4. Gulf of Alaska Shallow water Flatfish (Executive Summary)

Benjamin J. Turnock, William T. Stockhausen, Thomas K. Wilderbuer and Mark E. Wilkins
NMFS Alaska Fisheries Science Center
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4.1 Introduction

Assessment for the shallow water flatfish complex has been moved to a biennial schedule to coincide with the expected receipt of new survey data. On alternate (even) years we will present an executive summary with last year's key assessment parameters and projections for this year. A discussion at the September 2006 Groundfish Plan Team meetings concluded the following two important points for updating information in off-year assessments:

1) Anytime the assessment model is re-run and presented in the SAFE Report, a full assessment document **must** be produced.
2) The single-species projection model **may** be re-run using new catch data without re-running the assessment model.

The shallow water complex is comprised of northern rock sole, southern rock sole, yellowfin sole, butter sole, starry flounder, English sole, sand sole and Alaska plaice. Northern and southern rock sole are in Tier 4 while the other species in the complex are in Tier 5. For further information regarding the shallow water flatfish complex, please see last year's full stock assessment (Turnock et al. 2009, http://www.afsc.noaa.gov/refm/docs/2009/GOAshallowflat.pdf).

4.2 Updated catch, ABCs and OFLs by species

The only new information available concerning the shallow water flatfish complex are the updated 2009 catch (8,483 t) and the best estimate of 2010 catch (4,752 t through October 16, 2010). Consequently, the recommended species-level ABCs and OFLs for 2011-12 are the same as those for 2010-11 from the 2009 assessment. These values, together with the 2009 and 2010 catches, are presented in the following table:

Species							Previous Assessment (2010-2011)[2]		Update Assessment (2011-2012)[3]	
Shallow-water flatfish	2009 Catch	2010 Catch[1]	Tier	FABC	FOFL	Biomass	ABC	OFL	ABC	OFL
Northern rock sole	3,852.9	2,158.3	4	0.204	0.245	95,846	16,085	18,953	16,085	18,953
Southern rock sole	2,917.7	1,634.5	4	0.162	0.192	191,765	26,064	30,460	26,064	30,460
Yellowfin sole	0.7	0.4	5	0.15	0.20	33,414	4,229	5,508	4,229	5,508
Butter sole	1,453.9	814.4	5	0.15	0.20	15,405	1,950	2,539	1,950	2,539
Starry flounder	157.4	88.2	5	0.15	0.20	33,264	4,210	5,483	4,210	5,483
English sole	84.9	47.6	5	0.15	0.20	18,671	2,363	3,078	2,363	3,078
Sand sole	11.9	6.7	5	0.15	0.20	2,808	355	463	355	463
Alaska plaice	3.5	2.0	5	0.15	0.20	7,788	986	1,284	986	1,284
Total shallow-water	8,483	4,752				398,961	56,242	67,768	56,242	67,768

[1]Through Oct. 16, 2010. [2]Recommended values for 2010, 2011. [3]Recommended values for 2011, 2012.

4.3 Area Apportionment

The recommended apportionment percentages are identical to last year using the 2009 survey biomass, because there is no new survey information. The following table shows the recommended apportionment for 2011-12:

Stock/Assemblage	Area:	Western	Central	West Yakutat	Southeast Outside	Total
Shallow water flatfish	Apportionment (%)	42.1	53.3	2.2	2.4	100
	Area ABC (t)	23,681	29,999	1,228	1,334	56,242

4.4 Research Priorities

More aging data is needed to improve estimates of natural mortality for Tier 5 species.

4.5 Summaries for Plan Team

Species/Assemblage	Year	Biomass	OFL[1]	ABC[1]	TAC[1]	Catch[2]
Shallow water flatfish	2007	365,766	62,418	51,450	19,972	8,788
	2008	436,591	74,364	60,989	22,256	7,390
	2009	436,591	74,364	60,989	22,256	8,483
	2010	398,961	67,768	56,242	20,062	
	2011	398,961	67,768	56,242		
	2012	398,961	67,768	56,242		

Stock/		2010				2011		2012	
Assemblage	**Area**	**OFL[1]**	**ABC[1]**	**TAC[1]**	**Catch[2]**	**OFL**	**ABC**	**OFL**	**ABC**
Shallow water flatfish	W	--	23,681	4,500	75	--	23,681	--	23,681
	C	--	29,999	13,000	4,675	--	29,999	--	29,999
	WYAK	--	1,228	1,228	1	--	1,228	--	1,228
	SEO	--	1,334	1,334	1	--	1,334	--	1,334
	Total	67,768	56,242	20,062	4,752	67,768	56,242	67,768	56,242

[1]As published in the Federal Register. [2]As of Oct. 16, 2010.
Note: Tables of ABCs, OFLs, and TACs published in the Federal Register are available for:
2009: http://www.fakr.noaa.gov/sustainablefisheries/specs09_10/goatable1.pdf
2010: http://www.fakr.noaa.gov/sustainablefisheries/specs09_10/goatable1.pdf

Appendix: Stock assessment model specification for the Gulf of Alaska Northern and Southern rock sole (*Lepidopsetta polyxystra and bilineata*) stocks

Teresa A'mar

Introduction

Rock sole are demersal fish and can be found in shelf waters to 600 m (Allen and Smith, 1988). Two species of rock sole are known to occur in the north Pacific Ocean, northern rock sole (*Lepidopsetta polyxystra*) and southern rock sole (*L. bilineata*) (Orr and Matarese, 2000). Adults of the northern rock sole are found from Puget Sound through the Bering Sea and Aleutian Islands to the Kuril Islands, while the southern rock sole is known from the southeast Bering Sea to Baja California (Stark and Somerton, 2002). These species have an overlapping distribution in the Gulf of Alaska (Wilderbuer and Nichol, 2009). Rock sole are most abundant in the Kodiak and Shumagin areas. The northern rock sole spawns in midwinter and spring, and the southern rock sole spawns in summer. Northern rock sole spawning occurred in areas where bottom temperatures averaged 3°C in January, and Southern rock sole spawning began in areas where bottom temperatures averaged 6°C in June (Stark and Somerton, 2002). Rock soles grow to approximately 60 cm and can live in excess of 20 years (http://www.afsc.noaa.gov/race/behavioral/rocksole_fbe.htm).

Both species are managed as part of the shallow-water flatfish complex, which also includes yellowfin sole (*Pleuronectes asper*), starry flounder (*Platichthys stellatus*), butter sole (*Pleuronectes isolepis*), English sole (*Pleuronectes vetulus*), Alaska plaice (*Pleuronectes quadrituberculatus*), and sand sole (*Psettichthys melanostictus*), as these species are caught in the shallow-water flatfish fishery (Turnock et al., 2009).

Data available

- Fishery data for 1978 through 2010
  - Total catch for the <u>shallow-water flatfish complex</u> by year starting in 1978 (where are these data?), and by year and area starting in 1991 (AFSC:BLEND tables BLEND[YY] for 1991 through 2002 and tables CAS[YYYY] for 2003 through 2010)
  - Length composition data for Unidentified/Northern/Southern <u>rock sole</u> samples from fishery observers for 1982 through 2010 (AFSC:NORPAC tables *_HAUL and *_LENGTH)
  - Percent (of biomass) of the shallow-water flatfish complex fishery observer samples that is U/N/S rock sole, by year and by area starting in 1991 (AFSC:NORPAC tables *_HAUL and *_SPECIES_COMPOSITION)
  - Ageing data will not be requested for fishery rock sole samples in 2010
- The NMFS GOA triennial/biennial bottom trawl survey for 1984 through 2009
  - Estimates of U/N/S rock sole abundance by year and INPFC area, by species starting in 1996 (AFSC:GOA table BIOMASS_TOTAL)
  - Length composition data for U/N/S rock sole by year, sex, and INPFC area, by species starting in 1996 (AFSC:GOA table SIZECOMP_TOTAL)
  - Age composition data for U/N/S rock sole by year and sex, by species starting in 1996 (AFSC:GOA table AGECOMP_TOTAL)

  - o Mean length-at-age data for U/N/S rock sole by year and sex, by species starting in 1996 (AFSC:GOA table AGECOMP_TOTAL)
- The ADF&G GOA nearshore bottom trawl survey for 1996 through 2009 (**are not used currently in the stock assessment model, as the length composition data are not sex-specific, although the data may be used in the future**)
  - o Estimates of abundance of U/N/S rock sole by year and area for 1996 through 2009 (Kally Spalinger, pers. comm.)
  - o Length composition data for U/N/S rock sole by year and area for 1996 through 2009 (Kally Spalinger, pers. comm.)
- Values for species- and sex-specific biological parameters for growth and maturity come from Stark and Somerton, 2002
- Additional information from the 2009 GOA shallow-water flatfish SAFE document

Undifferentiated data

There are data are for unidentified (U) rock sole in many years, e.g., estimates of survey biomass, estimates of survey length and age composition, and fishery length composition, including fishery length composition data for 2010. The model estimates of length and age composition and survey abundance for U rock sole are calculated using the estimated numbers-at-length or -at-age for northern (N) and southern (S) rock sole.

Fishery and survey length and age composition data for unsexed U/N/S rock sole are not used.

Population dynamics

Rock sole are caught in the shallow-water flatfish fishery and are not targeted specifically, as they co-occur with several other species. The rock sole species were differentiated in survey data beginning in 1996, and were differentiated in the fishery beginning in 1997. Data for more recent years have the species listed as northern, southern, or “unidentified” rock sole as adult northern and southern rock sole are difficult to differentiate visually (K. Rand, NOAA, pers. comm.). Thus, the statistical catch-at-age population dynamics model describes both species (as stocks caught in a multispecies fishery) and is also sex-specific.

The number of animals aged one and older is governed by the equation:

$$N_{p,s,y+1,a} = \begin{cases} N_{p,s,y+1,1} & \text{if } a = 1 \\ N_{p,s,y,a-1}\, e^{-(M_{p,s,a-1} + \tilde{S}_{p,s,y,a-1} F_{p,s,y})} & \text{if } 1 < a < x_p \\ N_{p,s,y,x-1}\, e^{-(M_{p,s,x-1} + \tilde{S}_{p,s,y,x-1} F_{p,s,y})} + N_{p,s,y,x}\, e^{-(M_{p,s,x} + \tilde{S}_{p,s,y,x} F_{p,s,y})} & \text{if } a = x_p \end{cases} \quad \text{(A.1)}$$

where $N_{p,s,y,a}$ is the number of fish of species *p* of sex *s* of age *a* at the start of year *y*;

$M_{p,s,a}$ is the (time-invariant) instantaneous rate of natural mortality for fish of species *p* of sex *s* of age *a* (assumed to be 0.2, per Turnock et al., 2009);

$\tilde{S}_{p,s,y,a}$ is the selectivity of harvesting on fish of species *p* of sex *s* of age *a* during year *y*;

$F_{p,s,y}$ is the fishing mortality on fully-selected ($\tilde{S}_{p,s,y,a} \to 1$) animals of species *p* of sex *s* during year *y*; and

x_p is the plus-group for species *p* (all fish in this age-class are mature and recruited to the fishery – assumed to be age 30 for both N and S rock sole).

Three options for the relationships between stock size and the number of subsequent recruits (at age 1) are available. The ratio of males to females at recruitment is assumed to be 1:1. Recruitment is lower than expected at unfished equilibrium when the spawning biomass is a small fraction of its unfished size for two of these relationships (Beverton-Holt and Ricker):

$$N_{p,y+1,1} = \frac{4R_{p,1}h_p\, SB_{p,y}}{\psi_{p,1}R_{p,1}\left(1-h_p\right)+\left(5h_p-1\right)SB_{p,y}} e^{\varphi_{p,y+1}-\sigma_R^2/2} \qquad \varphi_{p,y} \sim N(0,\sigma_R^2) \qquad \text{(A.2a)}$$

$$N_{p,y+1,1} = \frac{SB_{p,y}}{\psi_{p,1}} \exp\left[A_{p,r}\left(1-\frac{SB_{p,y}}{\psi_{p,1}R_{p,1}}\right)\right] e^{\varphi_{p,y+1}-\sigma_R^2/2} \qquad \varphi_{p,y} \sim N(0,\sigma_R^2) \qquad \text{(A.2b)}$$

but not for the third:

$$N_{p,y+1,1} = \bar{R}_{p,1}\, e^{\varphi_{p,y+1}-\sigma_R^2/2} \qquad \varphi_{p,y} \sim N(0,\sigma_R^2) \qquad \text{(A.3)}$$

where $SB_{p,y}$ is the female spawning biomass of species *p* during year *y* at the time of peak spawning (corresponding to 1 April for northern rock sole and 15 July for southern rock sole (Stark and Somerton, 2002)):

$$SB_{p,y} = \sum_{a=1}^{x} f_{p,y,a}\, N_{p,s,y,a} e^{-frac_p(M_{p,s,a}+\tilde{S}_{p,s,y,a}F_{p,s,y})}, \; s = female \qquad \text{(A.4)}$$

$frac_p$ is the fraction of the year at which spawning for species *p* takes place (set to 3/12 for Northern rock sole and 6.5/12 for Southern rock sole);

$R_{p,1}$ is the number of age-1 animals of species *p* at unfished equilibrium;

$\psi_{p,1}$ is spawning biomass-per-recruit in the absence of exploitation for species *p*;

h_p is the steepness of the stock-recruitment relationship for species *p* ($h_p = 1\Big/\left(1+4e^{-A_{p,r}}\right)$ for the Ricker model);

$\bar{R}_{p,1}$ is average age-1 recruitment for species *p*;

σ_R is the log-scale standard deviation of the random fluctuations in recruitment about the underlying deterministic stock-recruitment relationship (set to 0.6);

$f^{spawn}_{p,y,a}$ is the contribution of fish of species *p* of age *a* to spawning during year *y*:

$$f^{spawn}_{p,y,a} = \sum_{l} \delta^{spawn}_{p,s,y,a,l}\, w^{spawn}_{p,s,y,l}\phi_{p,y,l}, \; s = female \qquad \text{(A.5)}$$

$\phi_{p,y,l}$ is the fraction of female fish of species *p* of length *l* that are mature/spawning during year *y*;

$w^{spawn}_{p,y,l}$ is the average mass of a spawning female fish of species *p* in length bin *l* during year *y*; and

$\delta^{spawn}_{p,y,a,l}$ is the proportion of female animals of age *a* in length bin *l* during the spawning season of species *p* during year *y* (Eqn. A.6d).

Growth and maturity

From Stark and Somerton, 2002:

Northern rock sole

- Males: L_∞=382, *k*=0.261, t_0=0.160;
- Females: L_∞=429, *k*=0.236, t_0=0.387, L_{T50} = 328 mm.

Southern rock sole

- Males: L_∞=387, *k*=0.182, t_0=-0.962;
- Females: L_∞=520, *k*=0.120, t_0=-0.715, L_{T50} = 347 mm.

[Note: many of the parameters below with the subscript *y* are not time-varying, although they may be in future model configurations.]

Mean length-at-age for animals of species *p* of sex *s* of age *a* at the beginning of the first year is:

$$L_{p,s,y,a} = L_{p,s,y,\infty} + (L_{p,s,y,young} - L_{p,s,y,\infty})e^{-k_{p,s,y}(a-\alpha_{p,s,young})} \quad \text{(A.6a)}$$

where $L_{p,s,y,\infty}$ is the mean asymptotic length of species *p* of sex *s* during year *y*;

$k_{p,s,y}$ is the growth coefficient of species *p* of sex *s* during year *y*;

$\alpha_{p,s,young}$ is a reference age greater than or equal to the youngest age of species *p* of sex *s* and is well-represented in the data (set to age 3); and

$L_{p,s,y,young}$ is the mean length at age $\alpha_{p,s,young}$ of species *p* of sex *s* during year *y*.

The mean length-at-age of species *p* of sex *s* at the beginning of each subsequent year is:

$$L_{p,s,y+1,a} = L_{p,s,y,a} + \left(L_{p,s,y,a} - L_{p,s,y,\infty}\right)\left(e^{-k_{p,s,y}} - 1\right) \quad \text{(A.6b)}$$

The mean length-at-age of species *p* of sex *s* at year fraction *t* in year *y* is:

$$L^t_{p,s,y,a} = L_{p,s,y,a} + \left(L_{p,s,y,a} - L_{p,s,y,\infty}\right)\left(e^{-t^*k_{p,s,y}} - 1\right) \quad \text{(A.6c)}$$

The proportion of animals of species *p* of sex *s* of age *a* in length bin *l* at year fraction *t* in year *y* is:

$$\delta^t_{p,s,y,a,l} = \begin{cases} \Phi\left(\dfrac{LB_1 - L^t_{p,s,y,a}}{\sigma^t_{p,s,y,a}}\right) & \text{if } l = 1 \\ \Phi\left(\dfrac{LB_{l+1} - L^t_{p,s,y,a}}{\sigma^t_{p,s,y,a}}\right) - \Phi\left(\dfrac{LB_l - L^t_{p,s,y,a}}{\sigma^t_{p,s,y,a}}\right) & \text{if } 1 < l < N_l \\ 1 - \Phi\left(\dfrac{LB_{N_l} - L^t_{p,s,y,a}}{\sigma^t_{p,s,y,a}}\right) & \text{if } l = N_l \end{cases} \quad \text{(A.6d)}$$

where LB_l is the lower bound of length bin l, in cm (1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, 47, 49, 51, 53, 55, 57, 59, and 61 cm); and
$\Phi(\bullet)$ is the cumulative normal probability distribution function.

The coefficient of variation (CV) of length-at-age increases linearly with expected length (which itself increases with age) and depends on year

$$\sigma^t_{p,s,y,a} = L^t_{p,s,y,a} \begin{cases} CV_{p,s,young} & \text{if } a \le \alpha_{p,s,young} \\ CV_{p,s,young} + \dfrac{(L^t_{p,s,y,a} - L_{p,s,y,young})}{(L_{p,s,y,old} - L_{p,s,y,young})}\left(CV_{p,s,old} - CV_{p,s,young}\right) & \text{if } \alpha_{p,s,young} < a < \alpha_{p,s,old} \\ CV_{p,s,old} & \text{if } a \ge \alpha_{p,s,old} \end{cases}$$

(A.6e)

where $CV_{p,s,young}$ is the CV for length at age $\alpha_{p,s,young}$ of species p of sex s (set to 1.5, given the results of the Age and Growth studies);
$CV_{p,s,old}$ is the CV for length at age $\alpha_{p,s,old}$ of species p of sex s (set to 4.0, given the results of the Age and Growth studies);
$\alpha_{p,s,old}$ is a reference age less than or equal to the oldest age of species p of sex s and is well-represented in the data (set to age 20); and
$L_{p,s,y,old}$ is the mean length at age $\alpha_{p,s,old}$ of species p of sex s during year y.

The mass-at-length (in grams) of species p of sex s at year fraction t during year y, $w^t_{p,s,y,l}$, is calculated using

$$w^t_{p,s,y,l} = \gamma_{p,s}\left(L^t_{p,s,y,a}\right)^{\eta_{p,s}} \quad \text{(A.6f)}$$

where $\gamma_{p,s}, \eta_{p,s}$ are the growth conversion parameters for animals of species p of sex s (set to 0.009984 and 3.0468, respectively, per Turnock et al., 2009).

Fishery and survey selectivity

The species- and sex-specific selectivity-at-length curves for the fishery and for the GOA NMFS bottom trawl survey are modeled using an ascending logistic function:

$$S_{p,s,l} = \left[\frac{1}{1+\exp[-\beta_{p,s}(l-\alpha_{p,s})]} \right]; \tilde{S}_{p,s,l} = \frac{S_{p,s,l}}{\max\limits_{l'}(S_{p,s,l'})} \quad \text{(A.7)}$$

where $\alpha_{p,s}, \beta_{p,s}$ are the parameters that determine the shape of the selectivity-at-length curve for animals of species *p* of sex *s*.

The selectivity-at-length curve for the ADF&G survey may be modeled using a double-normal function. The double-normal function is composed of 3 sections: an ascending curve for smaller fish (*asc*), a plateau at which selectivity equals 1.0, and a descending curve for larger fish (*dsc*). The 3 sections have 2 intersections. The sections are joined using steep logistic functions $join_1$ and $join_2$,

$$S_{y,l} = asc_l(1-join_{1,l}) + join_{1,l}\left(1-join_{2,l}+dsc_l\, join_{2,l}\right);\ \tilde{S}_{y,l} = \frac{S_{y,l}}{\max\limits_{l'}(S_{y,l'})} \quad \text{(A.8a)}$$

$$asc_l = 1-(1-\beta_5)\left(\frac{1-e^{-\frac{(L_{mid,l}-\beta_1)^2}{\beta_3}}}{1-e^{-\frac{(L_{mid,1}-\beta_1)^2}{\beta_3}}} \right) \quad \text{(A.8b)}$$

$$dsc_l = 1-(1-\beta_6)\left(\frac{1-e^{-\frac{(L_{mid,l}-\beta_2)^2}{\beta_4}}}{1-e^{-\frac{(L_{mid,N_l}-\beta_2)^2}{\beta_4}}} \right) \quad \text{(A.8c)}$$

$$join_{1,l} = \frac{1}{\left(1+e^{-20\frac{L_{mid,l}-\beta_1}{1+|L_{mid,l}-\beta_1|}}\right)} \quad \text{(A.8d)}$$

$$join_{2,l} = \frac{1}{\left(1+e^{-20\frac{L_{mid,l}-\beta_2}{1+|L_{mid,l}-\beta_2|}}\right)} \quad \text{(A.8e)}$$

where $L_{mid,l}$ is the midpoint of length bin *l*;
N_l is the total number of length bins (21);
β_1 is the first length at which $S = 1.0$;
β_2 is the last length at which $S = 1.0$;

β_3 is the parameter which determines the slope of the ascending part (> 0) of the selectivity curve;

β_4 is the parameter which determines the slope of the descending part (> 0) of the selectivity curve;

β_5 is the selectivity at $L_{mid,1}$ (between 0 and 1); and

β_6 is the selectivity at L_{mid,N_l} (between 0 and 1).

Selectivity-at-length is converted to species- and sex-specific selectivity-at-age accounting from the proportion of fish of species p of sex s of age a which are in length bin l at year fraction t [7/12, the midpoint of the shallow-water flatfish fishery catch, e.g., June, July, or August (see the 2002 – 2009 In-season management reports); 7/12 for the NMFS GOA bottom trawl survey and 7.333/12 for the ADF&G nearshore bottom trawl survey (similar to Dorn et al. (2009)] in year y, i.e.:

$$\tilde{S}_{p,s,y,a} = \sum_l \delta^t_{p,s,y,a,l} \tilde{S}_{p,s,l} \tag{A.9}$$

Catches

Under the assumption of continuous fishing throughout the year (although the fishery occurs between March and October; see the 2002 – 2009 In-season management reports), the fully-selected fishing mortality of rock sole is calculated by solving the following [with respect to the observer-estimated fraction of U/N/S rock sole in the shallow-water flatfish catch]:

$$\hat{C}_y = \sum_p \sum_s \sum_{a=1}^{x} \hat{C}_{p,s,y,a} \sum_l w_{p,s,y,l} \delta^t_{p,s,y,a,l} \tilde{S}_{p,s,l} \tag{A.10}$$

where $\hat{C}_y$ is the estimated catch (in mass) of combined U/N/S rock sole during year y; and

$\hat{C}_{p,s,y,a}$ is the estimated catch (in numbers) of fish of species p of sex s of age a during year y

$$\hat{C}_{p,s,y,a} = \frac{\tilde{S}_{p,s,y,a} F_{p,s,y}}{M_{p,s,a} + \tilde{S}_{p,s,y,a} F_{p,s,y}} N_{p,s,y,a} (1 - e^{-(M_{p,s,a} + \tilde{S}_{p,s,y,a} F_{p,s,y})}) \tag{A.11}$$

Surveys

The data used to estimate the values for the parameters of the operating model are available from two fishery-independent sources: 1) the NMFS GOA bottom trawl survey (Martin, 1997; Britt and Martin, 2000); and 2) the ADF&G crab/groundfish nearshore bottom trawl survey (Blackburn and Pengilly, 1994). The data for each survey include indices of abundance and survey size-composition. Age-composition data are available for the NMFS GOA bottom trawl survey.

The model estimates of the survey biomass indices are calculated using the equation:

$$\hat{I}_{p,d,y} = \hat{q}_{p,d}\hat{B}^{e}_{p,d,y} \tag{A.12}$$

where $\hat{I}_{p,d,y}$ is the model estimate of the biomass index of species *p* for survey *d* in year *y*;

$\hat{q}_{p,d}$ is the model estimate of catchability of species *p* for survey *d*;

$\hat{B}^{e}_{p,d,y}$ is the model estimate of the total biomass of species *p* available to survey *d* in year *y*:

$$\hat{B}^{e}_{p,d,y} = \sum_{a=1}^{x}\sum_{s} N_{p,s,y,a}\, e^{-frac_d(M_{p,s,a}+\tilde{S}_{p,s,y,a}F_{p,s,y})} \sum_{l} w^{d}_{p,s,y,l}\delta^{d}_{p,s,y,a,l}\tilde{S}^{d}_{l} \tag{A.13}$$

$\tilde{S}^{d}_{l}$ is the length-specific selectivity pattern for the survey type *d* (an ascending logistic function for the NMFS bottom trawl survey, and a dome-shaped function for the ADF&G survey);

$\delta^{d}_{p,s,y,a,l}$ is the proportion of animals of species *p* of sex *s* of age *a* in length bin *l* during year *y* when survey *d* takes place (Eqn. A.6d)

$w^{d}_{p,s,y,l}$ is the average mass of a fish of species *p* of sex *s* in length bin *l* in year *y* during survey *d*; and

$frac_d$ is the fraction of the year at which survey *d* takes place.

