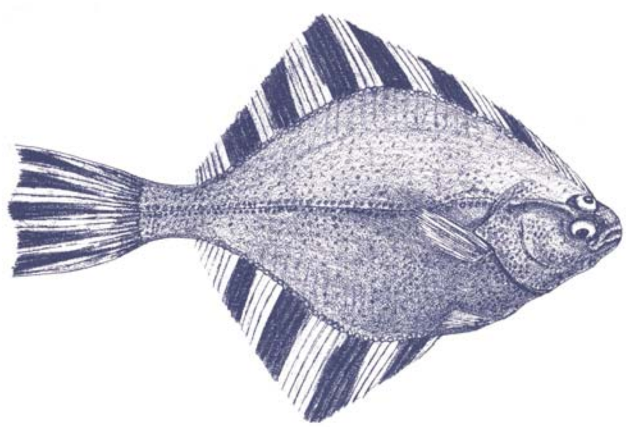
An Assessment of Starry Flounder

off California, Oregon, and Washington



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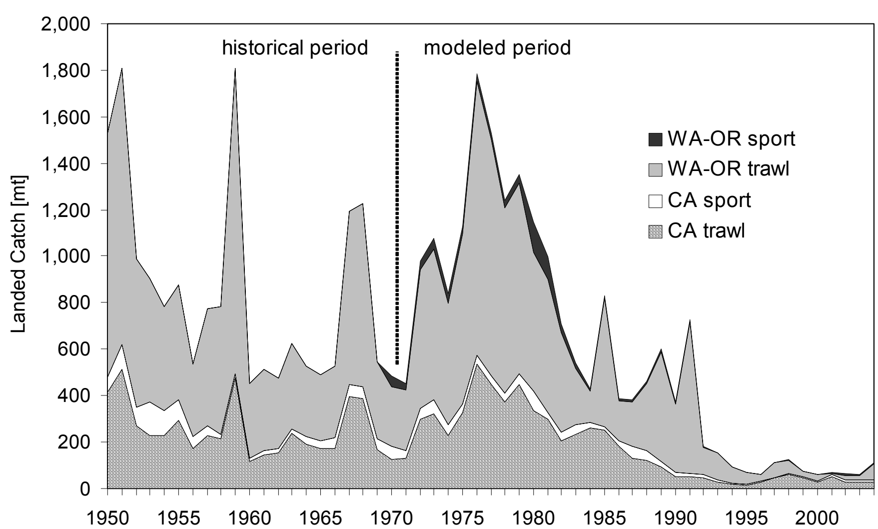
EXECUTIVE SUMMARY

Stock: This stock assessment pertains to the population of starry flounder (*Platichthys stellatus*) residing along the west coast of the United States, from Point Conception (lat. 34°30' N) to Cape Flattery (lat. 48°30' N). For the purpose of assessing the status of this stock, two models were developed, i.e., one for the southern area (California) and one for the northern area (Oregon and Washington). This distinction between northern and southern sub-populations was due to a difference in population trends in the two areas, as indicated by an analysis of commercial trawl logbook catch-per-unit-effort.

Catches: The fisheries for starry flounder, in both the northern and southern regions, were divided into trawl and sport components. Catches in the southern trawl fishery were obtained from published information for the period 1915-2004. Historical catches in the northern trawl fishery were estimated by ratio to English sole landings, with more recent landings from PACFIN. Southern sport landings were gathered from published sources and RECFIN data. Northern sport landings were estimated by ratio to southern catches and with RECFIN data.

Recent Starry Flounder Landings [mt]

	California		Washington-Oregon	
Year	Trawl	Sport	Trawl	Sport
1993	30.0	6.8	116.3	3.0
1994	17.3	3.8	71.3	0.0
1995	15.0	3.8	50.3	0.0
1996	27.8	3.0	30.8	0.0
1997	45.8	3.0	63.0	2.3
1998	61.5	6.0	53.3	3.0
1999	48.0	3.8	22.5	2.3
2000	28.5	5.3	25.5	0.0
2001	49.5	9.0	7.5	6.0
2002	30.0	5.3	18.8	11.3
2003	29.3	6.8	18.0	6.0
2004	29.3	6.8	72.0	6.0



Data and assessment: This is the first fishery evaluation of starry flounder and separate models were developed for the northern and southern areas (see above). For both analyses the statistical assessment model (SS2 version 1.18) was configured to estimate population characteristics for the period 1970-2004, with the initial state determined from historical catches in equilibrium with the modeled populations. Data used in the northern model included trawl landings, sport landings, and a fishery dependent CPUE statistic determined from analysis of commercial Oregon-Washington trawl logbook data. The southern model used similar information from California and, in addition, a pre-recruit survey of age-1 abundance collected by CDFG in the San Francisco Bay and Sacramento-San Joaquin River estuary. Recruitment deviations were estimated in both models, although selectivity patterns were fixed external to the model after analysis of trawl length composition information from the PACFIN-BDS data base and sport length composition information from the RECFIN data base. Growth and other life history parameters were also fixed, largely based on a detailed study of starry flounder by Orcutt (1950). Finally, spawner-recruit steepness (h = 0.80) and variability (σ_r = 1.00) were also held constant.

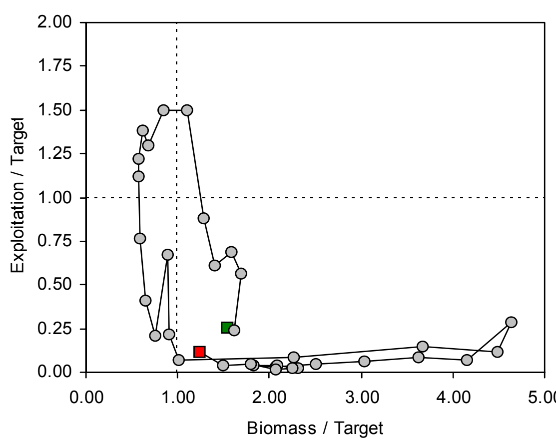
Unresolved problems and major uncertainties: One of the most significant areas of uncertainty in the starry flounder assessment was the estimate of natural mortality rate, which was quite high (0.30 yr^{-1} for females and 0.45 yr^{-1} for males). In addition, the length composition of commercial trawl landings was very poorly known, as was the discard rate (assumed to be 25% of the catch) and the occurrence of market-based retention by fishermen.

Reference points: The following reference points were obtained from the base models for the northern and southern areas:

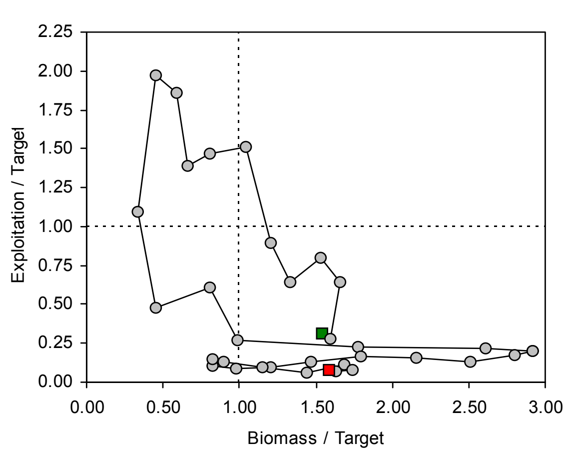
Biological Reference Points

Quantity	Northern	Southern
Unfished spawning biomass (SB_0)	4,824 mt	2334 mt
Unfished summary (age 2+) biomass (B_0)	12,102 mt	5854 mt
Unfished recruitment (R_0)	2,854 (age-0)	1,381 (age-0)
$SB_{40\%}$ (MSY proxy stock size = 0.4 × SB_0)	1,930 mt	934 mt
Exploitation rate at MSY (flatfish proxy $F_{40\%}$)	16.9%	16.9%
MSY ($F_{40\%}$ × 40% × B_0)	818 mt	396 mt

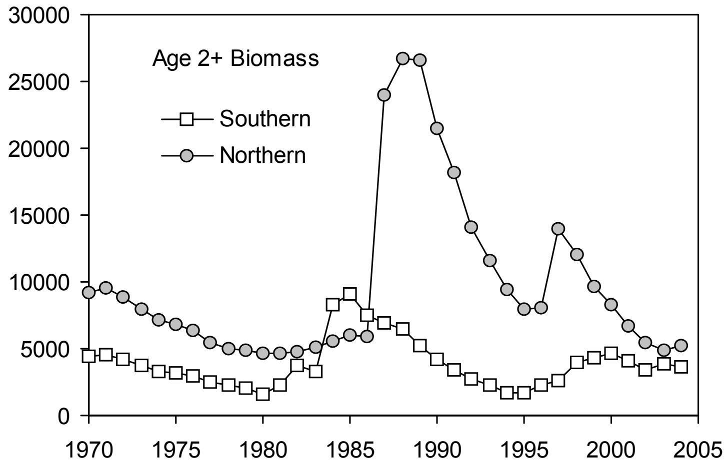
Northern (Washington-Oregon) Model

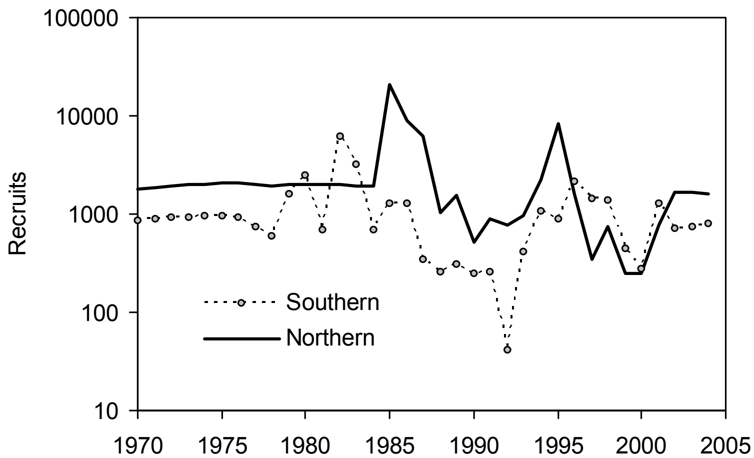


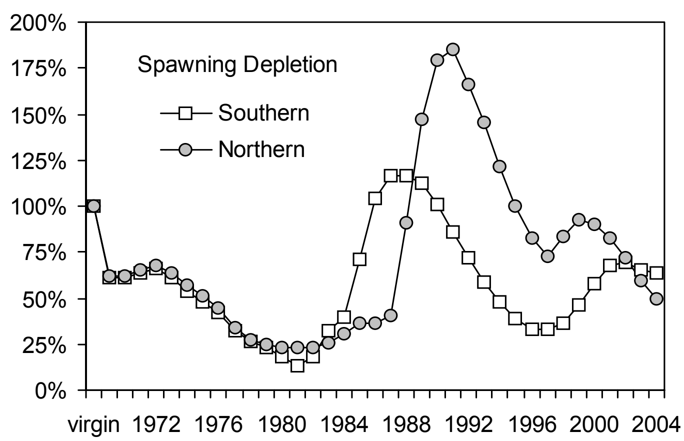
Southern (California) Model



Stock biomass: Biomass time series (summary biomass (age 2+), recruitment, and spawning depletion) for the northern and southern assessment models are shown below.







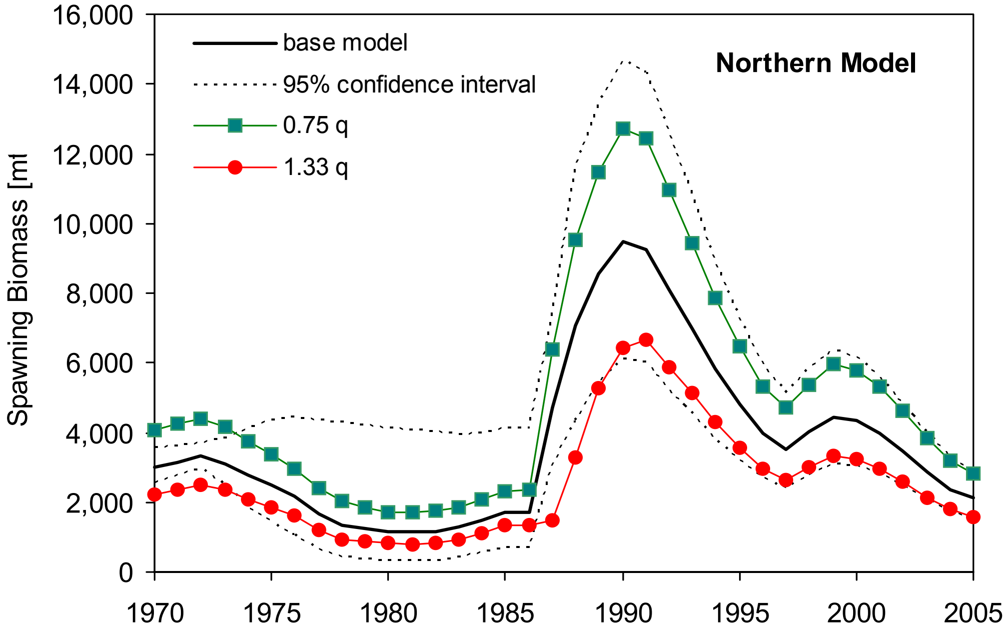
Time series of stock biomass, recruitment, and exploitation rates for the two area models are provided below. Note that discard was assumed to be 25% of total catch.

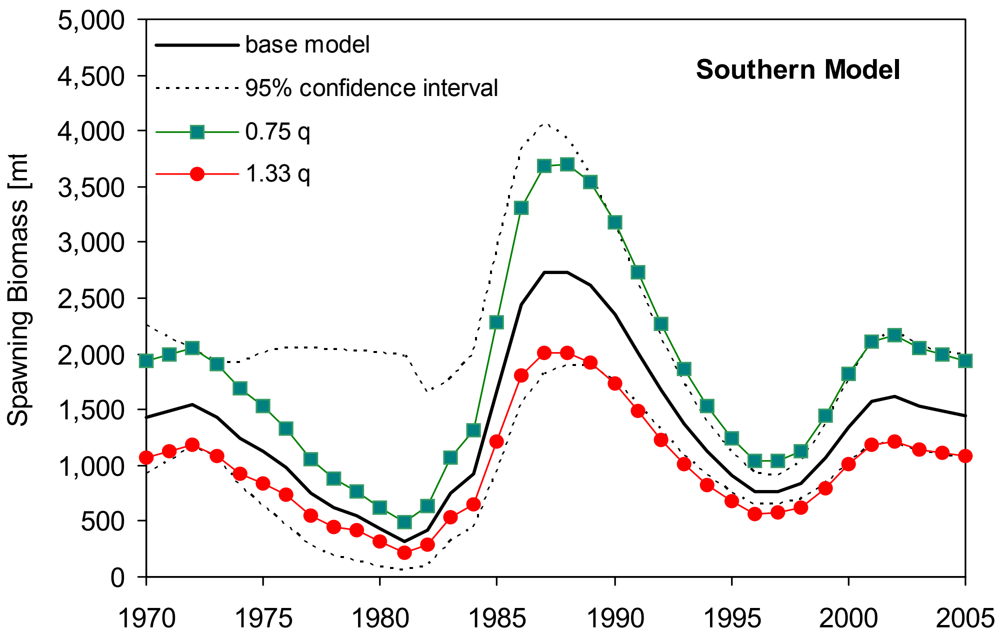
	Total Biomass	Age-2+ Biomass	Spawning Biomass	Age-0 Recruits	Trawl Catch	Trawl Exp. Rate	Sport Catch	Sport Exp. Rate	Stock Depletion
Southern Area (California) Model Results									
virgin	5,927	5,854	2,335	1,381	0	0.0%	0	0.0%	100%
1990	4,190	4,176	2,350	246	70	1.9%	24	0.7%	101%
1991	3,447	3,434	2,014	261	70	2.3%	19	0.6%	86%
1992	2,788	2,781	1,676	41	64	2.6%	14	0.6%	72%
1993	2,306	2,292	1,370	414	40	2.0%	9	0.5%	59%
1994	1,772	1,730	1,126	1,078	23	1.5%	5	0.3%	48%
1995	1,734	1,682	914	911	20	1.4%	5	0.3%	39%
1996	2,366	2,281	773	2,135	37	1.9%	4	0.2%	33%
1997	2,659	2,566	771	1,461	61	2.7%	4	0.2%	33%
1998	4,038	3,964	841	1,372	82	2.4%	8	0.2%	36%
1999	4,418	4,374	1,076	446	64	1.7%	5	0.1%	46%
2000	4,686	4,667	1,351	273	38	0.9%	7	0.2%	58%
2001	4,091	4,046	1,576	1,300	66	1.8%	12	0.3%	68%
2002	3,438	3,387	1,622	708	40	1.3%	7	0.2%	69%
2003	3,903	3,865	1,528	746	39	1.2%	9	0.3%	65%
2004	3,654	3,613	1,485	809	39	1.2%	9	0.3%	64%
2005	3,503	3,460	1,445	807	--	--	--	--	62%
Northern Area (Washington-Oregon) Model Results									
virgin	12,253	12,102	4,824	2,854	0	0.0%	0	0.0%	100%
1990	21,499	21,449	8,658	525	392	2.0%	13	0.1%	179%
1991	18,269	18,230	8,945	890	869	5.4%	10	0.1%	185%
1992	14,130	14,087	8,031	770	158	1.3%	7	0.1%	166%
1993	11,679	11,632	7,011	970	155	1.5%	4	0.0%	145%
1994	9,561	9,472	5,856	2,203	95	1.2%	0	0.0%	121%
1995	8,305	8,005	4,824	8,284	67	1.0%	0	0.0%	100%
1996	8,319	8,083	3,991	1,597	41	0.6%	0	0.0%	83%
1997	14,052	14,006	3,521	340	84	0.7%	3	0.0%	73%
1998	12,105	12,074	4,034	752	71	0.7%	4	0.0%	84%
1999	9,698	9,674	4,462	251	30	0.3%	3	0.0%	92%
2000	8,345	8,332	4,357	252	34	0.5%	0	0.0%	90%
2001	6,770	6,741	3,995	763	10	0.2%	8	0.1%	83%
2002	5,506	5,439	3,472	1,667	25	0.5%	15	0.3%	72%
2003	4,928	4,840	2,875	1,661	24	0.6%	8	0.2%	60%
2004	5,307	5,220	2,393	1,628	96	2.1%	8	0.2%	50%
2005	5,526	5,441	2,121	1,603	--	--	--	--	44%

Uncertainty in estimates of stock spawning biomass for the northern (Washington-Oregon) and southern (California) stock asssessment models.

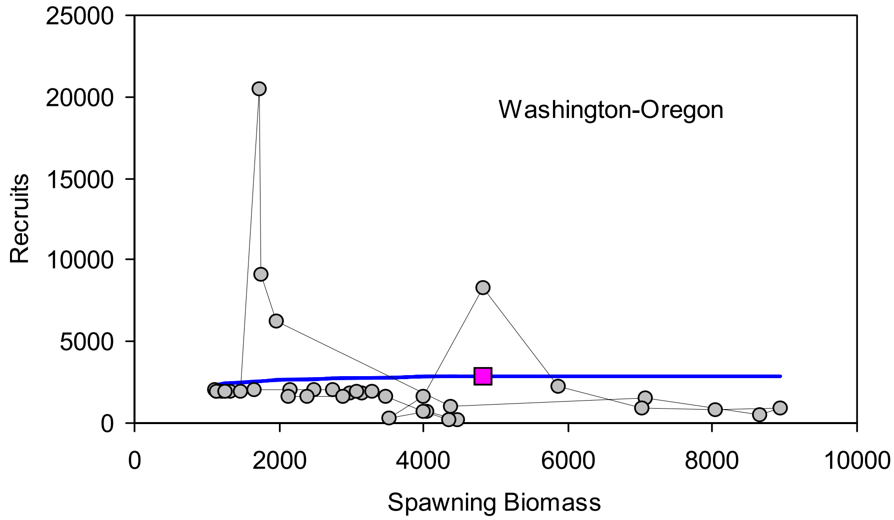
	Northern Area			Southern Area		
Year	Spawning Biomass	Standard Error	CV	Spawning Biomass	Standard Error	CV
1970	3,010	261	0.087	1,437	326	0.227
1971	3,159	218	0.069	1,492	272	0.182
1972	3,309	177	0.053	1,553	220	0.141
1973	3,102	326	0.105	1,433	212	0.148
1974	2,757	555	0.201	1,245	276	0.222
1975	2,497	709	0.284	1,124	333	0.296
1976	2,166	805	0.372	977	375	0.384
1977	1,664	851	0.512	751	402	0.535
1978	1,355	849	0.627	618	405	0.655
1979	1,237	830	0.671	548	399	0.728
1980	1,152	812	0.705	427	387	0.906
1981	1,143	806	0.706	317	363	1.148
1982	1,171	793	0.677	420	325	0.773
1983	1,293	779	0.602	751	338	0.451
1984	1,490	775	0.520	928	372	0.401
1985	1,711	789	0.461	1,659	480	0.289
1986	1,717	792	0.461	2,440	556	0.228
1987	4,740	1,045	0.220	2,725	553	0.203
1988	7,096	1,751	0.247	2,729	499	0.183
1989	8,536	1,944	0.228	2,615	422	0.161
1990	9,460	2,106	0.223	2,350	343	0.146
1991	9,270	2,046	0.221	2,014	269	0.134
1992	8,096	1,810	0.224	1,676	207	0.124
1993	6,985	1,530	0.219	1,370	157	0.114
1994	5,814	1,247	0.214	1,126	118	0.105
1995	4,791	998	0.208	915	88	0.097
1996	3,969	797	0.201	773	67	0.087
1997	3,506	670	0.191	771	66	0.085
1998	4,017	751	0.187	841	85	0.101
1999	4,442	805	0.181	1,076	133	0.124
2000	4,336	764	0.176	1,351	189	0.140
2001	3,976	682	0.171	1,577	231	0.146
2002	3,455	578	0.167	1,622	245	0.151
2003	2,861	470	0.164	1,528	232	0.152
2004	2,381	377	0.158	1,485	230	0.155
2005	2,112	329	0.156	1,445	231	0.160

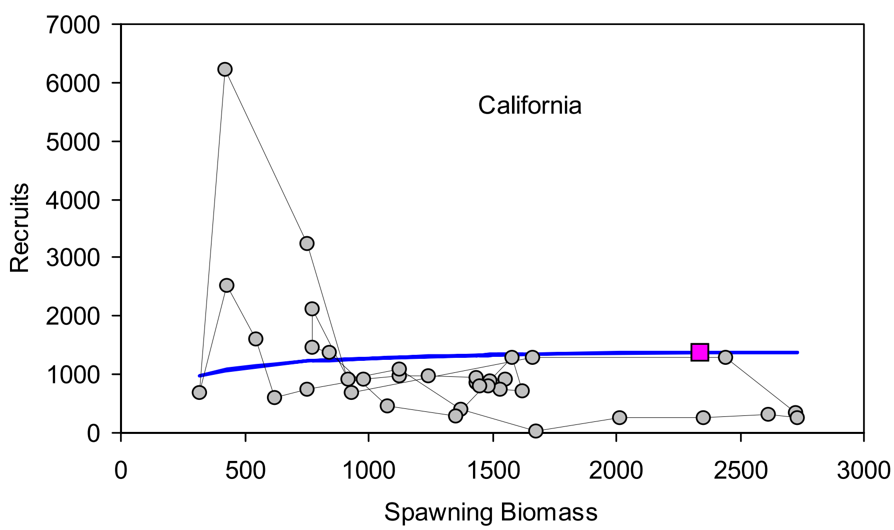
Uncertainty in model estimates of spawning biomass. The base model from each area is shown as black bold, bracketed by the 95% confidence interval calculated from the standard error of the estimate. To reflect uncertainty in stock size, trawl logbook CPUE catchability was perturbed to a degree consistent with the calculated confidence interval in 2005.





Recruitment: In the assessments, recruitment was modeled assuming a Beverton-Holt relationship, with steepness (***h***) fixed at a value of 0.80 and recruit variability (σ_r) fixed at 1.00. Recruitment deviations were estimated for the period 1970-2002 in the northern model and 1970-2003 in the southern model. The virgin recruitment parameter ($\ln[R_0]$) was the key estimated parameter in both assessments. Both stocks showed evidence of strong recruitment in the 1982-85 period, weak recruitment from the late 1980s into the early 1990s, and then strong recruitment in the mid 1990s.





Exploitation status: Both the northern and southern stocks are estimated to be well above the 40% of SB_0 precautionary threshold (44% of SB_0 in Washington-Oregon and 62% in California). In addition, recent exploitation rates have been well below the F_{msy} proxy for flatfish (see phase-plots under Reference Points above). Recent landings in both areas have been less than 20% of the calculated ABC based on harvesting at an $F_{40\%}$ rate.

Management performance: This is the first stock assessment of starry flounder on the U. S. west coast and the species has not been actively managed by the PFMC. Nearshore trawl closures adopted by the States of Washington and California many years ago have almost certainly led to substantial reductions in fishing impacts on starry flounder populations. Because southern (California) and northern (Washington-Oregon) areas display similar, but distinctive, trends in trawl logbook CPUE, an area-based management scheme may be desirable.

Forecasts: The northern and southern population assessments were projected forward under the default PFMC harvest policy (i.e., $F_{40\%}$ w/ 40:10 reduction). Results are presented below:

Northern Area		Biomass	Biomass		trawl	trawl	sport	sport
year	40:10	Age 2+	Spawning	Depletion	catch	harv. rate	catch	harv. rate
2005	1.00	5441	2121	44%	754.4	16.0%	155.9	3.3%
2006	0.95	4918	1693	35%	653.1	15.3%	135.0	3.1%
2007	0.89	4638	1464	30%	579.3	14.3%	120.0	2.9%
2008	0.86	5437	1351	28%	647.7	13.8%	134.4	2.8%
2009	0.87	5915	1395	29%	719.5	14.0%	149.2	2.9%
2010	0.90	6192	1501	31%	783.4	14.5%	162.3	3.0%
2011	0.93	6369	1591	33%	828.4	14.9%	171.6	3.1%
2012	0.94	6498	1655	34%	859.3	15.2%	178.0	3.1%
2013	0.95	6588	1697	35%	880.0	15.3%	182.2	3.1%
2014	0.96	6651	1724	36%	893.8	15.4%	185.1	3.2%
2015	0.96	6693	1743	36%	903.2	15.5%	187.0	3.2%
2016	0.97	6722	1755	36%	909.6	15.5%	188.4	3.2%
Southern Area		Biomass	Biomass		trawl	trawl	sport	sport
year	40:10	Age 2+	Spawning	Depletion	catch	harv. rate	catch	harv. rate
2005	1.00	3460	1445	62%	484.4	16.0%	99.9	3.3%
2006	1.00	2934	1143	49%	410.2	16.0%	84.7	3.3%
2007	1.00	2606	930	40%	363.6	16.0%	75.3	3.3%
2008	0.94	2873	788	34%	374.3	15.1%	77.7	3.1%
2009	0.92	3030	755	32%	388.8	14.8%	80.6	3.0%
2010	0.93	3117	777	33%	406.2	15.0%	84.1	3.1%
2011	0.95	3167	805	34%	419.6	15.2%	86.9	3.1%
2012	0.96	3203	826	35%	428.8	15.3%	88.8	3.1%
2013	0.96	3228	839	36%	434.9	15.4%	90.1	3.2%
2014	0.97	3245	847	36%	438.7	15.5%	90.9	3.2%
2015	0.97	3257	852	37%	441.2	15.5%	91.4	3.2%
2016	0.97	3265	856	37%	443.0	15.6%	91.7	3.2%

Decision table: Uncertainty in the stock assessments was measured by calculating the 95% confidence interval of spawning biomass in 2004. To capture this variability in the projection model, the catchability coefficient (***q***) from the trawl logbook CPUE time series was fixed and perturbed by ×0.75 and ×1.33 from the base model, representing high and low states of nature, respectively. Management action alternatives considered were: (1) harvesting using the recent 5-year average catch, (2) harvesting at the default $F_{40\%}$ w/ 40:10 reduction OY, and (3) harvesting at a level of catch intermediate between these two alternatives. Results are presented below.

Decision table for the northern starry flounder stock assessment model.

