STATUS OF THE CALIFORNIA SHEEPHEAD (*SEMICOSSYPHUS PULCHER*) STOCK (2004)

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EXECUTIVE SUMMARY

Stock: California Sheephead (*Semicossyphus pulcher*) is found along the coast of California from Monterey Bay southward down into Baja California, Mexico. Sheephead have been fished recreationally and commercially for most of the last century.

Catches: Post-1950 commercial landings peaked both in the 1950s and the 1990s with recreational fishing showing an increase in landings in the 1980s and both commercial and recreational landings have been lower in recent years.

Data and assessment: The California population of California Sheephead was assessed using a "Stock Synthesis" (hereafter called Synthesis) length-based model. Landings data were summarized as four distinct fisheries: three commercial fisheries (hook and line, setnet and trap) and one recreational fishery. Landings data were supplemented by four abundance indices and length composition data associated with each of the four fisheries. Three of the four abundance indices were catch per unit effort (CPUE) measures based on landings and effort data from the California Passenger Fishing Vessel (CPFV) logbook recreational fishery for different time frames and units of effort. The fourth abundance index was based on the California Cooperative Oceanic Fisheries Investigation (CalCOFI) larval survey data. Selectivity curves differed among fisheries and the selectivity of the three CPUE indices from the recreational fishery were assumed to have the same selectivity as estimated for the recreational fishery.

Status of the stock: Changes in the spawning potential ratio based on estimated current and unfished mature female and male spawning biomass indicates that the stock is below the target level of 50% of the unfished condition described by the Nearshore Fishery Management Plan (NFMP). For the most likely scenario, the spawning potential ratio of California Sheephead (based on mature biomass) has been reduced to 20% of the unfished condition. Application of the NFMP 60/20 policy indicates that a reduction in allowable catch is warranted.

Recommendations: Data needs include sex-specific age and length records of individual fish (also by location and fishing depth, if possible) from the recreational and commercial fisheries. These data are needed to 1) resolve uncertainty about growth rates and the coefficient of variation in individual size at age; 2) specify current age and lengths at maturity; 3) specify current age and length at sex change; and to determine the extent of spatial variability in these life history features. Further refinement of the sex change dynamics and relevant life history parameters (especially individual variation in growth) would also improve our ability to interpret the fishery data. Behavioral studies of the effect of removing territorial males and the speed with which replacement dominant males and harems are re-established would help resolve whether total fishing closure in some areas is more or less effective than reduced fishing intensity in all areas. Finally, further information on the abundance and exploitation of Sheephead in Mexico would improve the ability to assess and manage Sheephead.

1. INTRODUCTION

California Sheephead (*Semicossyphus pulcher*; previously *Pimelometopon pulchrum*) is in the genus Labridae. Most species in this genus are small reef fish that are not exploited. In contrast, California Sheephead can grow to sizes that exceed 80 cm and are found in shallow temperate waters along the Pacific coast from Monterey Bay, California to Cabo San Lucas, Mexico (Figure 1.1). In this report, we describe the first quantitative stock assessment of this species although it has been fished commercially and recreationally for a large part of the past century.

Sections 2 through 7 of this report were prepared prior to a formal stock assessment review, and are mostly unchanged from the material that was initially presented to the Review Panel. Many aspects of the assessment model were changed during the review, and the Panel asked for some follow-up analyses. The final assessment model based on the review is given in section 8, and is the Assessment Team's best effort to accommodate the Review Panel's recommendations. However, Section 8 itself was not reviewed by the Panel.

2. HISTORY OF FISHERY

2.1 Commercial Fishery: Beginning with the salted fish fishery in the 1800s, California Sheephead have maintained a presence in the California nearshore fishery. From the early 1920s, Sheephead sporadically appeared in reported landings for the nearshore fishery, with booms in harvest from 1927 to 1931, and again from 1943 to 1947, peaking in 1928 at 370,000 lbs.

Excluding these periods of high landings, the average annual commercial harvest averaged just 10,000 lbs until the live-fish fishery appeared in the 1980s. The development of this new fishery corresponded to an upward trend in landings, ultimately reaching a peak of 366,000 lbs in 1997. During this time, prices, adjusted for inflation, increased from $0.10/lb in the 1940s to 1980s to over $9.00/lb for live-fish in the 1990s (Stephens 2001).

In just three years (between 1989 and 1992), the nearshore, live-fish trap fishery increased from 2 to 27 boats landing over 52,000 lbs of live fish (Palmer-Zwahlen et al. 1993). Sheephead accounted for more than 88% of live fish landed in the developing live-fish fishery, which has greatly contributed to the large increase in total commercial landings. During the early years of the fishery, commercial hook and line Sheephead landings totaled more than 165,000 lbs, of which over 66% belonged to the live-fish fishery (Palmer-Zwahlen et al. 1993).

2.2 Recreational Fishery: Sheephead are caught by hook and line as well as by spearfishers (Young 1973). Landings in the recreational fishery for Sheephead exceeded commercial catch between 1980 and 1989 (Figure 2.1, Schroeder and Love 2002), and most likely before this as well, except during the two boom times for the commercial fishery (Palmer-Zwahlen et al. 1993). In 2002, Sheephead ranked 13th in landings in the southern California recreational fishery. Large, old individuals are especially vulnerable to depletion by recreational spearfishing because of the ease at which they can be spotted and speared (CDFG 2003).

2.3 Artisanal Fishery: Sheephead represent a large proportion of the artisanal fishery in Baja California, Mexico, comprising over 25% of the catch, with this proportion increasing in summer

months. This fishery is primarily comprised of individuals or small groups fishing with hook and line on boats less than 8 m long, fishing less than 15 fathoms from shore. The artisanal fishery tends to be a mixed fishery dominated by *Sebastes ssp*. In 1994, a study of the artisanal fishery of the northwestern coast of Baja California (from Santo Tomas to south of Punta Canoas) found that of 2490 fish caught (representing 2692.7 kg), six hundred forty-five (26%) were Sheephead. In this sample, the mean standard length of Sheephead was 312.2 ± 56.8 mm (Rosales-Casian and Gonzalez-Camaho 2003).

2.4 Regulation: Of the 19 nearshore species managed under the Nearshore Fishery Management Plan (NFMP), 16 (13 species of nearshore rockfish, California scorpionfish, cabezon, and kelp greenling) are designated as groundfish and fall under the management authority by the Pacific Fishery Management Council (PFMC). California Sheephead, monkeyface prickleback (also called monkeyface eel), and rock greenling do not have groundfish designation, thus do not fall under the management by the PFMC. Furthermore, the PFMC has not actively managed cabezon or kelp greenling. This lack of PFMC management led to State of California regulations for California Sheephead, the two greenling species, and cabezon (CDFG 2002). Regulations for California Sheephead tend to fall under the general nearshore fishery regulations. The commercial fishery for both trap and hook and line gear is a restricted access fishery. Permits for the live-fish trap fishery began in 1996 in southern California and a statewide Nearshore Fishery Permit began in 1999. These permits are limited to individuals who have participated in the fishery the previous year as well as meeting historical catch criteria.

The Sheephead trap and hook and line fisheries reached optimal yield (OY) levels and closed early for all years, beginning in 2001. According to the NFMP, "Optimum yield (OY) is defined in FGC §97 as the amount of fish taken in a fishery that does all of the following: (a) provides the greatest overall benefit to the people of California, particularly with respect to food production and recreational opportunities, and takes into account the protection of marine ecosystems, and (b) is the MSY of the fishery, reduced by relevant economic, social, or ecological factors, and (c) in the case of an overfished fishery, provides for rebuilding to a level consistent with producing MSY in the fishery (CDFG 2002)." The 2002 OY was set to half that of total recent catches, and allocated almost 50,000 lbs more to the recreational fishery than the commercial fishery.

Size restrictions on Sheephead were fairly minimal before 1999 for both the recreational and commercial fisheries. In 1999, CDFG set the minimum catch size for the commercial fishery to 12 inches (total length) and followed with the same size limit for the recreational fishery in 2001. To further decrease commercial harvest, the minimum commercial harvest size was increased to 13 inches in 2001. Also in 2001, the 10 fish recreational bag limit was reduced to five (NFMP Table 1.2-17, CDFG 2002)

In 2002, the Sheephead fishery was aligned with the nearshore rockfish fishery for both the commercial and recreational fisheries (CDFG 2002). Sheephead are not to be taken commercially north of Point Conception, Santa Barbara County during March and April, and south of Point Conception during January and February. This essentially represents a seasonal closure because the bulk of landings occur south of Point Conception (CDFG 2002). Other

season and area closures affecting the Sheephead fishery result from management of the nearshore fishery. In 2001, taking Sheephead deeper than 20 fathoms in a Cowcod Conservation Area was banned.

3. BIOLOGICAL INFORMATION

The California Sheephead is a protogynous (female to male) sequential hermaphrodite (Warner 1973; Warner 1975) found near-shore along the Pacific Coast of California and Mexico and into the Gulf of Mexico (Miller and Lea 1972). Sheephead are generalist carnivores (Cowen 1983) and feed on species such as mussels (Robles and Robb 1993) and red sea urchins (*Strongylocentrotuys franciscanus*) (Tegner and Dayton 1981; Cowen 1983) and may play an important role in regulating the density of their prey (Cowen 1983; Hobson and Chess 1986; Robles 1987; Robles and Robb 1993).

3.1 Age and Natural Mortality: Two studies used observed patterns of age structure to estimate (annual) natural mortality in California Sheephead by assuming age- and sex- independent mortality. Warner (1975) estimated the annual survival at Catalina Island, California and Guadalupe Island, Mexico to be approximately 0.7 while Cowen (1990) estimated annual survivorship in 5 different populations ranging from 0.577 at Guadalupe Island, Mexico to 0.745 at San Nicolas Island, California (see Table 3.1, Figure 1.1). Since the relationship between mortality rate and survivorship is given by $S=e^{-M}$ (where M is annual natural mortality rate and S is annual survival), we use M=0.35 as the baseline natural mortality and conduct sensitivity

analyses on natural mortality by allowing the parameter to vary ranging from 0.05 to 0.5 in our assessment. The oldest fish ever reported was 53 years old (Fitch 1974). However, size at age data based on dorsal spines found fish that were at most 21 years old (Cowen 1990). Therefore we used the 53-year-old fish to set a realistic lower bound on mortality. Based on Hoenig (1983), this corresponds with a constant mortality of 0.07 approximately. Thus we use 0.05 as a lower bound for our sensitivity analyses. The upper bound was determined by the populations with the lowest observed survival (see Table 3.1).

3.2 Growth: The precise growth patterns as well as size and age distributions of Sheephead in the wild appear to vary slightly among sites and over time (Warner 1973; Warner 1975; Cowen 1990; DeMartini et al. 1994). The largest individual ever observed was 91 cm (Miller and Lea 1972). DeMartini et al. (1994) found the relationship (R^2=0.92 $p<0.0001$ N=61) between total length (in inches) L_T and wet body weight W (in grams) to be

$$\ln W = \ln 0.688 + 2.723 \ln L_T \qquad (3.1)$$

We used the following relationship from the Recreational Fisheries Information Network (RecFIN) database to convert total length (L_T) in cm to fork length (L_F) in cm

$$L_F = -1.4564 + 1.094\, L_T \qquad (3.2)$$

For our model, we used the power relationship in Equation 3.1 and the length conversion from Equation 3.2 to calculate the expected relationship (Figure 3.1) between fork length in centimeters L_F and body weight in kilograms W

$$W=aL_F^b \qquad \text{where } a=0.000026935 \text{ and } b=2.857 \qquad (3.3)$$

Using linear regression, we found the relationship between standard length and total length for California Sheephead using individual lengths from the Central California Spearfishing Tournament database (CenCAL, N=100). We excluded one data point because it reported the biologically impossible situation where total length was less than standard length. This gave the relationship between standard length in cm L_s and total length in cm L_T

$$L_T = 0.604 + 1.207\ L_S \qquad (3.4)$$

We used the size at age data (converted into fork length using Equations 3.2 and 3.4) for Catalina Island, California published in Warner (1973) for our baseline estimates and size at age data from Cowen (1990) for sensitivity analyses on these parameters. Because we did not have any age data from the fisheries or surveys, we fixed the growth parameters within any single run of the model rather than allow them to be estimated. However, we performed sensitivity analyses on these growth parameters as described in greater detail below.

We found the best-fit estimates of growth parameters by minimizing the sum of squared deviations between the predicted and observed size at age (Hilborn and Mangel 1997). We

compared the ability of four different methods of fitting the growth parameters k and L_{inf} to predict the observed growth data. We first used a Ford Plot (Quinn and Deriso 1999) with an unconstrained L_{inf} and found the growth parameter k and asymptotic size L_{inf} that best fit the data. Second, we used a Ford Plot but constrained L_{inf} to be the maximum observed size of 91 cm and only fit the growth rate k. Both of these approaches lead to a good fit between the predicted change in size between ages and the observed size at age data (SS_1=18.68 and SS_2=19.15). Third, we fit the growth rate k using the Schnute (1981) parameterization of the von Bertalanffy growth equation with an estimated L_{inf} using t_1=1, L_1=12.92 and t_2=13, L_2=52.60 cm fork length (the smallest and largest ages for which a mean size at age was given in Warner (1975) data). Finally, we fit the Schnute (1981) parameterization with the asymptotic size L_{inf} set to maximum observed size. The estimated mean size at age predicted from the best-fit growth parameters using the third and fourth approach did not fit the data well (SS_3=1988.71 and SS_4=1687.07). The Ford plot with an unconstrained asymptotic size (predicting the size at time t+1 from time t) gave the best fit to the observed size at age data and thus we used these estimates of the growth parameters in the baseline version of the model (k=0.068, L_{inf}=83.86 cm, Figure 3.2). Although this gave a smaller asymptotic size than the maximum size ever reported, it was a better fit with the observed size at age data and is consistent with the maximum length of fish observed in the fisheries (see Section 4). Because Synthesis uses the Schnute parameterization of the von Bertalanffy growth equation (Schnute 1981; Methot 2000), we used the parameters t_1=1 (years), L_1=12.92 (cm fork length), t_2=13 (years), L_2=52.60 (cm fork length) and k=0.068 as the baseline values in our model (Figure 3.2). We also used the same method to find growth parameters for the other populations for which we had data (Warner 1975; Cowen 1990) and used each set of growth parameters (given in Table 3.1, Figure 3.3) in a separate run

of the model as a sensitivity analysis on size at age. We also used the error bars in the mean size at age data given in Warner (1975) to estimate a coefficient of variation in size. The small sample sizes (N=2 to 12 for each age class) led to a very high estimate for coefficient of variation of growth per age class (CV=0.3) so we used this value as an upper bound for the Synthesis model and allowed the model to estimate the coefficient of variation at age (CV_1 and CV_2).

3.3 Distribution and Abundance: Sheephead are found from Monterey Bay to the Gulf of California (see Figure 1.1) but are uncommon north of the Point of Conception and are much less common in the Gulf of California than along the Pacific Coast (Miller and Lea 1972). In the Channel Islands, densities of 1475-1525 individuals of all sizes per hectare have been observed (Davis and Anderson 1989) while Cowen (1985) reports densities ranging from 16-290 adult fish per hectare.

3.4 Dispersal: Tagged adult Sheephead were usually caught again on the same reef (DeMartini et al. 1994), showed little movement (Davis and Anderson 1989) and a high rate of recapture (71%, 36 of 51 individuals) (DeMartini et al. 1994). Although weak population structure has been found between southern California and Baja California, Mexico (Waples and Rosenblatt 1987), the genetic structure is consistent with frequent dispersal among populations, probably at the early life stages although adults may disperse short distances through deep water. Bernardi et al. (2003) found no genetic structure between populations of Sheephead both when comparing Pacific and Gulf of California populations and when comparing California with Mexican populations along the Pacific coast (F_{ST}=0) (Bernardi et al. 2003). Thus, there appears to be high

levels of gene flow between populations of Sheephead, at least for evolutionary time scales (Bernardi et al. 2003).

3.5 Recruitment: Recruitment patterns are temporally and seasonally variable (Cowen 1985; Cowen 1985; Cowen 1991). Sheephead have a pelagic larval stage prior to recruitment in shallow waters. Although the pelagic larval duration ranges from 37-78 days, the size at settlement varies little (range 12.7-16 mm and mean 13.5 mm) and growth after settlement is not affected by age at settlement (Cowen 1991). A comparison of 9 years of recruitment data found that recruitment patterns (based on field transects as well as age structure data) are highly variable but can be related to oceanographic data and proximity to other populations that may supply larva (Cowen 1985). Cowen (1985) also found a positive relationship between adult density and recruitment, but did not report any other evidence of density-dependence. Sheephead larval availability depends on season and peaks July to October and larva are found mainly nearshore (Cowen 1985).

3.6 Maturity and Sex Change: California Sheephead individuals have been observed to mature at about 4 years of age and with a mean standard length of 20 cm (Warner 1975) although individual variation as well as differences among populations exist (Cowen 1990). Sex change occurs at approximately 30 cm standard length at an age of 7-8 years although it can occur at standard lengths as low as 18 cm and ages as young as 4 years (Warner 1975; Cowen 1990). The degree to which sex change is determined by endogenous versus exogenous cues is not known. However, sex change appears to depend on size rather than age and the size at sex change is consistent with predictions of the size-advantage model (Cowen 1990). Populations with higher

growth rates and higher survival also have larger sizes at sex change and sex ratio seemed to affect population patterns of sex change as well (Cowen 1990). Warner (1975) reports the frequency of immature individuals, mature females and mature males at Catalina Island, California. We used these data to find the L_{50} (length at which the proportion mature or male is 50%) for maturity and sex change. We then fit these data to a logistic function estimating the slope parameter that minimized the sum of squared deviations between the predicted and observed proportion of mature individuals and the proportion of mature individuals that are female for use in the model. We used the parameters based on the Catalina Island data for our baseline model and use the other maturity and sex change parameters for sensitivity analyses (see Table 3.1, Figure 3.4).

3.7 Fecundity: Reproduction occurs June through early October, while sex change occurs during the winter months (Warner 1975; Cowen 1990). Females appear to spawn multiple times during the reproductive season. DeMartini et al. (1994) estimated that females spawn approximately 86 times per year (about every 1.3 days) and calculated the batch fecundity of females to be 5755 eggs per spawning event, but found no significant relationship between the number of eggs released per kilogram of body weight and total female body weight (an average of 15 eggs per gram of body weight or 15,000 eggs per kg, DeMartini et al. 1994). From these data, we estimate both the total egg production of a female based on her weight (Figure 3.5 dashed line) as well as the annual total egg production per kilogram of female body weight (batch fecundity per kg and number of patches per year, Figure 3.6 dashed line).

Warner (1975) found that the ovary weight (O_W in grams) of females scaled with standard length (L in cm) according to

$$O_W=0.00131\ L^{2.95} \qquad (3.4)$$

Warner (1975) also found that on average females have 5377 yolky oocytes per gram of female gonad. Thus it is also possible to estimate the total and mass-specific egg production from Warner (1975) and the weight-length relationship given in Equation 3.3 (Figures 3.5 and 3.6). The difference in the exponents between Equation 3.3 and 3.4 imply that a weak increase in mass-specific egg production is predicted (Figure 3.6). However, in the weight and size range in which individuals are actually expected to be female, the relationship is nearly linear. Furthermore, one set of data measured the number of eggs being spawned while the other counted the number of oocytes in the gonad. These lead to slightly different estimates of total egg production. However, the general functional form is basically the same (Figures 3.5 and 3.6). Since the number of eggs actually spawned by females is a better estimate of total egg production, we used the DeMartini at al.(1994) based estimates of fecundity for our baseline version of the model. However, we explored the effect of the lower oocyte production from Warner (1975) as one of our sensitivity analyses.

Nothing is known about fertilization rates or sperm production in California Sheephead. At high fishing mortality, the potential for sperm limitation exists since fishing may remove large males preferentially (Alonzo and Mangel 2004). However in Sheephead, large males may experience sperm competition from smaller males (Adreani et al. In Press) and thus sperm production may

be high in this species (Birkhead and Møller 1998) making the species less prone to sperm limitation.

4. DATA SOURCES AND INITIAL ANALYSIS

4.1 Fishery Catch Data: We divided the catches into four separate fisheries, three commercial and one recreational. The commercial fishery was divided by three gear groups: hook and line, trap and setnet. We attributed all commercial landings to the hook and line fishery prior to 1978, when the Pacific States Marine Fisheries Commission (PSMFC) began a sampling program so catch could be estimated by gear. The recreational catch is landed primarily by the Commercial Passenger Fishing Vessel (CPFV) fleet. Logbook-based catch estimates consistently began around 1947. Table 4.1 summarizes commercial (by gear) and recreational catch used in this assessment.

Commercial Catch: Commercial landings date back to 1916 and come from three sources. We used landings from 1916 – 1977 that were reported in *California's Living Marine Resources: A Status Report*, which include landings brought into California from Mexico. We did not have catch data for any other fishery prior to 1947, so we calculated the mean catch from 1937-1946 (55.47 metric tons, assumed all hook and line) for the historical catch value used in the baseline model.

We obtained the estimated catch by gear for 1978 – 2003 (1980 data missing) from the California Cooperative Survey (CALCOM) database (Brenda Erwin, Pers. Comm.). Expansion procedures were used to estimate commercial catch from sampling commercial market categories (Pearson and Erwin 1997). The Sheephead market category is fairly clean, which makes estimating catch for Sheephead more precise than for other species (e.g. rockfish). Catch for trawl, miscellaneous and unknown gears were low and were allocated proportionally to the annual landings of the other gear groups. All commercial landings were converted from pounds to metric tons. During the 1980s some Sheephead were landed under the "miscellaneous rockfish" market category (Chris Hoeflinger, Pers. Comm.). This practice was not detected by the limited amount of port sampling at that time. The contribution of "miscellaneous rockfish" landings to Sheephead catch is treated as negligibly small in this assessment.

We considered three other sources of commercial landings for this assessment: Pacific Coast Fisheries Information Network (PacFIN), Pacific Fisheries Environmental Laboratory (PFEL) and the Commercial Fisheries Information System (CFIS). We found no significant differences in the overlapping time periods for all available sources (Figure 4.1a). We therefore used the CFIS estimates (also separated by gear) to fill in for the 1980 missing year in the CALCOM data. We also compared sources that included catch brought into California from Mexico. PFEL reports landings not including Mexico catch beginning in 1928. *California's Living Marine Resources: A Status Report* includes Mexico catch beginning in 1916. The landings between the two sources from 1928-1977 showed no significant difference (Figure 4.1b).

Recreational Catch: Recreational catch estimates came from two sources. We obtained recreational landings in numbers of fish from 1947-1979 for the Commercial Passenger Fishing Vessel (CPFV) fleet from historical Department of Fish and Game (DFG) Fish Bulletins. We converted numbers of fish to metric tons using an average 3.1 pounds per fish (Young 1969). Landings were also inflated to account for recreational dive take and discards. We estimated dive removal to be 2700 fish per year (Young 1973) and applied this back to 1955, which is approximately the time SCUBA began. Discards were estimated by using the mean discard rate (15%) for 1980-1989 from the Recreational Fisheries Information Network (RecFIN). We compared this rate to the logbook discard information from 2000-2003, which was also 15%.

In 1980, the Marine Recreational Fishing Statistical Survey (MRFSS) began sampling, and from 1980-2003 (with a hiatus from 1990-1992) estimated landings, effort and discards are available from the RecFIN website. We increased the RecFIN estimated landings by an additional 3.84 metric tons per year (an average 2700 fish per year at 3.1 pounds per fish) to account for the estimated dive take. For the years 1990-1992, we used the landings data from the DFG Fish bulletins and estimated catch (including dive) and discards as described above for the 1947-1979 time period.

We did not include the removals of Sheephead taken by spearfishing in this assessment for two reasons. To calculate dive take we used an estimated 3.1 pounds per fish (Young 1973), which would underestimate removals with this gear in the model, considering they target larger fish. If the 3.1 average sized fish were used, that would account for an additional 0.043 metric tons a year, which is minor. We concluded there was not enough information to identify Spearfishing

as its own fishery. Secondly, these fish were speared in Central California, and we focused our assessment on the Southern California population.

4.2 Abundance and CPUE: We used four surveys in this assessment, one to produce an index of larval abundance and three to produce indices of catch per unit effort (CPUE) in the recreational fishery.

CalCOFI Larval Survey: To create an index of larval production for Sheephead, we used the California Cooperative Oceanic Fisheries Investigations (CalCOFI) data (Richard Charter, Pers. Comm.). These data have been collected in most years since 1951, and are used to track trends in larval production in southern California and Mexico (Moser et al. 2001).

The initial analysis began with manta and bongo tows pertaining to southern California and Mexico (lines 77-120), with all stations and months included. We used data from the typical Sheephead spawning season (June through October). If less than 5 larvae were examined in the survey over all years in a single month, those months were excluded from our frame. Station numbers greater than 65 were excluded, since no larvae were found outside of the nearshore area. Subsetting this dataset resulted in some years being excluded from the analysis, where in other missing years, surveys were not attempted at all.

We ran this subset of CalCOFI data through a delta-lognormal Generalized Linear Model (GLM) with year, month and station effects (Stefansson 1996). The spawning output index and catch are

variable from year to year (Figure 4.2). Several years had only one positive tow with Sheephead larvae, so we could not jackknife estimates of precision (at least two are needed).

Recreational Catch per Unit Effort (CPUE): Beginning in 1936, CPFVs were required to turn in a daily log, reporting the number of anglers aboard as well as the total catch in numbers of fish by species. Due to World War II, there was a delay in recreational fishing and partyboats did not begin turning in the mandatory logs and reporting catch consistently until 1947. Initially, effort was reported in angler days, which switched to angler hours in 1960. Recreational catch and effort data were taken from 2 sources: CPFV logbooks reported in Fish and Game Bulletins (1947-1979) and logbook block data provided by the Department of Fish and Game (1980-2003) (Wendy Dunlap, Pers. Comm.).

We separated the CPFV logbooks reported in Fish and Game Bulletins into two time periods due to differing units of effort. From 1947-1961, we used catch per angler day and from 1960-1981 we used catch per angler. We did not use angler hours due to missing angler hour information from 1977-1981. We also investigated converting the earlier CPUE estimates in units of angler days to anglers (1.216 conversion factor) for a one-unit time series from 1947-1981 (Figure 4.3). There were differences in the 1947-1961 time period based on the differing units of effort ($p=.004$), but they showed similar trends. After running a sensitivity analysis on the one-unit time series CPUE (which did not affect the outcome), we felt that using the separate two-unit time series for CPUE would avoid additional uncertainty error. In all cases, the model is more tenuous in the earlier years.

The third CPUE index (catch per angler hour) was calculated using block data from CPFV logbooks for the time period 1980-2003. In the initial analysis of this time series, we calculated an index for the entire area with all blocks included using 1980-1994 data (data available at the time). We ran a delta-gamma GLM with year, month and block effects (Stefansson 1996). We found that 70% of the cumulative sum of block values came from 40 individual blocks. We limited further analysis to these 40 blocks because the GLM assumes a proportional change is equally meaningful in all blocks. This assumption seems to be better met for those blocks in which Sheephead are most abundant.

We charted the top 40 blocks and came up with 5 distinct geographic fishing areas: the Channel Islands (including San Miguel, Santa Rosa and Santa Cruz Islands), San Nicolas Island, Santa Catalina Island, San Clemente Island and the Banks (Tanner and Cortez) (Figure 4.4a). We found each area had different seasonal and annual patterns (Figures 4.4 b & c) using all data from 1980-2003 (once available) so we ran five separate delta-gamma GLMs to estimate a local index value for each area (I_j). To estimate precision, we used the jackknife function so there would be a variance associated with each index in each area. We assume the local index represents the density of fish in each area and that blocks (n_j) are of equal area. The population of fish is proportional to the product of density and area. The combined index, I, is

$$I = \sum (I_j n_j) \qquad (4.2)$$

Similarly, we estimated the variance for the combined index using combined variances:

$$Var(I) = \sum (n_j^{\ 2} \ \mathrm{var}(I_j)) \qquad (4.3)$$

Figure 4.4d represents the combined catch per unit effort index for the 5 geographic areas in the southern California CPFV fishery from 1980-2003, reconstructing the population as a whole. We further analyzed a sixth nearshore area and the catch per unit effort was so small that it did not affect our previous analysis.

The reduction in bag limit enacted in 2002 probably had a small effect on CPUE. Based on bag size compositions from 1998 to 2001, truncating bags larger than five down to five fish results in a 2.5% reduction in CPUE (indicating that the 2002 and 2003 CPUEs might be a slight underestimate of abundance). The actual reduction is smaller than this because of sharing over-limit catches with other fishermen ("bag-sharing") and because bag composition in 2002 and 2003 indicate that the limit was not strictly enforced. No correction for the change in bag limit was made in this assessment. Overall, the results of regulations from management in recent years (bag limits, trip limits, mesh size in the trap fishery) should be further analyzed once there is enough information to detect the impacts.

4.3 Fishery Length Composition Data: Length compositions came from many sources, commercial and recreational. Since all length composition data were reported in either fork length or total length (mm), we converted all lengths in the model to fork length using the conversion equation provided by RecFIN (see Equation 3.2). Once converted to fork lengths

(cm), we set up 2 cm bins to calculate length compositions, starting at 18 cm. We did not have any size at age data above 50 cm, so all lengths 50 cm or larger were binned together in the 50 cm bin. We excluded any length compositions in which five or less individuals were sampled per fishery in a given year. If more than one data source covered any one year, the source with the largest sample size was used. Table 4.2 summarizes sample sizes available and used for the baseline model. Length compositions for each fishery are shown in Figures 4.5 a-d.

