex)

- Spawning fisheries - sex specific selectivity functions (in addition to sex specific movement to spawning grounds).
- WCSI Inside and South – full selectivity of oldest fish. WCSI North selectivity allowed to decline for older fish.
- Some indication change in WCSI North fishery age comp related to change in operation of the fishery – potential change in selectivity of the fishery. Include two time blocks for WCSI North fishery selectivity (pre and post 2000 *or 2005*?). Substantial improvement in fit to fishery age comps.
- Cook Strait. Two time blocks pre/post 2006. Related to change in fleet (large vessels). Approximates full select of older fish for early period.
- Non spawning fisheries – equivalent selectivity male and female. Double Normal selectivity functions allowing for lower selectivity of older fish in some fisheries (Snares, Chatham Rise shallow).

Exploratory modelling - configuration

- Stock Synthesis, not CASAL but can do similar things (& SS more flexible).
- No priors (B0 E/W, acoustic *q*s, trawl survey *q*s).
- Constant *M* at age; base *M* values for Female and Male.
- Selectivity functions: fishery, trawl survey (relax constraints).
- Limit influence of commercial age composition data regarding estimation of stock status. Trawl survey process error (0.1) fixed, ESS age comp fixed.
- Alternative stock, region, movement configurations. Starting point is current hypothesis. Similar structure to “western focus” model.
- Fishery abbreviations: Esp = Cook Strait; Espn1 = Chatham Rise, shallow; Espn2 = Chatham Rise, deep; Wnsp1 = Snares; Wnsp2 = Sub Antarctic (Campbell/Aucklands Is); WspI = WCSI Inside 25 nm; WspS = WCSI South Outside 25 nm; WspN = WCSI North (2).
- Initially partitioned trawl surveys by age groupings: juvenile, sub adult, adult, old.

Exploratory modelling – some initial observations

- Key issues relate to (trawl survey) selectivity, movement, regional structure, etc.
- Numerous (50+) model options initially investigated.
- Diagnostics – likelihood components, model properties.
- Flexible fishery selectivities enable relatively good fit to age comps from range of scenarios.
- Scenarios that didn't link SubA to WCSI (e.g. *Test_Null3_recdev*) have very poor fits to the SubA trawl survey indices (4-6yr, 7-10 yr) and some deterioration in fit to age comps.
- Other spatial linkages considered more plausible: CR > Snares > SubA (Western); Snares (sub adult) <> Cook (Eastern); (WCSI North + Cook = Eastern spawning ??).
- Initial model options constraining linkage between CR and SubA (via trawl survey selectivities). Resulted in large biomass on CR, including Western biomass and low movement rates to SubA region. Relates to the rate of depletion of the younger fish (4-6 years) = high recruitment/biomass in the mid 1990s. Similar model configurations also estimated a strong declining selectivity for the CR trawl survey – large biomass to support subsequent Western catches.

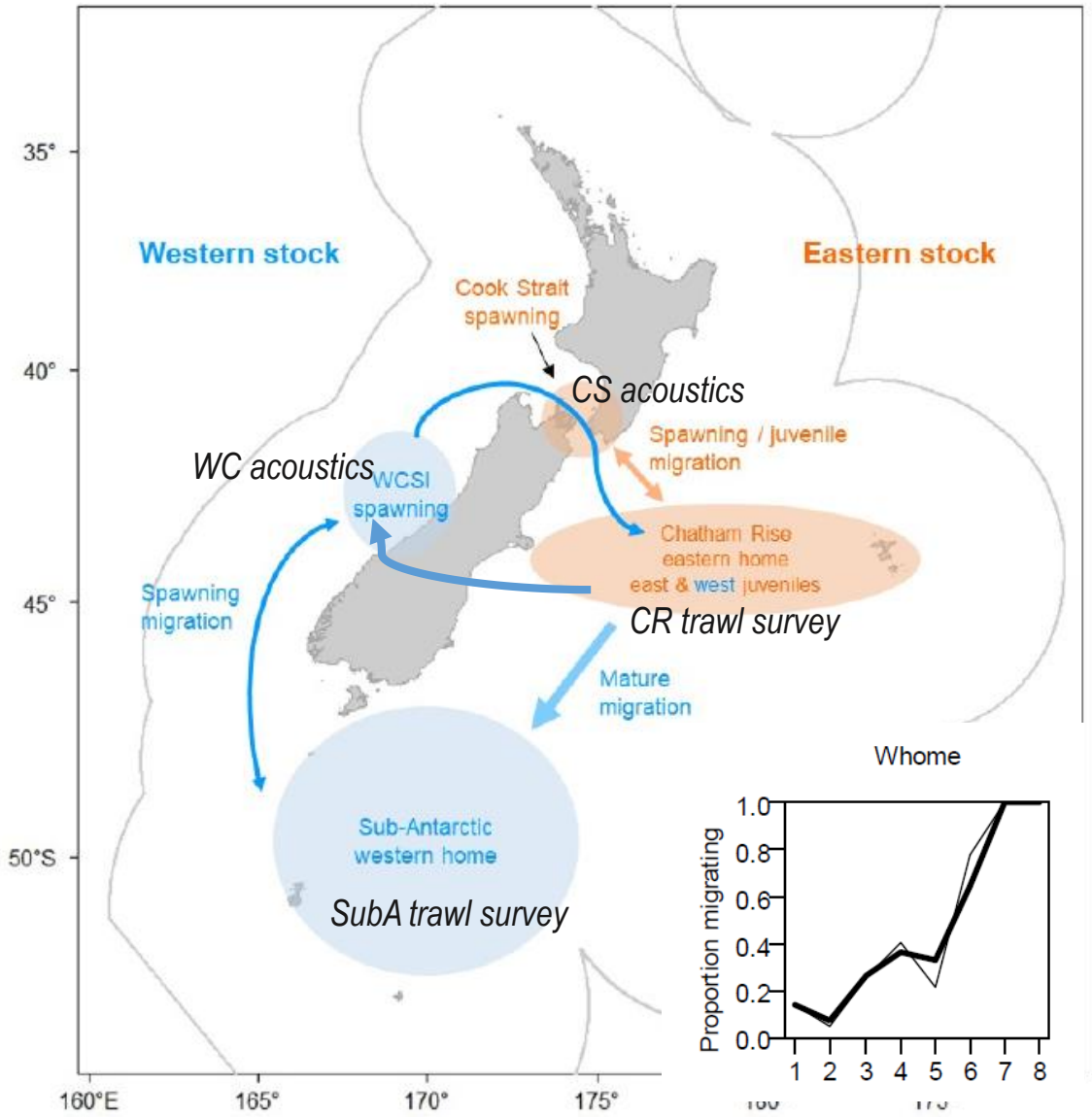


Figure 1: Hoki juvenile nurseries, spawning grounds and migration routes for the eastern and western stocks.

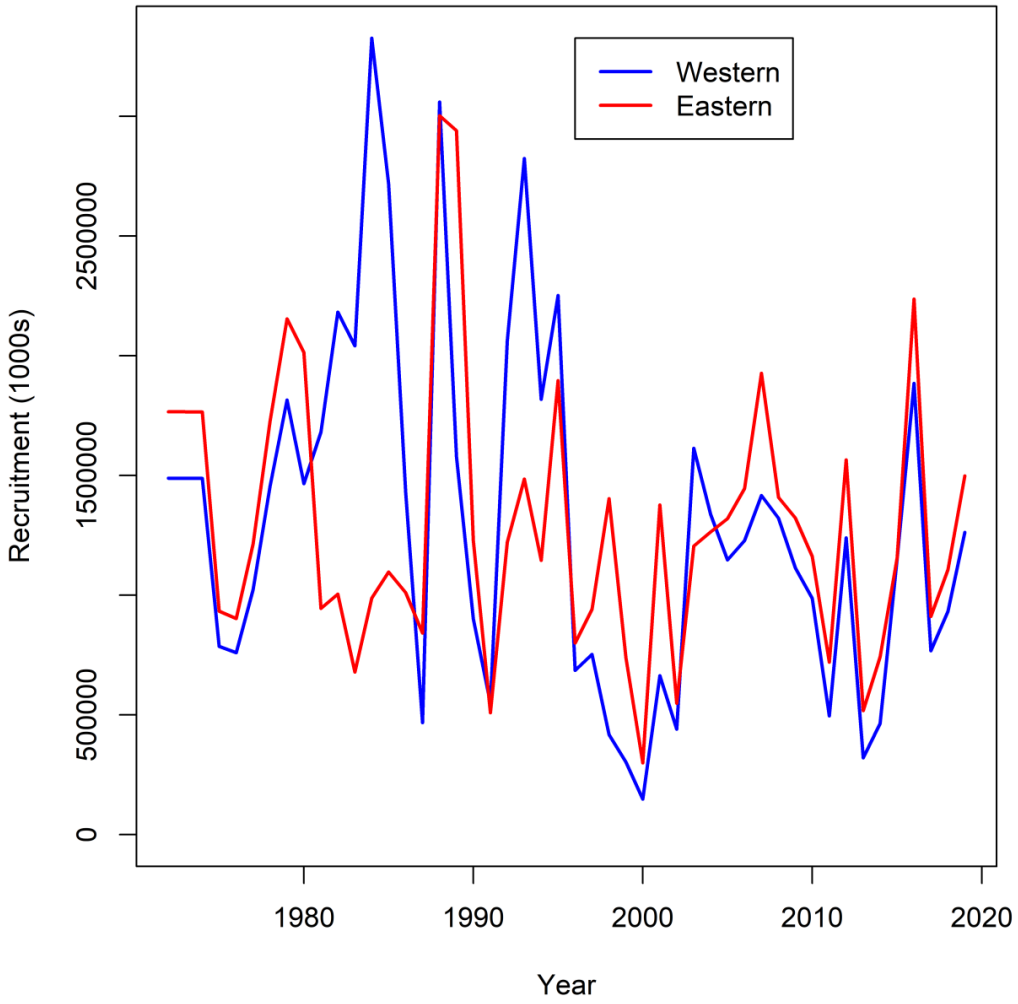
Initial and *MovementEst* models

Partition fisheries in each Region based on length/age composition of catches.

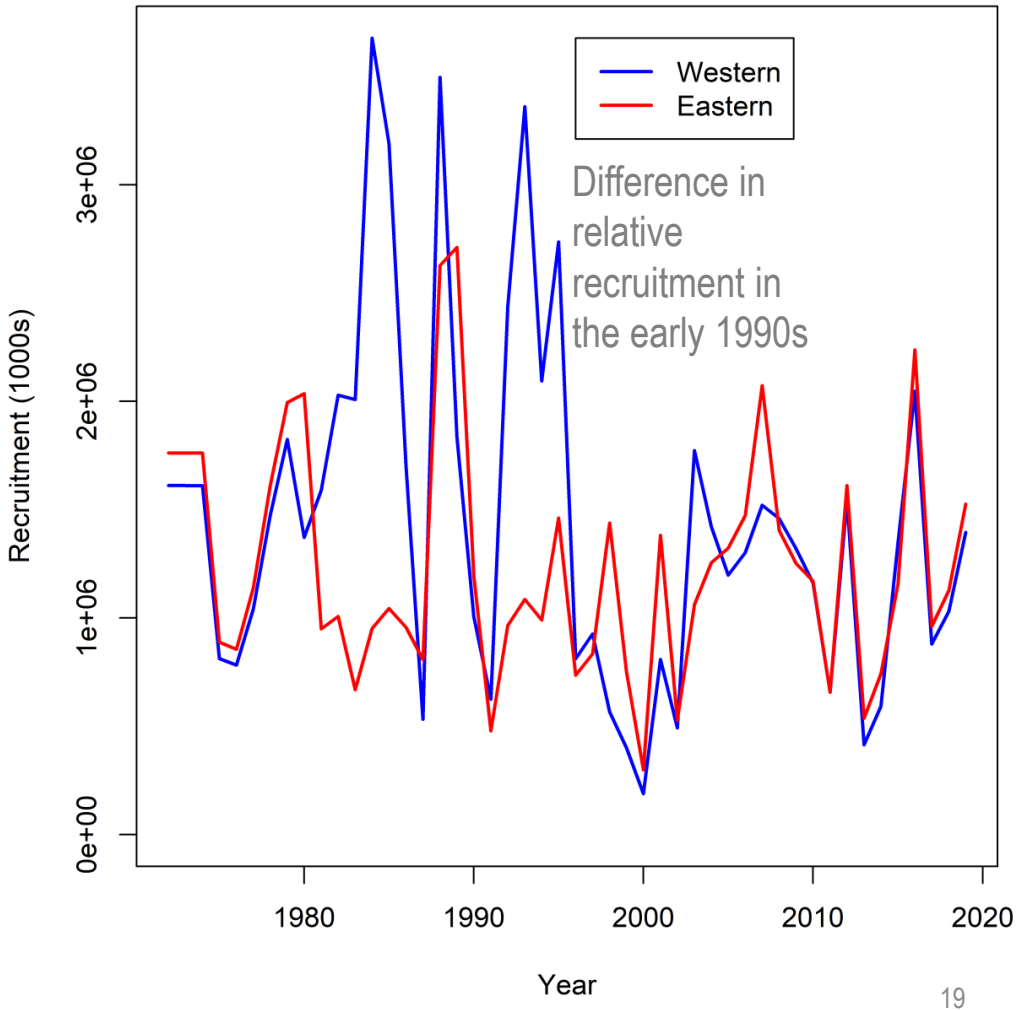
Based on current stock hypothesis. One directional movement of Western fish from CR.

Additional movement direct from CR to WCSI. Those fish then move to SubA after spawning.