Boldt and Zador (2009) state that "…the gears used by the Japanese vessels in the [NMFS GOA bottom trawl] surveys prior to 1990 were quite different from the survey gear used aboard American vessels in subsequent surveys and likely resulted in different catch rates for many of these groups" and Thompson et al. (2009) note that "the [NMFS GOA bottom trawl] survey used 30-minute tows during that period [1984-1993], but 15-minute tows thereafter [from 1996 on]", the NMFS GOA bottom trawl survey [data] is separated into three periods with respect to selectivity: 1984-1987 and 1990-1993, and 1996 on; $\hat{q}$ is set to 1.0 for all years.

Initial conditions

The initial conditions are similar to those in the GOA Pacific cod stock assessment (which uses Stock Synthesis 3), in that both N and S rock sole stocks start out in 1977 with non-zero catches and not in equilibrium (Thompson et al., 2009).

Ageing error

The proportion of animals of age *a* assigned to age bin *i* is

$$\theta_{a,i} = \begin{cases} \Phi\left(\dfrac{ALB_1 - \varpi_a}{\tau_a}\right) & \text{if } i = 1 \\ \Phi\left(\dfrac{ALB_{i+1} - \varpi_a}{\tau_a}\right) - \Phi\left(\dfrac{ALB_i - \varpi_a}{\tau_a}\right) & \text{if } 1 < i < x \\ 1 - \Phi\left(\dfrac{ALB_x - \varpi_a}{\tau_a}\right) & \text{if } i = x \end{cases} \qquad \text{(A.14)}$$

where ϖ_a is the mean age assigned to animals of true age *a*;

ALB_i is the lower bound of age bin *i*; and

τ_a is the standard deviation of ageing error for age *a* (set based on ageing results from survey samples so there is low ageing error for ages 1 and 2 [0.001] and increasing linearly for ages 3+ so that ageing error at age 11 is ~60% [slope of 0.066], based on the results of the Age and Growth studies).

Parameter estimation

The estimable parameters of the operating model are the parameters of the stock-recruitment relationship for each species, initial recruitment (before 1977) for each species, the deviations in recruitment (initial conditions and about the stock-recruitment relationship) for each species, the annual fishing mortalities, the parameters that define fishery and survey selectivity-at-length for each species and sex, and survey catchability for each species and survey period. Survey length composition data are not used for model fitting when there are survey age composition data for that year, species, and sex.

The objective function is

$$
\begin{aligned}
obj\_fun = &\sum_y \left[\ln\left(rsfrac_y C_y\right) - \ln\left(\hat{C}_y\right)\right]^2 / 2\sigma_y^2 \\
&+\sum_y \sum_p \sum_d \left[\ln\left(I_{p,d,y}\right) - \ln\left(\hat{I}_{p,d,y}\right)\right]^2 / 2\sigma_{p,d,y}^2 \\
&-\sum_y \sum_p \sum_s \sqrt[3]{\mathrm{H}^f_{p,s,y}} \sum_l p_{p,s,y,l}\left[\ln(p_{p,s,y,l}+o) - \ln(\hat{p}_{p,s,y,l}+o)\right] \\
&-\sum_y \sum_d \sum_p \sum_s \sqrt{\mathrm{H}^l_{p,s,d,y}} \sum_l p_{p,s,d,y,l}\left[\ln(p_{p,s,d,y,l}+o) - \ln(\hat{p}_{p,s,d,y,l}+o)\right] \\
&-\sum_y \sum_d \sum_p \sum_s \sqrt{\mathrm{H}^a_{p,s,d,y}} \sum_a p_{p,s,d,y,a}\left[\ln(p_{p,s,d,y,a}+o) - \ln(\hat{p}_{p,s,d,y,a}+o)\right] \\
&+\sum_a \left(\nu_a\right)^2 /(2\sigma_R^2) + \sum_y \sum_p \left(\varphi_{p,y}\right)^2 /(2\sigma_R^2) + \sum_p U_p \ln\left(\sigma_R\right) \\
&+\sum_{y=1977}^{1996} \left[\ln(F_{northern,female,y}+o) - \ln(F_{southern,female,y}+o)\right]^2 \\
&+\sum_{y=1997}^{2010} \sum_p \left[\ln\left(NSfrac_{p,y} C_y\right) - \ln\left(\hat{C}_{p,y}\right)\right]^2 / 2\sigma_y^2
\end{aligned}
\qquad \text{(A.15)}
$$

where C_y is the observed catch (in mass) of shallow-water flatfish during year *y*;

$rsfrac_y$ is the observer-estimated fraction of shallow-water flatfish catch that is U/N/S rock sole in year *y*;

$NSfrac_{p,y}$ is the observer-estimated fraction of shallow-water flatfish catch that is species *p* in year *y*, scaled to total across species to $rsfrac_y$ (see Table 3 and Fig. 2);

σ_y is the standard deviation of catch for year *y* (set to 0.05);

$I_{p,d,y}$ is the observed index of abundance for species *p* for survey *d* in year *y*;

$\sigma_{p,d,y}$ is the standard deviation of abundance of species *p* for survey *d* in year *y*;

$p_{p,s,d,y,a}$ is the observed proportion of fish of species *p* of sex *s* of age *a* at the time of survey *d* in year *y*;

$\hat{p}_{p,s,d,y,a}$ is the estimated proportion of fish of species *p* of sex *s* of age *a* at the time of survey *d* in year *y*,

$$\hat{p}_{p,s,d,y,a} = N_{p,s,d,y,a} / \sum_a N_{p,s,d,y,a} \ ;$$

$N_{p,s,d,y,a}$ is the number of fish of species *p* of sex *s* of age *a* at the time of survey *d* in year *y*;

$p_{p,s,d,y,l}$ is the observed proportion of fish of species *p* of sex *s* in length bin *l* at the time of survey *d* in year *y*;

$\hat{p}_{p,s,d,y,l}$ is the estimated proportion of fish of species *p* of sex *s* in length bin *l* at the time of survey *d* in year *y*,

$$\hat{p}_{p,s,d,y,l} = NS_{p,s,d,y,l} / \sum_l NS_{p,s,d,y,l} \ ;$$

$NS_{p,s,d,y,l}$ is the number of fish of species *p* of sex *s* in length bin *l* at the time of survey *d* in year *y*,

$$NS_{p,s,d,y,l} = \sum_a \delta^d_{p,s,y,a,l} \tilde{S}^d_l N_{p,s,y,a}\, e^{-(frac_d * M_{p,s,a} + \tilde{S}_{p,s,y,a} F_{p,s,y})} ;$$

$p_{p,s,y,l}$ is the observed proportion of fish of species *p* of sex *s* caught in the fishery in length bin *l* in year *y*;

$\hat{p}_{p,s,y,l}$ is the estimated proportion of fish of species *p* of sex *s* caught in the fishery in length bin *l* in year *y*,

$$\hat{p}_{p,s,y,l} = NC_{p,s,y,l} / \sum_l NC_{p,s,y,l} ;$$

$NC_{p,s,y,l}$ is the number of fish of species *p* of sex *s* caught in the fishery in length bin *l* in year *y*,

$$NC_{p,s,y,l} = \sum_a \delta^t_{p,s,y,a,l} \tilde{S}_{y,l} N_{p,s,y,a} \frac{\tilde{S}_{p,s,y,a} F_{p,s,y}}{M_{p,s,a} + \tilde{S}_{p,s,y,a} F_{p,s,y}} (1 - e^{-(M_{p,s,a} + \tilde{S}_{p,s,y,a} F_{p,s,y})}) ;$$

$\mathrm{H}^f_{p,s,y}$ is the sample size for fishery length composition data of species *p* of sex *s* for year *y*;

$\mathrm{H}^l_{p,s,d,y}$ is the length composition sample size of species *p* of sex *s* for survey *d* in year *y*;

$\mathrm{H}^a_{p,s,d,y}$ is the age composition sample size of species *p* of sex *s* for survey *d* in year *y*;

U_p is the number of years that recruitment is estimated (34, for 1977 – 2010); and

o is a small number (0.00001).

The effective sample size for the age and length proportions is

$$effN = \frac{\sum_n \hat{p}_n (1 - \hat{p}_n)}{\sum_n (p_n - \hat{p}_n)^2} \qquad \text{(A.16)}$$

(McAllister and Ianelli, 1997).

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Table 1 – Estimated catch (in metric tonnes) (as of 2010-08-06) for shallow-water flatfish (swff) from the Stock Assessment and Fishery Evaluation (SAFE) report and the Alaska Regional Office Catch Accounting System (CAS). Percent and estimated catch of unidentified (U), northern (N), and southern (S) rock sole from the NMFS Fishery Monitoring and Analysis (FMA, Observer Program) division

Year	SWFF catch (2009 SAFE)	SWFF catch (CAS)	% U/N/S rock sole (FMA)	Est. U/N/S rock sole catch
1991	5,298.0	5,224.5	92.449	4,830.0
1992	8,783.0	8,333.7	80.897	6,741.7
1993	9,715.0	9,113.5	80.815	7,365.0
1994	3,943.0	3,842.9	64.064	2,461.9
1995	5,430.0	5,436.8	79.306	4,311.7
1996	9,350.0	9,372.2	68.049	6,377.7
1997	7,775.0	7,778.9	77.194	6,004.8
1998	3,565.0	3,566.6	76.390	2,724.6
1999	2,577.0	2,546.2	76.117	1,938.1
2000	6,928.0	6,928.2	75.386	5,222.8
2001	6,162.0	6,163.0	84.078	5,181.7
2002	6,195.0	7,186.8	81.567	5,862.0
2003	4,465.0	4,648.5	77.551	3,605.0
2004	3,094.0	3,094.2	66.396	2,054.4
2005	4,769.0	4,805.1	83.167	3,996.2
2006	7,641.0	7,651.7	82.706	6,328.4
2007	8,793.0	8,735.0	86.370	7,544.5
2008	9,708.0	9,726.1	77.681	7,555.3
2009	5,774.0	8,483.9	77.169	6,546.9
2010		2,483.9	22.088	548.7

Table 2 – Fishery observer sampled catch in metric tonnes (as of 2010-08-06) for unidentified (U), northern (N), and southern (S) rock sole, and shallow water flatfish (SWFF)

Year	U - Foreign	U - Domestic	N - Domestic	S - Domestic	SWFF - Foreign	SWFF - Domestic	%SWFF catch observed
1974	0.020				0.020		
1975	0.094				0.098		
1976	0.217				0.229		
1977	0.249				0.256		
1978	0.505				0.534		
1979	2.133				2.155		
1980	0.934				1.484		
1981	0.772				0.798		
1982	5.474				6.005		
1983	27.424				35.229		
1984	9.524				12.424		
1985	8.331				10.414		
1986	6.531				8.592		
1987	81.187	0.075			100.887	0.084	
1988	9.977	1.271			14.540	1.610	
1989	0.122	1.287			0.122	2.347	
1990		50.896				60.583	0.759
1991		96.547				104.433	1.999
1992		76.587				94.672	1.136
1993		67.155				83.098	0.912
1994		27.191				42.444	1.104
1995		50.760				64.005	1.177
1996		58.873				86.515	0.923
1997		61.099	1.683	2.354		84.379	1.085
1998		24.016	5.006	7.652		48.010	1.346
1999		8.436	5.136	5.224		24.694	0.970
2000		33.342	5.656	7.752		62.016	0.895
2001		40.723	7.233	8.914		67.640	1.098
2002		46.401	6.752	5.558		71.979	1.002
2003		26.087	3.853	6.649		47.181	1.015
2004		15.758	2.289	7.181		37.996	1.228
2005		20.715	2.022	3.627		31.700	0.660
2006		22.449	5.831	3.142		37.993	0.497
2007		42.505	4.605	7.567		63.306	0.725
2008		36.540	4.935	9.463		65.574	0.674
2009		28.739	5.828	6.997		53.860	0.635
2010		7.585	2.575	2.871		58.998	1.975

Table 3 – Percent by mass of shallow-water flatfish fishery observer samples that are U/N/S rock sole (as of 2010-08-06)

Year	%U - Foreign	%U - Domestic	%N	%S	% U/N/S	Est U/N/S catch (mt)
1974	100.0					
1975	96.0					
1976	94.8					
1977	97.1					
1978	94.6					
1979	99.0					
1980	62.9					
1981	96.8					
1982	91.2					
1983	77.8					
1984	76.7					
1985	80.0					
1986	76.0					
1987	80.5	89.6				
1988	68.6	79.0				
1989	100.0	54.8				
1990		84.0			84.0	6,705.3
1991		92.4			92.4	4,830.0
1992		80.9			80.9	6,741.7
1993		80.8			80.8	7,365.0
1994		64.1			64.1	2,461.9
1995		79.3			79.3	4,311.7
1996		68.0			68.0	6,377.7
1997		72.4	2.0	2.7	77.2	6,004.8
1998		50.0	10.4	15.9	76.4	2,724.6
1999		34.2	20.8	21.2	76.1	1,938.1
2000		53.8	9.1	12.5	75.4	5,222.8
2001		60.2	10.7	13.2	84.1	5,181.7
2002		64.5	9.4	7.7	81.6	5,862.0
2003		55.3	8.2	14.1	77.6	3,605.0
2004		41.5	6.0	18.9	66.4	2,054.4
2005		65.3	6.4	11.4	83.2	3,996.2
2006		59.1	15.3	8.3	82.7	6,328.4
2007		67.1	7.3	12.0	86.4	7,544.5
2008		55.7	7.5	14.4	77.7	7,555.3
2009		53.4	10.8	13.0	77.2	6,546.9
2010		12.9	4.4	4.9	22.1	548.7

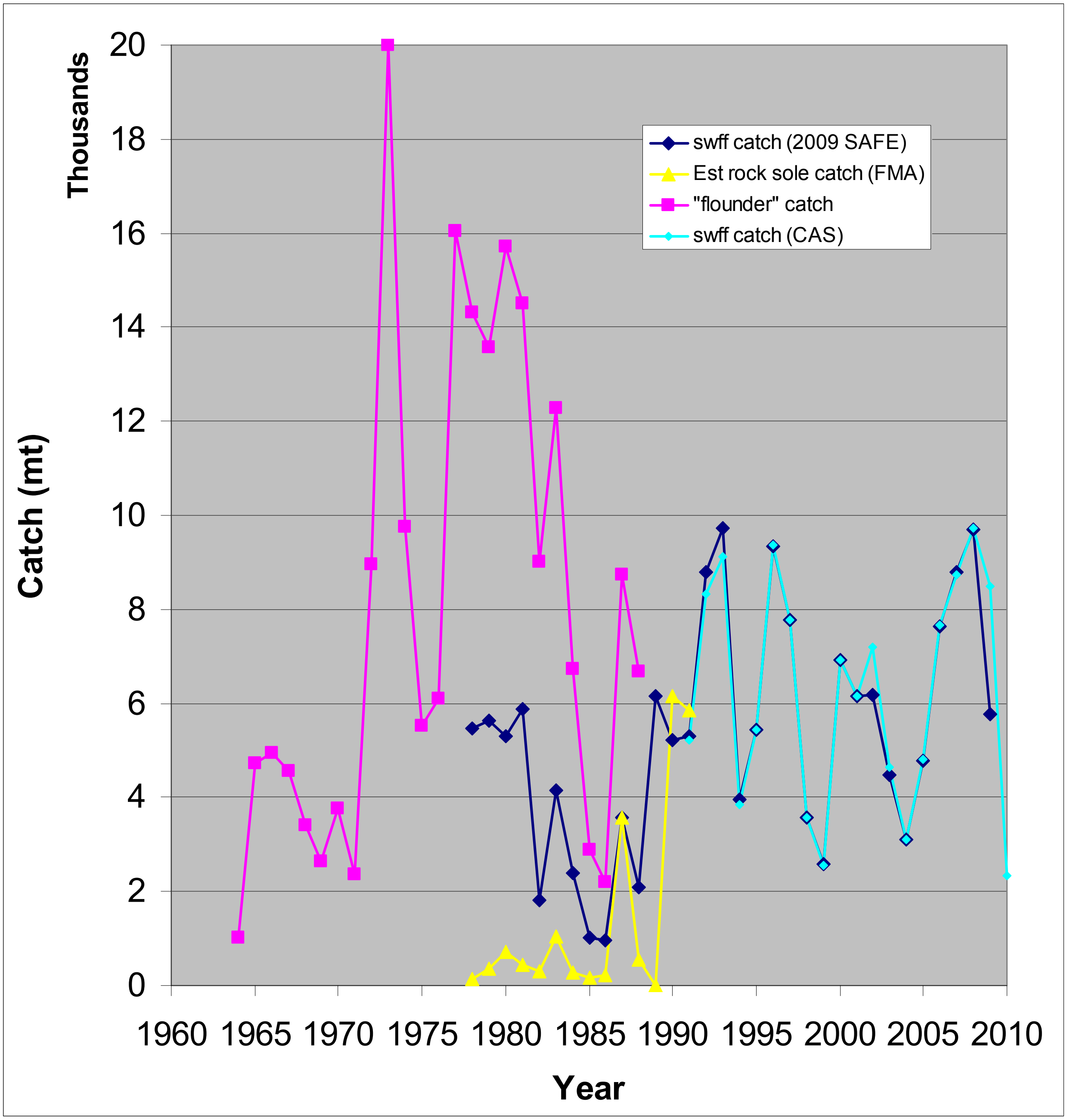


Figure 1 – Estimated catch for GOA "flounders", shallow-water flatfish, and rock sole (see Table 1)

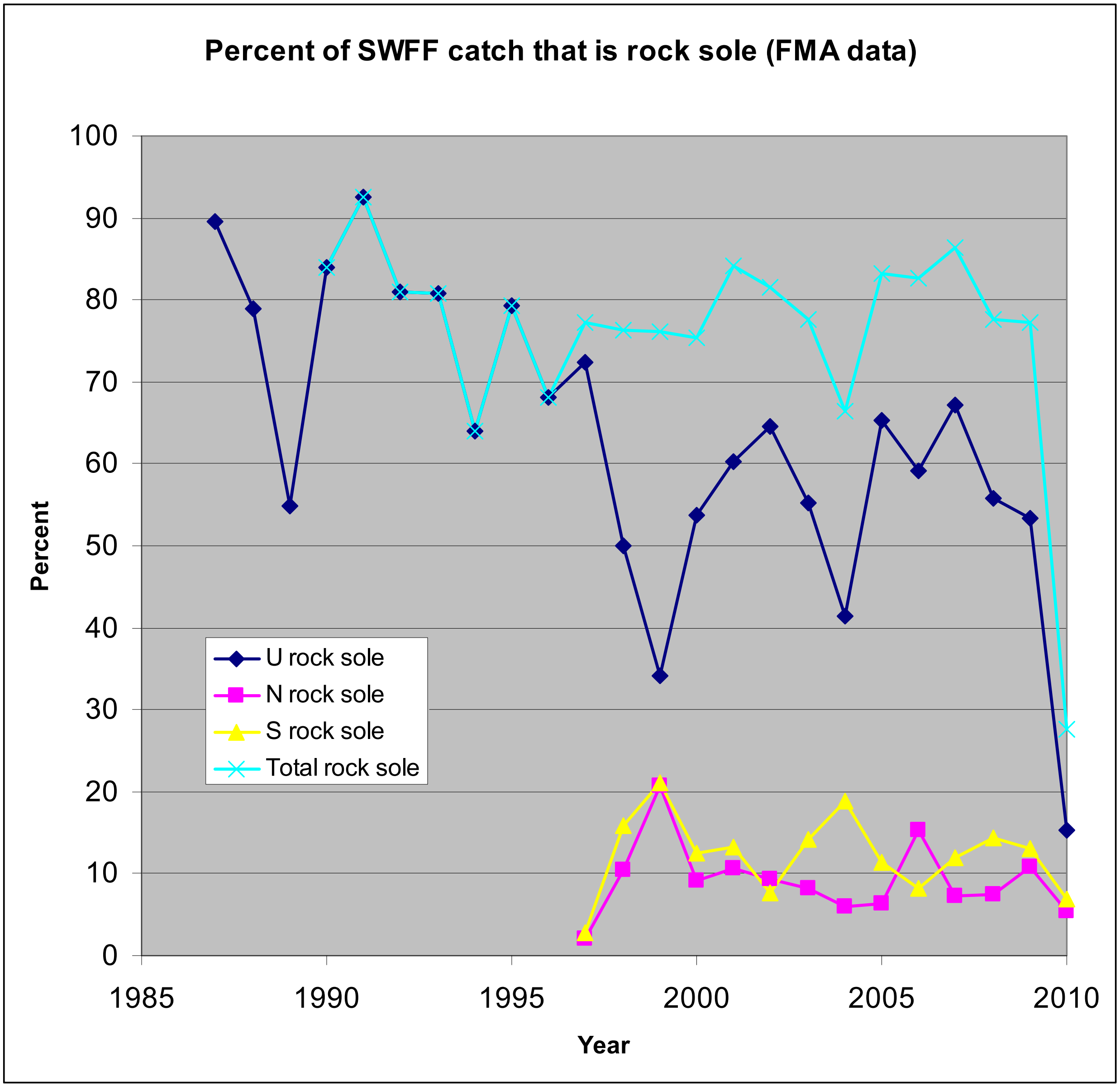


Figure 2 – Percent of the shallow-water flatfish catch that is U/N/S rock sole (based on observer data)