Commercial Lengths: We obtained fork length compositions for commercial landings from two sources. The CALCOM sampling database covered years 1993-2003 (no data in 1994). Average lengths of Sheephead were fairly similar over the years in the hook and line (49.9 cm) and trap fisheries (51.5 cm). We did not use the CALCOM lengths for trap gear because only one or two samples were taken in each year; however, CALCOM is our main source for lengths in the hook and line fishery (n=107).

The second source used for commercial lengths were from the Archive Market Data provided by the Department of Fish and Game (Steve Wertz, Pers. Comm.). Sheephead did not appear in the dataset until 1993, and lengths were available for most years from 1993-2003. All trap lengths used came from this data set (n=1064) as well as the lengths from the setnet fishery (n=58).

Recreational Lengths: There were more data on length available from the recreational fishery than for the commercial fishery. We used CPFV length information from RecFIN and two CPFV sampling programs conducted in southern California during the 1970s and the 1980s. The length information from Central California (CenCAL) Spearfishing Tournament was also evaluated

(Dave VenTresca, Pers. Comm.). We chose not to use this source because they represent large targeted Sheephead in Central California, and this assessment is focused on the Southern California population.

We generated recreational length compositions (n=2849) for CPFVs from 1980-2003 (no data 1990-1992) through RecFIN. The peak frequency of Sheephead lengths sampled on CPFVs centers around 30cm (fork length) with 88% of all measured fish ranging between 22 and 44 cm. We assumed all fish measured were landed with hook and line.

We also used Sheephead length compositions collected from two southern California CPFV sampling programs. The first program sampled from 1975-1978 and 1683 Sheephead were measured (Collins and Crooke In prep.). The second sampling program was conducted from 1984-1989 (Ally et al. 1991) where 3472 Sheephead were measured. The average size of fish landed from 1975-2003 (no lengths in some years) is variable throughout the time period (Figure 4.6).

5. SINGLE-SEX APPROXIMATION

Most stock dynamic models either assume that population production scales with mature adult biomass or that individual fecundity increases (monotonically) with length or age. However, in a protogynous species, as individuals grow older and larger they change from female to male and thus traditional combined-sex models will overestimate the production of eggs at the population

level. Similarly, traditional split-sex models (that assume males and females can occur in all age classes) cannot readily incorporate the absence of males in early age and size classes and the predominance of males in later ages and larger sizes. It is certainly preferable to consider the existence of sex change when relating spawning stock biomass and production to recruitment, abundance and landings.

We therefore developed, for the first time, a combined-sex (or single-sex) stock assessment model that includes a dome-shaped maturity function that incorporates both maturity and sex change. To confirm that the predicted population dynamics would be unaltered by combining sex change and maturity, we created two separate, parallel models. First, a split-sex sex-changing population where individuals are born female and mature and become male with a certain probability (Alonzo and Mangel 2004). Second, a combined-sex model that considers individuals starting at the same initial size as the split-sex population where cohort fecundity declines, simulating the sex change from female to male.

5.1 Model Description: We developed identical two-sex (i.e. sex-changing) and single-sex (i.e. combined-sex) models, where the sole difference between the two models resides in the maturity and fecundity functions. For growth, maturity, fecundity and mortality, we used the same parameters described in Section 3 and given in Table 3.1, see Table 5.1 for all model parameters. Both models use the difference equation-version of the von Bertalanffy growth equation (Equation 5.1, Figure 5.1 Gulland 1983) for length and weight estimates where *L(a)*

$$\begin{aligned} L(a+1) &= L(a)\exp\left(-k\exp\left(\varepsilon_g\right)\right) + L_\infty\left(1-\exp\left(-k\exp\varepsilon_g\right)\right) \\ W(a) &= cL(a)^d \end{aligned} \tag{5.1}$$

is the length at age in cm, k is the growth rate, ε_g is the normally distributed uncertainty term for the growth rate, L_∞ is the asymptotic size in cm, $W(a)$ is at age in kg, and c and d are the length-to weight multipliers. In the weight equation and all subsequent equations, length-at-age is suppressed to age. In both models, mortality is autocorrelated and varies annually, where ρ is the autocorrelation parameter and ε_m is uncertainty

$$M(t+1) = \rho M(t) + \sqrt{1-\rho^2}\,\varepsilon_m. \qquad (5.2)$$

We assume that sex does not affect growth, so we used the same size-based fishery calculations for both models. Fishing selectivity for fishery i, θ_i (Figure 5.2 Methot 2000), is a length-based, four- parameter double logistic where β_1 is the steepness parameter

$$\theta_i(a) = \text{pr}\{\text{capture}\}_i = \frac{T_i}{\left(1+\exp\left(-\beta_{1_i}\left(L-\beta_{2_i}\right)\right)\right)\left(1+\exp\left(\beta_{3_i}\left(L-\beta_{4_i}\right)\right)\right)} \text{ where } i = 1,2...\text{n} \qquad (5.3)$$

of the ascending side, β_2, in our case, a length, is the midpoint of the ascending side, β_3 is the steepness parameter of the descending side, β_4 is the midpoint of the descending side, also a length in cm, and T_i is the scaling factor (Methot 2000). We specify two different hypothetical fisheries with different θ_i and effort, E_i, for each fishery, loosely based on size composition of landings from the data. Total fishing mortality, F, for each size-at-age is

$$F(a) = \sum E_i \theta_i(a). \qquad (5.4)$$

We calculated annual catch, C_i, for each fishery, i, for the single-sex and sex-changing models whose total populations are represented interchangeably as $N(a,t)$ in equation 5.5 with observation error, ε_f.

$$C_i(t) = \sum_a N_i(a,t)\left(1 - \exp\left(M(t) - F(a)\right)\right)\frac{E_i\theta_i}{\left(M(t)\right) + F(a)}\varepsilon_f \qquad (5.5)$$

5.2 Creating the Single-Sex and Two-Sex Models: Because Sheephead are protogynous sequential hermaphrodites, fecundity estimates in the form of egg production must include not only the proportion of the female population becoming mature, but also the loss of females as mature females become male. We chose to capture this in two ways: 1) as a single-sex model where the entire population is female and the fecundity for each age class is determined by the proportion of the age class that is reproductive as females and 2) as a sex-changing model where the fecundity for each age class is determined simply by the number of females that are mature and the number of females is reduced as females become male. In the sex-changing model, all individuals recruited to the population as females, and became mature with a probability at each length-at-age, then became male with a different probability at each length-at-age, (Figure 5.3)

$$p_m(a) = \frac{1}{1 + \exp\left(r\left(L - L_{50_m}\right)\right)} \qquad (5.6)$$

represented by $p_f(a)$ in an equation similar to Equation. 5.6, with r determining the rate of maturity between lengths and L_{50_m} is the length at which half the length class is mature. Because

population size is represented in the single-sex approximation as only female, a single equation had to encapsulate maturity and the switch from male to female. We adjusted the probability of maturity based on the conditional between becoming male given that an individual is a mature female (Equation 5.7).

$$p_s(a) = p_m(a)p_f(a) \tag{5.7}$$

Since a portion of the mature females transition to males, the total proportion of mature females in the cohort declines independently, resulting in a decrease in the number of individuals who can produce eggs for that cohort (Figure 5.4).

We determine the number of eggs produced, φ (Equation 5.8), from a relationship

$$\begin{aligned} \varphi(a)_{\text{sex changing}} &= \sigma N_{\text{female}}(a,t)p_m(a)W(a) \\ \varphi(a)_{\text{single sex}} &= \sigma N(a,t)p_s(a)W(a) \end{aligned} \tag{5.8}$$

between body weight, *W(a)*, and fecundity where σ is the eggs/kg multiplier. We calculate the total number of eggs for the age class by multiplying the estimated number of eggs produced by the size of the age class, *N(a,t)*, and the proportion of the age class that is mature or producing eggs. We use the Beverton-Holt recruitment (Mace and Doonan 1988; Dorn 2002) where total recruitment is given by equation 5.9 and h is the steepness parameter, φ is the total number of eggs produced used in place of spawning stock biomass, R_0 is virgin recruitment, and ϕ_0 is the measure of virgin eggs per recruit and ε_r is process uncertainty in recruitment:

$$N_{\text{female}}(1,t+1) = \frac{0.8R_0 h \sum_a \varphi(a)_{\text{sex changing}}}{0.2\phi_0 R_0 (1-h) + (h-0.2)\sum_a \varphi(a)_{\text{sex changing}}} \varepsilon_r$$
$$N(1,t+1) = \frac{0.8R_0 h \sum_a \varphi(a)_{\text{single sex}}}{0.2\phi_0 R_0 (1-h) + (h-0.2)\sum_a \varphi(a)_{\text{single sex}}} \varepsilon_r \tag{5.9}$$

We use an age-structure model to generate population dynamics. In the sex-changing model, males and females must maintain separate population dynamics, with individuals within each age class leaving the female population with a certain probability to join the male population (Equation 5.10a). The single-sex model (Equation 5.10b) uses a single population

$$N_{\text{female}}(a+1,t+1) = \exp(-M(t)-F(a))\left(N_{\text{female}}(a,t)p_f(a)\right)$$
$$N_{\text{male}}(a+1,t+1) = \exp(-M(t)-F(a))\left(N_{\text{male}}(a,t) + N_{\text{female}}(a,t)\left(1-p_f(a)\right)\right) \tag{5.10a}$$

$$N(a+1,t+1) = \exp(-M(t)-F(a))N(a,t) \tag{5.10b}$$

to represent both the male and female populations.

Both models produced identical results without stochasticity (Figure 5.5) and identical long-term averages with stochasticity in population size as well as catch yields. Combining sex change and maturity into a single fecundity equation did not change the population dynamics, as long as the order of maturity, sex change, reproduction, and mortality were correct.

6. STOCK SYNTHESIS MODEL

6.1 Model description: We used the size- and age-structured version of the "Stock Synthesis" program, hereafter referred to as Synthesis, (Methot 1990; Methot 1998; Methot 2000) to model the population dynamics of the California Sheephead stock. Synthesis is an age and size-structured model that projects the survival, growth and reproduction of individual age classes. Synthesis can incorporate ageing errors and individual variation in growth. Synthesis has three main components: First, the population model is used to project the size and age structure. Second, an observation model uses data inputs (in our case landings, CPUE data, survey information and length compositions, see Section 4) and selectivity functions (logistic functions with potentially both ascending and descending components) to relate the simulated population to the data. Third, a statistical model uses a likelihood approach to estimate the best-fit parameters for the model. Synthesis allows a variety of data types to be combined and used to estimate parameters in one formulation. A single log-likelihood function is used to calculate the total log-likelihood value associated with the model and allows emphasis factors to control the weight of each type of data and parameter in influencing the total likelihood. The likelihood calculation of our model assumed a multinomial error structure for the length compositions and log-normal error for the surveys. For more details see Methot (2000).

The preexisting version of Synthesis was not able to incorporate the sex-changing life history of Sheephead. As described above, the population dynamics of Sheephead can be approximated by a combined-sex model with a double logistic maturity function (where only individuals that are mature and female produce eggs, see Section 5). We therefore used a version of Synthesis

modified by Rick Methot to allow the maturity function to have both ascending and descending portions of the equation (synl32r.exe, 1251 KB in size, compiled April 5, 2004). There were 4 parameters associated with the maturity function (see Table 3.1); these gave the probability of being mature and being female (i.e. the probability of producing eggs). We assumed that spawning occurs in June for the model, the maximum age class in the model is 20 years of age (an accumulation ages, accounting for all older fish), and mortality rates are time- and age-independent. For the original runs of the model we assumed equal likelihood weights (of 1.0) for all data sources (landings of the four fisheries, length compositions of the four fisheries, three CPUE indices and the CalCOFI survey). We used a convergence criterion of 0.001 log-likelihood units for all runs of the model.

Because CPUE data were only available starting in 1947, the landings data described above were used to generate a landings record from 1947-2003, as well as to estimate historical catch prior to 1947 (see Section 4 for details). Therefore, we used the model to project the population size structure and abundance during these years. The landings data were used within the model to estimate fishing mortality and the model assumed that mortality is independent between the four fisheries (hook and line, setnet, trap and recreational). As a result, the fishing mortality for fishery i for an age (a) and size (l) class $F_{a,l}(i,t)$ is given as the product of the selectivity of the fishery for that size and age class ($s_{a,l}(i,t)$) and the total instantaneous fishing mortality of that fishery F(i,t)

$$F_{a,l}(i,t) = s_{a,l}(i,t)\, F(i,t) \qquad (6.1)$$

Synthesis estimated the selectivity function associated with each of these fisheries based on length composition data associated with each fishery (the available length composition data are described in Section 4) and the statistical model found the parameters for the ascending and where applicable the descending portions of the selectivity functions that best fit the data and population projections.

Since no age data associated with the fisheries or surveys were available, the selectivities were fit as only size-dependent and we explored the possibility of both descending and ascending portions of the functions (option 8 within Synthesis). The ascending function includes three parameters: an initial selectivity, a slope, and an inflection point. Including the descending portion of the function adds four parameters: a size at which the transition from ascending to descending occurs, a slope, a final selectivity, and an inflection point for the descending portion of the function.

The three CPUE indices were based on recreational landings and effort data and were therefore assumed to exhibit the same selectivity as the recreational fishery. The CalCOFI survey was fit as a spawning biomass index and the maturity and fecundity schedules serve as the selectivity curve (see below).

We calculated expected growth from the von Bertalanffy growth equation as parameterized by Schnute (1981) using the growth parameters described in Section 3. Growth was assumed to depend on age but be independent of time, sex, or maturity. We used Synthesis to calculate the annual production of eggs from the predicted abundance of individuals at each length, the

proportion of individuals predicted to be mature and female at that length and the expected individual egg production of a fish of that length. Synthesis was used to calculate individual fecundity from the expected weight W(L) of a fish at a given length L (determined by the allometric relationship described in Equation 3.3) and a linear relationship between mass-specific egg production and total body weight. For most years (1947-2000), we allowed recruitment to be freely estimated within Synthesis. However for the most recent years (2001-2003), we set recruitment to the model-estimated background recruitment level since the length compositions from the fisheries would not reflect abundance in these age classes because it takes a fish 3-4 years to be large enough to recruit to the fishery. We allowed the model to fit a Beverton-Holt stock recruitment curve, but we only used this curve to estimate recruitment in sensitivity analyses of the baseline model. As part of our sensitivity analyses, we also explored the possibility of other recent years or the first decade of the model being set at the estimated background recruitment level.

There were 14 likelihood components: Eight associated with the landings and length compositions for each fishery, four associated with the CPUE indices and CalCOFI survey and two associated with the recruitment function. However for all baseline runs of the model the recruitment model was fit but not used and therefore their likelihood weights were set to zero.

6.2 Model selection: Initial runs of the model focused on finding starting values for the selectivity parameters and recruitment. We started by allowing the selectivities to only fit the ascending portion of the selectivity functions. Once the model was stabilized we also explored the possibility of allowing both ascending and descending portions of the selectivity function.

The trap fishery was the only one for which the model ever fit a descending limb. However, in later runs of the model the descending limb did not improve the fit of the model. Therefore in the final baseline model, all selectivities were fit as ascending only.

In initial runs of the model, the coefficient of variation in growth parameters (CV_1 and CV_2) were fixed and were later allowed to be estimated with an upper bound of 0.29. We also conducted a sensitivity analysis on CV as described below. During model selection, we also explored the possibility of allowing recruitment to be freely estimated for all years as well as increasing the likelihood weight of the estimated stock recruitment curve. This did not affect the historical situation but may influence the forward projections and interpretation of the current status of the stock. The freely estimated recruitment values more closely reflected the trends in the CalCOFI larval abundance index and therefore we used the freely estimate values that are not fit to a stock recruitment curve for the baseline model. However, extensive sensitivity analyses explored the influence of varying all of these assumptions (see below).

Because Synthesis was constrained by the age and length structure, estimates of precision that are externally estimated (e.g. jack knife estimates of standard error for abundance indices) often lead to values that are more precise than Synthesis is capable of fitting to the data. In initial runs of the model, the standard error portion of the surveys was not used. In later runs of the model, we used the internally estimated root mean square error (RMSE) of the deviates to estimate the standard error value for all four abundance indices. These standard error values were updated in the data file whenever the results of the model run lead to a different estimated standard error

(when rounded to the nearest tenth). In the final runs of the model the standard error of each survey stabilized so that they did not require updating.

The original runs of the model used the actual sample sizes of the length compositions (with a maximum of 200). However, we also adjusted the length composition standard sizes to an estimated effective sample size. Synthesis provides an empirical estimate of the effective sample size for each length composition used in the model. Rather than use these effective sample sizes directly, we used these values to estimate the relationship between the true and empirical effective sample size as suggested by MacCall (1999). For the hook and line and trap fisheries, the relationship between true sample size and the empirically estimated effective sample size did not have a significant slope. We therefore replaced the true sample size with the mean of the effective sample sizes calculated by Synthesis for that fishery. For the recreational and setnet fisheries, the relationship between the true sample size and the effective sample size calculated by Synthesis exhibited a significant slope (but negative intercept). We therefore fit the slope only (the intercept was set at zero) between the true and Synthesis generated effective sample sizes. We then used this slope to generate estimated effective samples sizes and replaced the true sample size with the externally estimated sample sizes for these two fisheries. The maximum value of 200 was retained but only influenced the values for the recreational fishery. Effective sample sizes were updated between model runs and the relationship between true sample sizes and final externally estimated sample sizes are given in Figure 6.1. The data file and parameter file used the in the final version of the baseline model are given in Appendix 1 and 2.

6.3 Characteristics of the baseline model:

1) The model considered the years from 1947 through 2003 and assumed that June was the month in which spawning occurred.

2) The selectivities for the three commercial (hook and line, setnet and traps) and one recreational fishery were fit as ascending only. The three CPUE indices were treated as surveys and linked to the selectivity of the recreational fishery. The CalCOFI survey was fit as a spawning biomass selectivity.

3) Natural mortality, growth, fecundity and maturity parameters were estimated outside of Synthesis and fixed for all runs of the model as described in Section 3. The coefficient of variation of growth at age 1 and 2 were fit with an upper bound of 0.29.

4) Recruitment was freely estimated based on the age and length compositions in all but the three most recent years where recruitment was set at the model-estimated background recruitment. The stock recruitment curve was estimated but not used in the baseline version of the model (with likelihood weights of zero for the stock recruitment function).

5) All data sources (landings, length compositions, and surveys) had equal likelihood weights within the model.

6.4 Results of the model: The likelihood components of the baseline model associated with each data source are given in Table 6.1 and the parameter values of the baseline model (estimated and fixed) are given in Table 6.2. All selectivities increased with length and all selectivity parameters were freely estimated. Trap and recreational fisheries appear to select fish in smaller size classes than the setnet and hook and line commercial fisheries, which appear to select mainly larger fish (Figure 6.2). Although some of the fisheries might have been expected to exhibit a dome shaped

selectivity, the fact that we did not have size at age data above 50 cm and hence binned the length compositions above this size may explain the absence of a descending limb in all cases.

The estimated historical total biomass and spawning stock biomass are shown in Figure 6.3a. Both total and spawning stock biomass were estimated to be lower in the 1950s than any time since, and current biomass is higher than this “initial” biomass but lower than estimated for 1960-1990. The lower biomass early in the model may correspond to lower water temperatures in the 1950s compared to the last 50 years. The spawning stock biomass and total biomass show similar trends although the spawning stock biomass shows larger relative variation through time than the total biomass. Historical recruitment is also estimated to have been highly variable through time with very low recruitment in the early years compared to the last 50 years. However recruitment was estimated to have been highest in the 1980s. The estimated relationship between spawning stock biomass and recruitment (SRR) is variable but relatively flat (Figure 6.3c) and the best-fit parameters of the stock recruitment curve reflect this basic pattern as well (Table 6.2, Appendix 1). The estimated historical spawning stock biomass per recruit was also estimated to vary greatly through time with low values in the 1950s and recent years with peaks in the early 1960s and early 1970s (Figure 6.4). We found no evidence for a relationship between estimated recruitment and sea surface temperature (using the Scripps pier sea surface temperatures; linear regression where recruitment= temperature, $F<0.001$ and $p=0.99$).

In general the model fit the abundance indices relatively well (Figure 6.4). We estimated Sheephead abundance to be low early in the trajectory, increase from the 1960s until the mid

1980s and then decline from 1985 onward (Figure 6.3a). Recruit per spawning biomass is also estimated to be highly variable through time (Figure 6.3c). The estimated landings of the commercial hook and line and trap fisheries also reflected this pattern (Figures 6.6 and 6.7). The setnet fishery did not harvest much biomass compared to the other three fisheries (Figure 6.8). Finally, the recreational fishery estimated catches were highest in 1980s and lowest in the 1950s (Figure 6.9). The model was also able to fit the length composition relatively well given the small sample size and number of years represented in some cases (Figure 6.10). Exploitation rate is also estimated to have varied temporally. Exploitation rate was estimated to be high in the late 1940s and 1950s and again starting in 1990 (Figure 6.11).

6.5 Sensitivity analyses and uncertainty: All sensitivity analyses were made in comparison to the baseline model described above. Unless mentioned otherwise, only one aspect of the model was changed at a time.

Natural mortality: Because mortality is a very important parameter that influences estimates of abundance and is difficult to estimate precisely and may vary through time, we conducted a variety of sensitivity analyses on the mortality parameter M in the model. As described in Section 3, we allowed mortality to range from 0.05 to 0.5 based on observed maximum ages for Sheephead. Mortality had a clear effect on estimates of total (Figure 6.12) and spawning biomass as well as on recruitment . We also allowed the model to estimate mortality. When the model was started at the baseline value of M=0.35, the model estimated a mortality rate of 0.35 with the likelihood indicating no significant increase in the fit to the data (Model estimating mortality: log-likelihood -342.548; Baseline model with fixed mortality value: log-likelihood -342.573).

However, a starting value of 0.05 led to a best-fit parameter estimate of 0.2 and the total likelihood as a function of natural mortality rate was relatively flat between M=0.2 and 0.4 (Figure 6.13). Because the model lacks data on actual age composition, it is unlikely that changes in the log-likelihood values for alternative values of natural mortality rate are a valid basis for identifying the best value of M.

Life History Parameters: Because the life history parameters such as growth, maturity (and sex change) and fecundity also have important effects on the productivity of a stock, we performed sensitivity analyses on these parameters in the model. In the baseline model, we allowed the coefficient of variation on growth (CV_1 and CV_2) at t_1 and t_2 to be estimated but estimated the size at age 1 (L_1), size at age 13 (L_2), and growth rate k externally (as described in Section 3) and fixed them within Synthesis. As a sensitivity analysis, we allowed some of the growth parameters to be estimated by the model (L_2 and k as well as CV_1 and CV_2). The starting values were the baseline case growth parameters. The model estimated a higher growth rate but similar size at age 13 (L_2) but this did not significantly improve the fit of the model (see Table 6.3).

Because the estimate of the coefficient of variation in growth was very high and higher than the estimated values of CV_1=0.14 and CV_2=0.26, we explored the effect of the two CV parameters on the predictions of the model. We only considered cases where CV_1=CV_2 since there was no biological reason to expect them to be different and examined the range from 0.10 to 0.29 in 0.01 increments. The coefficient of variation of growth had a strong effect on estimates of total biomass, recruitment and spawning stock biomass estimates and is a major source of uncertainty in this model (Figure 6.14).

As another sensitivity analysis, we ran otherwise identical versions of the model but varied the life history parameters (mortality, growth and maturity) in accordance with the estimates from the five different populations for which we had data (see Section 3 and Table 3.1). These life history parameters have a combined effect on the estimates of total biomass, recruitment and spawning biomass (Figures 6.15 and 6.16). However the two sets of parameters for Guadalupe Island did not fit the data (Figure 6.17) and lead to very different population estimates. In contrast, the parameters based on California populations all fit the data similarly well and led to the same general interpretation of the data (Figures 6.15-6.17).

We also ran a version of the model with a slope and significant intercept of the mass-specific fecundity relationship as described in Section 3 (where instead of an intercept of 129 the slope and intercept are 34.1 and 5.5; all fecundity parameters are scaled by 10,000 for computational efficiency). Although it led to a difference in individual fecundity, the same general patterns were predicted.

Clearly, the life history parameters determining mortality and growth had a strong effect on the interpretation of the available data. Therefore although we focused on the baseline case for making management recommendations we also examined a range of values of natural mortality and coefficient of variation in growth to determine how imprecision in these estimates would affect our recommendations. We also considered all four sets of life history parameters from California that fit the data well.

Recruitment: We varied the emphasis on the stock-recruitment relationship from 0 to 1 in 0.1 increments. Using the stock recruitment curve decreased the variability of the estimated recruitment through time (Figure 6.18) but not the overall trend. Changing whether recruitment early in the model (1947-1958) was set as the background level or freely estimated only affected predicted population trajectories in those years but all differences were completely gone by the 1960s. We also allowed the last three years to be read off the estimated stock-recruitment curve rather than set at the background level. This only affected the recruitment estimates in those years and values from the stock recruitment curve and freely estimated were at or near zero while the background recruitment level was higher.

Randomization of starting values: We also explored the effect of randomizing the initial values for all parameters. Starting values were sampled from a uniform distribution within $\pm$ 15% of the baseline value. This procedure was repeated twenty times and had no significant effect on either the log-likelihood (variation was at most 0.125 likelihood units), individual parameter values or predicted population trajectories.

Data: In our model we had four sources of abundance indices (three CPUEs from the recreational fishery and the CalCOFI survey) and length composition data for each of the four fisheries considered in our model (see Section 4). We explored the impact of individual data sources on the outcome of the model by increasing and decreasing their likelihood weights over the range 0.25, 0.50, 1.0, 2.0 and 4.0 while holding the likelihood weight of all other data sources at one (Figure 6.19-6.23). Only the CPFV logbook CPUE from 1980-2003 did not appear to be in agreement with the other data sources. We also explored the effect of decreasing or increasing

the likelihood weight (using the same range) of all the surveys while holding all of the length composition sources at a constant likelihood weight of 1.0 as well as the reverse. This led to the same overall pattern.

Finally, we ran the model with the CPFV logbook based survey for 1947-1981 as one survey rather as two separate surveys by calibrating the effort units (see Section 4 for a complete description). This had very little effect on the fit to the survey data (Figure 6.24) or the outcome of the model (Figure 6.25).

7. STATUS OF THE STOCK AND PROJECTIONS

Using the estimated unfished and current spawning biomass, we calculated the estimated spawning potential ratio (female SPR) of the stock. However, the spawning biomass only represents female biomass and the selectivities of the fisheries estimated by Synthesis indicate that mainly males are targeted by the fishery (Figure 6.2). Although males do not produce eggs, sperm limitation can affect reproduction of a stock (Alonzo and Mangel 2004). Furthermore, large males have been observed to be territorial in this species, and may play an important role in reproduction (Adreani et al. In Press). Therefore, we also examined the “male spawning potential ratio” (male SPR) and the ratio of total biomass to recruits or the total spawning potential ratio (total SPR). Based on the results of the baseline model, we estimated an exploitation rate of 0.11 for Sheephead in 2003 and female SPR is estimated to be reduced to 80% of the unfished level. However, male and total SPR appear to be reduced by a much greater amount (Figure 7.1).

However, the estimates of both current and unfished biomass (and thus exploitation as well) depend on natural mortality, various life history parameters and the coefficient of variation in growth. These variables in the model, especially natural mortality, represent important sources of uncertainty. We therefore examined the effect of natural mortality on the estimated status of the stock (Figure 7.2). We choose to examine two further estimates of natural mortality based on the oldest fish ever aged (53 years) and the oldest fish found in the samples (21 years) used to estimate the life history parameters (Warner 1975; Cowen 1990). Using the relationship published by Hoenig (1983), we estimated natural mortality rates of 0.07 and 0.2 depending on whether the maximum age of 53 years or 21 years was used. The predicted SPR is very much affected by the estimate of natural mortality (Figures 7.1 and 7.2) because of the effect of natural mortality on the estimated total biomass (Figures 6.12 and 6.13). The coefficient of variation in growth has a similar effect on estimated biomass (Figure 6.14) leading to a similar affect on the estimated SPR (Table 7.1). We also examined the 4 sets of life history parameters and estimated the current SPR (female, male and total) based on these different combinations of life history parameters (Figure 7.3). Clearly natural mortality and growth have important effects on estimated biomass and thus the interpretation of the data with respect to the status of the stock. Whether California Sheephead is believed to be below target levels currently depends on deciding what measure best represents the status of a sex-changing stock. Clearly natural mortality and variation in growth will also affect our interpretation of the current status of Sheephead. Although a clear relationship between male spawning biomass and recruitment may not exist, the relationship between female biomass and recruitment is no more obvious (Figure 6.3c).

We also used Synthesis to explore possible future projections for Sheephead. In these projections, recruitment was sampled from estimated recruitments from 1970-1995 and fishing mortality was fixed. In each single projection, the variability in recruitment led to variability in the predicted total and spawning biomass in the future (Figure 7.4). However, these predictions are consistent with the observed and estimated historical abundance of Sheephead. For every scenario, we ran 100 projections over 100 years. We used these projections to determine the range of possible values for expected total and spawning biomass (Figures 7.5 and 7.6). We examined the effect of no fishing (fishing mortality F=0) as well as fishing pressure similar to (F=0.2) and greater than current levels (F=0.5). As expected, increasing fishing mortality shifts the distribution of expected future biomass to the left (i.e. decreases expected biomass, Figure 7.7). These projections do not take into account the potential effect of male depletion on reproduction of the stock since our model assumes that recruitment is independent of spawning female or male biomass. We also explored the effect of natural mortality on projected biomass. Decreasing natural mortality leads to a decrease in expected future biomass (Figure 7.8) in the same way as natural mortality affected the historical estimates of biomass. Similar patterns exist when the coefficient of variation in size is varied (Figure 7.9).