Initial model

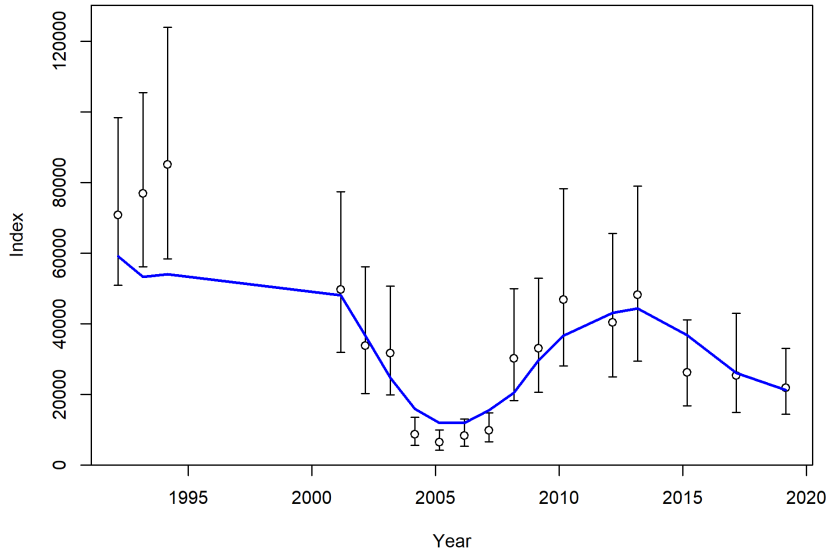


MovementEst model

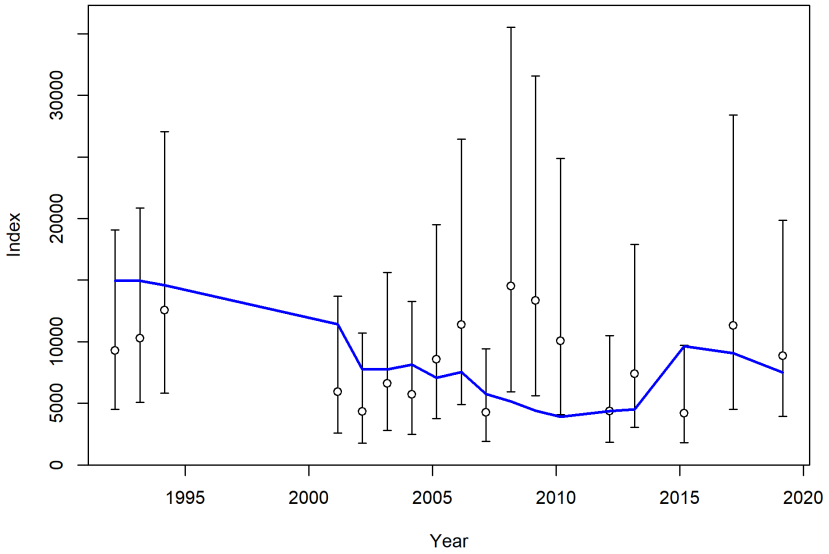


Initial model

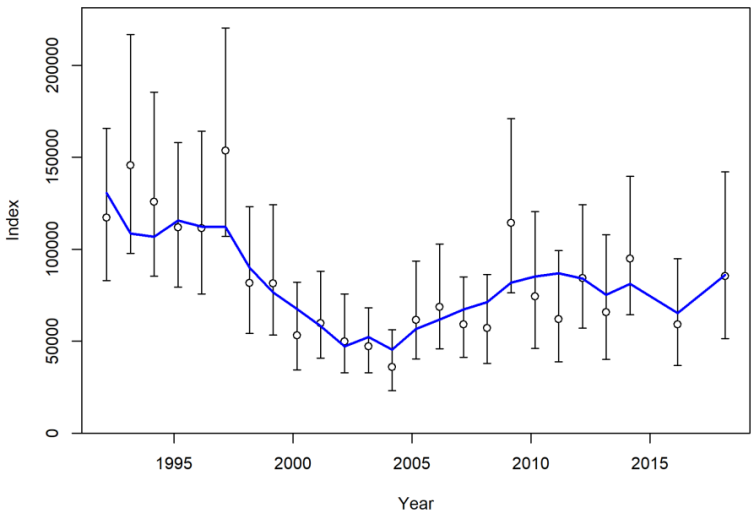
SA trawl survey 3-10 yr



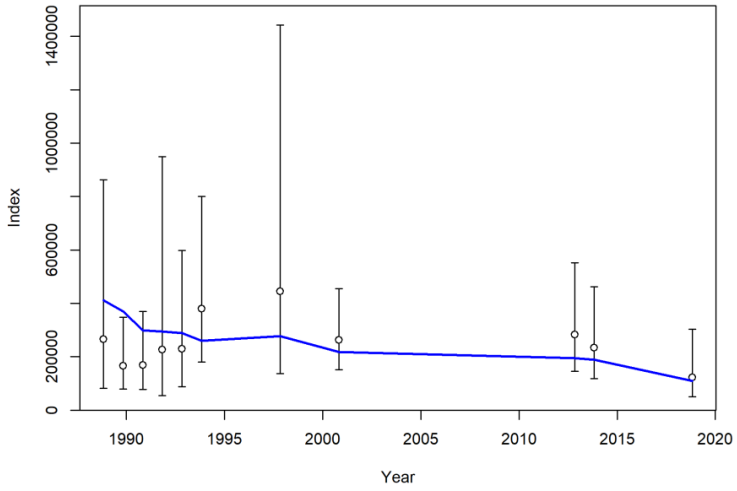
SA trawl survey 11-17 yr



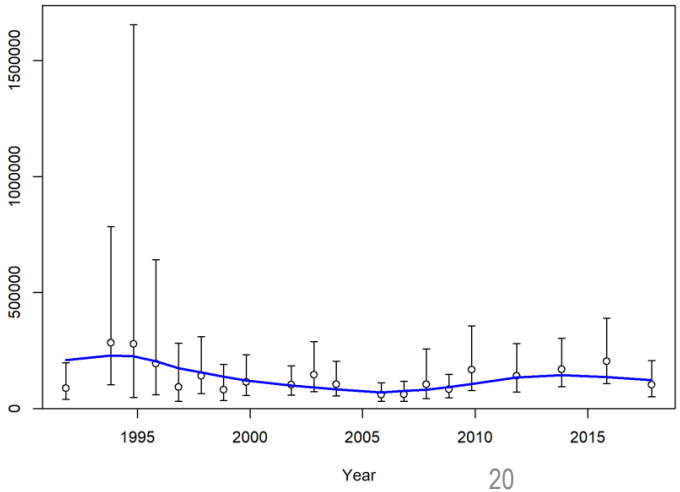
CR trawl survey 2-17 yr



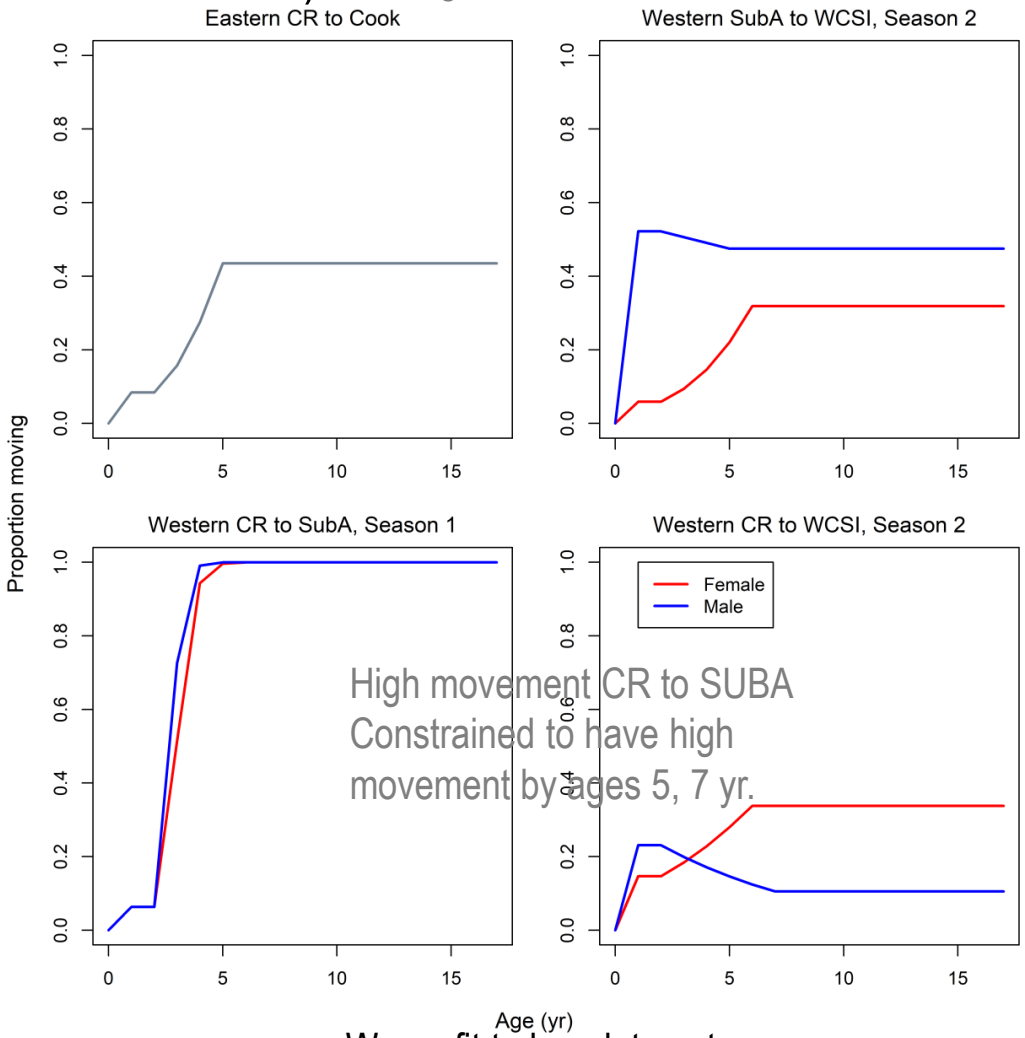
WC Acoustics



CS Acoustics



Movement - *Initial* model (movement from CR constrained) *.\Testing_Version5\BASE*



Worse fit to key data sets.

Movement - *MovementEst* model

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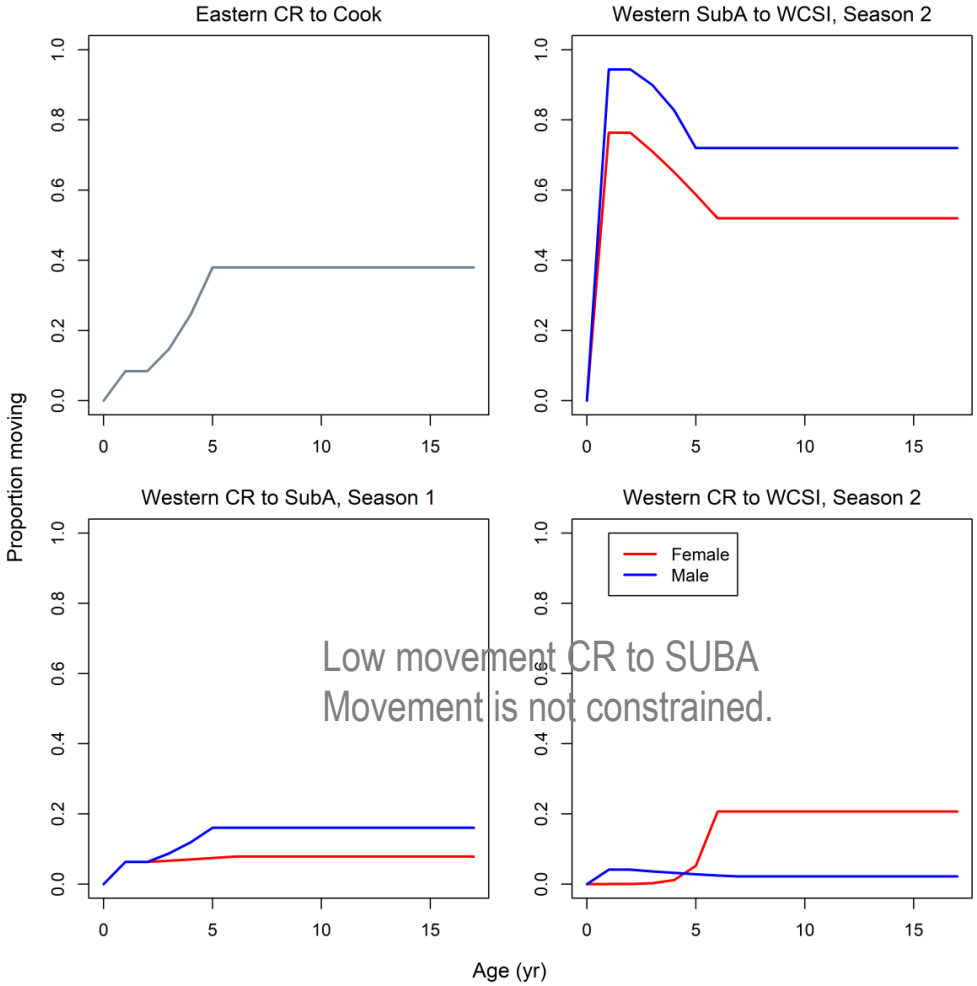
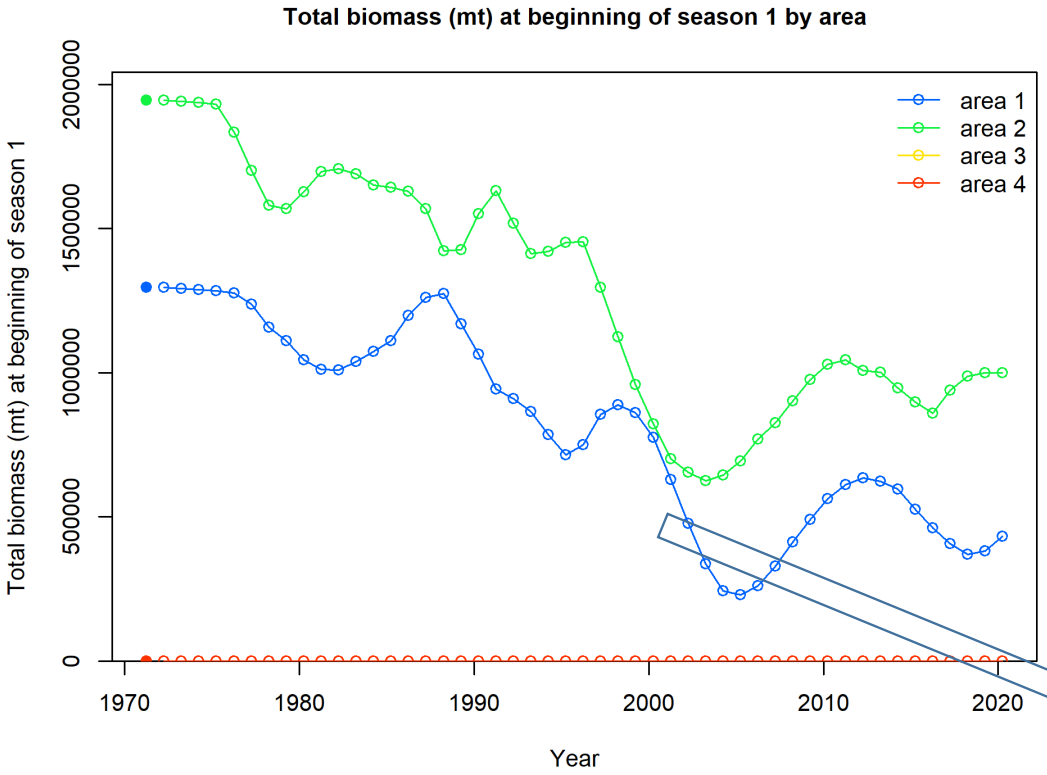
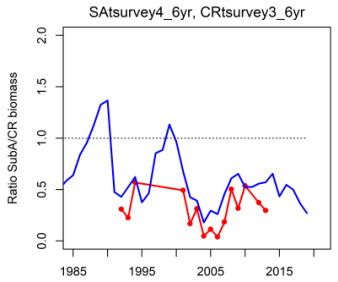


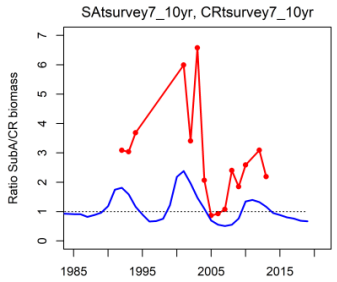
Superior model fit to key data sets.

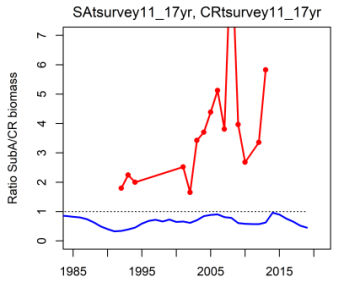
Initial model

Higher total biomass in Chatham Rise region (area 2) compared to Sub Antarctic region (area 1)



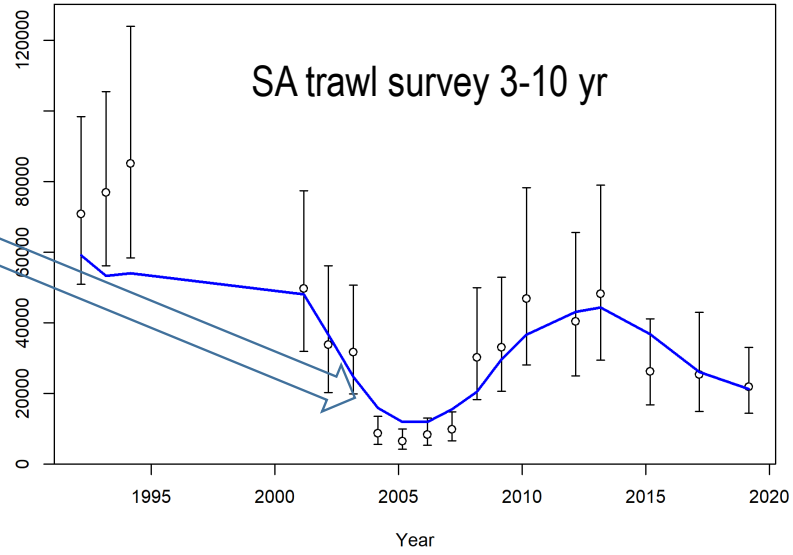






Biomass ratio SubA/CR

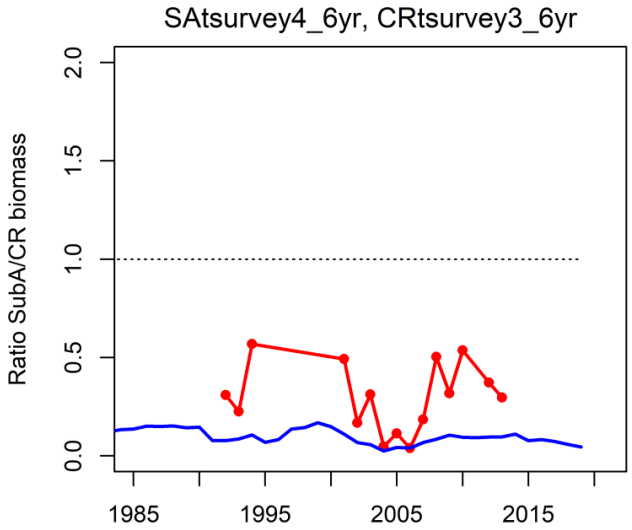
Trawl survey and Model

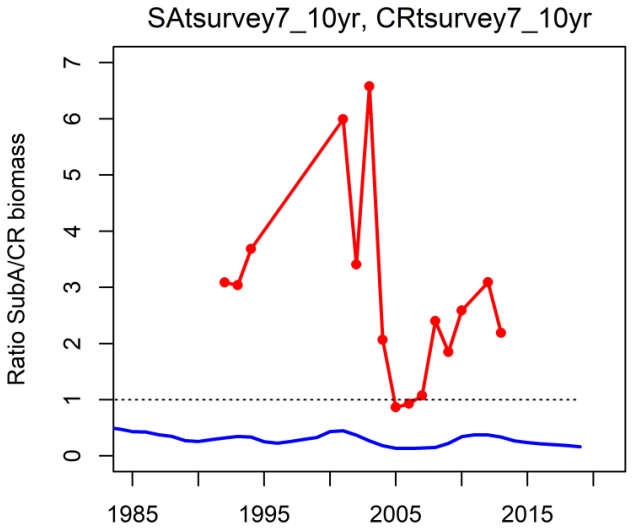


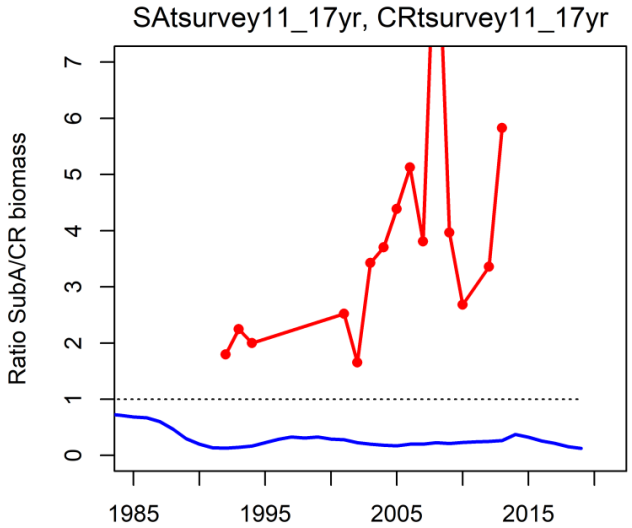
Need a relative low level of (vulnerable) biomass in the SubA to fit the decline in TS biomass indices given the amount of catch that was taken from SUBA+WCSI fisheries.