				State of Nature					
				1.33 q **Low Stock Size** less likely (p=0.33)		1.00 q **Base Model** more likely (p=0.35)		0.75 q **High Stock Size** less likely (p=0.32)	
Management Action	Year	Trawl Catch	Sport Catch	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
	2005	38	8	1592	39%	2112	44%	2811	47%
	2006	38	8	1581	39%	2063	43%	2711	46%
	2007	38	8	1643	41%	2109	43%	2737	46%
Low Catch	2008	38	8	1732	43%	2194	45%	2817	47%
	2009	38	8	1924	47%	2409	50%	3063	52%
(Average	2010	38	8	2185	54%	2710	56%	3419	58%
of last 5 yr)	2011	38	8	2454	61%	3023	62%	3793	64%
	2012	38	8	2707	67%	3318	68%	4145	70%
	2013	38	8	2930	72%	3578	74%	4456	75%
	2014	38	8	3119	77%	3798	78%	4717	79%
	2015	38	8	3277	81%	3980	82%	4933	83%
	2016	38	8	3406	84%	4129	85%	5109	86%
	2005	396	82	1592	39%	2112	44%	2811	47%
	2006	345	71	1399	35%	1876	39%	2520	42%
	2007	308	64	1324	33%	1783	37%	2405	41%
Medium Catch	2008	343	71	1311	32%	1766	36%	2383	40%
	2009	380	79	1414	35%	1892	39%	2540	43%
(Intermediate	2010	412	85	1573	39%	2093	43%	2798	47%
between low	2011	435	90	1729	43%	2296	47%	3063	52%
and high)	2012	450	93	1866	46%	2478	51%	3304	56%
	2013	461	95	1981	49%	2631	54%	3509	59%
	2014	468	97	2075	51%	2757	57%	3678	62%
	2015	473	98	2152	53%	2860	59%	3816	64%
	2016	476	99	2216	55%	2944	61%	3928	66%
	2005	754	156	1592	39%	2112	44%	2811	47%
	2006	652	135	1217	30%	1688	35%	2329	39%
	2007	579	120	1013	25%	1463	30%	2078	35%
High Catch	2008	649	135	910	22%	1353	28%	1960	33%
	2009	722	150	936	23%	1399	29%	2034	34%
(OY – $F_{40\%}$	2010	786	163	1000	25%	1506	31%	2198	37%
with 40:10	2011	832	172	1040	26%	1597	33%	2355	40%
adjustment)	2012	863	179	1054	26%	1662	34%	2482	42%
	2013	884	183	1054	26%	1704	35%	2580	43%
	2014	898	186	1046	26%	1732	36%	2653	45%
	2015	908	188	1034	26%	1751	36%	2710	46%
	2016	914	189	1020	25%	1763	36%	2754	46%

Decision table for the southern starry flounder stock assessment model.

				State of Nature					
				1.33 q **Low Stock Size** less likely (p=0.32)		1.00 q **Base Model** more likely (p=0.36)		0.75 q **High Stock Size** less likely (p=0.32)	
Management Action	Year	Trawl Catch	Sport Catch	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
	2005	44	9	1081	55%	1443	62%	1928	68%
	2006	44	9	1042	53%	1386	59%	1848	65%
	2007	44	9	1018	52%	1344	58%	1781	63%
Low Catch	2008	44	9	1007	51%	1314	56%	1727	61%
	2009	44	9	1055	54%	1357	58%	1761	62%
(Average	2010	44	9	1147	58%	1453	62%	1864	66%
of last 5 yr)	2011	44	9	1250	64%	1565	67%	1988	70%
	2012	44	9	1349	69%	1675	72%	2112	75%
	2013	44	9	1437	73%	1772	76%	2224	78%
	2014	44	9	1511	77%	1855	80%	2317	82%
	2015	44	9	1572	80%	1922	82%	2393	84%
	2016	44	9	1622	83%	1976	85%	2455	87%
	2005	264	54	1081	55%	1443	62%	1928	68%
	2006	227	47	921	47%	1264	54%	1725	61%
	2007	204	42	812	41%	1134	49%	1569	55%
Medium Catch	2008	209	43	743	38%	1046	45%	1455	51%
	2009	216	45	752	38%	1047	45%	1447	51%
(Intermediate	2010	225	46	804	41%	1105	47%	1511	53%
between low	2011	232	48	863	44%	1175	50%	1595	56%
and high)	2012	236	49	917	47%	1242	53%	1678	59%
	2013	239	49	962	49%	1299	56%	1751	62%
	2014	241	50	1000	51%	1347	58%	1811	64%
	2015	243	50	1031	53%	1385	59%	1858	66%
	2016	243	50	1056	54%	1415	61%	1897	67%
	2005	484	100	1081	55%	1443	62%	1928	68%
	2006	410	85	800	41%	1141	49%	1601	56%
	2007	363	75	611	31%	928	40%	1359	48%
High Catch	2008	374	78	493	25%	786	34%	1188	42%
	2009	388	80	471	24%	754	32%	1144	40%
(OY – $F_{40\%}$	2010	406	84	486	25%	775	33%	1173	41%
with 40:10	2011	419	87	498	25%	803	34%	1217	43%
adjustment)	2012	428	89	501	26%	824	35%	1257	44%
	2013	434	90	498	25%	838	36%	1289	45%
	2014	438	91	493	25%	846	36%	1312	46%
	2015	441	91	487	25%	851	36%	1329	47%
	2016	442	92	481	25%	855	37%	1342	47%

Research and data needs:

There are no discard data available for starry flounder, nor are there meaningful data regarding the size and/or age composition of trawl landings. These are high priority data needs for the next starry flounder stock assessment. In addition, because the existing NOAA Fisheries trawl survey does not extend into water shallow enough to catch this species, it is important to start a fishery-independent estimate of abundance . Updating Orcutt's (1950) life history parameters would also be desirable, especially obtaining accurate estimates of variation in length-at-age..

INTRODUCTION

Starry flounder, *Platichthys stellatus* [Pallas], is a member of the family Pleuronectidae, which contains the “right-eyed” flounders. Members of this flatfish family are distinctive in possessing: (1) monomorphic optic chiasmae, (2) ribs, (3) one or two post-cleithra on each side, (4) pre-operculae with free margins, and (5) eyes normally on right side of the head (Orcutt 1950). Nonetheless, although most individual starry flounder are right-eyed, a large proportion of individuals are left-eyed (Kramer *et al*. 1995). Perhaps the most characteristic visual feature of this species is the distinctive light-dark bars that occur on both the dorsal and anal fins (see title page illustration). In addition, the skin of larger specimens is rough and possesses numerous small tubercles that make it somewhat difficult to fillet. Nonetheless, it is considered to be highly regarded as a food fish and is an important recreational species in some areas. Some of the common names applied to this species in the literature and among fishermen are: starry flounder, rough jacket, diamond flounder, English sole, sole, and swamp flounder (Orcutt 1950). Starry flounder, however, is the official common name accepted by the American Fisheries Society (Bailey *et al*. 1970).

Starry flounder have a very broad geographic distribution around the rim of the north Pacific Ocean. In the eastern Pacific it has been recorded from Los Angeles to the Aleutian Islands, although it is rare south of Point Conception (Orcutt 1950, Kramer *et al*. 1995). In the western Pacific it ranges south, from the Bering Sea past the Kamchatka Peninsula and Sea of Okhotsk, and into the Sea of Japan off Korea. Off the west coast of the United States it is found commonly in nearshore waters, especially in the vicinity of estuaries. It has a quite shallow bathymetric distribution, with most individuals occurring in waters less than 80 m, although specimens have been collected off the continental shelf in excess of 350 m (Orcutt 1950, Kramer *et al*. 1995).

This species is found on gravel, clean shifting sand, hard stable sand, and mud substrata, but fishermen report the largest catches over soft sand. Prey from mud (sternapsid worms) and sand (*Siliqua patula* clams) habitats have been observed in the stomach of a single individual, suggesting fish move freely from one habitat type to another (Orcutt 1950). Starry flounder also consume crabs, shrimps, worms, clams and clam siphons, other small mollusks, small fishes, nemertean worms, and brittle stars (Hart 1973).

From a habitat perspective starry flounder is remarkable in its tolerance to low salinity conditions, i.e., it is a euryhaline species that is capable of tolerating a wide range of salinities. The species has been collected 75 miles upstream in the Columbia River and in the Sacramento and San Joaquin Rivers starry flounder have been observed in salinities of 0.02-0.06 ppt, i.e., essentially freshwater (Orcutt 1950). Most these specimens were immature fish that apparently were rearing in the “estuary.” Young starry flounder are a common species in estuarine habitats along the west coast (see Orcutt 1950, Sopher 1974, Pearson 1989, NOAA 1991, Baxter et al. 1999, and Kimmerer 2002).

Most starry flounder that have grown to a size that is vulnerable to capture in commercial and recreational fisheries are in the 11-15" range and are under 1.5 kg (3 lb) in weight, although specimens as large as 37", weighing 9 kg (20 lb) have been observed. Young fish (age 0-2) are sometimes found in the intertidal zone within estuaries.

Spawning occurs primarily during the winter months of December and January, at least in central California, according to Orcutt (1950), who observed females with fully ripe eggs (900-940 µm diameter) only during those months. Spawning may occur somewhat later in the year (Feburary-April) off British Columbia and Washington (Hart 1973, Love 1996). Based on larval rearing studies, Orcutt (1950) was able to show that 4-d larvae are 3.5 mm long and have used up their yolk reserves, entering the critical period when feeding is required for further survival and development. The smallest metamorphosed specimen that Orcutt (1950) observed, which had settled to the bottom of Elkhorn Slough, Monterey County, was 10.5 mm and was collected in mid-March. Thus, egg/larval development apparently takes about 2-3 months to occur. Settled young-of-the-year (age-0) are found principally in estuaries, as are the age-1 fish (Orcutt 1950, Baxter *et al*. 1999, Kimmerer 2002). Based on a detailed series of monthly seine samples, Orcutt (1950) was able to show that starry flounder are 110 mm in length by the anniversary of their birth. By age-2 many fish have migrated to into ocean habitats adjacent to their natal estuaries. Reproductive maturity occurs at age-2 yr for males and age-3 yr for females, when the fish are ~28 cm and ~35 cm, respectively. Adults appear to move seasonally into shallow water to spawn, perhaps in proximity to estuaries to take advantage of estuarine flows that would advect fertilized eggs near the bottom into nursery areas.

There is little information on regional variation in stock structure. Tagging studies have shown that fish are relatively sedentary and move little during their adult lives (Love 1996). Orcutt (1950) and Hart (1973) noted that, over the entire geographic range of starry flounder from the Korean Peninsula to Point Conception, there are gradients in the incidence of sinistral (left-handed) individuals. Specifically, nearly all starry flounder in Japan are sinistral, whereas in Alaska 67% of fish display that characteristic. On the U. S. west coast the incidence of left-handed fish drops to 50-60%. However, whether this character is genetically or environmentally determined is unknown. Lacking any biological evidence of distinct geographical heterogeneity that could be construed to be an important determinant of stock structure (e.g., genetic, growth, or natural mortality), I assumed that starry flounder on the U. S. west coast are all members of a common breeding population with similar biological characteristics.

DATA

Life History Parameters

A comprehensive study of the life history of starry flounder (*Platichthys stellatus*) was completed by Orcutt (1950) in the Monterey Bay region during the period 1946-49. His research covered a wide range of subjects, including: (1) systematics, (2) distribution and habitat, (3) commercial catch, (4) habits, (5) feeding and food, (6) parasites, (7) spawning, (8) embryological and larval development, (9) age determination, (10) rate of growth, (11) age and size at first maturity, (12) sexual dimorphism, (13) geographic variations, and (14) hybridization. Of particular importance to this assessment was his research on age determination, rate of growth, and maturation.

Orcutt's (1950) measured the Standard Length (SL) in millimeters of his specimens, but allowed that because "regulations of a fishery are usually based upon total length, a measure more readily accepted by fishermen" there was a need to develop a conversion for measurements. He therefore provided results showing that "the standard length of this species was found to be 81.95 percent of its total length and displayed no appreciable variation in different size groups." Thus, to convert his measurements from SL [mm] to TL [cm] I used the following equation: $TL = 0.12203 \times SL$. He also provided data on the sex-specific relationship between SL and weight [gm], which I re-analyzed. Together it was possible to conduct an analysis to estimate length-weight parameters for starry flounder, i.e., $Wt = \alpha TL^{\beta}$, where Wt is weight in [kg]. The data for males and females were fit separately after log-log transformation. Sex-specific regressions were compared in ANCOVAs and, based on assumed homogeneity in slope and intercept, were found to not be statistically different ($P=0.224$ for differences in slope, $P=0.224$ for differences in adjusted means). Consequently the data were pooled and a single length-weight relationship developed for both sexes (Figure 1), with bias-corrected parameters estimates as follows: $\alpha = 1.474 \times 10^{-5}$ and $\beta = 2.973$.

Orcutt (1950) studied spawning seasonality of starry flounder in Monterey Bay by noting ripe, spawning, and spent fish in his samples, as well as by studying of histological preparations of maturing ova from ovaries taken throughout the year. He found that "the height of spawning season in Monterey Bay was reached during the winter months of December and January but early spawners are found in November and late spawners in February."

In his study scales were validated as an effective aging stucture by: (1) determining larval growth rate in laboratory rearing experiments, (2) identifying the size of age-1 fish in a frequency distribution plot of commercial length samples taken in November-January, (3) confirming through marginal increment analysis that the scale annulus (slow growth, narrow circuli) formed during November-December, (4) following the growth of the 1946 cohort from settlement as age-0 fish in March through 18 months of life, and (5) back-calculation of growth using scale annual increment data. His results showed convincingly that 3-d old larvae are 3.2 mm long, settlement occurs about 2 months later in March at a size of 26 mm SL, fish 1-yr old are ~110 mm SL, and ~210 mm SL by age 2.

I used Orcutt's (1950) pooled results to estimate growth curves for male and female starry flounder. To do this, I first converted his SL measurements to TL measurements (see above) and then used the Schnute (1981) parameterization of the von Bertalanffy growth equation (i.e., estimate L_1 and L_2 at ages $\tau_1 = 2$ yr and $\tau_2 = 6$ yr and the growth coefficient K). Results are presented in Table 1 and Figure 2.

In addition to information presented in Orcutt (1950), unvalidated age estimates were obtained from specimens of starry flounder collected in Monterey Bay from 2001-2004 (Don Pearson, NOAA Fisheries, SWFSC, Santa Cruz, CA, pers. comm.). These data were also fit to a von Bertalanffy growth curve, the residuals determined, and the CV of length at age summarized. Results show (Figure 3) that variation in length at age is approximately 10% of mean age throughout the lifespan.

Estimates of maturity and fecundity are also available in Orcutt (1950). In particular, for both sexes he tabulated the number of immature and mature fish by age class, which I used in conjunction with the growth model (see above), to calculate the proportion mature as a function of TL [cm]. Results show (Figure 4) that male flounder mature at a smaller (younger) size than do females. In his original data, 95% of 2-yr old males were mature, whereas no females were. When considered on a length basis, females are 50% mature at a size of 36.9 cm TL.

With respect to fecundity, Orcutt (1950) states, that "*Platichthys stellatus* spawns but once a year at a definite and relatively short season" and that "evidence of spawning taking place but once a year was found while sampling for growth studies. These samples revealed that recently metamorphosed fish occur only in the months of March, April, and May." Moreover, he makes the isolated statement that "The number of eggs spawned at a season by a fish 565 mm SL with and ovary 262 mm long was determined to be about 11,000,000 by counting a gram of eggs and multiplying the number by the combined weight of both ovaries." Using his length-weight data it is possible to show that the weight-specific fecundity of this single female fish was ~2,500 egg/gm, which is considerable. However, because no other information on fecundity was presented, I have assumed in the stock assessment model that the egg output of the spawning stock is proportional to female spawning biomass.

Natural mortality rate (M) is an important parameter in any age-structured stock assessment. I estimated sex-specific values of M for starry flounder in several ways, using the life history data described above. These estimates were primarily based upon application of sex-specific life history invariants for pleuronectiform fishes reported by Beverton (1992). In particular, I was able to estimate the following quantities for starry flounder using information provided in Orcutt (1950), i.e., the von Bertalanffy growth coefficient (K), length at maturity (L_{mat}), age at maturity (T_{mat}), maximum asymptotic length (L_∞), and the ratio L_{mat} / L_∞ (Table 2). Moreover, Beverton (1992) reported the relationship between L_{mat}/L_∞, T_{mat}/T_{max}, $M{\cdot}T_{max}$, and $K{\cdot}T_{max}$, by sex, for flounders. Thus, it was possible to estimate starry flounder T_{max} in two different ways (see Table 2). Those estimates (♂: 5-6 yr, ♀: 7-9 yr) are quite consistent with the maximum ages of starry flounder reported by Orcutt (1950), i.e., (♂: 5 yr, ♀: 7 yr). Given estimates of maximum age (T_{max}), it was possible to estimate M using the regression equation approach of Hoenig (1983) and using Beverton's $M{\cdot}T_{max}$ pleuronectiform invariant. Thus, for each sex, I calculated four estimates of M, which ranged 0.69-0.83 yr^{-1} for males and 0.44-0.58 yr^{-1} for females. I then averaged these estimates, resulting in 0.76 yr^{-1} for males and 0.51 yr^{-1} for females.

Based on these considerations, the stock assessment model was initially configured with the female instantaneous natural mortality rate fixed at 0.50 yr^{-1} and male natural mortality fixed at 0.75 yr^{-1} (see above). However, this was a topic that the Stock Assessment Review Panel devoted considerable attention to in their evaluation. In particular, the Panel requested a variety of supplementary analyses, which were completed (see Appendix A) and, based on those results, recommended that female and male natural mortality rates in the base model be reduced to $M_♀$ = 0.30 yr^{-1} and $M_♂$ = 0.45 yr^{-1}. These changes were adopted in all further model runs.

Landings

A variety of information sources were consulted in attempting to develop comprehensive time series of starry flounder catch statistics. The primary source of information regarding commercial landings was the PACFIN data base, for which annual statistics are available starting in 1981. Preliminary examination of data from PACFIN indicated that trawl gear is the only significant source of commercial flounder catch. However, due to differences in trawl logbook CPUE statistics from northern and southern areas (see discussion below), PACFIN landings from the States of Washington and Oregon were combined to represent a "northern" trawl fishery (WA-OR trawl), whereas California trawl landings were kept separate to represent a "southern" trawl fishery[1].

Next, it was possible to extend the California trawl landings time series to earlier years by summarizing digital fish ticket data provided by the California Department of Fish & Game for the years 1969-80 (Don Pearson, NOAA Fisheries, SWFSC, Santa Cruz, CA, pers. comm.). Because arrowtooth flounder catches were very small during this period, the sum of the "unspecified flounder" and "starry flounder" market categories was used, which agreed with PACFIN results from the early 1980s. Moreover, data presented in Heimann and Carlisle (1970) provide estimates of starry flounder landings in California during the period 1916-68. Thus, using these three sources of information, it was possible to assemble a time series of California trawl landings from 1916-2004, which is presented in Figure 5.

In order to develop a time series of landings from the WA-OR trawl fishery, for years earlier than 1981, it was assumed that the development of the nearshore flatfish fishery off the west coast of the United States could be understood by examining regional patterns of English sole catches. Specifically, although significant trawl catches of nearshore flatfish species (both English sole and starry flounder) were evident before World War II off California (Figure 5), the fishery to the north did not develop until the onset of the war (Figure 6). Reconstructed landings from the English sole fishery (Ian Stewart, NOAA Fisheries, NWFSC, Seattle, WA, pers. comm.) indicate that at that time landings in the northern fishery expanded rapidly, reaching ~5 times the southern area catch by 1945. Subsequently northern catches declined, relative to southern catches, and ultimately stabilized at a value roughly twice that of the south. I assumed that starry flounder trawl catches off the States of Washington and Oregon followed an identical pattern as that depicted for English sole and I estimated northern landings by the product of the north-south English sole catch ratio (Figure 6) and California trawl landings of starry flounder (Figure 5). To test the validity of this approach, I compared predicted catches for the northern area with observed catches for the period 1981-1997. This evaluation showed no bias in the estimated values. Finally, the full composite time series of northern trawl landings showed that the reconstructed catches (i.e., pre-1981) are consistent with more recent PACFIN data (Figure 7).

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[1]During the STAR panel meeting it was discovered that the PACFIN trawl landings data from the State of Washington that were initially incorporated into the model were in error, i.e., they included Puget Sound catches. The error was subsequently corrected.

The RECFIN data base was used to assemble recreational landings for the period 1980-2004 from both southern (CA) and northern (WA-OR) areas. Note that landings for the period 1990-92, when the MRFSS program went unfunded, were estimated by simple linear interpolation between RECFIN landings for 1989 and 1993.

Similar to the situation encountered in the commercial trawl fishery, results presented in an early CDFG Fish Bulletin (Young 1969) allowed a crude estimation of recreational catches of starry flounder in California prior to the existence of our current data gathering systems. Young (1969) reported Commercial Passenger Fishing Vessel (CPFV) landings of "miscellaneous flatfish" for the period 1947-67 and indicated that starry flounder comprised the most important constituent in the central and northern California fishery. Young also tabulated annual CPFV fishing effort [anglers $\cdot$ yr^{-1}] for 1960-67. Using Young's data, that time period can be used as a base period for developing a predictive relationship ($P < 0.05$) between CPFV effort and miscellaneous flatfish catch (Figure 8). Then, using total CPFV effort statistics presented in Oliphant (1979) and Oliphant *et al*. (1990), I estimated the catch of miscellaneous flatfish in the California CPFV fishery during the period 1967-86. Comparison (by ratio estimation *sensu* Cochran 1977) of these data with reported starry flounder landings in the RECFIN data base during the 1980-86 period, indicated that one miscellaneous flatfish in the CPFV fishery is equivalent to 2.23 kg of starry flounder in the recreational fishery. Finally, using this estimator I predicted California sport catches of starry flounder for the period 1947-79, which yielded a historical time series of landings that is generally consistent with observed RECFIN catches during more recent years (Figure 9).

Lastly, in order to develop a presumptive catch time series for the recreational fishery in the north (WA-OR) prior to 1980, I calculated the ratio of Washington-Oregon landings to California for the 1980-2003 time period using the available RECFIN data. That analysis showed that the northern catch of starry flounder in the sport fishery, over the last 2+ decades, is 85% of that in California (Figure 10). That ratio was then used to estimate recreational starry flounder catches in Washington and Oregon from 1970-79.

Results presented in Table 3 and Figure 11 show the complete set of landings data and reconstructions used in the stock assessment. Note that for the purpose of starting the stock assesment model, which began in 1970, I assumed historical landings for each fishery as follows: (a) CA trawl: 1916-69 average = 250 mt, (b) WA trawl: 1950-69 average = 557 mt, (c) CA sport: 1960-69 average = 35 mt, and (d) WA-OR sport: in ratio (85%) to CA sport = 30 mt.

<u>Length Compositions</u>

There is very little data available concerning the size of starry flounder that are harvested in west coast trawl fisheries. For example, in the entire PACFIN biological data system (BDS), there are only 297 length measurements. Consequently, I summarized those data into a frequency tabulation to establish a putative size composition that could be used to estimate selectivity in the trawl fishery. Results show (Figure 12) that starry flounder first appear in commercial trawl samples at a size of ~30 cm TL and they, apparently, are fully vulnerable by 35 cm TL, which is the mode of the length-frequency distribution. Given the limited size data, I assumed that the rising portion of the observed distribution could be use to estimate the parameters of an asymptotic, logistic selectivity curve (solid line in figure), which was fixed in the assessment model.

Although there were substantially more length data available from the RECFIN data set (N = 4,047), given that recreational landings represent only 6% of all landings from 1970-2004 and the RECFIN compositions showed little dynamic behavior, I saw little merit in summarizing the information on an annual basis. Instead, when pooled over years (like the commercial trawl data), results show that sport-caught starry flounder first become vulnerable to capture at a size of 20 cm TL and are apparently fully vulnerable by 30 cm TL (Figure 13). Thus, the implied selectivity of fish in the recreational fishery is shifted by ~5 cm to smaller sizes, relative to the trawl fishery. To estimate selectivity, I fit a logistic curve to the ascending portion of the distribution and fixed the selectivity parameters in the assessment model to those values.

Trawl Logbook CPUE

The PACFIN system contains information concerning groundfish trawling activity in a logbook database, which includes data from all three west coast states, i.e., Washington, Oregon, and California (WOC). For this assessment the logbook data, which are extensive (Table 4), were analyzed with the intent of producing an annual index of relative abundance. The procedure used in analyzing the data were: (1) evaluate the spatial distribution of all starry flounder reported in the logbook data and identify discrete "areas" of abundance, (2) subset the entire logbook database to only include areas producing appreciable catches of starry flounder, (3) calculate catch-per-unit-effort (CPUE = lbs/hr) for all tows conducted in valid areas (including zero catch tows), and (4) model annual trends in abundance (CPUE) using a "Δ-lognormal" Generalized Linear Model (GLM) (Stefánsson 1996).

To determine the spatial distribution of starry flounder, all tows associated with a positive catch were selected, which still amounted to thousands of hauls each year. The haul "set" latitude was then rounded to the nearest 0.5° and the set depth was rounded to the nearest 5 fathoms. Frequency tabulations of total catch by latitude and depth bins were calculated, which are shown in Figures 14 and 15. Results for California show that starry flounder occurs in discrete zones along the coast, particularly in the Gulf of the Farallons and Eureka areas. In Oregon and Washington the distribution is more continuous, with a higher proportion of the total logbook catch reported from Washington. With respect to depth distribution, starry flounder are found predominately shallower than 32 fathoms, where over 90% of the catch is taken.

These findings were then used to subset the data into latitudinal and depth strata where starry flounder were likely to be caught. In particular, only tows set in water shallower than 32 fathoms were included in the analysis of CPUE, and these were classfied into 3 depth bins (i.e., 0-15 fathom, 15-25 fathoms, and 25-32 fathoms). Similarly, only tows set in the Gulf of the Farallons (36.75°≤ lat ≤38.25°), Eureka (40.25°≤ lat ≤41.75°), Oregon (43.25°≤ lat ≤45.25°), and Washington "areas" (45.75°≤ lat ≤48.25°) were included. This classification defined four areas that each accounted for at least 5% of the total catch and excluded any single latitudinal bin accounting for less than 1% of the total catch (e.g., 45.5°N). In addition, tows with missing values for: (1) depth, (2) latitude, (3) tow duration, (4) year, (5) month, and (6) vessel identification number were removed.

This subset of data was used to define tows conducted in appropriate starry flounder habitat, whether fish were caught or not, i.e., the data were sparsed to include zero catch tows. To remove the influence of fishermen that rarely caught starry flounder, only vessels with at least 5 positive tows were included. Furthermore, the month of capture was collapsed into the four quarters of the year (January-March, April-June, July-September, and October-December). Lastly, CPUE was calculated as the ratio of adjusted pounds[2] caught to tow duration [lbs/hr].

Annual summary statistics showing the total number of valid tows and the proportion of valid tows that were positive for starry flounder, within each of the four designated areas, are presented in Table 5. Likewise, summary statistics by year and area of total starry flounder catch, effort, and catch-per-unit-effort (CPUE) are given in Table 6.

All GLMs conducted used the SAS (version 8.02) procedure GENMOD and incorporated 5 main effects (i.e., year, depth, season, fishing vessel, and area). Each was included as a factor in a discrete classification and CPUE was treated as the dependent variable. A problem that often led to lack of convergence in the GENMOD procedure, specifically when used to model the binomial part of the Δ-lognormal model, was due to imprecision in the parameter estimates of certain specific vessels. This occurred when estimating the probability of non-zero catch (P) for boats that only had positive catches (the logit transformation ($\ln[P/(1-P)]$) goes to infinity as P goes to one). However, those vessels were the exception, accounting for about 3% of all valid hauls. Consequently, they were excluded from the analysis, a filter that effectively required each vessel to report at least one negative tow.

Due to the importance of tow "area" on the analysis, a number of ways of spatially aggregating the data were evaluated. Specifically, a "State" model was considered, wherein results from the Gulf of the Farallons and Eureka areas were combined, yielding three strata (California, Oregon, and Washington). In addition, a "regional" model was considered that pooled the data from Oregon and Washington (North) to contrast with the information from California (South).

A variety of analyses were then conducted to evaluate the importance of year×area interactions and to develop a plausible way of accounting for them. When a significant interaction occurs between year and area effects, the fundamental statistical implication is that separate CPUE time series need to be developed for each area. This was accomplished in two different ways. Namely, the data were fit to a single model with year×area interaction, but with common vessel, season, and depth effects. Alternatively, the data were stratified by area and fit independently of one another. In either case, year- and area-specific estimates of CPUE can be obtained. Presented in Table 7 is a list of the Δ-lognormal GLMs that were completed.

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[2]At the review panel meeting it was discovered that not all valid catches of starry flounder had been included in the analysis, because positive starry flounder tows that were landed in the State of Washington were not accounted for. Subsequently, the missing records were included by aggregating catches reported in the '**apounds_wdfw**' field with values reported in the '**apounds**' the field. Thus, the final GLM analysis included all pertinent data.

Results in the table can assist in evaluating what is the "best" model to use in estimating the abundance of starry flounder. First, the table is divided into columns that pertain to the binomial part of the Δ-lognormal model (probability of a positive catch) and the lognormal part (the distribution of positive catches) (see Stefánsson 1996). For each "part" the number of parameters (K), the log-likelihood ($\ln[\mathcal{L}]$), and the sample size (N) is given. Also provided is the Bayesian Information Criterion (BIC), which attempts to measure the optimal balance between model parsimony and realism (Burnham and Anderson 2002). Specifically the BIC is calculated as:

$$BIC = -2 \cdot \log \mathcal{L}(\theta|\text{data}) + K \cdot \log(N)$$

While similar in many respects to the Akaike Information Criterion (AIC), the BIC requires a greater improvement in fit in order to add additional parameters when data sets are large (i.e., it penalizes the information content of large samples). For different models fit to the same data set, the lower the BIC the better the model, however it isn't possible to make valid comparisons of models fit to different data sets (i.e., different values of N).

Results in Table 7 are also organized by row into three groups. The first group (models 1a, 1b, 1c, and 1d), which are comparable to one another, shows that a State×Year model has the lowest BIC, relative to the null model (no location effect whatsoever), a non-interactive "area" based model, and a model with Region×Year interaction.