8. REVISED MODEL FOLLOWING THE PANEL REVIEW

8.1 Requested changes to the model: The review panel requested a number of changes. For greater resolution of the size distributions, we recalculated the length composition data so that instead of binning all lengths above 50 cm, we examined 2 cm bins for the entire range of

observed lengths (18 cm to 78 cm). The panel also requested that we use an externally estimated coefficient of variation of size at age. We used the error bars from the mean size at age data for Catalina Island reported in Warner (Figure 3.2 1975) to estimate the coefficient of variation in growth (CV) by taking the average of the CV across all age groups (CV_1=CV_2=0.11). This was done because the length composition data did not show any clear modal progression of cohorts that would allow the model to reliably estimate the variation in individual growth around the growth equation. We therefore used the best available data to estimate CV_1 and CV_2 externally.

The panel also requested that we consider alternative estimates of natural mortality (M) because the Catalina-based estimate of mortality was probably an overestimate of natural mortality due to fishing in the area. Given that the best documented maximum observed age of a fish was 20 years (Cowen 1990), we used the Hoenig relationship (Hoenig 1983) to estimate a baseline natural mortality of 0.20. We also considered the possibility that the actual natural mortality was lower (M=0.15) because the maximum observed age could be reduced due to exploitation. A single fish that was reported to be 53 years old based on its opercles (Fitch 1974) was not used to estimate maximum age since all other reported samples gave much lower estimates of maximum ages, between 15 and 30 years (Limbaugh 1955; Warner 1975; Cowen 1985; Cowen 1990). We also examined the effect of a higher natural mortality (M=0.3) on the results of the model based on empirical estimates of mortality (Warner 1975; Cowen 1990). Published estimates of mortality for California Sheephead range from 0.29 to 0.55 (see Table 3.1). However to use these values in the model as natural mortality assumes that fishing mortality at these sites was negligible and hence that estimated mortality could be equated with natural mortality. Thus,

M=0.3 should be considered the higher end of the reasonable range of estimates for natural mortality.

As requested by the panel, we explored the treatment of recruitment and added a low emphasis (likelihood weight of 0.01) on the stock recruitment curve. Estimates of recruitment in the early years are tenuous because length composition data was only available starting in 1975. A low emphasis on the stock recruitment curve allows recruitment to be based on the stock-recruitment relationship when there is not much data available but to be determined by the data when available. Because the stock-recruitment curve was estimated, we used this relationship to estimate recruitment in 2001-2003 for the final model. The length composition data could not estimate recent recruitment events because it takes at least 3-4 years for individuals to recruit to the fishery. We also fixed the steepness parameter of the stock-recruitment relationship at the previously estimated value of 0.99. The standard deviation parameter of the stock-recruitment curve was fixed at 0.8 as requested by the panel. During the review, we determined that the absence of Sheephead larvae in the CalCOFI survey was due to the fact that labrid larvae were not identified to species until 1961 (Moser et al. 1994). Therefore the CalCOFI abundance index for Sheephead started in 1961 for the final version of the model. Finally, to stabilize the model, the initial age composition was changed from using the background recruitment level to the virgin recruitment level.

Due to the changes made to the model, we also reexamined the selectivities of the fisheries. Although the model could fit a descending limb for the trap and recreational fisheries, this did not significantly improve the fit of the model. Therefore, the final model allowed the

selectivities for all four fisheries to be ascending only. Model selection also explored the effect of the model changes on the root mean square error of the surveys and the effective sample size as described in section 6. Although small changes in the estimated effective sample size and standard error did occur, they were not significant and therefore the standard error of the surveys and effective sample sizes were left the same as in the previous version of the model.

Due to the plasticity of life history characteristics and seeming inconsistencies between the fitted models and empirical data, at the request of the panel, we reestimated and refitted the length and maturity data from Cowen (1990) and Warner (1975). Warner's length data and Cowen's maturity and length data had to be read off of the published figures which led to imprecision in the data entered into the model. Further imprecision in the Cowen data resulted from the conversion of age based maturity data to size based maturity data. Errors in calculating the Cabo Thurloe maturity data, as well as in converting between standard, total, and fork lengths were corrected from the version presented to the panel and we improved the method of converting age-based data to length-based data by switching from binned lengths to actual lengths (Table 8.1, Figure 8.1).

The large variation in life history characteristics between locations leads to difficult management questions in choosing the best policy for the population as a whole when many of our biological reference points are dependent on our understanding of such characteristics. Given that we know very little about the triggers of sex change and maturity, only that it tends to be size based, it is difficult to say how density and sex ratio affect sex change. Many fish species show density dependent somatic growth (Lorenzen and Enberg 2002), suggesting an interaction between

population density and age at maturity or sex change, given the length-sex change-or-maturity relationship. A possible manifestation of this interaction could be that variation in size at maturity or sex change in the different populations are driven by density resulting in these seemingly population specific life history characteristics. To our knowledge there are no data addressing sex ratio and size or age at sex change for Sheephead.

Because maturity and sex-change schedules are likely to interact strongly with growth curves, we treat the existing sets of recalculated life history parameters corresponding to Table 3.1, now in Table 8.1 as "packages." Accordingly, we compared SPR relationships for the sets of life history parameters at the four mainland Sheephead study areas: Cabo Thurloe and San Benitos Islands in Mexico, and San Nicolas and Santa Catalina Islands off southern California (Figure 8.17). The Catalina Island pattern used as the basis of this assessment is quite similar to the results for Cabo Thurloe. In contrast, the life history parameters for San Nicolas Island and the San Benitos Islands indicate that severe depression of the female SPR would occur at the current exploitation rate. The reason for the latter responses can be seen in Figure 8.1. Maturity and sex change at San Nicolas Island occurred at much larger sizes, and few fish would reach maturity or sex-change. For the parameters obtained from the San Benitos Islands, sex change happens so soon after maturity that overall production of females is low and would be less able to withstand exploitation. With the exception of Catalina Island, these cases are not intended to reflect actual conditions, but rather are intended to answer "what-if" kinds of questions.

8.2 Results of the final model: We present the results of the final Sheephead stock assessment model for the scenario where natural mortality M=0.2 as well as to alternative cases where

M=0.15 and M=0.3 for comparison. The likelihood components and final parameter values for the model are given in Tables 8.2 and 8.3. The parameter and data files for the final model are given in Appendix 3 and 4. The fishery selectivities estimated by the model indicate that smaller fish are taken by the recreational and trap fishery compared to the hook and line and setnet commercial fisheries (Figure 8.2). However, all fisheries target mature individuals while the hook and line and setnet fishery select mainly males (Figure 8.2). When natural mortality M=0.2, the historical total biomass and spawning biomass was estimated to start out low, increase during the late 1970s and early 1980s and then decline starting in the late 1980s (Figure 8.3a). In contrast, a natural mortality of M=0.15 led to the interpretation that the total and spawning biomass were high in the 1950s but declined before rising again in the late 1970s and early 1980s (Figure 8.4a). When natural mortality M=0.3, the changes in historical total and spawning biomass are similar to the case when M=0.2 except that the overall estimates of biomass are higher (Figure 8.5a). Estimates of recruitment also depend slightly on the estimate of natural mortality (Figure 8.3b-8.5b). Although the stock-recruitment relationship estimated by the model differs among the alternative estimates of natural mortality (Figures 8.3c-8.5c), a clear stock-recruitment relationship does not exist for any case. The fit between the observed and predicted abundance indices is good for all three natural mortality estimates and all three versions of the final model lead to the interpretation that the abundance of Sheephead has declined in the last 15-20 years (Figures 8.6-8.8). The fit between the predicted and observed length compositions were also relatively good and almost identical among the three estimates of natural mortality (Figure 8.9). Exploitation rate is also estimated to have increased in recent history regardless of the estimate of natural mortality (Figure 8.10).

We calculated the spawning potential ratio of Sheephead based on the total mature biomass since both male and female biomass contribute to spawning potential. This leads to the interpretation, independent of natural mortality, that Sheephead have declined below target levels (Figure 8.11 CDFG 2002). For the most likely scenario (M=0.2), the spawning potential ratio based on mature biomass is estimated to be (at the current exploitation rate of 0.23) approximately 20% of the unfished spawning potential ratio. A lower estimate of natural mortality leads to an even greater estimated reduction in the spawning potential ratio of California Sheephead.

We also projected the expected distribution of total biomass in the absence of fishing and following the 60/20 policy of the Nearshore Fishery Management Plan (CDFG 2002). These projections indicate that the expected distribution of total biomass is variable (Figure 8.12) in all scenarios. Although estimates of future biomass do depend on the estimate of natural mortality, all scenarios indicate that Sheephead biomass can be expected to vary through time even in the absence of fishing (Figures 8.12 and 8.13). In the presence of fishing, total biomass will depend on actual natural mortality (Figure 8.14). However for the most plausible scenario, the allowable catch following the NFMP policy is low at the present time when M=0.2 (Figure 8.15) as well for lower estimates of natural mortality. Even higher estimates of natural mortality lead to the prediction that catch may have to be reduced substantially under the NFMP policy.

The decline in the catch per unit effort (CPUE) index is reflected in the model output, and indicates a decline in abundance since the mid-1980s. The model results indicate two combined causes for the decline, increased fishing pressure, and reduced recruitment. It is unclear whether the reduced recruitment is associated with the effects of increased fishing pressure, but the

recruitment levels during the intense fishing since 1993 are clearly lower than were seen at similar population level earlier when fishing was less intense (Figures 8.3c, 8.4c and 8.5c). Any decline in abundance that is directly due to fishing pressure is quickly reversible, and abundance and associated CPUE should recover quickly, to the extent allowed by recent recruitment levels. If the decline in recruitment is due to fishing effects, recruitment levels also should increase quickly with a reduction in fishing intensity. However if the decline in recruitment is due to a prolonged change in environmental conditions, a reduction in fishing pressure would not result in recovery to earlier levels of abundance, but catch levels must nonetheless be reduced because the lower recruitments would be incapable of supporting historical catch levels.

In our projections, we assume that decline in CPUE is due solely to fishing pressure, i.e., recruitment will return to previous levels under reduced fishing pressure. Yield (Figure 8.15) and biomass (Figure 8.16) projections use the same scenario as Figure 8.14 and are separated into females only (a) and all mature biomass (b). If average recruitment has declined, equivalent catch levels will be proportionally lower than are given by the projections.

8.3 Sources of Uncertainty: Natural and density-dependent variation in life history characteristics between localities is a key source of uncertainty for management. We have no new information on life history parameters for Sheephead, and as requested by CDFG, we used the four mainland study areas as possible alternative scenarios (Figure 8.17). Results were discussed at the end of Section 8.1. Appropriate management is strongly dependent on the life history parameters of the population, and it is possible that those parameters differ from place to place. Despite those potential differences, note that for all populations, relative mature SPR

approaches $SPR_{50\%}$ at an exploitation rate around 0.08, suggesting that this may be invariant, and therefore may be a generally useful reference point for management.

The most important source of uncertainty in the model is the estimate of natural mortality. Independent of the natural mortality scenario, however, Sheephead appear to have been declining in abundance and have exhibited a decline in the spawning potential ratio below target levels with zero or substantially decreased catch allowed under projections following the NFMP (Figures 8.10 and 8.15 CDFG 2002). Another source of uncertainty includes the lack of data on the abundance and exploitation of Sheephead in Mexico. Although our data included some fish from Mexico landed in the U.S., data were not available to indicate the status of the stock in Mexico. However, recruitment probably occurs between Mexican and U.S. and the populations are probably linked demographically. This leads to some uncertainty which should be considered when determining management strategies for Sheephead in California.

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11. TABLES AND FIGURES

Table 3.1 Mortality, growth and maturity parameter estimates for five populations from Warner (1975) and Cowen (1990). See the text for a description of how the parameters were determined. Parameters for Catalina (in bold) were used in the baseline model and the other parameter estimates were used for sensitivity analyses.

	POPULATION					
PARAMETER	***Catalina Island(Warner)***	***Guadalupe Island (Warner)***	***San Benitos Island (Cowen)***	***Guadalupe Island (Cowen)***	***Cabo Thurloe (Cowen)***	***San Nicolas Island (Cowen)***
Mortality	**0.35**	0.46	0.43	0.55	0.41	0.29
Maximum age in the sample	**20**	12	10	9	12	21
Estimated L_{inf}	**83.86**	46.03	83.85	45.46	464.16	85.19
k growth	**0.068**	0.064	0.064	0.064	0.007	0.064
L1 (age 1)	**12.92**	14.76	10.93	10.93	10.93	16.40
L2 (age 13)	**52.60**	31.47	49.91	29.39	49.84	53.17
L50 maturity	**25.24**	20.55	33.65	23.44	18.76	31.33
L50 sexchange	**36.77**	24.71	31.77	36.12	26.35	34.64
k maturity (slope)	**1.060**	4.169	0.190	1.506	1.338	0.152
k sexchange (slope)	**0.32**	0.33	3.75	0.81	0.31	0.23

Table 4.1 Historical California Sheephead landings (mtons) by fishery, 1916-2003.

	Hook & Line	Trap	Setnets	Total Commercial	Recreational	TOTAL
1916	1.61	0.00	0.00	1.61	0.00	1.61
1917	2.68	0.00	0.00	2.68	0.00	2.68
1918	10.42	0.00	0.00	10.42	0.00	10.42
1919	8.15	0.00	0.00	8.15	0.00	8.15
1920	6.61	0.00	0.00	6.61	0.00	6.61
1921	10.85	0.00	0.00	10.85	0.00	10.85
1922	8.26	0.00	0.00	8.26	0.00	8.26
1923	14.35	0.00	0.00	14.35	0.00	14.35
1924	11.01	0.00	0.00	11.01	0.00	11.01
1925	22.14	0.00	0.00	22.14	0.00	22.14
1926	63.02	0.00	0.00	63.02	0.00	63.02
1927	72.30	0.00	0.00	72.30	0.00	72.30
1928	169.04	0.00	0.00	169.04	0.00	169.04
1929	130.83	0.00	0.00	130.83	0.00	130.83
1930	110.54	0.00	0.00	110.54	0.00	110.54
1931	89.97	0.00	0.00	89.97	0.00	89.97
1932	40.64	0.00	0.00	40.64	0.00	40.64
1933	26.58	0.00	0.00	26.58	0.00	26.58
1934	65.11	0.00	0.00	65.11	0.00	65.11
1935	85.29	0.00	0.00	85.29	0.00	85.29
1936	58.32	0.00	0.00	58.32	0.00	58.32
1937	36.95	0.00	0.00	36.95	0.00	36.95
1938	32.67	0.00	0.00	32.67	0.00	32.67
1939	32.37	0.00	0.00	32.37	0.00	32.37
1940	28.28	0.00	0.00	28.28	0.00	28.28
1941	22.28	0.00	0.00	22.28	0.00	22.28
1942	22.80	0.00	0.00	22.80	0.00	22.80
1943	68.51	0.00	0.00	68.51	0.00	68.51
1944	76.50	0.00	0.00	76.50	0.00	76.50
1945	113.21	0.00	0.00	113.21	0.00	113.21
1946	121.17	0.00	0.00	121.17	0.00	121.17
1947	87.77	0.00	0.00	87.77	21.03	108.79
1948	45.46	0.00	0.00	45.46	27.91	73.37
1949	28.81	0.00	0.00	28.81	24.97	53.78
1950	30.03	0.00	0.00	30.03	23.09	53.13
1951	27.86	0.00	0.00	27.86	33.01	60.87
1952	16.43	0.00	0.00	16.43	26.65	43.08
1953	16.07	0.00	0.00	16.07	28.05	44.12
1954	13.24	0.00	0.00	13.24	34.77	48.00
1955	5.97	0.00	0.00	5.97	26.64	32.61
1956	2.98	0.00	0.00	2.98	27.75	30.73
1957	5.00	0.00	0.00	5.00	28.26	33.27
1958	5.16	0.00	0.00	5.16	33.14	38.29
1959	4.64	0.00	0.00	4.64	31.56	36.21
1960	2.15	0.00	0.00	2.15	22.50	24.65

(cont.)	Hook & Line	Trap	Setnets	Total Commercial	Recreational	TOTAL
1961	5.72	0.00	0.00	5.72	28.43	34.15
1962	9.22	0.00	0.00	9.22	25.65	34.87
1963	12.71	0.00	0.00	12.71	33.66	46.37
1964	8.13	0.00	0.00	8.13	47.21	55.34
1965	5.51	0.00	0.00	5.51	71.19	76.70
1966	7.25	0.00	0.00	7.25	89.49	96.74
1967	8.90	0.00	0.00	8.90	72.85	81.75
1968	5.78	0.00	0.00	5.78	57.32	63.10
1969	6.03	0.00	0.00	6.03	84.09	90.11
1970	1.73	0.00	0.00	1.73	67.65	69.38
1971	4.02	0.00	0.00	4.02	65.77	69.79
1972	3.21	0.00	0.00	3.21	58.08	61.29
1973	1.39	0.00	0.00	1.39	78.60	79.99
1974	1.69	0.00	0.00	1.69	52.96	54.65
1975	2.74	0.00	0.00	2.74	53.15	55.89
1976	3.78	0.00	0.00	3.78	57.08	60.86
1977	2.91	0.00	0.00	2.91	49.94	52.85
1978	0.94	0.49	3.63	5.05	59.48	64.53
1979	0.23	0.45	3.32	4.00	55.58	59.57
1980	0.85	1.08	2.20	4.13	143.57	147.69
1981	0.36	0.36	5.13	5.86	106.97	112.83
1982	0.44	0.82	4.08	5.34	92.03	97.37
1983	0.88	0.34	4.50	5.73	155.35	161.08
1984	1.96	0.28	9.15	11.40	131.20	142.59
1985	0.17	0.08	12.67	12.93	200.20	213.12
1986	0.39	0.00	12.88	13.27	223.30	236.57
1987	2.76	0.00	12.16	14.92	108.09	123.01
1988	2.84	0.00	10.47	13.31	178.84	192.15
1989	7.84	0.00	7.25	15.09	64.64	79.73
1990	49.60	0.00	6.54	56.14	60.00	116.14
1991	80.43	0.00	6.66	87.09	73.63	160.72
1992	111.20	0.00	6.14	117.34	45.50	162.84
1993	127.11	11.88	4.33	143.31	78.24	221.56
1994	27.06	89.92	0.72	117.70	121.12	238.81
1995	26.40	88.20	0.47	115.08	54.52	169.60
1996	20.89	92.83	0.68	114.40	81.22	195.62
1997	22.02	115.69	1.28	138.98	59.81	198.79
1998	24.79	93.32	0.94	119.04	76.51	195.55
1999	11.24	46.68	0.90	58.82	84.94	143.76
2000	15.16	62.31	1.21	78.68	100.09	178.77
2001	10.96	55.78	1.39	68.13	58.85	126.98
2002	10.34	43.71	0.66	54.71	60.26	114.96
2003	10.87	36.98	0.15	48.00	68.51	116.51
TOTAL	2512.47	741.20	119.50	3373.17	3924.88	7298.05
AVERAGE	28.55	8.42	1.36	38.33	44.60	82.93

Table 4.2 Initial sample sizes used for length composition data in the baseline model.

		SAMPLE SIZE (n)	
		Available	Used
Commercial			
	Hook and Line	162	119
	Trap	1072	1064
	Setnet	67	58
	Commercial Subtotal	1301	1241
Recreational			
	Hook and Line	8004	7294
TOTAL*		**9305**	**8535**

•Source data did not overlap between years. Source with larger sample size in a year was used. No year was used that had < 5 samples.

Table 5.1 A description of the parameters and variables in the Single-Sex Approximation Model.

Parameter	Description
$L(a)$	Length at age
k	Growth rate
L_∞	Asymptotic size
ε_g, ε_m, ε_f, ε_r	Error and uncertainty terms
$W(a)$	Weight at age
c	Weight to length scalar
d	Weight to allometry
$M(t)$	Auto-correlated mortality term
ρ	Auto-correlation term
θ_i	Selectivity for fishery, i
T_i	Scaling factor for selectivity
β_{1i}, β_{3i}	Steepness for fishing selectivity
β_{2i}, β_{4i}	Midpoint size for selectivity curves
$F(a)$	Fishing mortality
E_i	Effort for fishery, i
$C(t)$	Catch at time, t
$p_m(a)$	Proportion of age class mature
L_{50m}	Size at which 50% of individuals mature
$p_f(a)$	Proportion of age class still female
L_{50f}	Size at which 50% of individuals are female
r	Rate of maturity or sex change
$p_s(a)$	Proportion of age class able to produce eggs
$\varphi(a)_{\text{sex change}}$, $\varphi(a)_{\text{single sex}}$	Number of eggs produced by age class
σ	Eggs produced per kg body weight
h	Steepness of recruitment curve at 20% of virgin SSB
R_0	Recruitment at virgin SSB
S_0	Virgin SSB
a	Maximum number of recruits produced
b	SSB needed to produce half of a
ϕ_0	Lifetime eggs per recruit without fishing

Table 6.1 Likelihood components, emphasis levels and their relative values in the final fit of the baseline model.

Likelihood component	Emphasis	Value
hook and line landings	1	-0.06
hooks and line length composition	1	-32.07
trap landings	1	0.00
trap length compositions	1	-42.90
setnet landings	1	0.00
setnet length composition	1	-12.87
recreational landings	1	-0.06
recreational length composition	1	-189.17
CPFV logbook CPUE (1947-1961)	1	-12.40
CPFV logbook CPUE (1960-1981)	1	-16.93
CPFV logbook CPUE (1980-2003)	1	10.10
CalCOFI SPB	1	-46.22
spawned-recruit curve- individual	0	-2450.28
recruit-recruit curve- mean	0	-267579.98
ending biomass	0	1036.96
total log-likelihood:		-342.5729

T**able 6.2** The parameter values and estimation status for the baseline model.

PARAMETER	VALUE	ESTIMATED?
Natural mortality	0.35	no
Maturity		
L_{50} Maturity	25.24	no
K (slope) maturity	1.06	no
L_{50} sex change	36.7	no
k (slope) sex change	0.32	no
Growth		
L_1	12.92	no
L_2	52.6	no
K	0.068	no
CV_1	0.14	yes
CV_2	0.26	yes
Recruitment		
Virgin recruitment (SR curve)	1.39	yes
Steepness parameter (SR curve)	0.70	yes
Standard deviation of recruitment	0.61	yes
Background recruitment	0.88	yes
Selectivities		
Hook and line: initial selectivity	0.0058	yes
Hook and line: inflection	1.0000	yes
Hook and line: slope	0.3081	yes
Traps: initial selectivity	0.0055	yes
Traps: inflection point	0.3506	yes
Traps: slope	0.6895	yes
Setnet: initial selectivity	0.0019	yes
Setnet: inflection	1.0000	yes
Setnet: slope	0.2549	yes
Recreational: initial selectivity	0.0012	yes
Recreational: inflection	0.3089	yes
Recreational: slope	0.5369	yes

Table 6.3 Sensitivity analyses on growth: The effect of allowing the growth parameters to be estimated within the Synthesis model.

PARAMETER	Baseline model	Growth parameters estimated
L_1	12.92 (fixed)	12.92 (fixed)
L_2	52.60 (fixed)	51.79 (estimated)
K	0.068 (fixed)	0.099 (estimated)
CV_1	0.14 (estimated)	0.13 (estimated)
CV_2	0.26 (estimated)	0.24 (estimated)
log-likelihood	-342.57	-340.57

Table 7.1 The effect of the coefficient of variation in growth on the estimated status of the stock as measured by the spawning potential ratio. The coefficient of variation in growth parameters (CV_1 and CV_2) were assumed to be equal and affect the estimated total biomass which therefore leads to different estimates of current exploitation among runs of the model that differ in CV_1 and CV_2.

CV	current exploitation	relative female SPR	relative male SPR	relative total SPR
0.10	0.07	0.87	0.54	0.77
0.20	0.11	0.80	0.39	0.70
0.30	0.20	0.68	0.19	0.59

Table 8.1. We refitted the length and maturity data from the Warner and Cowen theses for all nearshore data sets. The life history parameters in this table were also used to calculate relative SPR in figure 8.17.

	Population			
Parameter	*Catalina Island (Warner)*	*San Benitos Island (Cowen)*	*Cabo Thruloe (Cowen)*	*San Nicolas Island (Cowen)*
Estimate L_{inf}	83.86	130	145.86	85.19
k growth	0.068	0.026	0.028	0.064
L_1 (age 1)	12.92	7.35	10.16	16.4
L_2 (age 13)	52.49	40.22	49.38	53.3
L_{50} maturity	25.24	26.9	21.8	33.3
L_{50} sex change	36.77	33.4	30.9	54.5
k maturity (slope)	1.06	0.88	0.52	0.78
k sex change (slope)	0.32	0.46	0.21	0.54

Table 8.2 Likelihood components, emphasis levels and their relative values in the final fit of the baseline model with M=0.20. Other options for M are shown for comparison.

		M=0.20	**M=0.15**	**M=0.30**
Likelihood component	**Emphasis**	**Value**	**Value**	**Value**
hook and line landings	1	0.00	0.00	0.00
hook and line length compositions	1	-46.78	-47.83	-45.49
trap landings	1	0.00	0.00	0.00
trap length compositions	1	-50.69	-51.82	-49.96
setnet landings	1	0.00	0.00	0.00
setnet length compositions	1	-24.77	-24.31	-26.15
recreational landings	1	0.00	0.00	0.00
recreational length compositions	1	-238.95	-245.74	-237.56
CPFV logbook CPUE (1947-1961)	1	-12.26	-12.29	-12.27
CPFV logbook CPUE (1960-1981)	1	-16.82	-16.96	-16.78
CPFV logbook CPUE (1980-2003)	1	4.56	-0.10	6.99
CalCOFI SPB	1	-34.43	-34.90	-34.44
Spawner-recruit curve - individual	0.01	-31.06	-19.57	-32.49
Spawner-recruit curve - mean	0.01	-312.35	-10.91	-344.13
Total log-likelihood		-423.57	-434.26	-419.42

Table 8.3 The parameter values and estimation status for the final Sheephead stock assessment model with M= 0.20. Other options for M are shown for comparison.

		M=0.20	M=0.15	M=0.30
PARAMETER	**STATUS**	**VALUE**	**VALUE**	**VALUE**
Natural Mortality	FIXED	0.2	0.15	0.3
Maturity				
L50 Maturity	FIXED	25.24	25.24	25.24
k (slope) maturity	FIXED	1.06	1.06	1.06
L50 sex change	FIXED	36.7	36.7	36.7
k (slope) sex change	FIXED	0.32	0.32	0.32
Growth				
L1	FIXED	12.92	12.92	12.92
LINF	FIXED	52.6	52.6	52.6
K	FIXED	0.068	0.068	0.068
CV1	FIXED	0.11	0.11	0.11
CV1	FIXED	0.11	0.11	0.11
Recruitment				
Virgin recruitment (SR curve)	ESTIMATED	0.219875	0.2	0.63445662
Steepness parameter (SR curve)	FIXED	0.99	0.99	0.99
Standard deviation of recruitment	FIXED	0.8	0.8	0.8
Background recruitment	FIXED	1.163816	1.163816	1.163816
Selectivities				
Hook and line: initial selectivity	ESTIMATED	0.007365	0.00939618	0.00381731
Hook and line: inflection point	ESTIMATED	0.520713	0.50218018	0.55852208
Hook and line: slope	ESTIMATED	0.302354	0.32276091	0.25454652
Traps: initial selectivity	ESTIMATED	0.011185	0.0115224	0.00705048
Traps: inflection point	ESTIMATED	0.178	0.17580839	0.1829147
Traps: slope	ESTIMATED	0.752285	0.76223522	0.7069142
Setnet: initial selectivity	ESTIMATED	0.000612	0.00082801	0.0002709
Setnet: inflection point	ESTIMATED	0.656452	0.6313351	0.68210677
Setnet: slope	ESTIMATED	0.179861	0.18568015	0.17189107
Recreational: initial selectivity	ESTIMATED	0.002149	0.00245944	0.00139085
Recreational: inflection point	ESTIMATED	0.14896	0.14578432	0.15768232
Recreational: slope	ESTIMATED	0.562873	0.57434163	0.54215113

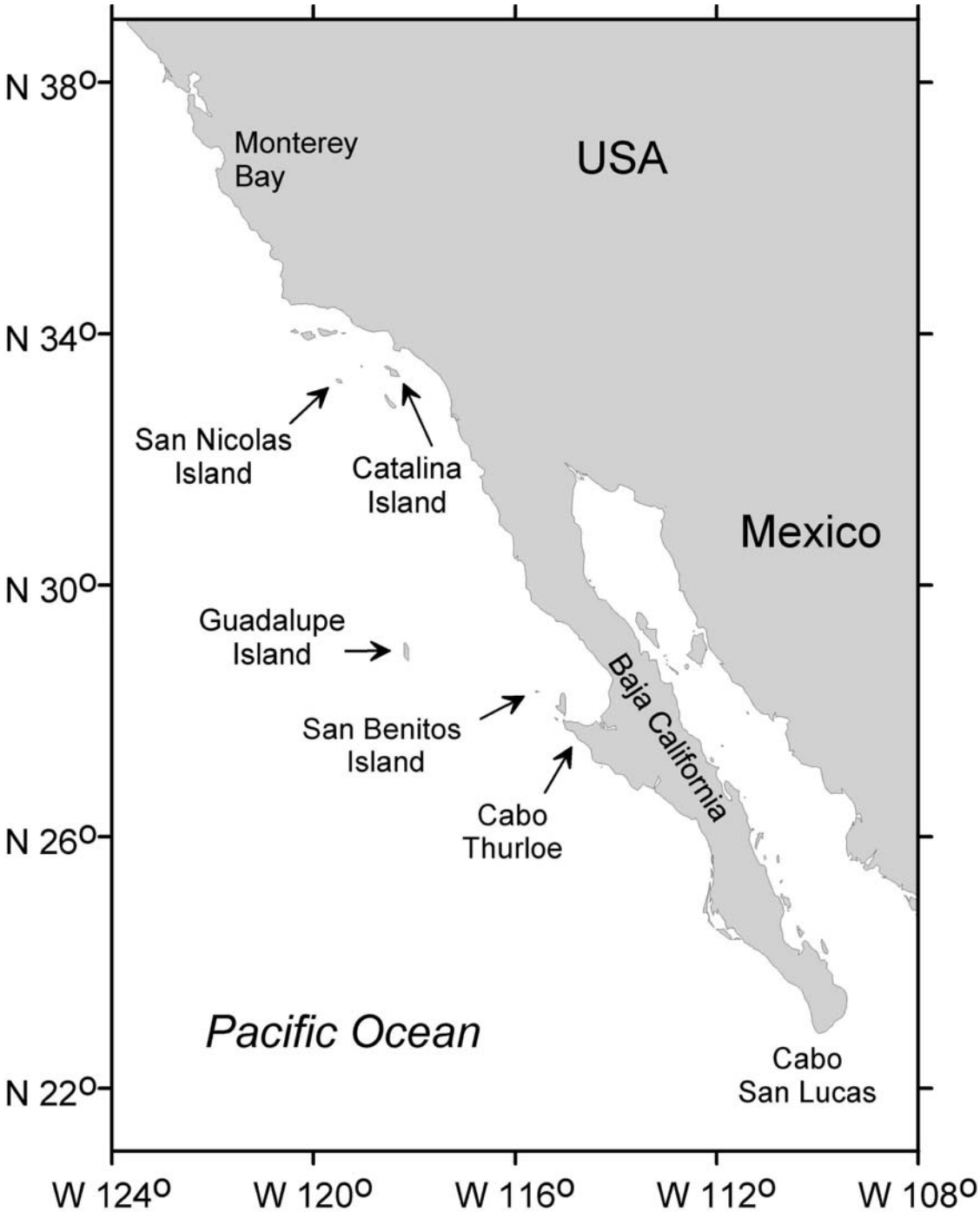


Figure 1.1 California Sheephead are found from Monterey Bay, CA to Cabo San Lucas, Mexico. The study areas from Warner (1975) and Cowen (1990) are also shown here.