MovementEst model

Model predicts that a low proportion of the biomass is in the Sub Antarctic relative to the Chatham Rise region. This is in contrast to the observed ratio of biomass from the trawl surveys (i.e. much higher proportion of the trawl survey biomass is in the SubA, assuming equivalent *q*s).







Evaluating potential linkages between data sets 1.

Correlations (coefficients) between likelihood components for each set of indices and age comps from series of model options that excluded each set of abundance indices in turn (11 Models Exclude 1-11 *MovementEst* model).

	CRtsurvey1yr	CRtsurvey2yr	CRtsurvey3_6yr	CRtsurvey7_10yr	CRtsurvey11_17yr	SAtsurvey3yr	SAtsurvey4_6yr	SAtsurvey7_10yr	SAtsurvey1	CSacous	Wcacous	Wnsp1	Wnsp2	WspN	WspS	Wspl	Ensp1	Ensp2	Esp	WspN_BT	
CRtsurvey1yr	1.000	-0.850	0.142	-0.543	0.358	0.362	0.473	-0.058	-0.381	-0.129	0.425	0.128	0.299	-0.038	0.169	0.043	-0.747	-0.839	0.266	-0.350	CRtsurvey1yr
CRtsurvey2yr	-0.850	1.000	-0.012	0.549	0.171	-0.344	-0.303	0.332	0.505	0.334	-0.248	-0.146	-0.137	0.101	-0.186	0.067	-0.702	-0.435	-0.579	0.458	CRtsurvey2yr
CRtsurvey3_6yr	0.142	-0.012	1.000	0.663	0.237	-0.293	-0.217	0.527	0.433	-0.167	-0.058	-0.354	-0.160	-0.109	-0.402	0.012	-0.410	-0.276	-0.655	0.204	CRtsurvey3_6yr
CRtsurvey7_10yr	-0.543	0.549	0.663	1.000	-0.045	-0.499	-0.499	0.392	0.495	0.089	-0.427	-0.332	-0.241	-0.007	-0.344	0.015	-0.113	0.061	-0.673	0.406	CRtsurvey7_10yr
CRtsurvey11_17yr	0.358	0.171	0.237	-0.045	1.000	0.148	0.330	0.447	-0.159	0.733	0.403	-0.374	0.071	-0.430	-0.362	0.016	-0.365	-0.350	-0.235	-0.290	CRtsurvey11_17yr
SAtsurvey3yr	0.362	-0.344	-0.293	-0.499	0.148	1.000	0.881	-0.324	-0.719	-0.100	0.699	-0.320	0.117	-0.664	0.331	-0.527	0.142	-0.041	0.571	-0.858	SAtsurvey3yr
SAtsurvey4_6yr	0.473	-0.303	-0.217	-0.499	0.330	0.881	1.000	0.753	-0.758	0.178	0.954	0.275	0.322	-0.682	-0.114	-0.095	0.137	0.003	0.496	-0.934	SAtsurvey4_6yr
SAtsurvey7_10yr	-0.058	0.332	0.527	0.392	0.447	-0.324	0.753	1.000	0.516	0.635	0.808	-0.157	0.124	-0.432	-0.586	0.200	-0.076	0.125	-0.936	-0.026	SAtsurvey7_10yr
SAtsurvey11_17yr	-0.381	0.505	0.433	0.495	-0.159	-0.719	-0.758	0.516	1.000	-0.108	-0.899	-0.177	-0.670	0.149	-0.509	-0.316	-0.283	-0.144	-0.782	0.826	SAtsurvey11_17yr
CSacous	-0.129	0.334	-0.167	0.089	0.733	-0.100	0.178	0.635	-0.108	1.000	0.255	-0.198	0.131	-0.279	-0.336	0.206	0.053	0.190	-0.371	-0.104	CSacous
Wcacous	0.425	-0.248	-0.058	-0.427	0.403	0.699	0.954	0.808	-0.899	0.255	1.000	0.033	0.460	-0.590	-0.078	0.121	0.140	0.066	0.278	-0.845	Wcacous
Wnsp1	0.128	-0.146	-0.354	-0.332	-0.374	-0.320	0.275	-0.157	-0.177	-0.198	0.033	1.000	0.535	0.345	0.398	0.345	0.134	0.070	0.426	0.194	Wnsp1
Wnsp2	0.299	-0.137	-0.160	-0.241	0.071	0.117	0.322	0.124	-0.670	0.131	0.460	0.535	1.000	0.370	0.642	0.865	0.057	0.044	0.206	-0.198	Wnsp2
WspN	-0.038	0.101	-0.109	-0.007	-0.430	-0.664	-0.682	-0.432	0.149	-0.279	-0.590	0.345	0.370	1.000	0.716	0.588	-0.172	-0.124	-0.088	0.639	WspN
WspS	0.169	-0.186	-0.402	-0.344	-0.362	0.331	-0.114	-0.586	-0.509	-0.336	-0.078	0.398	0.642	0.716	1.000	0.649	0.046	-0.055	0.456	0.059	WspS
Wspl	0.043	0.067	0.012	0.015	0.016	-0.527	-0.095	0.200	-0.316	0.206	0.121	0.345	0.865	0.588	0.649	1.000	0.012	0.099	-0.157	0.180	Wspl
Ensp1	-0.747	-0.702	-0.410	-0.113	-0.365	0.142	0.137	-0.076	-0.283	0.053	0.140	0.134	0.057	-0.172	0.046	0.012	1.000	0.961	0.341	-0.268	Ensp1
Ensp2	-0.839	-0.435	-0.276	0.061	-0.350	-0.041	0.003	0.125	-0.144	0.190	0.066	0.070	0.044	-0.124	-0.055	0.099	0.961	1.000	0.079	-0.120	Ensp2
Esp	0.266	-0.579	-0.655	-0.673	-0.235	0.571	0.496	-0.936	-0.782	-0.371	0.278	0.426	0.206	-0.088	0.456	-0.157	0.341	0.079	1.000	-0.518	Esp
WspN_BT	-0.350	0.458	0.204	0.406	-0.290	-0.858	-0.934	-0.026	0.826	-0.104	-0.845	0.194	-0.198	0.639	0.059	0.180	-0.268	-0.120	-0.518	1.000	WspN_BT

Identifies a number of “clusters” in the model fits.

Positive correlation between CR 3-6yr and SA 7-10yr.
Negative correlation CR7-10yr and SA4-6yr.
Weak negative correlation CR3-6yr and SA4-6yr.
Negative correlation Esp Age and CR biomass indices. Positive correlation Esp Age and SA 3yr, SA4-6 yr indices.

Evaluating potential linkages between data sets 2.

Correlations (coefficients) in residuals from each set of indices (paired observations by year) – preliminary model *Test3* (including movement CS <> SA).

Corr coefficients

	CRtsurvey11_17yr	CRtsurvey1yr	CRtsurvey2yr	CRtsurvey3_6yr	CRtsurvey7_10yr	CSacous	SAtsurvey1	SAtsurvey3yr	SAtsurvey4_6yr	SAtsurvey7_10yr	WCacous
CRtsurvey11_17yr	1.000	0.137	0.484	-0.075	0.282	0.496	0.535	0.150	0.567	0.487	0.214
CRtsurvey1yr	0.137	1.000	-0.207	0.077	0.037	0.197	0.206	0.107	-0.280	0.009	-0.134
CRtsurvey2yr	0.484	-0.207	1.000	-0.004	0.335	0.133	0.274	-0.317	0.001	0.204	0.606
CRtsurvey3_6yr	-0.075	0.077	-0.004	1.000	0.528	0.372	-0.332	0.033	0.249	0.197	0.122
CRtsurvey7_10yr	0.282	0.037	0.335	0.528	1.000	0.471	0.126	0.279	0.359	0.445	0.379
CSacous	0.496	0.197	0.133	0.372	0.471	1.000	-0.384	0.442	0.412	0.266	0.545
SAtsurvey11_17yr	0.535	0.206	0.274	-0.332	0.126	-0.384	1.000	-0.219	0.088	0.362	0.559
SAtsurvey3yr	0.150	0.107	-0.317	0.033	0.279	0.442	-0.219	1.000	0.357	-0.172	-0.978
SAtsurvey4_6yr	0.567	-0.280	0.001	0.249	0.359	0.412	0.088	0.357	1.000	0.576	-0.879
SAtsurvey7_10yr	0.487	0.009	0.204	0.197	0.445	0.266	0.362	-0.172	0.576	1.000	0.395
WCacous	0.214	-0.134	0.606	0.122	0.379	0.545	0.559	-0.978	-0.879	0.395	1.000

Paired observations (N)

	CRtsurvey11_17yr	CRtsurvey1yr	CRtsurvey2yr	CRtsurvey3_6yr	CRtsurvey7_10yr	CSacous	SAtsurvey1	SAtsurvey3yr	SAtsurvey4_6yr	SAtsurvey7_10yr	WCacous
CRtsurvey11_17yr	25	25	25	25	25	17	15	15	15	15	7
CRtsurvey1yr	25	25	25	25	25	17	15	15	15	15	7
CRtsurvey2yr	25	25	25	25	25	17	15	15	15	15	7
CRtsurvey3_6yr	25	25	25	25	25	17	15	15	15	15	7
CRtsurvey7_10yr	25	25	25	25	25	17	15	15	15	15	7
CSacous	17	17	17	17	17	20	13	13	13	13	4
SAtsurvey11_17yr	15	15	15	15	15	13	18	18	18	18	4
SAtsurvey3yr	15	15	15	15	15	13	18	18	18	18	4
SAtsurvey4_6yr	15	15	15	15	15	13	18	18	18	18	4
SAtsurvey7_10yr	15	15	15	15	15	13	18	18	18	18	4
WCacous	7	7	7	7	7	4	4	4	4	4	11

Model development – Initial model(s)

- Key issues relate to alternative scenarios of trawl survey selectivity/movement CR vs Sub Ant.
- Direct transition of fish from CR > SubA results in unrealistic distribution of biomass and low selectivity of older fish by CR trawl survey.
- Fitting age specific indices from trawl surveys (*q*s) informed decisions regarding parameterisation of overall trawl survey selectivities.
- Relax SubA trawl survey selectivity assumptions – younger fish (4-10 yr). Two options for CR selectivity with equivalent movement constraints (proportion move 100% by age 5(male) or 6 (female)):

i. Chatham Rise survey selectivity estimated - flexible.

ii. Chatham Rise survey selectivity fixed – constant (= 1.0)

Initial model structure – primary data sets

- Fisheries catch: Chatham Rise (2); Sub Antarctic (2); WCSI (3); Cook (1).
- Fishery age comps (ESS 10).
- SA trawl survey indices 4-17 yr (process error 0.1), i.e., exclude 1-3 yr.
- SA trawl survey age comps 4-17 yr (ESS 10) i.e., exclude 1-3 yr.
- CR trawl survey indices 2-17 yr (exclude 1 yr).
- CR trawl survey age comps 2-17 yr (ESS 10) (exclude 1 yr).
- CS acoustic indices (no additional process error). Indexing 4-17 yr biomass.
- WCSI acoustic indices (no additional process error). Indexing 4-17 yr biomass.
- For comparative purposes, also included CR 1 yr indices and SubA 3yr indices.

Initial model structure – configuration 2

- Four Regions: Chatham Rise; Sub Antarctic; WCSI (spawn); Cook (spawn).
- No priors on Acoustic q, trawl survey q, Biomass E/W.
- Natural mortality constant (M 0.30; F 0.25).
- Recruitment. Two "stocks" = growth morphs; temporal variation in recruitment deviates (E & W).
- Recruitment (E & W) assigned to CR region.
- Movement age/sex specific. Ramp function from 2yr-5yr (male), 2yr-6yr (female).
- Movement (W) CR > SA (fix 1.0 at max age); SA > WCSI; CR > WCSI; WCSI > SA.
- Movement (E) CR > CS; CS > CR; CR > SA (Snares); SA (Snares) > CS.
- Age Selectivity SA trawl survey 4-10 yr Estimated, 11-17yr equivalent.
- Age Selectivity CR trawl survey indices 2-10 yr Estimated, 11-17yr equivalent OR 2-17 yr Fixed (1.0).
- Acoustic Indices 4-17 yr biomass at spawning ground.

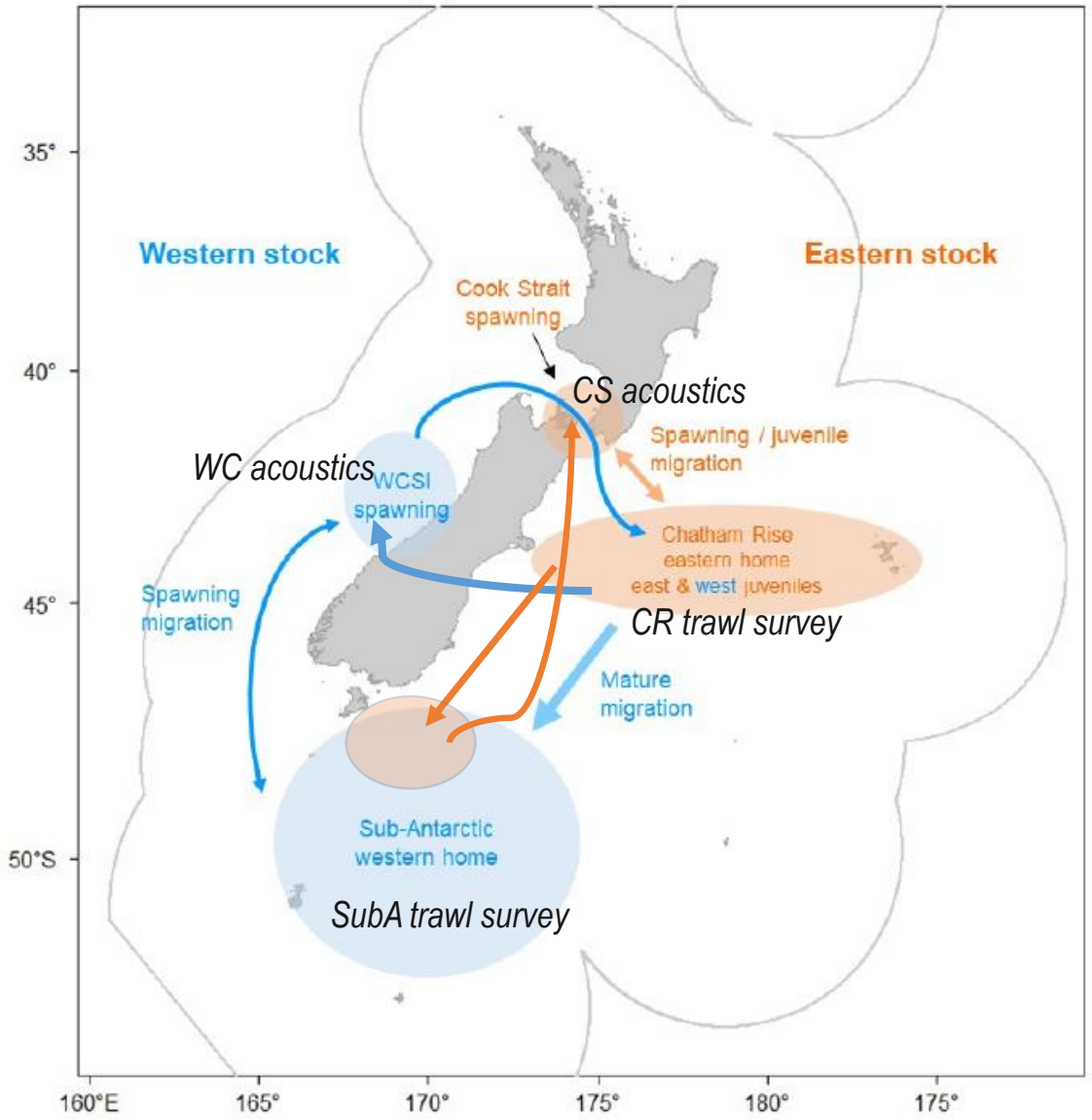


Figure 1: Hoki juvenile nurseries, spawning grounds and migration routes for the eastern and western stocks.