Next, to compare the State×Year interaction model to a model that treated each State as a separate, independent stock unit (Separate State in model group 2) the data were subsetted to insure comparability of the BIC statistic. Note that in so doing, the sample size fell from 47,735 tows to 41,945 tows for the binomial part and from 30,656 tows to 27,008 tows for the lognormal positive part. The reason for these sample size reductions is that more fishing vessels were included in the "interactive" analysis due to the presence of boats that straddled latitudinal boundaries. With the constraints that were imposed, i.e., at least 5 or more positive landings of starry flounder and at least one negative tow (see above) this effectively reduced the number of qualifying vessels when separate analyses were conducted by each area.

Results for model group 2 indicated that, depending on which component of the Δ distribution was considered (i.e., binomial or lognormal portions), either a "state" or "region" based analysis was preferred. Considering the general paucity of information available concerning starry flounder biology, of these two alternatives, I favored the more parsimonious choice and elected to describe starry flounder abundance patterns using a region-based model, wherein the U. S. west coast is divided into two regions, i.e., a southern region (California) and a northern region (Washington and Oregon). Given that modeling decision, the data were re-analyzed using the established criteria for subsetting these data (see above), which increased the total sample size to something intermediate between model groups 1 & 2 (model 3, Table 7).

Results for model 3 are presented in Table 8 and Figure 16. Note that the coefficient of variation (CV) for each estimate is based on a jackknife re-sampling routine that is the same as that used in Ralston and Dick (2003). Note also, that insufficient data were available during the early portion of the time series (1983-86) with which to estimate year effects in the northern region. The figure shows that trawl catch rates in the northern area have been higher than in the south. There is also more high-frequency variability in the results for WA-OR. Nonetheless, the two time series show positive co-variation (Figure 17). In particular, catch rates were generally high in the mid- to late-eighties, declined to a series of low values in the early- to mid-nineties, and then showed some tendency to increase thereafter. A notable discrepancy exists, however, for the last three years of the series (2001-2003), which were anomalously low in the north.

Age-1 Abundance Survey

In 1979 the Interagency Ecological Program (IEP) designed a plan to collect biological and physical data from San Francisco Bay and the Sacramento/San Joaquin River Estuary (Baxter *et al*. 1999). The plan has been largely implemented by the Bay-Delta Division of the California Department of Fish and Game (CDFG) with the objective of determining the effects of freshwater outflow from the delta on the abundance and distribution of marine and estuarine fishes, shrimps, and crabs. Sampling was initiated in 1980 at a multiplicity of sites throughout the Bay and delta, using a variety of sampling gears (beach seine, otter trawl, midwater trawl, and plankton net). Samples have typically been collected monthly and a continuous 25 year record is available through 2004.

One species that is encountered regularly in the otter trawl surveys is starry flounder (Baxter 1999). Consequently, a data request was made to CDFG to provide IEP catch statistics pertinent to that species, which subsequently supplied a summary of data in the form of an Excel spreadsheet (Kathryn Hieb, CDFG, Central Valley Bay-Delta Branch, Stockton, CA, pers comm.). In particular, based on monthly samples collected since 1980, they provided an annual catch statistic for age-0, age-1, and age-2+ starry flounder (Table 9, Figure 18). Assignment of age groups in the survey depends upon length and month of capture (Figure 19) and is consistent with the growth curve described previously (Orcutt 1950). Given the similarity, of trend among the three statistics, I used the age-1 time series as a pre-recruit index in the stock assessment model.

MODEL

Selection

A severe limitation was imposed on the stock assessment by the absence of any significant size or age composition information for the trawl fishery (see Figure 12), which has accounted for in excess of 94% of all landings since 1970 (Table 3). Given the restricted amount of data available to the assessment (i.e., life history information, landings statistics, trawl logbook CPUE, and the CDFG pre-recruit index), I attempted to build a model that, at a minimum, could utilize what information was available. The principal decision in selecting a model was in partitioning the logbook CPUE data into area, State, regional, and coastwide analyses (Table 7). A consideration of the BIC led to separate models being developed for California versus Washington-Oregon, even though abundance trends appear to be related coastwide (Figure 17). That decision was reinforced by the fact that the life history data were gathered exclusively in California (Orcutt 1950) and the pre-recruit survey was based on samples collected in the San Francisco Bay – Sacramento/San Joaquin River delta.

The development and selection of assessment models, therefore, was dictated purely by the availability of relevant information that could be included in the analysis. For the southern area that included landings, logbook CPUE, and the pre-recruit survey. In the northern area the data were restricted to landings and logbook CPUE. Life history, discard, and selectivity characteristics were not estimated in either model, but were assumed equal in both areas.

Description

The Stock Synthesis II program (SS2) was used to model the starry flounder stock (Methot and Taylor 2004, Methot 2005). In the model (see appended control file), I fixed the natural mortality rate to be 0.30 yr^{-1} for females and 0.45 yr^{-1} for males (see Appendix A). Likewise, I assigned two growth "morphs," one male and one female, with characteristics given by the parameter values listed in Table 1. Length variability at age was fixed at a CV of 10% at reference ages of 2 and 6 yr (Figure 3). Importantly, no attempt was made to estimate any growth parameters within the model. In addition, male and female length-weight parameters were assumed equal (Figure 1) and female maturity was fixed according to the schedule shown in Figure 4. Egg output of the stock was set equal to spawning biomass.

The model was configured to span the 1970-2004 time period, with earlier historical landings producing an equilibrium population structure. Given the long time series of relatively stable landings (see Figures 5, 7, and 9) this probably is a reasonable assumption. Landings values (Table 3) were inflated by an assumed fixed discard rate of 25% (catch = landings ÷ [1.00 - 0.25]), which is similar in average magnitude to English sole (Ian Stewart, NOAA Fisheries, NWFSC, Seattle, WA, pers. comm.). Inflated catch was then entered into the data file to account for all fishery removals (see appended data file). No information was available concerning starry flounder size retention and no effort was made to model that possibility.

Separate models were developed for each of the two areas (southern and northern), each with two fisheries (trawl=1 and recreational=2). In both models the spawner-recruit curve was of the Beverton-Holt variety, with steepness (h) fixed at a value of 0.80, based on results presented in Myers *et al*. (1999). $Ln(R_0)$ was estimated in phase 1 and is the key parameter estimated in the assessment. Moreover, the standard deviation of recruitments (σ_r) was fixed at a value of 1.00, based on interannual variability in the number of age-1 fish collected in IEP-CDFG surveys conducted in the San Francisco Bay area (Table 9). Recruitment deviations were estimated for the period 1970-2003 in the southern model and for the period 1970-2002 in the northern model[3]. Lastly, selectivity curves for both trawl and recreational fisheries were parameterized as asymptotic, logistic functions (Figure 20) with the inflection and slope fixed based on results presented in Figures 12 and 13. Identical selectivity curves were used in both the southern and northern models.

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[3]Initial modeling results presented at the stock assessment review estimated recruitment deviations for the 1979-2003 period in the southern model and 1985-2002 in the northern model, these time intervals having been selected based on years with available logbook and pre-recruit data. However, upon the advice of the panel, recruitment deviations were estimated starting in the first year of the model (1970).

Base-Run Results

Southern Area

Results of fitting the SS2 model to the southern area data, with the model configured as described above, are presented in Table 10 and Figures 21-27. Results in Table 10 provide the estimated time series from 1970 to 2005 for key model outputs, including total biomass (age 0+), summary/exploitable biomass (age 2+), female spawning biomass, age-0 recruits, trawl fishery catches (inflated from landings by a 25% discard factor), trawl fishery exploitation rate, sport fishery catch (also inflated), sport fishery exploitation rate, and overall stock depletion (current year spawning biomass ÷ virgin spawning biomass). Figures 21-27, respectively, summarize the following information: (1) fit of the model to the logbook CPUE data, (2) fit of the model to the age-1 pre-recruit survey, (3) the estimated spawner-recruit relationship, (4) time series of exploitation rates in the trawl and sport fisheries, (5) times series of age-2+ biomass and spawning depletion, (6) a phase plot of annual harvest rate and stock size relative to target values (i.e., $F_{40\%}$ and $B_{40\%}$), and (7) the time series of spawning biomass with associated statistical uncertainty obtained by delta method approximation using the Hessian and variance-covariance matrices (presented as normal and lognormal errors [see Burnham *et al*. 1987]).

The model fits to the two data sources relatively well. It is noteworthy that the marked increase in the logbook CPUE statistic from 1983-85 was preceded by the highest value in the pre-recruit time series (1982 year-class) and that increasing recruitment during the latter part of the 1990s (following the 1992 El Niño year-class) was associated with increasing logbook CPUE. Thus, there was a remarkable consistency between these two disparate data sources.

The model indicates that the stock had been significantly depleted by 1970 (62% of B_0), which is consistent with the long time series of substantial trawl landings off California (Figure 5). The stock declined during the 1970s, apparently due to a high exploitation rate in the trawl fishery, but recruitment from the huge 1982 year-class led to a rapid and dramatic increase in exploitable and spawning biomass, such that by 1987 spawning biomass was 17% greater than the unexploited level. Currently the stock is estimated to be above the target population level and exploitation rates are well below the $F_{40\%}$ value.

Northern Area

Comparable results for the northern area model are presented in Table 11 and Figures 28-33. Results for the Washington-Oregon model show that it did a reasonably good job of fitting the trawl logbook CPUE statistic, although there was no other data source with which to verify the trend. Like the southern area model, exploitation rates were quite high during the late 1970s, reaching in excess of 25% in the trawl fishery. The estimated population trajectory also shows the stock was significantly impacted by historical fisheries in 1970 (62% of B_0), was reduced to a level below the overfished threshold in 1980, but rebuilt to a population size substantially in excess of virgin conditions by 1990. Thus, there is a remarkable similarity in estimated population dynamics between the northern and southern models, in spite of complete independence of the data used to estimate model parameters.

Reference Points

The following reference points were obtained from the base models for the northern and southern areas:

Biological Reference Points

Quantity	Northern	Southern
Unfished spawning biomass (SB_0)	4,824 mt	2334 mt
Unfished summary (age 2+) biomass (B_0)	12,102 mt	5854 mt
Unfished recruitment (R_0)	2,854 (age-0)	1,381 (age-0)
$SB_{40\%}$ (MSY proxy stock size = 0.4 × SB_0)	1,930 mt	934 mt
Exploitation rate at MSY (flatfish proxy $F_{40\%}$)	16.9%	16.9%
MSY ($F_{40\%}$ × 40% × B_0)	818 mt	396 mt

Uncertainty and Sensitivity

Results presented in Table 12 provide the time series of spawning biomass, the standard error of the estimate, and the corresponding coefficient of variation (CV) for the northern and southern starry flounder stock assessment models. In the terminal year of the assessment model, i.e., 2005, the CV was 16% in both models. Uncertainty during the late 1970s and early 1980s was much greater, however, ranging as high as 70% and 114% in the northern and southern models, respectively. These data are also shown in Figure 34, which was used to develop a decision table analysis to capture the overall uncertainty in the stock assessment (see below).

A variety of sensitivity analyses were conducted, especially for the southern area model, and presented to the STAR Panel for consideration in the initial draft of the assessment. These included scanning (profiling) on: (1) the spawner-recruit steepness parameter ($\boldsymbol{h}$), (2) spawner-recruit residual variance parameter (σ_r), (3) natural mortality rate ($\boldsymbol{M}$), and (4) the virgin recruitment parameter ($\log_e[\boldsymbol{R_0}]$). Those sensitivity results were uniformly consistent with expectation (i.e., lower steepness, spawner-recruit variance, and natural mortality rate are associated with greater spawning biomass estimates). Those results are not presented here.

One of the advantages of the SS2 modeling environment (Methot and Taylor 2004, Methot 2005), which is constructed as an ADMB template file, is the ability to conduct MCMC analyses using the converged files. MCMC simulations were conducted for both the southern and northern starry flounder models and results were presented to the review panel for consideration. One problem with those results was that the trace never converged to a series with an autocorrelation correlation coefficient of less than 0.30, even after 10^7 draws and thinning at 10^4. Because of this, the panel chose not to utilize the MCMC results in expressing stock assessment uncertainty and they are not presented here.

Forecast

Stock projections for the California (southern) and Washington-Oregon (northern) models are presented in Table 13. In the table a 12 year forecast is presented that is based on harvesting the two sub-stocks at the Council's default harvest policy for flatfish (ABC based on $F_{40\%}$ harvest rate and OY based on a 40:10 precautionary adjustment to the ABC). Presented are:

(1) the 40:10 precautionary adjustment factor, (2) age-2+ biomass, (3) spawning biomass, (4) spawning depletion, (5) age-0 recruits obtained from the spawner-recruit curve, (6) the calculated trawl catch and exploitation rate, and (7) the calculated sport catch and exploitation rate. Note that forecasts were based on an allocation between sport and trawl fisheries determined by the ratio of the average catches from the two fisheries over the last five years (2000-2004), which was 83% trawl and 17% sport in the southern area, with an identical allocation in the northern area.

The forecast shows that under the existing PFMC harvest policy, substantially greater harvests are possible. For example, by 2016 the fisheries are forecasted to yield 535 mt in California and 1,098 mt in Washington and Oregon, compared with actual landings in 2004 equal to 36 mt and 78 mt, respectively (Table 3). This indicates that these stocks are currently greatly underutilized, although it must be clearly stated that the forecast is predicated on the inherent productivity of the stock that was assumed in the spawner-recruit relationship. Specifically, the spawner-recruit steepness parameter was fixed a $\boldsymbol{h} = 0.80$, which presumes relatively high productivity (Myers *et al*. 1999). Moreover, nearshore closures to trawling off the States of Washington and California would make it difficult, if not impossible, to achieve such landings.

Decision Table Analysis

The STAR panel elected to highlight variability in the estimate of spawning biomass in the terminal year of the model (SB_{2005}) as a means of depicting alternative states of nature in a decision table analysis. Results from the northern and southern models had shown (Table 12, Figure 34) that the CV of SB_{2005} was 16%. To construct a model that would reflect this level of statistical uncertainty, the catchability coefficient ($\boldsymbol{q}$) for the trawl logbook CPUE series was artificially perturbed and then fixed, such that the resulting estimate of SB_{2005} in the perturbed model deviated from the base model to a degree consistent with a CV of 16%. An evaluation of perturbations equal to ($0.75 \times \boldsymbol{q}$) and ($1.33 \times \boldsymbol{q}$) indicated that estimates of SB_{2005} were consistent with a CV of 16% (see Figure 34). Consequently, decision tables for the northern and southern starry flounder models were constructed based on states of nature defined by perturbations to trawl logbook $\boldsymbol{q}$ as shown in the table below:

Sub-stock	Model	perturbation	$\boldsymbol{q}$	log(likelihood)
North	low	1.33	0.00496	-72.711
North	base	1.00	0.00373	-72.644
North	high	0.75	0.00280	-72.763
South	low	1.33	0.00509	-63.834
South	base	1.00	0.00383	-63.708
South	high	0.75	0.00287	-63.815

When each of these 'fixed-q' alternatives was fitted to the data, estimates of SB_{2005} for the northern model were 1592 mt (low), 2112 mt (base), 2811 mt (high). For the southern model estimates of SB_{2005} were 1081 mt (low), 1443 mt (base), and 1928 mt (high). It is interesting to note the similarity of estimates of $\boldsymbol{q}$ from the two areas, which differ by less than 3%. This implies that a nominal unit of effort (trawl·hr) in the two areas has an equivalent proportional effect on stock. This may be due to an similar amount of starry flounder habitat in the two areas.

Note also that there was very little difference in total model likelihood among the three states of nature. To assign a probability to each of the three states for each sub-stock, differences in log-likelihood were calculated from the base model (i.e., base case = 0, high and low alternatives < 0), which were then antilogged (base model = 1.00), and the values normalized to sum to 1.00. For the northern model this resulted in P = 0.33_{low}, 0.35_{base}, and 0.32_{high}, whereas for the southern model results were P = 0.32_{low}, 0.36_{base}, and 0.32_{high}. From a qualitative perspective we can say that the base case is more likely and the alternatives less likely.

To define a range of possible management actions to apply to the 3 states of nature, the STAR panel recommended the following three alternatives: (1) conduct a 12 year forecast of stock dynamics assuming that annual catches in the trawl and sport fisheries were equal to their average values over the last five years [low catch scenario], (2) conduct the forecast using the estimated OY based on the PFMC's default $F_{40\%}$ w/ 40:10 reduction harvest policy [high catch scenario], and (3) conduct the forecast using catch levels intermediate between the high and low catch scenarios [medium catch scenario].

Results of the decision analysis for the southern area are presented in Table 14 and for the northern area in Table 15. In the table the estimated spawning biomass and spawning depletion is reported for each year of the forecast (2005-2016), state of nature, and management action. Results show that if harvests are maintained at their current "low" level the stocks are forecast to grow, which is due principally to the assumed value of spawner-recruit steepness ($\boldsymbol{h}$ = 0.8). If catches are "high" the two stocks should decline, and in the low stock size alternative, approach the overfished minimum stock size threshold by 2016. For the intermediate/medium catch scenarios, stock size is not estimated to change substantially from 2005 to 2016 in the southern area model, whereas modest growth of the stock would be expected to occur in the northern area model.

RESPONSE TO STAR PANEL REVIEW

During the course of reviewing the stock assessment, the STAR Panel made a number of requests for additional analysis. Several of these were simple clarifications of material presented in the draft assessment document. Others, however, were more substantial, and these are listed below with a point-by-point response to each:

Evaluate alternative estimates of natural mortality

The STAR Panel was uncomfortable with the initial estimates of natural mortality derived in Table 2, which were quite high (i.e., $M_{♀} = 0.50\ yr^{-1}$ and $M_{♂} = 0.75\ yr^{-1}$). As a consequence, a variety of alternative estimations were requested, which are summarized in Appendix A. Based on a discussion of these results, it was mutually decided to lower estimates of natural mortality to $M_{♀} = 0.30\ yr^{-1}$ and $M_{♂} = 0.45\ yr^{-1}$ in both the northern and southern assessment models.

Develop tables that show summary statistics of the trawl logbook data

In response to this request the logbook data were summarized to show, for each year and area, (a) the total number valid tows, (b) the number of tows positive for starry flounder, (c) the total catch of starry flounder, (d) the total valid trawling effort, and (e) the nominal catch-per-unit-effort based on the summary statistics. This request was satisfied and two new tables were added to the document (see Tables 5 and 6). As a result of this exercise, an error was discovered in the Δ-lognormal GLM analysis, due to the exclusion of positive hauls of starry flounder landed in Washington ports. This error was detected and corrected during the review.

Display measures of uncertainty based on the Hessian approximation

The initial draft of the stock assessment document contained a variety of sensitivity analyses, including scans of the effect of natural mortality ($\boldsymbol{M}$), steepness ($\boldsymbol{h}$), and spawner-recruit variability (σ_r) on model fit and estimates of ending biomass and depletion. In addition, preliminary results of MCMC integration were presented. However, for the purpose of expressing uncertainty in the starry flounder stock assessment, the panel found it sufficient to present estimates of the coefficient of variation (CV) of spawning biomass resulting from the Hessian approximation (i.e., the delta method). Those results were summarized in Table 12 and are shown graphically in Figures 27, 33, and 34. Initial parameter sensitivity and MCMC results were excluded from the final stock assessment document.

Evaluate the effect of assuming the stock was in equilibrium in 1970

The Panel requested that an analysis be conducted to ascertain the effect of starting the southern base model in 1970 with the population assumed to be in equilibrium with historical catches equal to 333 mt and 47 mt from the trawl and recreational sectors, respectively. To accomplish this the Panel requested that the base model be compared with a model that started in 1915 with no historical catch, but with annual catches from 1915-1969 equal to 333 mt and 47 mt. Results showed (Figure 35) that assuming the population was in equilibrium with historical catches of this of this magnitude had a detectable but minor influence (8%) on population estimates between 1970-75, but that by the ending year of the model there was no appreciable difference in estimates of either exploitable biomass (i.e., both models within 0.5% of each other) or spawning depletion (both models equal to 61%). Note that this analysis was conducted prior to lowering female and male natural mortality rates (see above).

ACKNOWLEDGMENTS

I would like to thank Rick Methot and, especially, Ian Stewart for their assistance in learning how to use the SS2 model. Also, discussions with other flatfish panel analysts, including Han-Lin Lai and Melissa Haltuch, were considerable assistance to me in framing my approach to this assessment. EJ Dick was helpful in processing the trawl logbook CPUE data through the Δ-lognormal GLM analyses and I thank Kathryn Hieb for providing me the CDFG-IEP pre-recruit survey data. Lastly, the STAR panelists (David Sampson, Jim Ianelli, Bob Mohn, Jon Volstad, Pete Leipzig, Michele Culver, and Brian Culver) were all constructive in their comments and I appreciate their thoughtful comments.

LITERATURE CITED

Bailey, R. M., J. E. Fitch, E. S. Herald, E. A Lachner, C. C Lindsey, C. R. Robins, and W. B. Scott. 1970. A List of Common and Scientific Names of Fishes from the United States and Canada. Amer. Fish. Soc., Spec. Publ. No. 6, Washington, DC, 150 p.

Baxter, R. 1999. Pleuronectiformes, pp. 369-415. In: Report on the 1980-1995 fish, shrimp, and crab sampling in the San Francisco Estuary, California. Interagency Ecological Program for the Sacramento-San Joaquin Estuary, Technical Report 63, California Department of Fish and Game, Stockton, CA, 503 p.

Baxter, R., K. Hieb, S. DeLeón, K. Fleming, and J. Orsi. 1999. Report on the 1980-1995 fish, shrimp, and crab sampling in the San Francisco Estuary, California. Interagency Ecological Program for the Sacramento-San Joaquin Estuary, Technical Report 63, California Department of Fish and Game, Stockton, CA, 503 p.

Beverton, R. J. H. 1992. Patterns of reproductive strategy parameters in some marine teleost fishes. J. Fish Biol. 41(Suppl. B):137-160.

Burnham, K. P., and D. R. Anderson. 2002. Model Selection and Multimodel Inference – a practical information-theoretic approach, 2nd edition. Springer, New York, 488 p.

Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, and K. H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release recapture. Amer. Fish. Soc. Monograph 5, 437 p.

CDFG. 1992. Estuary dependent species. Exhibit entered by the California Department of Fish and Game, State Water Resources Control Board, Water Quality/Water Rights Proceed. San Francisco Bay/Sacramento-San Joaquin Delta, WRINT-DFG Exhibit 6.

Cochran, W. G. 1977. Sampling Techniques. John Wiley & Sons, New York, 428 p.

Hart, J. L. 1973. Pacific Fishes of Canada. Fish. Res. Bd. Canada, Bull. 180, 740 p.

Heimann, R. F.G., and J. G. Carlisle, Jr. 1970. The California marine fish catch for 1968 and historical review 1916-68. Calif. Dept. Fish and Game Fish Bull. No. 149, 70 p.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82(1):898-903.

Jones, R. 1987. An investigation of length composition analysis using simulated length compositions, pp. 217-238. In: D. Pauly and G. R. Morgan (eds.), Length-Based Methods in Fisheries Research, ICLARM Conference Proceedings 13, International Center for Living Aquatic Resource Management, Manila, Philippines, and Kuwait Institute for Scientific Research, Safat, Kuwait.

Kimmerer, W. J. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? Mar. Ecol. Prog. Ser. 243:39-55.

Kramer, D. E., W. H. Barss, B. C. Paust, and B. E. Bracken. 1995. Guide to Northeast Pacific Flatfishes – Families Bothidae, Cynoglossidae, and Pleuronectidae. Sea Grant Marine Advisory Bulletin No. 47, 104 p.

Love, M. 1996. Probably more than you want to know about the fishes of the Pacific coast. Really Big Press, Santa Barbara, CA, 381 p.

Methot, R. D. 2005. User Manual for SS2 – Model Version 1.10, February 6th, 2005, NOAA Fisheries, Seattle, WA.

Methot, R. D., and I. G. Taylor. 2004. Technical Description of the Stock Synthesis II Assessment Program. DRAFT: October 11, 2004, 28 p.

Myers, R. A., K. G. Bowen, and N. J. Barrowman. 1999. Maximum reproductive rate of fish at low population sizes. Can. J. Fish. Aquat. Sci. 56:2404-2419.

NOAA. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries, Vol II: species life history summaries, pp. 266-270. In: NOAA's Estuarine Living Marine Resources Program, U. S. Dept. Comm., National Oceanic and Atmospheric Administration, National Ocean Service.

Oliphant, M. S. 1979. California marine fish landings for 1976. Calif. Dept. Fish and Game Fish Bull. No. 170, 56 p.

Oliphant, M. S., P. A. Gregory, B. J. Ingle, and R. Madrid. 1990. California marine fish landings for 1977-1986. Calif. Dept. Fish and Game Fish Bull. No. 173, 52 p.

Orcutt, H. G. 1950. The life history of the starry flounder *Platichthys stellatus* (Pallas). Calif. Dept. Fish and Game Fish Bull. No. 78, 64 p.

Pearson, D. E. 1989. Survey of fishes and water properties of South San Francisco Bay, California, 1973-82. NOAA Tech. Rep. NMFS 78, U. S. Dept. Comm., 21 p.

Ralston, S., and E. J. Dick. 2003. The status of black rockfish (*Sebastes melanops*) off Oregon and Northern California in 2003, 70 p. In: Status of the Pacific Coast Groundfish Fishery Through 2003, Stock Assessment and Fishery Evaluation, Volume 1. Pacific Fishery Management Council, Portland, OR.

Schnute, J. 1981. A versatile growth model with statistically stable parameters. Can. J. Fish. Aquat. Sci. 38:1128-1140.

Sopher, T. R. 1974. A trawl survey of the fishes of Arcata Bay, California. MS Thesis, Humboldt State University, 103 p.

Stefánsson, G. 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. ICES J. Mar. Sci. 53:577-588.

Young, P. H. 1969. The California partyboat fishery 1947-1967. Calif. Dept. Fish and Game Fish Bull. No. 145, 91 p.

Table 1. Estimates of von Bertalanffy growth parameters for male and female starry flounder based on an analysis of information reported in Orcutt (1950). Statistical estimates are based on back-calculated length-at-age data, which are similar to observed lengths at age.

Sex	Parameter	Estimate
male	L_1 (age 2 yr)	27.0 cm
	L_2 (age 6 yr)	49.7 cm
	K	0.426 yr^{-1}
female	L_1 (age 2 yr)	27.6 cm
	L_2 (age 6 yr)	59.1 cm
	K	0.251 yr^{-1}

Table 2. Life history parameters, pleuronectiform invariants, and estimates of natural mortality for starry flounder.

Parameter	Units	Male	Female	Source
		"Measured" Quantities		
K	[yr^{-1}]	0.426	0.251	based on Orcutt (1950)
L_{mat}	[cm TL]	22.6	36.9	based on Orcutt (1950)
T_{mat}	[yr]	1.71	2.83	based on Orcutt (1950)
L_∞	[cm TL]	54.8	77.3	based on Orcutt (1950)
L_{mat} / L_∞	[ ]	0.41	0.48	based on Orcutt (1950)
		Pleuronectid Life History Invariants		
L_{mat} / L_∞	[ ]	0.47	0.52	Table I – Beverton (1992)
T_{mat} / T_{max}	[ ]	0.28	0.39	Table I – Beverton (1992)
$M \cdot T_{max}$	[ ]	4.5	4.0	Table II – Beverton (1992)
$K \cdot T_{max}$	[ ]	2.3	2.3	Figure 7 – Beverton (1992)
		"Derived" Quantities		
T_{max1}	[yr]	6.11	7.26	$T_{mat} \div (T_{mat}/T_{max})$
M_{Hoe1}	[yr^{-1}]	**0.69**	**0.58**	fish regression – Hoenig (1983)
M_{Bev1}	[yr^{-1}]	**0.74**	**0.55**	$(M \cdot T_{max}) \div T_{max1}$
T_{max2}	[yr]	5.4	9.2	$(K \cdot T_{max}) \div K$
M_{Hoe2}	[yr^{-1}]	**0.78**	**0.46**	fish regression – Hoenig (1983)
M_{Bev2}	[yr^{-1}]	**0.83**	**0.44**	$(M \cdot T_{max}) \div T_{max2}$
M	[yr^{-1}]	0.76	0.51	average

Table 3. West coast landings [mt] of starry flounder used in the stock assessment.

Year	CA trawl	CA sport	WA-OR trawl	WA-OR sport
1916	205.9		0.0	
1917	522.5		0.0	
1918	371.4		0.0	
1919	197.6		0.0	
1920	218.4		0.0	
1921	133.2		0.0	
1922	244.6		0.0	
1923	230.9		0.0	
1924	172.3		0.0	
1925	269.6		0.0	
1926	302.9		0.0	
1927	267.7		0.0	
1928	181.4		0.0	
1929	263.4		0.1	
1930	177.4		0.1	
1931	77.0		0.1	
1932	246.7		0.3	
1933	207.7		0.3	
1934	243.7		0.6	
1935	297.6		2.2	
1936	281.8		28.7	
1937	442.2		99.1	
1938	246.2		102.9	
1939	335.3		230.3	
1940	364.7		503.6	
1941	272.9		559.0	
1942	167.9		461.3	
1943	229.2		822.8	
1944	166.3		819.5	
1945	153.1		610.0	
1946	231.1		791.2	
1947	239.1	29.0	725.1	
1948	183.8	36.8	507.0	
1949	161.7	47.1	399.4	
1950	414.5	65.6	1,051.2	
1951	512.1	109.2	1,189.5	
1952	271.0	79.5	637.5	
1953	227.9	144.5	532.6	
1954	227.0	107.9	447.7	
1955	294.9	87.2	496.5	
1956	170.3	53.3	314.3	
1957	228.8	43.2	503.1	
1958	213.7	20.6	548.9	
1959	474.9	17.3	1,318.1	
1960	117.5	13.0	323.1	
1961	143.0	20.8	348.9	
1962	153.4	20.0	300.8	
1963	236.5	17.8	369.4	
1964	191.0	32.2	302.4	
1965	171.6	35.1	281.8	
1966	172.7	45.1	306.8	

Table 3 (continued).