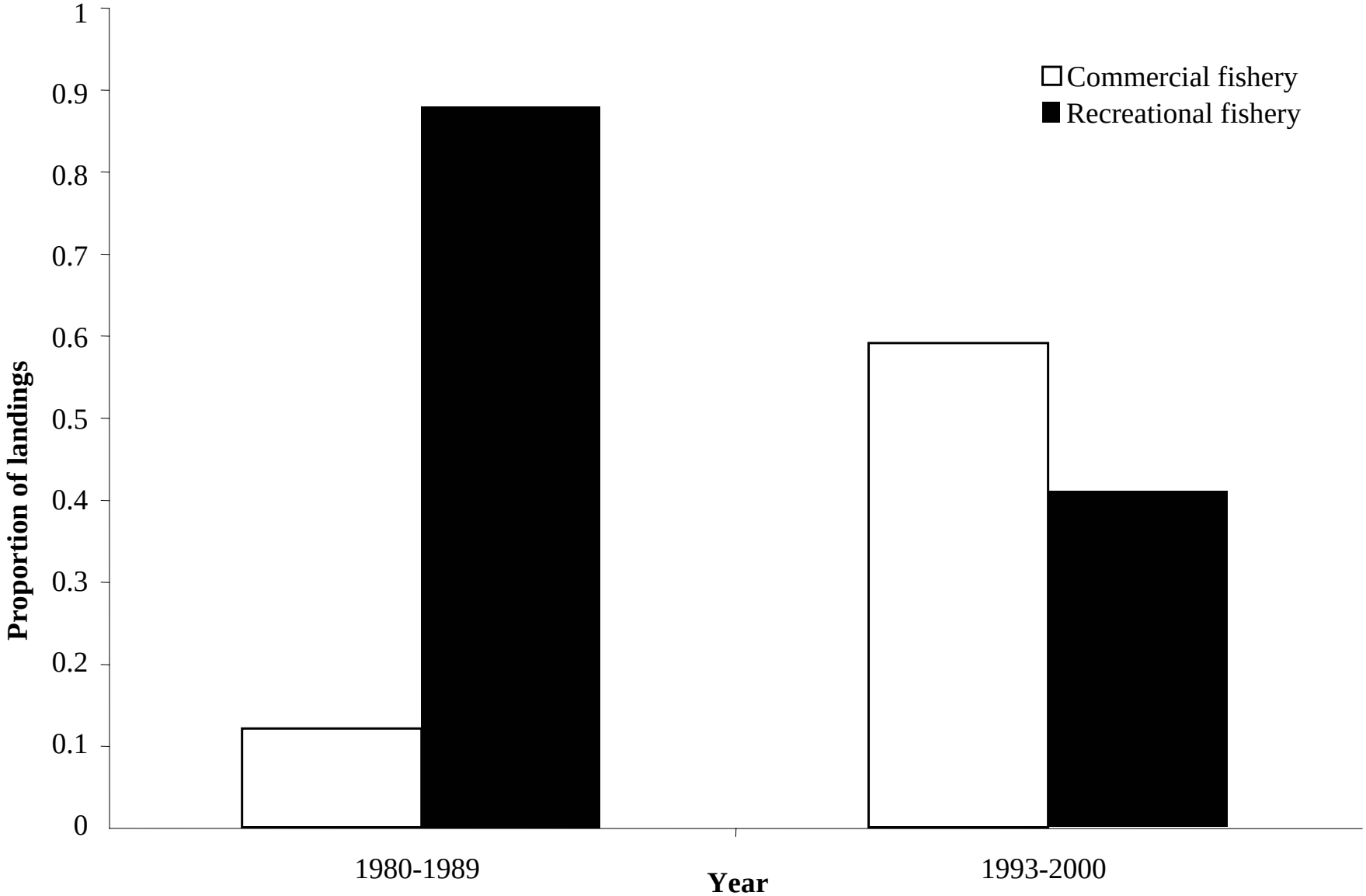


Figure 2.1 Proportion of total landings from the commercial and recreational fisheries during two periods from Schroeder and Love 2002.

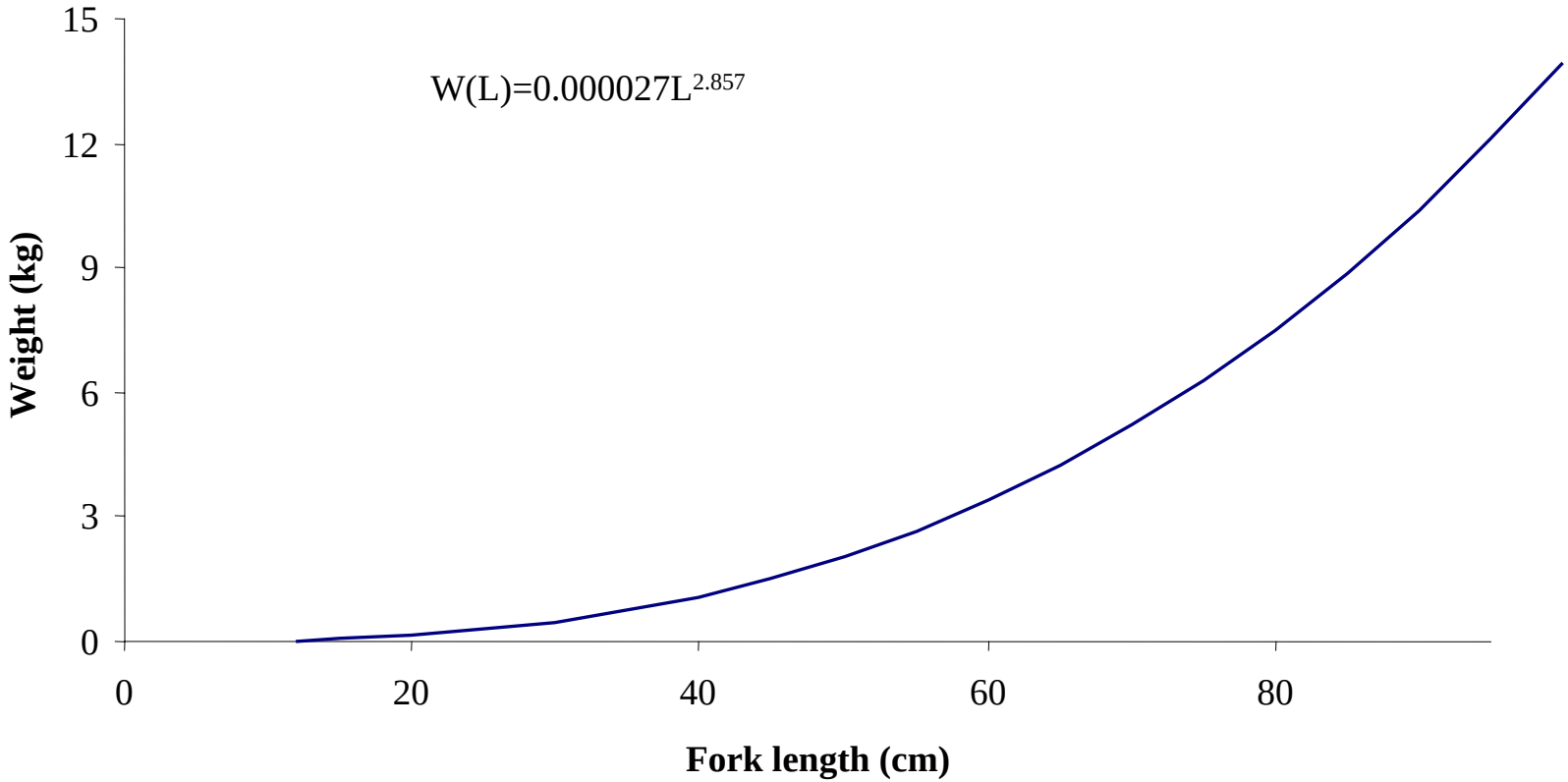


Figure 3.1 The power relationship between length in cm and weight in kg (converted from DeMartini et al. 1994).

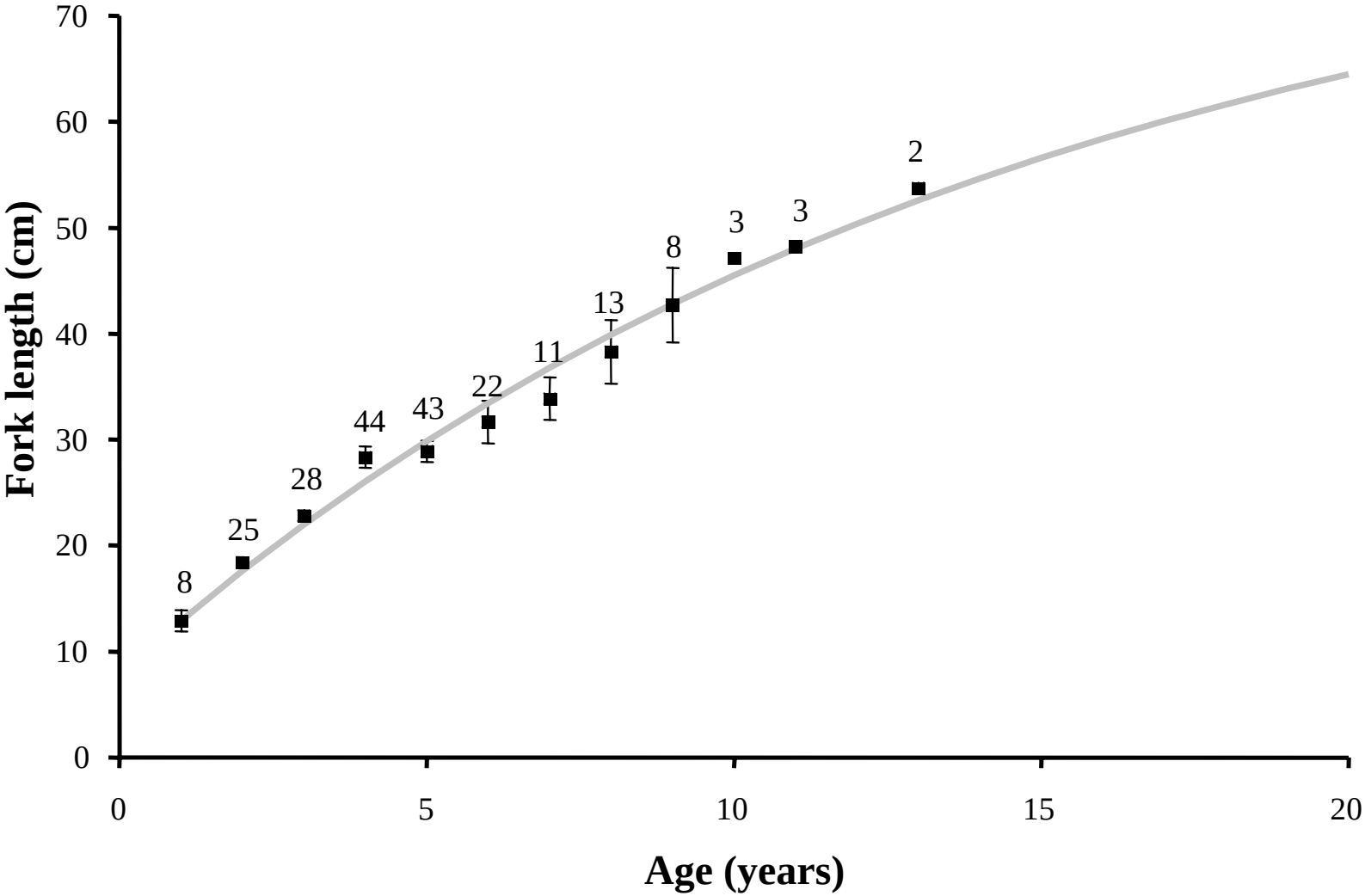


Figure 3.2 Predicted size at age using the best-fit growth parameters compared with the observed mean size at age data from Warner (1975). Error bars show the 95% confidence interval around the mean size at age and sample sizes per age are also given.

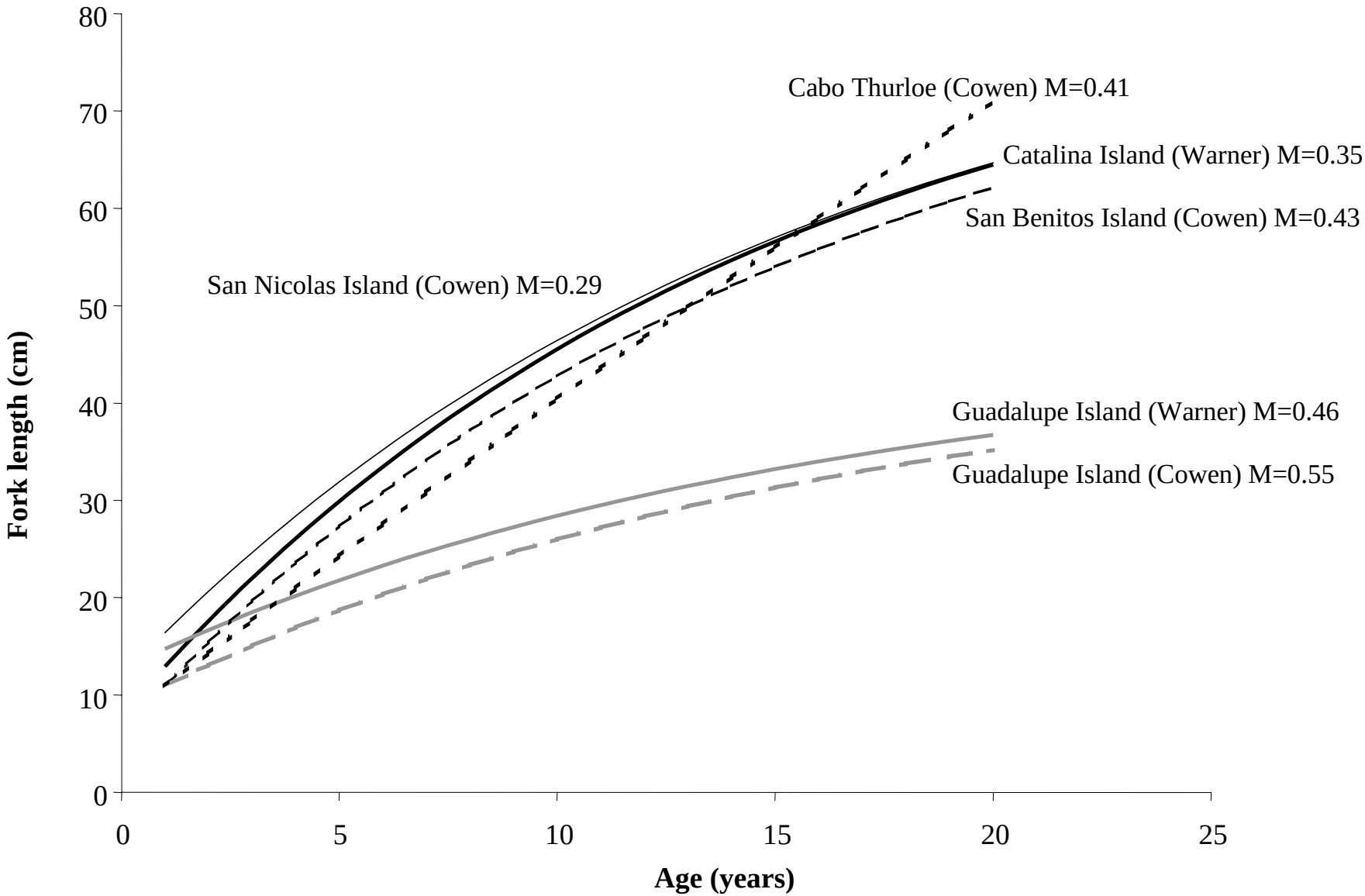


Figure 3.3 Variation among populations in growth. The parameter values for each population are given in Table 3.1.

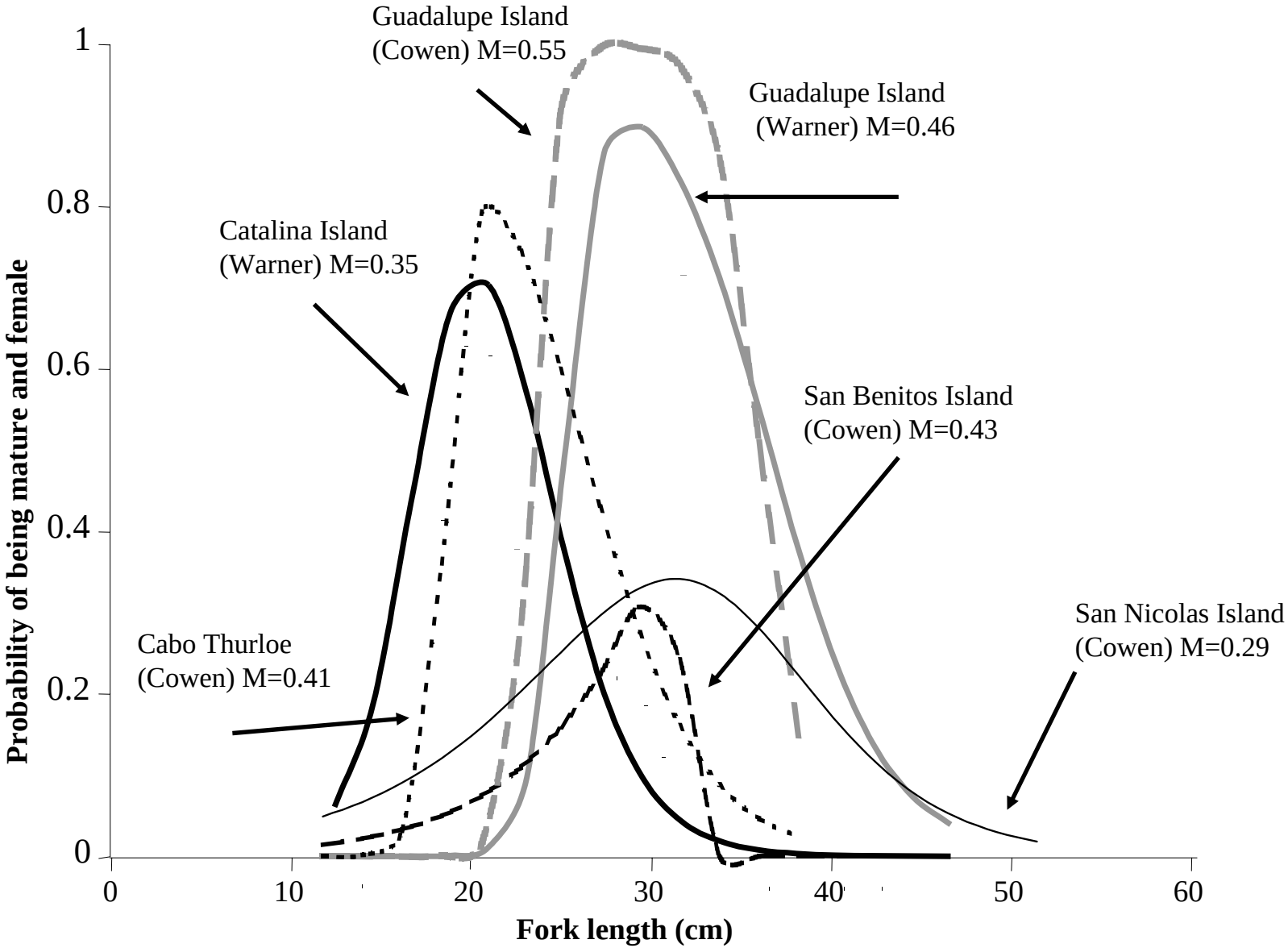


Figure 3.4 Variation among populations in maturity and sex change. Parameter values are given in Table 3.1.

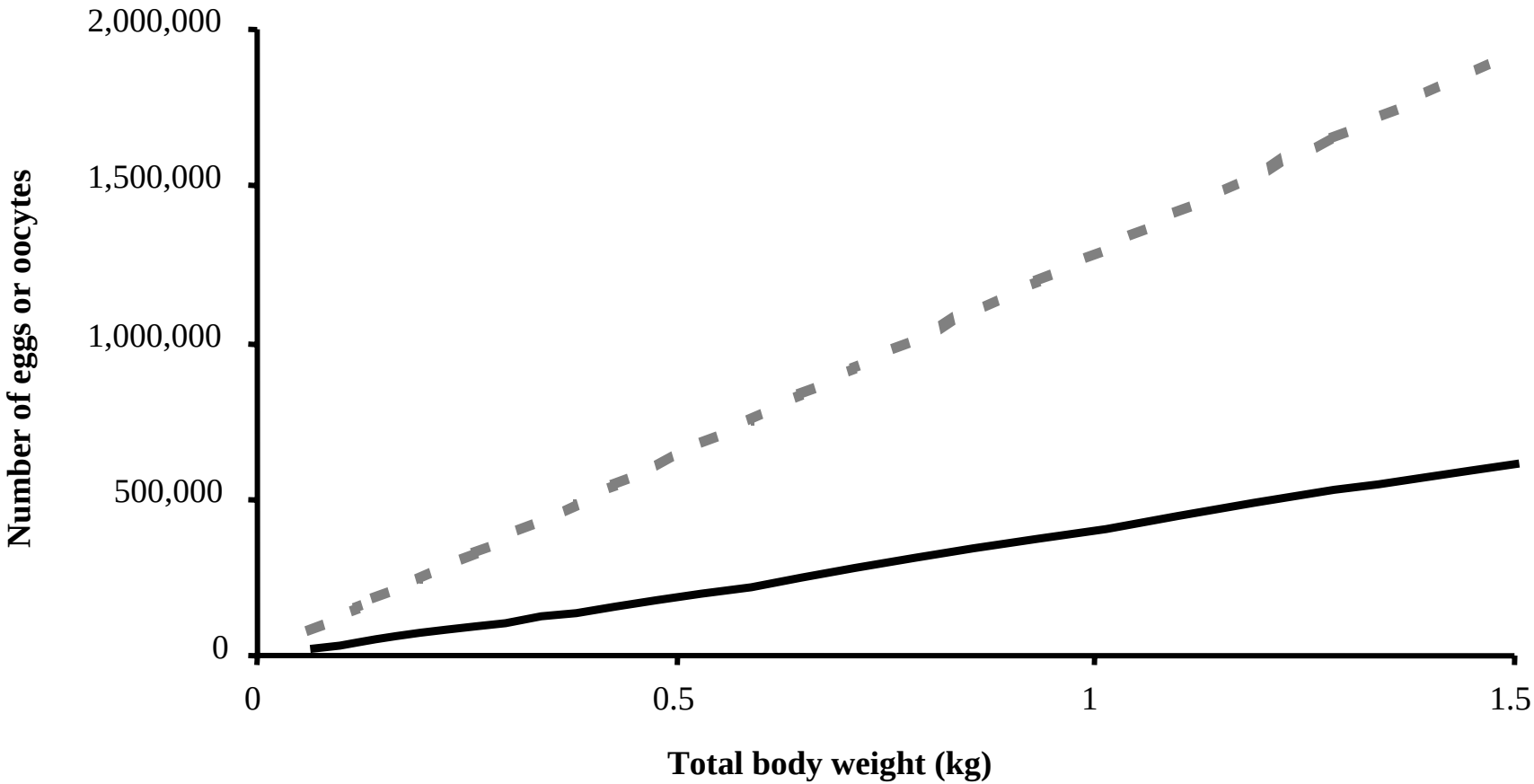


Figure 3.5 The relationship between annual egg production or the estimated number of oocytes per female as a function of total body weight in kilograms. The dashed gray line shows the estimated total egg production of females as a function of their body weight (data for the estimate taken from DeMartini et al. 1994). We use this relationship in the baseline Synthesis model. The solid black line shows the number of oocytes per female as a function of female body weight (data for the estimate taken from Warner 1975 and the weight/length relationship published in DeMartini et al. 1994). We used this relationship in a sensitivity analysis.

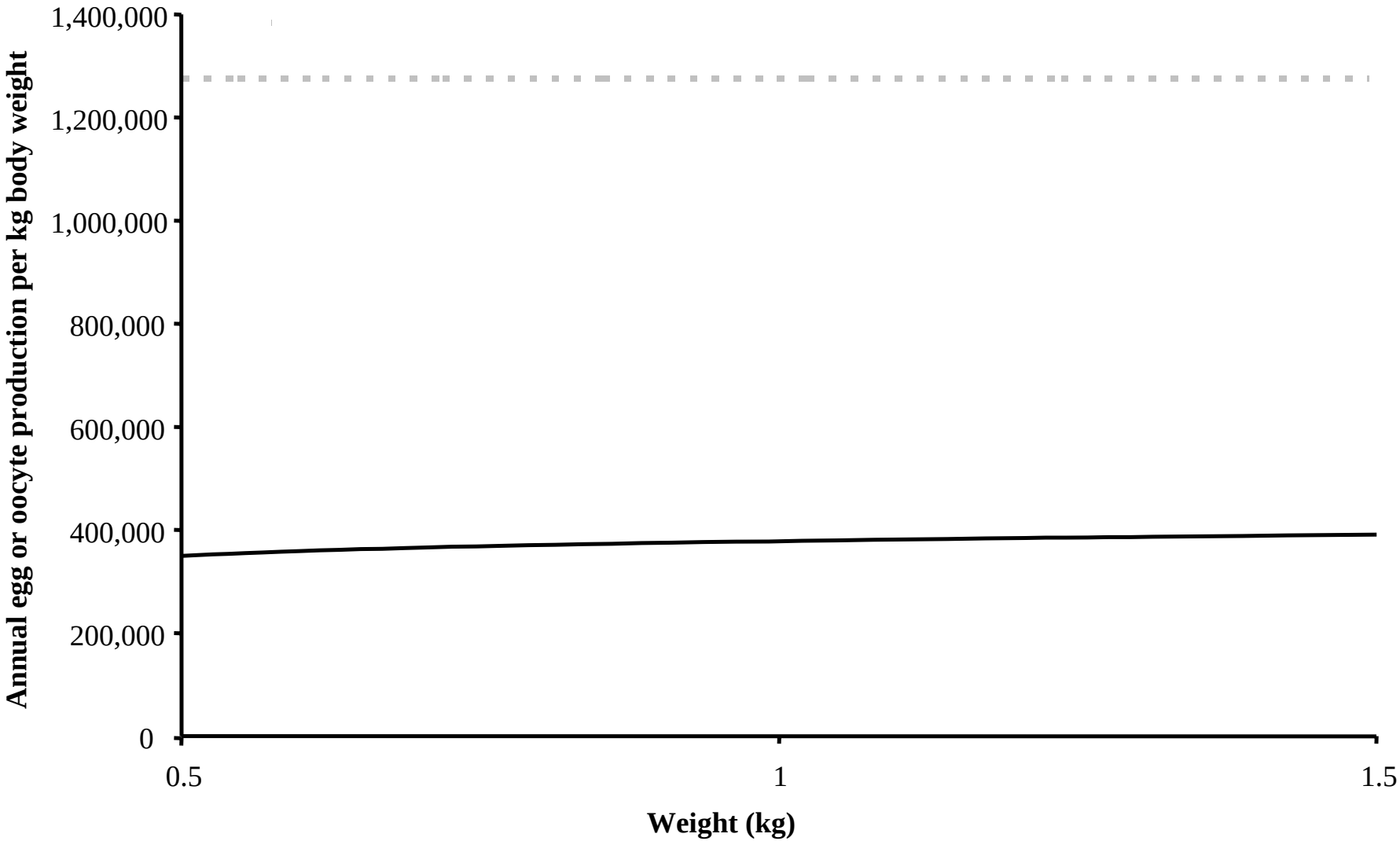


Figure 3.6 Weight-specific egg production did not increase with individual body weight. The weight range shown is for the weights and lengths (15cm to 50 cm approximately) in which some individuals might be mature and female. The dashed gray line shows the expected number of eggs produced annually per kilogram of female body weight (data for the estimate taken from DeMartini et al. 1994). The solid black line shows the expected number of oocytes per kilogram of female body weight (data for the estimate taken from Warner 1975 and the weight/length relationship published in DeMartini et al. 1994). We used the data from DeMartini et al (1994) for the baseline model (slope=0 intercept=129,000) and the Warner derived slope and intercept (slope=55,000 and intercept=341,000) as a sensitivity analysis.