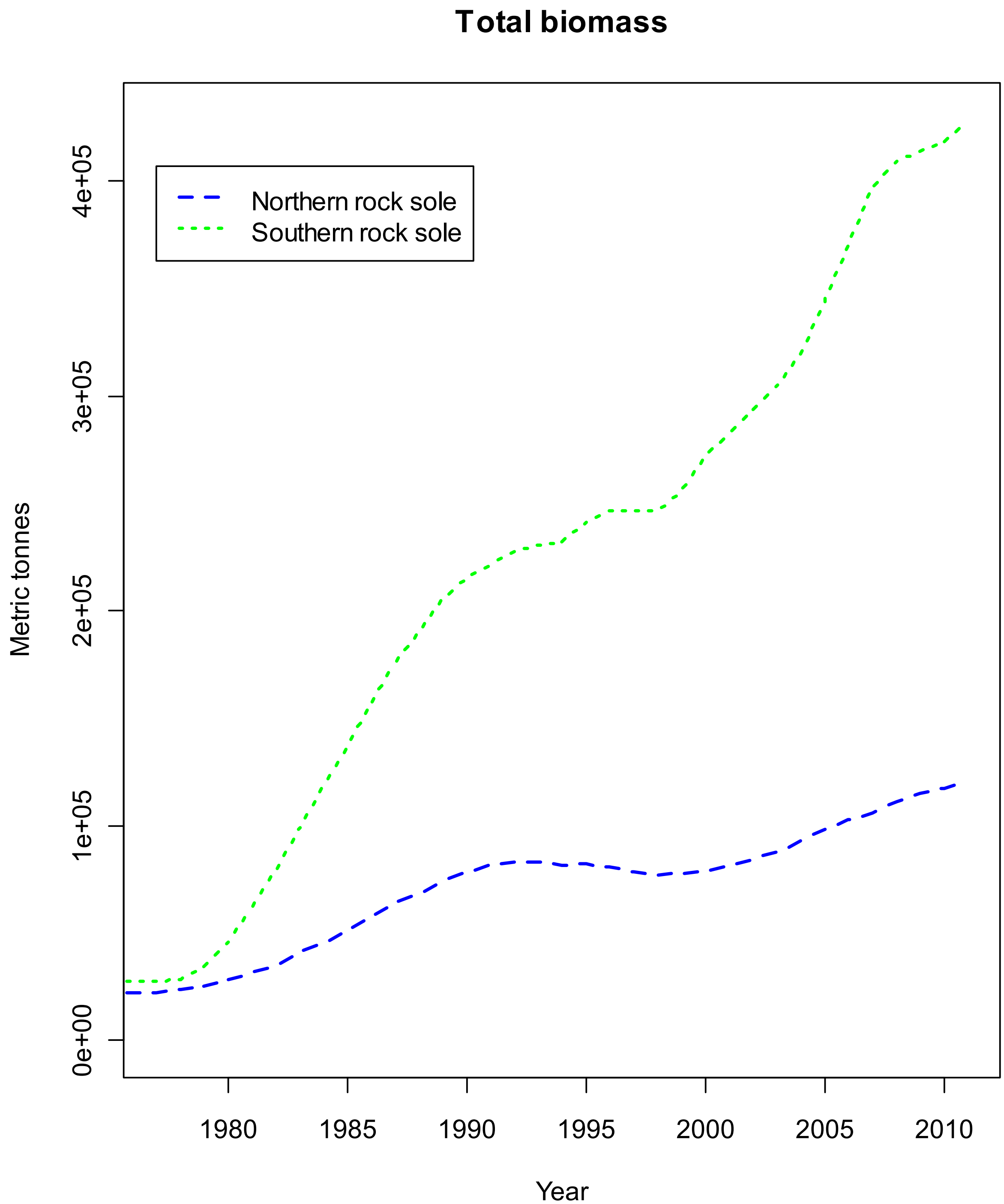


Figure 3 – Estimated total (age 2+) biomass of northern and southern rock sole

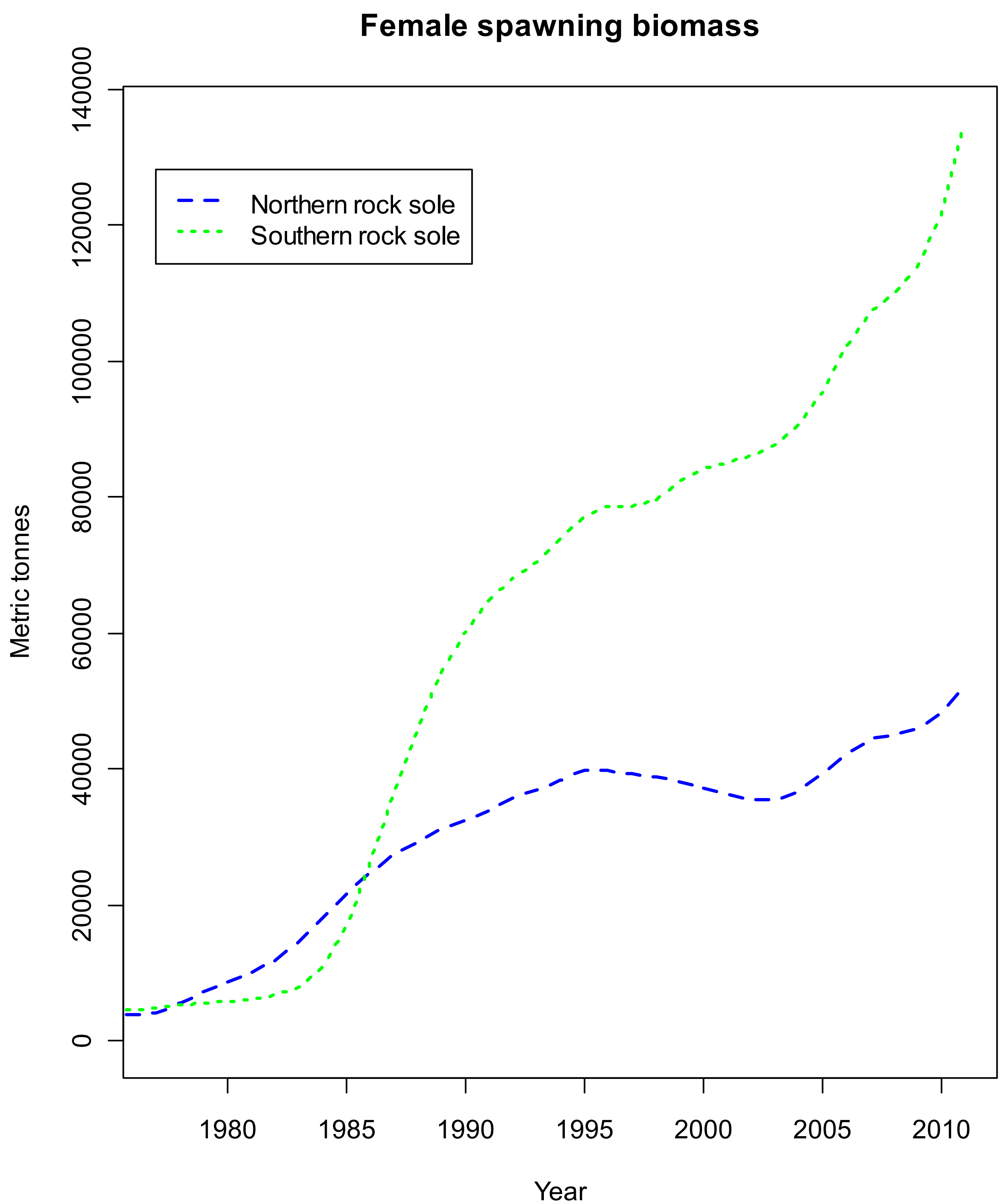


Figure 4 – Estimated female spawning biomass of northern and southern rock sole

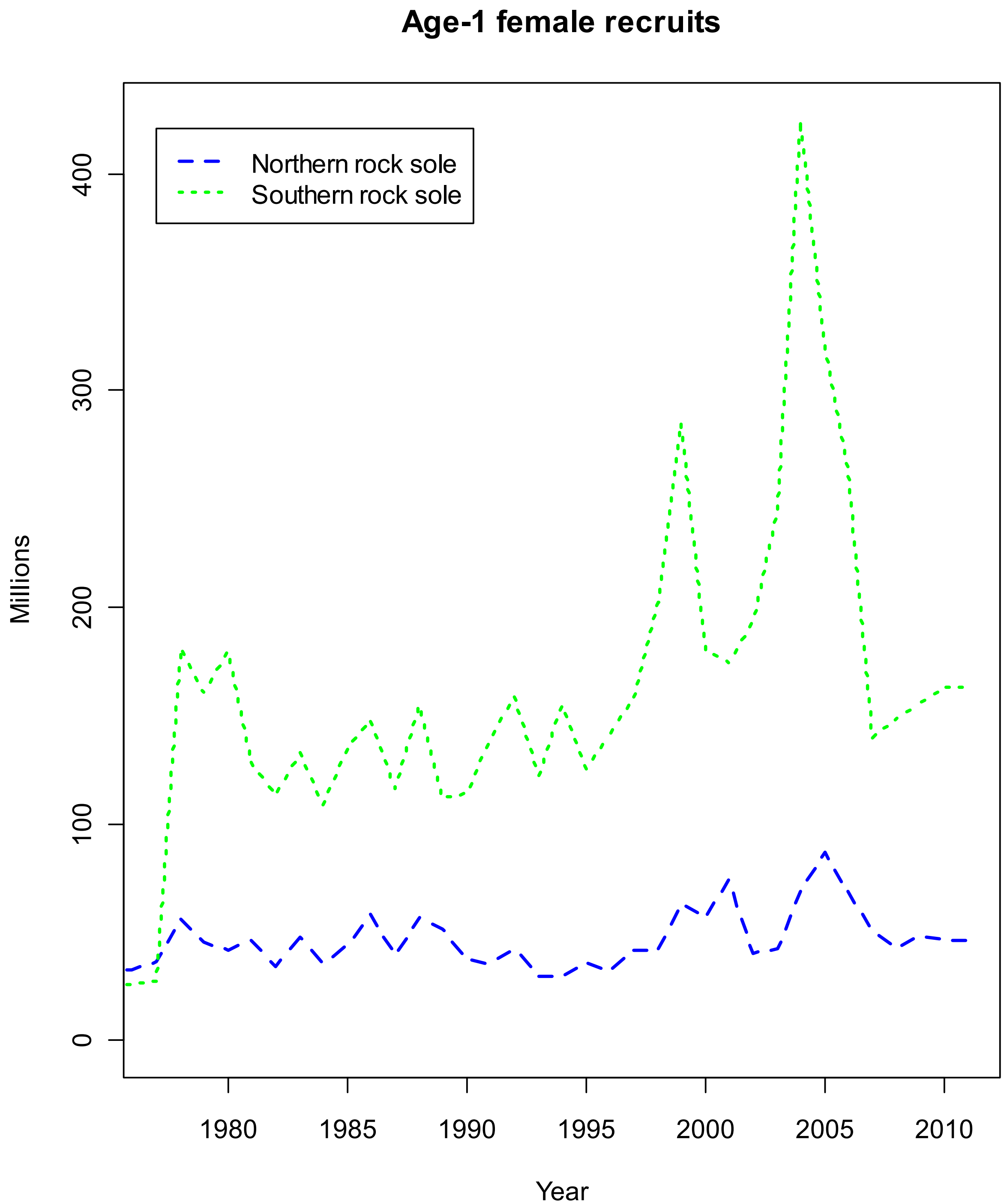


Figure 5 – Estimated age-1 female recruits for northern and southern rock sole; the number of age-1 male recruits is equal to the number of age-1 female recruits in each year (1:1 ratio).

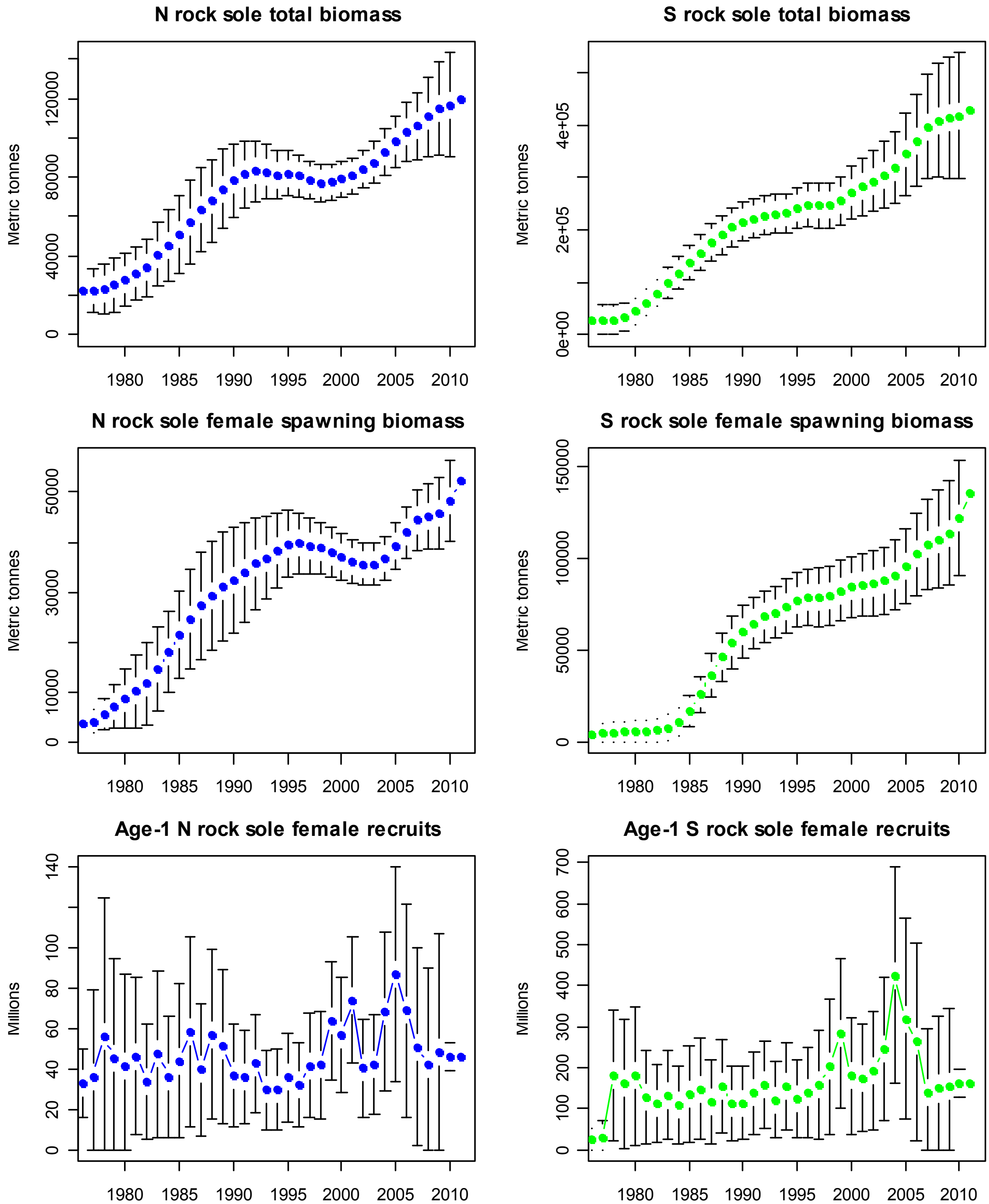


Figure 6 – Estimates of total (age 2+) and spawning biomass and age-1 recruits for northern (N) and southern (S) rock sole

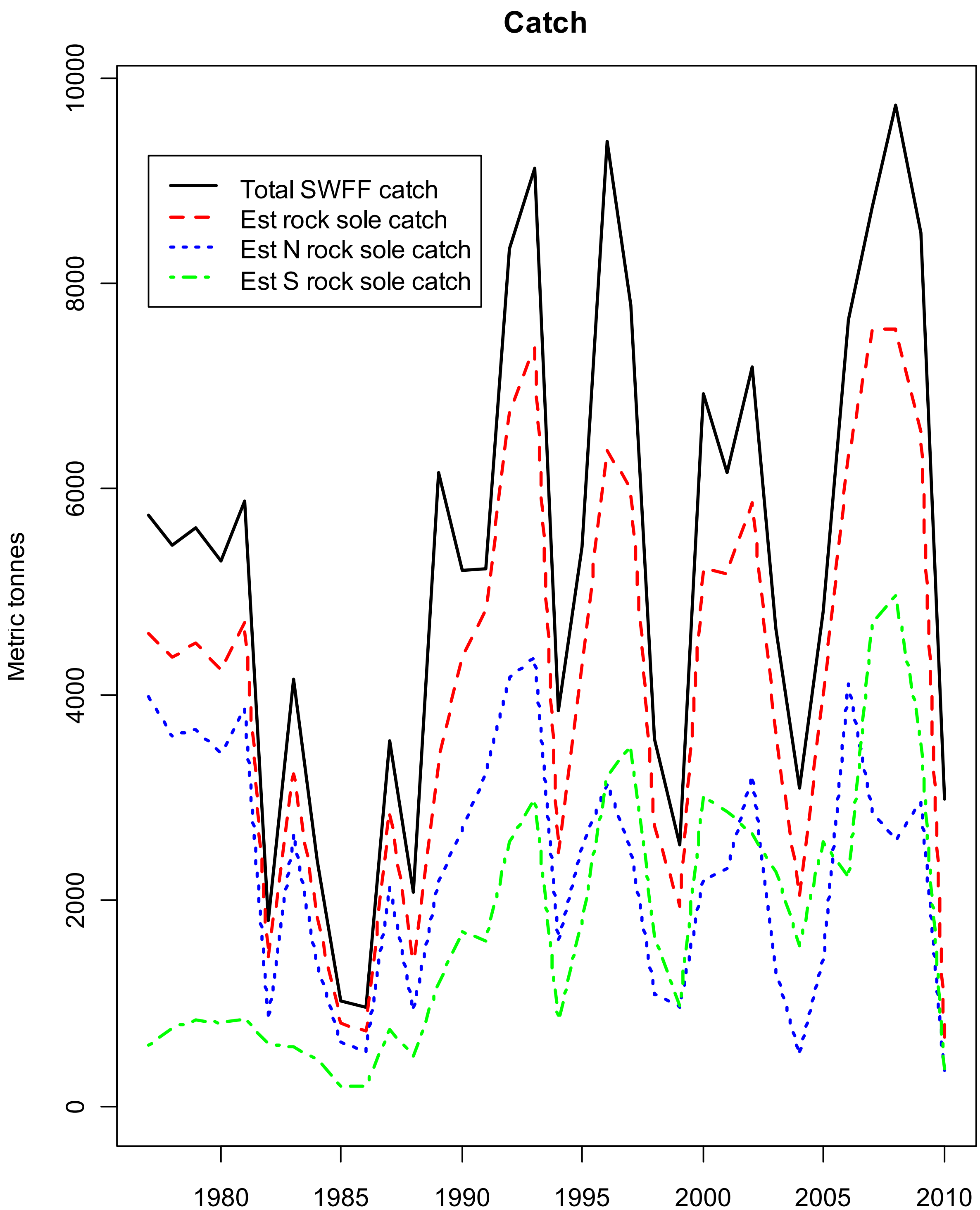


Figure 7 – Total shallow-water flatfish catch, observer-estimated total (U/N/S) rock sole catch, and estimated northern (N) and southern (N) rock sole catch

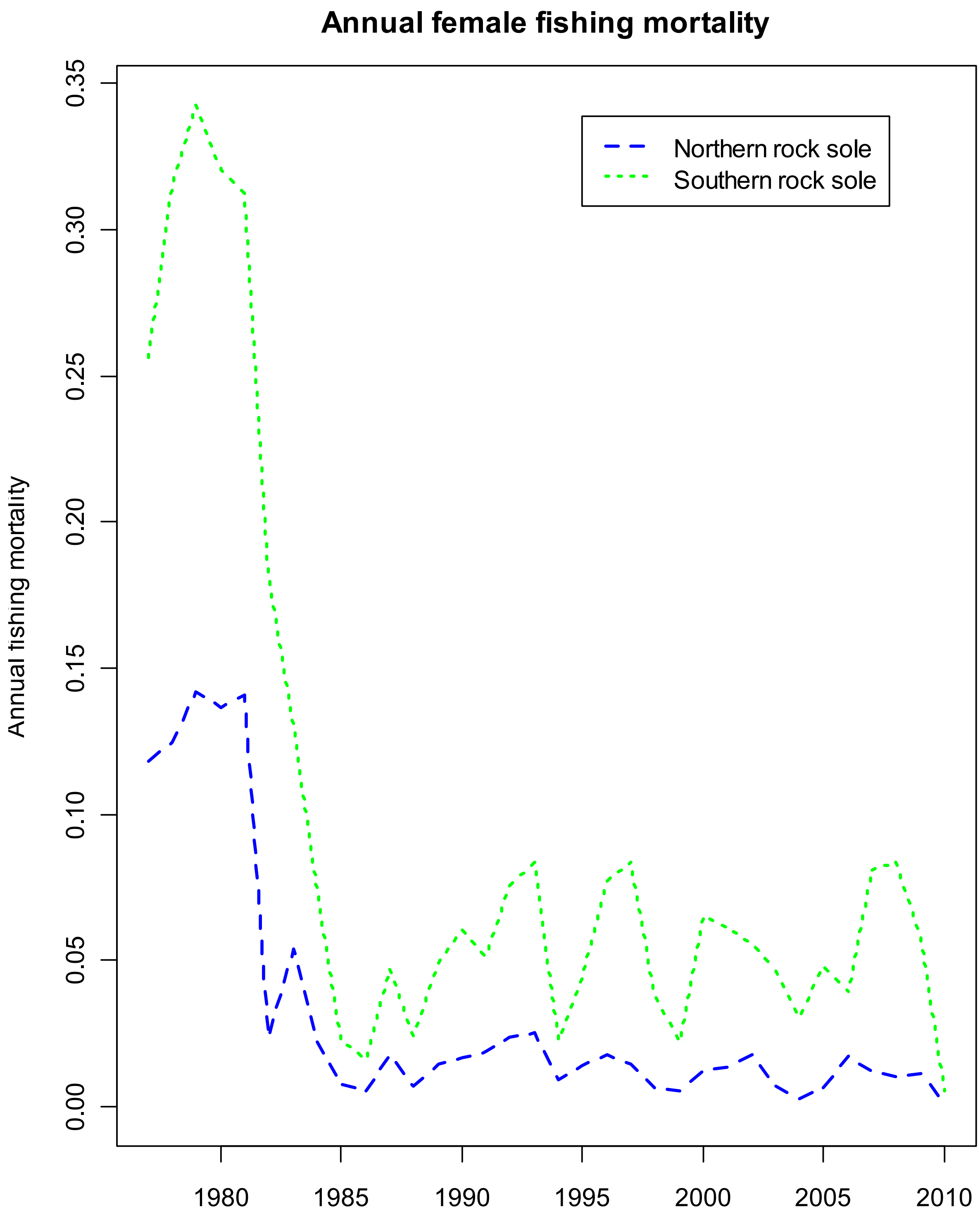
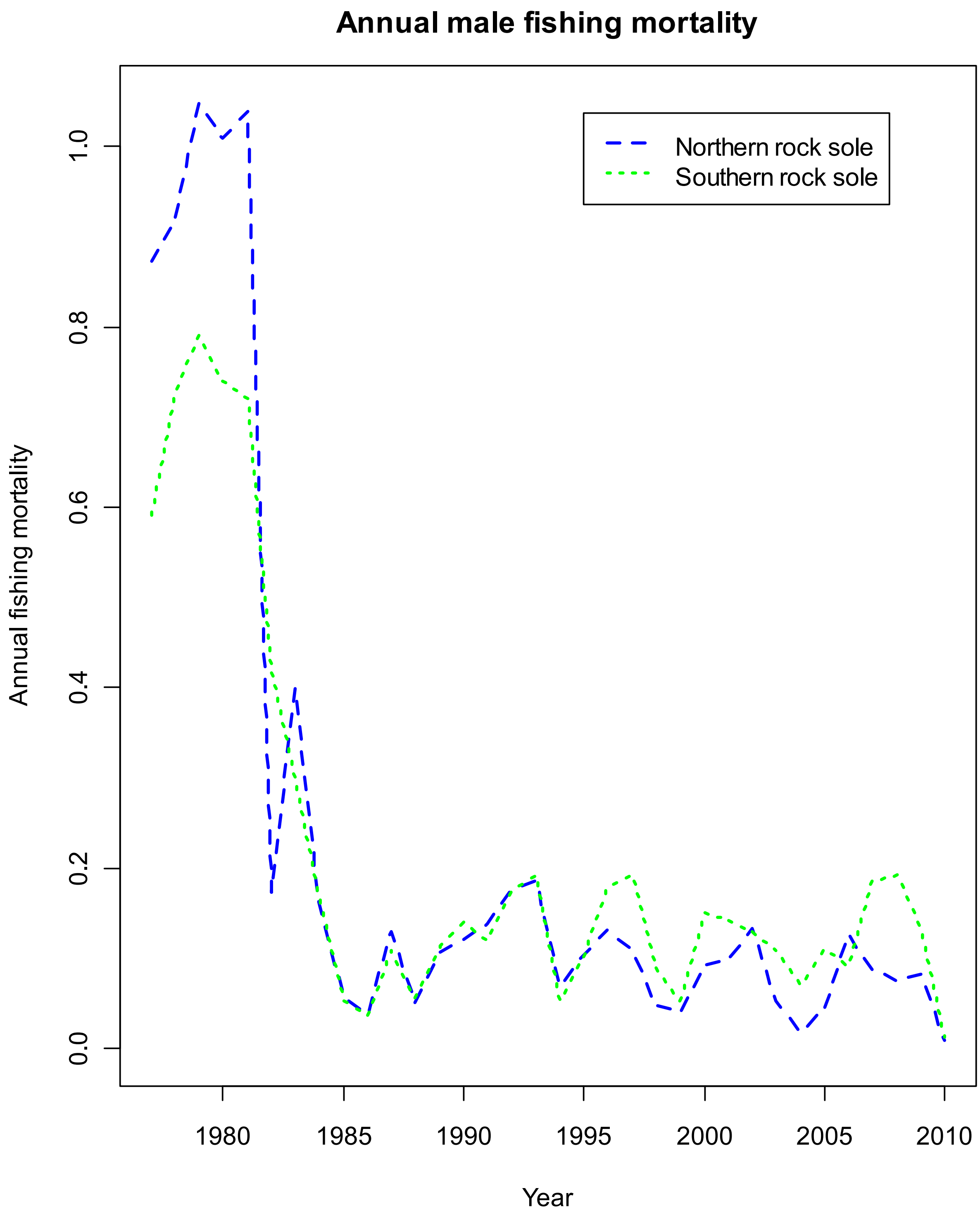


Figure 8 – Estimated annual fishing mortality, by species and sex.