Year	CA trawl	CA sport	WA-OR trawl	WA-OR sport
1967	395.0	54.1	743.8	
1968	388.4	51.8	787.2	
1969	169.9	45.4	328.2	
1970	126.0	54.8	256.5	47.3
1971	129.0	35.3	260.3	30.0
1972	299.3	44.3	597.8	37.5
1973	324.0	56.3	649.5	48.0
1974	228.0	46.5	523.5	39.8
1975	324.8	38.3	732.8	32.3
1976	536.3	36.0	1,181.3	30.8
1977	449.3	33.8	1,019.3	28.5
1978	373.5	36.0	799.5	30.8
1979	448.5	43.5	822.0	36.8
1980	336.0	84.0	598.5	128.3
1981	297.0	29.3	573.8	96.8
1982	204.8	38.3	429.8	36.8
1983	234.8	38.3	245.3	21.8
1984	260.3	24.0	133.5	12.8
1985	252.8	14.3	552.8	11.3
1986	181.5	24.8	170.3	9.0
1987	128.3	51.8	194.3	8.3
1988	120.0	42.0	291.8	8.3
1989	93.0	21.8	474.8	12.0
1990	52.5	18.0	294.0	9.8
1991	52.5	14.3	651.8	7.5
1992	48.0	10.5	118.5	5.3
1993	30.0	6.8	116.3	3.0
1994	17.3	3.8	71.3	0.0
1995	15.0	3.8	50.3	0.0
1996	27.8	3.0	30.8	0.0
1997	45.8	3.0	63.0	2.3
1998	61.5	6.0	53.3	3.0
1999	48.0	3.8	22.5	2.3
2000	28.5	5.3	25.5	0.0
2001	49.5	9.0	7.5	6.0
2002	30.0	5.3	18.8	11.3
2003	29.3	6.8	18.0	6.0
2004	29.3	6.8	72.0	6.0

Table 4. Trawl logbook files used in calculation of CPUE statistic.

Year	Filename	Date	Time	Filesize
1981	lbk_81_051304.sas7bdat	5/13/2004	1:44 PM	24,446 KB
1982	lbk_82_051304.sas7bdat	5/13/2004	1:47 PM	25,314 KB
1983	lbk_83_051304.sas7bdat	5/13/2004	2:06 PM	22,414 KB
1984	lbk_84_051304.sas7bdat	5/13/2004	2:08 PM	17,958 KB
1985	lbk_85_051304.sas7bdat	5/13/2004	2:28 PM	20,825 KB
1986	lbk_86_051304.sas7bdat	5/13/2004	2:30 PM	19,482 KB
1987	lbk_87_082004.sas7bdat	9/15/2004	11:45 AM	51,316 KB
1988	lbk_88_082004.sas7bdat	9/15/2004	11:45 AM	56,886 KB
1989	lbk_89_082004.sas7bdat	9/15/2004	11:45 AM	67,683 KB
1990	lbk_90_082004.sas7bdat	9/15/2004	11:45 AM	52,446 KB
1991	lbk_91_082004.sas7bdat	9/15/2004	11:45 AM	66,258 KB
1992	lbk_92_082004.sas7bdat	9/15/2004	11:45 AM	62,473 KB
1993	lbk_93_082004.sas7bdat	9/15/2004	11:45 AM	67,290 KB
1994	lbk_94_082004.sas7bdat	9/15/2004	11:45 AM	52,315 KB
1995	lbk_95_082004.sas7bdat	9/15/2004	11:45 AM	54,658 KB
1996	lbk_96_082004.sas7bdat	9/15/2004	11:45 AM	59,704 KB
1997	lbk_97_082004.sas7bdat	9/15/2004	11:45 AM	61,720 KB
1998	lbk_98_082004.sas7bdat	9/15/2004	11:45 AM	52,119 KB
1999	lbk_99_082004.sas7bdat	9/15/2004	11:45 AM	47,351 KB
2000	lbk_00_082004.sas7bdat	9/15/2004	11:45 AM	36,079 KB
2001	lbk_01_090304.sas7bdat	9/03/2004	8:42 AM	35,276 KB
2002	lbk_02_083104.sas7bdat	9/15/2004	11:45 AM	31,671 KB
2003	lbk_03_083104.sas7bdat	9/15/2004	11:45 AM	29,312 KB

Table 5. Summary of valid tows obtained from the west coast trawl logbook data base, meeting the criteria established for designating effort conducted in starry flounder habitat. Data compiled by year and area (EUR = Eureka, FAR = Gulf of Farallones, ORE = Oregon, WSH = Washington). See text for further description.

	Tows					Proportion (+)			
Year	EUR	FAR	ORE	WSH	Total	EUR	FAR	ORE	WSH
1983	218	30			248	0.495	0.267		
1984	334	10			344	0.689	0.200		
1985	616	61			677	0.726	0.820		
1986	549	541			1,090	0.641	0.593		
1987	42	622	451	2,686	3,801	0.500	0.738	0.639	0.561
1988	572	993	249	1,993	3,807	0.549	0.688	0.627	0.667
1989	7	528	516	2,488	3,539	0.286	0.661	0.812	0.667
1990	10	791	568	1,853	3,222	0.000	0.681	0.748	0.630
1991	4	713	1,026	2,615	4,358	0.000	0.718	0.724	0.719
1992	2	1,367	593	1,504	3,466	0.500	0.698	0.669	0.623
1993	55	1,933	814	1,341	4,143	0.600	0.403	0.736	0.601
1994	243	1,508	540	1,301	3,592	0.506	0.485	0.696	0.633
1995	198	903	67	1,060	2,228	0.606	0.537	0.851	0.612
1996	382	1,214	165	539	2,300	0.754	0.609	0.697	0.672
1997	505	2,194	419	608	3,726	0.804	0.740	0.759	0.648
1998	430	1,648	299	498	2,875	0.947	0.732	0.789	0.675
1999	198	1,391	214	512	2,315	0.909	0.746	0.813	0.689
2000	57	1,169	75	351	1,652	0.684	0.675	0.720	0.695
2001	335	1,308	114	286	2,043	0.848	0.740	0.772	0.675
2002	164	1,578	80	727	2,549	0.738	0.474	0.675	0.640
2003	69	1,188	85	518	1,860	0.609	0.746	0.471	0.573
Total	4,990	21,690	6,275	20,880	53,835				

Table 6. Summary of catch, effort, and raw CPUE from valid tows obtained from the west coast trawl logbook data base, meeting established criteria. Data summarized by year and area (EUR = Eureka, FAR = Gulf of Farallones, ORE = Oregon, WSH = Washington).

	Catch (lb)					Effort (hr)					CPUE (lb/hr)			
Year	EUR	FAR	ORE	WSH	Total	EUR	FAR	ORE	WSH	Total	EUR	FAR	ORE	WSH
1983	10,915	1,945			12,860	472	110			582	23.14	17.64		
1984	23,556	53			23,609	827	42			870	28.47	1.26		
1985	66,878	7,270			74,148	1,656	217			1,873	40.39	33.44		
1986	48,134	45,776			93,910	1,360	1,993			3,354	35.39	22.97		
1987	1,173	61,258	34,183	292,597	389,211	98	2,325	1,208	5,305	8,936	11.97	26.34	28.30	55.15
1988	27,911	89,798	16,416	473,266	607,391	1,241	2,571	683	3,833	8,329	22.48	34.93	24.04	123.46
1989	36	41,239	66,347	801,866	909,488	16	1,917	1,544	5,118	8,594	2.32	21.51	42.98	156.69
1990	0	32,927	23,155	467,125	523,207	11	2,488	1,612	3,461	7,571	0.00	13.24	14.36	134.98
1991	0	44,451	57,908	1,054,707	1,157,066	7	2,589	2,771	4,880	10,247	0.00	17.17	20.90	216.14
1992	76	38,516	16,491	148,122	203,205	3	4,564	1,343	2,759	8,669	24.52	8.44	12.28	53.69
1993	907	18,284	31,314	178,331	228,836	269	6,129	2,210	2,308	10,917	3.37	2.98	14.17	77.25
1994	3,442	14,916	21,640	112,565	152,563	637	4,670	1,118	2,232	8,657	5.40	3.19	19.36	50.43
1995	4,127	10,175	2,335	88,545	105,182	448	3,141	166	1,918	5,674	9.22	3.24	14.06	46.15
1996	13,098	19,511	4,031	44,540	81,180	913	4,228	379	738	6,257	14.35	4.62	10.64	60.39
1997	21,154	43,766	20,692	95,163	180,775	1,095	7,885	1,019	889	10,888	19.32	5.55	20.30	107.07
1998	34,629	58,739	17,822	75,147	186,337	1,042	6,797	849	706	9,395	33.22	8.64	20.98	106.44
1999	12,837	43,327	12,475	25,793	94,432	489	5,779	537	786	7,591	26.23	7.50	23.24	32.82
2000	2,733	35,357	1,978	48,463	88,531	156	4,581	185	445	5,366	17.56	7.72	10.67	108.95
2001	38,683	45,622	3,997	7,838	96,140	978	4,513	280	383	6,154	39.54	10.11	14.29	20.47
2002	8,741	37,808	3,446	31,746	81,741	302	5,452	233	1,073	7,060	28.94	6.93	14.81	29.58
2003	3,089	39,498	2,042	26,374	71,003	191	4,458	205	758	5,613	16.16	8.86	9.97	34.78
Total	322,119	730,236	336,272	3,972,188	5,360,815	12,212	76,451	16,342	37,592	142,596				

Table 7. Model evaluation and selection of the Δ-lognormal GLM model for estimating time series of abundance from the commercial trawl logbook data base. In addition to area and year effects described below, all models also included factors for season, depth, and vessel.

		Binomial				Positive (lognormal)			
Model	Description	K	ln(ℒ)	N	BIC	K	ln(ℒ)	N	BIC
1a.	Null (no area effect)	186	-26829	47,735	55662	187	-49230	30,656	100392
1b.	Areas (no interaction)	189	-26699	47,735	55434	190	-49156	30,656	100275
1c.	Region×Year Interaction	202	-26566	47,735	55307	203	-48674	30,656	99446
1d.	State×Year Interaction	219	-26465	47,735	**55289**	220	-48465	30,656	**99203**
2a.	Separate State	226	-22927	41,945	48259	229	-40531	27,008	**83398**
2b.	State×Year (subset data)	203	-23087	41,945	48335	204	-41933	27,008	85947
2c.	Separate Region (subset data)	197	-23063	41,945	**48224**	199	-40926	27,008	83883
3.	Separate Region (N-S)	203	-25518	46,011	53216	205	-45807	29,699	93726

Table 8. Year effects from Δ-lognormal GLM model applied to southern (California) and northern (Washington-Oregon) regions. Coefficients of variation (CV) obtained from jackknife re-sampling.

	South		North	
Year	CPUE	CV	CPUE	CV
1983	11.88	0.2936	–	–
1984	17.94	0.1438	–	–
1985	31.21	0.0832	–	–
1986	21.97	0.0848	–	–
1987	22.80	0.0761	73.92	0.1222
1988	24.14	0.0847	85.88	0.1133
1989	17.92	0.0975	101.31	0.0985
1990	11.65	0.0826	61.83	0.1211
1991	14.81	0.0788	82.28	0.1026
1992	9.78	0.0690	31.92	0.1157
1993	4.46	0.1349	37.93	0.1013
1994	4.97	0.1061	28.93	0.0909
1995	5.43	0.0973	24.34	0.0949
1996	7.69	0.0802	25.49	0.1118
1997	8.30	0.0548	45.21	0.1001
1998	13.76	0.0533	57.91	0.0914
1999	14.07	0.0498	19.71	0.1051
2000	13.35	0.0752	53.34	0.1151
2001	14.39	0.0587	18.19	0.1301
2002	11.50	0.1179	10.90	0.1135
2003	13.89	0.0702	14.00	0.1396

Table 9. Abundance statistics for starry flounder captured in IEP-CDFG monthly surveys conducted in San Francisco Bay and the Sacramento/San Joaquin River delta. The CV for the age-1 statistic is calculated from the annual standard error of the mean catch from monthly samples (February-October).

Year	age-0	age-1	CV	age-2
1980	13714	689	(0.203)	1625
1981	63	1434	(0.290)	1223
1982	5169	293	(0.260)	2299
1983	3250	4017	(0.170)	2916
1984	1128	1440	(0.275)	3604
1985	1204	291	(0.321)	1294
1986	1982	477	(0.182)	1218
1987	57	395	(0.298)	1282
1988	138	128	(0.274)	704
1989	239	73	(0.660)	323
1990	613	66	(0.471)	307
1991	378	107	(0.464)	479
1992	0	138	(0.330)	353
1993	263	0		96
1994	258	69	(0.756)	121
1995	3200	177	(0.496)	143
1996	2625	281	(0.465)	316
1997	3783	489	(0.272)	703
1998	3221	776	(0.261)	953
1999	1693	558	(0.194)	976
2000	70	156	(0.200)	323
2001	11	85	(0.366)	469
2002	528	20	(0.949)	177
2003	3845	278	(0.300)	281
2004	1345	294		

Table 10. Population trends from the base model for the southern area (California) starry flounder population.

	Total Biomass	Age-2+ Biomass	Spawning Biomass	Age-0 Recruits	Trawl Catch	Trawl Exp. Rate	Sport Catch	Sport Exp. Rate	Stock Depletion
virgin	5,927	5,854	2,335	1,381	0	0.0%	0	0.0%	100%
equilibrium	4,533	4,460	1,437	1,381	333	8.6%	47	1.2%	62%
1970	4,518	4,460	1,437	862	168	4.3%	73	1.9%	62%
1971	4,628	4,582	1,492	886	172	4.3%	47	1.2%	64%
1972	4,246	4,198	1,553	913	399	10.8%	59	1.6%	67%
1973	3,772	3,723	1,433	937	432	13.2%	75	2.3%	61%
1974	3,380	3,329	1,245	961	304	10.5%	62	2.1%	53%
1975	3,211	3,160	1,124	976	433	15.7%	51	1.8%	48%
1976	2,995	2,945	977	919	715	27.9%	48	1.9%	42%
1977	2,593	2,550	751	752	599	27.0%	45	2.0%	32%
1978	2,330	2,295	618	592	498	24.9%	48	2.4%	26%
1979	2,089	2,027	548	1,616	598	33.8%	58	3.2%	23%
1980	1,687	1,574	427	2,526	448	32.5%	112	8.0%	18%
1981	2,365	2,287	316	683	396	20.2%	39	1.9%	14%
1982	4,003	3,800	420	6,233	273	8.4%	51	1.5%	18%
1983	3,538	3,299	751	3,243	313	10.7%	51	1.7%	32%
1984	8,358	8,263	928	691	347	4.9%	32	0.4%	40%
1985	9,176	9,121	1,659	1,278	337	4.2%	19	0.2%	71%
1986	7,555	7,487	2,439	1,286	242	3.6%	33	0.5%	104%
1987	6,989	6,949	2,725	342	171	2.8%	69	1.1%	117%
1988	6,532	6,516	2,729	261	160	2.8%	56	1.0%	117%
1989	5,241	5,226	2,615	310	124	2.7%	29	0.6%	112%
1990	4,190	4,176	2,350	246	70	1.9%	24	0.7%	101%
1991	3,447	3,434	2,014	261	70	2.3%	19	0.6%	86%
1992	2,788	2,781	1,676	41	64	2.6%	14	0.6%	72%
1993	2,306	2,292	1,370	414	40	2.0%	9	0.5%	59%
1994	1,772	1,730	1,126	1,078	23	1.5%	5	0.3%	48%
1995	1,734	1,682	914	911	20	1.4%	5	0.3%	39%
1996	2,366	2,281	773	2,135	37	1.9%	4	0.2%	33%
1997	2,659	2,566	771	1,461	61	2.7%	4	0.2%	33%
1998	4,038	3,964	841	1,372	82	2.4%	8	0.2%	36%
1999	4,418	4,374	1,076	446	64	1.7%	5	0.1%	46%
2000	4,686	4,667	1,351	273	38	0.9%	7	0.2%	58%
2001	4,091	4,046	1,576	1,300	66	1.8%	12	0.3%	68%
2002	3,438	3,387	1,622	708	40	1.3%	7	0.2%	69%
2003	3,903	3,865	1,528	746	39	1.2%	9	0.3%	65%
2004	3,654	3,613	1,485	809	39	1.2%	9	0.3%	64%
2005	3,503	3,460	1,445	807	--	--	--	--	62%

Table 11. Population trends from the base model for the northern area (Washington-Oregon) starry flounder population.

	Total Biomass	Age-2+ Biomass	Spawning Biomass	Age-0 Recruits	Trawl Catch	Trawl Exp. Rate	Sport Catch	Sport Exp. Rate	Stock Depletion
virgin	12,253	12,102	4,824	2,854	0	0.0%	0	0.0%	100%
equilibrium	9,395	9,244	2,986	2,854	742	9.2%	40	0.5%	62%
1970	9,363	9,244	2,986	1,810	342	4.2%	63	0.8%	62%
1971	9,672	9,574	3,135	1,862	347	4.1%	40	0.5%	65%
1972	8,947	8,847	3,285	1,921	797	10.3%	50	0.6%	68%
1973	8,051	7,948	3,079	1,969	866	12.4%	64	0.9%	64%
1974	7,320	7,215	2,734	2,020	698	11.1%	53	0.8%	57%
1975	6,937	6,829	2,475	2,060	977	16.4%	43	0.7%	51%
1976	6,442	6,333	2,146	2,069	1,575	28.5%	41	0.7%	44%
1977	5,576	5,468	1,644	2,021	1,359	28.6%	38	0.8%	34%
1978	5,109	5,004	1,334	1,966	1,066	24.5%	41	0.9%	28%
1979	4,963	4,858	1,216	1,972	1,096	25.9%	49	1.1%	25%
1980	4,771	4,667	1,128	1,981	798	19.6%	171	4.2%	23%
1981	4,787	4,681	1,113	2,008	765	18.8%	129	3.1%	23%
1982	4,873	4,768	1,135	1,971	573	13.8%	49	1.2%	24%
1983	5,204	5,101	1,254	1,928	327	7.3%	29	0.6%	26%
1984	5,663	5,561	1,471	1,930	178	3.7%	17	0.3%	30%
1985	6,686	6,024	1,735	20,445	737	14.0%	15	0.3%	36%
1986	6,637	5,899	1,759	9,084	227	4.4%	12	0.2%	36%
1987	24,398	24,003	1,958	6,268	259	1.3%	11	0.1%	41%
1988	26,901	26,727	4,383	1,054	389	1.7%	11	0.0%	91%
1989	26,617	26,547	7,077	1,531	633	2.7%	16	0.1%	147%
1990	21,499	21,449	8,658	525	392	2.0%	13	0.1%	179%
1991	18,269	18,230	8,945	890	869	5.4%	10	0.1%	185%
1992	14,130	14,087	8,031	770	158	1.3%	7	0.1%	166%
1993	11,679	11,632	7,011	970	155	1.5%	4	0.0%	145%
1994	9,561	9,472	5,856	2,203	95	1.2%	0	0.0%	121%
1995	8,305	8,005	4,824	8,284	67	1.0%	0	0.0%	100%
1996	8,319	8,083	3,991	1,597	41	0.6%	0	0.0%	83%
1997	14,052	14,006	3,521	340	84	0.7%	3	0.0%	73%
1998	12,105	12,074	4,034	752	71	0.7%	4	0.0%	84%
1999	9,698	9,674	4,462	251	30	0.3%	3	0.0%	92%
2000	8,345	8,332	4,357	252	34	0.5%	0	0.0%	90%
2001	6,770	6,741	3,995	763	10	0.2%	8	0.1%	83%
2002	5,506	5,439	3,472	1,667	25	0.5%	15	0.3%	72%
2003	4,928	4,840	2,875	1,661	24	0.6%	8	0.2%	60%
2004	5,307	5,220	2,393	1,628	96	2.1%	8	0.2%	50%
2005	5,526	5,441	2,121	1,603	--	--	--	--	44%

Table 12. Time series of spawning biomass [mt] from the northern and southern area models with associated estimates of uncertainty (delta method approximation).

	Northern Area			Southern Area		
Year	Spawning Biomass	Standard Error	CV	Spawning Biomass	Standard Error	CV
1970	3,010	261	0.087	1,437	326	0.227
1971	3,159	218	0.069	1,492	272	0.182
1972	3,309	177	0.053	1,553	220	0.141
1973	3,102	326	0.105	1,433	212	0.148
1974	2,757	555	0.201	1,245	276	0.222
1975	2,497	709	0.284	1,124	333	0.296
1976	2,166	805	0.372	977	375	0.384
1977	1,664	851	0.512	751	402	0.535
1978	1,355	849	0.627	618	405	0.655
1979	1,237	830	0.671	548	399	0.728
1980	1,152	812	0.705	427	387	0.906
1981	1,143	806	0.706	317	363	1.148
1982	1,171	793	0.677	420	325	0.773
1983	1,293	779	0.602	751	338	0.451
1984	1,490	775	0.520	928	372	0.401
1985	1,711	789	0.461	1,659	480	0.289
1986	1,717	792	0.461	2,440	556	0.228
1987	4,740	1,045	0.220	2,725	553	0.203
1988	7,096	1,751	0.247	2,729	499	0.183
1989	8,536	1,944	0.228	2,615	422	0.161
1990	9,460	2,106	0.223	2,350	343	0.146
1991	9,270	2,046	0.221	2,014	269	0.134
1992	8,096	1,810	0.224	1,676	207	0.124
1993	6,985	1,530	0.219	1,370	157	0.114
1994	5,814	1,247	0.214	1,126	118	0.105
1995	4,791	998	0.208	915	88	0.097
1996	3,969	797	0.201	773	67	0.087
1997	3,506	670	0.191	771	66	0.085
1998	4,017	751	0.187	841	85	0.101
1999	4,442	805	0.181	1,076	133	0.124
2000	4,336	764	0.176	1,351	189	0.140
2001	3,976	682	0.171	1,577	231	0.146
2002	3,455	578	0.167	1,622	245	0.151
2003	2,861	470	0.164	1,528	232	0.152
2004	2,381	377	0.158	1,485	230	0.155
2005	2,112	329	0.156	1,445	231	0.160

Table 13. Stock projections of the southern and northern starry flounder stock under the standard PFMC $F_{40\%}$ 40:10 harvest policy.

Year	40:10 Adjust	Age-2+ Biomass	Spawn Biomass	Depletion	Age-0 Recruits	Trawl Catch	Trawl Harvest Rate	Sport Catch	Sport Harvest Rate
					California				
2005	1.00	3,460	1,445	62%	807	484.4	16.0%	99.9	3.3%
2006	1.00	2,934	1,143	49%	1,297	410.2	16.0%	84.7	3.3%
2007	1.00	2,606	930	40%	1,262	363.6	16.0%	75.3	3.3%
2008	0.94	2,873	788	34%	1,230	374.3	15.1%	77.7	3.1%
2009	0.92	3,030	755	32%	1,222	388.8	14.8%	80.6	3.0%
2010	0.93	3,117	777	33%	1,227	406.2	15.0%	84.1	3.1%
2011	0.95	3,167	805	34%	1,235	419.6	15.2%	86.9	3.1%
2012	0.96	3,203	826	35%	1,240	428.8	15.3%	88.8	3.1%
2013	0.96	3,228	839	36%	1,243	434.9	15.4%	90.1	3.2%
2014	0.97	3,245	847	36%	1,245	438.7	15.5%	90.9	3.2%
2015	0.97	3,257	852	37%	1,246	441.2	15.5%	91.4	3.2%
2016	0.97	3,265	856	37%	1,247	443.0	15.6%	91.7	3.2%
					Washington-Oregon				
2005	1.00	5,441	2,121	44%	1,603	754.4	16.0%	155.9	3.3%
2006	0.95	4,918	1,693	35%	2,559	653.1	15.3%	135.0	3.1%
2007	0.89	4,638	1,464	30%	2,496	579.3	14.3%	120.0	2.9%
2008	0.86	5,437	1,351	28%	2,459	647.7	13.8%	134.4	2.8%
2009	0.87	5,915	1,395	29%	2,474	719.5	14.0%	149.2	2.9%
2010	0.90	6,192	1,501	31%	2,507	783.4	14.5%	162.3	3.0%
2011	0.93	6,369	1,591	33%	2,533	828.4	14.9%	171.6	3.1%
2012	0.94	6,498	1,655	34%	2,549	859.3	15.2%	178.0	3.1%
2013	0.95	6,588	1,697	35%	2,560	880.0	15.3%	182.2	3.1%
2014	0.96	6,651	1,724	36%	2,566	893.8	15.4%	185.1	3.2%
2015	0.96	6,693	1,743	36%	2,570	903.2	15.5%	187.0	3.2%
2016	0.97	6,722	1,755	36%	2,573	909.6	15.5%	188.4	3.2%

Table 14. Decision table analysis for the southern starry flounder stock assessment model. See text for further description.

				State of Nature					
				1.33 q **Low Stock Size** less likely (p=0.32)		1.00 q **Base Model** more likely (p=0.36)		0.75 q **High Stock Size** less likely (p=0.32)	
Management Action	Year	Trawl Catch	Sport Catch	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
	2005	44	9	1081	55%	1443	62%	1928	68%
	2006	44	9	1042	53%	1386	59%	1848	65%
	2007	44	9	1018	52%	1344	58%	1781	63%
Low Catch	2008	44	9	1007	51%	1314	56%	1727	61%
	2009	44	9	1055	54%	1357	58%	1761	62%
(Average	2010	44	9	1147	58%	1453	62%	1864	66%
of last 5 yr)	2011	44	9	1250	64%	1565	67%	1988	70%
	2012	44	9	1349	69%	1675	72%	2112	75%
	2013	44	9	1437	73%	1772	76%	2224	78%
	2014	44	9	1511	77%	1855	80%	2317	82%
	2015	44	9	1572	80%	1922	82%	2393	84%
	2016	44	9	1622	83%	1976	85%	2455	87%
	2005	264	54	1081	55%	1443	62%	1928	68%
	2006	227	47	921	47%	1264	54%	1725	61%
	2007	204	42	812	41%	1134	49%	1569	55%
Medium Catch	2008	209	43	743	38%	1046	45%	1455	51%
	2009	216	45	752	38%	1047	45%	1447	51%
(Intermediate	2010	225	46	804	41%	1105	47%	1511	53%
between low	2011	232	48	863	44%	1175	50%	1595	56%
and high)	2012	236	49	917	47%	1242	53%	1678	59%
	2013	239	49	962	49%	1299	56%	1751	62%
	2014	241	50	1000	51%	1347	58%	1811	64%
	2015	243	50	1031	53%	1385	59%	1858	66%
	2016	243	50	1056	54%	1415	61%	1897	67%
	2005	484	100	1081	55%	1443	62%	1928	68%
	2006	410	85	800	41%	1141	49%	1601	56%
	2007	363	75	611	31%	928	40%	1359	48%
High Catch	2008	374	78	493	25%	786	34%	1188	42%
	2009	388	80	471	24%	754	32%	1144	40%
(OY – $F_{40\%}$	2010	406	84	486	25%	775	33%	1173	41%
with 40:10	2011	419	87	498	25%	803	34%	1217	43%
adjustment)	2012	428	89	501	26%	824	35%	1257	44%
	2013	434	90	498	25%	838	36%	1289	45%
	2014	438	91	493	25%	846	36%	1312	46%
	2015	441	91	487	25%	851	36%	1329	47%
	2016	442	92	481	25%	855	37%	1342	47%

Table 15. Decision table analysis for the northern starry flounder stock assessment model. See text for further description.