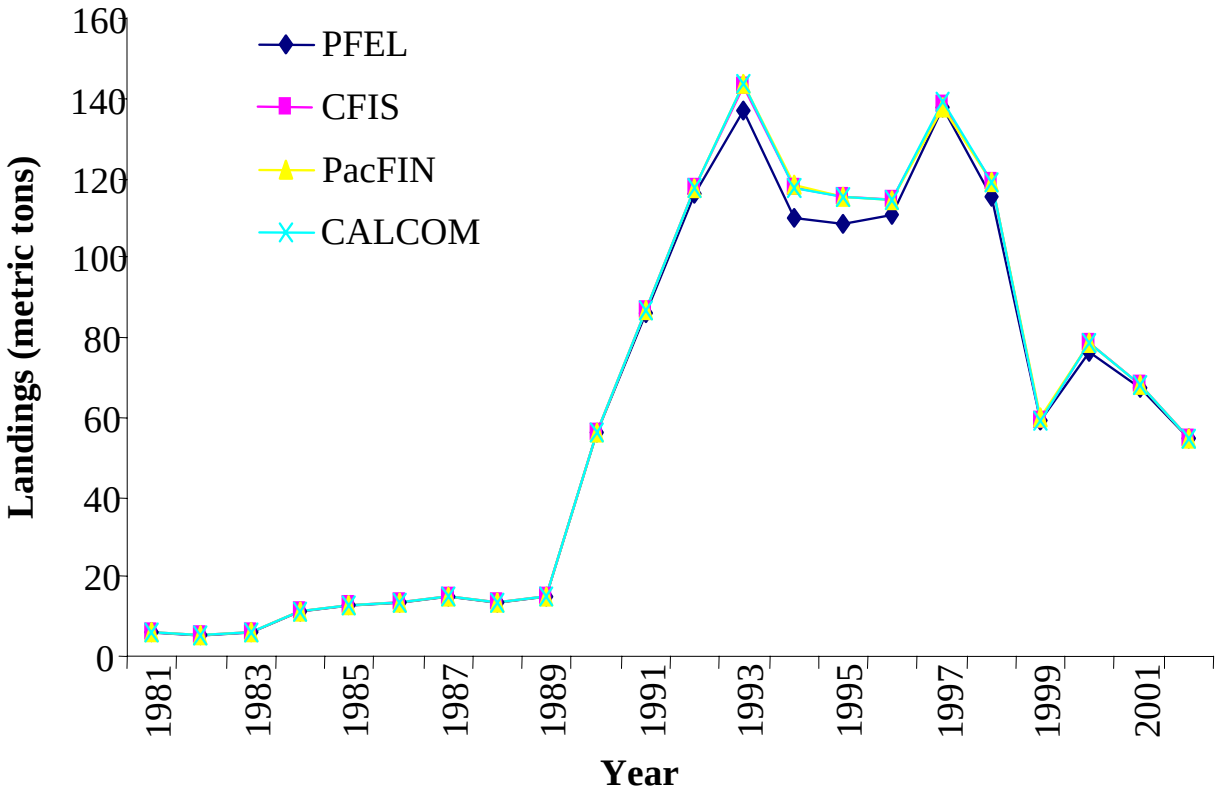


Figure 4.1a Comparing commercial landings (metric tons) by data source for overlapping time periods (1981-2002). No significant differences were detected (p=0.999).

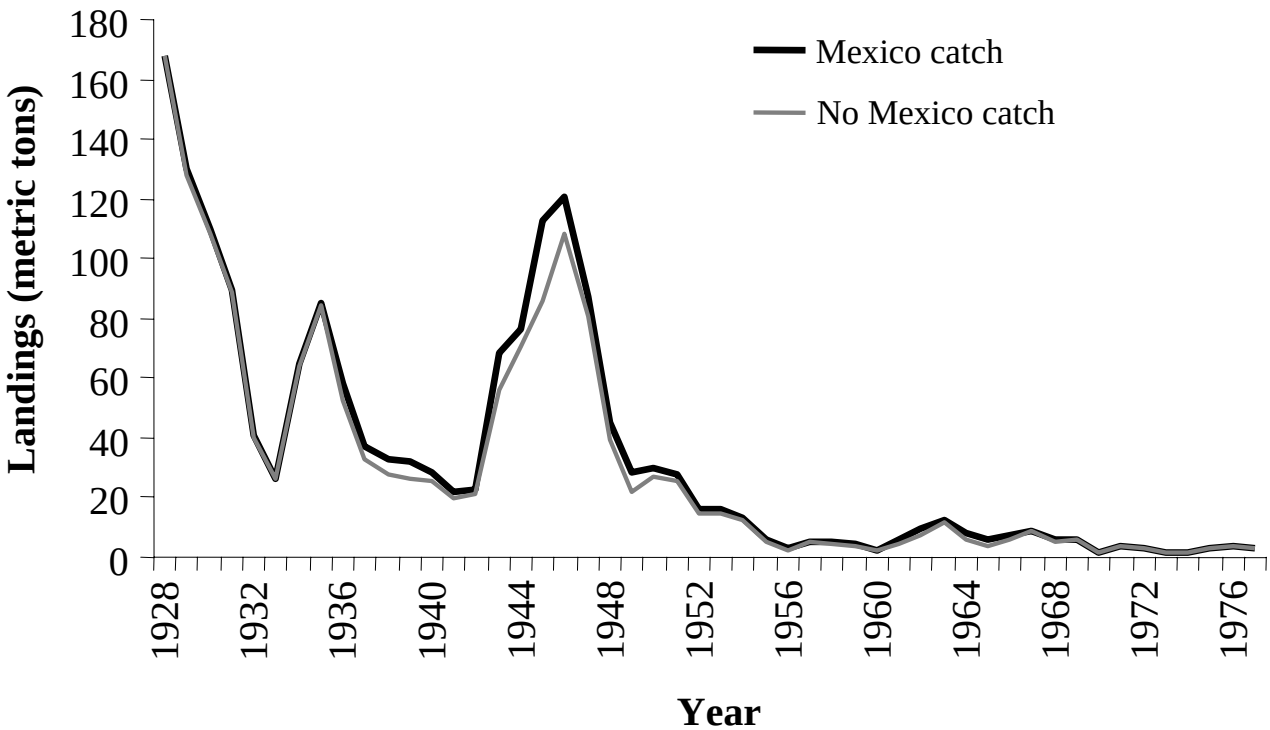


Figure 4.1b Comparing total Sheephead removals between two data sources; one including catch in Mexico (California's Living Marine Resources - CLMR) and the other not including Mexico catch (PFEL). We used landings caught in Mexico and brought into California for total removals in our baseline model.

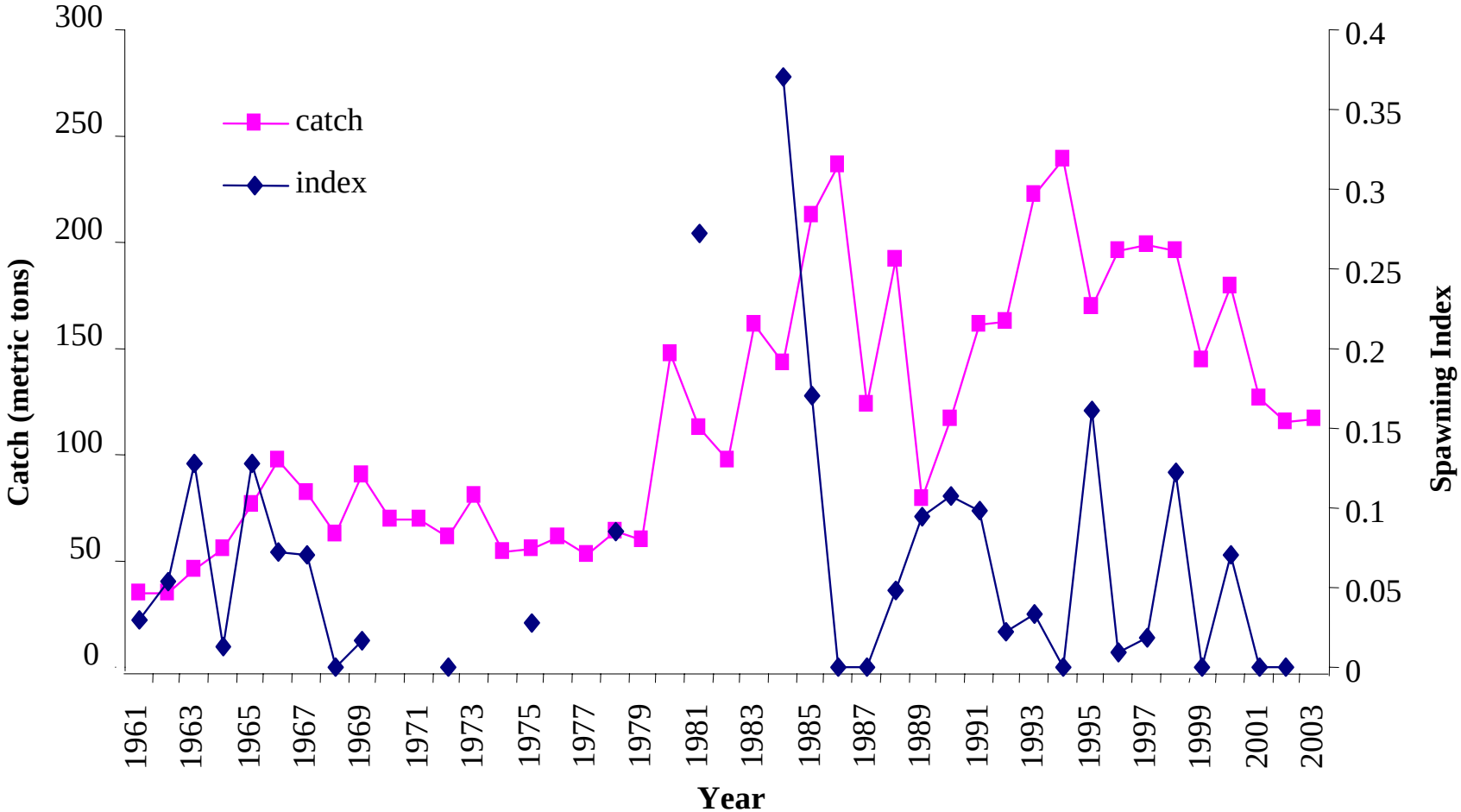


Figure 4.2 Comparing the annual variation (1961-2003) of landings ($p<0.001$) and the index of abundance ($p=0.032$) from CalCOFI larval surveys. Sheephead larvae appeared in the CalCOFI survey in 1961.

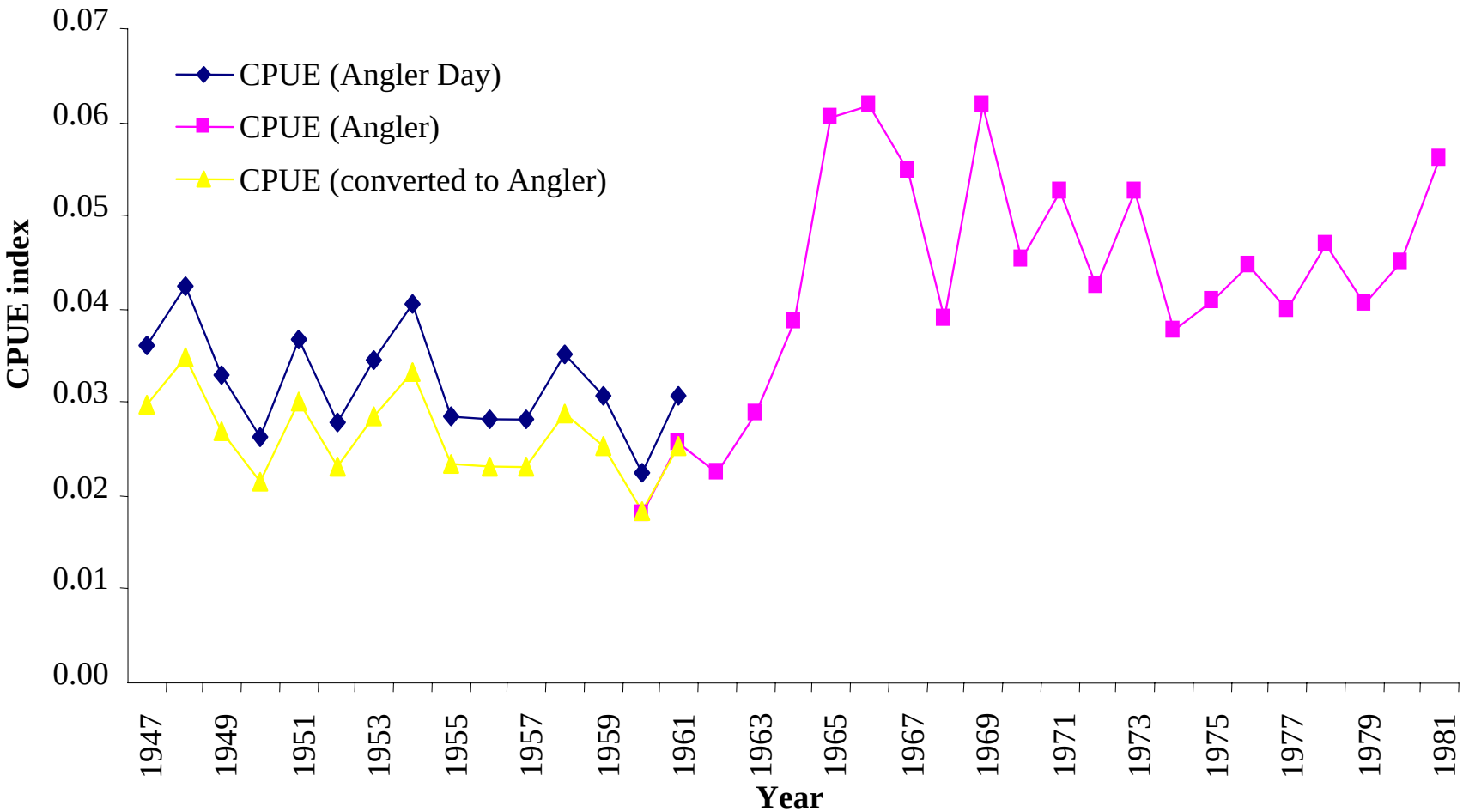


Figure 4.3 Comparing units of catch per unit effort from 1947-1981from CPFV logbooks. Converting catch per angler day to make one series of catch per angler does not change the general trend in those years; however, there is a difference between the two indices (p=0.004). We used the separated time series of differing units in the baseline model; catch per angler day from 1947-1961 and catch per angler from 1960-1981.

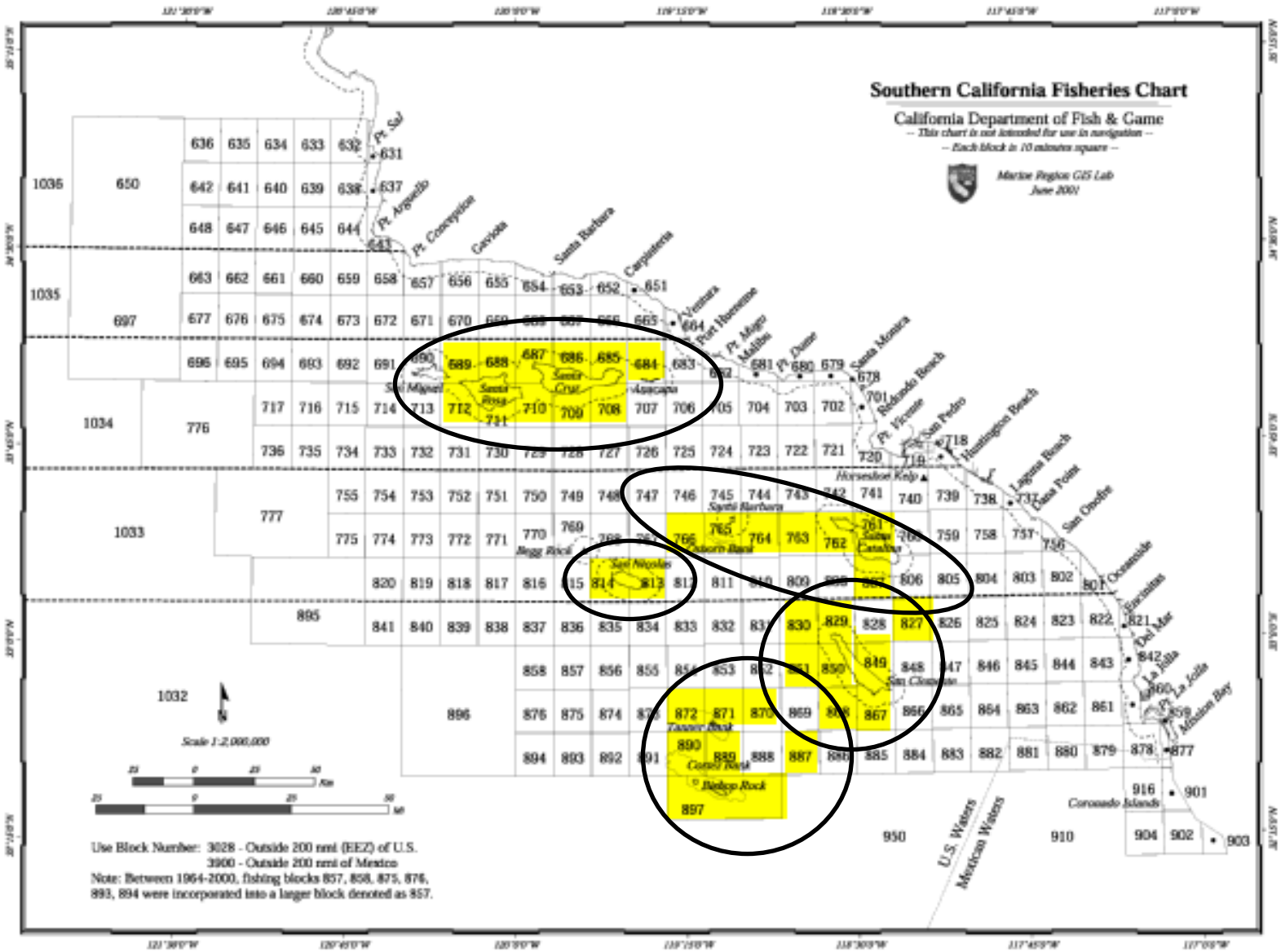
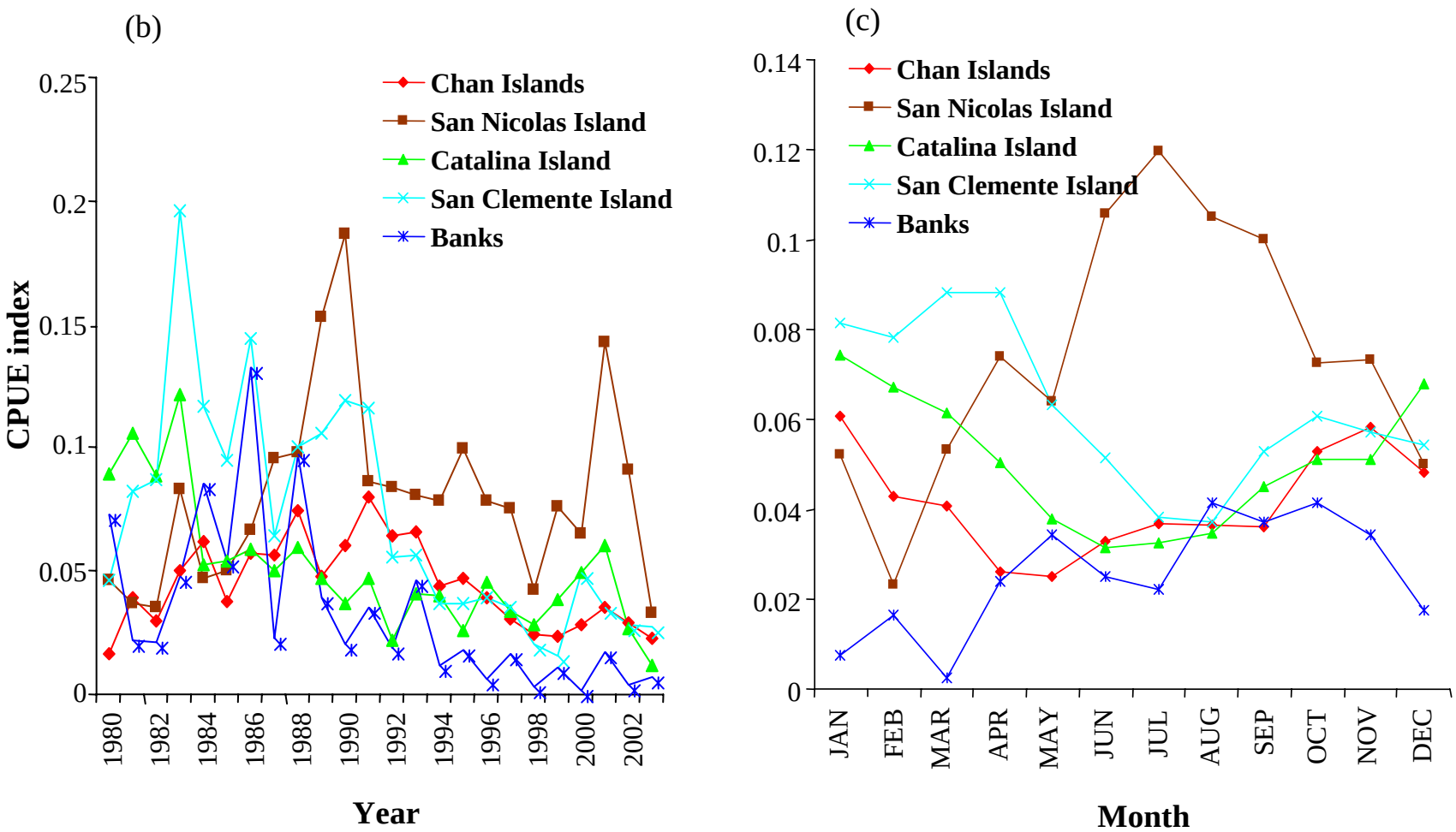


Figure 4.4a The CPUE index from 1980-2003 was calculated using logbook block information. Once run through a GLM, we found that 70% of the cumulative block values were in the following five geographic regions: Northern Channel Islands, San Nicolas Island, Santa Catalina Island, San Clemente Island, and Tanner and Cortez Banks.



Figures 4.4 (b) shows the variability in the CPUE Index and (c) monthly effects for each Geographic Fishing Area. A separate glm was run for each area considering the interactions shown here.

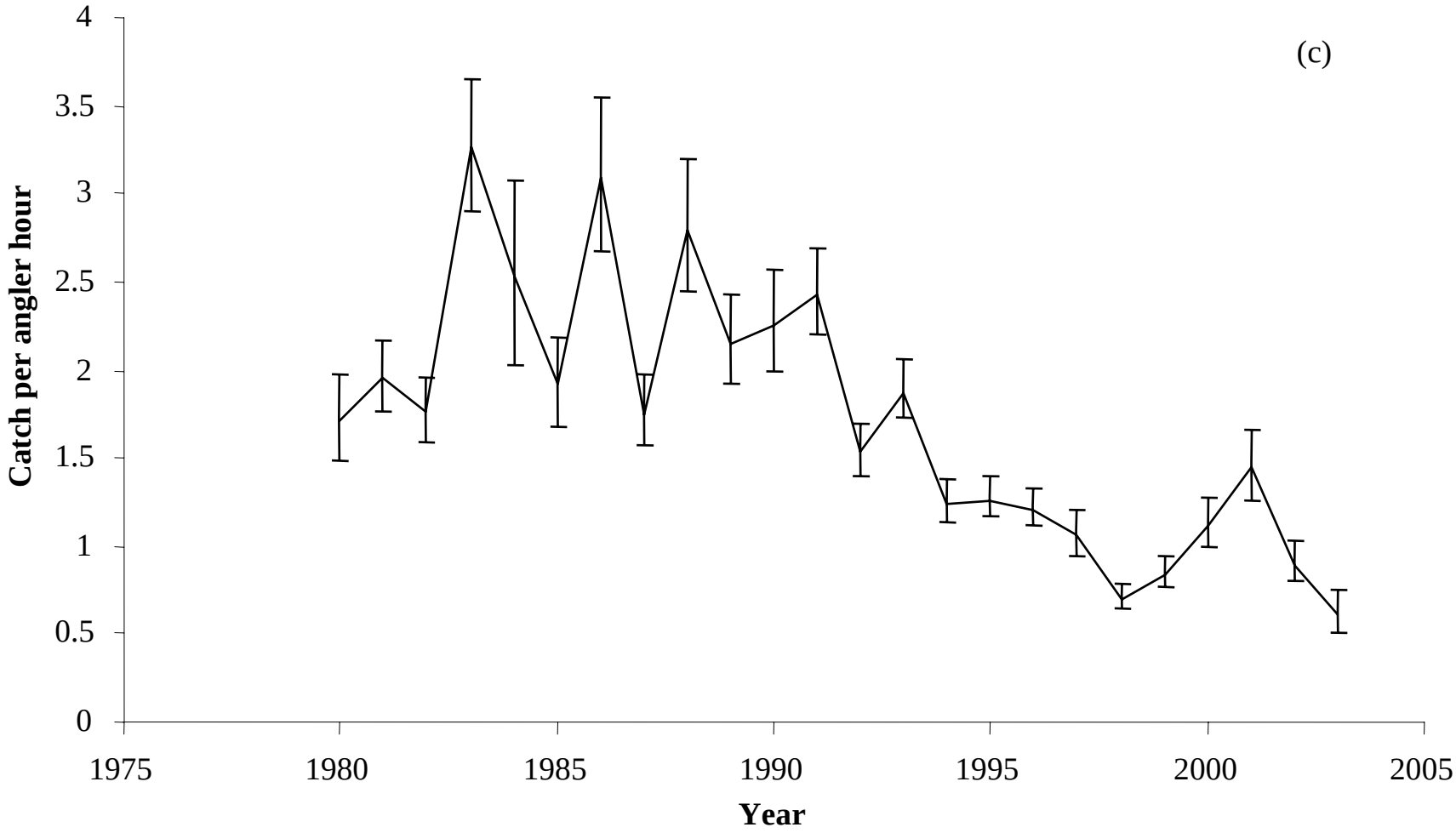
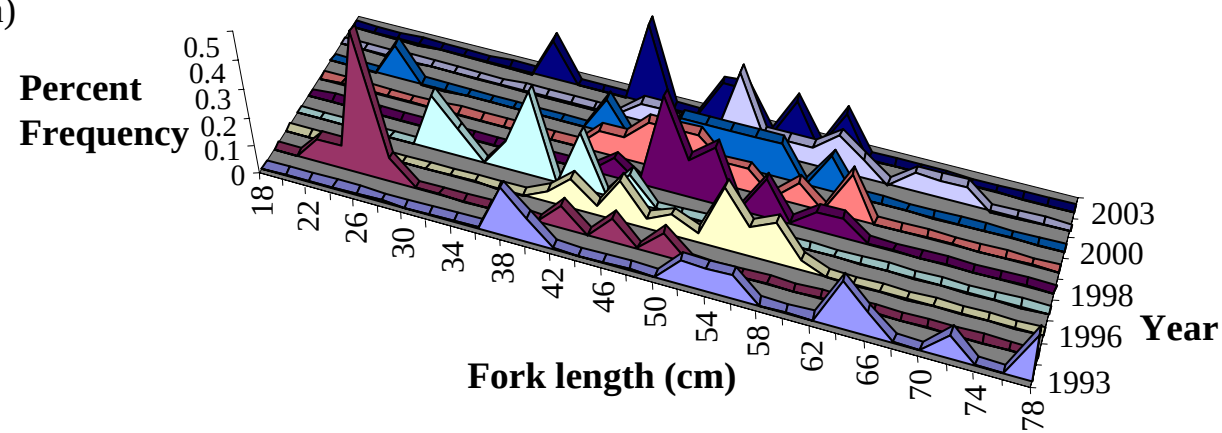
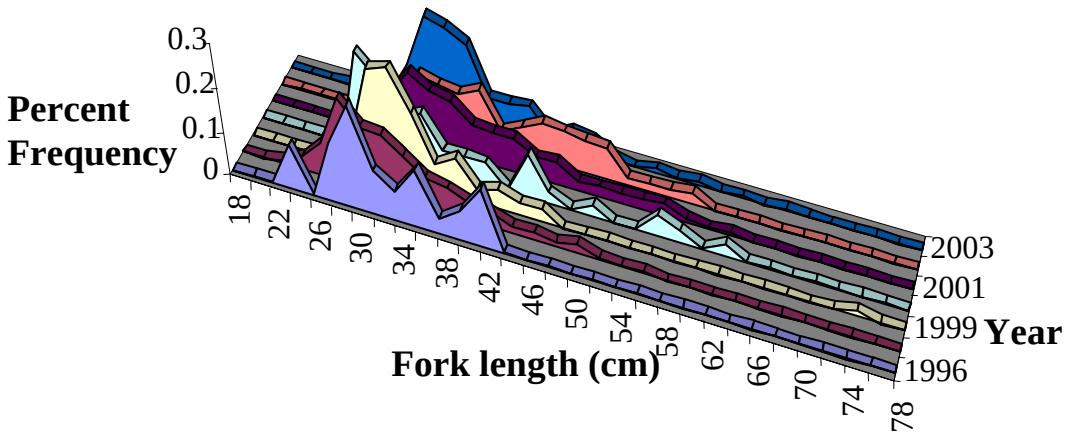


Figure 4.4d Southern California CPFV logbook index (1980-2003) calculated using block information from 5 separate geographic areas (+-1SE).