CRselectEst, CRselectFix models

Partition fisheries in each Region based on length/age composition of catches.

Additional movement direct from CR to WCSI. Those fish then move to SubA after spawning.

Also considered additional movement of Eastern sub adults to Snares. Then to the Cook Strait fishery to spawn, returning to CR.

Initial model structure – Fishery configuration

- Age Selectivity CR Shallow. Double Normal, sex invariant.
- Age Selectivity CR Deep. Double Normal, sex invariant (revisit with logistic?).
- Age Selectivity SA Snares. Double Normal, sex invariant.
- Age Selectivity SA South. Logistic, sex invariant.
- Age Selectivity WCSI Inside. Logistic, sex specific.
- Age Selectivity WCSI South. Double Normal, sex specific.
- Age Selectivity WCSI North. Double Normal, sex specific. Two time blocks (pre, post 2000).
- Age Selectivity CS. Double Normal, sex specific. Two time blocks (pre, post 2006).

Movement parameterisation

CRselectEst, CRselectFix models

WESTERN
#seas=1, morph=3, source=1 dest=2, age1=2, age2=5
1 3 2 1 2 5 # move fish from CR to SubA at start of season 2
2 3 1 3 2 5 ## move fish to WCSI from SubAnt at start of Season 3 = spawning
2 3 2 3 2 7 ## move fish to direct to WCSI from CR at start of Season 3 = spawning
3 3 3 1 1 2 ## all fish return to SubA from WCSI end of season 3

EASTERN
2 2 2 4 2 5 ## move E fish to Cook at start of Season 3 - no younger fish
3 2 4 4 2 5 ## stay in Cook after spawning = none
3 2 4 2 2 5 ## move E fish from Cook to CR at end of Season 3
1 2 2 1 2 6 ## move young fish from CR to Snares at start of season 2 - no large fish move
2 2 1 4 2 5 ## move from Snares to Cook - to spawn

Model	CR select	
Initial	Estimated, age 2-5yr	Casal like movement West CR > SA < > WC; East CR <> CS
MovementEst	Estimated, age 2-5yr	Same movement dynamics; relax movement constraints.
Initial2	Estimated, age 2-5yr	Fit to SA trawl survey 4-17yr indices and age
MovementEst2	Estimated, age 2-5yr	Fit to SA trawl survey 4-17yr indices and age
CRselectEst	Estimated, age 2-10yr	Movement West CR > SA < > WC; East CR <> CS, CR <> SA
CRselectFix	Fixed = 1.0	As above
CRselectEst_WCSInorthWest	Estimated, age 2-10yr	WCSI North fishery assigned to the Cook Strait model region (=Eastern fish)
CRselectFix__WCSInorthWest	Fixed = 1.0	WCSI North fishery assigned to the Cook Strait model region (=Eastern fish)
A range of others…..		

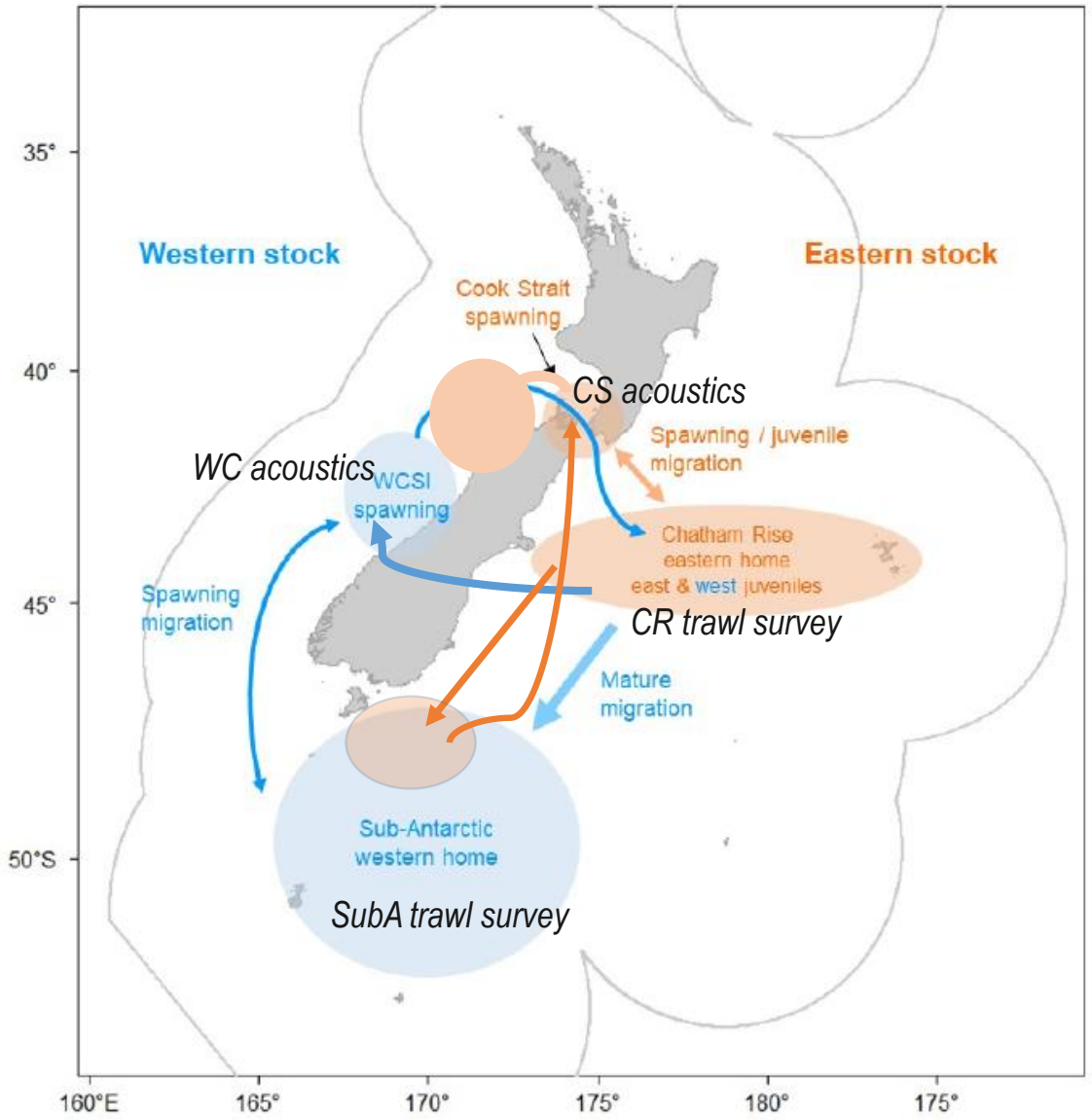


Figure 1: Hoki juvenile nurseries, spawning grounds and migration routes for the eastern and western stocks.

WCSInorthEast models

Partition fisheries in each Region based on length/age composition of catches.

Additional movement direct from CR to WCSI. Those fish then move to SubA after spawning.

Also considered additional movement of Eastern sub adults to Snares. Then to the Cook Strait fishery to spawn, returning to CR.

And incorporate WCSI Northern fishery (catches and age comp) to be part of the Eastern spawning component.

Likelihoods

	SA survey	CR survey	CS ac	WC ac	SAs age	CRs age	CSf age	WCf age				Saf age		CRf age	
								North1	S	Inside	North2	Snare	SubA	shall	deep
Initial	*-6.3*	-30.6	-11.2	-3.5	*21.6*	25.0	30.3	11.6	34.5	31.5	19.4	32.2	13.3	24.1	22.4
MovementEst	*-12.7*	-29.1	-12.2	-3.9	*13.8*	25.0	29.1	12.3	32.0	31.0	19.1	28.4	13.6	24.7	22.0
Initial2	-15.1	-30.4	-12.0	-4.2	383.7	23.6	45.7	10.8	31.9	30.7	17.2	30.1	16.6	23.2	21.1
MovementEst2	-15.3	-29.4	-12.4	-3.9	379.1	23.5	27.6	11.5	33.3	31.3	18.5	28.0	17.6	23.7	20.5
CRselectEst	-7.8	-30.9	-10.9	-4.3	20.3	22.2	28.8	10.5	33.8	30.0	19.2	28.9	14.3	23.2	22.5
CRselectFix	-5.8	-30.7	-11.0	-6.3	20.5	24.8	36.3	10.3	30.7	29.2	18.1	28.1	13.7	23.0	21.7
CRselectEst_WCSInorthEast	-8.2	-30.2	-11.0	-5.2	19.2	22.9	31.4	15.1	32.4	27.6	21.6	28.0	14.2	24.0	22.5
CRselectFix__WCSInorthEast	-3.1	-30.8	-11.2	-5.9	20.6	27.1	32.9	14.4	33.1	28.0	23.3	27.8	14.0	23.7	22.0

Initial and *MovementEst* models SA is only ***4-10yr*** age classes (indices and age comps); other models 4-17 yr age classes (including Initial2 and MovementEst2).

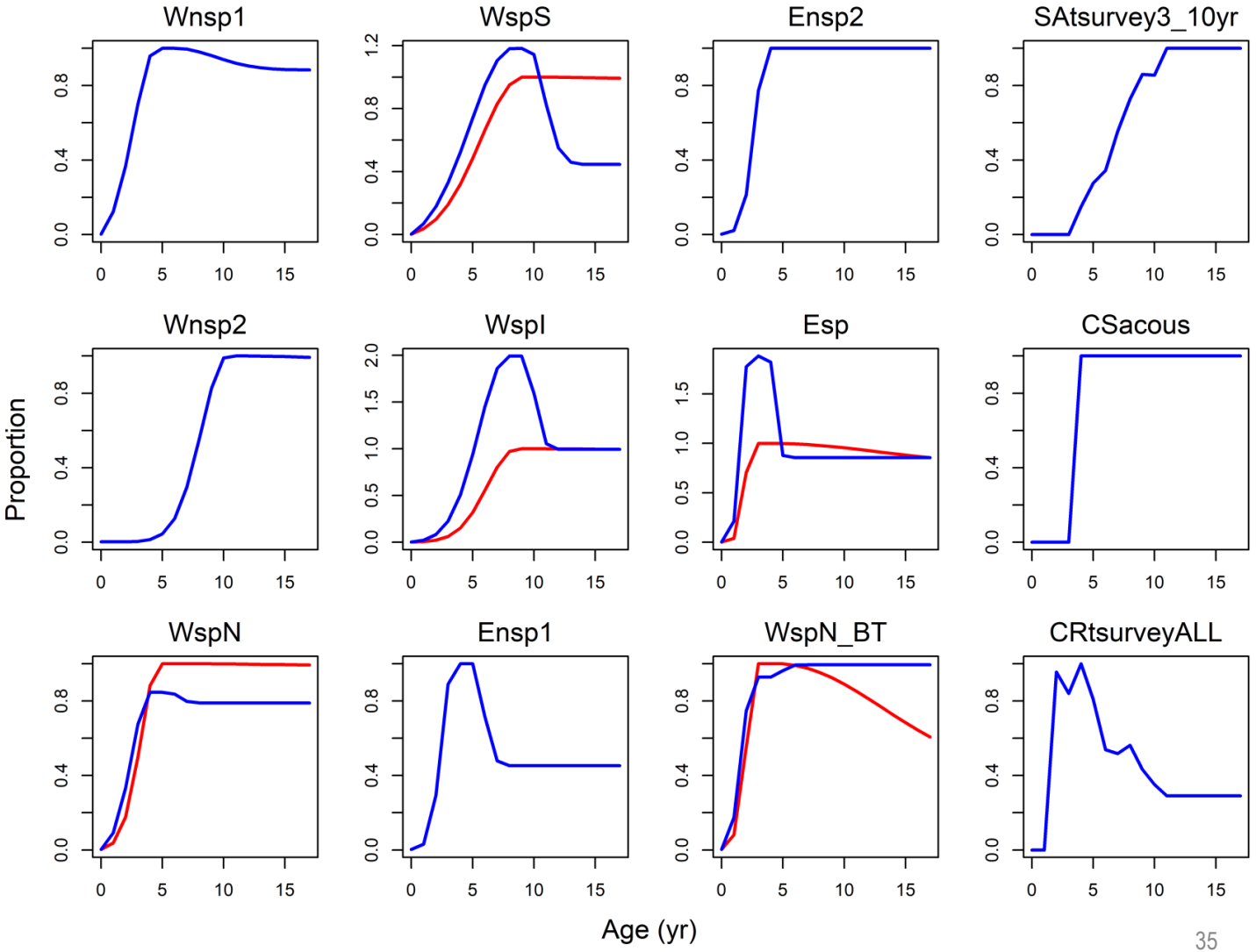
MovementEst model has best overall fit but not directly comparable and other diagnostics are poor

CRselectEst model - Selectivity

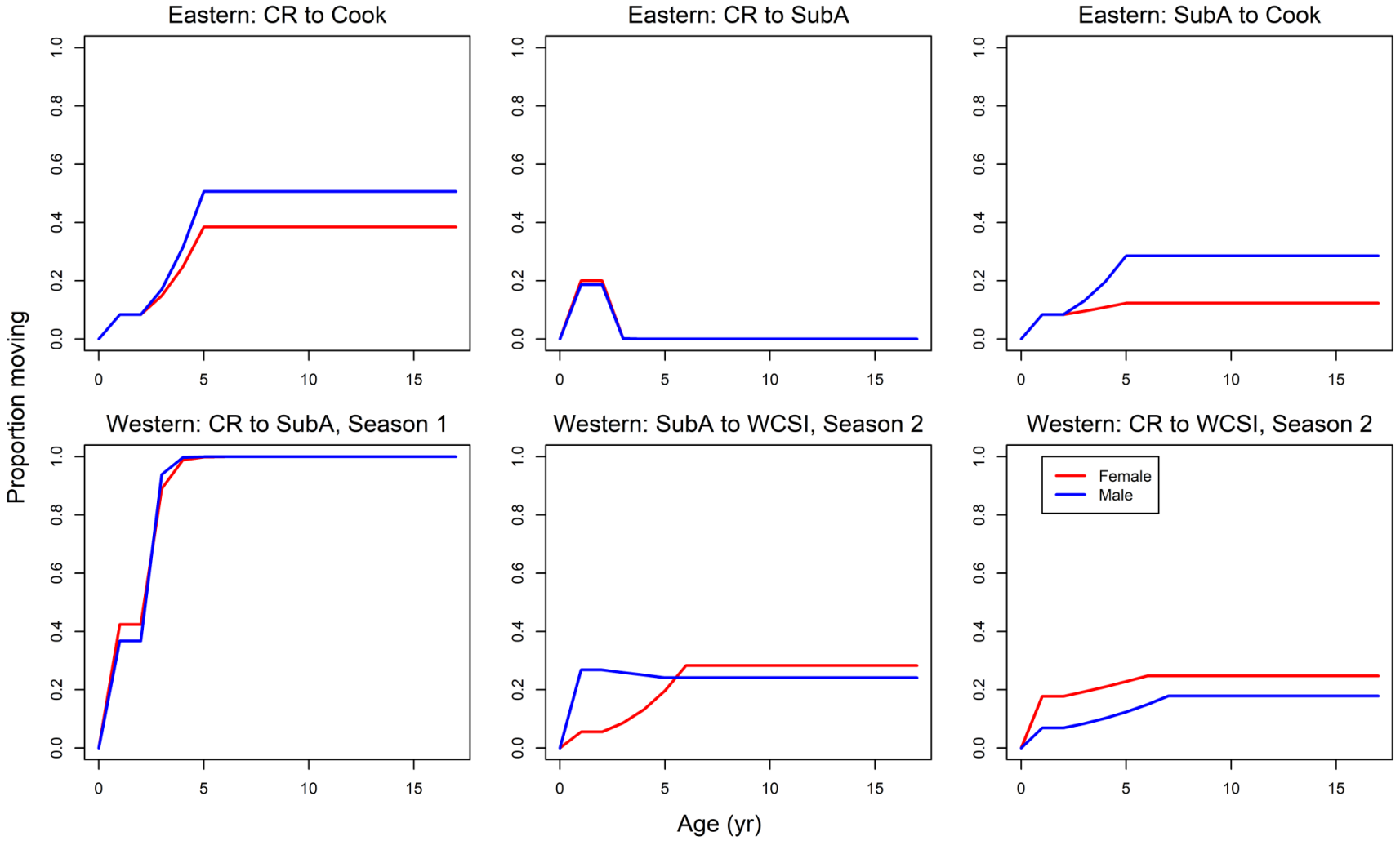
CR trawl survey selectivity steadily declines for ages over 5 yr.