				State of Nature					
				1.33 q		1.00 q		0.75 q	
				Low Stock Size		**Base Model**		**High Stock Size**	
				less likely (p=0.33)		more likely (p=0.35)		less likely (p=0.32)	
Management Action	Year	Trawl Catch	Sport Catch	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
	2005	38	8	1592	39%	2112	44%	2811	47%
	2006	38	8	1581	39%	2063	43%	2711	46%
	2007	38	8	1643	41%	2109	43%	2737	46%
Low Catch	2008	38	8	1732	43%	2194	45%	2817	47%
	2009	38	8	1924	47%	2409	50%	3063	52%
(Average	2010	38	8	2185	54%	2710	56%	3419	58%
of last 5 yr)	2011	38	8	2454	61%	3023	62%	3793	64%
	2012	38	8	2707	67%	3318	68%	4145	70%
	2013	38	8	2930	72%	3578	74%	4456	75%
	2014	38	8	3119	77%	3798	78%	4717	79%
	2015	38	8	3277	81%	3980	82%	4933	83%
	2016	38	8	3406	84%	4129	85%	5109	86%
	2005	396	82	1592	39%	2112	44%	2811	47%
	2006	345	71	1399	35%	1876	39%	2520	42%
	2007	308	64	1324	33%	1783	37%	2405	41%
Medium Catch	2008	343	71	1311	32%	1766	36%	2383	40%
	2009	380	79	1414	35%	1892	39%	2540	43%
(Intermediate	2010	412	85	1573	39%	2093	43%	2798	47%
between low	2011	435	90	1729	43%	2296	47%	3063	52%
and high)	2012	450	93	1866	46%	2478	51%	3304	56%
	2013	461	95	1981	49%	2631	54%	3509	59%
	2014	468	97	2075	51%	2757	57%	3678	62%
	2015	473	98	2152	53%	2860	59%	3816	64%
	2016	476	99	2216	55%	2944	61%	3928	66%
	2005	754	156	1592	39%	2112	44%	2811	47%
	2006	652	135	1217	30%	1688	35%	2329	39%
	2007	579	120	1013	25%	1463	30%	2078	35%
High Catch	2008	649	135	910	22%	1353	28%	1960	33%
	2009	722	150	936	23%	1399	29%	2034	34%
(OY – $F_{40\%}$	2010	786	163	1000	25%	1506	31%	2198	37%
with 40:10	2011	832	172	1040	26%	1597	33%	2355	40%
adjustment)	2012	863	179	1054	26%	1662	34%	2482	42%
	2013	884	183	1054	26%	1704	35%	2580	43%
	2014	898	186	1046	26%	1732	36%	2653	45%
	2015	908	188	1034	26%	1751	36%	2710	46%
	2016	914	189	1020	25%	1763	36%	2754	46%

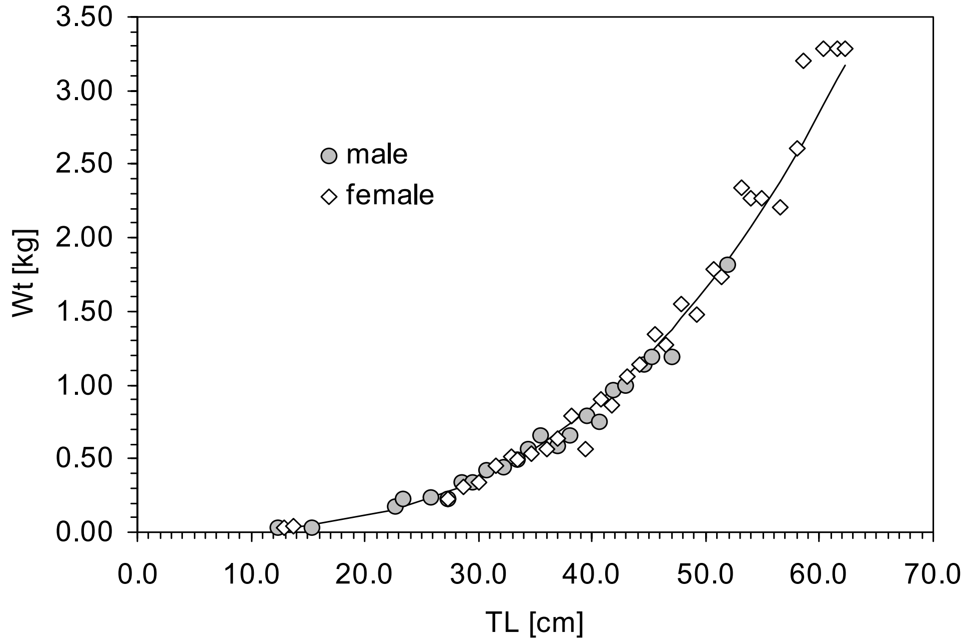


Figure 1. Length-weight regression developed from data presented in Orcutt (1950). Statistical analysis showed no difference between sexes.

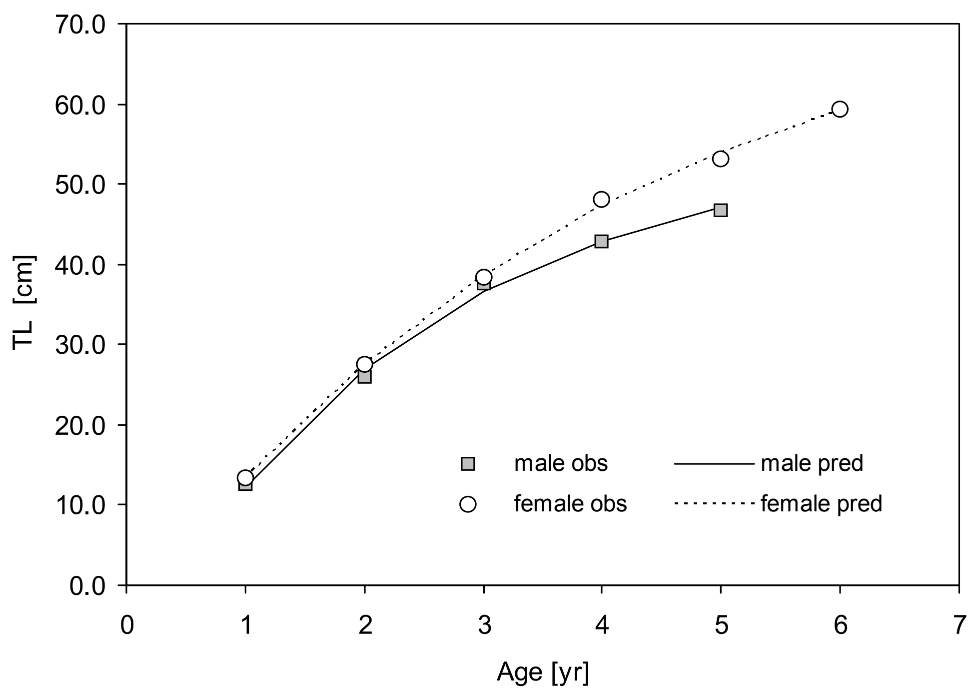


Figure 2. Estimated von Bertalanffy growth curves for male and female starry flounder based upon data in Orcutt (1950).

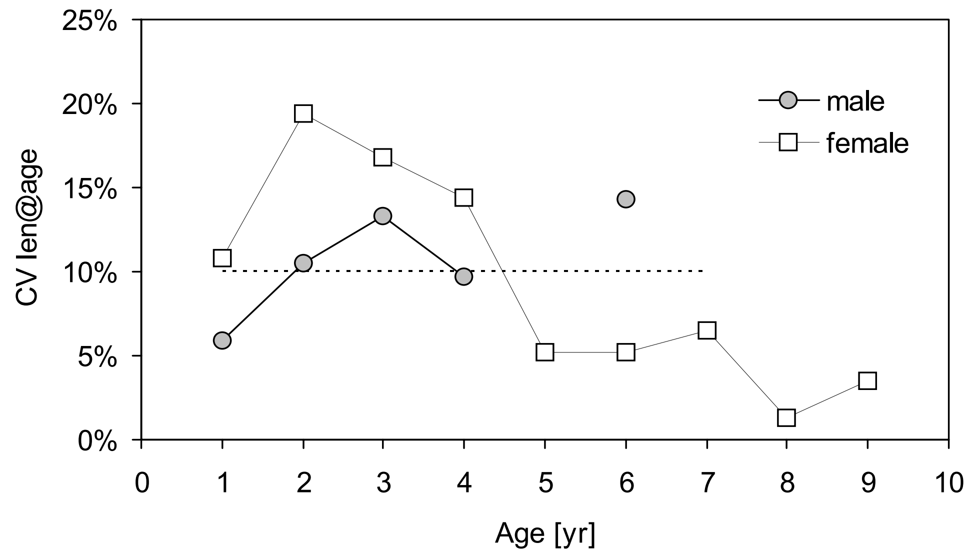


Figure 3. Variability in starry flounder length at age, based upon un-validated estimates of age obtained from otoliths. For the assessment model a CV of 10% was assumed for males and females throughout their lifespan.

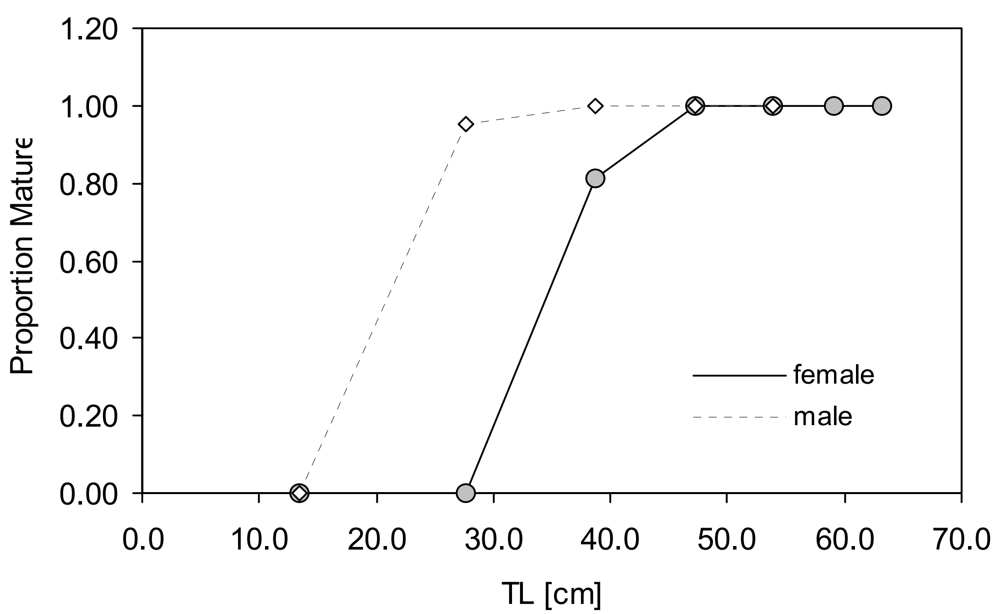


Figure 4. Maturity of starry flounder, based on an analysis of data presented in Orcutt (1950).

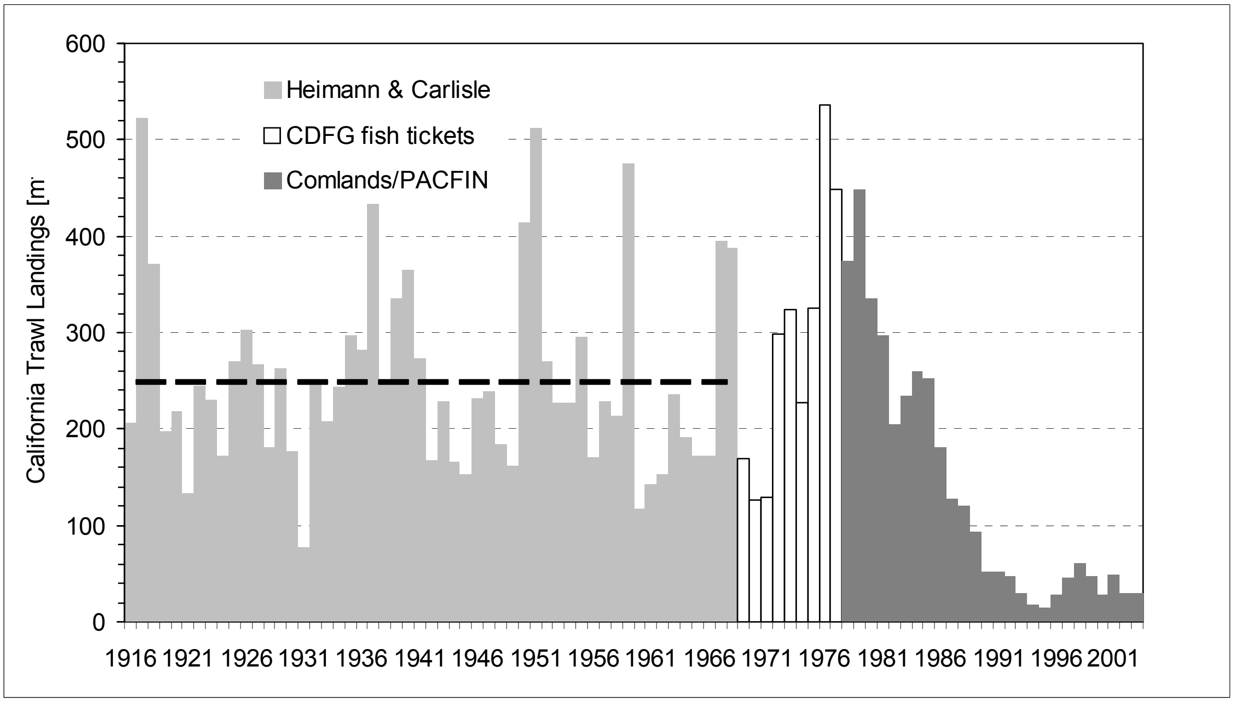


Figure 5. Landings of starry flounder in the California trawl fishery. The horizontal dashed line shows average landings over the period 1916-1969 (250 mt), which was used as an initial equilibrium estimate of landings.

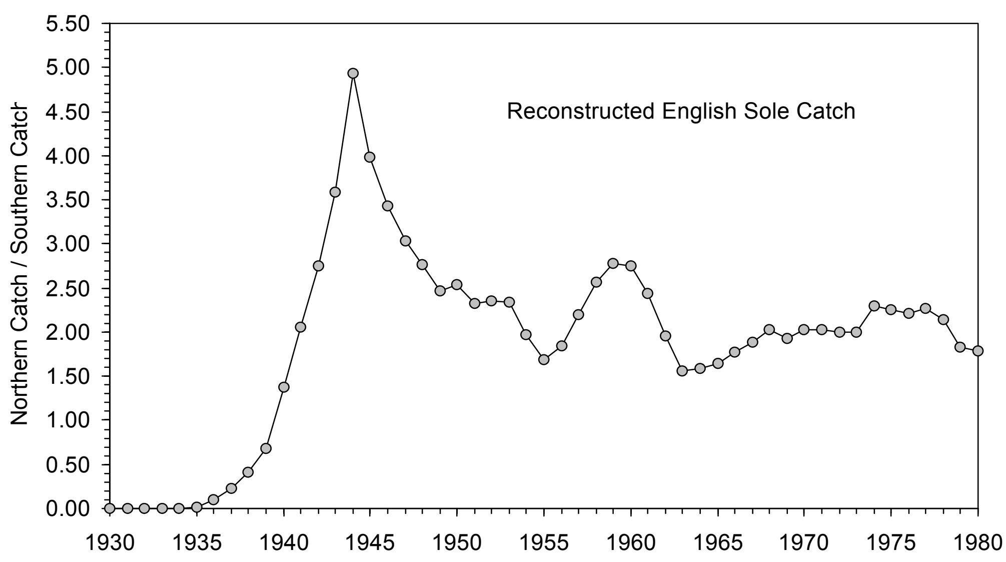


Figure 6. The ratio of English sole catch in the northern area (COL-VAN) relative to the catch in the southern area (MON-EUR). Annual values calculated as the ratio of centered, five-year, running means of the reconstructed English sole catch history (I. Stewart, pers. comm.).

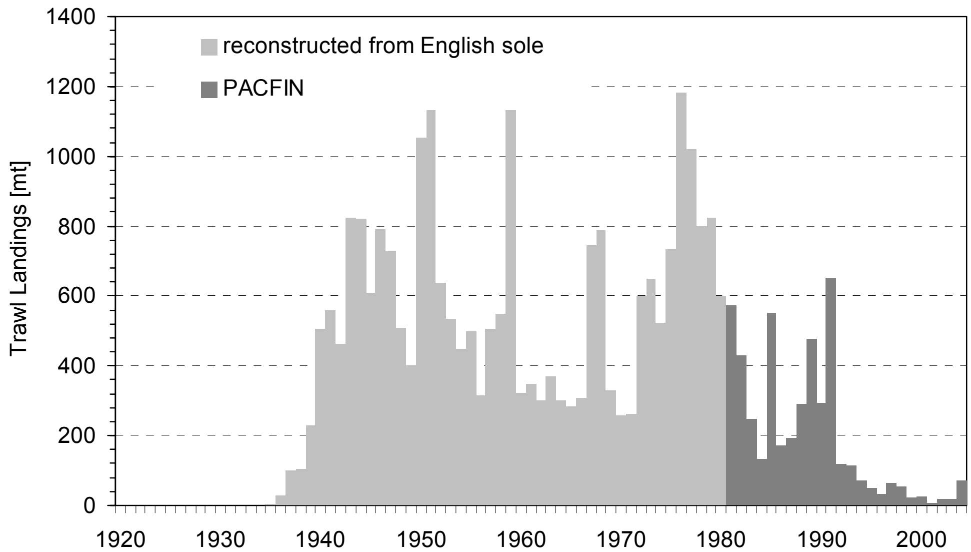


Figure 7. Landings of starry flounder in the Washington-Oregon trawl fishery based on recent PACFIN data and a reconstruction using English sole (see text for more discussion).

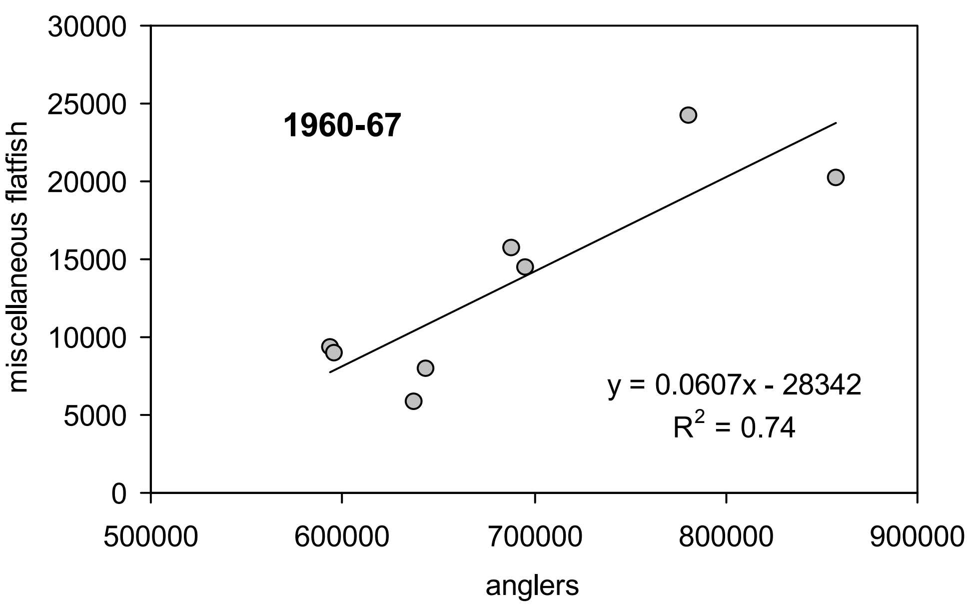


Figure 8. Relationship between California recreational CPFV fishing effort (anglers $\cdot$ yr^{-1}) and the catch of miscellaneous flatfish. Data from Young (1969).

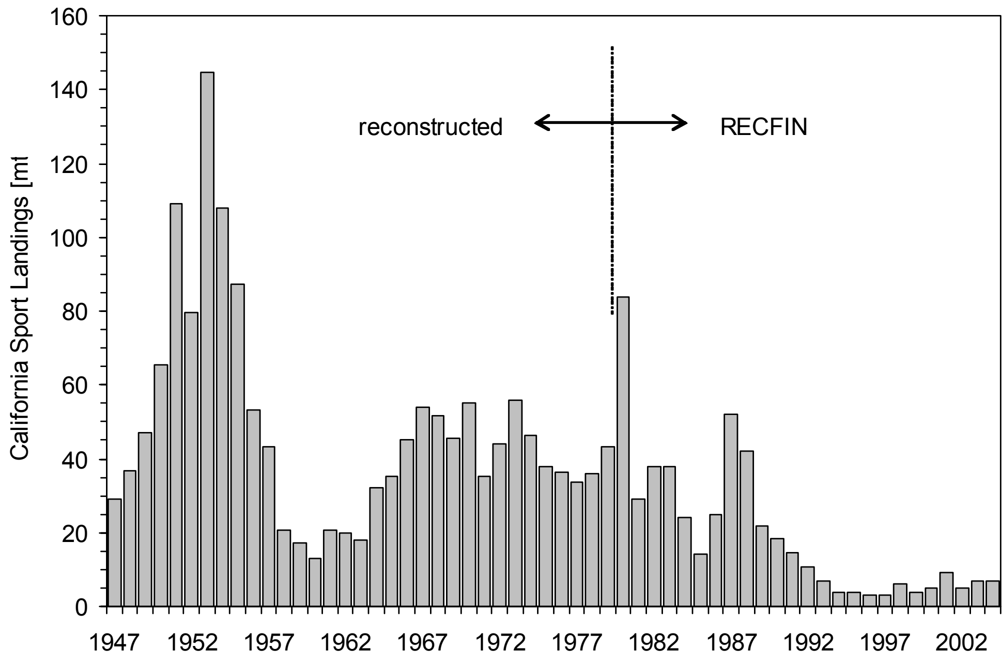


Figure 9. Estimated landings of starry flounder in the California sport fishery (1947-2004). Landings prior to 1980 are reconstructed from (a) CPFV effort statistics, (b) miscellaneous CPFV flatfish catch, and (c) the ratio of CPFV catch to RECFIN landings. See text for further discussion.

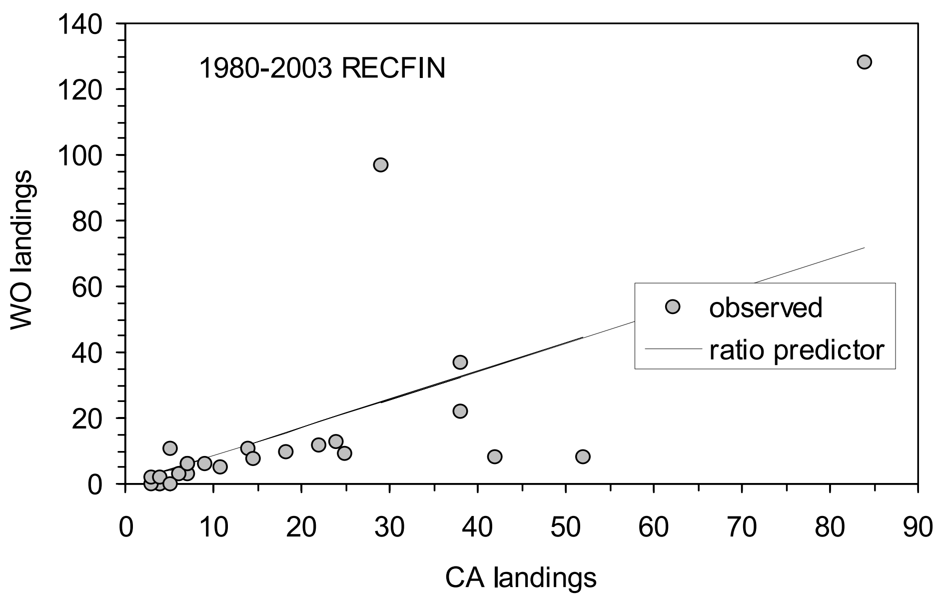


Figure 10. Relationship between observed RECFIN catches of starry flounder in the northern area and those predicted by ratio from southern landings. The estimated ratio was used to predict northern catches during the period 1970-79.

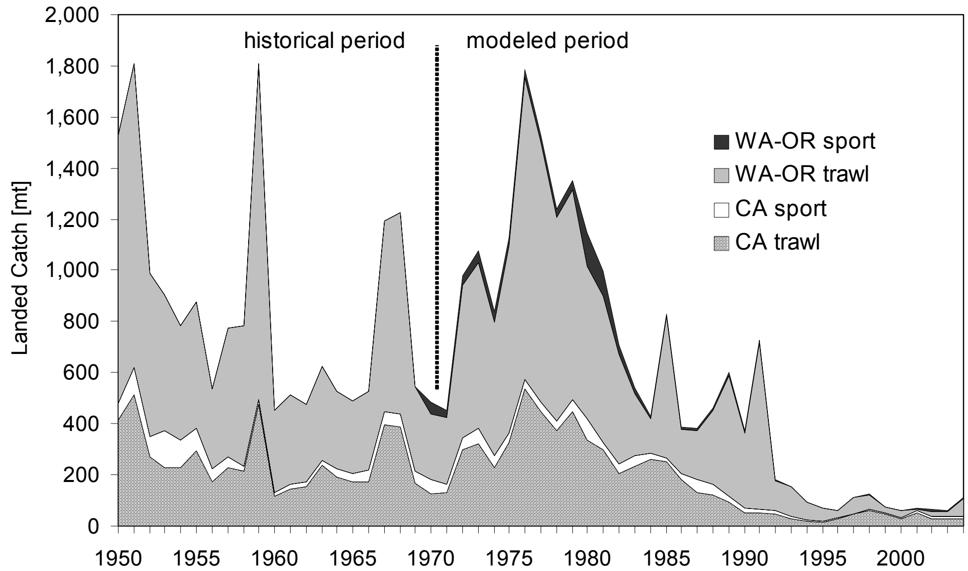


Figure 11. Estimated landings of starry flounder in northern and southern, trawl and recreational fisheries. Note the predominance of the commercial fishery. Landings prior to 1970 were used simply to set historical catch levels for the assessment model.

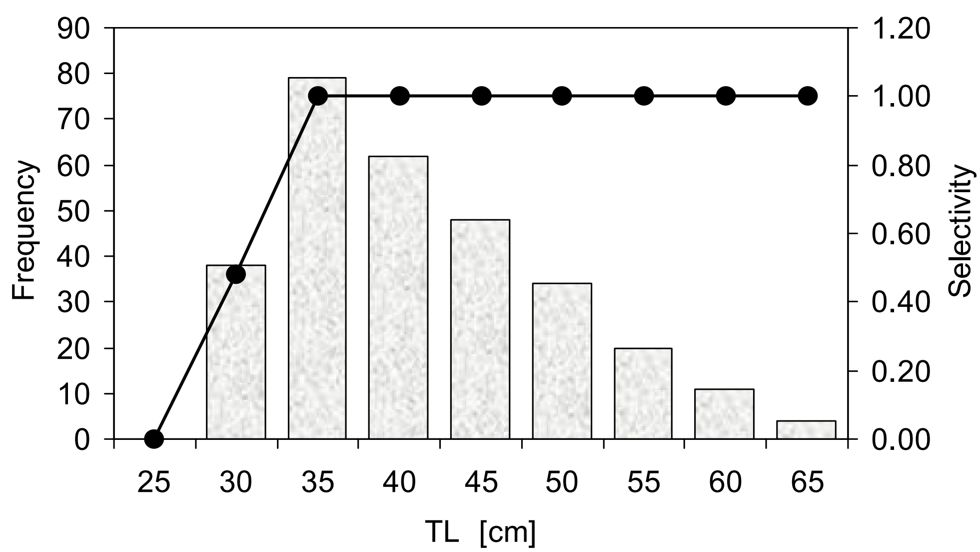


Figure 12. Length frequency distribution for starry flounder sampled in the west coast trawl fishery (N = 297, source PACFIN BDS).

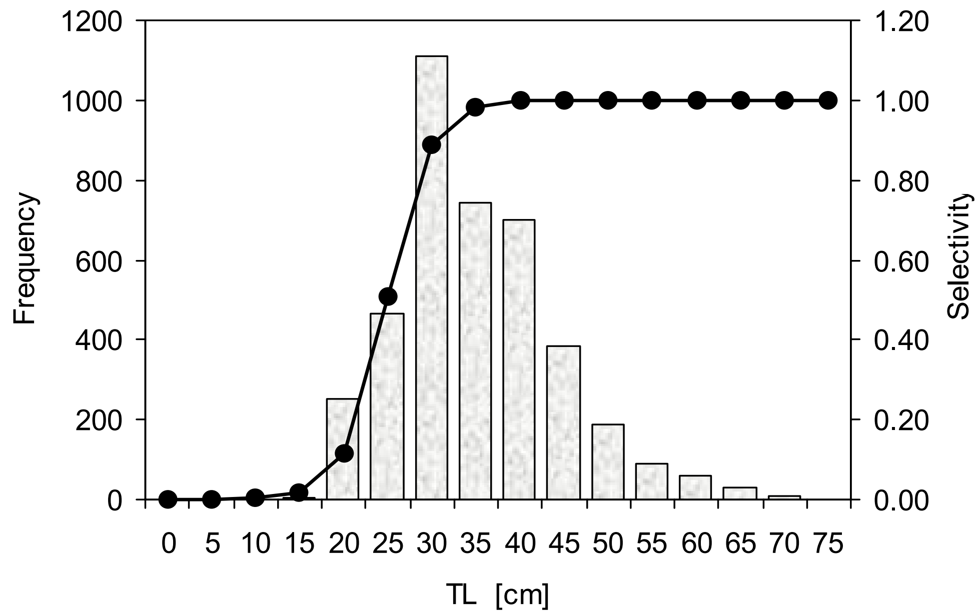


Figure 13. Length frequency distribution for starry flounder sampled in the recreational fishery (N = 4,047, source RECFIN).