(a)

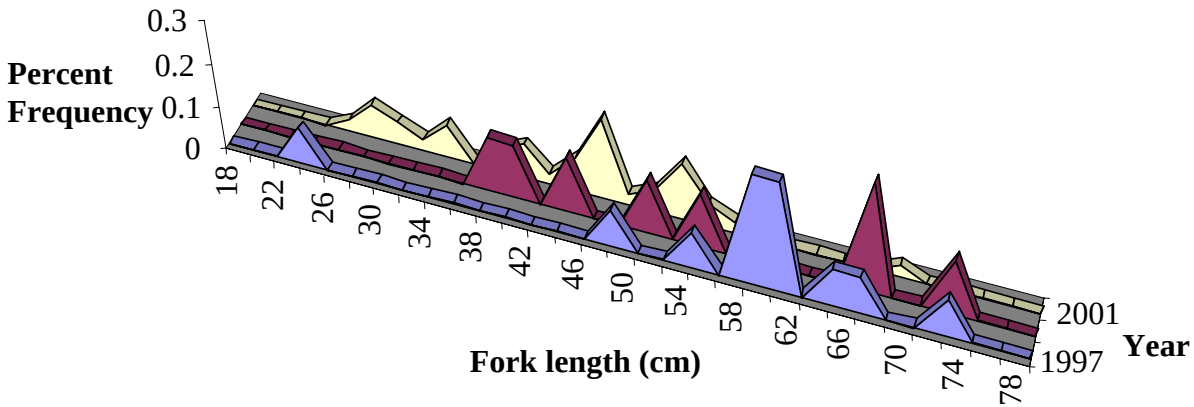


(b)

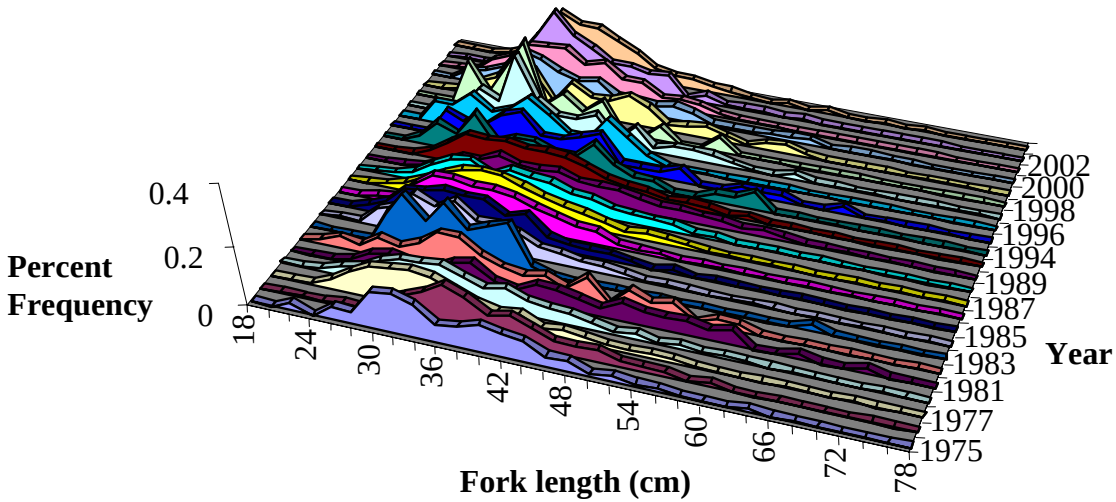


Figures 4.5 shows length compositions for the commercial (a) hook-and-line and (b) trap fisheries.

(c)



(d)



Figures 4.5 shows length compositions for the (c) setnet and (d) recreational fisheries.

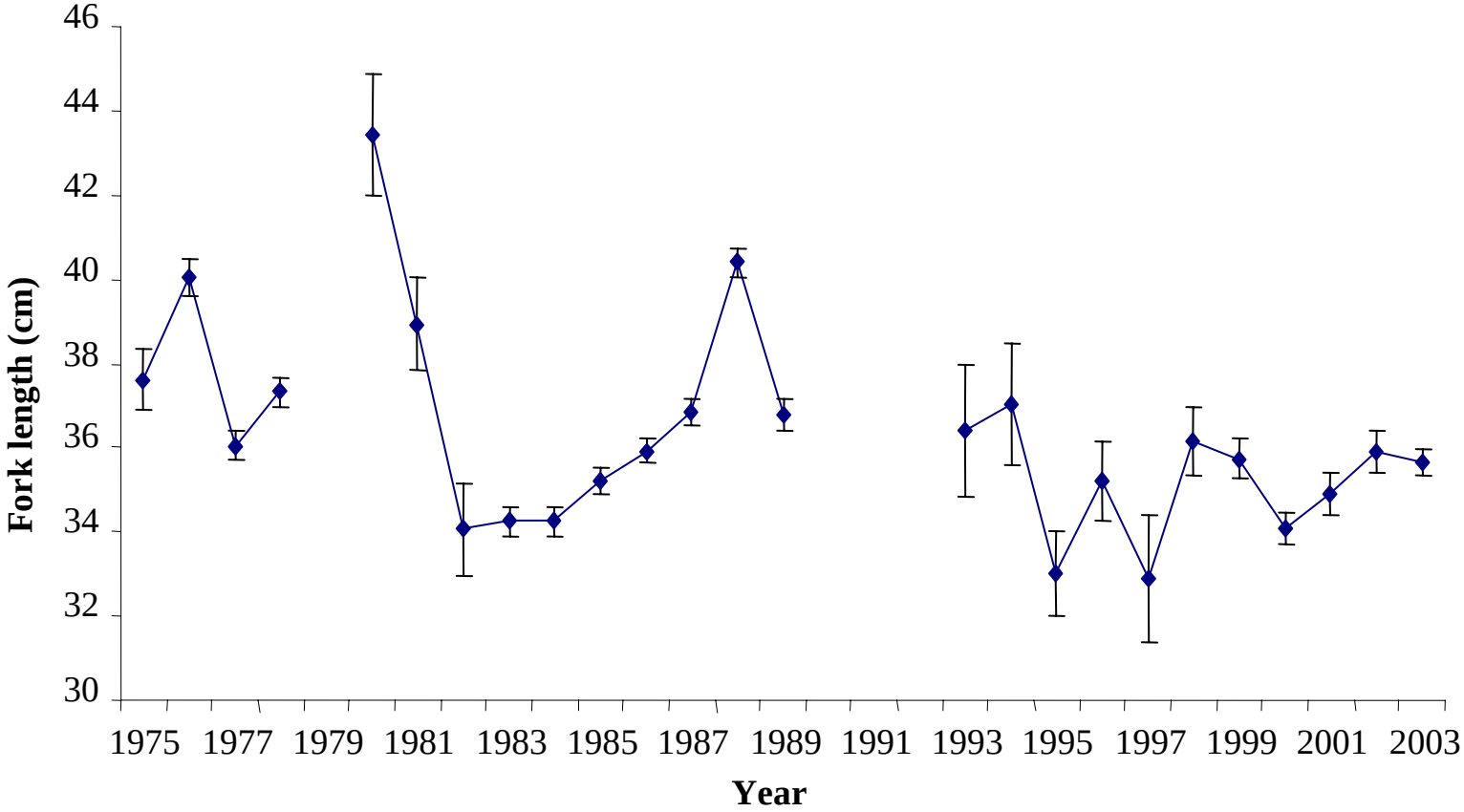


Figure 4.6 Average lengths of California Sheephead landed on CPFV's, 1975-2003 (some years missing). Data for the 1975-1978 sample period are from Collins and Crooke, 1984-1989 sample period are from Ally et al, and all other years are from RecFIN (+- 1SE).

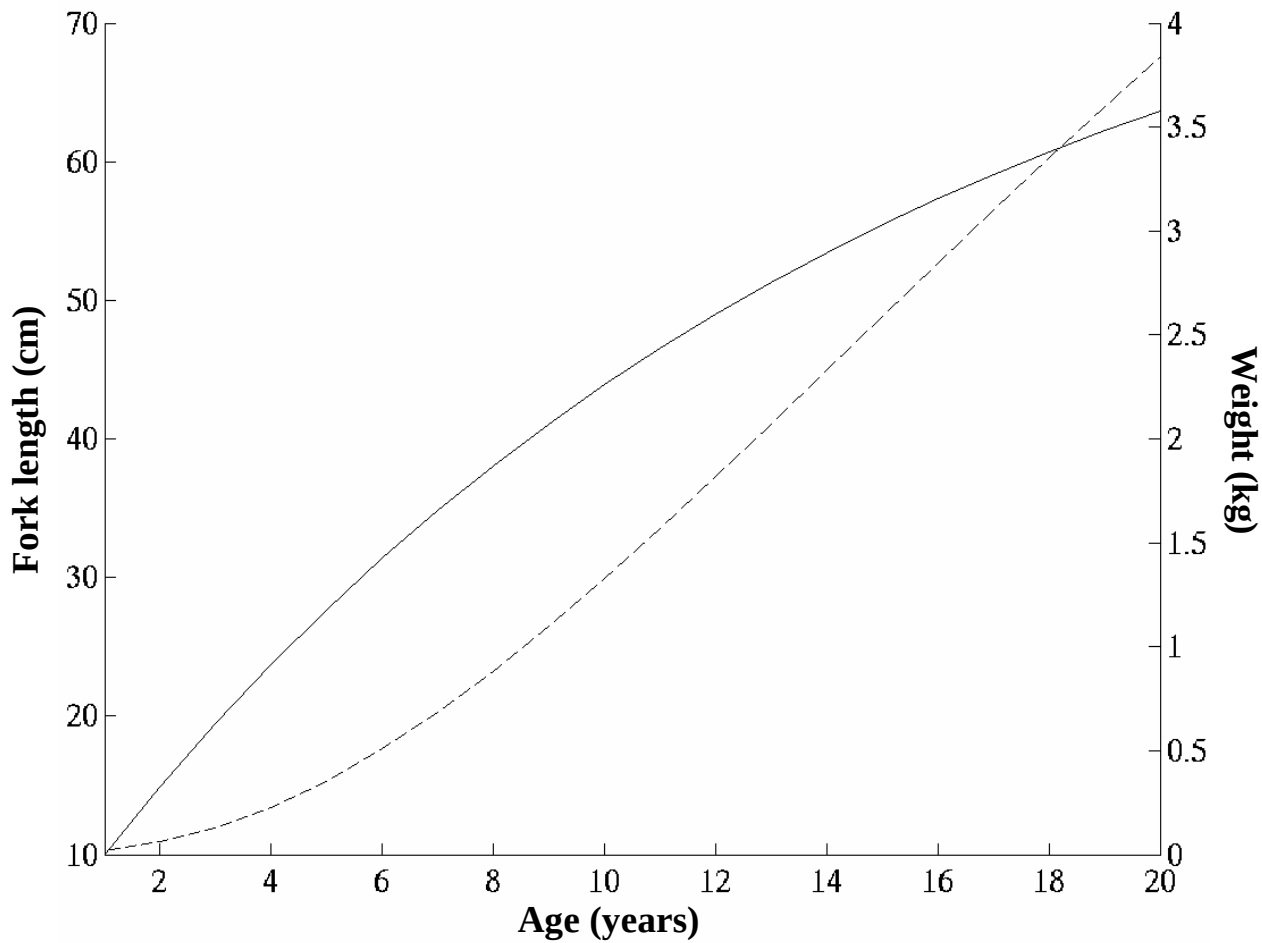


Figure 5.1 Sheephead size-at-age from the Catalina Island population used in the model. Fork length in cm (solid) and weight in kg (dashed).

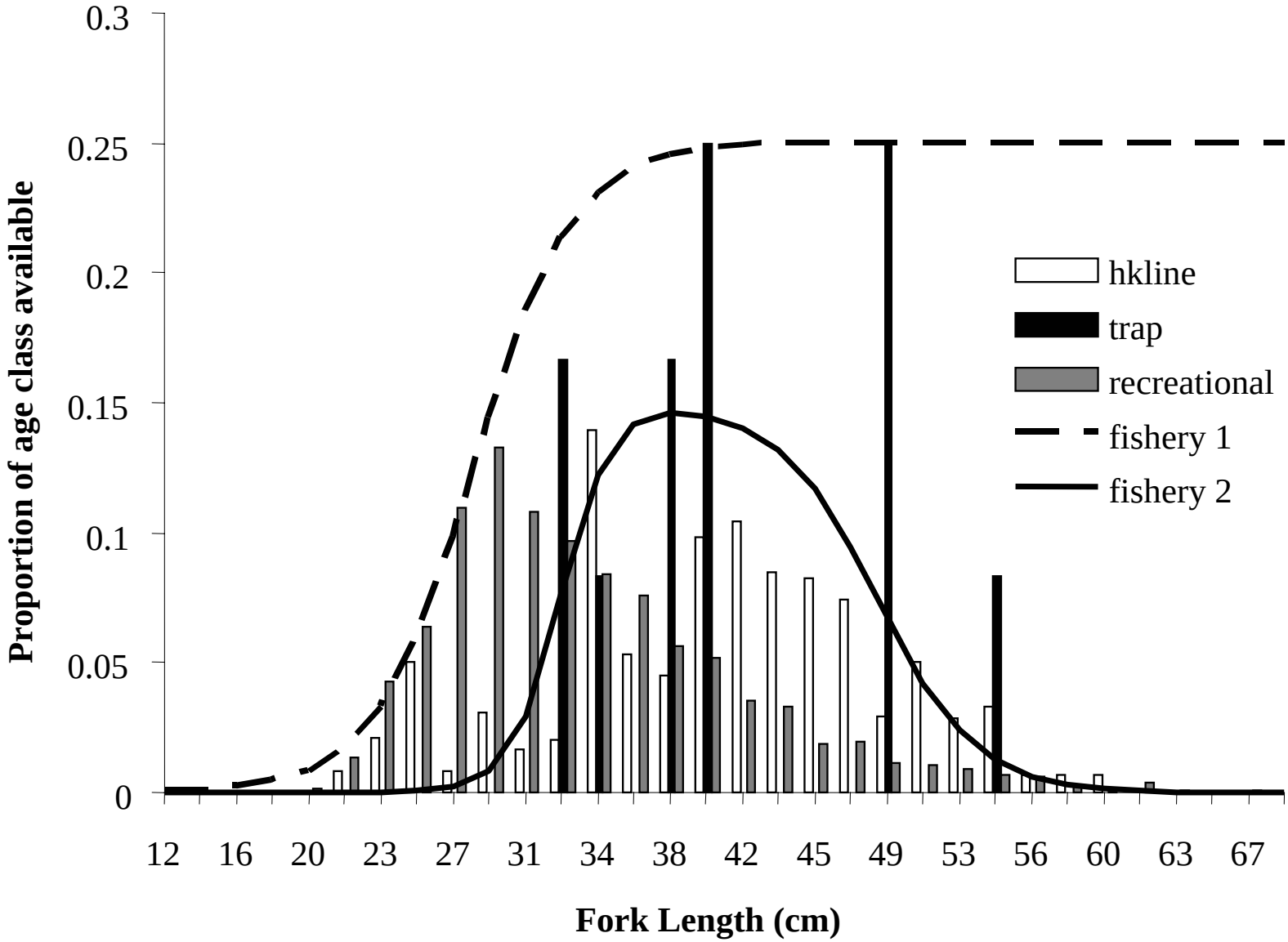


Figure 5.2 Selectivities used in the single-sex approximation model (lines) and size distribution of the trap (black bars), recreational (grey bars), and hook and line (white bars) fisheries for Sheephead.

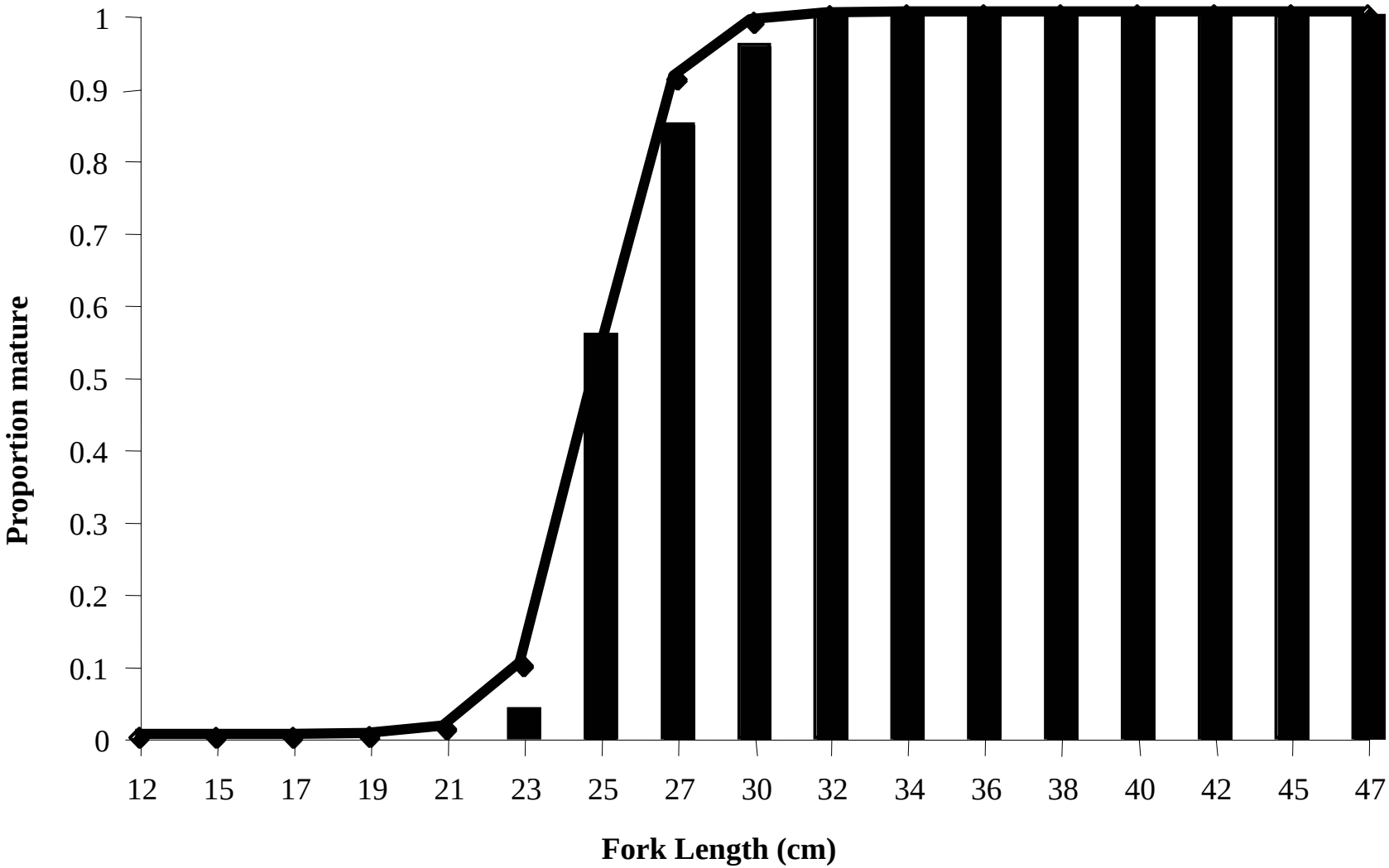


Figure 5.3a Proportion of length class mature, regardless of sex. The bars show maturity data from Warner (1978), and the fitted line is calculated from Equation 5.6.

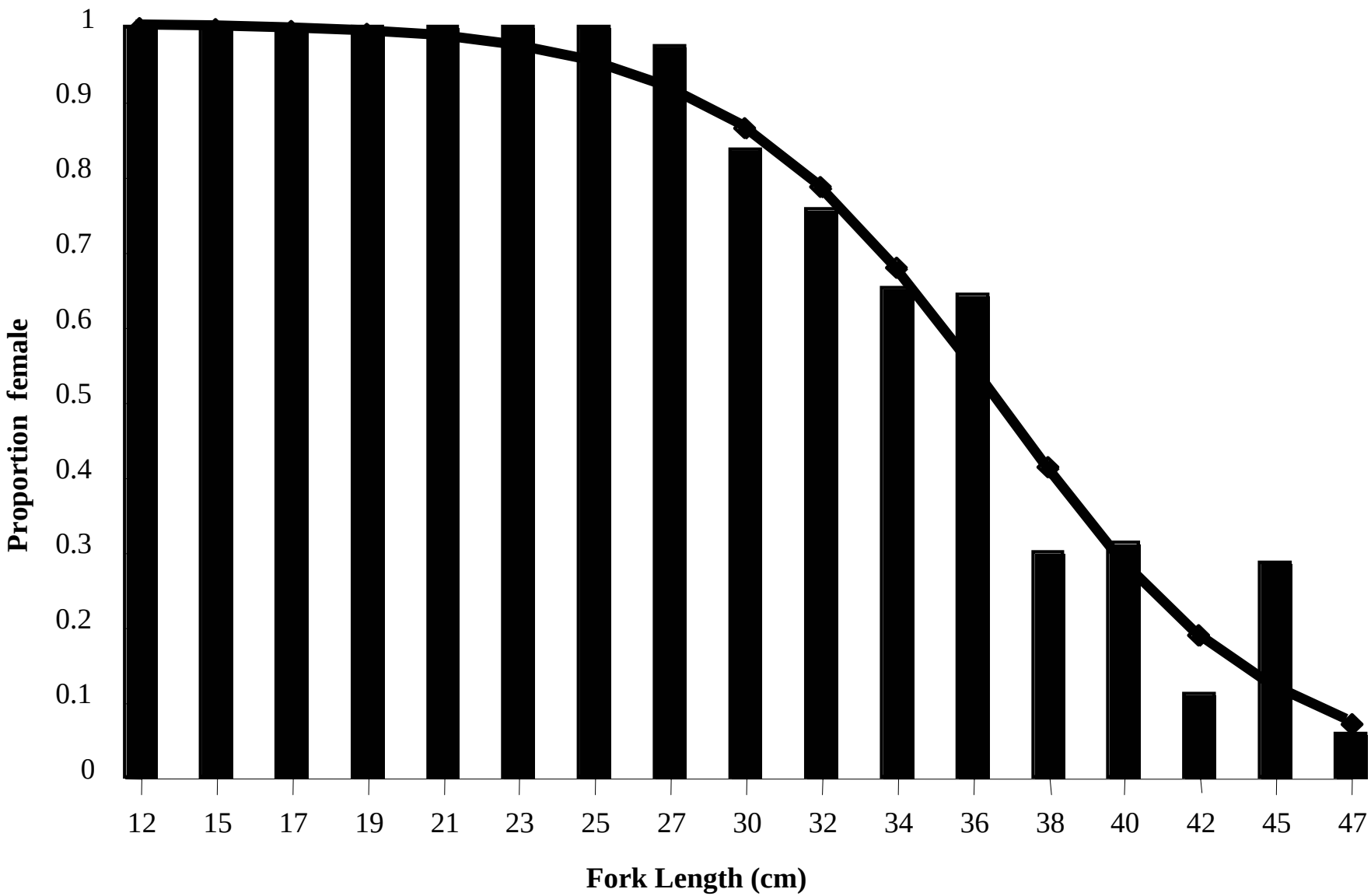


Figure 5.3b Proportion of length class female, regardless of maturity. The bars show sex-change data from Warner (1978), and the fitted line is calculated from Equation 5.6.

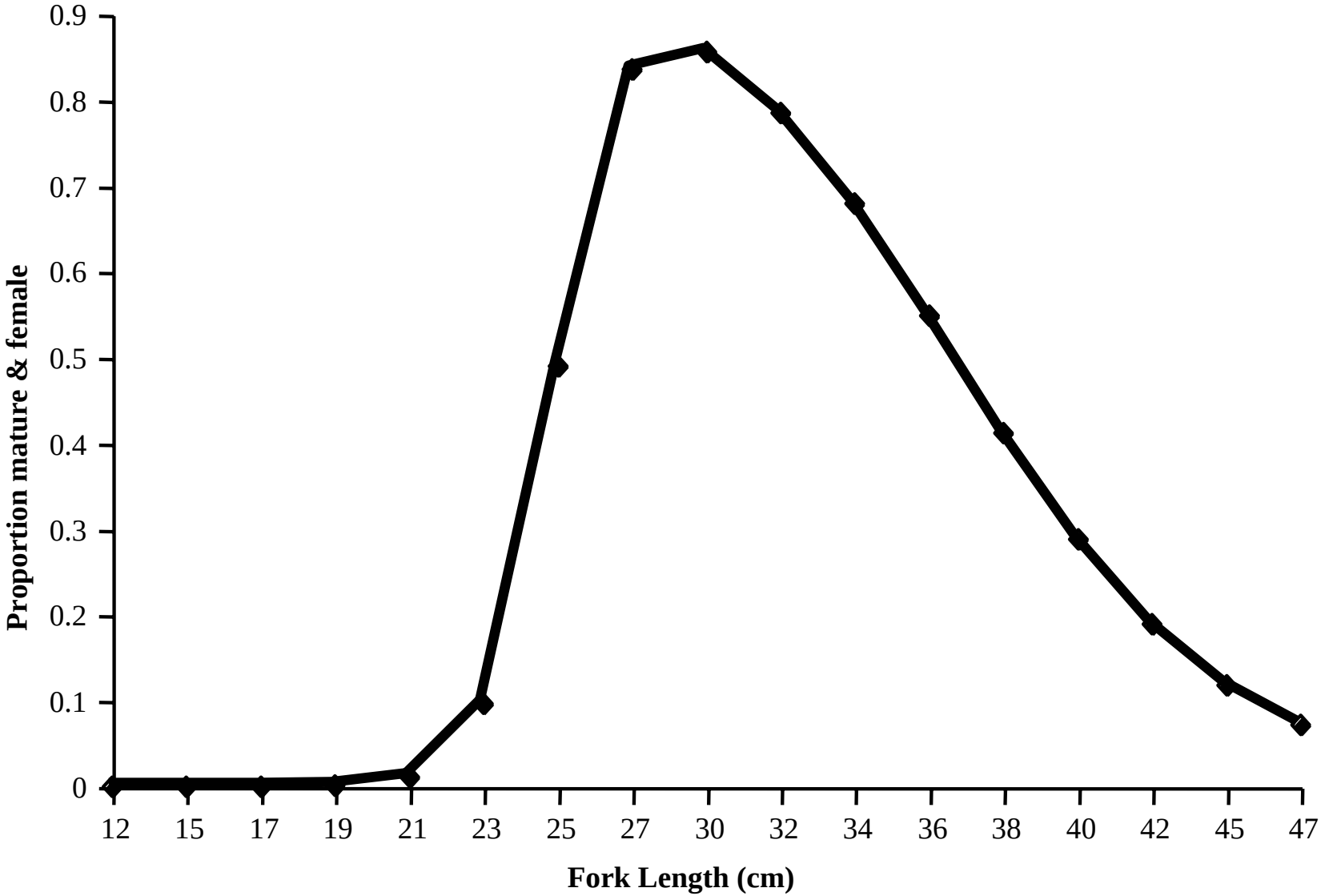


Figure 5.4 Proportion of length class mature and female for the single-sex model calculated from Equation 5.7.

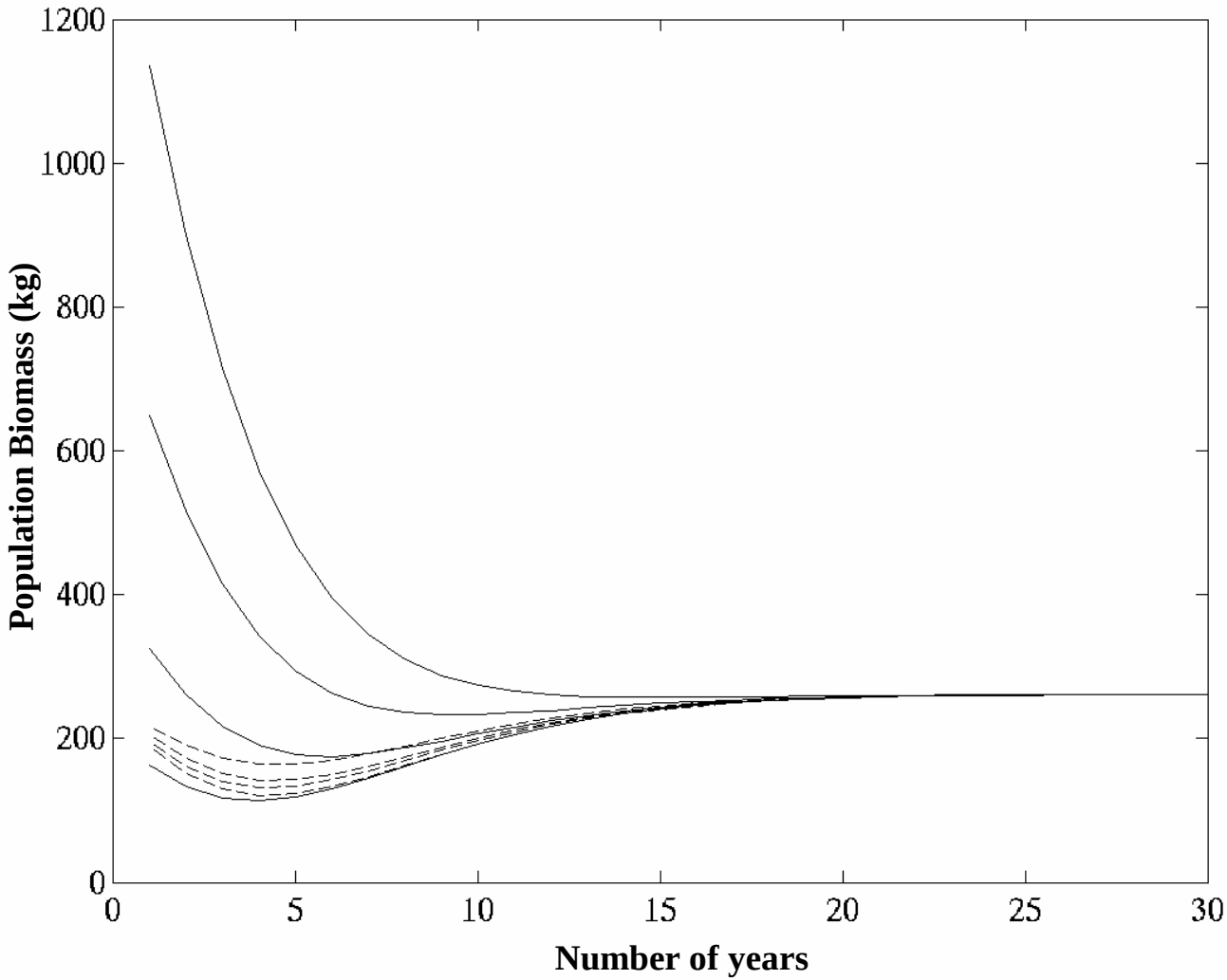


Figure 5.5 Population dynamics of the single-sex and sex-changing models from the model start with arbitrary population sizes. The single-sex model (dashed) started with a larger population than the sex-changing model (solid) and they converge.