Annual male fishing mortality
Northern rock sole
Southern rock sole
Annual fishing mortality
0.0
0.2
0.4
0.6
0.8
1.0
1980
1985
1990
1995
2000
2005
2010
Year

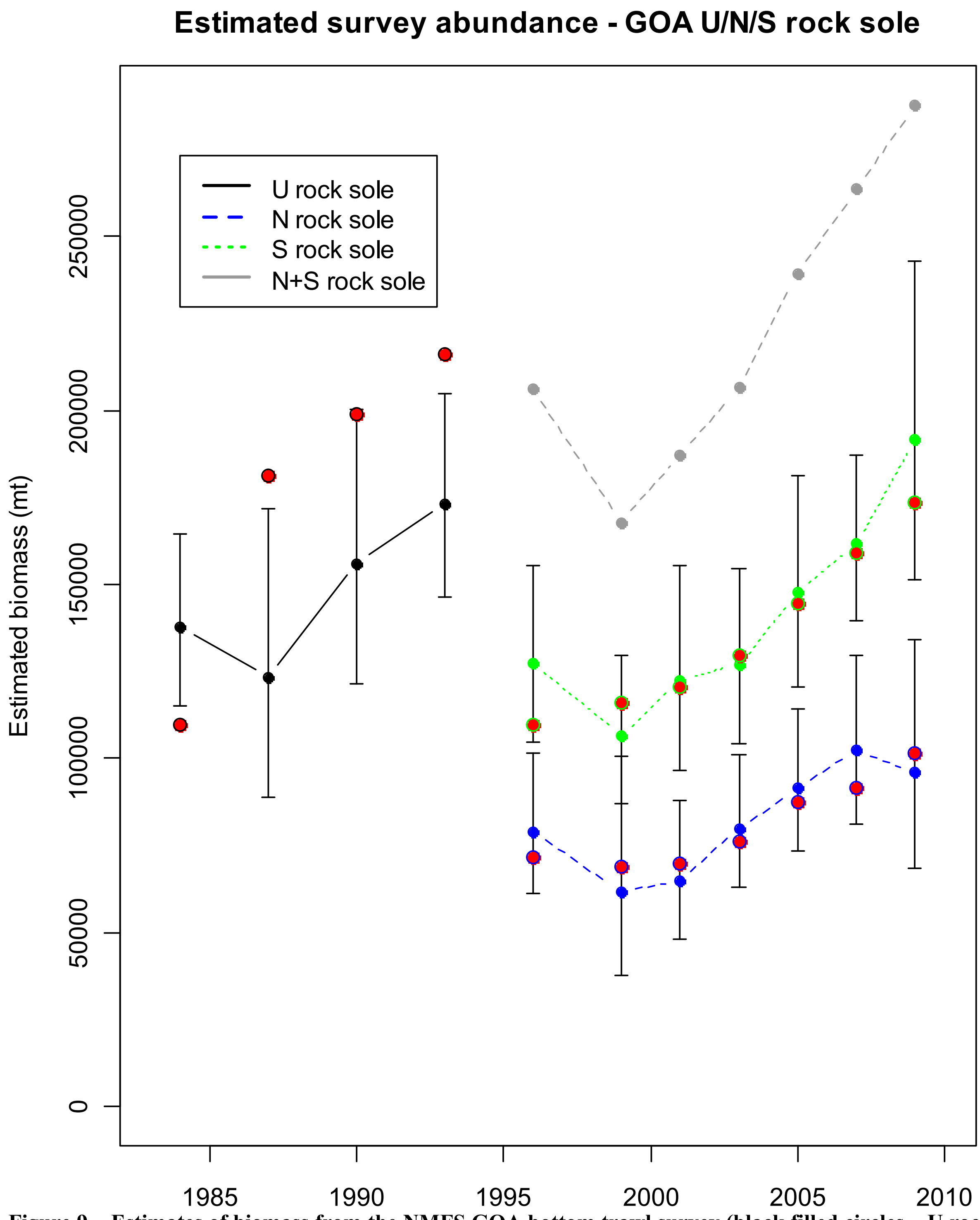


Figure 9 – Estimates of biomass from the NMFS GOA bottom trawl survey (black filled circles – U rock sole, blue filled circles – N rock sole, green filled circles – S rock sole, red filled circles – model estimates)

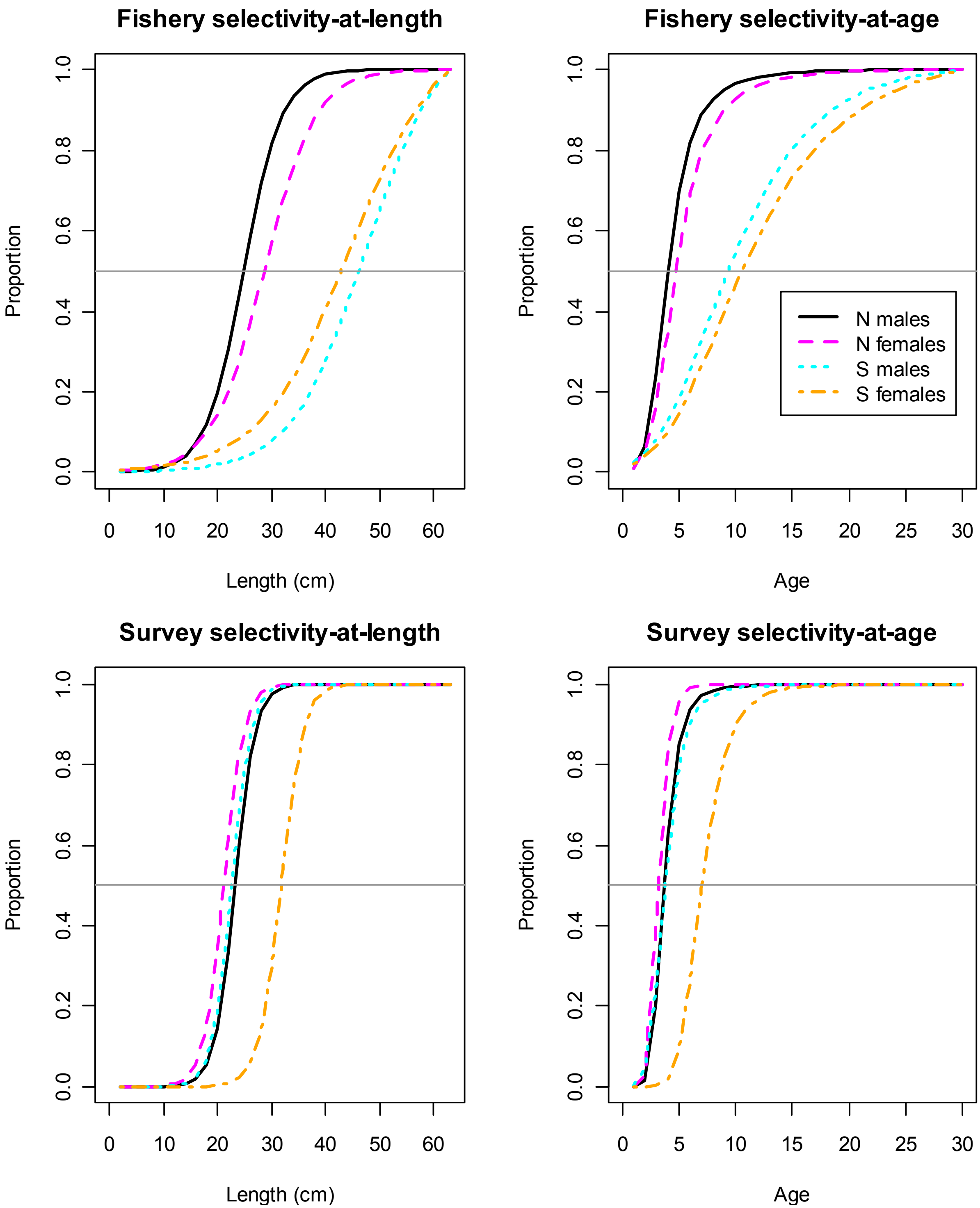
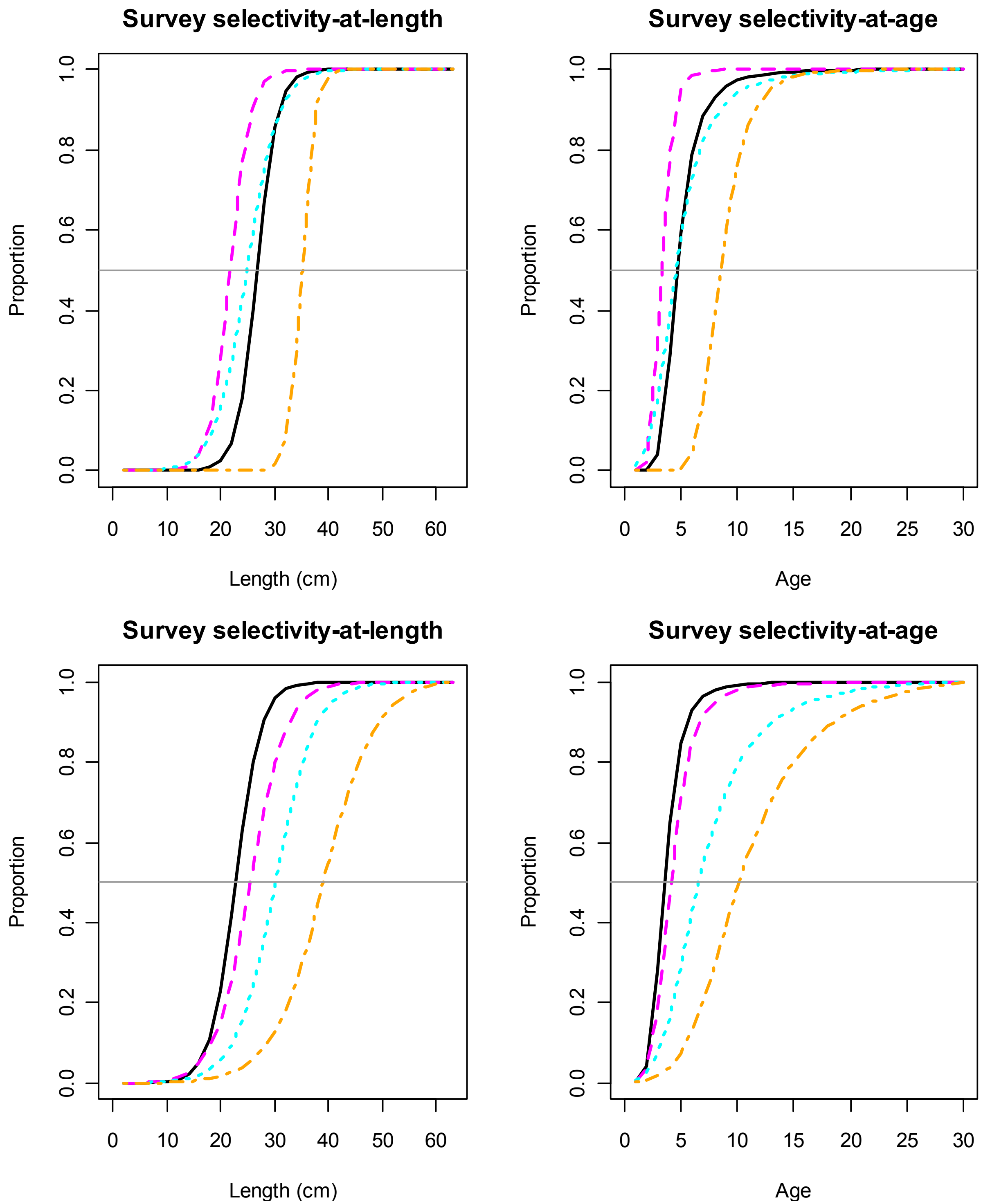


Figure 10 – Fishery and survey (1984-1987, 1990-1993, and 1996 on) selectivity-at-length and -at-age, by species and sex


Survey selectivity-at-length
Proportion
Length (cm)
Survey selectivity-at-age
Proportion
Age
Survey selectivity-at-length
Proportion
Length (cm)
Survey selectivity-at-age
Proportion
Age

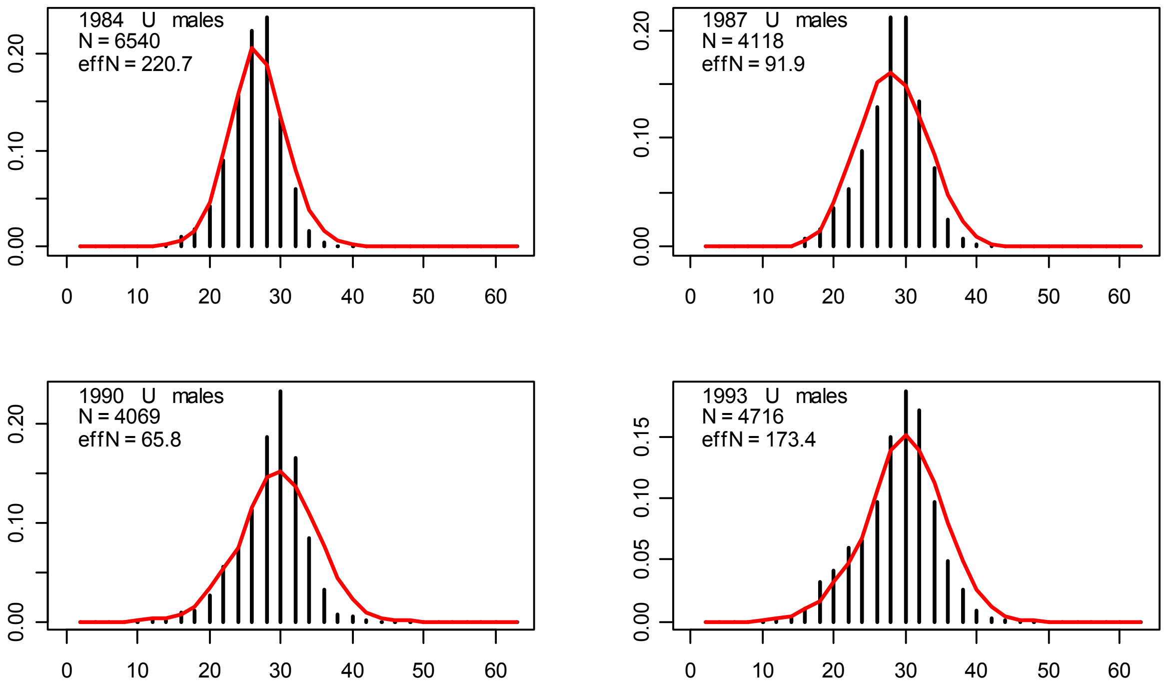
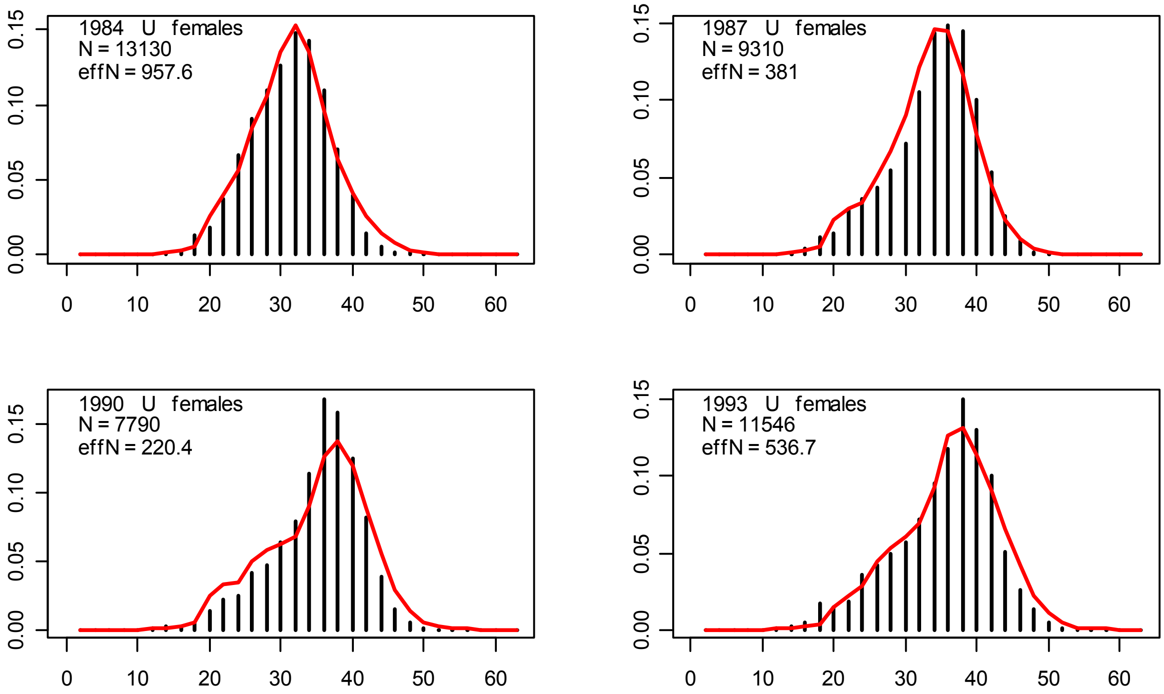
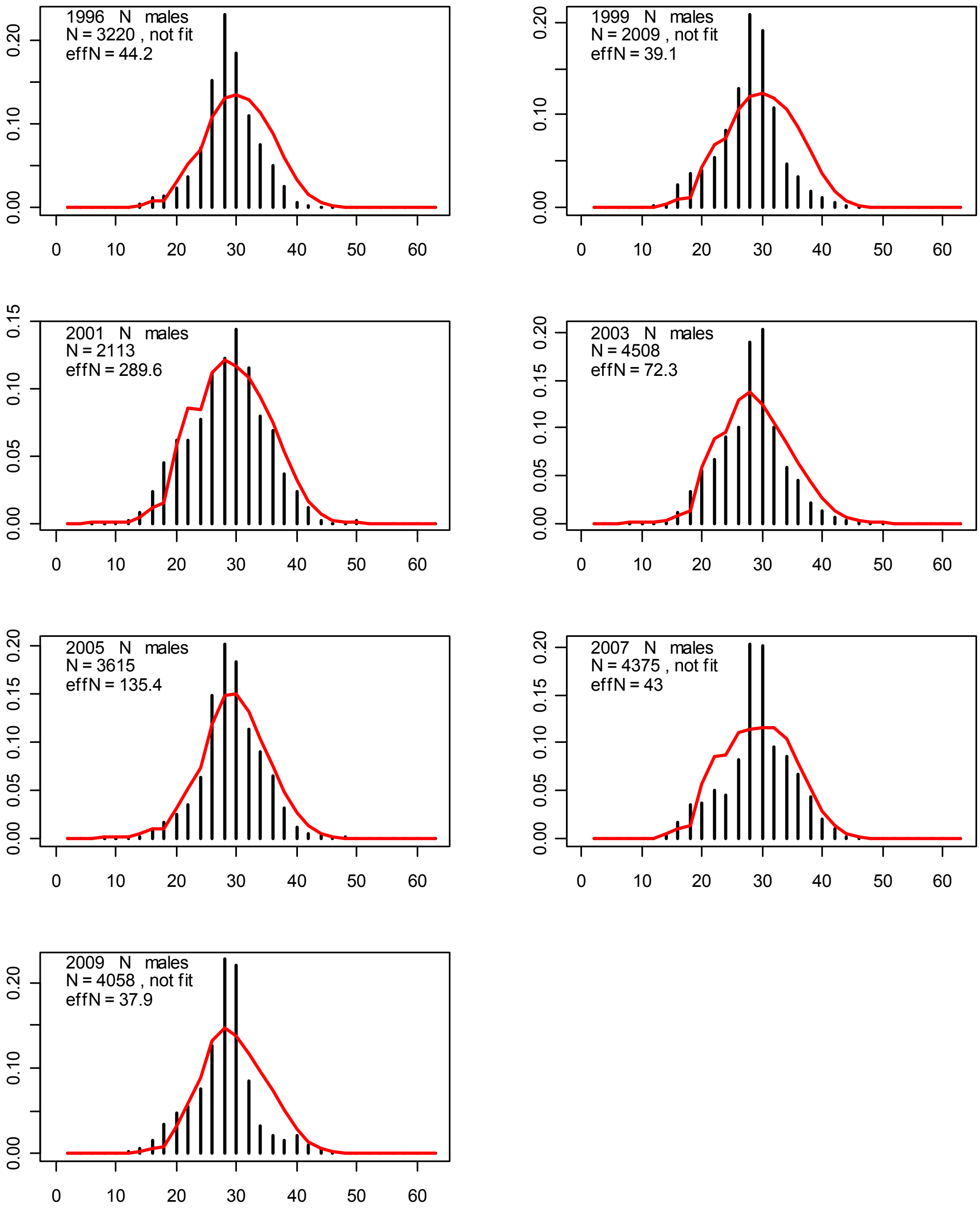
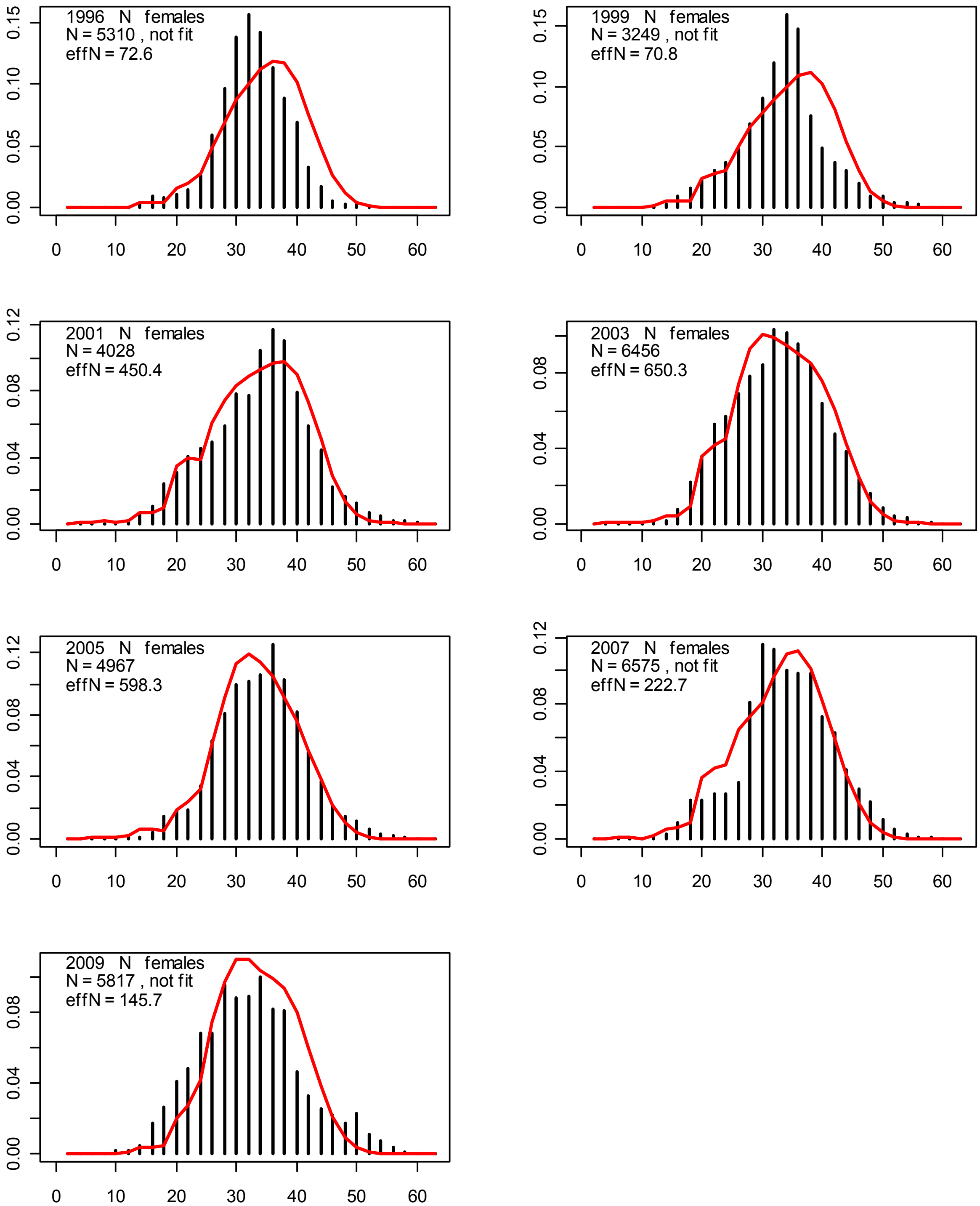
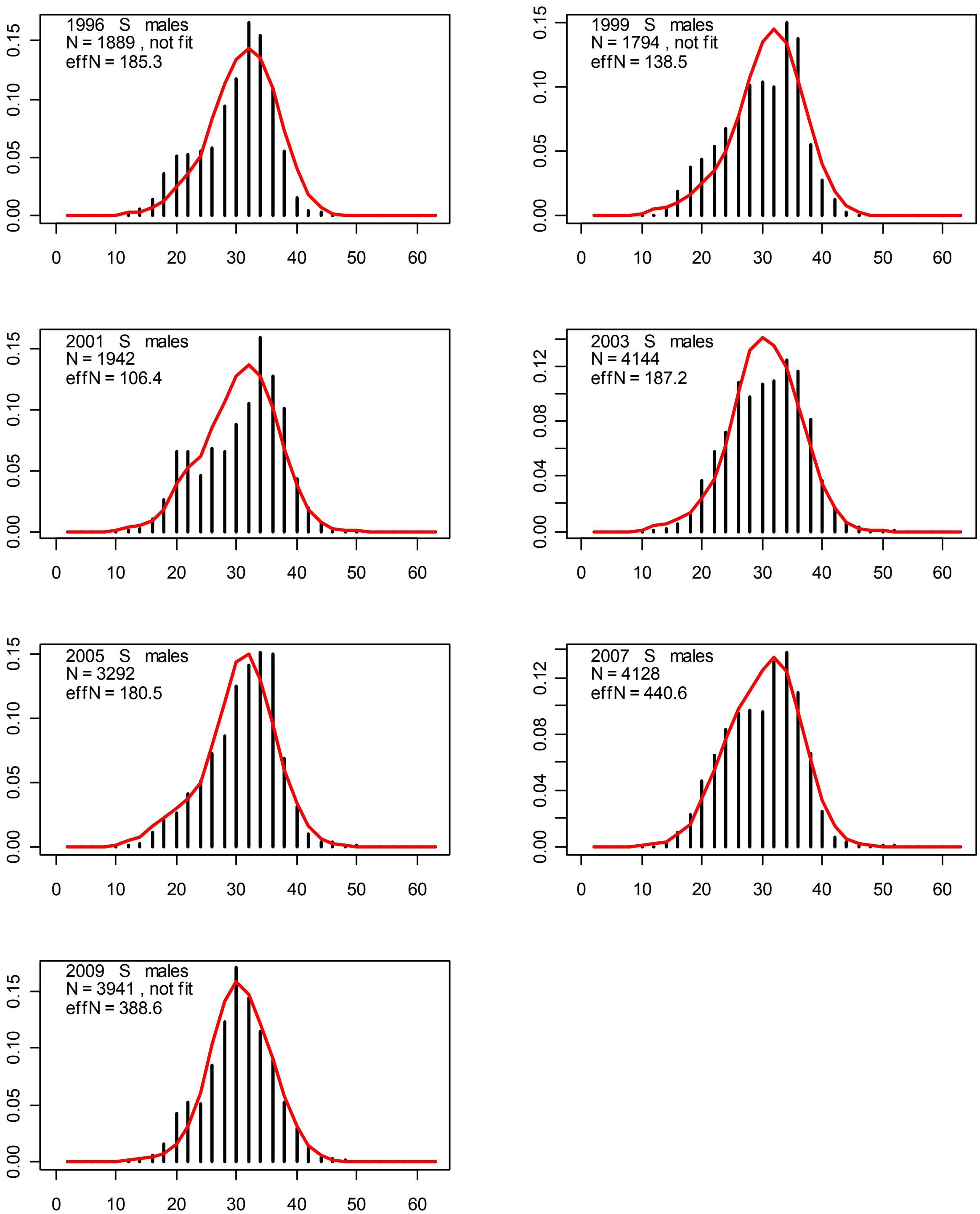