Female Red

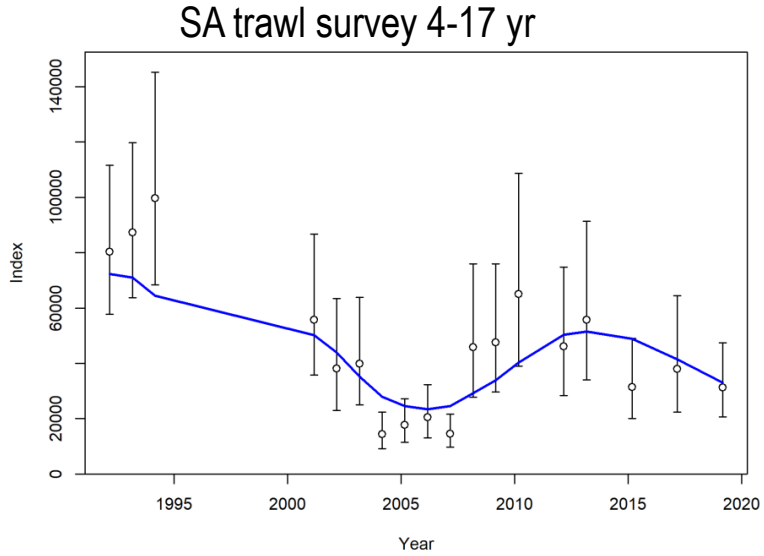
High selectivity of young fish in the Snares fishery.