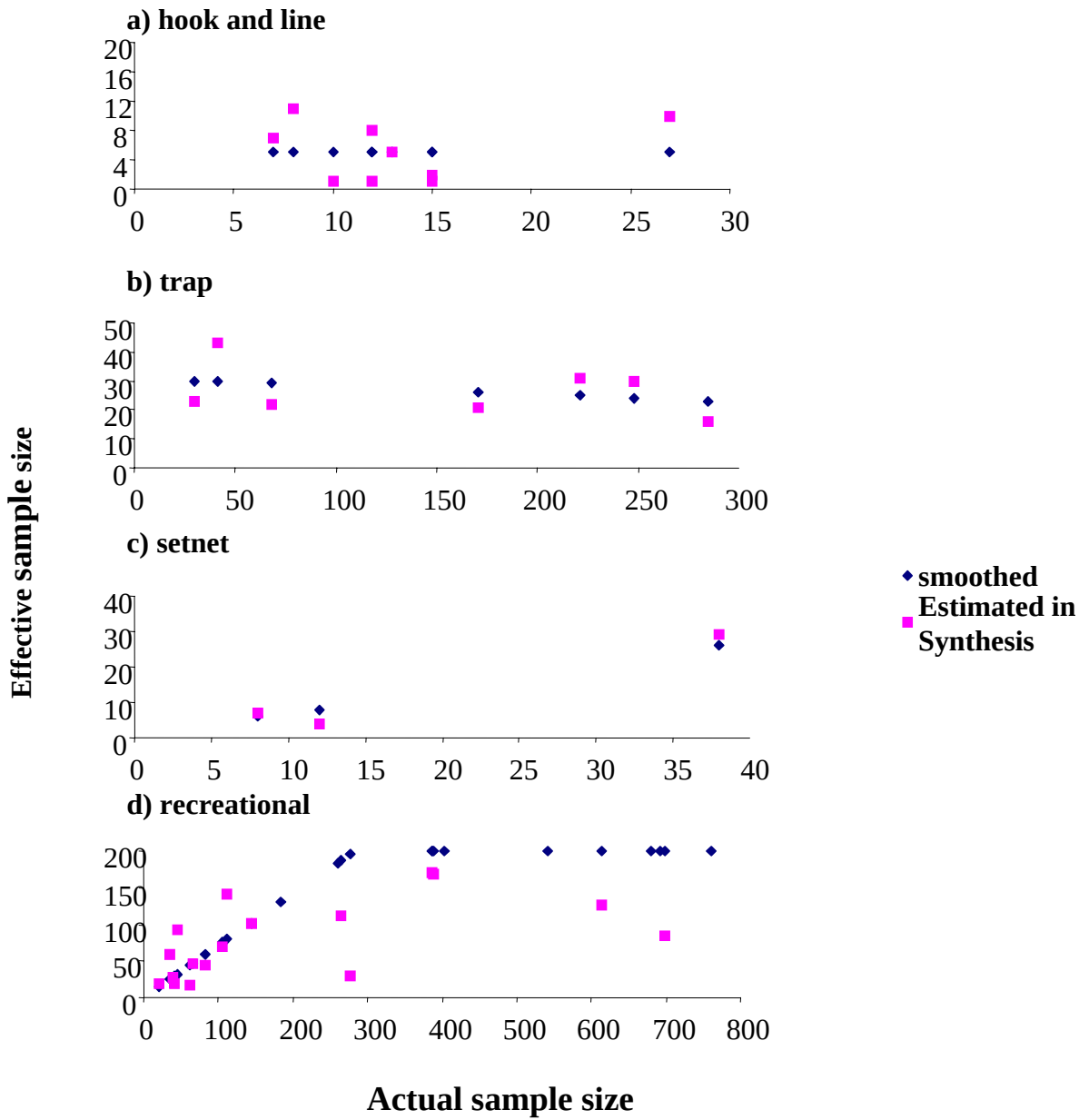


Figure 6.1 Effective sample sizes used in the Synthesis model.

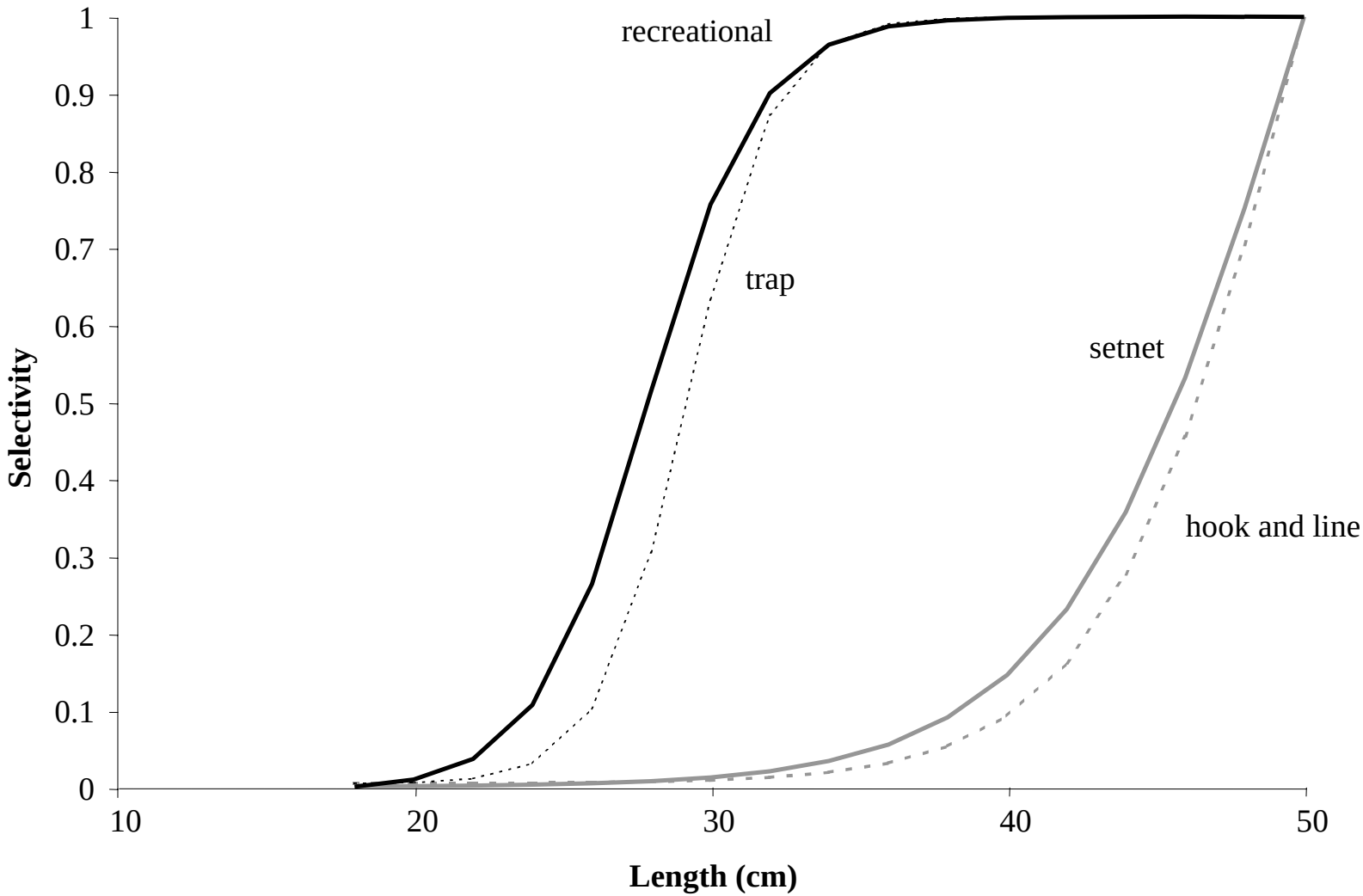


Figure 6.2 The selectivities for each of the four fisheries in the best-fit Synthesis model.

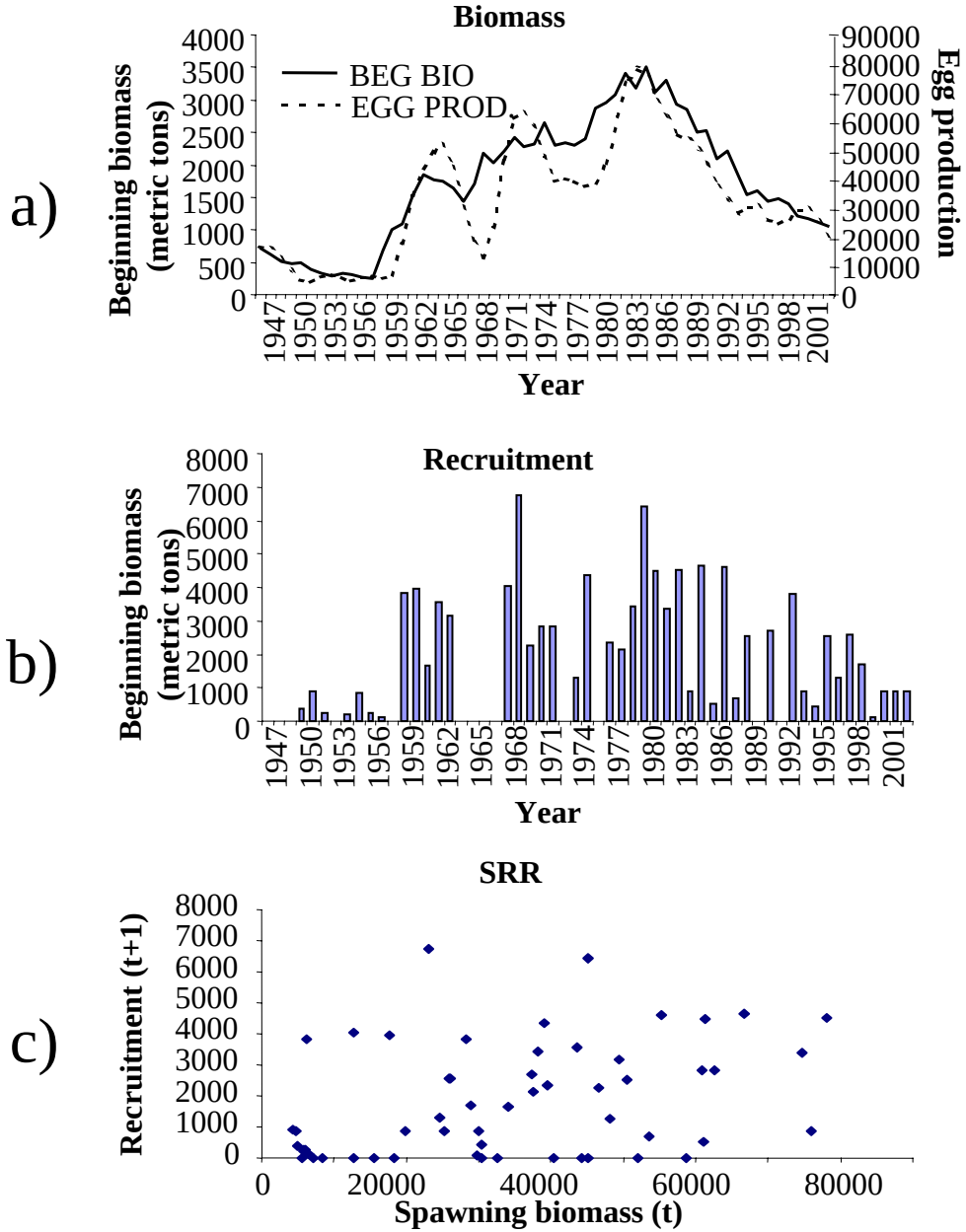


Figure 6.3 (a) The historical total biomass and female spawning biomass (b) recruitment, and (c) the relationship between recruitment and spawning biomass estimated by the baseline Synthesis model.

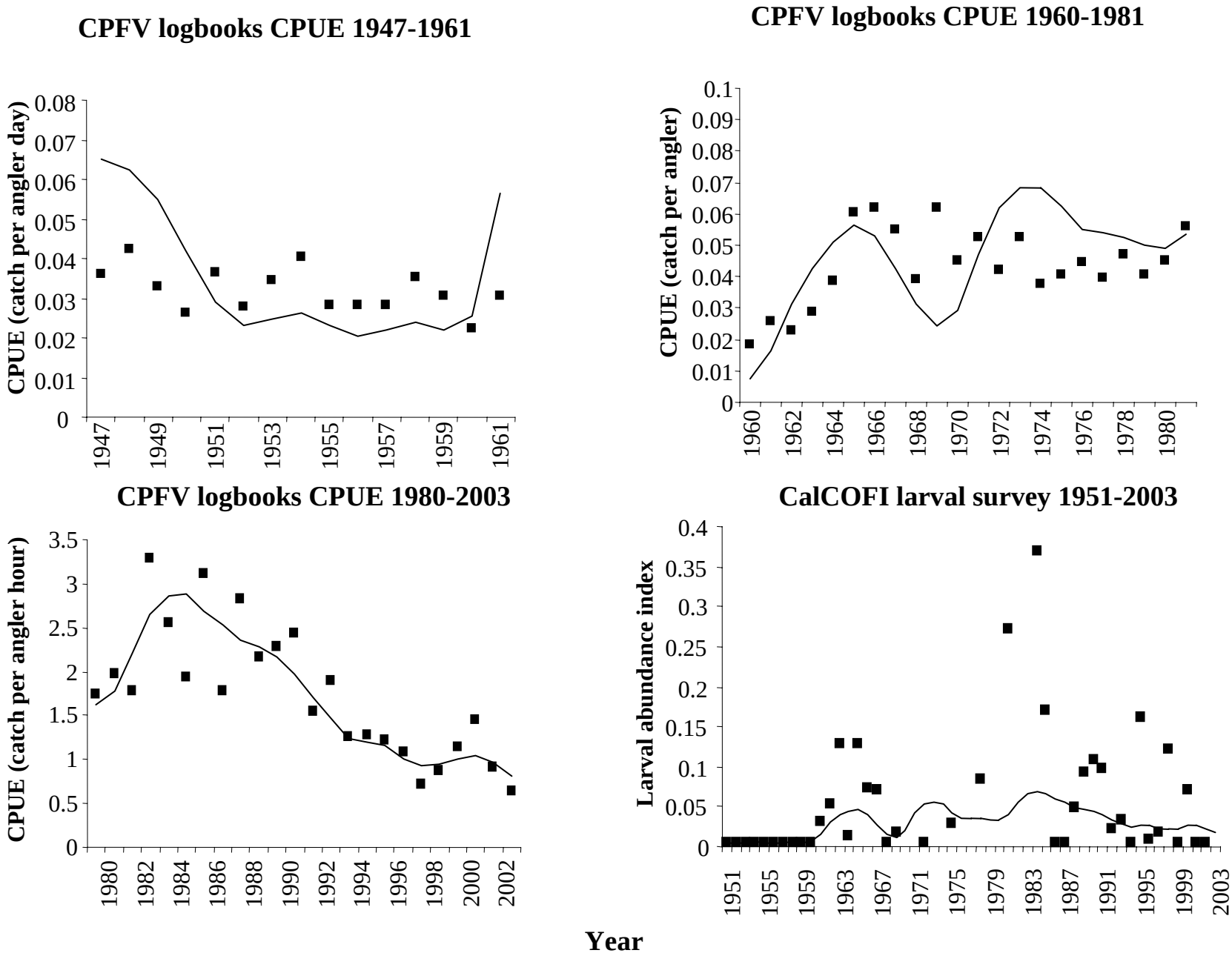


Figure 6.4 The estimated (solid line) and observed (black squares) abundance indices for the baseline Synthesis model.

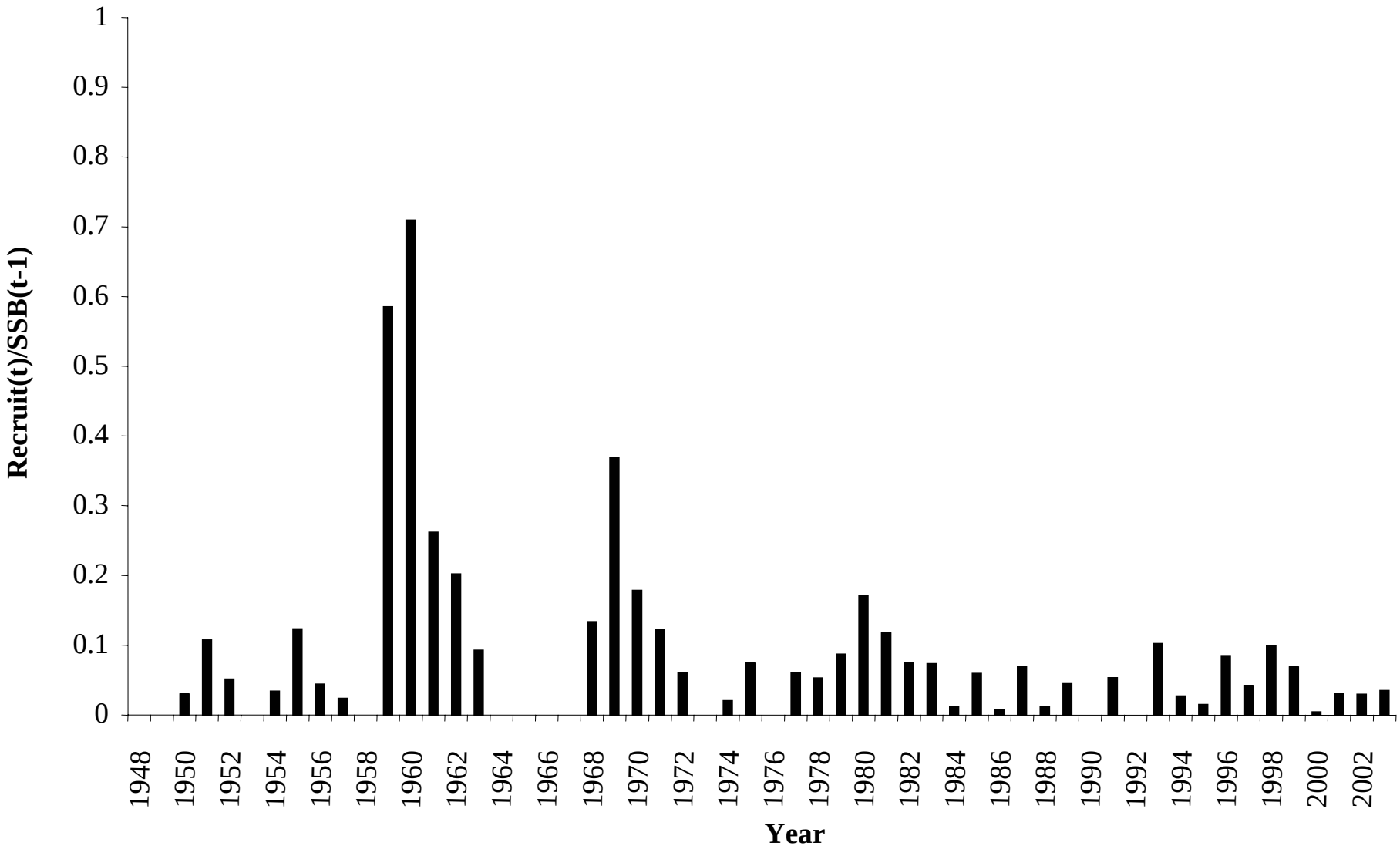


Figure 6.5 Recruit per spawning biomass was estimated to be variable through time in the baseline Synthesis model.

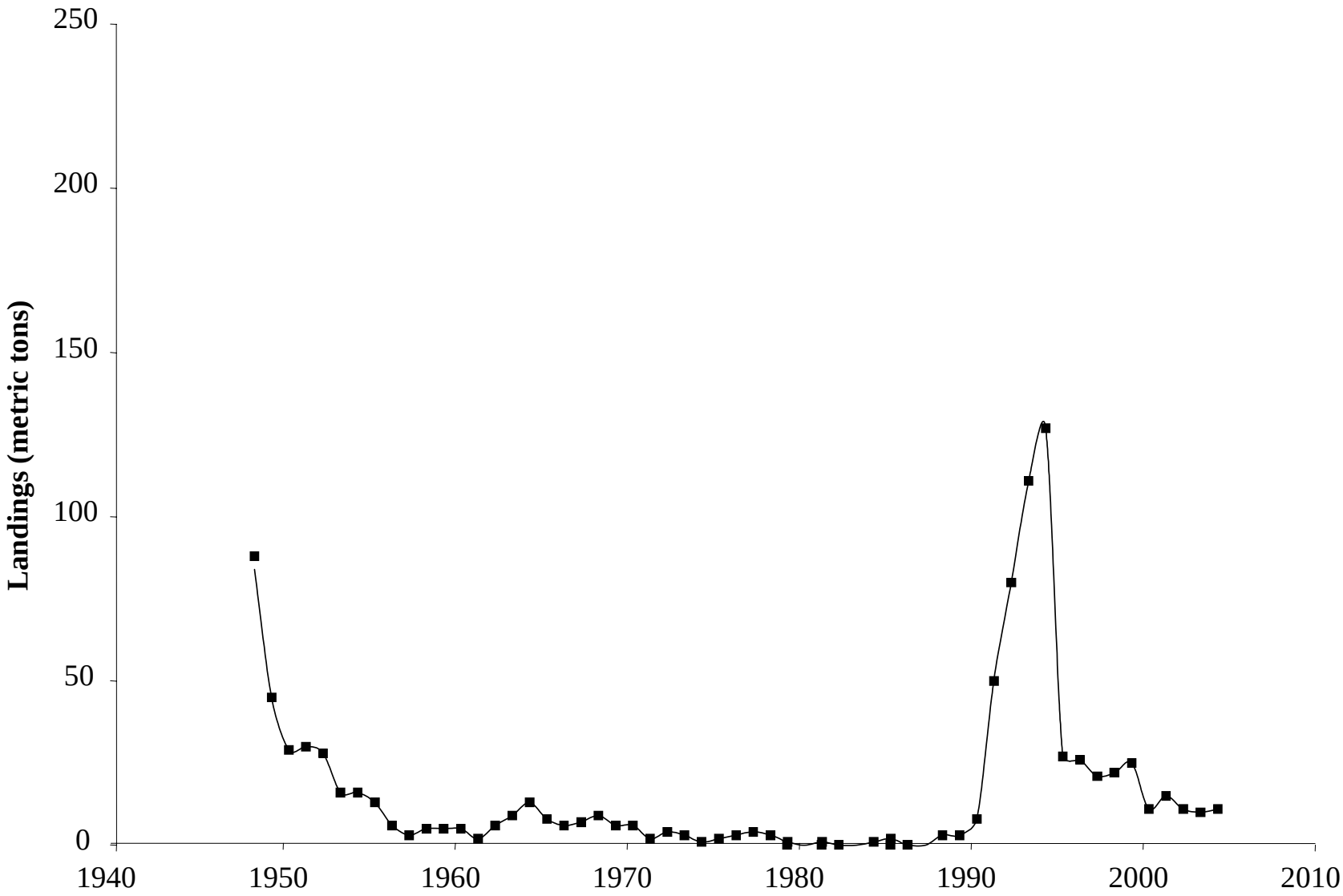


Figure 6.6 Landings for the hook and line commercial fishery in the Synthesis model.

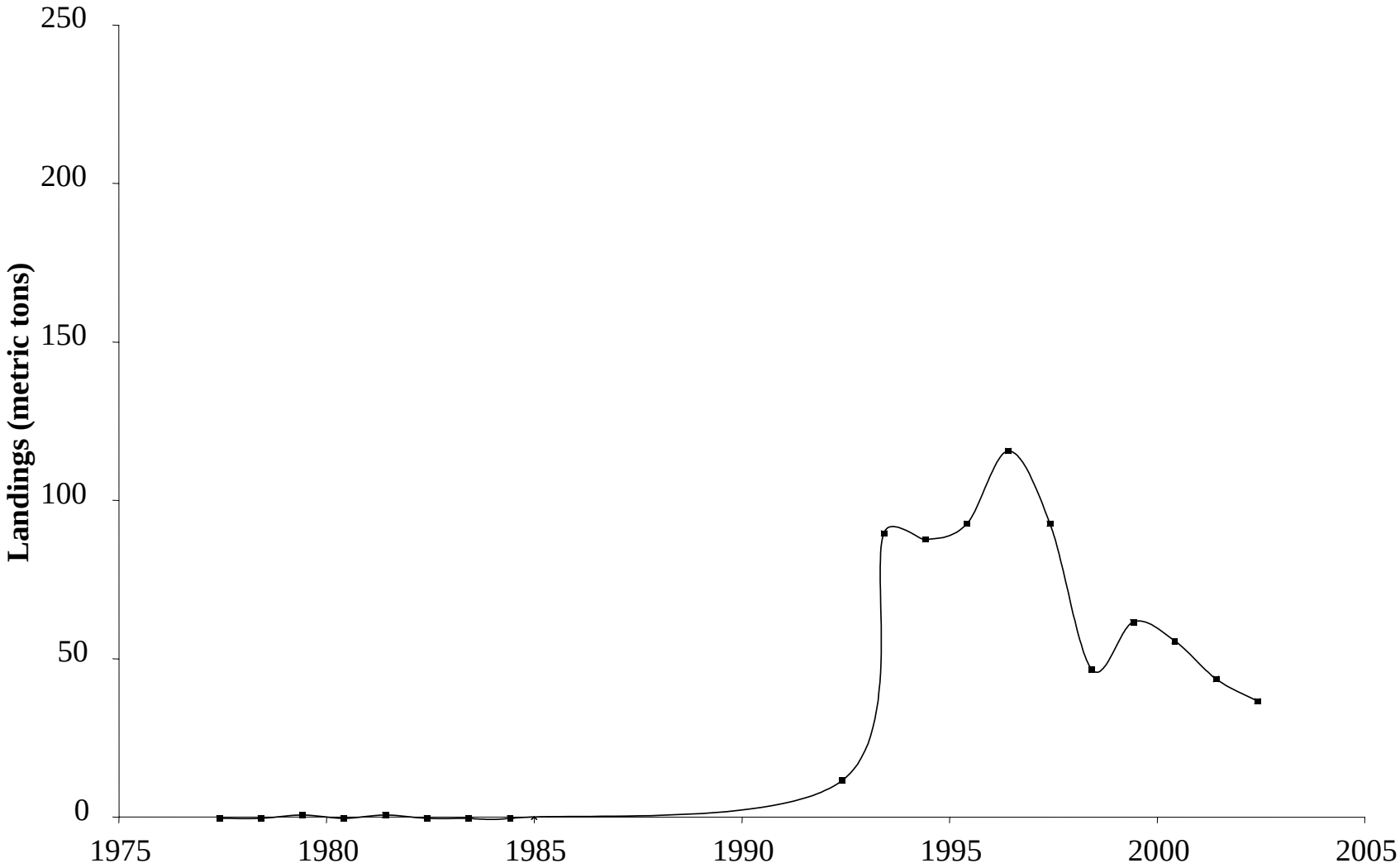


Figure 6.7 Landings for the trap commercial fishery in the Synthesis model.