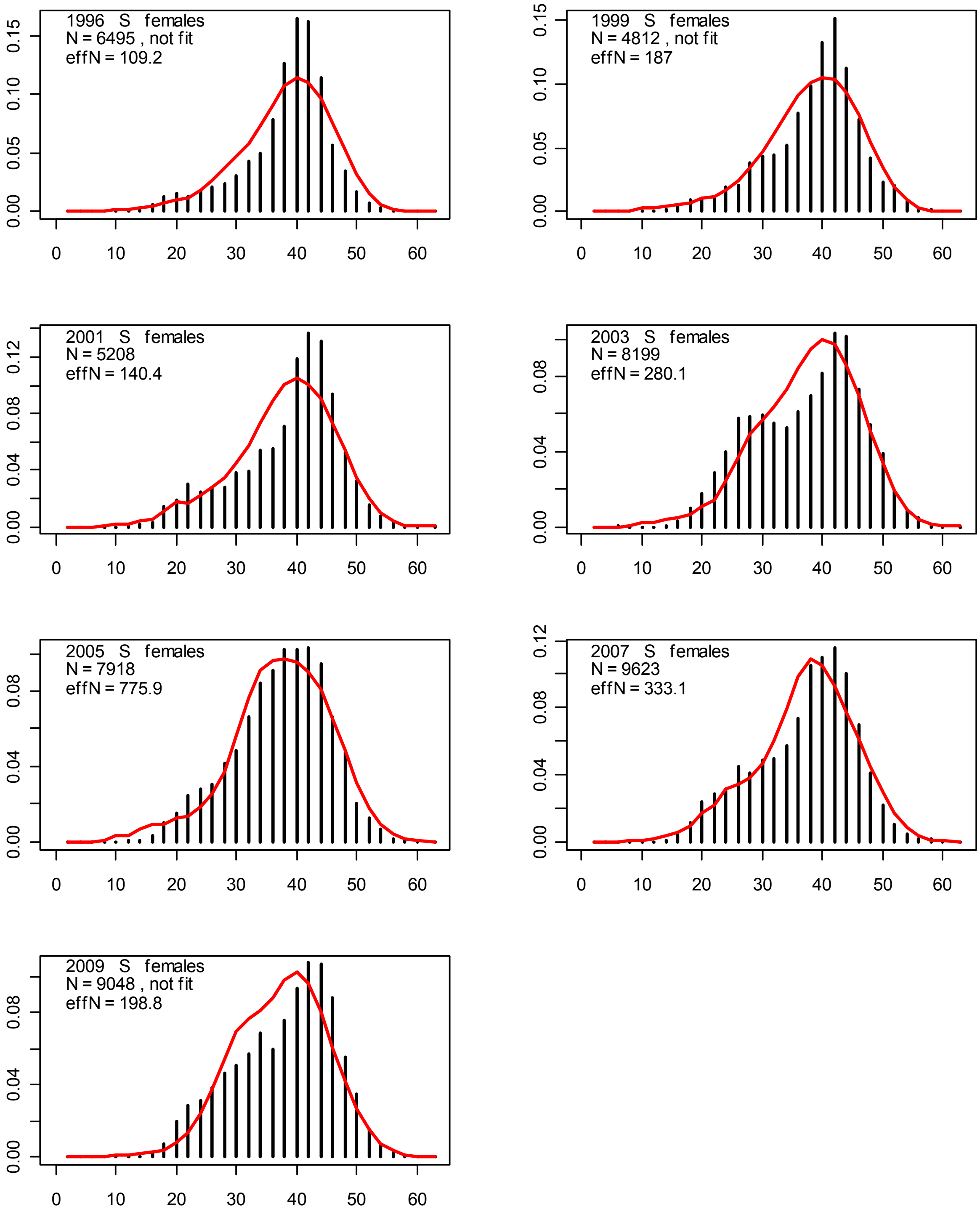
Figure 11 – Length distributions for the NMFS GOA bottom trawl survey, by species and sex (black vertical lines – data, red lines – model estimates)


1984 U females
N = 13130
effN = 957.6
1987 U females
N = 9310
effN = 381
1990 U females
N = 7790
effN = 220.4
1993 U females
N = 11546
effN = 536.7
0.00
0.05
0.10
0.15
0
10
20
30
40
50
60


1996 N males
N = 3220 , not fit
effN = 44.2
1999 N males
N = 2009 , not fit
effN = 39.1
2001 N males
N = 2113
effN = 289.6
2003 N males
N = 4508
effN = 72.3
2005 N males
N = 3615
effN = 135.4
2007 N males
N = 4375 , not fit
effN = 43
2009 N males
N = 4058 , not fit
effN = 37.9
0.00
0.05
0.10
0.15
0.20
0 10 20 30 40 50 60


1996 N females
N = 5310 , not fit
effN = 72.6
1999 N females
N = 3249 , not fit
effN = 70.8
2001 N females
N = 4028
effN = 450.4
2003 N females
N = 6456
effN = 650.3
2005 N females
N = 4967
effN = 598.3
2007 N females
N = 6575 , not fit
effN = 222.7
2009 N females
N = 5817 , not fit
effN = 145.7
0 10 20 30 40 50 60
0.00 0.05 0.10 0.15
0.00 0.04 0.08 0.12


1996 S males
N = 1889 , not fit
effN = 185.3
1999 S males
N = 1794 , not fit
effN = 138.5
2001 S males
N = 1942
effN = 106.4
2003 S males
N = 4144
effN = 187.2
2005 S males
N = 3292
effN = 180.5
2007 S males
N = 4128
effN = 440.6
2009 S males
N = 3941 , not fit
effN = 388.6


1996 S females
N = 6495 , not fit
effN = 109.2
1999 S females
N = 4812 , not fit
effN = 187
2001 S females
N = 5208
effN = 140.4
2003 S females
N = 8199
effN = 280.1
2005 S females
N = 7918
effN = 775.9
2007 S females
N = 9623
effN = 333.1
2009 S females
N = 9048 , not fit
effN = 198.8
0.00
0.05
0.10
0.15
0.04
0.08
0.12
0
10
20
30
40
50
60

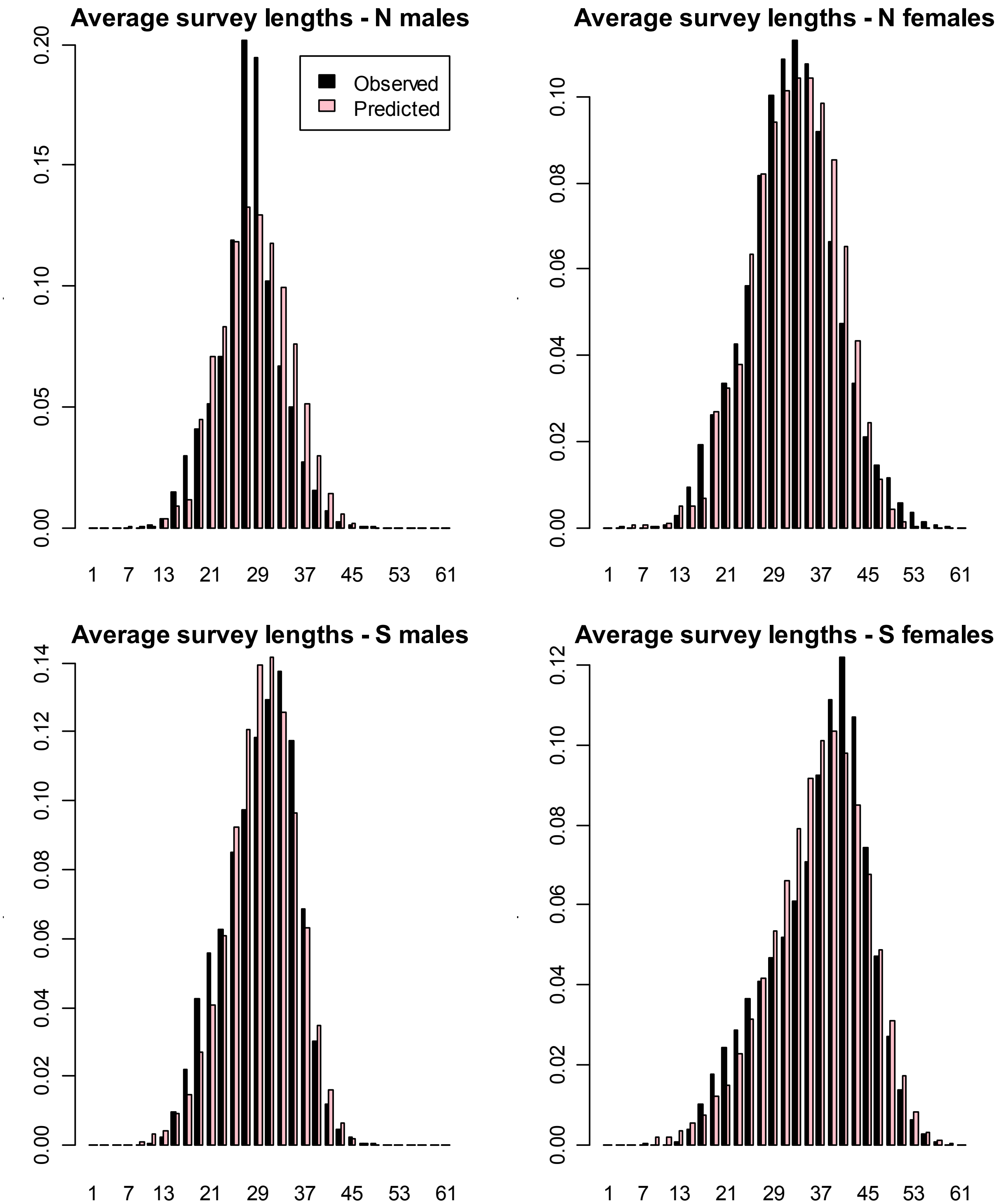


Figure 12 – Weighted average across years of observed and predicted survey length distributions, by species and sex

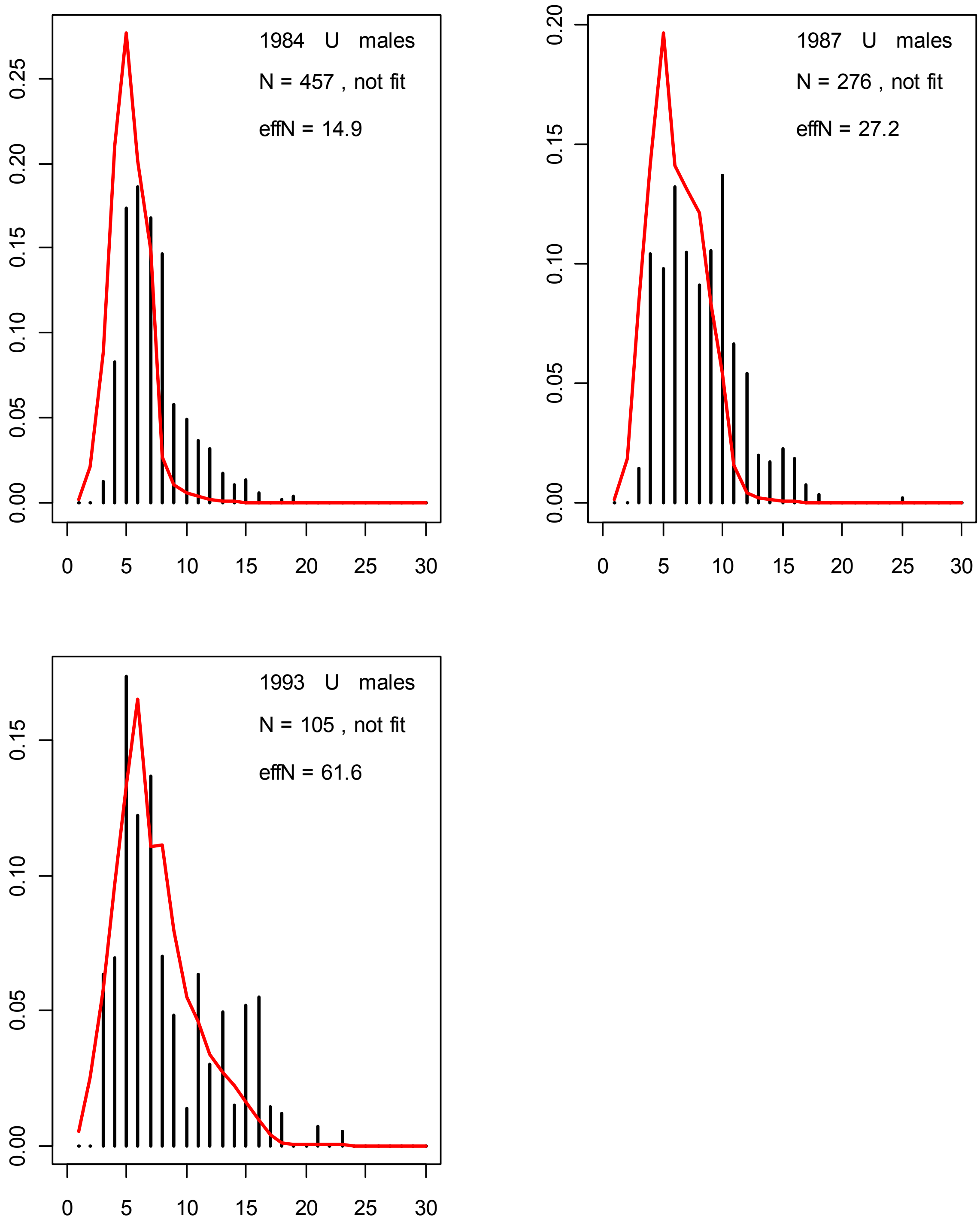
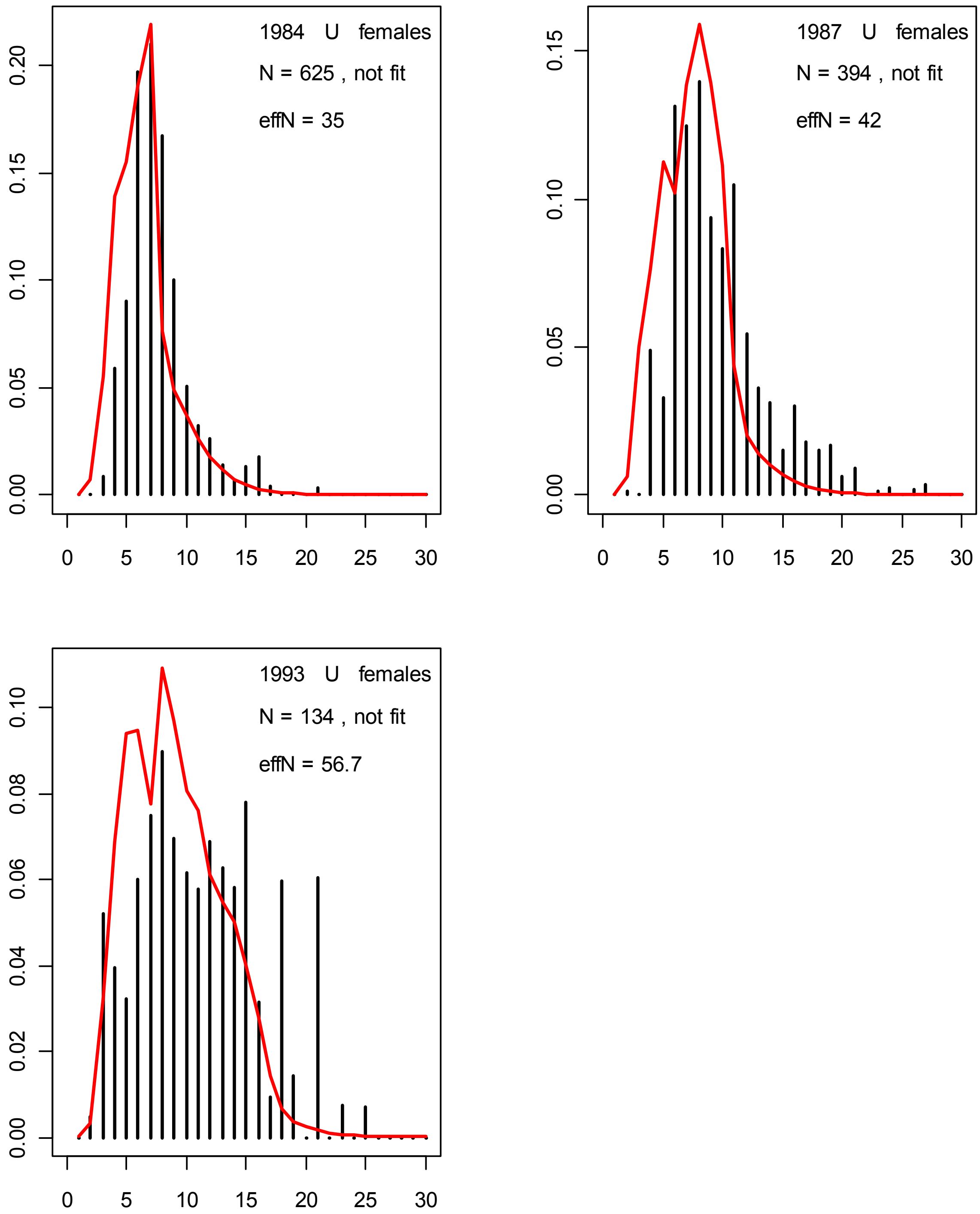
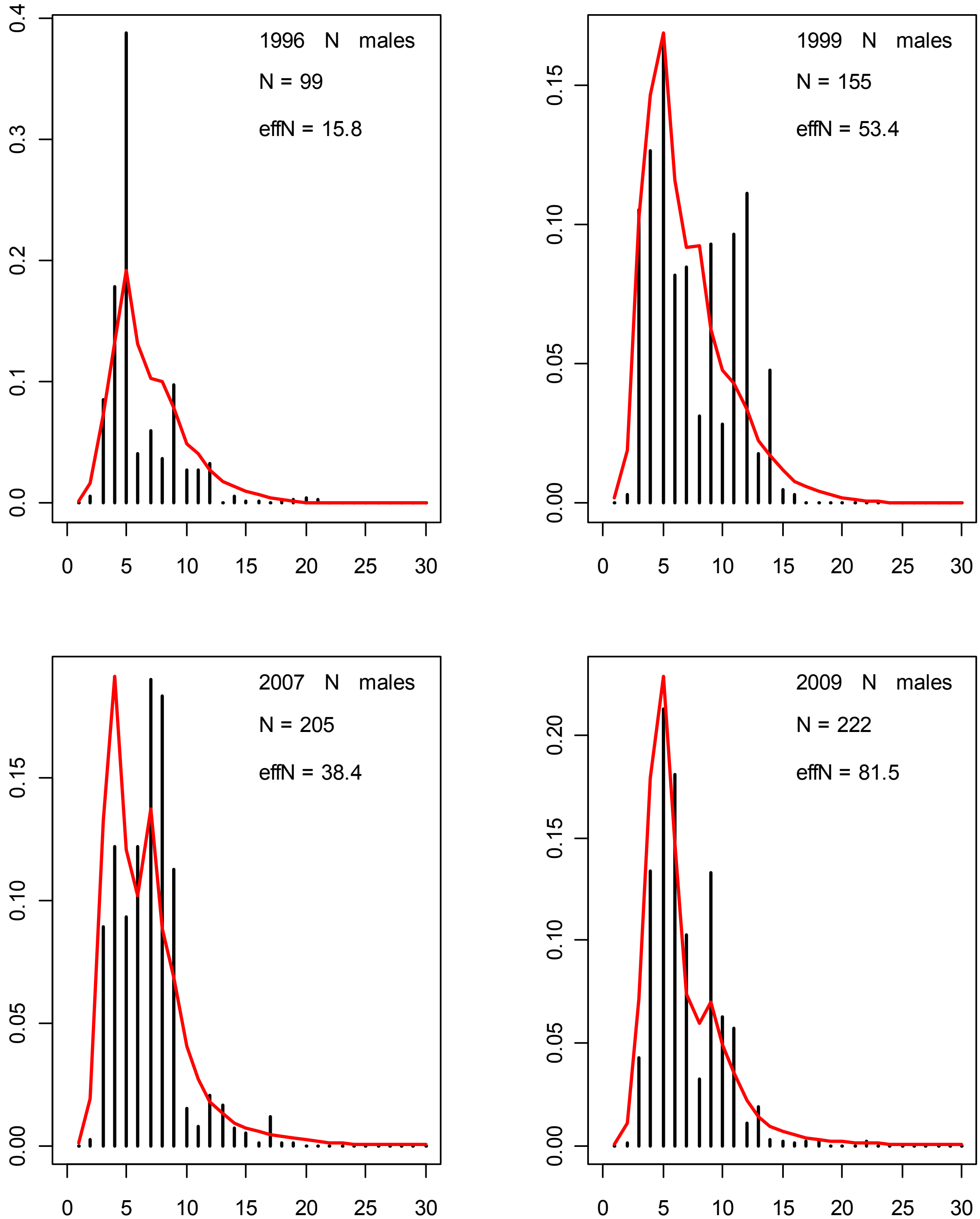
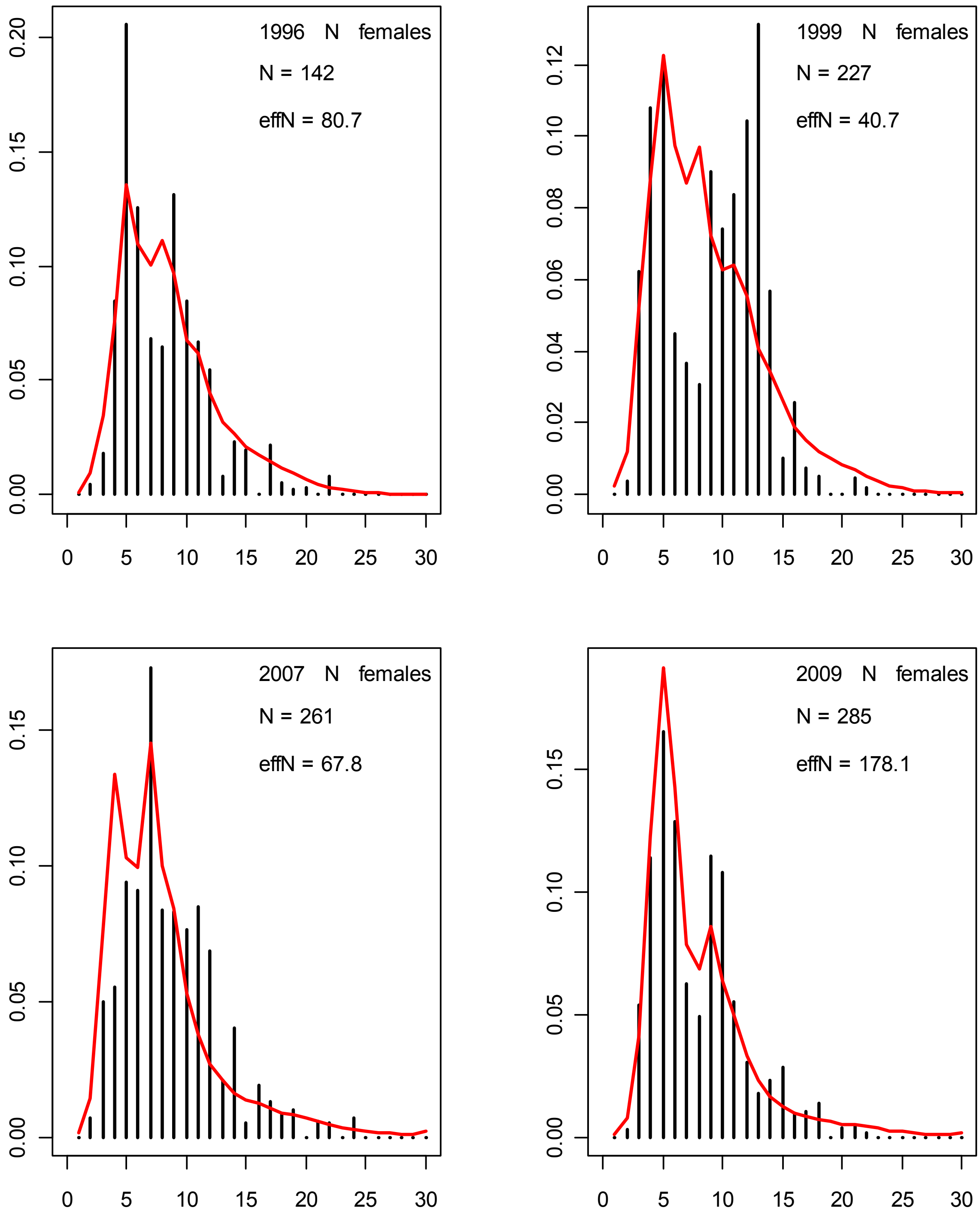