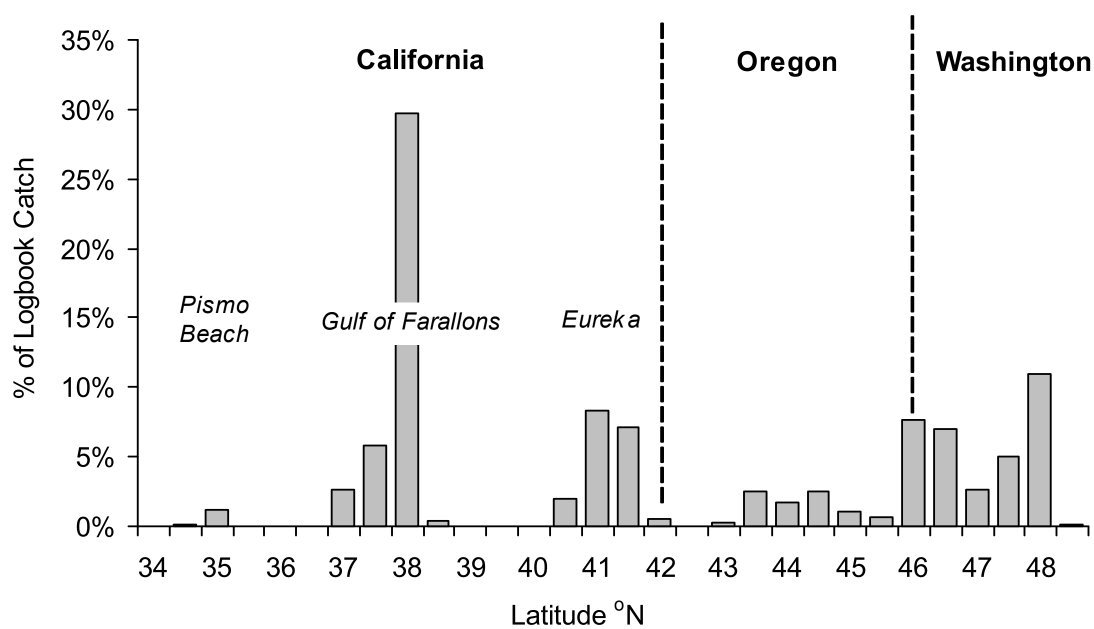


Figure 14. Latitudinal distribution of reported starry flounder catch in the west coast trawl logbook data set.

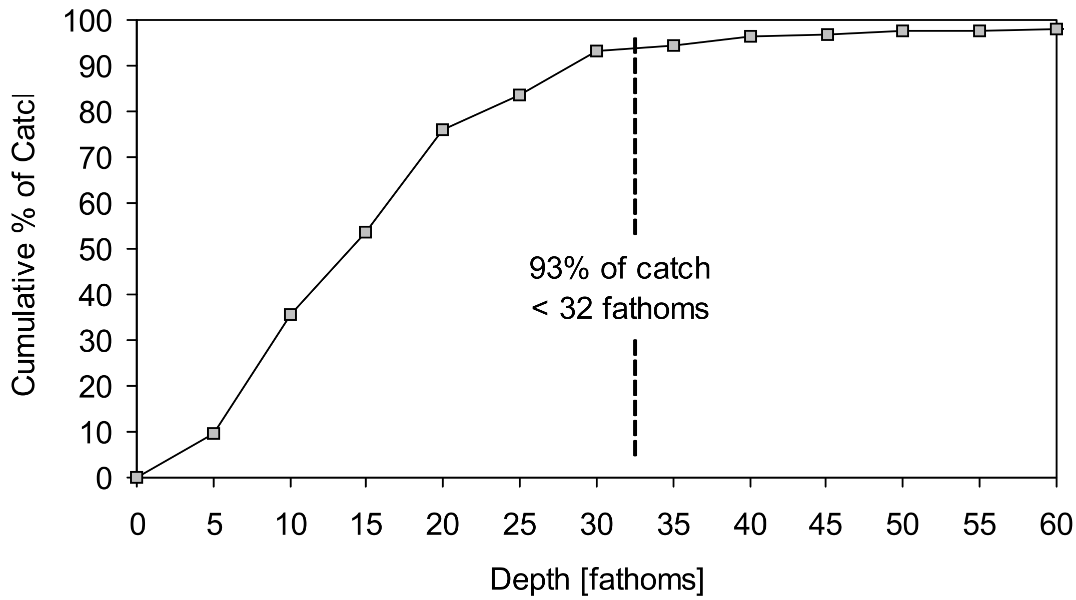


Figure 15. Cumulative depth distribution of starry flounder catch in the west coast trawl logbook data set.

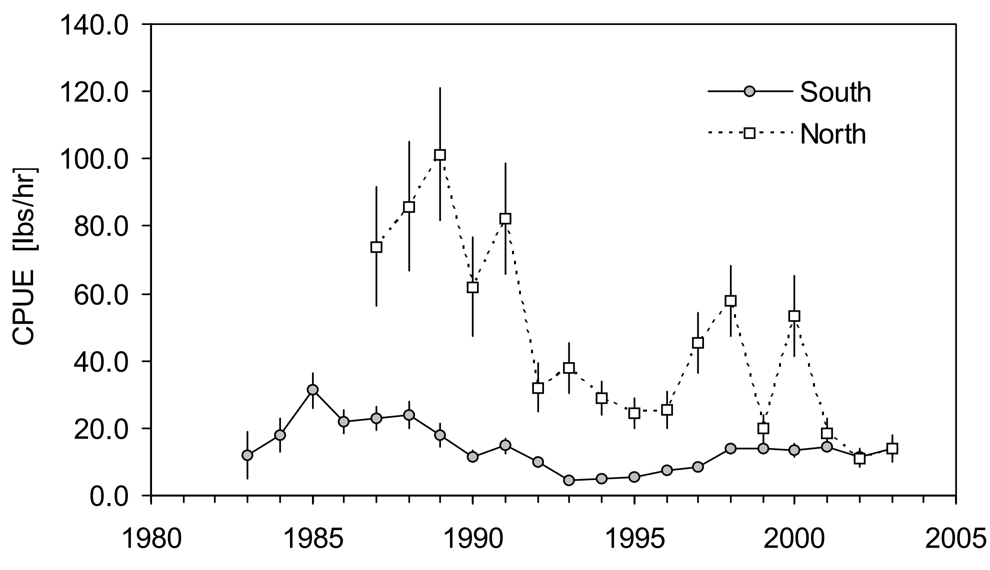


Figure 16. Year effects from separate Δ-lognormal GLMs for southern (California) and northern (Washington-Oregon) regions.

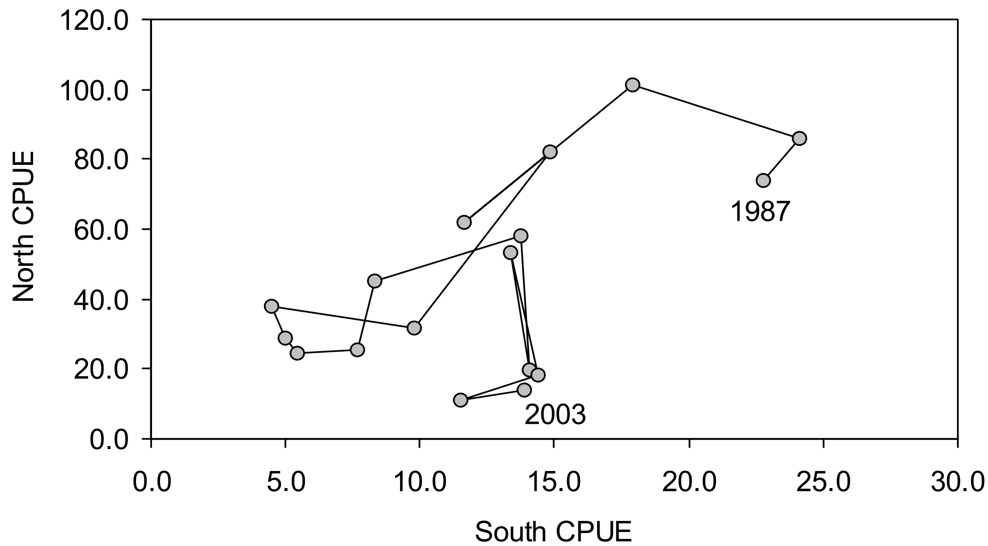


Figure 17. Co-variation in annual estimates of CPUE (lbs/hr) of starry flounder trawl fisheries conducted in California (CA) and Washington-Oregon (WA-OR).

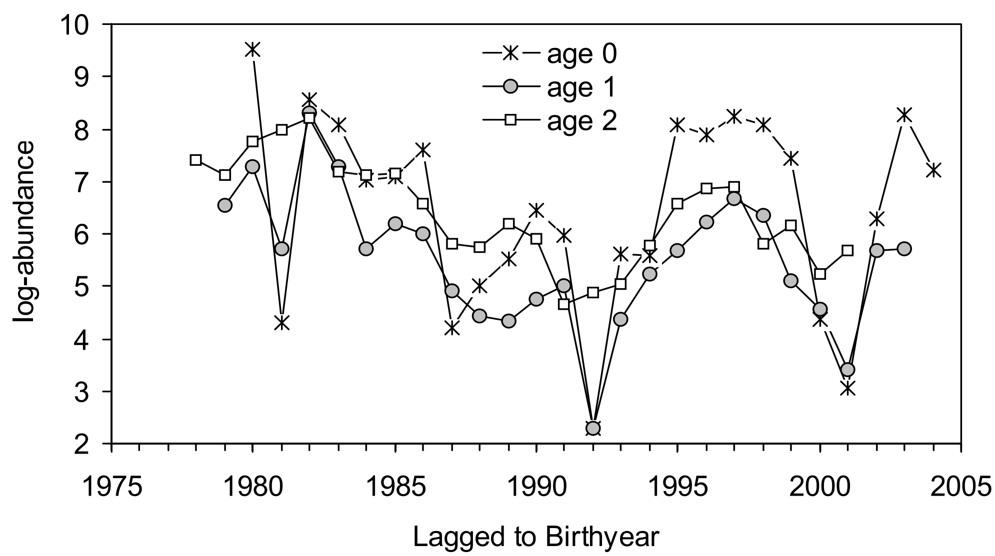


Figure 18. Time series of abundance of age-0, age-1, and age-2 starry flounder in CDFG/IEP surveys of the San Francisco Bay and Sacramento/San Joaquin estuary (Baxter *et al*. 1999).

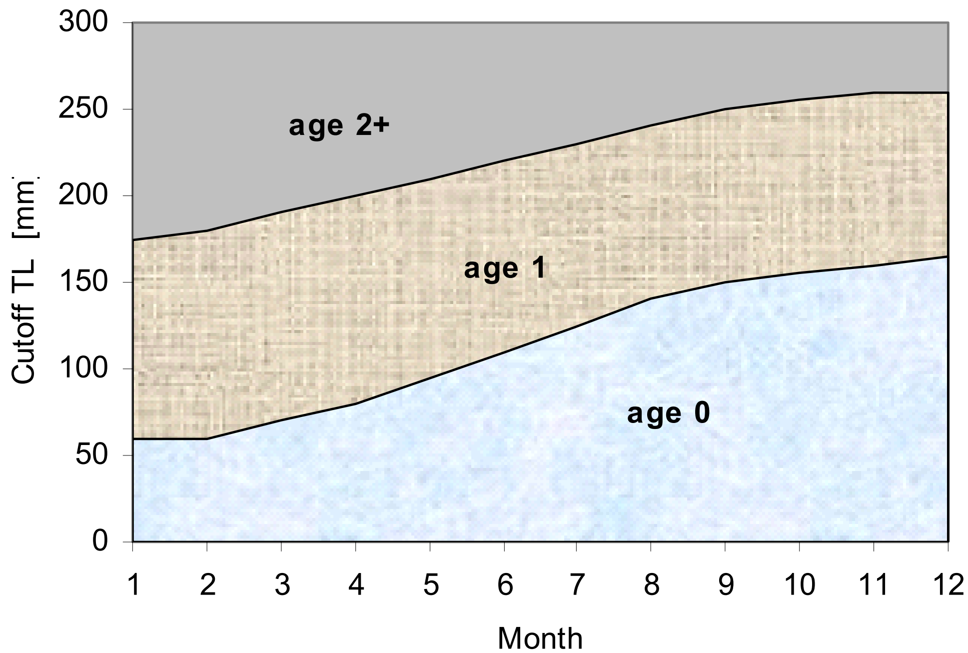


Figure 19. Length criteria used to identify age cohorts in the CDFG/IEP survey. Assigned criteria are generally consistent with Orcutt (1950).

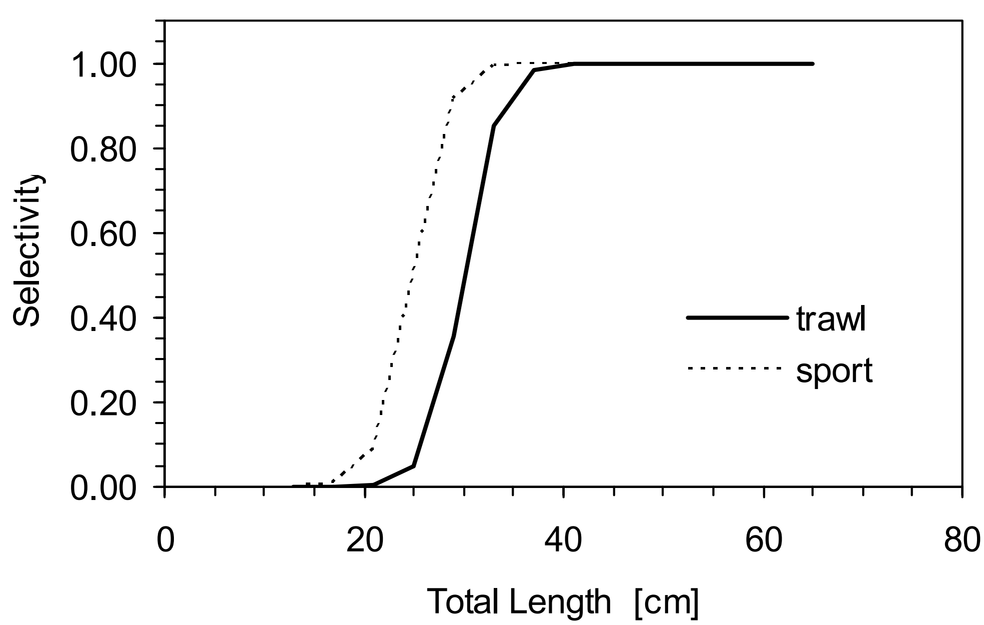


Figure 20. Selectivity curves for trawl and recreational fisheries used in the SS2 assessment model.

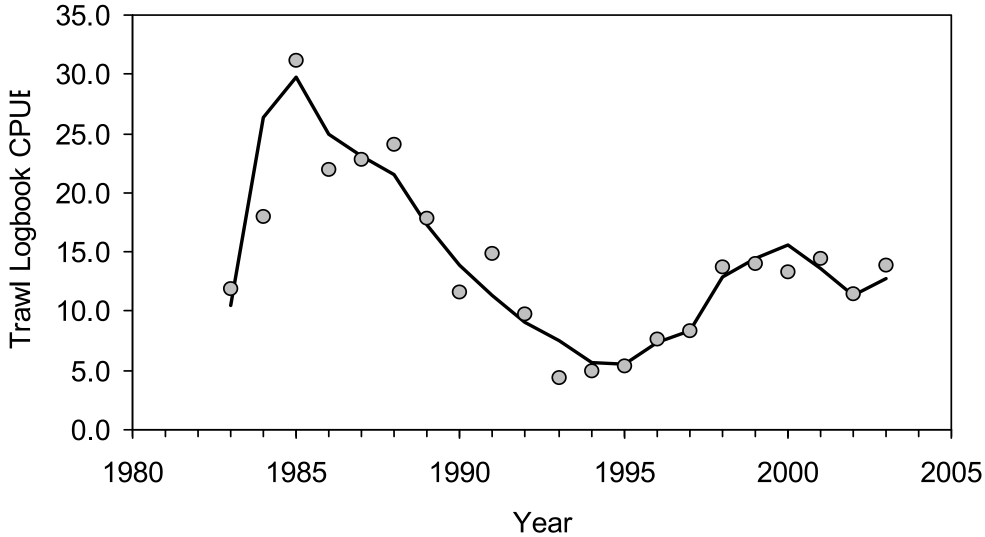


Figure 21. Fit of the southern starry flounder stock assessment model (solid line) to the southern trawl logbook index (year effect from Δ-lognormal GLM).

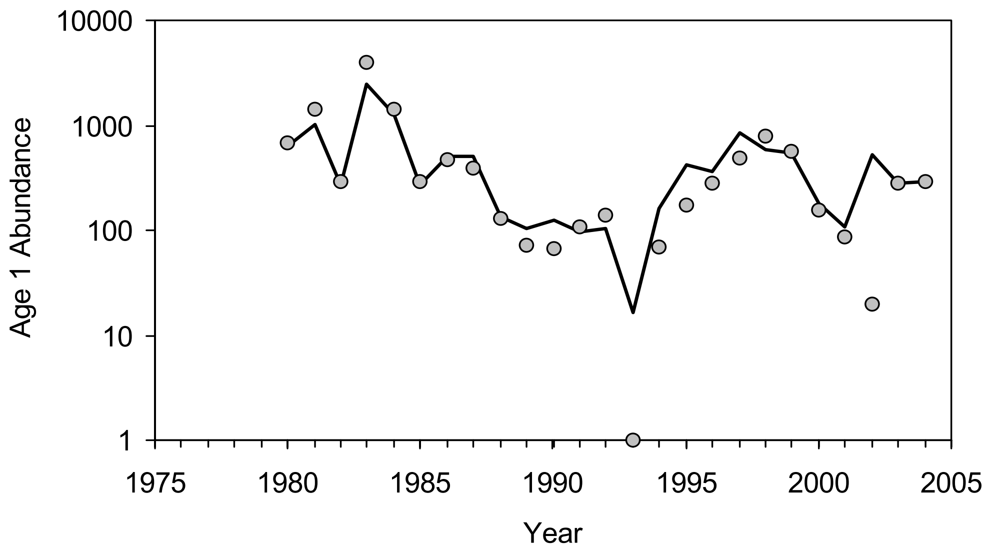


Figure 22. Fit of the southern starry flounder stock assessment model (solid line) to the CDFG/IEP pre-recruit survey index of age-1 abundance from San Francisco Bay and the Sacramento/San Joaquin estuary.

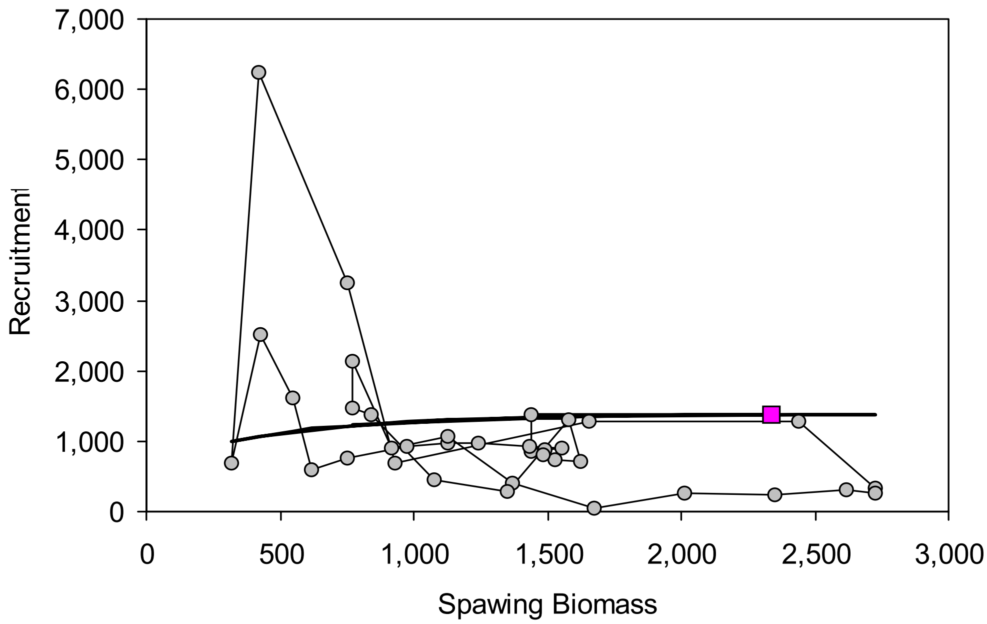


Figure 23. Estimated spawner-recruit relationship for starry flounder in the southern area. The magenta square represents the estimated unexploited condition (S_0, R_0). In fitting this relationship steepness was fixed at a value of h = 0.80.

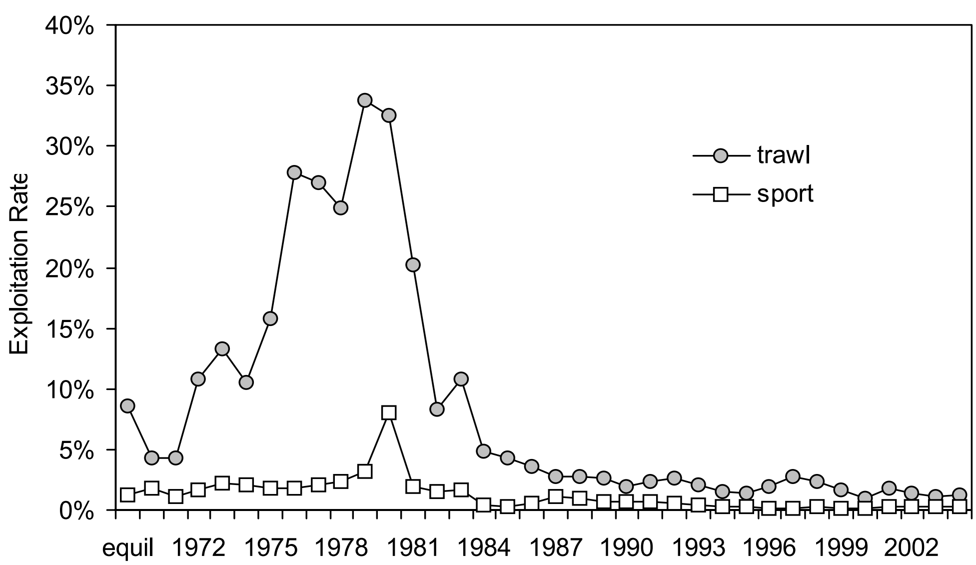


Figure 24. Base model estimates of exploitation rate for the trawl and sport fisheries in the southern region (California). The first value in the time series labeled "equil" represents the equilibrium exploitation rate needed to produce historical catches.

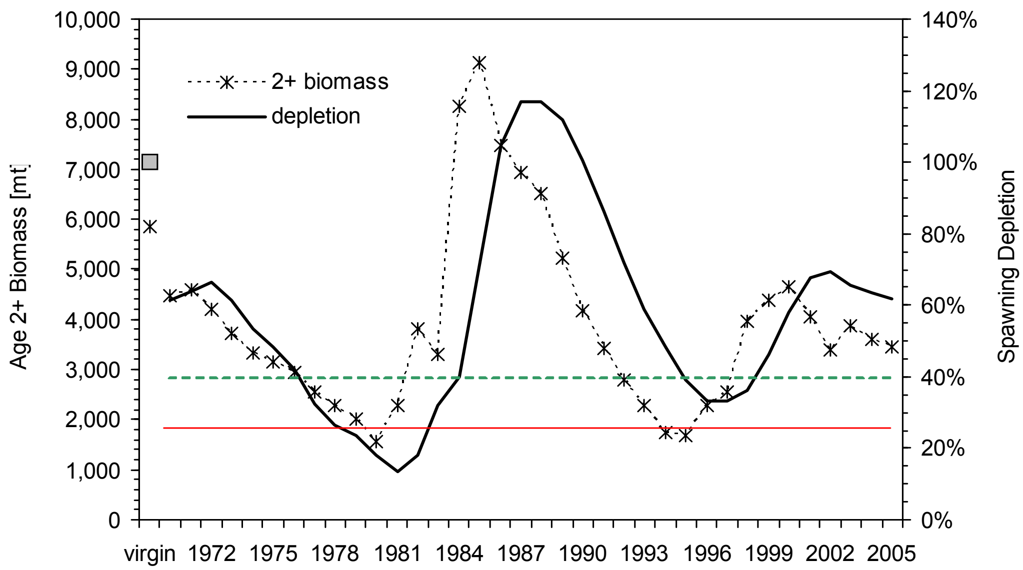


Figure 25. Time series of age-2+ exploitable biomass and spawning depletion (current spawning biomass ÷ virgin spawning biomass) for the southern starry flounder stock. The green dashed line represents the target spawning biomass depletion level under exploitation ($SB_{40\%}$) and the solid red line shows the overfished limit reference point ($SB_{25\%}$).

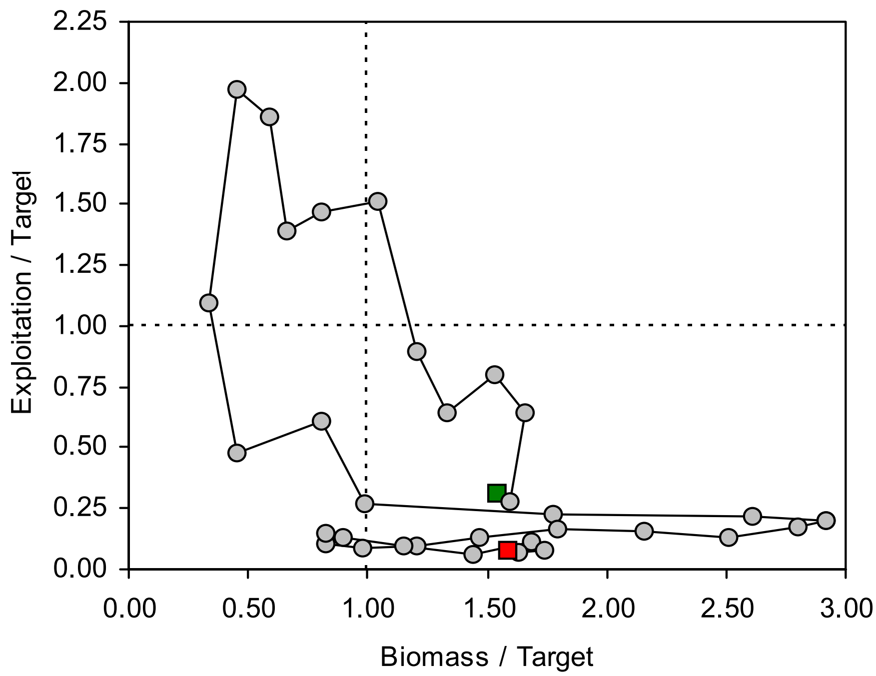


Figure 26. Phase plot of starry flounder in the southern area. Plotted on the x-axis is the time series of spawning biomass relative to the target level ($SB_{40\%}$). Plotted on the y-axis is the time series of annual exploitation rate relative to the target level ($F_{40\%}$). [Green=1970, Red=2004]

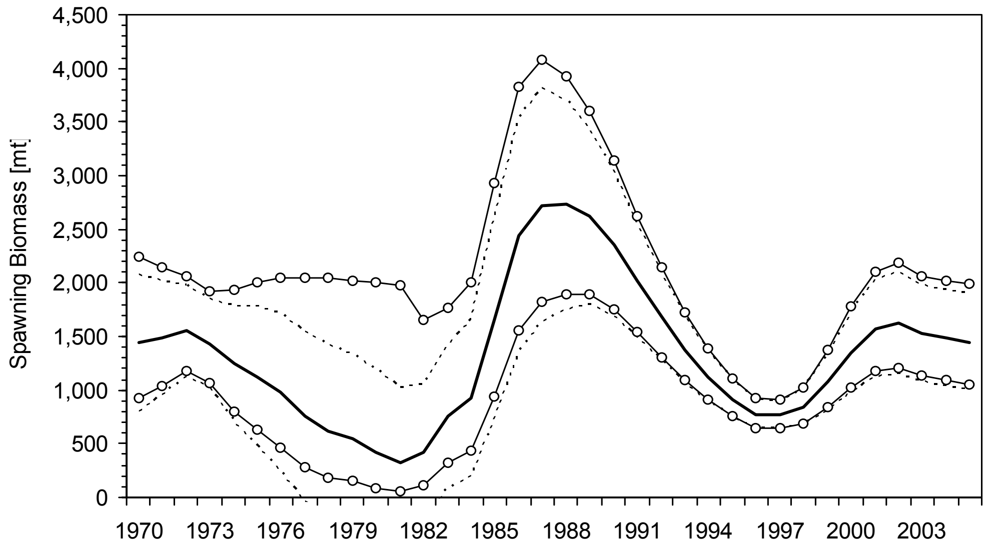


Figure 27. Time series of spawning biomass for southern starry flounder with associated statistical uncertainty. The bold line represents the base model result, bracketed by a 95% confidence interval from a normal distribution (dashed line) and from a lognormal distribution (open circles).

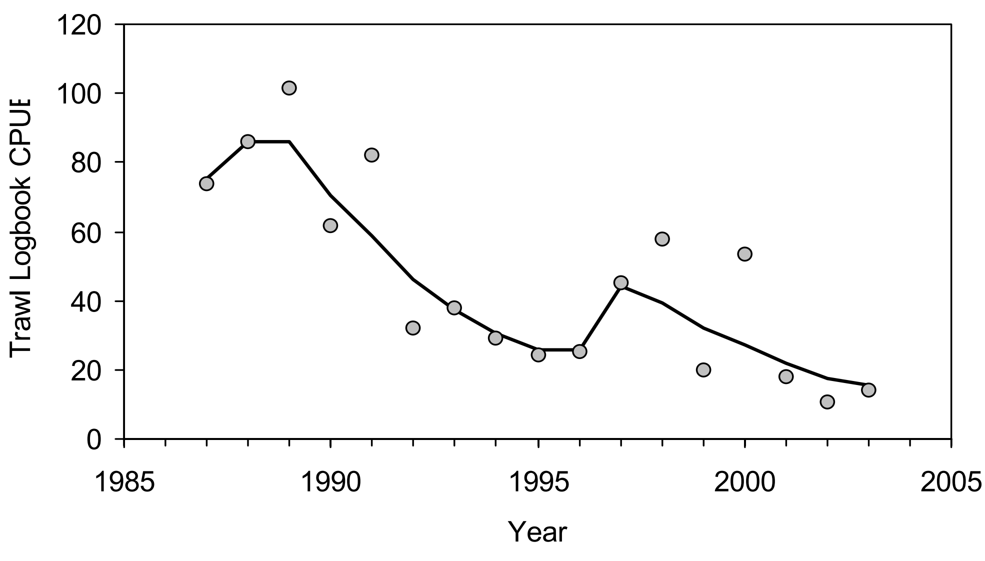


Figure 28. Fit of the northern starry flounder stock assessment model (solid line) to the southern trawl logbook index (year effect from Δ-lognormal GLM).