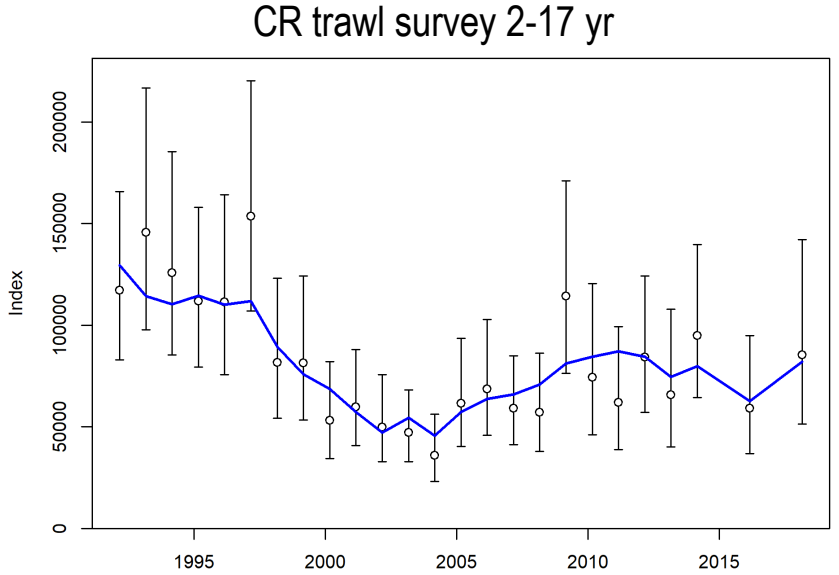


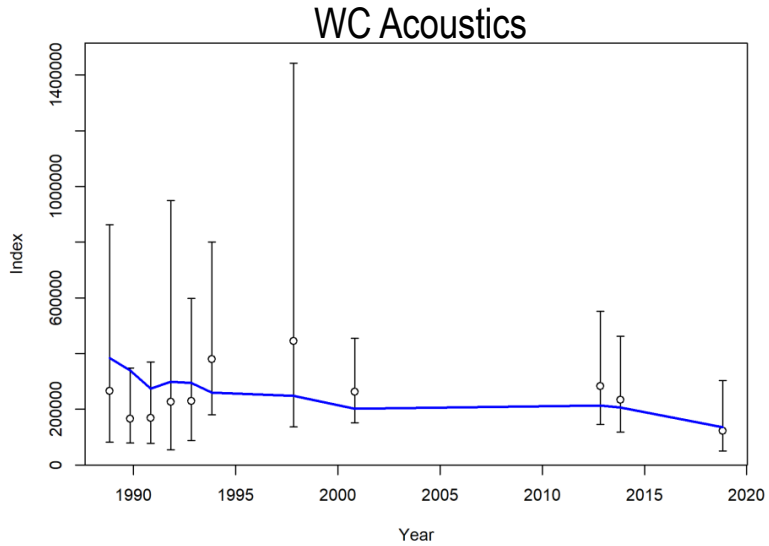
CRselectEst model - Movement

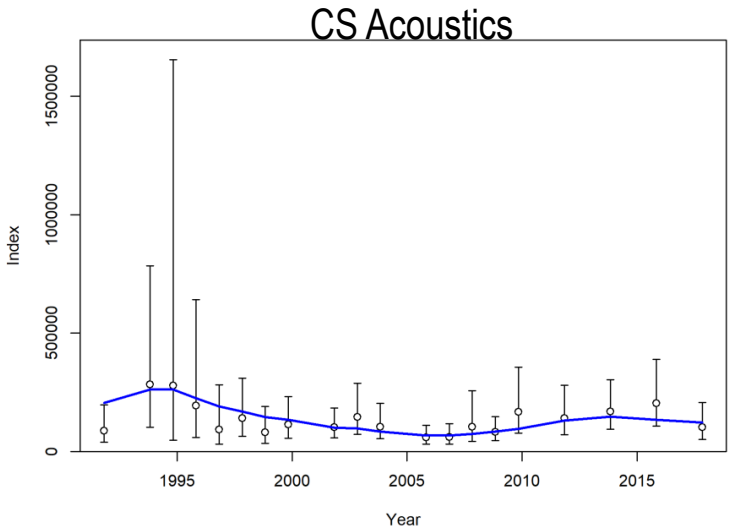


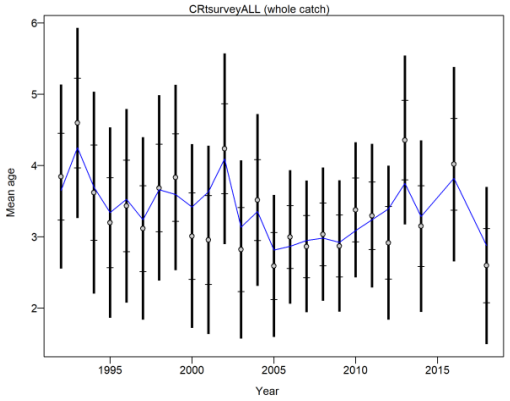
CRselectEst model

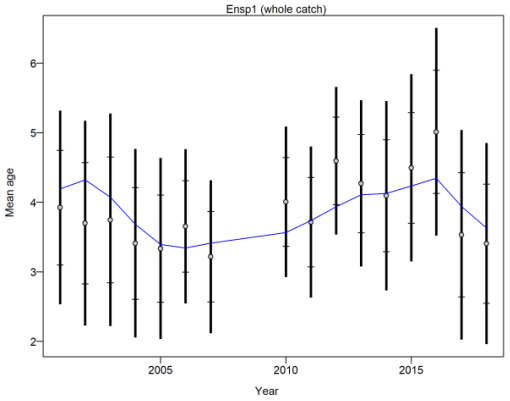


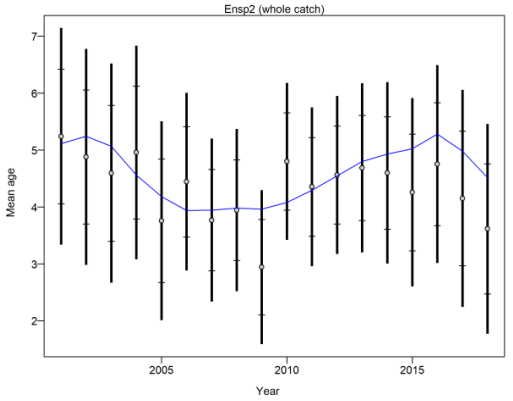


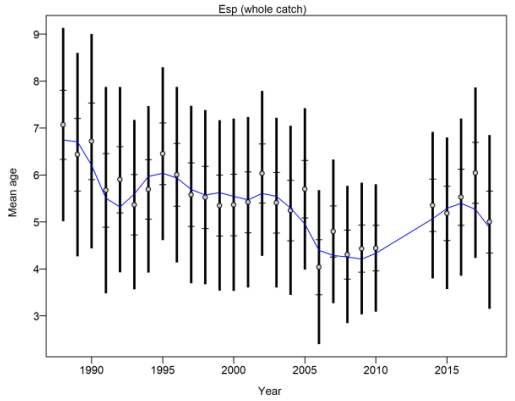


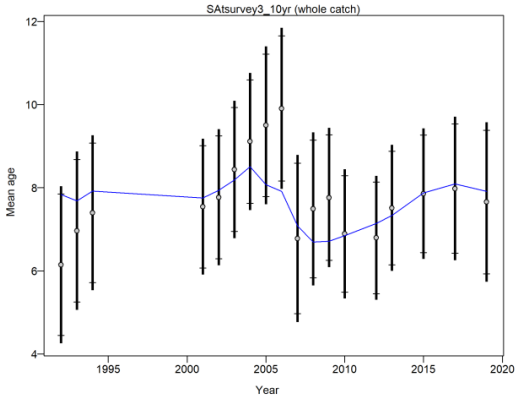


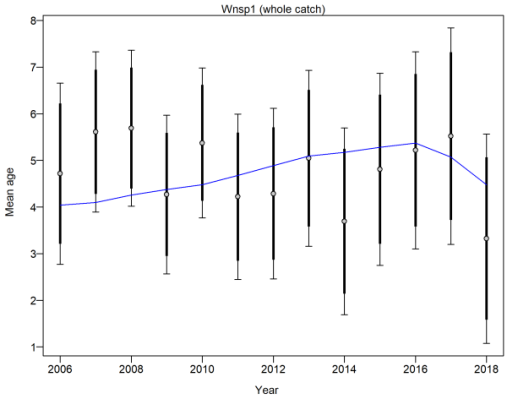


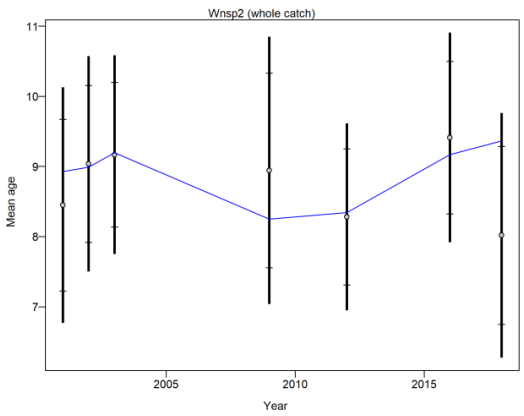




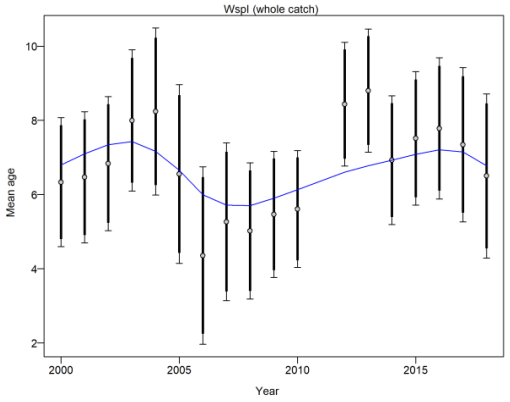


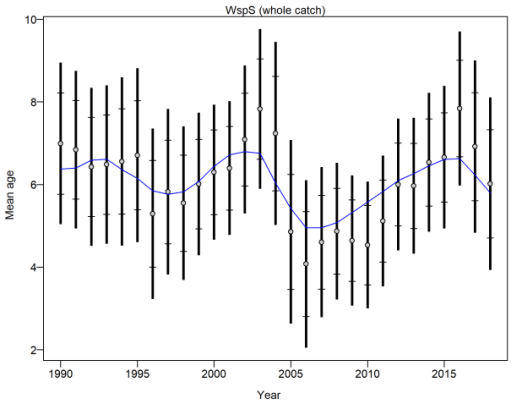


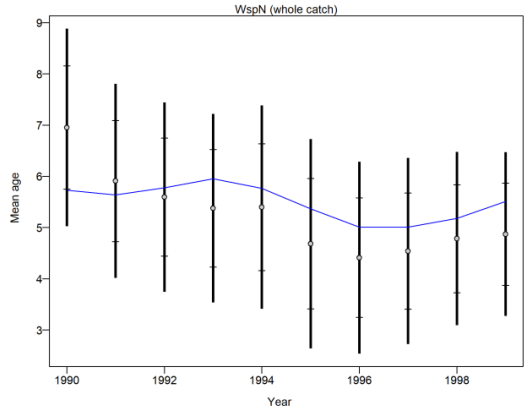


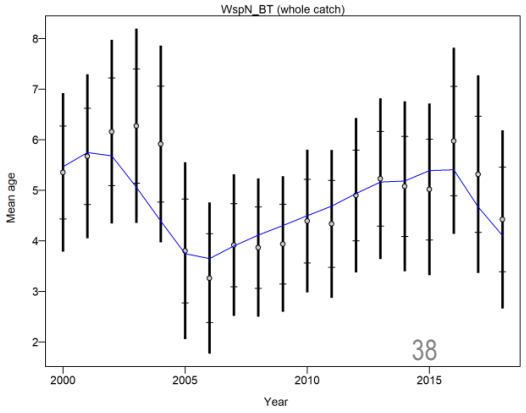


CRselectEst model

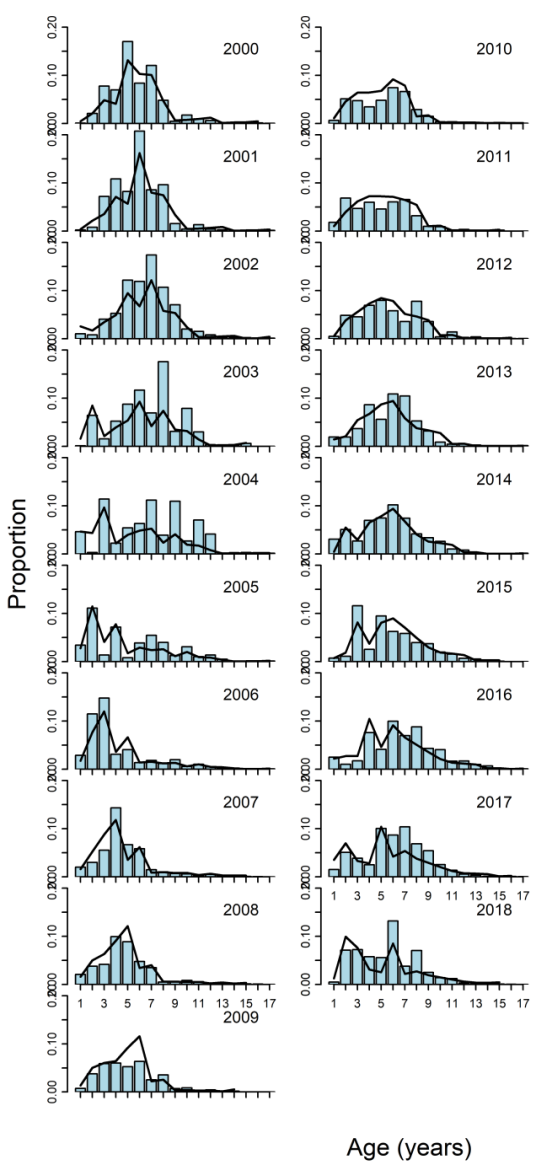




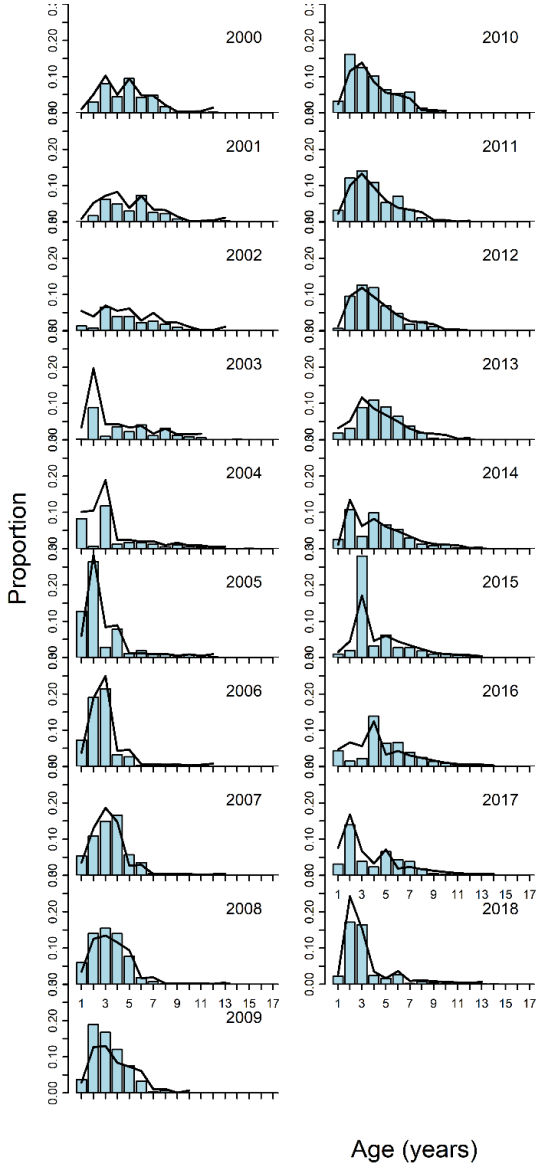




WCSI North
Females

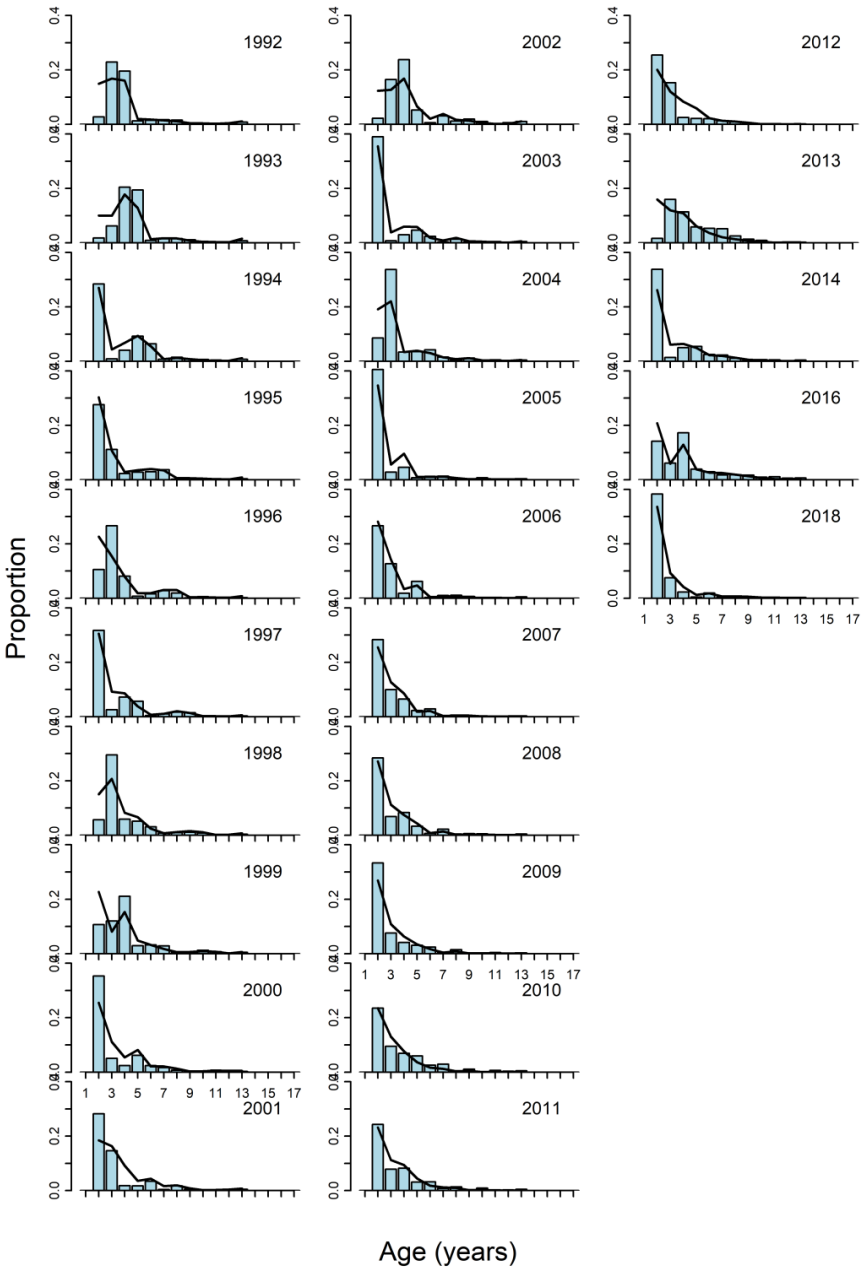


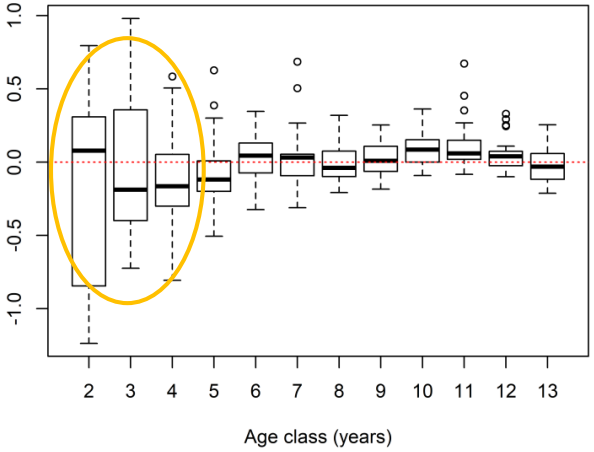
WCSI North
Males

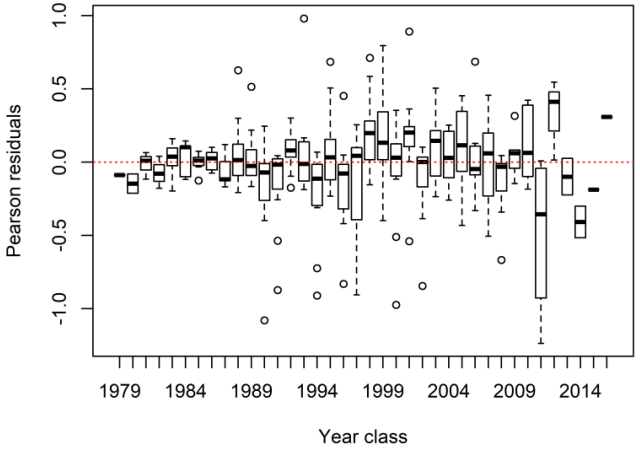


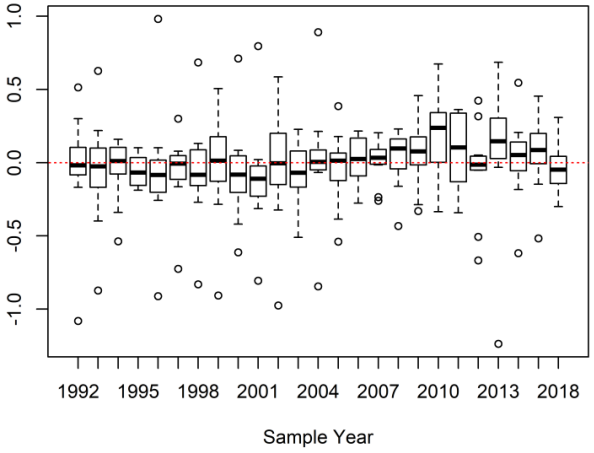
CRselectEst model

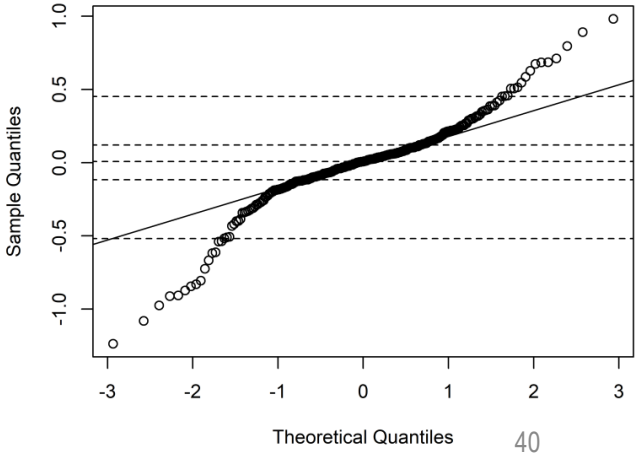
Chatham Rise Survey Females





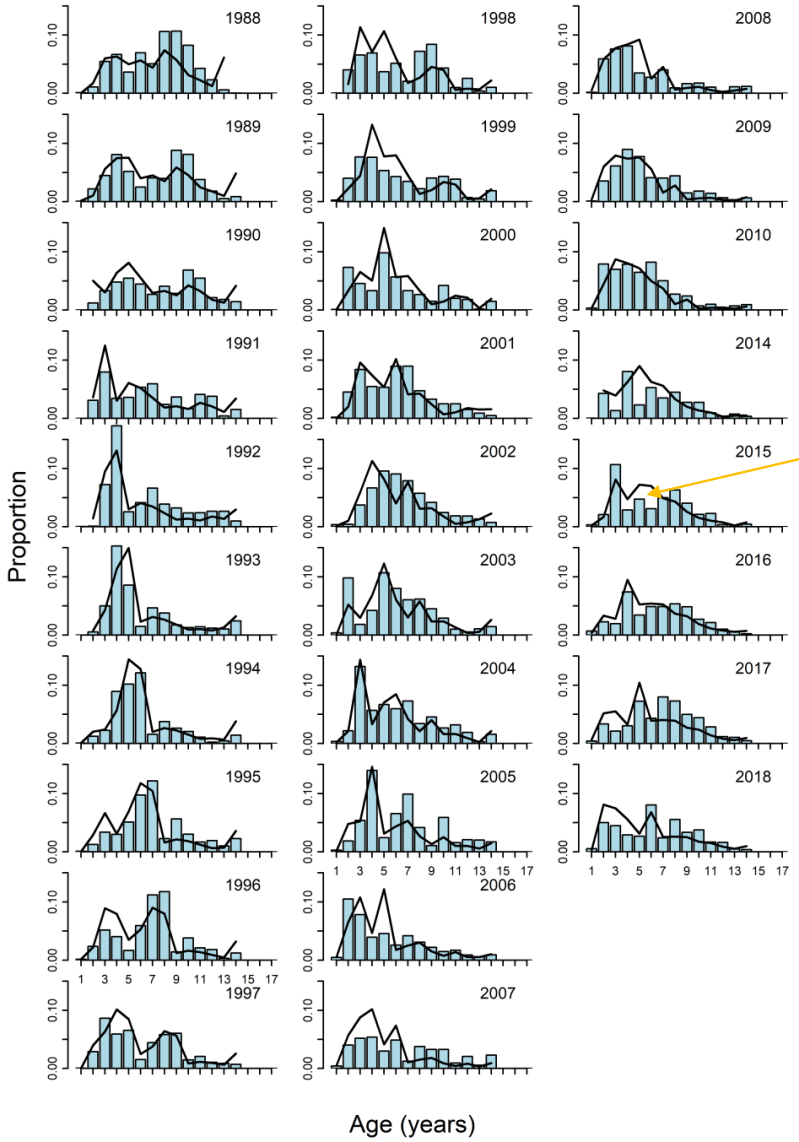


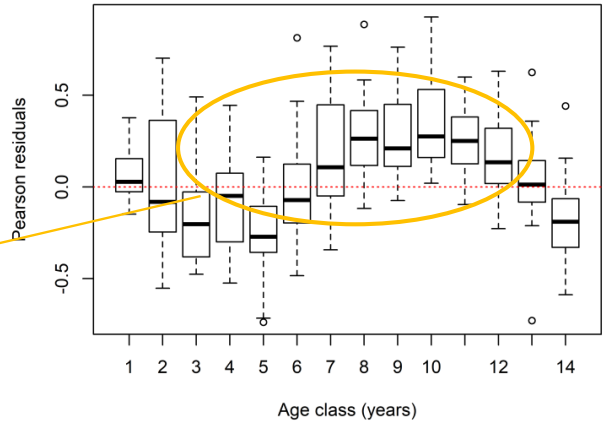


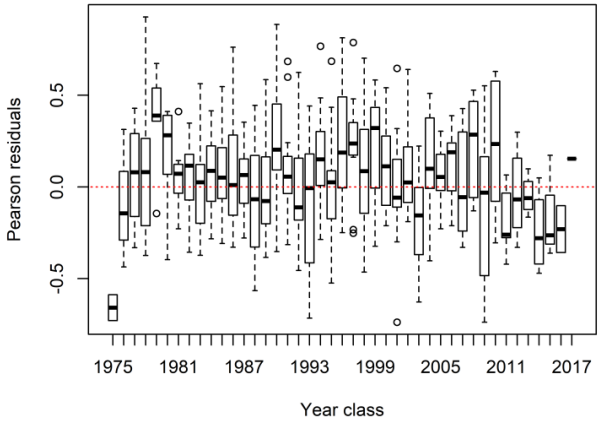


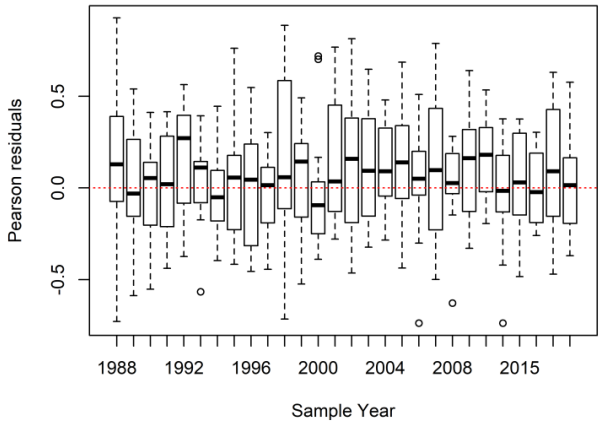
CRselectEst model

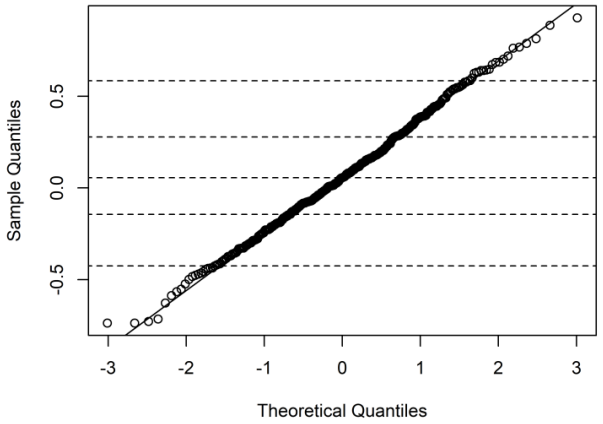
Cook Strait Females





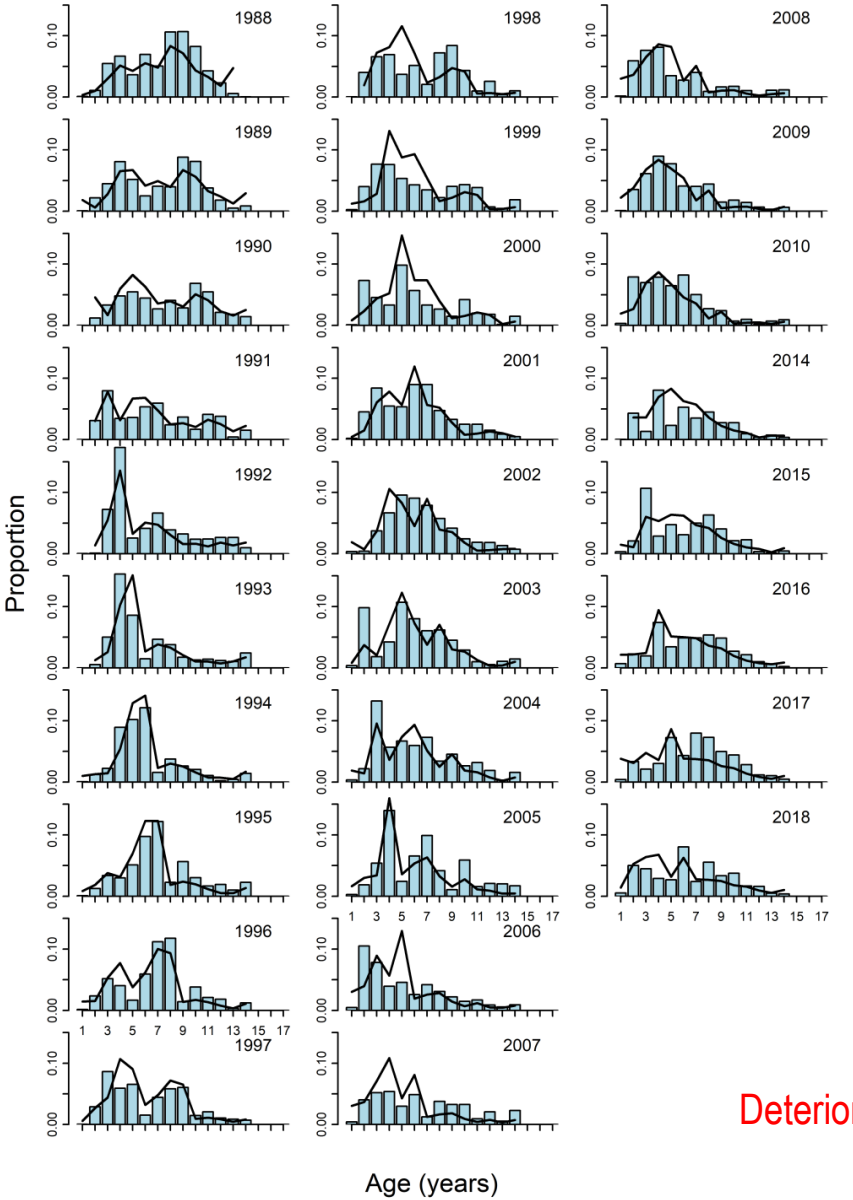


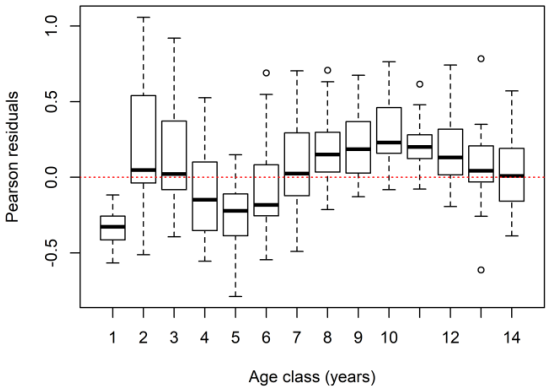


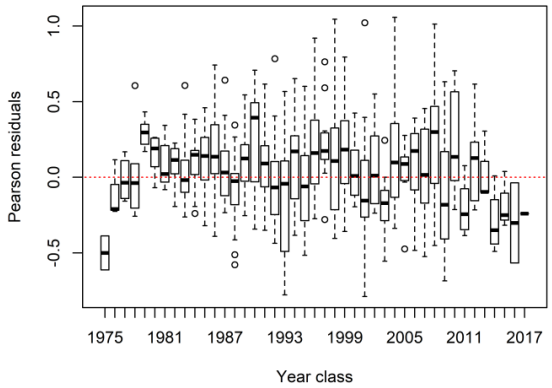


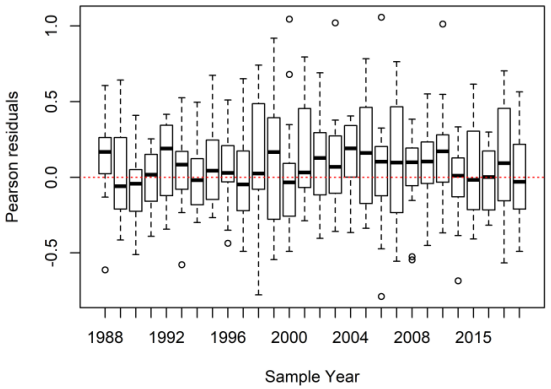
CRselectFix model

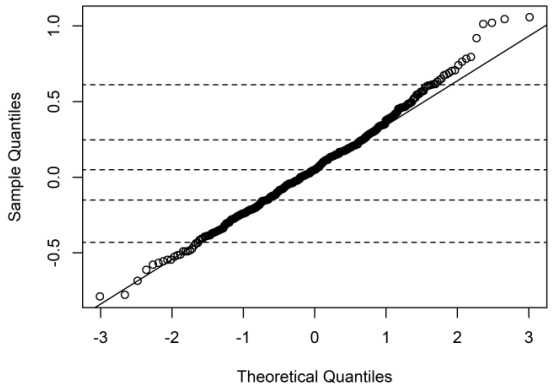
Cook Strait Females





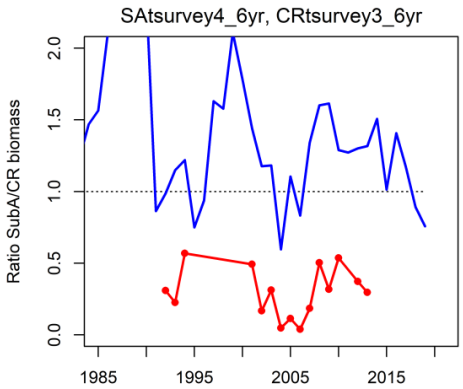


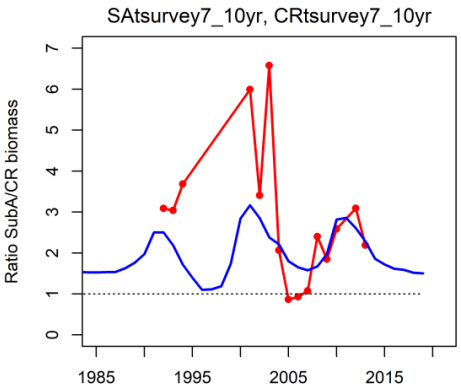


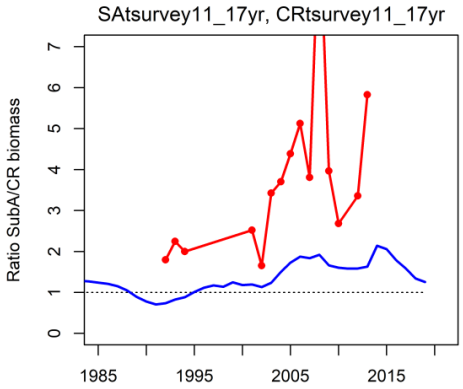


Deterioration in fit (likelihood value) compared to the *CRselectEst* model

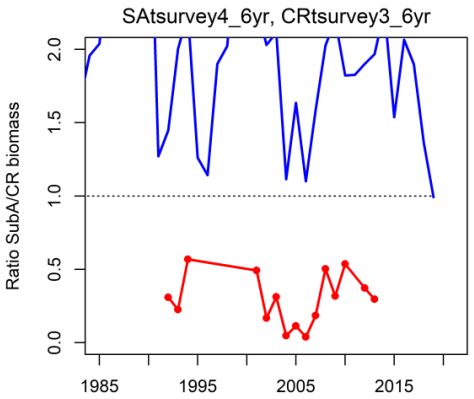
CRselectEst