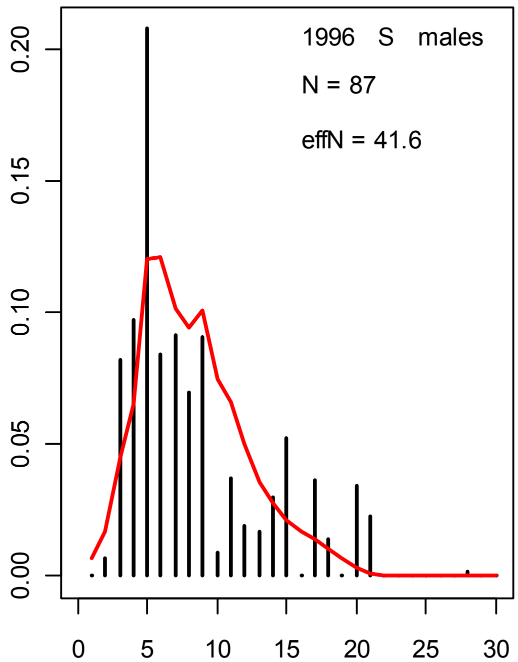
Figure 13 – Age distributions for the NMFS GOA bottom trawl survey, by species and sex (black vertical lines – data, red lines – model estimates)

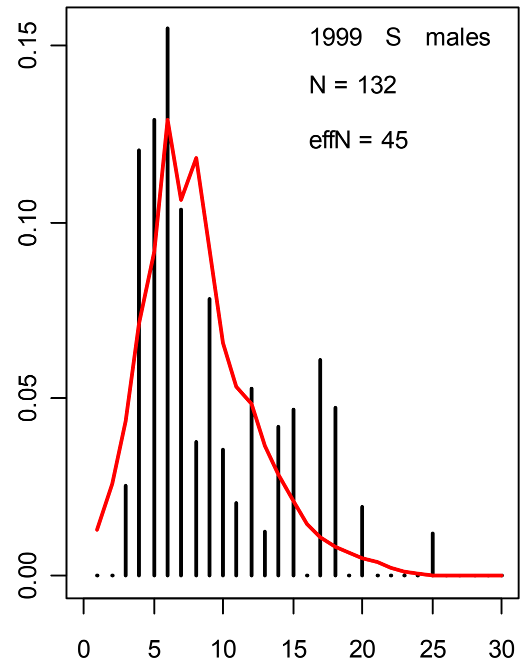

1984 U females
N = 625 , not fit
effN = 35
1987 U females
N = 394 , not fit
effN = 42
1993 U females
N = 134 , not fit
effN = 56.7
0.00
0.05
0.10
0.15
0.20
0.02
0.04
0.06
0.08
0
5
10
15
20
25
30

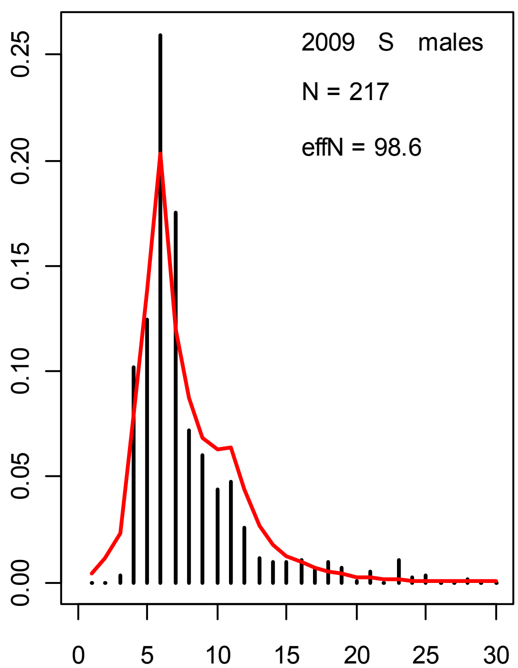

1996 N males
N = 99
effN = 15.8
1999 N males
N = 155
effN = 53.4
2007 N males
N = 205
effN = 38.4
2009 N males
N = 222
effN = 81.5

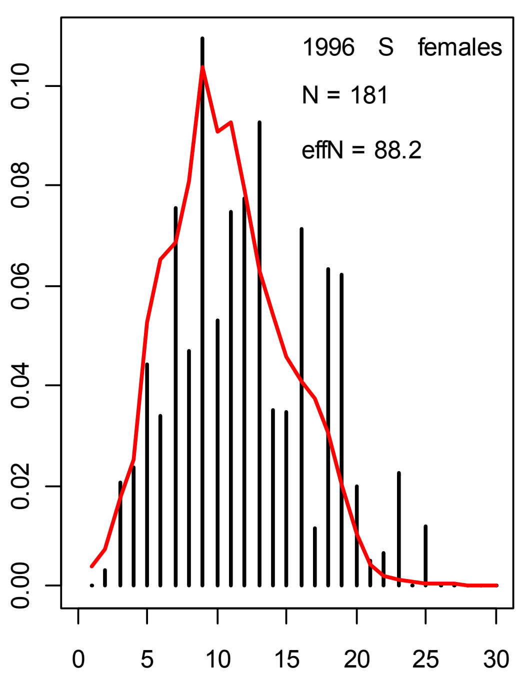


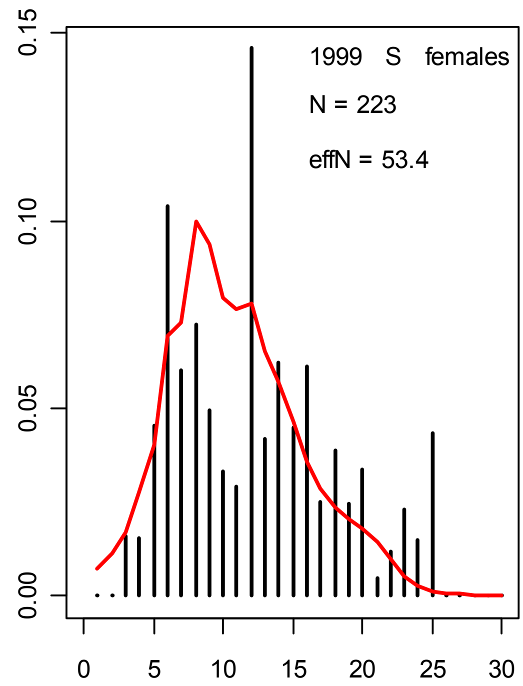
1996 N females
N = 142
effN = 80.7
1999 N females
N = 227
effN = 40.7
2007 N females
N = 261
effN = 67.8
2009 N females
N = 285
effN = 178.1

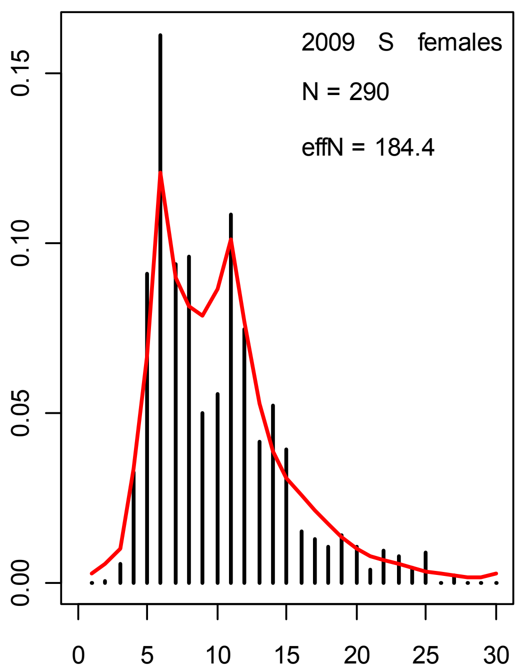

1996 S males
N = 87
effN = 41.6
0.00 0.05 0.10 0.15 0.20
0 5 10 15 20 25 30


1999 S males
N = 132
effN = 45
0.00 0.05 0.10 0.15
0 5 10 15 20 25 30


2009 S males
N = 217
effN = 98.6
0.00 0.05 0.10 0.15 0.20 0.25
0 5 10 15 20 25 30


1996 S females
N = 181
effN = 88.2
0.00
0.02
0.04
0.06
0.08
0.10
0
5
10
15
20
25
30


1999 S females
N = 223
effN = 53.4
0.00
0.05
0.10
0.15
0
5
10
15
20
25
30


2009 S females
N = 290
effN = 184.4
0.00
0.05
0.10
0.15
0
5
10
15
20
25
30

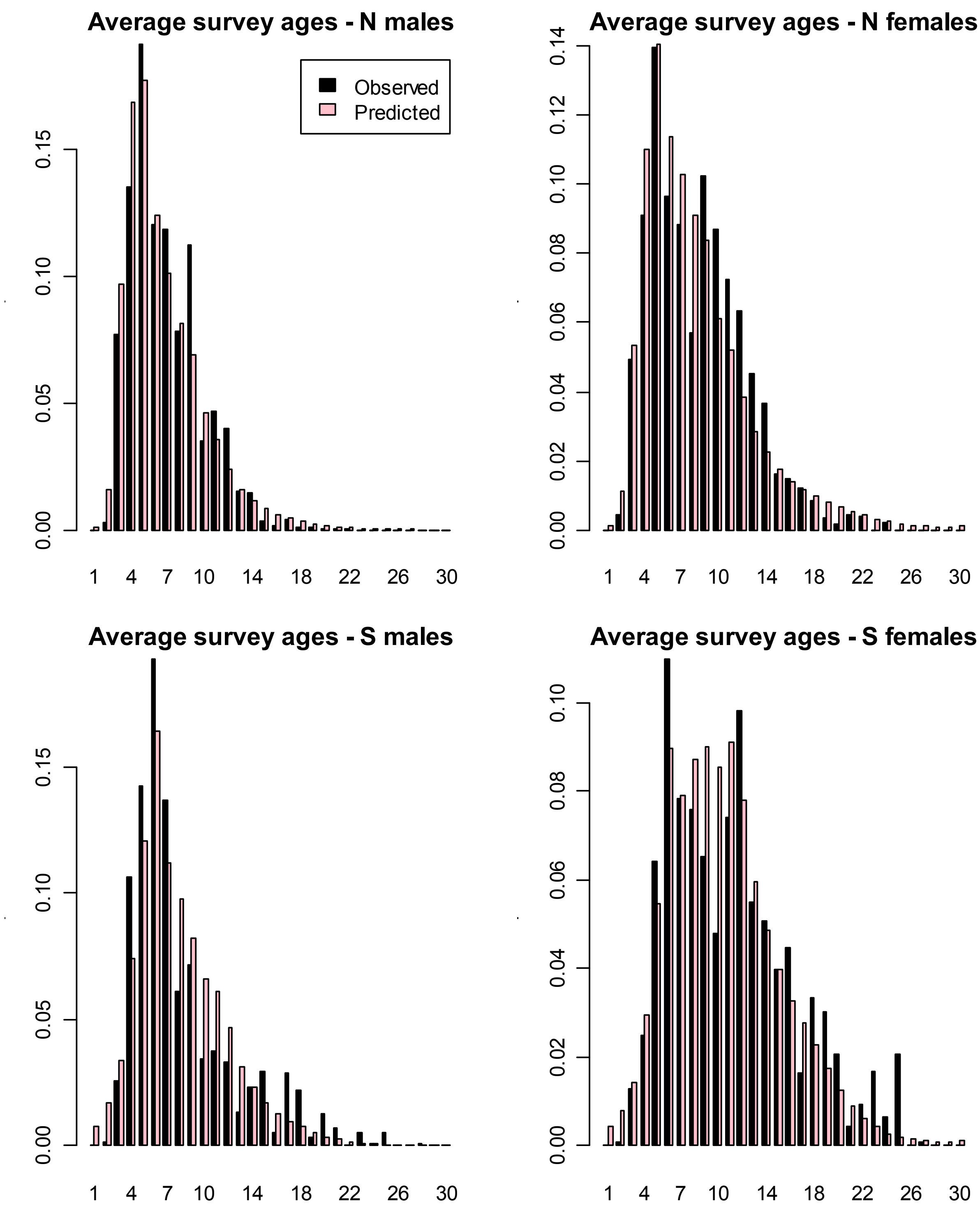


Figure 14 – Weighted average across years of observed and predicted survey age distributions, by species and sex

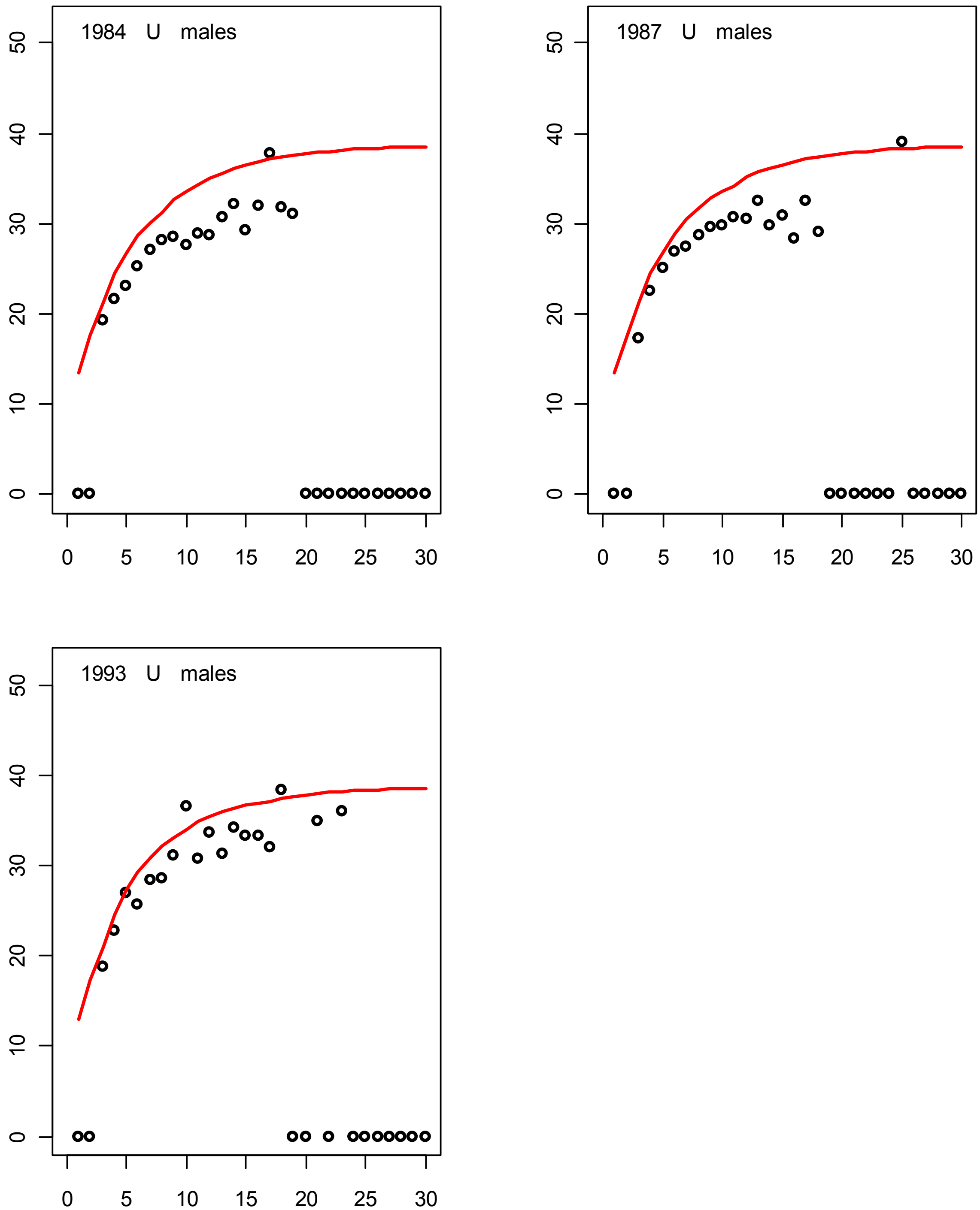
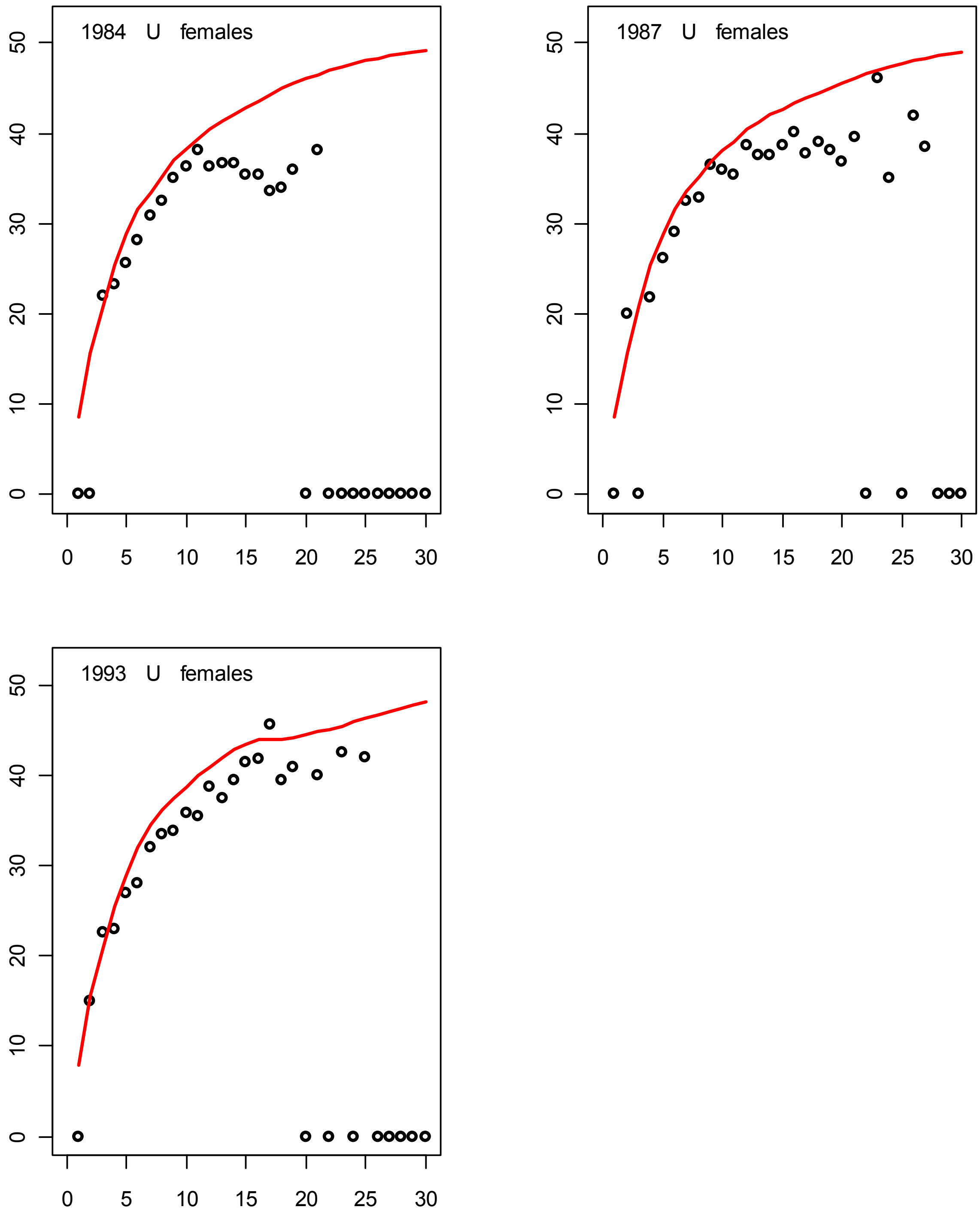
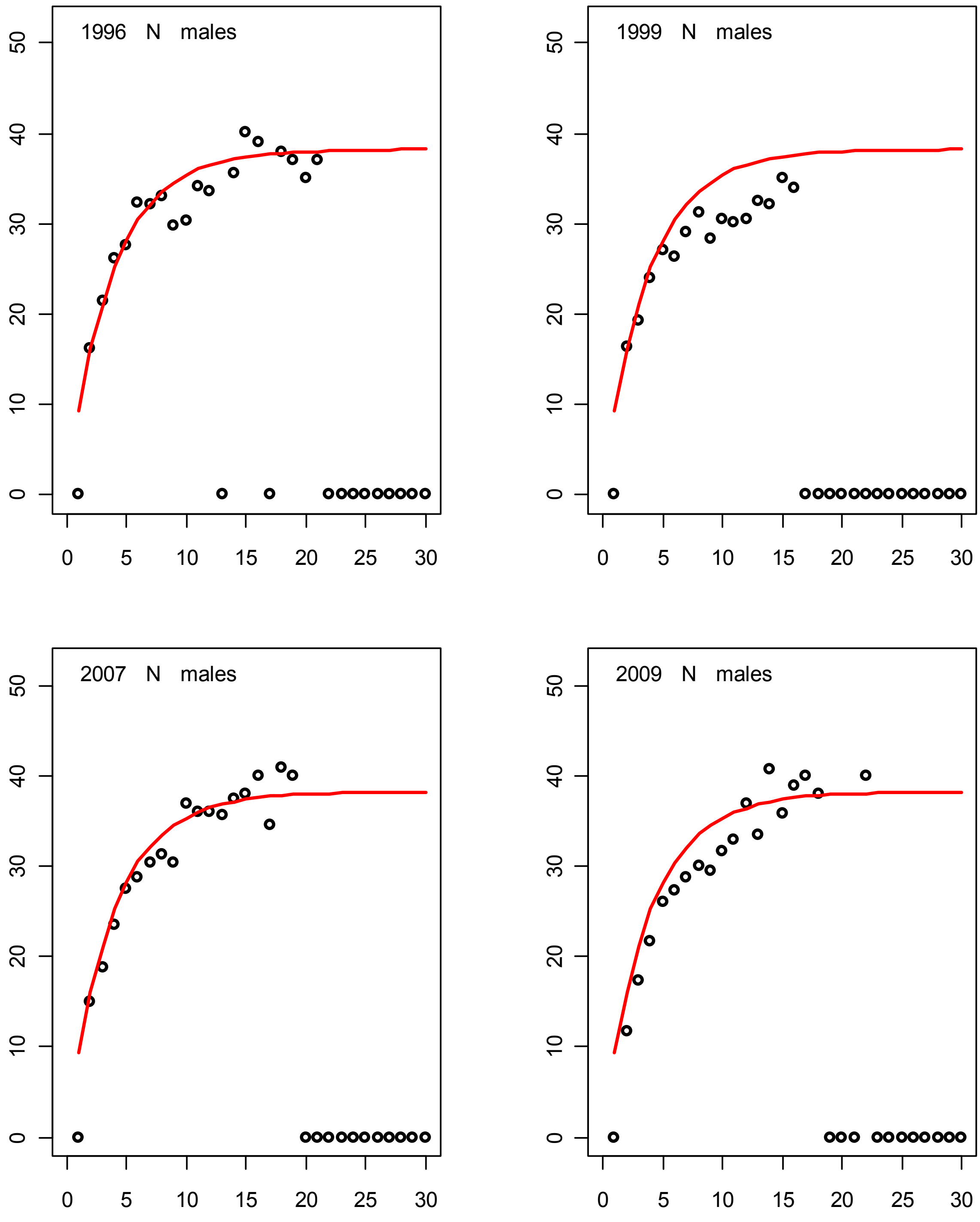
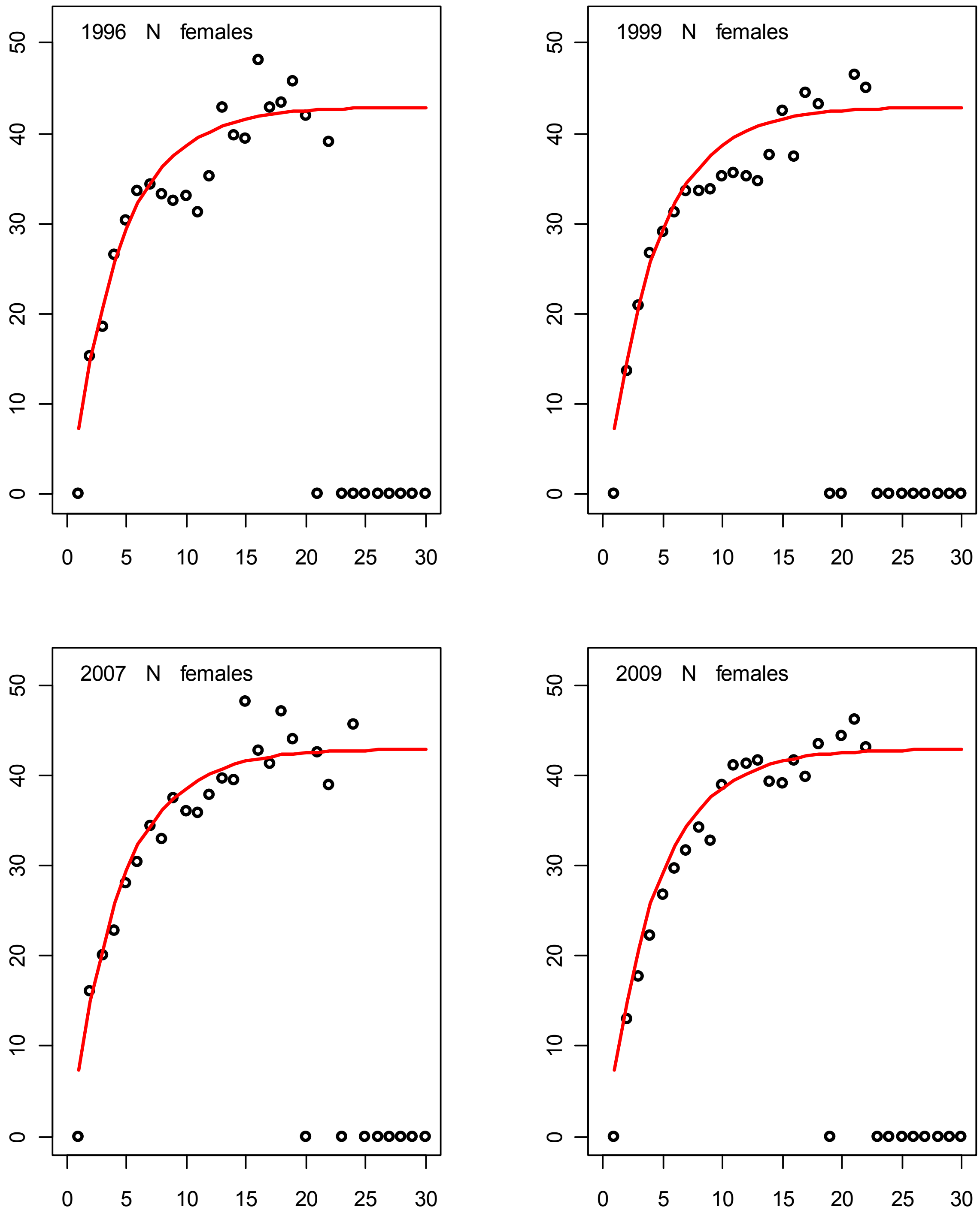
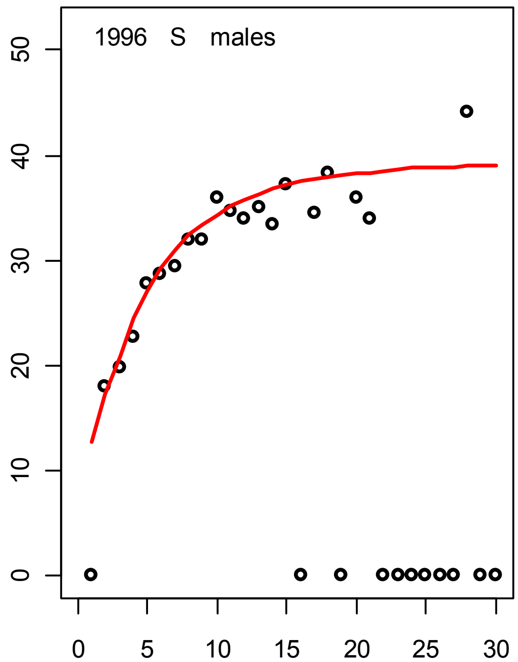