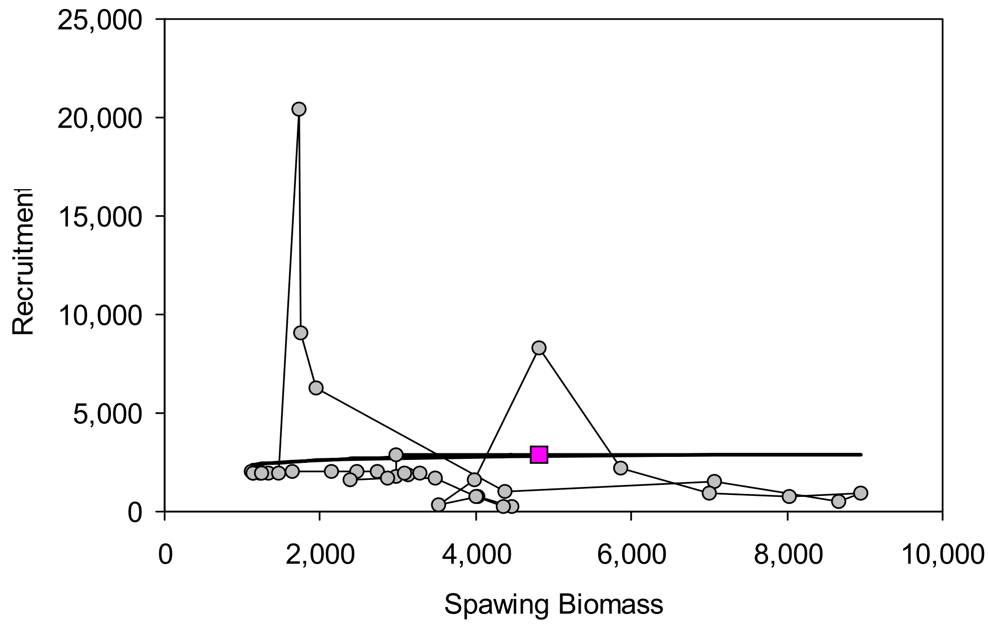


Figure 29. Estimated spawner-recruit relationship for starry flounder in the northern area. The magenta square represents the estimated unexploited condition (S_0, R_0). In fitting this relationship steepness was fixed at a value of h = 0.80.

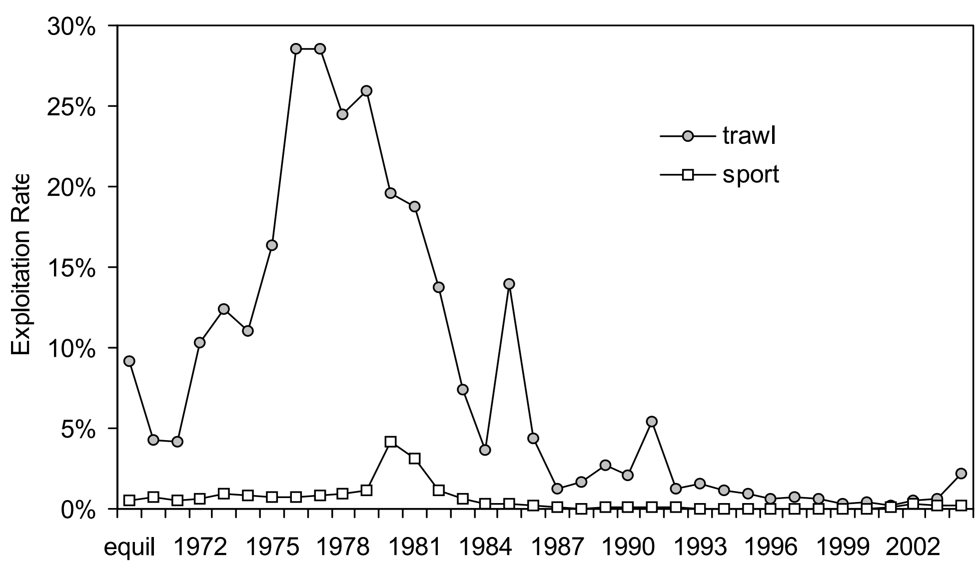


Figure 30. Base model estimates of exploitation rate for the trawl and sport fisheries in the northern region (Washington-Oregon). The first value in the time series labeled “equil” represents the equilibrium exploitation rate needed to produce historical catches.

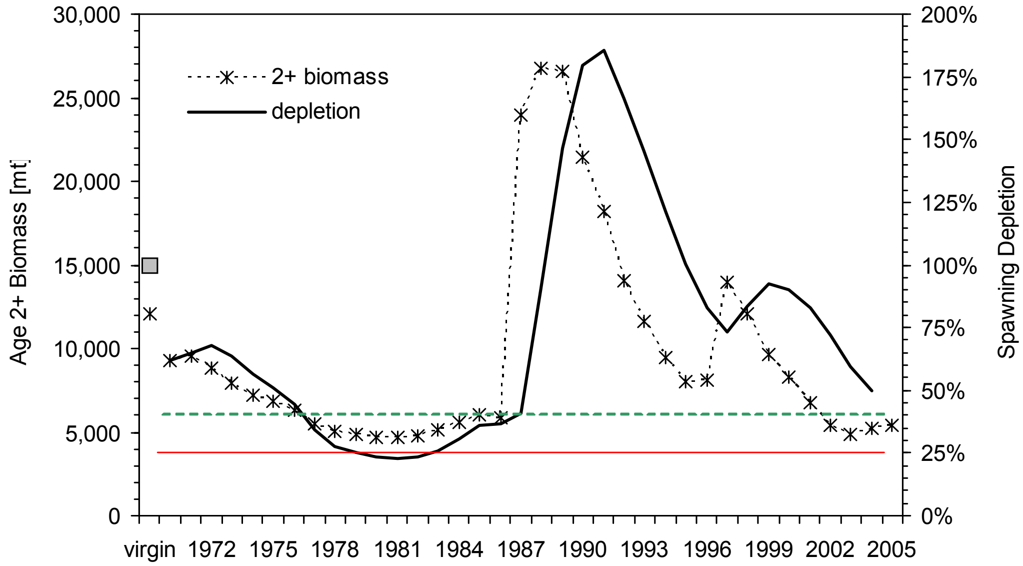


Figure 31. Time series of age-2+ exploitable biomass and spawning depletion (current spawning biomass ÷ virgin spawning biomass) for the northern starry flounder stock. The green dashed line represents the target spawning biomass depletion level under exploitation ($SB_{40\%}$) and the solid red line shows the overf[illegible]

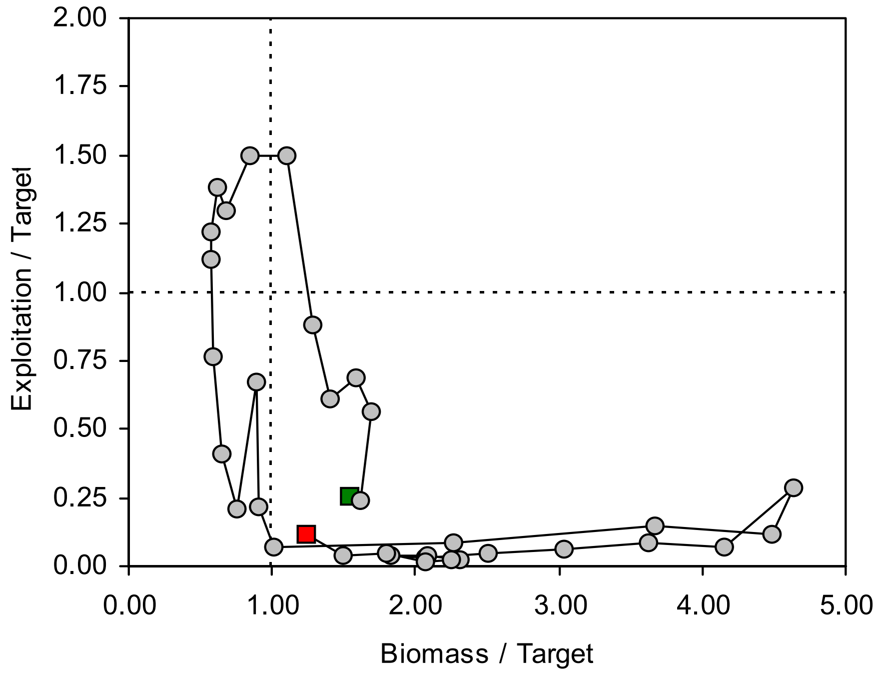


Figure 32. Phase plot of starry flounder in the northern area. Plotted on the x-axis is the time series of spawning biomass relative to the target level ($SB_{40\%}$). Plotted on the y-axis is the time series of annual exploitation rate relative to the target level ($F_{40\%}$). [Green=1970, Red=2004]

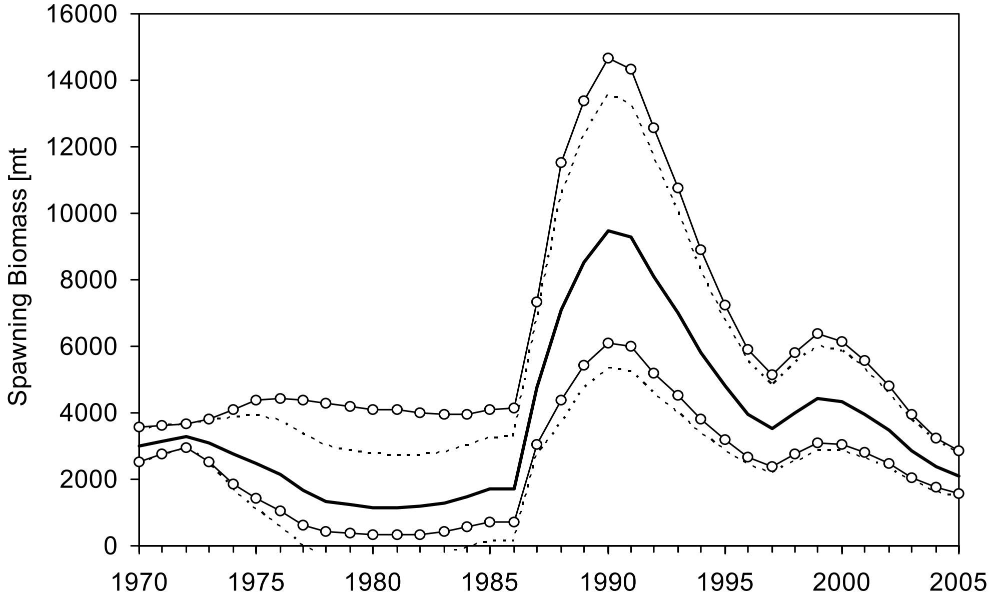


Figure 33. Time series of spawning biomass for northern starry flounder with associated statistical uncertainty. The bold line represents the base model result, bracketed by a 95% confidence interval from a normal distribution (dashed line) and from a lognormal distribution (open circles).

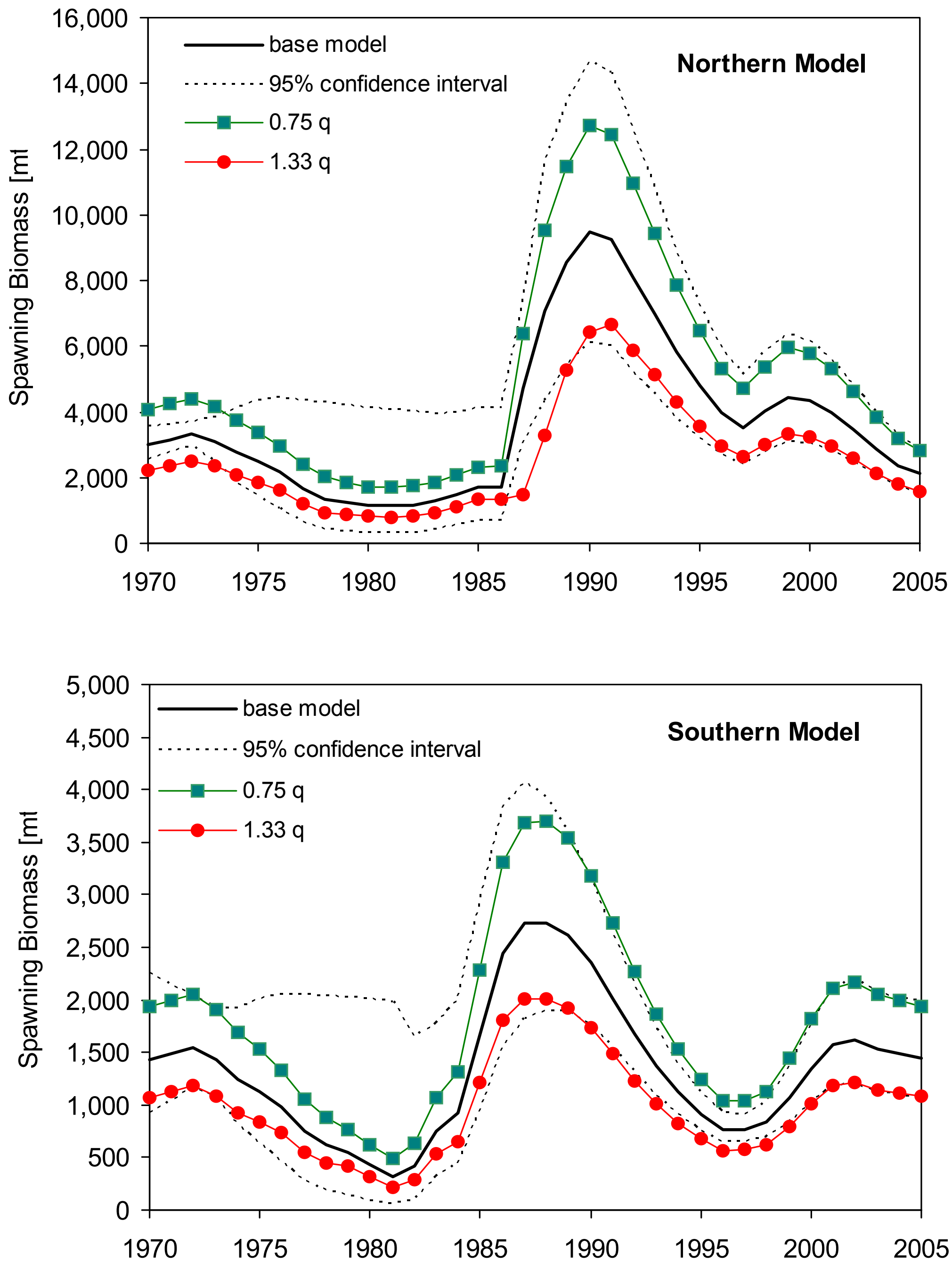
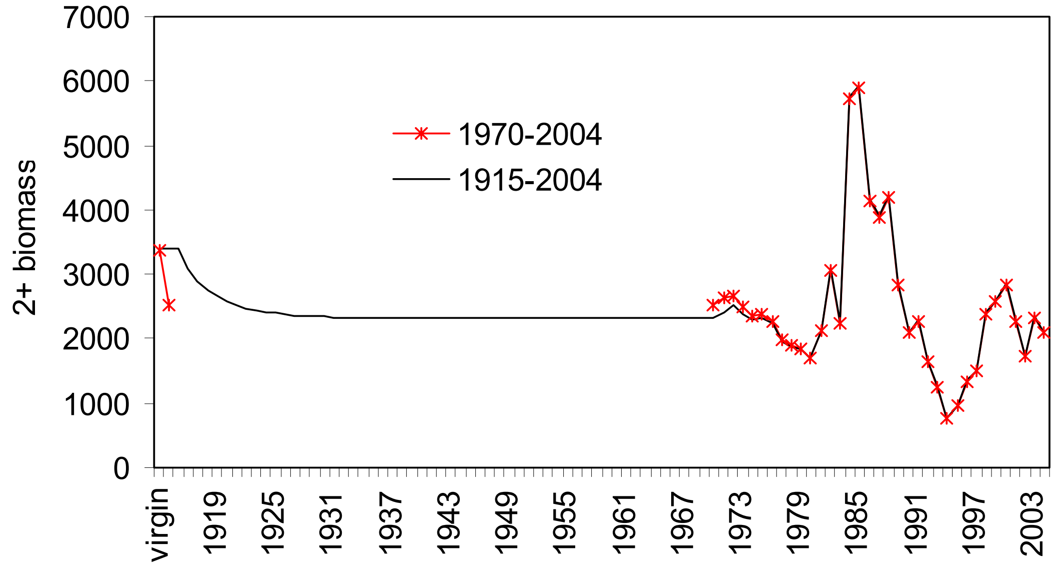


Figure 34. Statistical uncertainty in northern and southern starry flounder stock assessments expressed as 95% confidence intervals (dashed lines). Also shown are stock trajectories obtained by perturbing the estimated trawl logbook CPUE catchability coefficient by ×0.75 and ×1.33. These latter models were used to depict alternative "states of nature" in decision analyses.



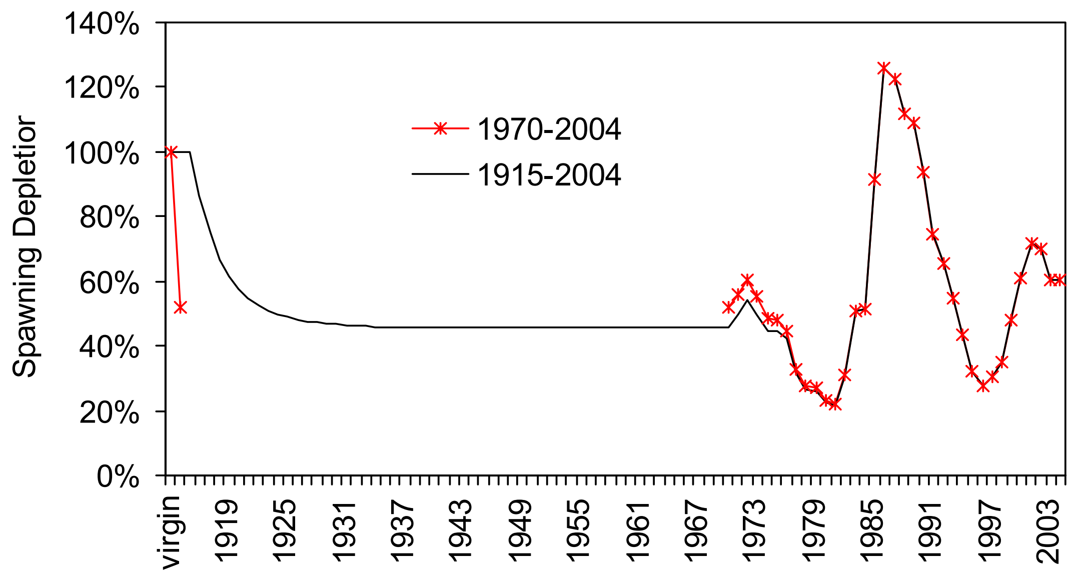


Figure 35. The effect of removing the 1970 equilibrium population assumption from the southern base model. Shown are time series of age 2+ biomass (above) and spawning depletion (below) for the base model (1970-2004) and a model that started in 1915 with no historical catches, but with annual catches of 333 mt and 47 mt from the trawl and recreational fisheries from 1915-1969 (labeled 1915-2004).

APPENDICES

A. Analyses completed for STAR Panel Evaluation of Natural Mortality

B. Southern Model – SS2 data file

C. Southern Model – SS2 control file

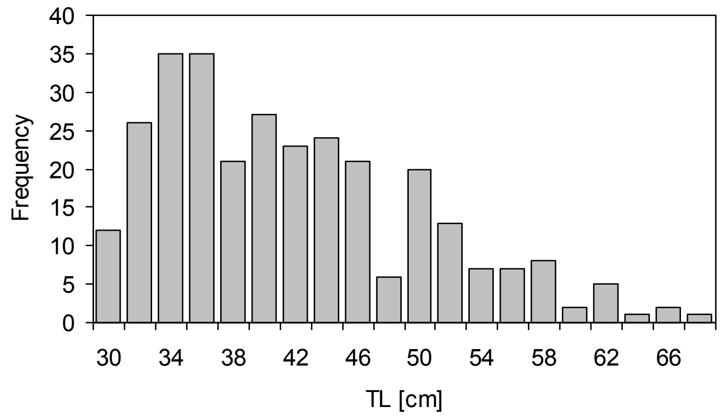
D. Northern Model – SS2 data file

E. Northern Model – SS2 control file

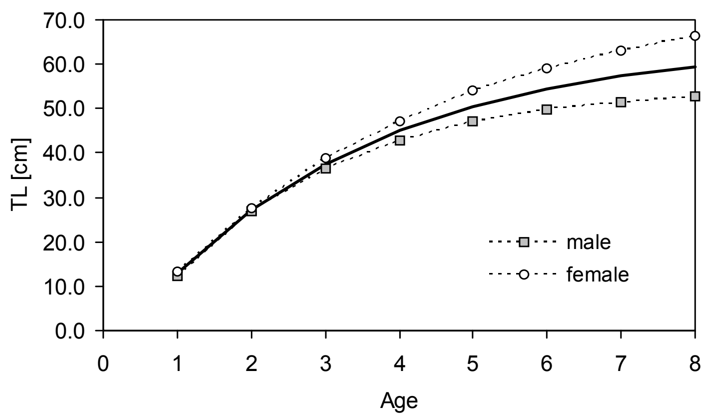
Appendix A. Analyses completed for STAR Panel Evaluation of Natural Mortality

Length-Converted Catch Curve

The STAR panel requested that the commercial length-frequency data be analyzed to estimate mortality rate using a cohort slicing approach. A length-based cohort analysis, as described by Jones (1987), was completed to fulfill that request. The commercial trawl length-frequency data obtained from the PACFIN Biological Data System (BDS) were used as input data to the analysis (see below).

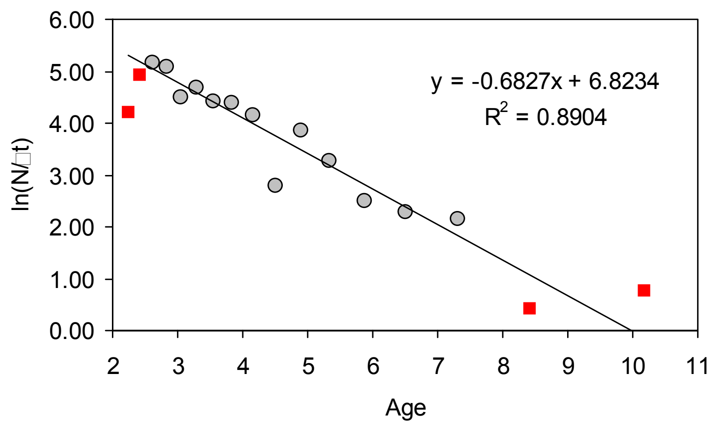


To convert the length-frequency distribution to a "length-converted catch curve" I first estimated a set of combined sex von Bertalanffy growth parameters. This was accomplished by averaging male and female length-at-age estimates from Orcutt (1950) and then fitting the averages to a single growth model, resulting in L_∞ = 64.8 cm, K = 0.323 yr^{-1}, t0 = 0.314 yr (see below).



The combined sex von Bertalanffy growth model was then used in conjunction with the length-frequency data in a length-converted catch curve analysis to estimate the total mortality rate, resulting in Z = 0.68 yr^{-1} (see below).

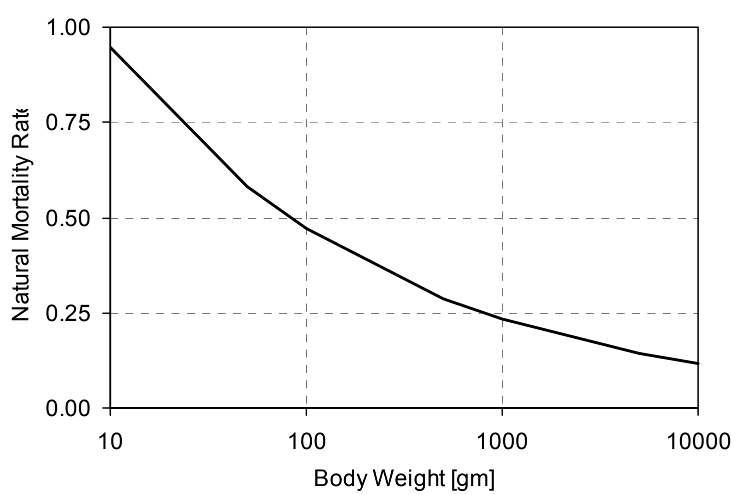
Because these data were collected over a variety of years and localities, it is difficult to make a clear interpretation of the total mortality estimate. Nonetheless, the Panel considered this



result to be consistent with lower values of natural mortality than 0.50-0.75 yr^{-1}.

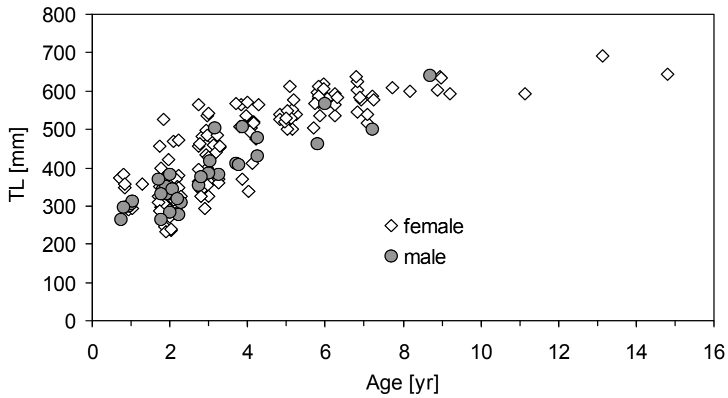
<u>Estimation of Natural Mortality Using Individual Weight</u>

The Panel requested that results in Lorenzen (1996) be used to estimate natural mortality in starry flounder. Through comparative analysis, he showed that natural mortality rate is related to fish size, with larger fish experiencing lower natural mortality rates. Moreover, he stratified his results among different types of ecosystems, including "ocean". Although an error was detected in his intercept parameter value (see his Table I), it was possible to obtain a reasonable estimate from results presented in his Figure 1. Given that starry flounder weights can easily range from 0.5-2.0 kg, his results (see below) suggests a natural mortality rate in the range of 0.20-0.30 yr^{-1}.

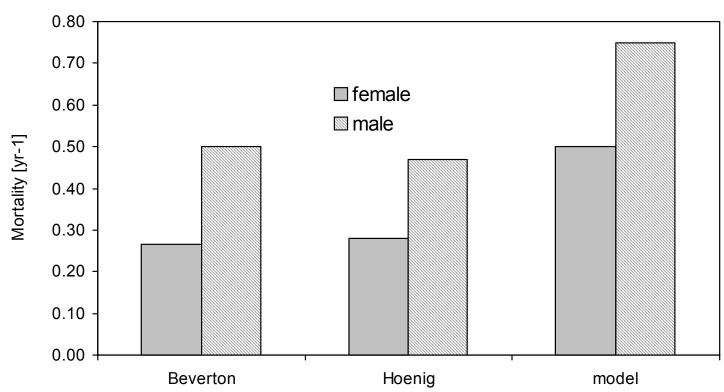


Estimation of Natural Mortality Rate Using Pearson Ages

The Panel also requested that natural mortality rate be estimated using the maximum age estimates observed by Pearson (see Life History Parameters in the main assessment document). While unvalidated, those data were used in the assessment model to estimate length variability at age (Figure 3). Moreover, they were gathered by an experienced age reader with many years of experience aging west coast groundfish. His data indicate that female starry flounder can reach an age of 15 yr, while males can reach 9 yr (see below). These maximum age estimates were obtained from examination of 141 female and 34 male specimens.



These maximum age values were used to estimate natural mortality by applying Hoenig's (1983) and Beverton's (1992) equations. The result (see below) indicates that $M_♀ = 0.27$-0.28, whereas $M_♂ = 0.47$-$0.50\ yr^{-1}$.



Conclusion

The STAR Panel recommended that female natural mortality be fixed at 0.30 yr^{-1} and male natural mortality be fixed at 0.45 yr^{-1}.