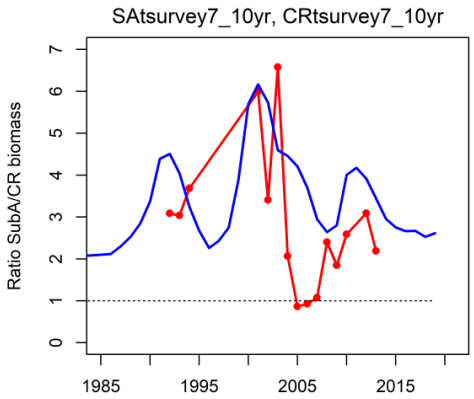


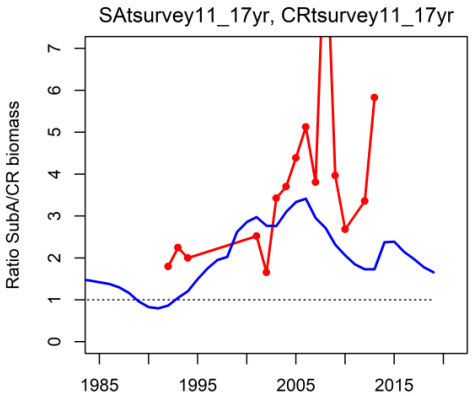




CRselectFix







Fix model moves more subadult Eastern fish into the Snares area and keeps them there until move to spawn (need to move all by max age).

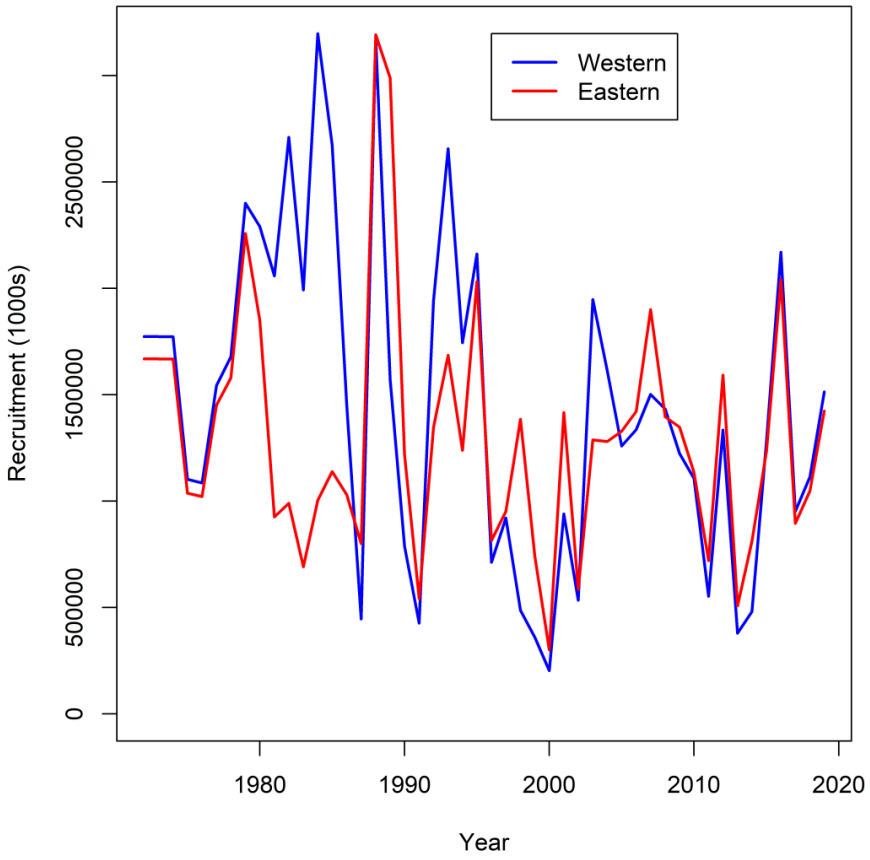
	SB0 E	SB0 W (SubA)	SB0 W (SubA + CR)	SB0 Total	WCSI SB0	E SB/SB0	W (subA) SB/SB0	W (SubA+CR) SB/SB0	Total SB/SB0	WCSI SB/SB0	Cook SB/SB0	CRf VB VB/VB0
Initial	1,260	1,179	1,211	2,471	476	0.358	0.251	0.252	0.306	0.281	0.358	0.429
MovementEst	1,256	776	1,311	2,568	547	0.418	0.133	0.269	0.341	0.183	0.422	0.508
Initial2	1,109	1,433	1,455	2,564	724	0.332	0.288	0.288	0.307	0.346	0.332	0.410
MovementEst2	1,052	1,265	1,664	2,716	392	0.376	0.260	0.285	0.320	0.264	0.382	0.454
CRselectEst	1,018	1,440	1,443	2,655	393	0.332	0.281	0.281	0.320	0.289	0.347	0.402
CRselectFix	732	1,249	1,281	2,376	891	0.260	0.220	0.220	0.286	0.284	0.273	0.326
CRselectEst_WCSInorthEast	1,812	629	631	2,656	363	0.331	0.274	0.274	0.332	0.348	0.352	0.412
CRselectFix__WCSInorthEast	1,210	719	747	2,391	326	0.211	0.303	0.300	0.294	0.330	0.243	0.283

Results of preliminary/exploratory modelling only. Not presented as estimates of stock status for management purposes, rather for the evaluation of a subset of alternative model options.

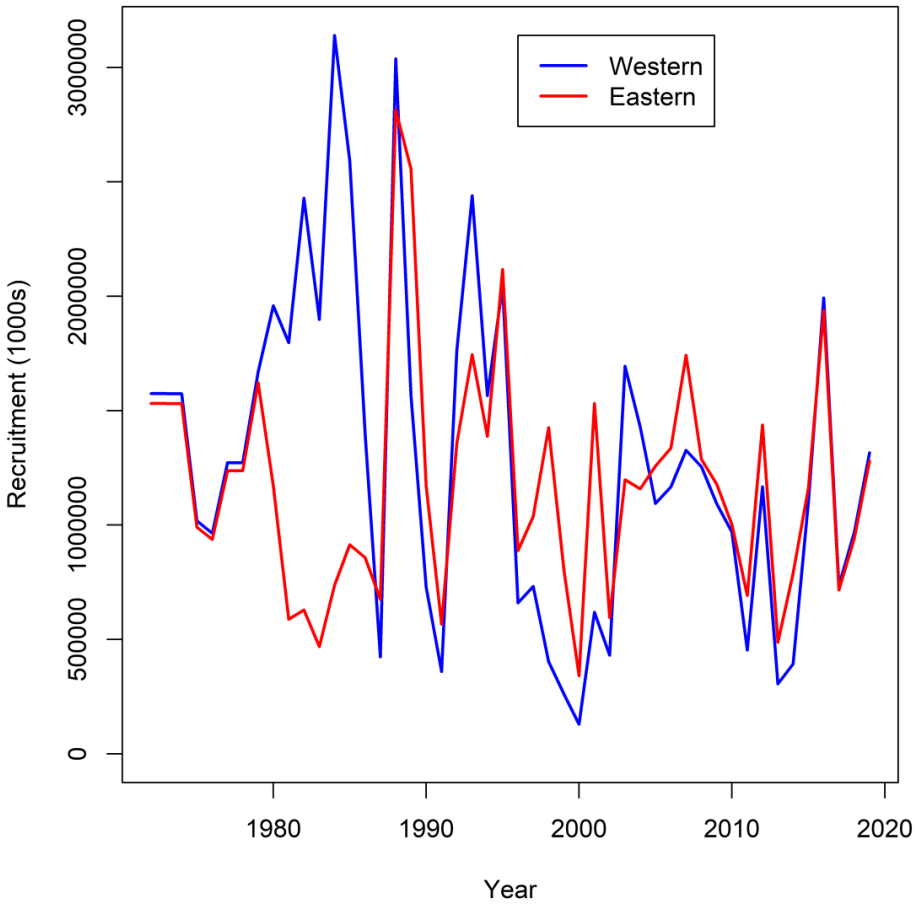
Terminal year (current) = 2017/2018 FY
SB = age 4yr and older for SB0E and SB0W (male and female), SB = fish in region for WCSI and Cook

Actual Biomass on spawning grounds depends on estimated movement – very little information regarding the magnitude of the movement. Best to consider relative biomass.

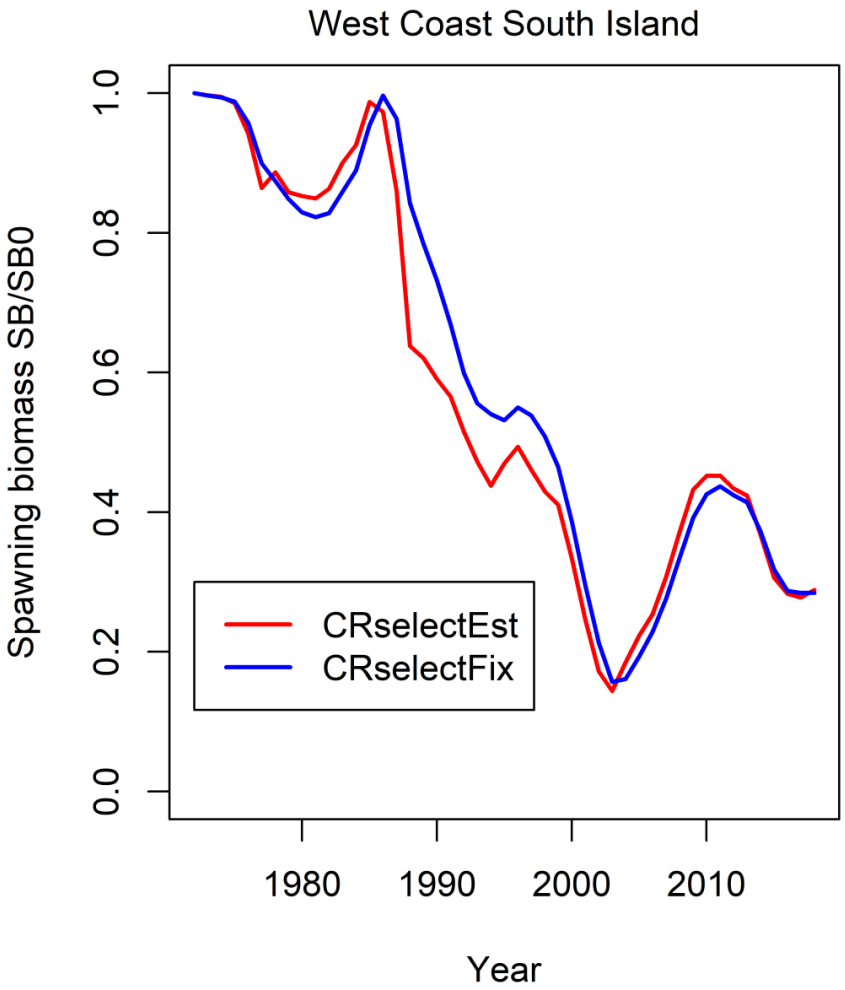
CRselectEst

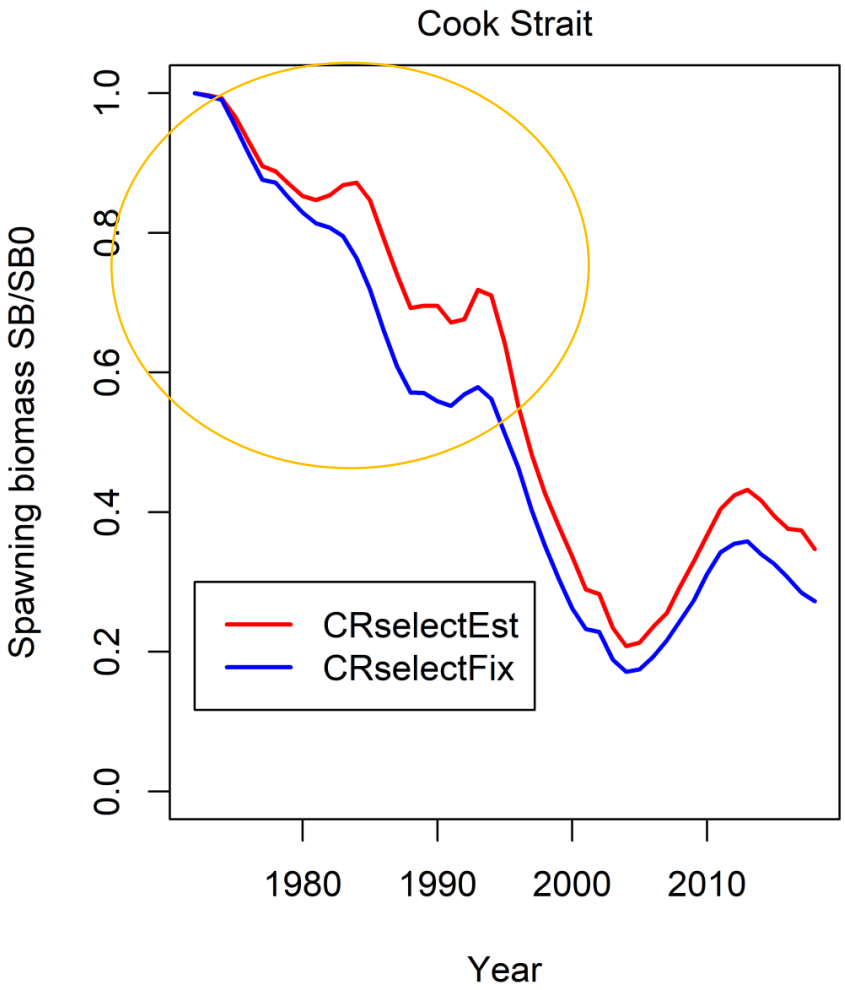


CRselectFix



Recruitment dynamics are very similar between East and West.
Need to evaluate partitioning recruitment E/W.