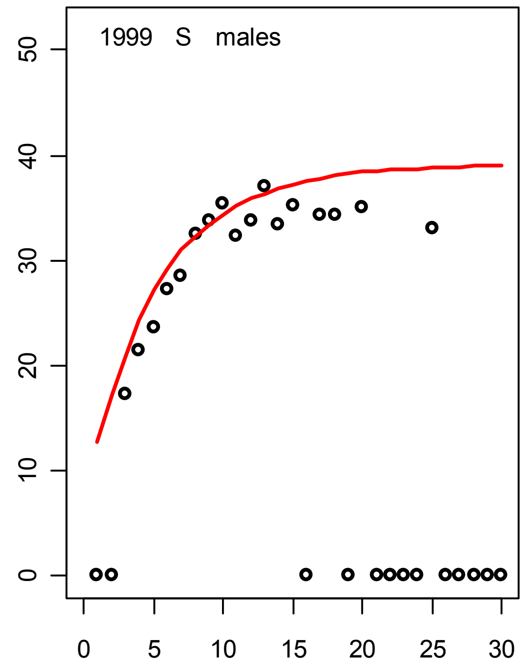
Figure 15 – Average length-at-age for the NMFS GOA bottom trawl survey, by species and sex (black circles – data, red lines – model estimates)

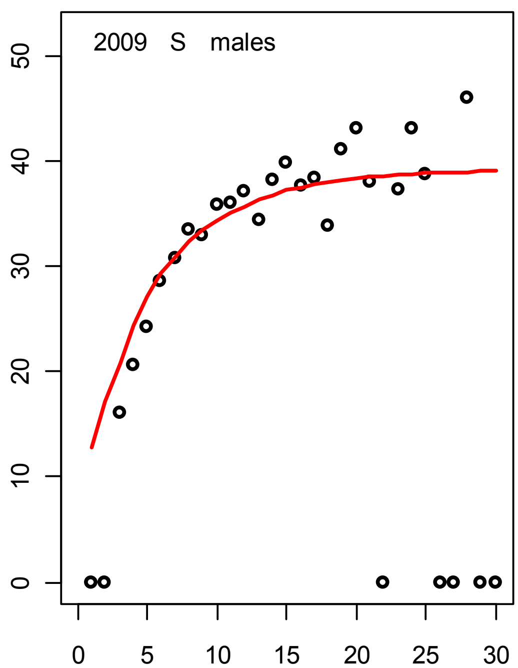

1984 U females
1987 U females
1993 U females
0
10
20
30
40
50
0
5
10
15
20
25
30

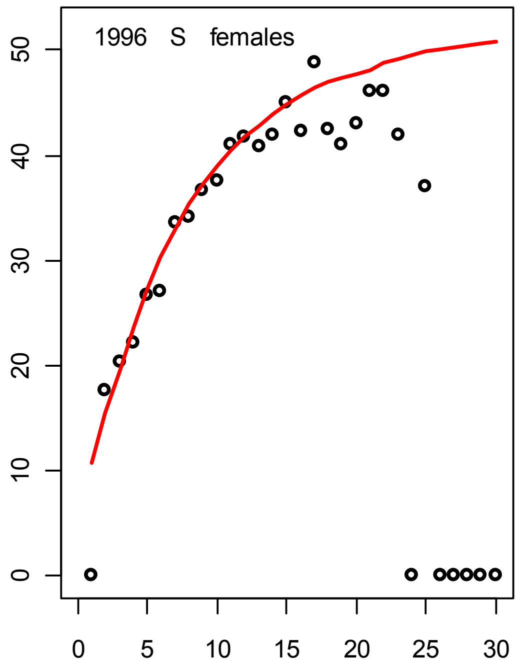

1996 N males
1999 N males
2007 N males
2009 N males
0
10
20
30
40
50
0
5
10
15
20
25
30

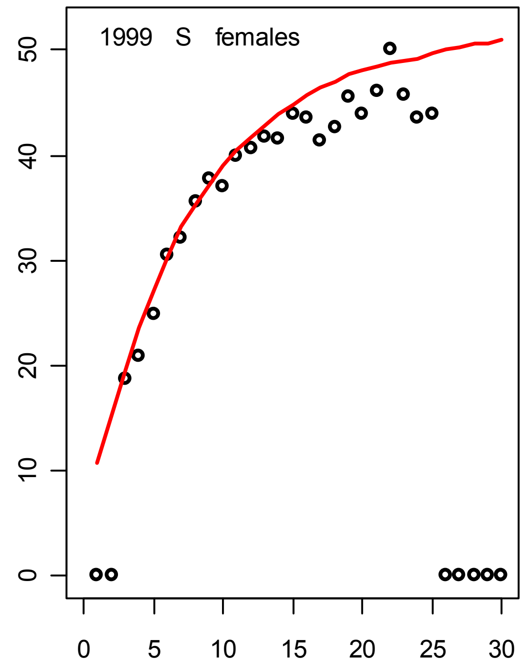

1996 N females
1999 N females
2007 N females
2009 N females
0
10
20
30
40
50
0
5
10
15
20
25
30

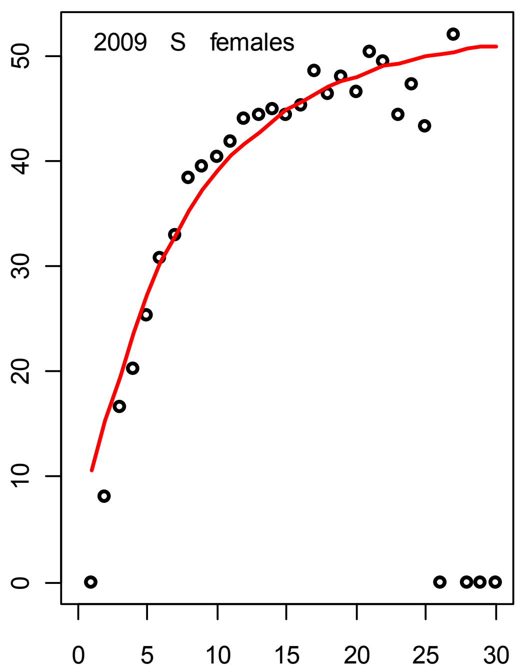

1996 S males
0
10
20
30
40
50
0
5
10
15
20
25
30


1999 S males
0
10
20
30
40
50
0
5
10
15
20
25
30


2009 S males
0
10
20
30
40
50
0
5
10
15
20
25
30


1996 S females
0
10
20
30
40
50
0 5 10 15 20 25 30


1999 S females
0
10
20
30
40
50
0 5 10 15 20 25 30


2009 S females
0
10
20
30
40
50
0 5 10 15 20 25 30

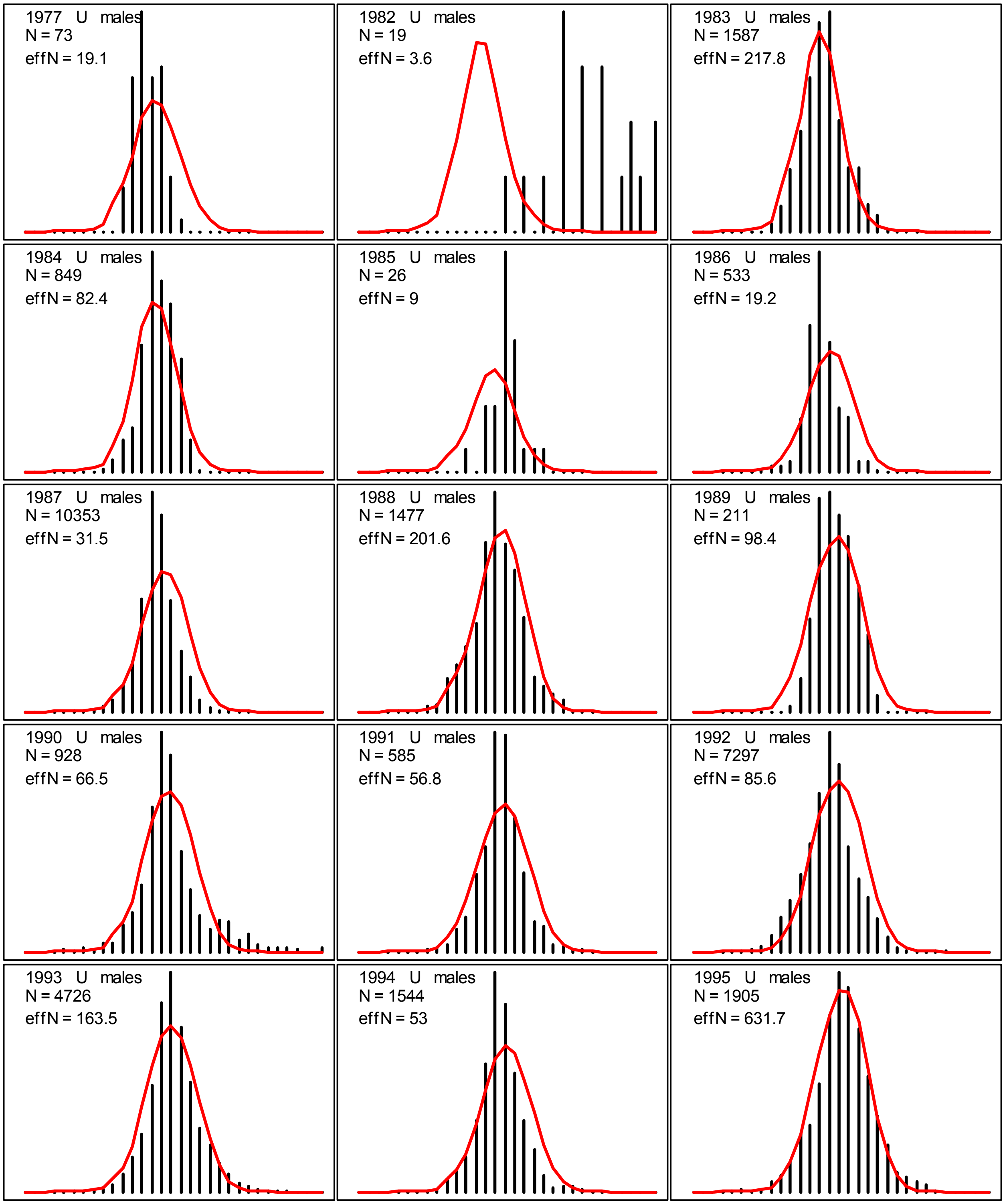
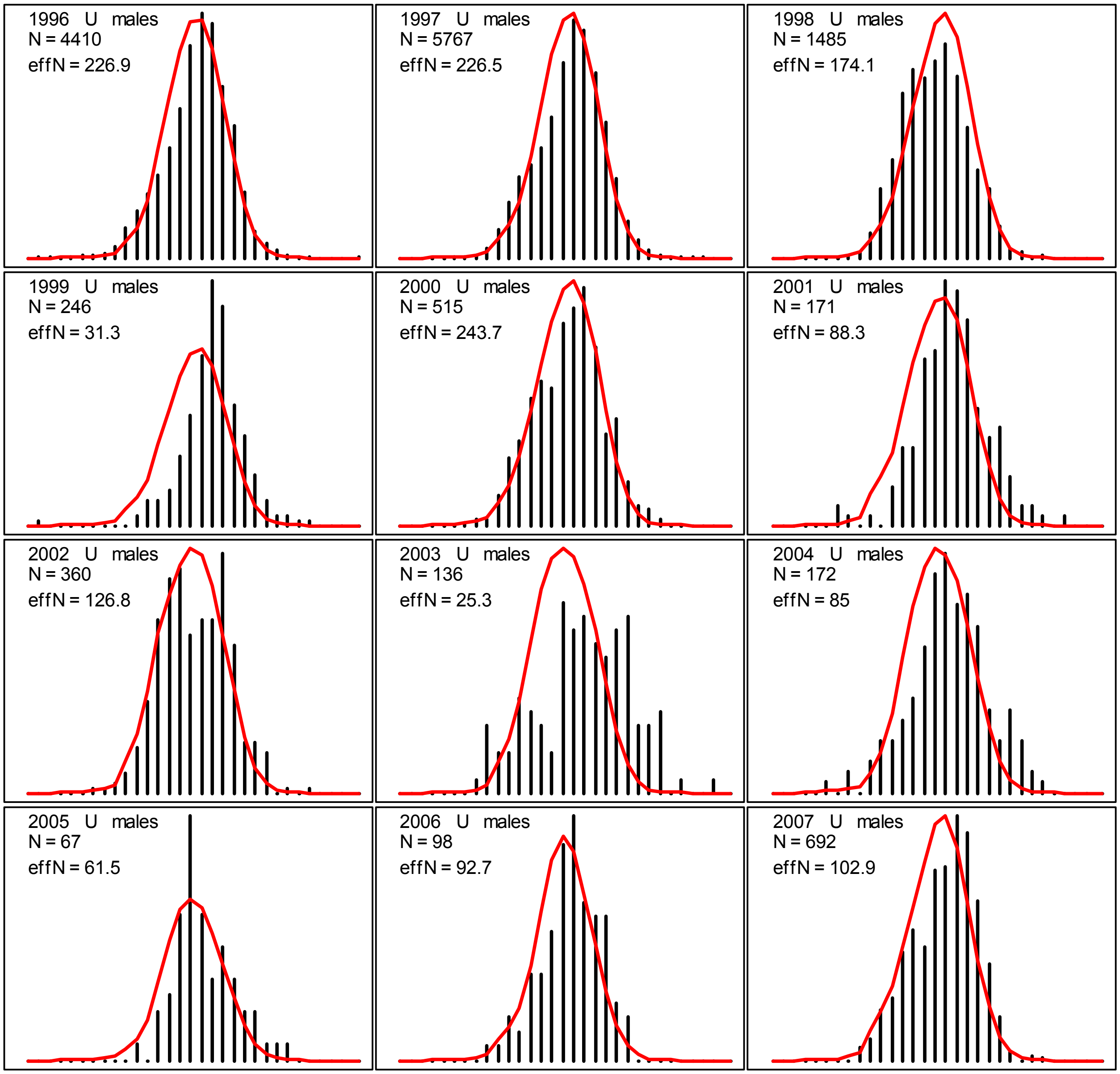
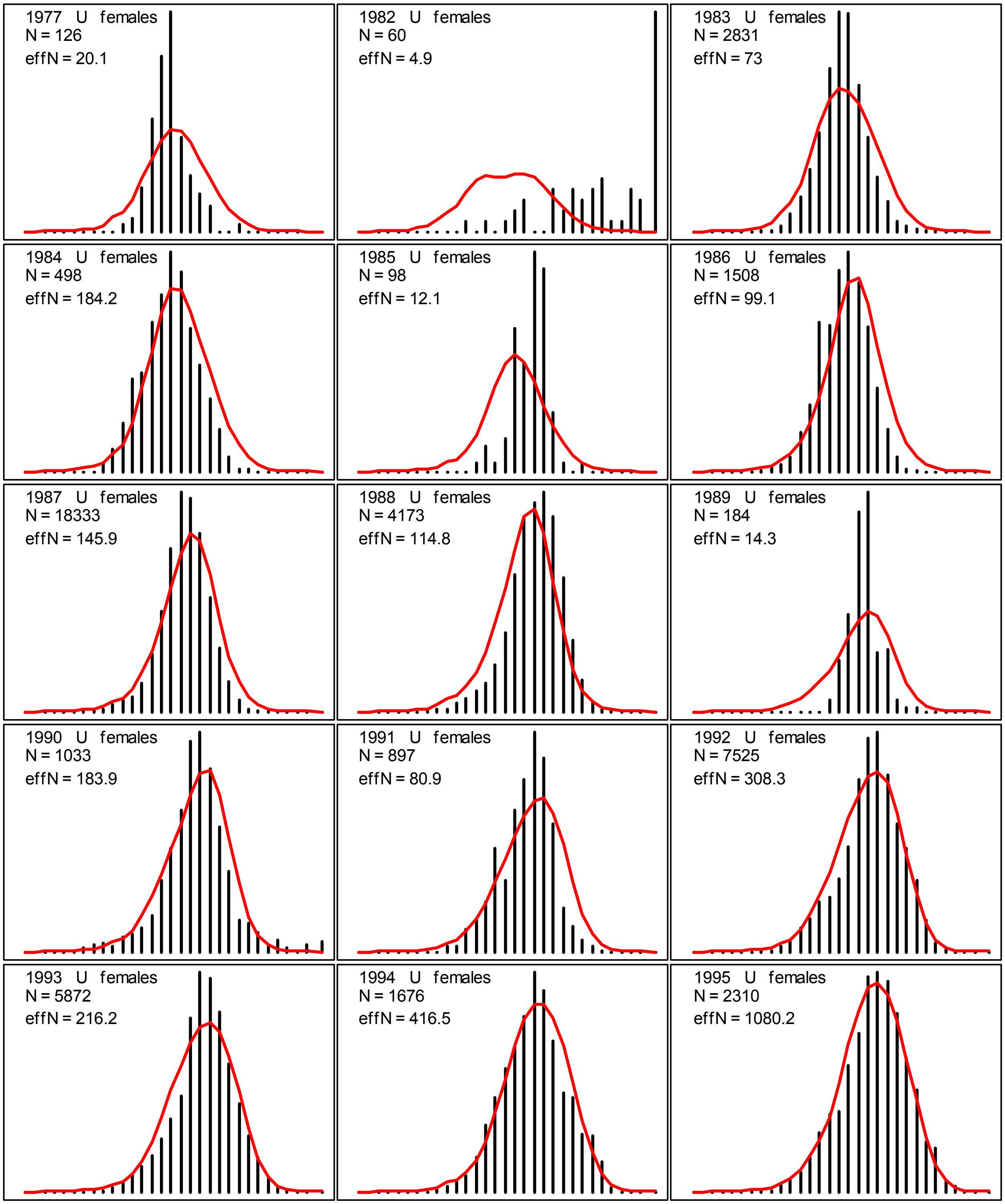
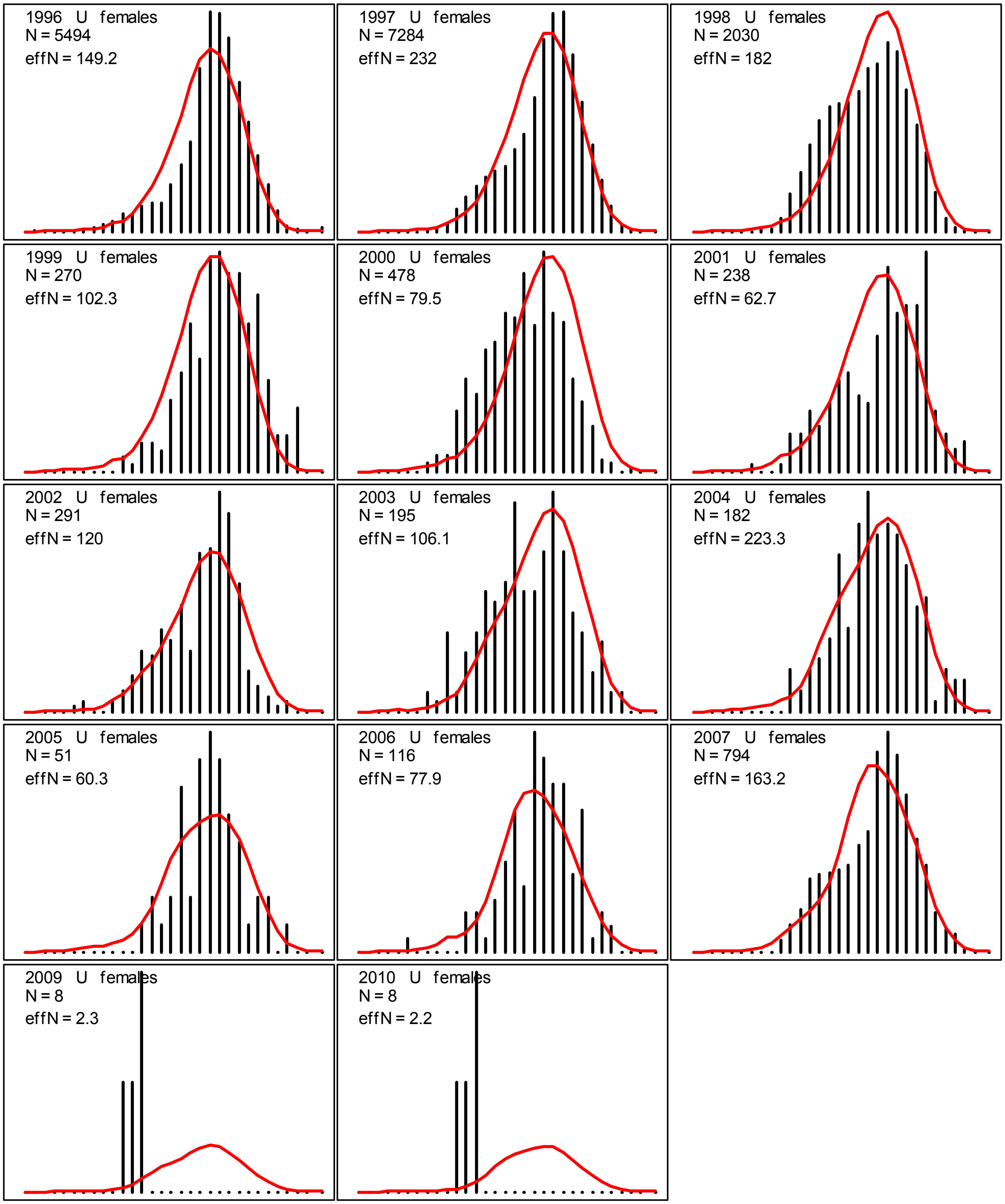
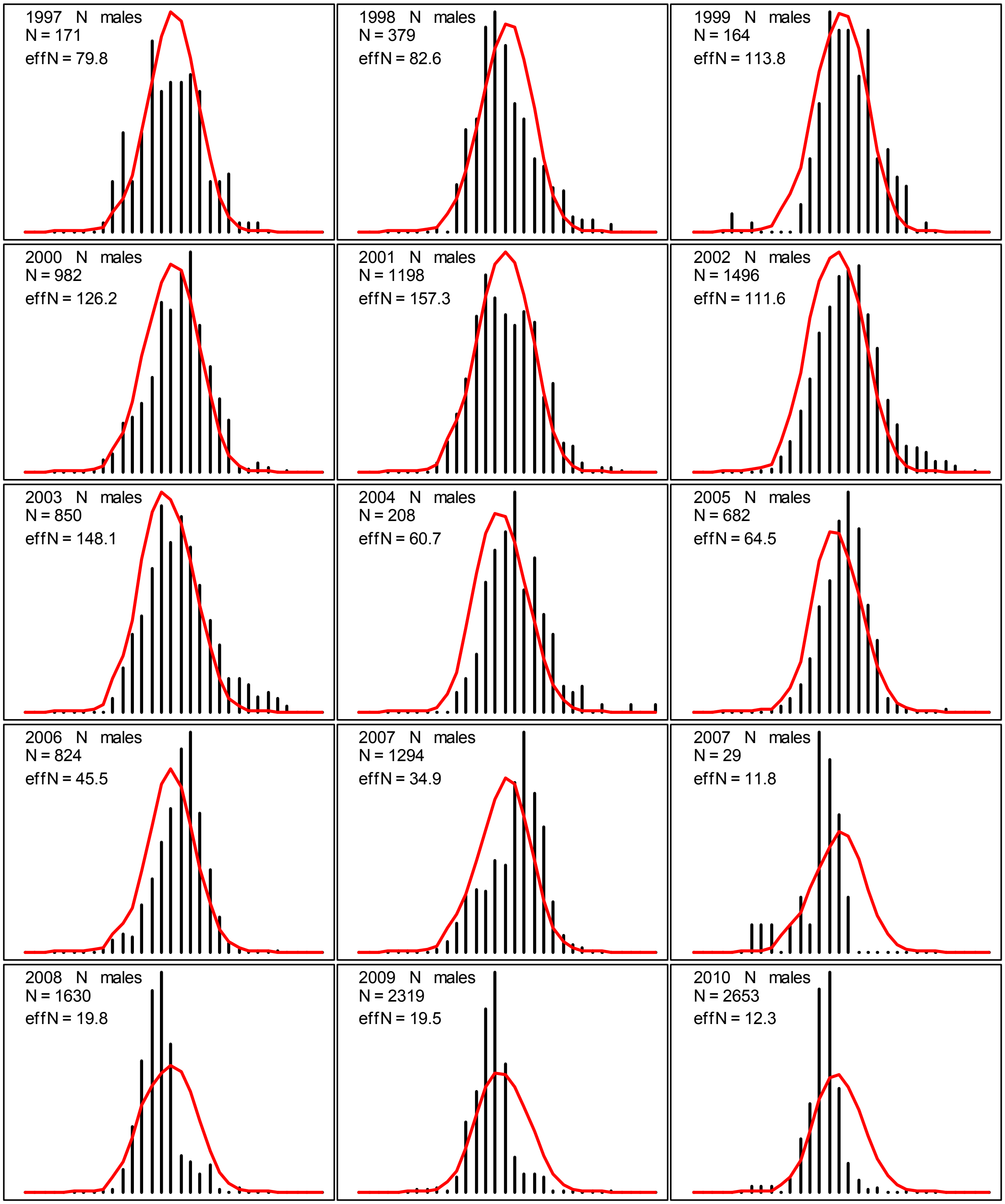