Appendix A – Data file for the southern (California) starry flounder model

```
# Southern model for starry flounder
# Begun 12/09, last updated: 12/9/04
# Steve Ralston
# MODEL DIMENSIONS
1970	# start_year
2004	# end_year
1		# N_seasons_per_year
12		#_vector_with_N_months_in_each_season
1		#_spawning_season_-_spawning_will_occur_at_beginning_of_this_season
2		#_N_fishing_fleets
1		# N surveys; data type ID below is sequential with the fisheries
CAtrawl%CAsport%CalFed
 0.5 0.5 0.5	#_surveytiming_in_season
2		#_number_of_genders(1/2)
20		#_accumulator_age;_model_always_starts_with_age_0

333	47	# initial_equilibrium catch	(mt) for each fishing fleet

# Total Catch series (mt)  – landings values inflated by an assumed 25% discard
# CAtrawl CAsport	#	Year
168	73	#	1970
172	47	#	1971
399	59	#	1972
432	75	#	1973
304	62	#	1974
433	51	#	1975
715	48	#	1976
599	45	#	1977
498	48	#	1978
598	58	#	1979
448	112	#	1980
396	39	#	1981
273	51	#	1982
313	51	#	1983
347	32	#	1984
337	19	#	1985
242	33	#	1986
171	69	#	1987
160	56	#	1988
124	29	#	1989
70	24	#	1990
70	19	#	1991
64	14	#	1992
40	9	#	1993
23	5	#	1994
```

20	5	#	1995
37	4	#	1996
61	4	#	1997
82	8	#	1998
64	5	#	1999
38	7	#	2000
66	12	#	2001
40	7	#	2002
39	9	#	2003
39	9	#	2004

#_Fishery & Survey CPUE series
46 #_N_observations
logbook cpue statistics (N=21) fleet1=southern trawl

#Year	Seas	Type	Value	CV		
1983	1	1	11.88	0.29	#	fleet1
1984	1	1	17.94	0.14	#	fleet1
1985	1	1	31.21	0.08	#	fleet1
1986	1	1	21.97	0.08	#	fleet1
1987	1	1	22.80	0.08	#	fleet1
1988	1	1	24.14	0.08	#	fleet1
1989	1	1	17.92	0.10	#	fleet1
1990	1	1	11.65	0.08	#	fleet1
1991	1	1	14.81	0.08	#	fleet1
1992	1	1	9.78	0.07	#	fleet1
1993	1	1	4.46	0.14	#	fleet1
1994	1	1	4.97	0.11	#	fleet1
1995	1	1	5.43	0.10	#	fleet1
1996	1	1	7.69	0.08	#	fleet1
1997	1	1	8.30	0.05	#	fleet1
1998	1	1	13.76	0.05	#	fleet1
1999	1	1	14.07	0.05	#	fleet1
2000	1	1	13.35	0.08	#	fleet1
2001	1	1	14.39	0.06	#	fleet1
2002	1	1	11.50	0.12	#	fleet1
2003	1	1	13.89	0.08	#	fleet1
# age 1 CDFG Bay-Delta Index (N=25)						
1980	1	3	689	0.20	#	CDFG pre-recruit
1981	1	3	1434	0.29	#	CDFG pre-recruit
1982	1	3	293	0.26	#	CDFG pre-recruit
1983	1	3	4017	0.17	#	CDFG pre-recruit
1984	1	3	1440	0.27	#	CDFG pre-recruit
1985	1	3	291	0.32	#	CDFG pre-recruit
1986	1	3	477	0.18	#	CDFG pre-recruit
1987	1	3	395	0.30	#	CDFG pre-recruit
1988	1	3	128	0.27	#	CDFG pre-recruit
1989	1	3	73	0.66	#	CDFG pre-recruit
1990	1	3	66	0.47	#	CDFG pre-recruit

```
1991	1	3	107	0.46	#	CDFG pre-recruit
1992	1	3	138	0.33	#	CDFG pre-recruit
1993	1	3	1	1.00	#	CDFG pre-recruit
1994	1	3	69	0.76	#	CDFG pre-recruit
1995	1	3	177	0.50	#	CDFG pre-recruit
1996	1	3	281	0.46	#	CDFG pre-recruit
1997	1	3	489	0.27	#	CDFG pre-recruit
1998	1	3	776	0.26	#	CDFG pre-recruit
1999	1	3	558	0.19	#	CDFG pre-recruit
2000	1	3	156	0.20	#	CDFG pre-recruit
2001	1	3	85	0.37	#	CDFG pre-recruit
2002	1	3	20	0.95	#	CDFG pre-recruit
2003	1	3	278	0.30	#	CDFG pre-recruit
2004	1	3	294	0.37	#	CDFG pre-recruit

# Discard section #
#_Discard_Biomass
2	# 1=biomass (mt),2=fraction
0	# N_discard observations

# Mean BodyWt (in kg)
0	# N observations
### ADD WCGOP DATA ###
# Partition=1 means discarded catch, 2 means retained catch, 0 means whole catch (discard+retained)
# Year	Seas	Type	Partition	Value	CV

-1		# 0.0001 # min_proportion_for_compressing_tails_of_observed_composition
0.0001	# constant added to expected frequencies

15	#_N_length_bins


#_lower_edge_of_length_bins



11	15	19	23	27	31	35	39	43	47	51	55	59	63	67


#	This is the section where lencomps are entered (both fishery & survey) - by year x season x fleet
0	#N_length_observations
# Gender = 1 means female only
# Gender = 2 means male only
# Gender = 3 means both (each) gender that together sum to 1.0

0	# No need for any ageing info
#20	#_N_age_bins
```

#_lower_age_of_age_bins

#1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
16 17 18 19 20 #

0 # no ageerr types defined
#1 #_number_of_ageerr_types

#_vector_with_stddev_of ageing_precision_for_each_AGE_and_type-one for each model age
type 1: opercular ages
values that follow are the average read ages within bins (if biased enter here)

#0.5 1.5 2.5 3.5 4.5 5.5 6.5 7.5 8.5 9.5 10.5 11.5 12.5 13.5 14.5
15.5 16.5 17.5 18.5 19.5 20.5 21.5 22.5 23.5 24.5 25.5 26.5 27.5 28.5
29.5 30.5 31.5 32.5 33.5 34.5 35.5 36.5 37.5 38.5 39.5 40.5

values that follow are standard deviations of multiple reads at age (or validation results)
#0 0 0.2336773 0.3703697 0.4673546 0.5425818 0.604047 0.6560151 0.7010318
0.7407394 0.7762591 0.8083906 0.8377243 0.8647087 0.8896923 0.9129516
0.9347091 0.9551472 0.9744167 0.9926441 1.0099364 1.0263848 1.0420678
1.0570536 1.0714015 1.0851637 1.098386 1.1111092 1.1233696 1.1351998 1.1466288
1.1576831 1.1683864 1.1787603 1.1888245 1.1985969 1.208094 1.2173309 1.2263214
1.2350784 1.2436137

0 #_N_age_observations

0 #_N_size@age_observations;

#_environmental_data
0 # N_variables

0 # N_observations

999 # end-of-file-marker

Appendix B – Control file for the southern (California) starry flounder model

```
# Southern model starry.ctl
# datafile: starry.dat
 2	#_N_growthmorphs

#_assign_sex_to	each_morph (1=female,2=male)
 1	2

 1	#_N_Areas_(populations)

#_each_fleet/survey_operates_in_just_one_area
#_but_different_fleets/surveys_can be assigned_to_share_same_selex(FUTURE_coding)
 1	1	1	# 2 fisheries and one surveys

 0	#do_migration_(0/1)

# time blocks for time varying parameters
 0	#_N_Block_Designs

# Natural_mortality_and_growth_parameters_for_each_morph
 2		# Last_age_for_natmort_young
 6		# First_age_for_natmort_old
 2		# age_for_growth_Lmin
 6		# age_for_growth_Lmax
 -4		# MGparm_dev_phase

# LO	HI	INIT	PRIOR	P_type	SD	PHASE	env-var	use_dev	dev_minyr dev_maxyr	dev_stddev
	block_type use_block
# morph1 females
0.1	0.6	0.3	0.22	0	0.1	-5	0	0	0	0	0	0	0	#M1_natM_young
-3	3	0	0	0	0.1	-5	0	0	0	0	0	0	0
#M1_natM_old_as_exponential_offset(rel_young)
10	35	27.6	30	0	3	-5	0	0	0	0	0	0	0	#M1_Lmin
35	80	59.13	60	0	10	-5	0	0	0	0	0	0	0	#M1_Lmax
0.10	0.40	0.251	.25	0	1	-5	0	0	0	0	0	0	0	#M1_VBK
0.02	0.25	0.1	.05	0	1	-5	0	0	0	0	0	0	0	#M1_CV-young
-3	3	0.1	1	0	1	-5	0	0	0	0	0	0	0
#M1_CV-old_as_exponential_offset(rel_young)

# morph2 males
0.1	0.9	0.4055	0	0	1	-5	0	0	0	0	0	0	0
#M2_natM_young_as_exponential_offset(rel_morph_1)
-3	3	0	0	0	1	-5	0	0	0	0	0	0	0
#M2_natM_old_as_exponential_offset(rel_young)
10	35	27.03	0	0	1	-5	0	0	0	0	0	0	0	#M2_Lmin_as_exponential_offset
35	80	49.73	0	0	1	-5	0	0	0	0	0	0	0	#M2_Lmax (exponential offset)
```

```
0.20	0.50	0.426	0	0	1	-5	0	0	0	0	0	0	0	#M2_VBK_as_exponential_offset
0.02	0.25	0.1	0	0	1	-5	0	0	0	0	0	0	0
#M2_CV-young_as_exponential_offset(rel_CV-young_for_morph_1)
-3	3	0.1	0	0	1	-5	0	0	0	0	0	0	0
#M2_CV-old_as_exponential_offset(rel_CV-young)

# Add 2+2*gender lines to read the wt-Len and mat-Len parameters
 -3	3	1.474E-05 2.44E-06	0	0.8	-3	0	0	0	0	0.5	0	0	#Female wt-len-1
 -3	3	2.973	3.34694	0	0.8	-3	0	0	0	0	0.5	0	0	#Female wt-len-2
 -3	3	36.89	55	0	0.8	-3	0	0	0	0	0.5	0	0	#Female mat-len-1
 -3	3	-0.836	-0.25	0	0.8	-3	0	0	0	0	0.5	0	0	#Female mat-len-2
 -3	3	1.	1.	0	0.8	-3	0	0	0	0	0.5	0	0	#Female eggs/gm intercept
 -3	3	0.	0.	0	0.8	-3	0	0	0	0	0.5	0	0	#Female eggs/gm slope
 -3	3	1.474E-05 2.44E-06	0	0.8	-3	0	0	0	0	0.5	0	0	#Male wt-len-1
 -3	3	2.973	3.34694	0	0.8	-3	0	0	0	0	0.5	0	0	#Female wt-len-2

# pop*gmorph lines For the proportion of each morph in each area
	0	1	0.5000	0.2	0	9.8	-3	0	0	0	0	0.5	0	0
	#frac to morph 6 in area 1
	0	1	0.5000	0.2	0	9.8	-3	0	0	0	0	0.5	0	0
	#frac to morph 6 in area 1

# pop lines For the proportion assigned to each area
	0	1	1	1	0	0.8	-3	0	0	0	0	0.5	0	0
	#frac to area 1

#_custom-env_read

0	#_	0=read_one_setup_and_apply_to_all_env_fxns;	1=read_a_setup_line_for_each_MGparm_with_Env-var>0


#_custom-block_read
0	#_	0=read_one_setup_and_apply_to_all_MG-blocks;	1=read_a_setup_line_for_each_block	x	MGparm_with_block>0


#	LO	HI	INIT	PRIOR	Pr_type	SD	PHASE

#_Spawner-Recruitment_parameters
1	# SR_fxn:  1=Beverton-Holt
#LO	HI	INIT	PRIOR	Pr_type	SD	PHASE
3	31	8.0	9.3	0	10	1	#Ln(R0)
0.2	1	0.80	0.788	2	0.075	-3	#steepness
0	2	1.0	0.8	0	0.8	-3	#SD_recruitments
-5	5	0	0	0	1	-3	#Env_link
-5	5	0	0	0	1	-3	#init_eq

 0 # index of environmental variable to be used
```

```
# recruitment_residuals
# Note: because phase is (-) rec_devs are not estimate -> stock-reduction SR
# start_rec_year    end_rec_year    Lower_limit    Upper_limit    phase
        1970        2003    -15    15    2

#init_F_setup, for each fleet
# LO    HI    INIT    PRIOR    P_type    SD    PHASE
 0    1    .1    0.05    0    1    1    # fleet CAtrawl
 0    1    .1    0.05    0    1    1    # fleet CAsport

# Catchability
#_add_parm_row_for_each_positive_entry_below(row_then_column)
# Float(0/1)    #Do-power(0/1)    #Do-env(0/1)    #Do-dev(0/1)    #env parm # for each fleet and survey

 1    0    0    0    0    1    # CAtrawl
 0    0    0    0    0    1    # CAsport
 0    0    0    0    0    1    # CalFed age-1 survey

# LO    HI    INIT    PRIOR    P_type    SD    PHASE
 -10    0    -5.5    -5.5    0    30    1    # log(Q) survey (not used, need one line for every "1" above)

#_SELEX_&_RETENTION_PARAMETERS
#_Length selex
# Selex_type  Do_retention(0/1)    Do_male    Mirrored_selex_number

 1    0    0    0    # fleet 1 CAtrawl, Size selex: 1=logistic
 1    0    0    0    # fleet 2 CAsport, Size selex: 1=logistic
 0    0    0    0    # CalFed age-1 survey (1.0 at all sizes)
#_Age selex
# Selex_type    Do_retention(0/1)    Do_male    Mirrored_selex_number

 10    0    0    0    # fleet 1 CAtrawl, Age selex: 10=flat
 10    0    0    0    # fleet 2 CAsport, Age selex: 10=flat
 11    0    0    0    # CalFed age-1 survey
# LO    HI    INIT    PRIOR    P_type    SD    PHASE  env-var    use_dev    dvminyr    dvmaxyr    dev_sd    Block_type useblock
# CA trawl length selectivity
 10    35    30    28    0    10    -50    0    0    0    0    0    0    0    #L50
 0.01    12    5    4    0    10    -50    0    0    0    0    0    0    0    #diff05-95
# CA sport length selectivity
 10    35    25    28    0    10    -50    0    0    0    0    0    0    0    #L50
 0.001    12    5    4    0    10    -50    0    0    0    0    0    0    0    #diff05-95
# CalFed age-1 survey selectivity
 1    2    1    1    0    10    -50    0    0    0    0    0    0    0    #minimum age
 1    2    1    1    0    10    -50    0    0    0    0    0    0    0    #maximum age

#_custom-env_read
 0    #_ 0=read_one_setup_and_apply_to_all;_1=Custom_so_read_1_each
#_custom-block_read
```

```
 0          #_ 0=read_one_setup_and_apply_to_all;_1=Custom_so_see_detailed_instructions_for_N_rows_in_Custom_setup
 -4         #_phase_for_selex_parm_devs

 1          #_max_lambda_phases:_read_this_Number_of_values_for_each_componentxtype_below
 0          #sd_offset (0/1)  multiple this times Log(sd) when calculating the likelihood

#_cpue_lambdas (one for each fleet/survey?)
 1          # fishery CAtrawl
 0          # no cpue statistics from the CAsport fishery
 1          # CalFed age-1 survey

# discard lambda
 1          # fishery south
 1          # fishery sport
 1          # calfed age-1

#_meanwtlambda(one_for_all_sources)
 0

#_lenfreq_lambdas
 0          # fishery south (no data)
 0          # fishery sport (no data)
 0          # calfed age-1  (no data)

#_age_freq_lambdas
 0          # fishery south (no data)
 0          # fishery sport (no data)
 0          # calfed age-1  (no data)

#_size@age_lambdas
 0          # fishery south (no data)
 0          # fishery sport (no data)
 0          # calfed age-1  (no data)

# initial F lambda
 1          # fishery CAtrawl

#_recruitment_deviations_lambda
 1

#_parm_prior_lambda
 1

#_parm_dev_timeseries_lambda
 1

# crashpen lambda
100
```

#max F
0.9

#_end-of-file-marker
999

Appendix C – Data file for the northern (Washington-Oregon) starry flounder model

```
# Northern model for starry flounder
# Begun 03/03/05, last updated: 03/03/05
# Steve Ralston
# MODEL DIMENSIONS
1970	# start_year
2004	# end_year
1		# N_seasons_per_year
12		#_vector_with_N_months_in_each_season
1		#_spawning_season_-_spawning_will_occur_at_beginning_of_this_season
2		#_N_fishing_fleets
0		# N surveys; data type ID below is sequential with the fisheries
WOtrawl%WOsport
0.5	0.5	#_surveytiming_in_season
2		#_number_of_genders(1/2)
20		#_accumulator_age;_model_always_starts_with_age_0

742	40	# initial_equilibrium catch	(mt) for each fishing fleet

# Total Catch series (mt)
#WOtrawl WOsport	#	Year
342	63	#	1970
347	40	#	1971
797	50	#	1972
866	64	#	1973
698	53	#	1974
977	43	#	1975
1575	41	#	1976
1359	38	#	1977
1066	41	#	1978
1096	49	#	1979
798	171	#	1980
765	129	#	1981
573	49	#	1982
327	29	#	1983
178	17	#	1984
737	15	#	1985
227	12	#	1986
259	11	#	1987
389	11	#	1988
633	16	#	1989
392	13	#	1990
869	10	#	1991
158	7	#	1992
155	4	#	1993
95	0	#	1994
```

67	0	#	1995
41	0	#	1996
84	3	#	1997
71	4	#	1998
30	3	#	1999
34	0	#	2000
10	8	#	2001
25	15	#	2002
24	8	#	2003
96	8	#	2004

#_Fishery & Survey CPUE series
17 #_N_observations
logbook cpue statistics (N=21) fleet1 and (N=17) fleet3

#Year	Seas	Type	Value	CV		
1987	1	1	73.92	0.12	#	fleet1
1988	1	1	85.88	0.11	#	fleet1
1989	1	1	101.31	0.10	#	fleet1
1990	1	1	61.83	0.12	#	fleet1
1991	1	1	82.28	0.10	#	fleet1
1992	1	1	31.92	0.12	#	fleet1
1993	1	1	37.93	0.10	#	fleet1
1994	1	1	28.93	0.09	#	fleet1
1995	1	1	24.34	0.09	#	fleet1
1996	1	1	25.49	0.11	#	fleet1
1997	1	1	45.21	0.10	#	fleet1
1998	1	1	57.91	0.09	#	fleet1
1999	1	1	19.71	0.11	#	fleet1
2000	1	1	53.34	0.12	#	fleet1
2001	1	1	18.19	0.13	#	fleet1
2002	1	1	10.90	0.11	#	fleet1
2003	1	1	14.00	0.14	#	fleet1

Discard section
#_Discard_Biomass
2 # 1=biomass (mt),2=fraction
0 # N_discard observations

Mean BodyWt (in kg)
0 # N observations
ADD WCGOP DATA
Partition=1 means discarded catch, 2 means retained catch, 0 means whole catch (discard+retained)
Year Seas Type Partition Value CV

-1 # 0.0001 # min_proportion_for_compressing_tails_of_observed_composition
0.0001 # constant added to expected frequencies

15 #_N_length_bins

#_lower_edge_of_length_bins

11 15 19 23 27 31 35 39 43 47 51 55 59 63 67

This is the section where lencomps are entered (both fishery & survey) - by year x season x fleet
0 #N_length_observations
Gender = 1 means female only
Gender = 2 means male only
Gender = 3 means both (each) gender that together sum to 1.0

0 # No need for any ageing info
#20 #_N_age_bins

#_lower_age_of_age_bins

#1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
16 17 18 19 20 #

0 # no ageerr types defined
#1 #_number_of_ageerr_types

#_vector_with_stddev_of ageing_precision_for_each_AGE_and_type-one for each model age
type 1: opercular ages
values that follow are the average read ages within bins (if biased enter here)

#0.5 1.5 2.5 3.5 4.5 5.5 6.5 7.5 8.5 9.5 10.5 11.5 12.5 13.5 14.5
15.5 16.5 17.5 18.5 19.5 20.5 21.5 22.5 23.5 24.5 25.5 26.5 27.5 28.5
29.5 30.5 31.5 32.5 33.5 34.5 35.5 36.5 37.5 38.5 39.5 40.5

values that follow are standard deviations of multiple reads at age (or validation results)
#0 0 0.2336773 0.3703697 0.4673546 0.5425818 0.604047 0.6560151 0.7010318
0.7407394 0.7762591 0.8083906 0.8377243 0.8647087 0.8896923 0.9129516
0.9347091 0.9551472 0.9744167 0.9926441 1.0099364 1.0263848 1.0420678
1.0570536 1.0714015 1.0851637 1.098386 1.1111092 1.1233696 1.1351998 1.1466288
1.1576831 1.1683864 1.1787603 1.1888245 1.1985969 1.208094 1.2173309 1.2263214
1.2350784 1.2436137

0 #_N_age_observations

0 #_N_size@age_observations;

#_environmental_data

0	#	N_variables
0	#	N_observations

999 # end-of-file-marker

Appendix D – Control file for the northern (Washington-Oregon) starry flounder model

```
# starry.ctl -- model for the northern area (Oregon & Washington)
# datafile: starry.dat
 2        #_N_growthmorphs

#_assign_sex_to     each_morph (1=female,2=male)
 1        2

 1        #_N_Areas_(populations)

#_each_fleet/survey_operates_in_just_one_area
#_but_different_fleets/surveys_can be assigned_to_share_same_selex(FUTURE_coding)
 1        1        # 2 fisheries and no survey

 0        #do_migration_(0/1)

# time blocks for time varying parameters
 0        #_N_Block_Designs

# Natural_mortality_and_growth_parameters_for_each_morph
 2                 # Last_age_for_natmort_young
 6                 # First_age_for_natmort_old
 2                 # age_for_growth_Lmin
 6                 # age_for_growth_Lmax
 -4                # MGparm_dev_phase

# LO    HI      INIT            PRIOR   P_type  SD      PHASE   env-var use_dev dev_minyr dev_maxyr     dev_stddev
        block_type use_block
# morph1 females
0.1     0.6     0.3     0.22    0       0.1     -5      0       0       0       0       0       0       0       #M1_natM_young
-3      3       0       0       0       0.1     -5      0       0       0       0       0       0       0
#M1_natM_old_as_exponential_offset(rel_young)
10      35      27.6    30      0       3       -5      0       0       0       0       0       0       0       #M1_Lmin
35      80      59.13   60      0       10      -5      0       0       0       0       0       0       0       #M1_Lmax
0.10    0.40    0.251   .25     0       1       -5      0       0       0       0       0       0       0       #M1_VBK
0.02    0.25    0.1     .05     0       1       -5      0       0       0       0       0       0       0       #M1_CV-young
-3      3       0.1     1       0       1       -5      0       0       0       0       0       0       0
#M1_CV-old_as_exponential_offset(rel_young)

# morph2 males
0.1     0.6     0.405   0       0       1       -5      0       0       0       0       0       0       0
#M2_natM_young_as_exponential_offset(rel_morph_1)
-3      3       0       0       0       1       -5      0       0       0       0       0       0       0
#M2_natM_old_as_exponential_offset(rel_young)
10      35      27.03   0       0       1       -5      0       0       0       0       0       0       0       #M2_Lmin_as_exponential_offset
35      80      49.73   0       0       1       -5      0       0       0       0       0       0       0       #M2_Lmax (exponential offset)
```

```
0.20	0.50	0.426	0	0	1	-5	0	0	0	0	0	0	0	#M2_VBK_as_exponential_offset
0.02	0.25	0.1	0	0	1	-5	0	0	0	0	0	0	0
#M2_CV-young_as_exponential_offset(rel_CV-young_for_morph_1)
-3	3	0.1	0	0	1	-5	0	0	0	0	0	0	0
#M2_CV-old_as_exponential_offset(rel_CV-young)

# Add 2+2*gender lines to read the wt-Len and mat-Len parameters
 -3	3	1.474E-05 2.44E-06	0	0.8	-3	0	0	0	0	0.5	0	0	#Female wt-len-1
 -3	3	2.973	3.34694	0	0.8	-3	0	0	0	0	0.5	0	0	#Female wt-len-2
 -3	3	36.89	55	0	0.8	-3	0	0	0	0	0.5	0	0	#Female mat-len-1
 -3	3	-0.836	-0.25	0	0.8	-3	0	0	0	0	0.5	0	0	#Female mat-len-2
 -3	3	1.	1.	0	0.8	-3	0	0	0	0	0.5	0	0	#Female eggs/gm intercept
 -3	3	0.	0.	0	0.8	-3	0	0	0	0	0.5	0	0	#Female eggs/gm slope
 -3	3	1.474E-05 2.44E-06	0	0.8	-3	0	0	0	0	0.5	0	0	#Male wt-len-1
 -3	3	2.973	3.34694	0	0.8	-3	0	0	0	0	0.5	0	0	#Female wt-len-2

# pop*gmorph lines For the proportion of each morph in each area
	0	1	0.5000	0.2	0	9.8	-3	0	0	0	0	0.5	0	0
	#frac to morph 6 in area 1
	0	1	0.5000	0.2	0	9.8	-3	0	0	0	0	0.5	0	0
	#frac to morph 6 in area 1

# pop lines For the proportion assigned to each area
	0	1	1	1	0	0.8	-3	0	0	0	0	0.5	0	0
	#frac to area 1

#_custom-env_read

0	#_	0=read_one_setup_and_apply_to_all_env_fxns;	1=read_a_setup_line_for_each_MGparm_with_Env-var>0


#_custom-block_read
0	#_	0=read_one_setup_and_apply_to_all_MG-blocks;	1=read_a_setup_line_for_each_block	x	MGparm_with_block>0


#	LO	HI	INIT	PRIOR	Pr_type	SD	PHASE

#_Spawner-Recruitment_parameters
1	# SR_fxn:  1=Beverton-Holt
#LO	HI	INIT	PRIOR	Pr_type	SD	PHASE
5	14	8.70	8.3	0	10	1	#Ln(R0)
0.2	1	0.80	0.788	2	0.075	-3	#steepness  (NOTE that I changed prior and SD to Get the beta to work [but I changed back])
0	2	1.0	0.8	0	0.8	-3	#SD_recruitments
-5	5	0	0	0	1	-3	#Env_link
-5	5	0	0	0	1	-3	#init_eq

 0 # index of environmental variable to be used
```

```
# recruitment_residuals
# Note: because phase is (-) rec_devs are not estimate -> stock-reduction SR
# start_rec_year    end_rec_year    Lower_limit    Upper_limit    phase
        1970        2002    -15     15      2

#init_F_setup, for each fleet
# LO      HI      INIT      PRIOR   P_type    SD      PHASE
 0        1       0.10      0.05    0         1       1       # fleet WOtrawl
 0        1       0.02      0.05    0         1       1       # fleet WOsport

# Catchability
#_add_parm_row_for_each_positive_entry_below(row_then_column)
# Float(0/1)    #Do-power(0/1)    #Do-env(0/1)    #Do-dev(0/1)    #env parm # for each fleet and survey

 1     0     0     0     0     1          # WOtrawl
 0     0     0     0     0     1          # WOsport

# LO    HI    INIT    PRIOR    P_type    SD    PHASE
 -10    0     -5.6    -5.6     0         20    2          # log(Q) survey (not used, need one line for every "1" above)

#_SELEX_&_RETENTION_PARAMETERS
#_Length selex
# Selex_type  Do_retention(0/1)    Do_male    Mirrored_selex_number

 1          0          0          0          # fleet 3 WOtrawl, Size selex: 1=logistic
 1          0          0          0          # fleet 4 WOsport, Size selex: 1=logistic
#_Age selex
# Selex_type    Do_retention(0/1)    Do_male    Mirrored_selex_number

 10         0          0          0          # fleet 3 WOtrawl, Age selex: 10=flat
 10         0          0          0          # fleet 4 WOsport, Age selex: 10=flat
# LO    HI    INIT    PRIOR    P_type    SD    PHASE  env-var    use_dev    dvminyr    dvmaxyr    dev_sd    Block_type useblock
# WO trawl length selectivity
 10     35    30      28       0         10    -50    0    0    0    0    0    0    0    #L50
 0.01   12    5       4        0         10    -50    0    0    0    0    0    0    0    #diff05-95
# WO sport length selectivity
 10     35    25      28       0         10    -50    0    0    0    0    0    0    0    #L50
 0.001  12    5       4        0         10    -50    0    0    0    0    0    0    0    #diff05-95

#_custom-env_read
 0     #_ 0=read_one_setup_and_apply_to_all;_1=Custom_so_read_1_each
#_custom-block_read
 0     #_ 0=read_one_setup_and_apply_to_all;_1=Custom_so_see_detailed_instructions_for_N_rows_in_Custom_setup
 -4    #_phase_for_selex_parm_devs

 1     #_max_lambda_phases:_read_this_Number_of_values_for_each_componentxtype_below
 0     #sd_offset (0/1)  multiple this times Log(sd) when calculating the likelihood
```

```
#_cpue_lambdas (one for each fleet/survey?)
 1		# fishery WOtrawl
 0		# no cpue statistics from the WOsport fishery

# discard lambda
 1		# WOtrawl
 1		# WOsport

#_meanwtlambda(one_for_all_sources)
 0

#_lenfreq_lambdas
 0		# WOtrawl (no data)
 0		# WOsport (no data)

#_age_freq_lambdas
 0		# WOtrawl (no data)
 0		# WOsport (no data)

#_size@age_lambdas
 0		# WOtrawl (no data)
 0		# WOsport (no data)

# initial F lambda
 1		# fishery CAtrawl

#_recruitment_deviations_lambda
 1

#_parm_prior_lambda
 1

#_parm_dev_timeseries_lambda
 1

# crashpen lambda
100

#max F
0.9
#_end-of-file-marker
999
```