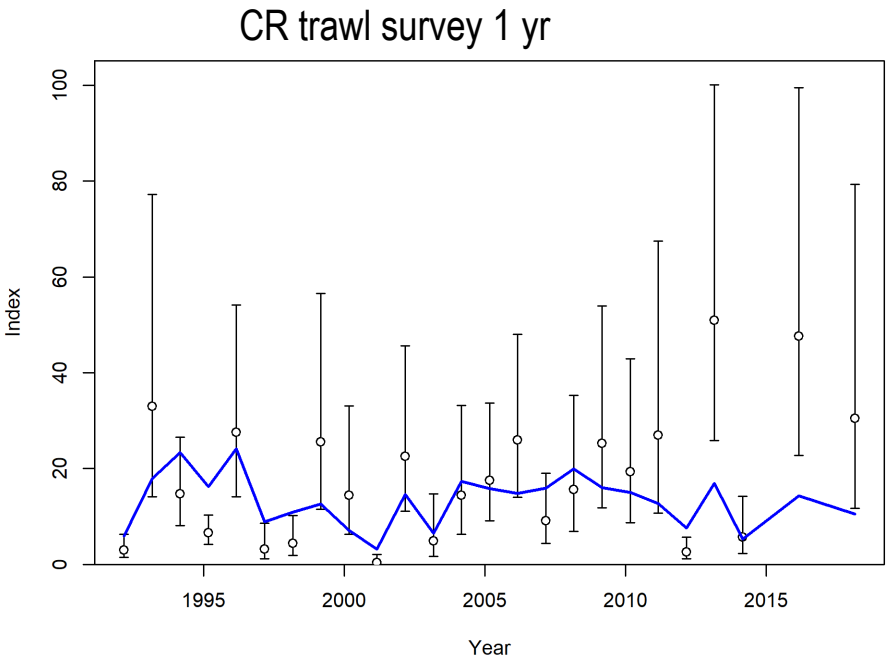




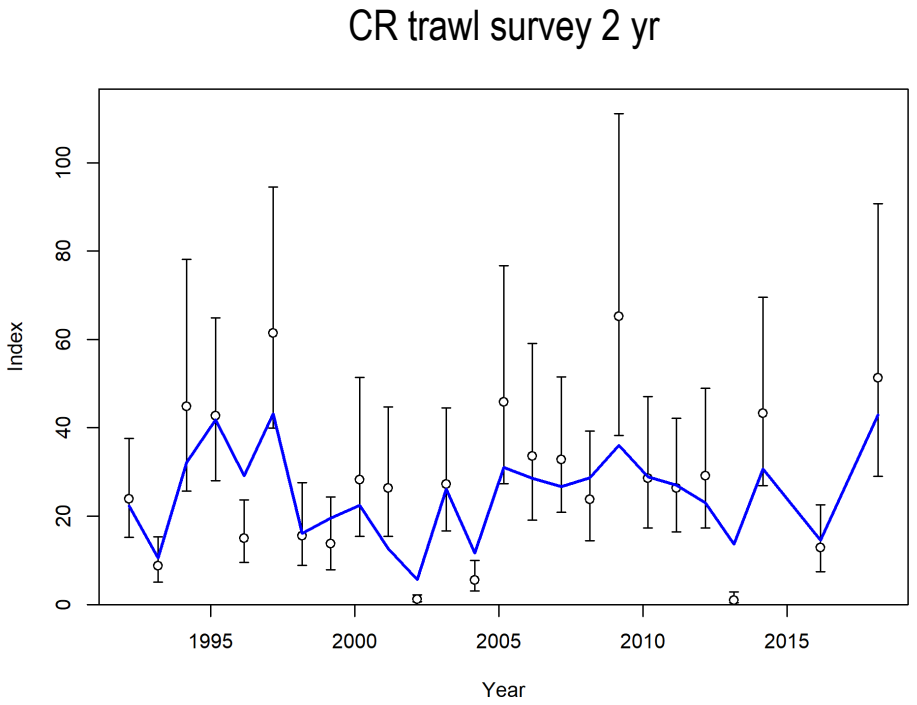
What was the level of depletion of the Eastern stock before CS acoustic surveys started in the early-mid 1990s?

Model estimates lower recruitment for East in 1980s which reduced biomass.

General observations

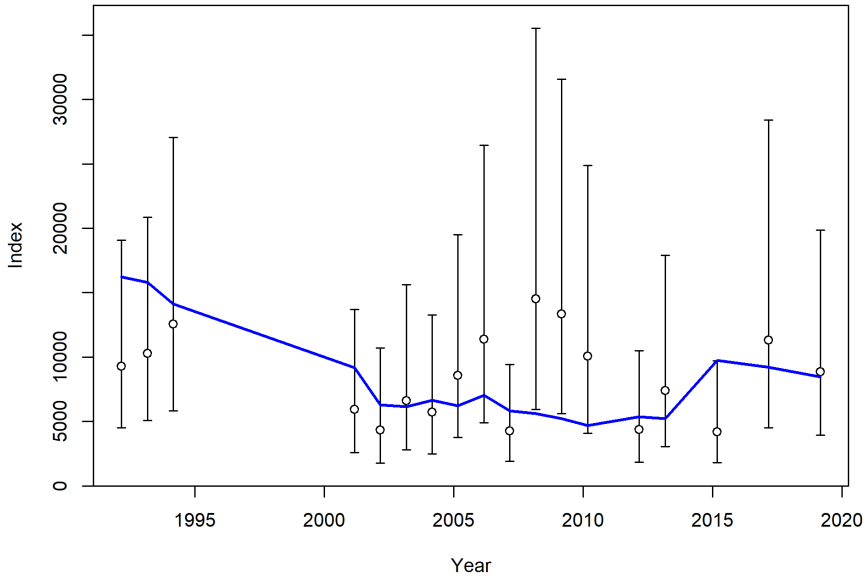


CR 1+ yr indices not included in model fit.
Recent observations of larger 1+ indices have not been estimated as strong year classes in model.
Larger indices are consistently under estimated.



CR 2+ yr indices not included in model fit.
Model under estimates the magnitude of the variation in the observed values.

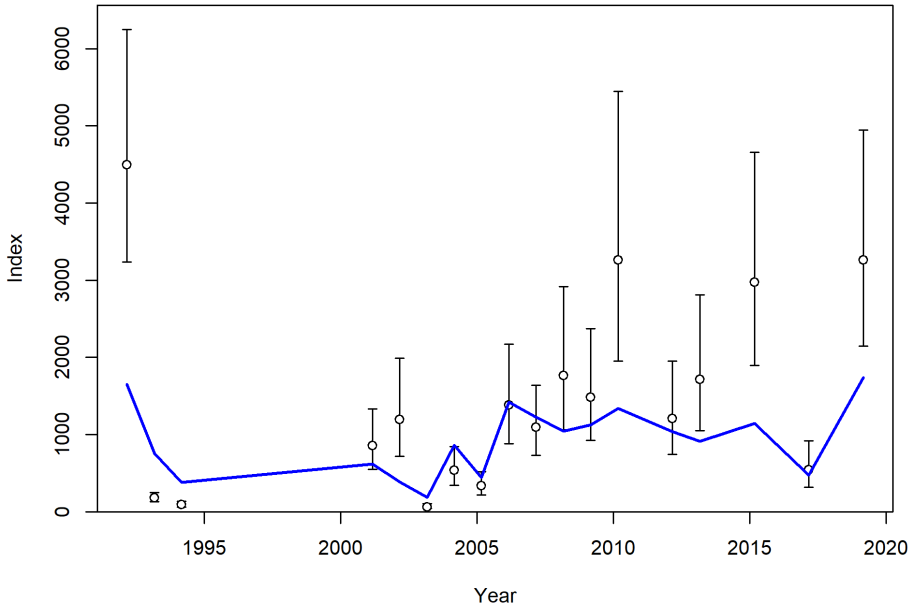
General observations



Lack of fit to SA 11-17 yr biomass indices in the late 2000s. No model options have been able to get close to fitting these observations.

Somewhat similar pattern from CR trawl survey.

Estimation of constant *M* did not appreciably change female *M* (from 0.25) while increased male *M* from 0.3 to 0.35. Result is fairly consistent across a range of model options.



Underestimates magnitude of the observed variation in 3 yr old fish from the SubA.

Key observations – model dynamics

1. Can not directly link abundance indices from CR and SubA trawl surveys. Sub adult component of population (3-6 yr) is not fully available to the two trawl surveys.
2. Variability in the distribution of sub adult fish (between the two surveys). Some indication of negative correlations in the residuals from CR and SubA trawl surveys [look at the residuals between surveys for the fits to individual year classes].
3. Transitional phase of sub adults before western orientated fish become fully available to SubA trawl survey (from age 7 yr).
4. Long time series of CR and SubA trawl survey observations – model has sufficient data available to implicitly link trends in year classes (age/biomass, catches) between the two surveys (augmented by comparable trends from acoustic surveys).
5. Decline in the SubA trawl survey biomass between early 1990s and mid 2000s can not be adequately accounted for by magnitude of catch from WCSI and SubA combined. Improved fit when removals from SubA taken from other regions (e.g. Snares fishery may include fish linked to Eastern areas).
6. Estimated levels of depletion for Western regions are (very) similar from a wide of model options. Depletion in Eastern regions is more uncertain, partly related to the age compositions from the Cook Strait fishery.
7. Recruitment dynamics are very similar for “Eastern” and “Western” fish.

Outstanding Issues – in approx. order of priority

1. CR trawl survey selectivity – full selectivity vs declining. External analyses – e.g. spatial analysis of trawl survey length based catch rates vs commercial CPUE.
2. Delay in availability of hoki to the SubA trawl survey, relative to the Snares fishery. Potential to partition Snares and model as a separate area (SubA trawl survey, seasonal CPUE, LF and age comps).
3. Models do not include 1+ age fish from CR trawl survey. Recent observations (strong year classes) are not consistent with model predictions of numbers of 1 year old fish.
4. Recruitment – sensitivity to assumptions regarding variation in recruitment E/W (will influence relative initial depletion).
5. Cook Strait age compositions. Investigate variation attributable to changes in fishery operation.
6. Other potential linkages: Cook Strait-Wairarapa. Need to investigate catch/CPUE data.
7. Productivity – key biological parameters should be revisited (growth, len-wt, M, defining mature/spawning biomass).
8. Spawning in other locations: Pegasus and Puysegur.
9. Some indication that oldest fish in population are not available to all the CR and SubA trawl surveys (comparable trends).
10. Models do not include 3yr (or 1-2yr) fish from SA trawl survey. Some indication that these fish represent local recruitment (higher q than SA4-6 yr), although do seem to be generally consistent with overall recruitment pattern.
11. Error structure of fit to CR trawl surveys. More variation in fit to 2-4 year fish compared to older age classes. Probably relates to variation in movement of fish from western CR. Alternative is to fit as separate (age specific) indices or higher juvenile M (was tried).
12. Some indication (from residuals) that variation in movement of younger fish from CR could be related to prevailing oceanographic conditions (residuals ~ SOI).

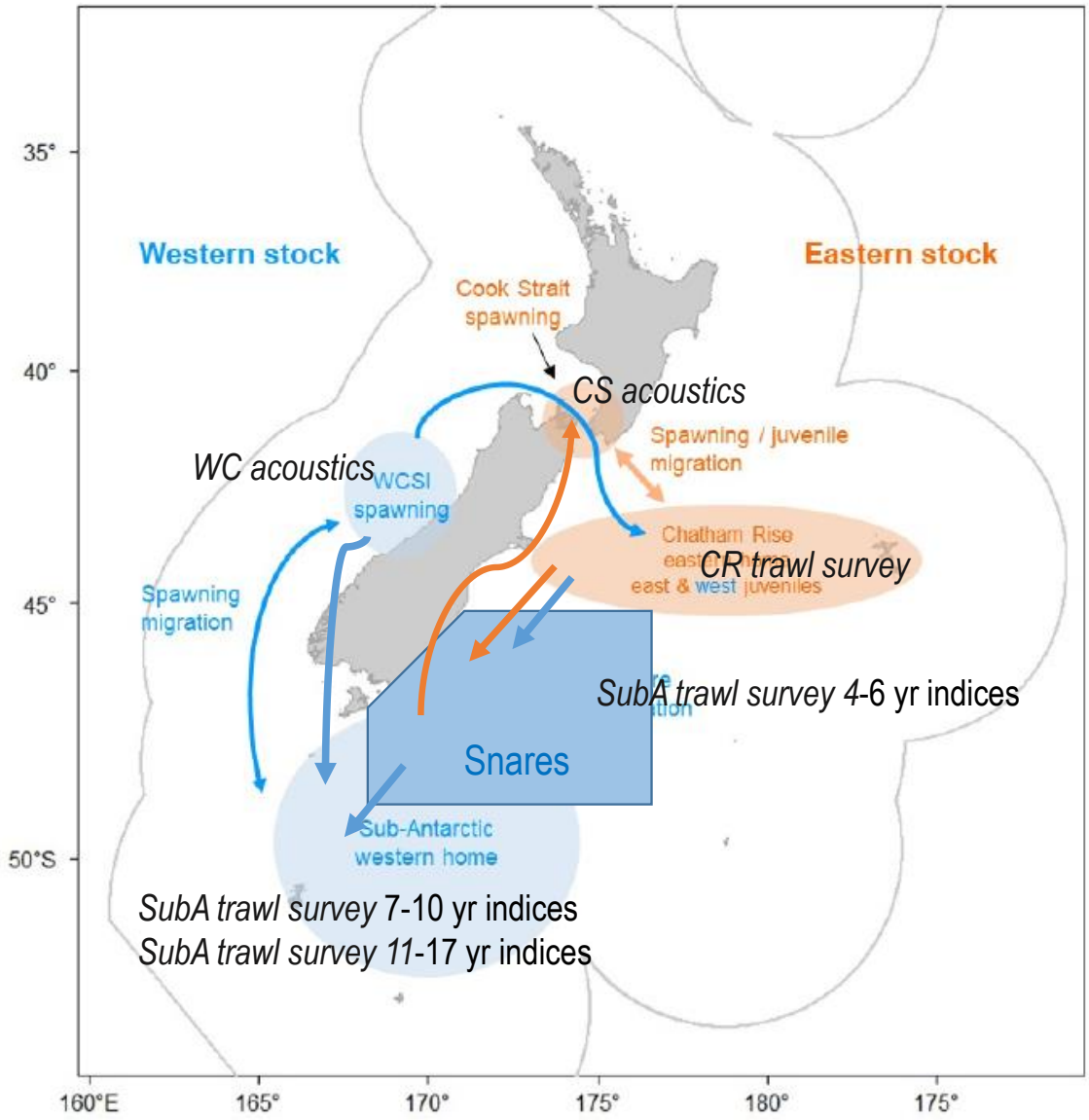


Figure 1: Hoki juvenile nurseries, spawning grounds and migration routes for the eastern and western stocks.

Partition fisheries in each Region based on length/age composition of catches

Snares Region model

Chatham Rise trawl survey selectivity 1.0 for all age classes. Decline in relative numbers at age driven by estimated movement.

Movement W fish from CR fixed at 1.0 for the oldest age classes (5yr males, 7yr females).

Seasonal (quarterly) CPUE indices by area (Snares, CR, SubA).
Length composition (and gonad stage) by area, quarter.

Partition SubA trawl survey by area (biomass and age comp).