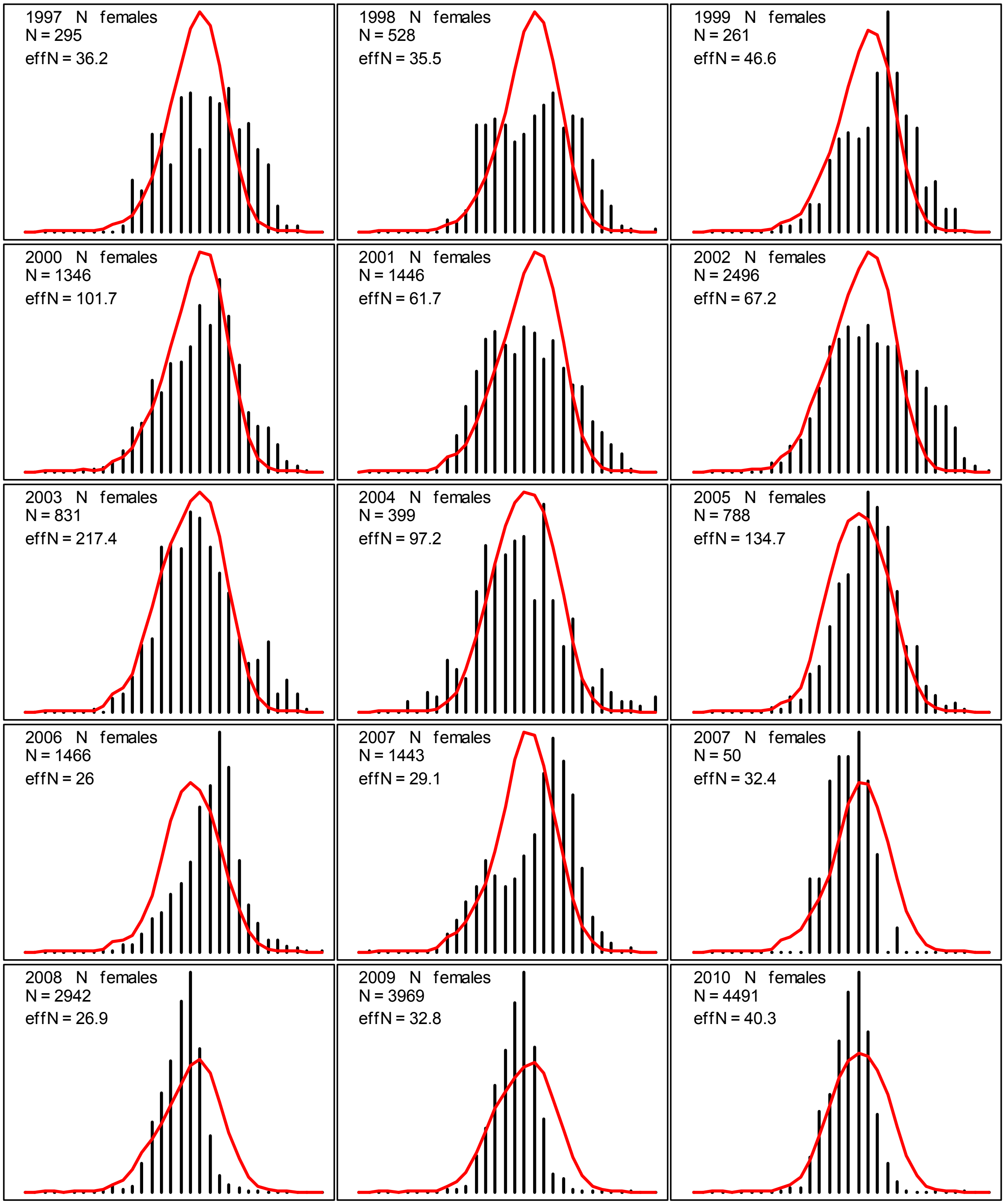
Figure 16 – Length distributions of rock sole catch in the observed shallow-water flatfish catch, by species and sex (black vertical lines – data, red lines – model estimates)

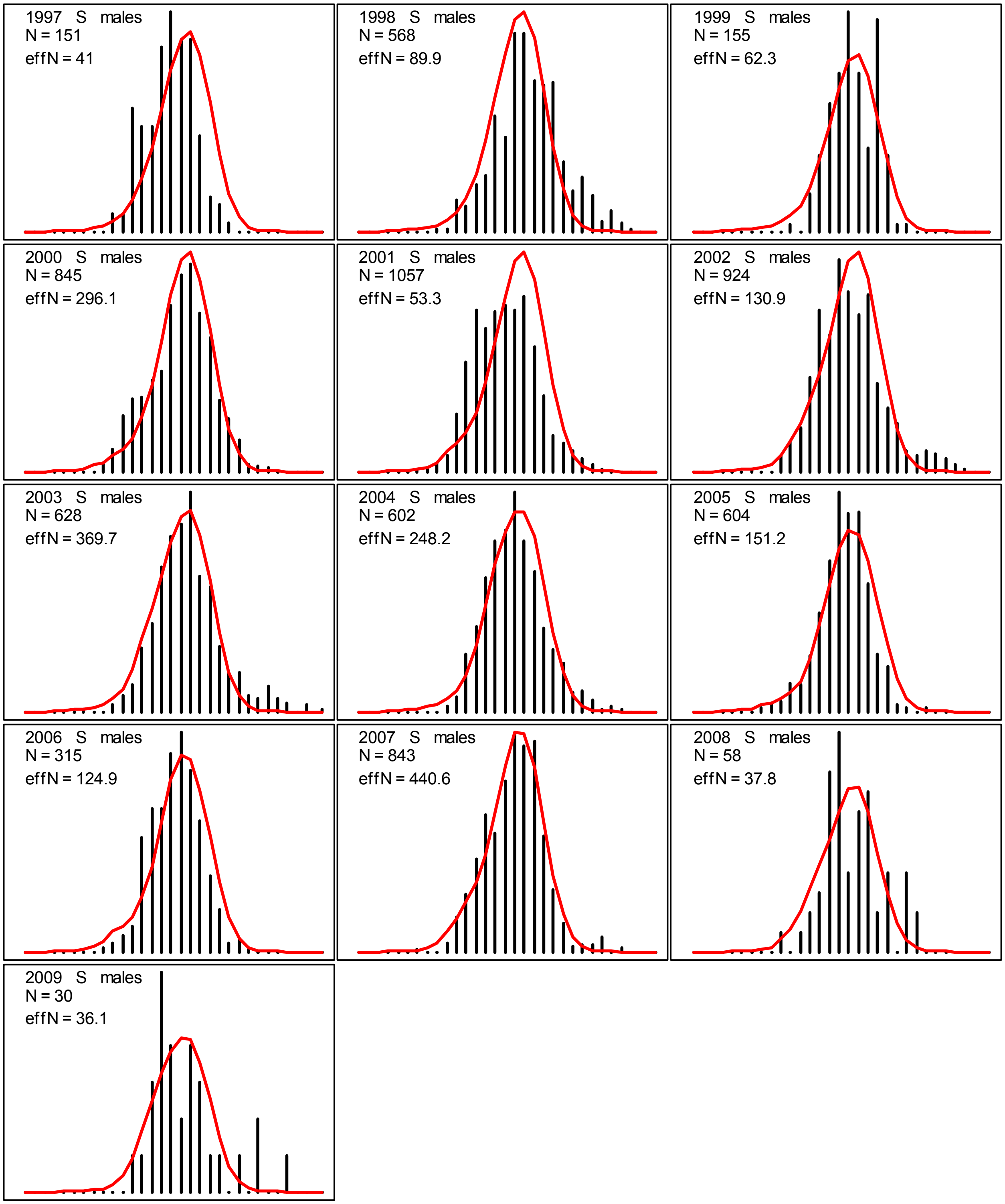

1996 U males
N = 4410
effN = 226.9
1997 U males
N = 5767
effN = 226.5
1998 U males
N = 1485
effN = 174.1
1999 U males
N = 246
effN = 31.3
2000 U males
N = 515
effN = 243.7
2001 U males
N = 171
effN = 88.3
2002 U males
N = 360
effN = 126.8
2003 U males
N = 136
effN = 25.3
2004 U males
N = 172
effN = 85
2005 U males
N = 67
effN = 61.5
2006 U males
N = 98
effN = 92.7
2007 U males
N = 692
effN = 102.9

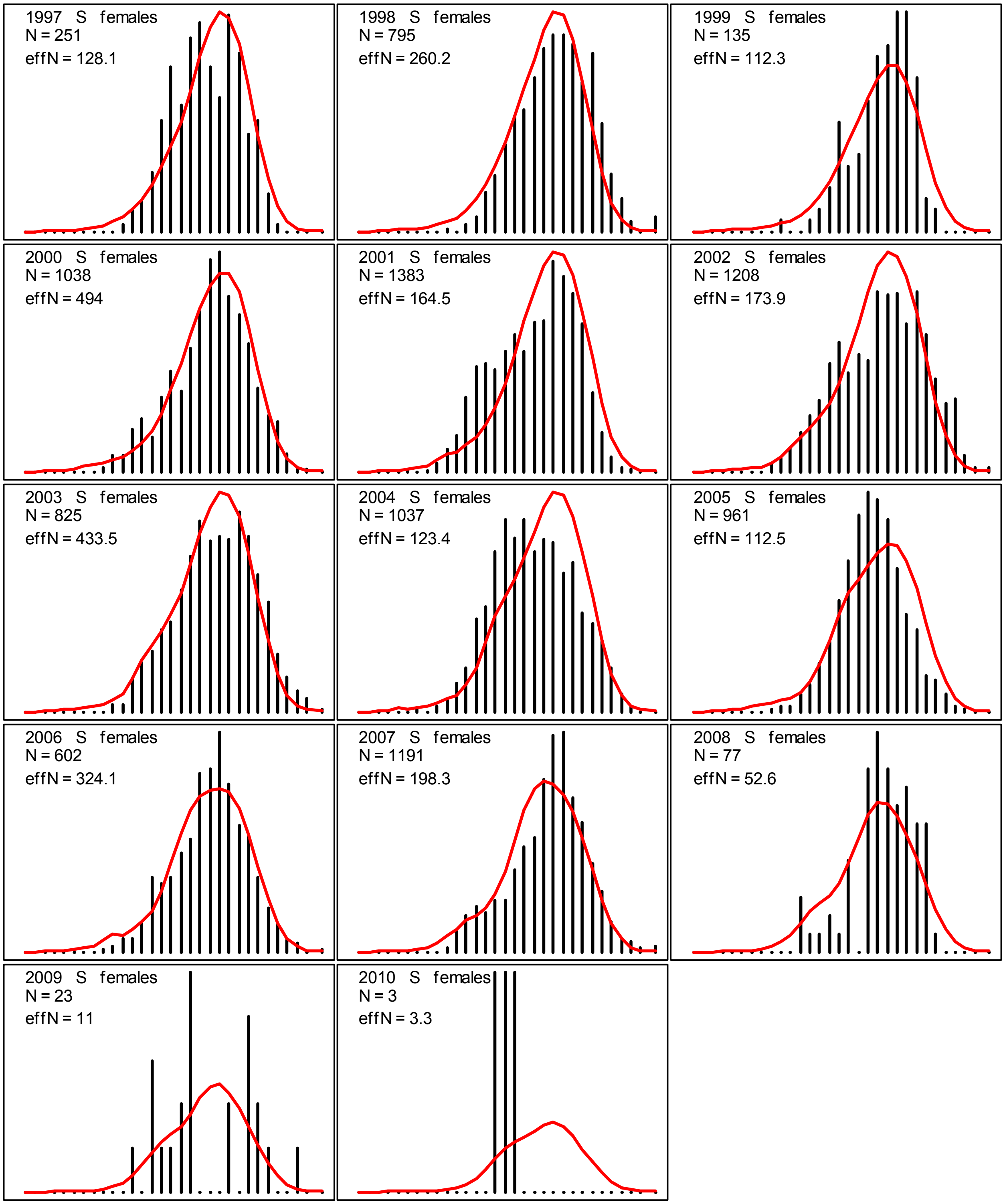

1977 U females
N = 126
effN = 20.1
1982 U females
N = 60
effN = 4.9
1983 U females
N = 2831
effN = 73
1984 U females
N = 498
effN = 184.2
1985 U females
N = 98
effN = 12.1
1986 U females
N = 1508
effN = 99.1
1987 U females
N = 18333
effN = 145.9
1988 U females
N = 4173
effN = 114.8
1989 U females
N = 184
effN = 14.3
1990 U females
N = 1033
effN = 183.9
1991 U females
N = 897
effN = 80.9
1992 U females
N = 7525
effN = 308.3
1993 U females
N = 5872
effN = 216.2
1994 U females
N = 1676
effN = 416.5
1995 U females
N = 2310
effN = 1080.2


1996 U females
N = 5494
effN = 149.2
1997 U females
N = 7284
effN = 232
1998 U females
N = 2030
effN = 182
1999 U females
N = 270
effN = 102.3
2000 U females
N = 478
effN = 79.5
2001 U females
N = 238
effN = 62.7
2002 U females
N = 291
effN = 120
2003 U females
N = 195
effN = 106.1
2004 U females
N = 182
effN = 223.3
2005 U females
N = 51
effN = 60.3
2006 U females
N = 116
effN = 77.9
2007 U females
N = 794
effN = 163.2
2009 U females
N = 8
effN = 2.3
2010 U females
N = 8
effN = 2.2


1997 N males
N = 171
effN = 79.8
1998 N males
N = 379
effN = 82.6
1999 N males
N = 164
effN = 113.8
2000 N males
N = 982
effN = 126.2
2001 N males
N = 1198
effN = 157.3
2002 N males
N = 1496
effN = 111.6
2003 N males
N = 850
effN = 148.1
2004 N males
N = 208
effN = 60.7
2005 N males
N = 682
effN = 64.5
2006 N males
N = 824
effN = 45.5
2007 N males
N = 1294
effN = 34.9
2007 N males
N = 29
effN = 11.8
2008 N males
N = 1630
effN = 19.8
2009 N males
N = 2319
effN = 19.5
2010 N males
N = 2653
effN = 12.3


1997 N females
N = 295
effN = 36.2
1998 N females
N = 528
effN = 35.5
1999 N females
N = 261
effN = 46.6
2000 N females
N = 1346
effN = 101.7
2001 N females
N = 1446
effN = 61.7
2002 N females
N = 2496
effN = 67.2
2003 N females
N = 831
effN = 217.4
2004 N females
N = 399
effN = 97.2
2005 N females
N = 788
effN = 134.7
2006 N females
N = 1466
effN = 26
2007 N females
N = 1443
effN = 29.1
2007 N females
N = 50
effN = 32.4
2008 N females
N = 2942
effN = 26.9
2009 N females
N = 3969
effN = 32.8
2010 N females
N = 4491
effN = 40.3


1997 S males
N = 151
effN = 41
1998 S males
N = 568
effN = 89.9
1999 S males
N = 155
effN = 62.3
2000 S males
N = 845
effN = 296.1
2001 S males
N = 1057
effN = 53.3
2002 S males
N = 924
effN = 130.9
2003 S males
N = 628
effN = 369.7
2004 S males
N = 602
effN = 248.2
2005 S males
N = 604
effN = 151.2
2006 S males
N = 315
effN = 124.9
2007 S males
N = 843
effN = 440.6
2008 S males
N = 58
effN = 37.8
2009 S males
N = 30
effN = 36.1


1997 S females
N = 251
effN = 128.1
1998 S females
N = 795
effN = 260.2
1999 S females
N = 135
effN = 112.3
2000 S females
N = 1038
effN = 494
2001 S females
N = 1383
effN = 164.5
2002 S females
N = 1208
effN = 173.9
2003 S females
N = 825
effN = 433.5
2004 S females
N = 1037
effN = 123.4
2005 S females
N = 961
effN = 112.5
2006 S females
N = 602
effN = 324.1
2007 S females
N = 1191
effN = 198.3
2008 S females
N = 77
effN = 52.6
2009 S females
N = 23
effN = 11
2010 S females
N = 3
effN = 3.3

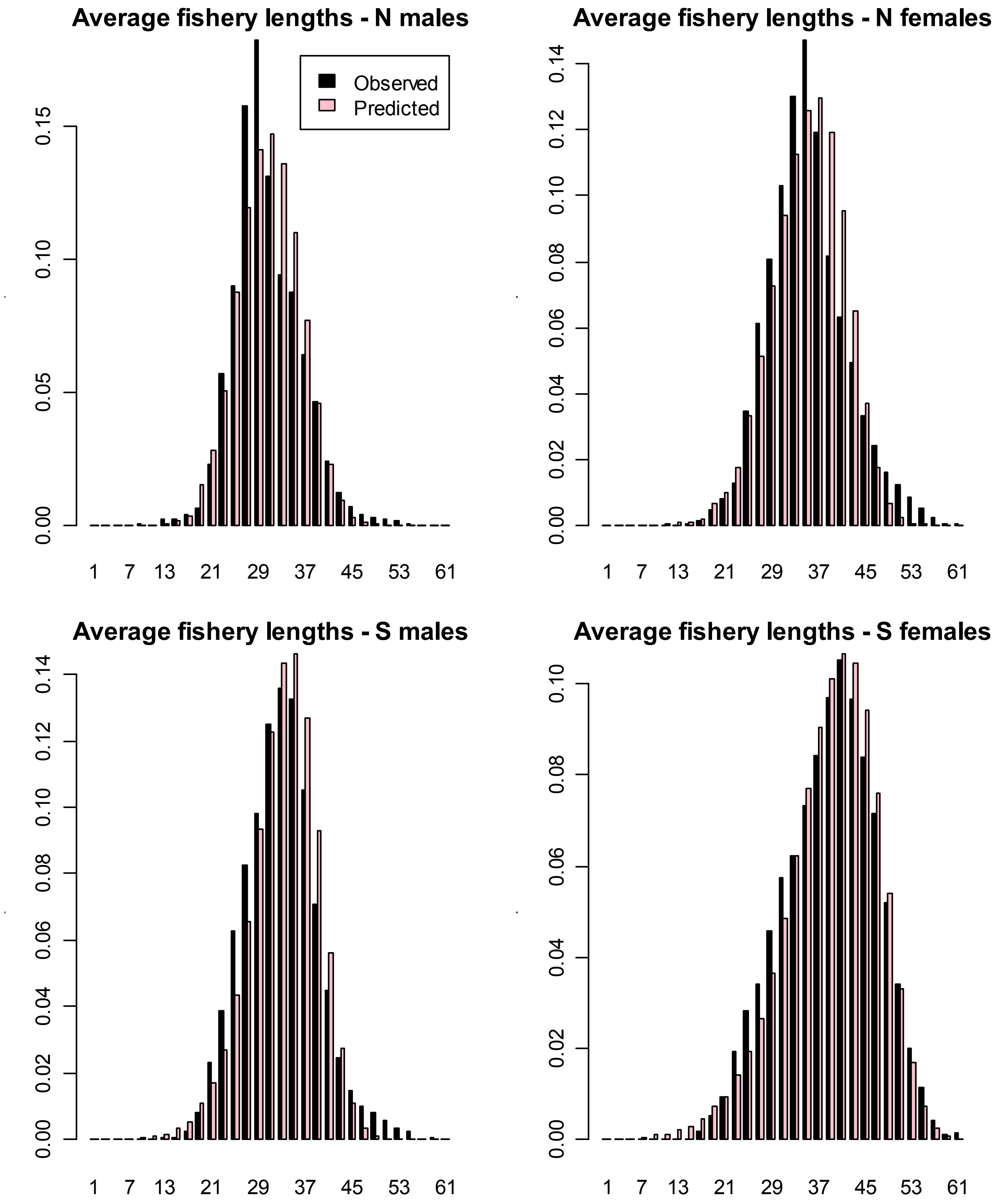


Figure 17 – Weighted average across years of observed and predicted fishery length distributions, by species and sex