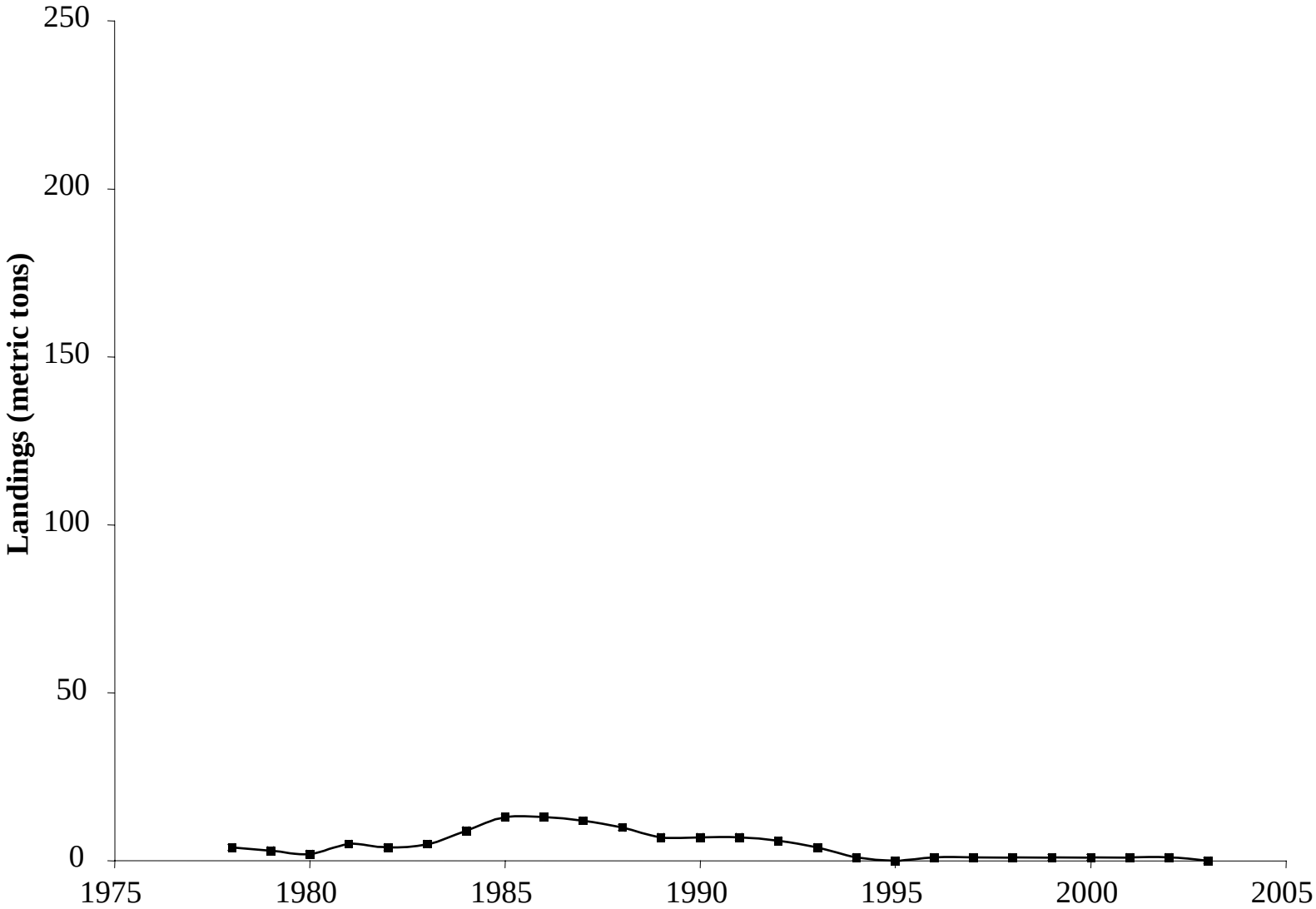


Figure 6.8 Landings for the setnet commercial fishery in the Synthesis model.

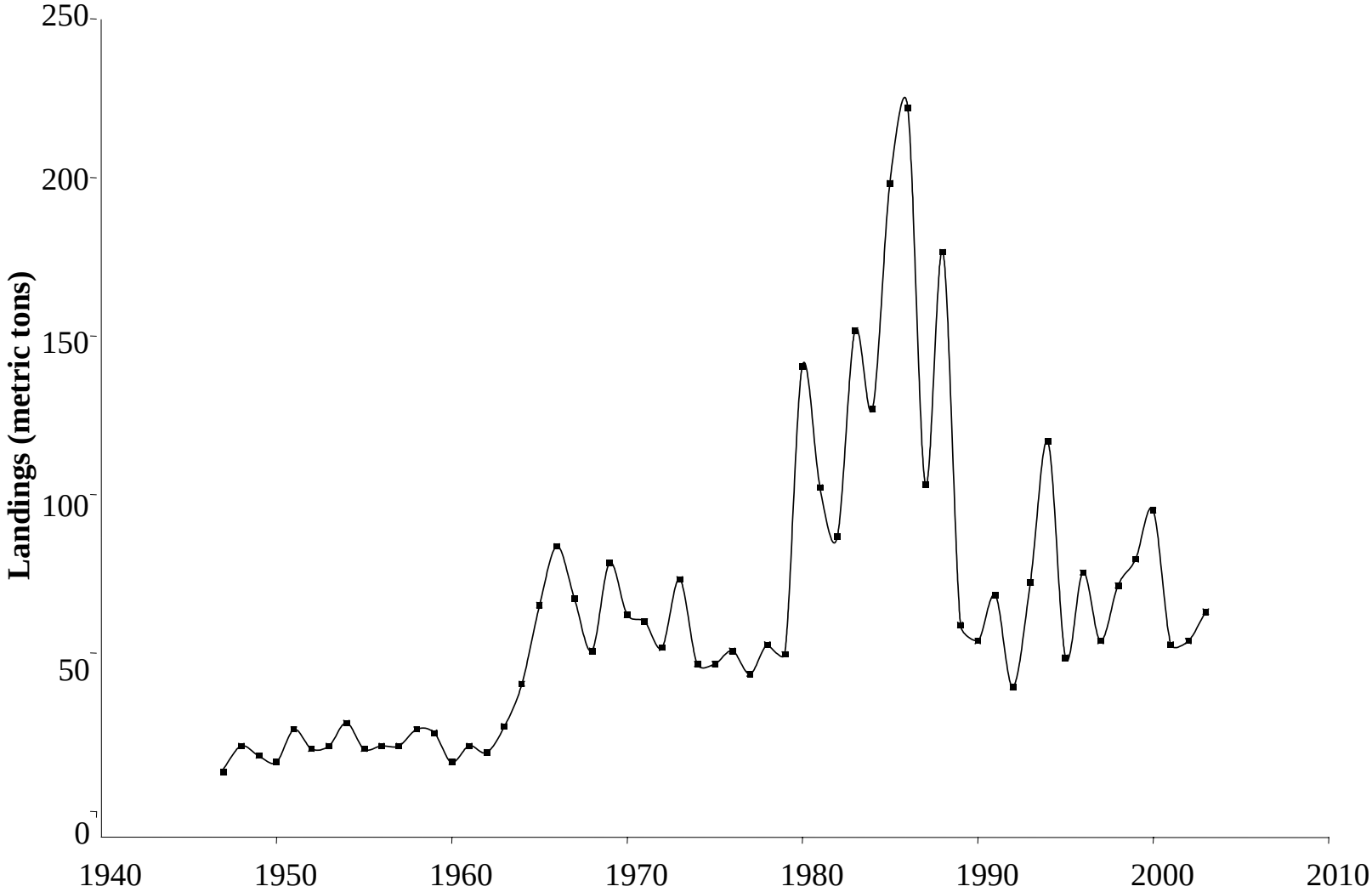


Figure 6.9 Landings for the recreational fishery in the Synthesis model.

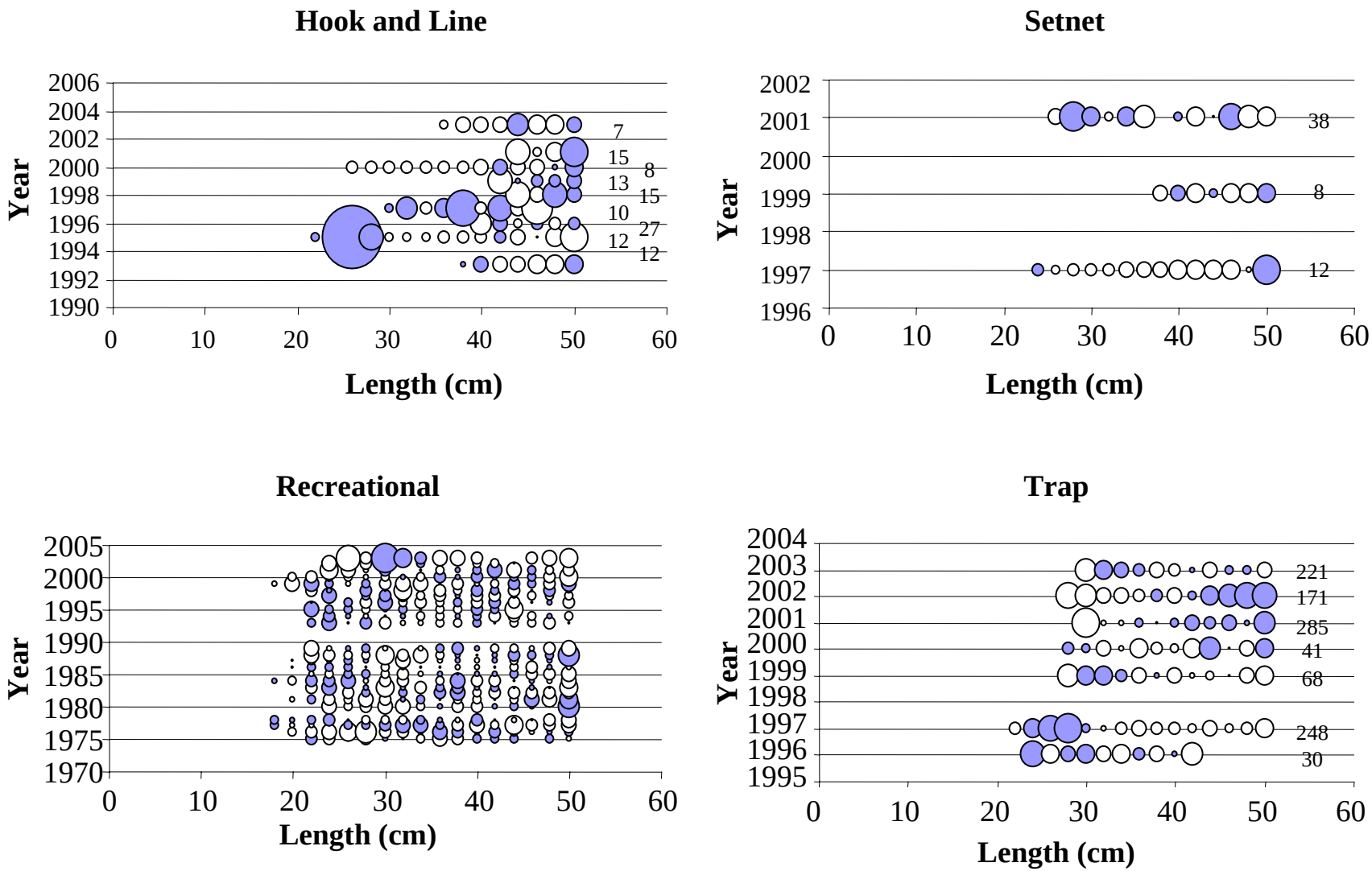


Figure 6.10 Bubble plots representing the fit between the observed and estimated length compositions for the baseline Synthesis model. The area of the circle indicates the deviation between the observed and estimated values. Filled circles represent a positive deviation and empty circles represent a negative deviation. Sample sizes are also given for the commercial fisheries.

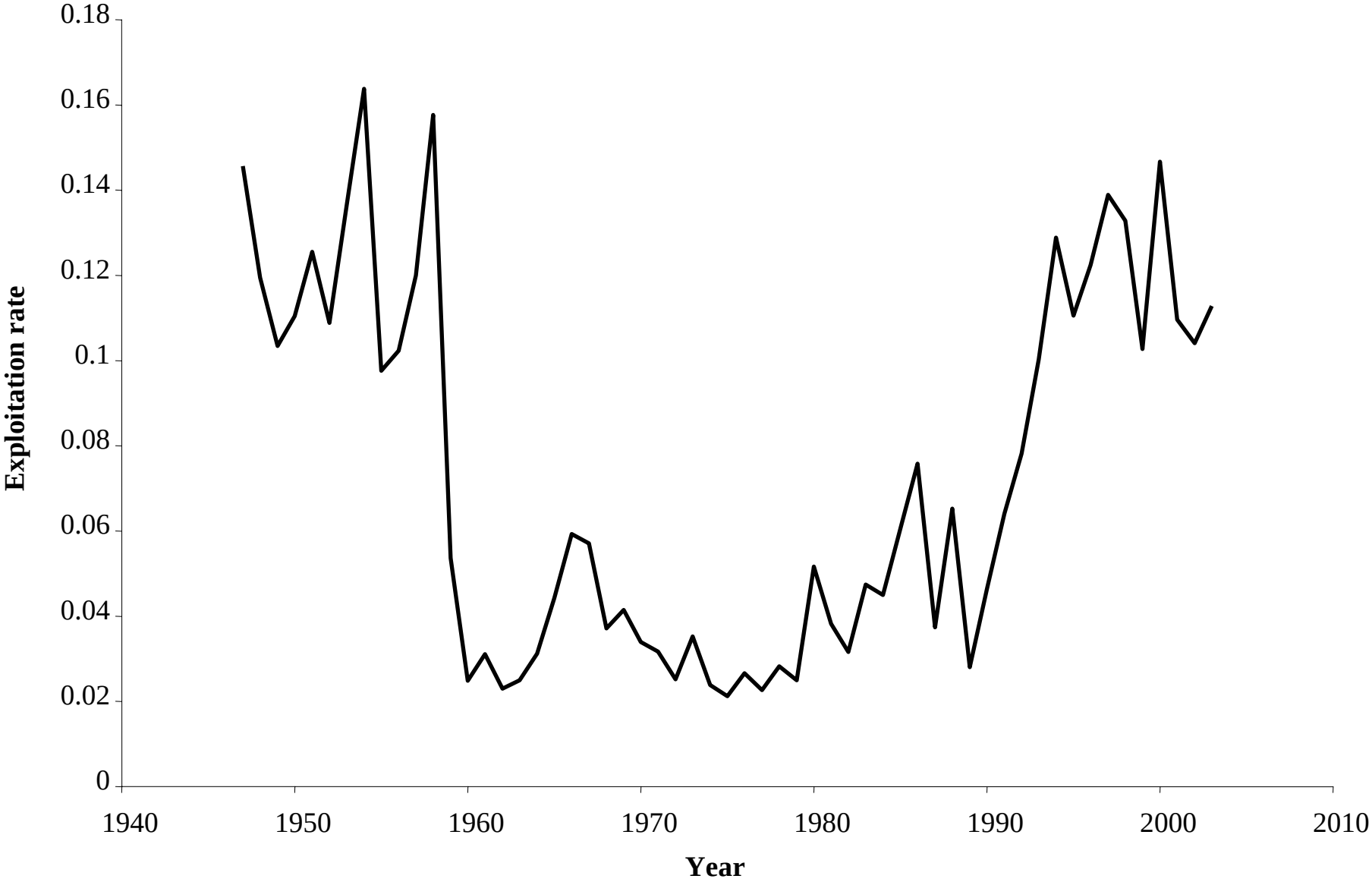


Figure 6.11 Historical exploitation rate of Sheephead as estimated by the baseline Synthesis model.

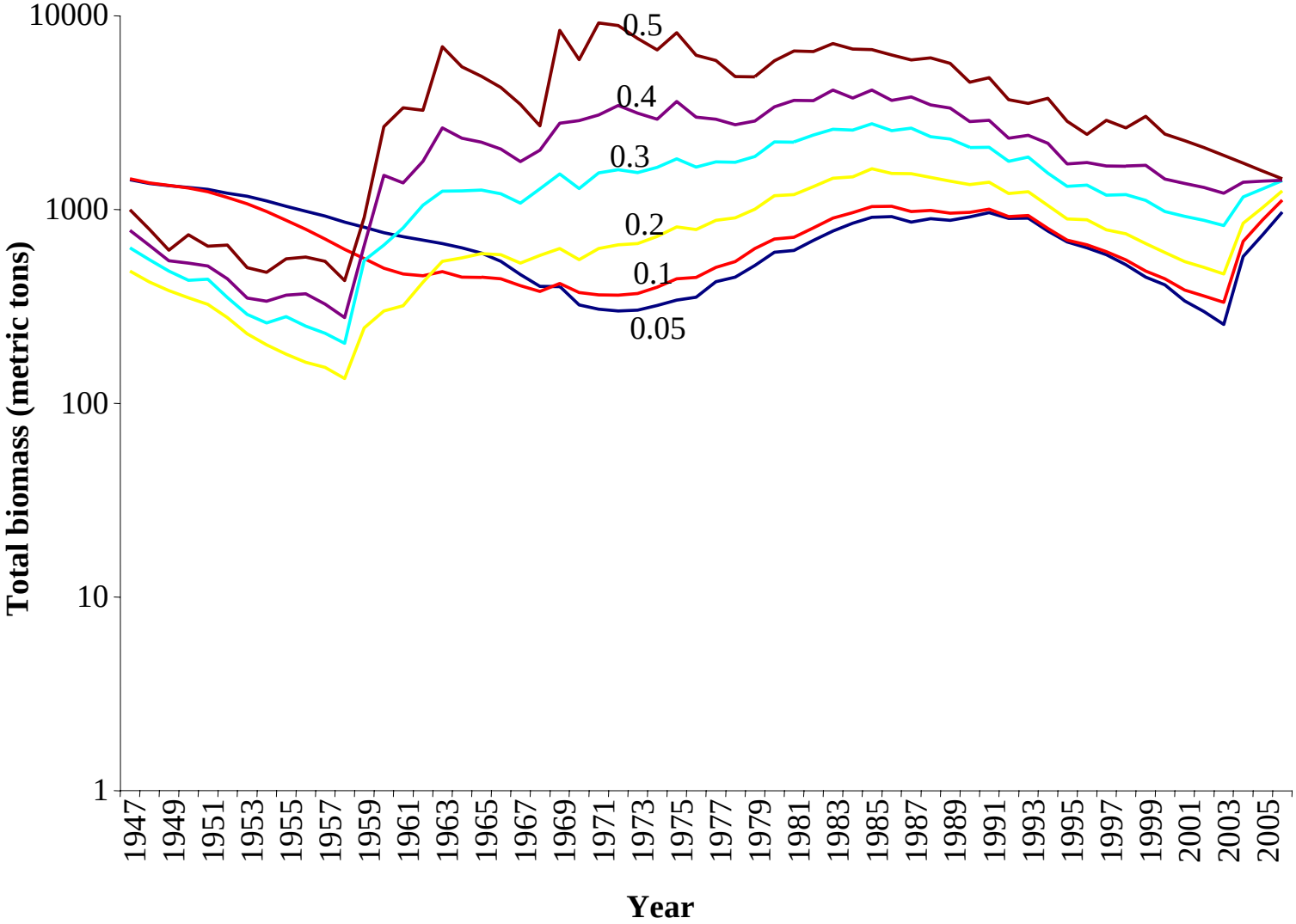


Figure 6.12 The predicted effect of natural mortality on the estimated total biomass. As M increases from 0.05 to 0.5 the estimated total biomass increases. Spawning biomass and recruitment exhibit similar patterns.

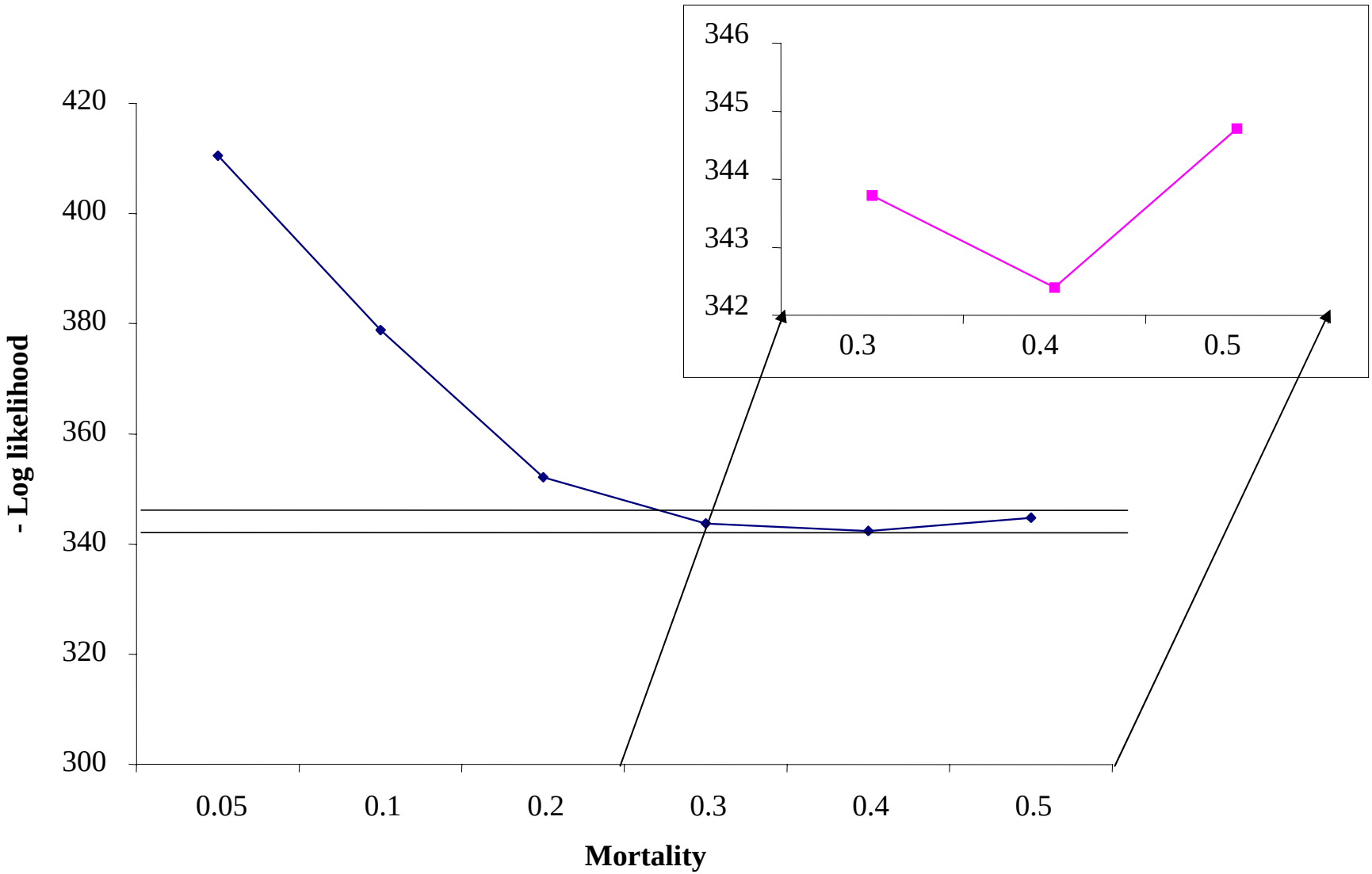


Figure 6.13 The total (negative) log-likelihood of the model for a sensitivity analyses of natural mortality rate as mortality varies from 0.05 to 0.5.

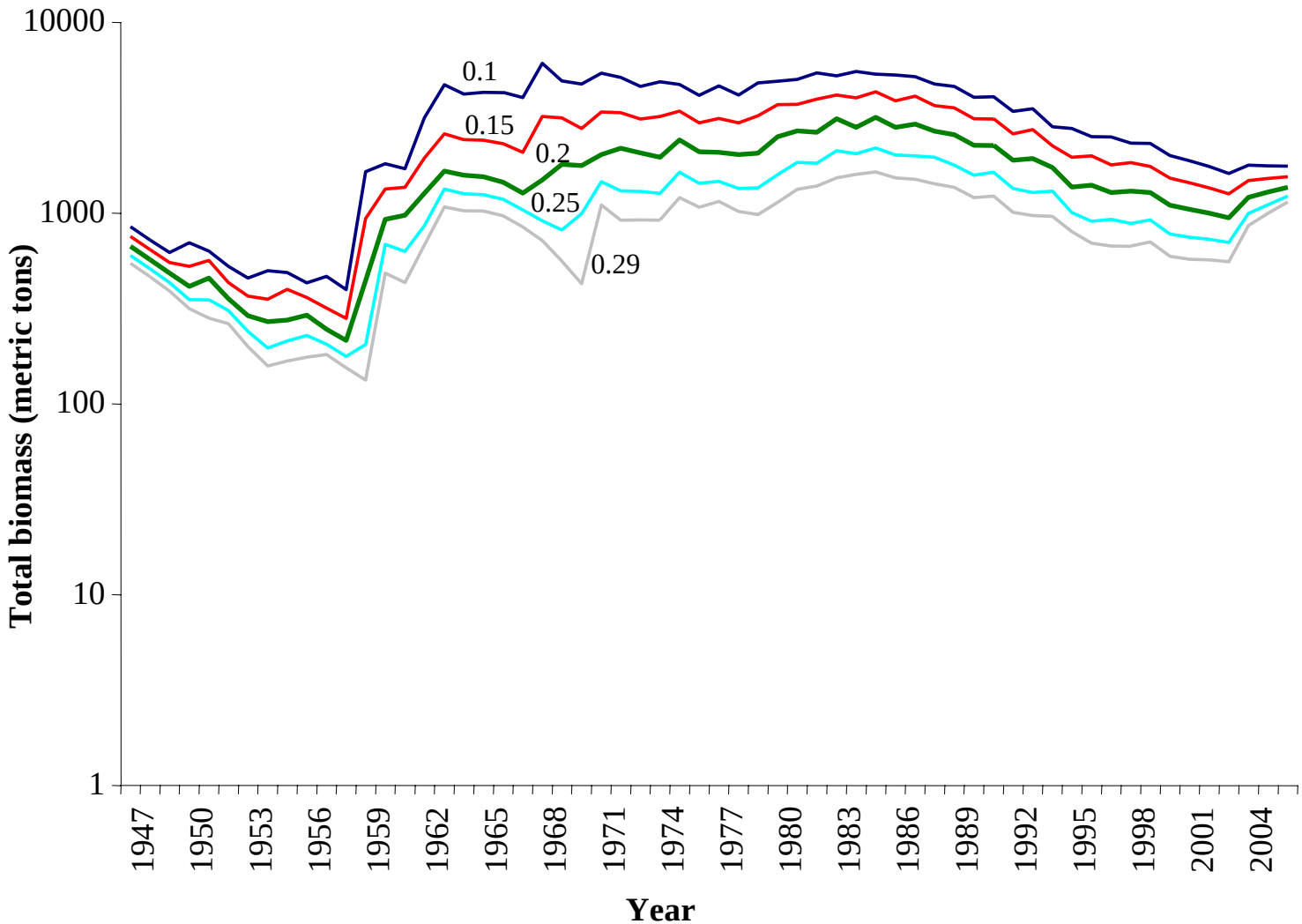


Figure 6.14 The effect of the coefficient of variation in growth (CV_1 and CV_2) on the estimated total biomass. As CV_1 and CV_2 increase from 0.10 to 0.29, the estimated total biomass decreases. Spawning biomass exhibits a similar pattern.

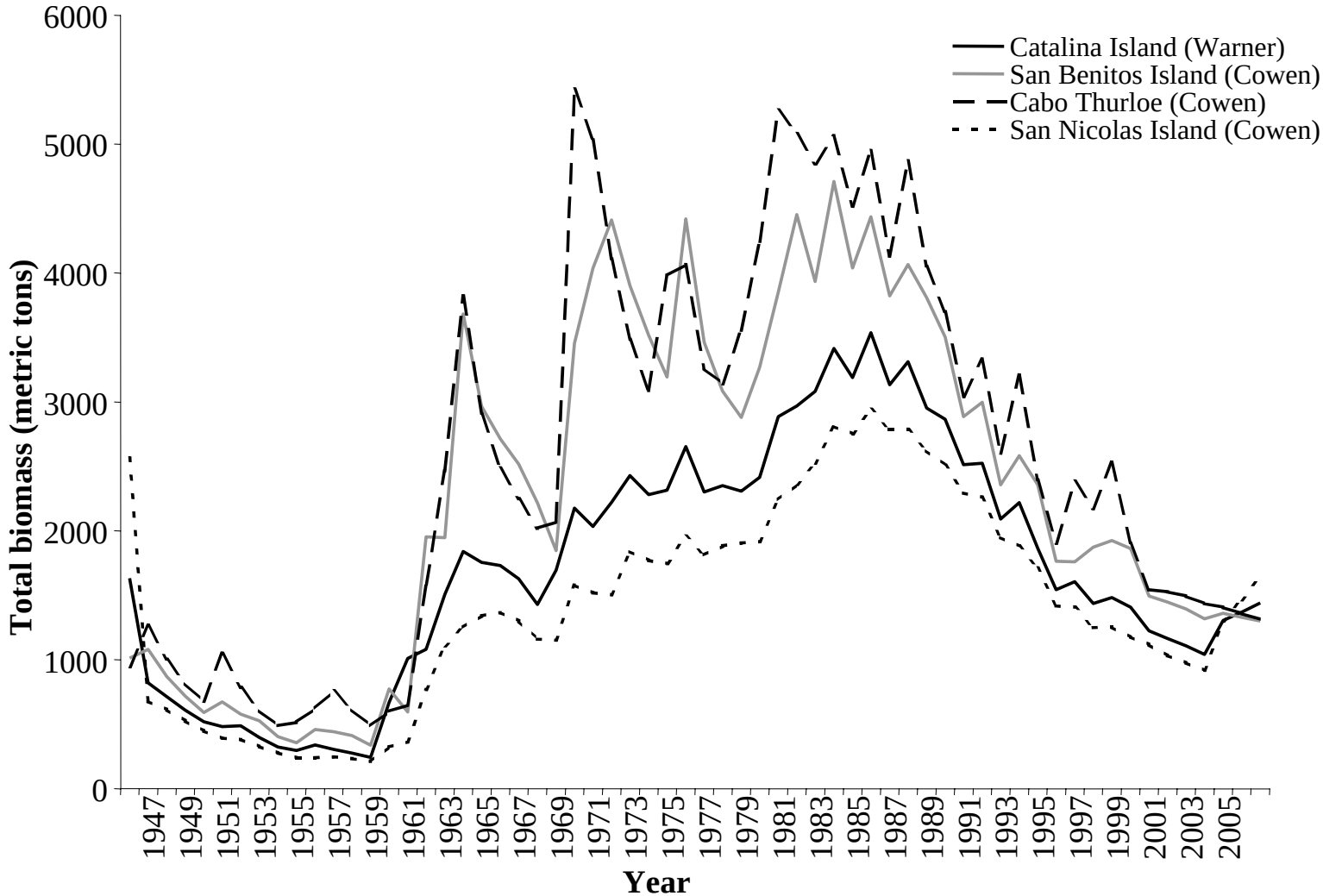


Figure 6.15 The predicted total biomass for the four sets of California life history parameters from Table 3.1. Spawning biomass and recruitment exhibit similar patterns.

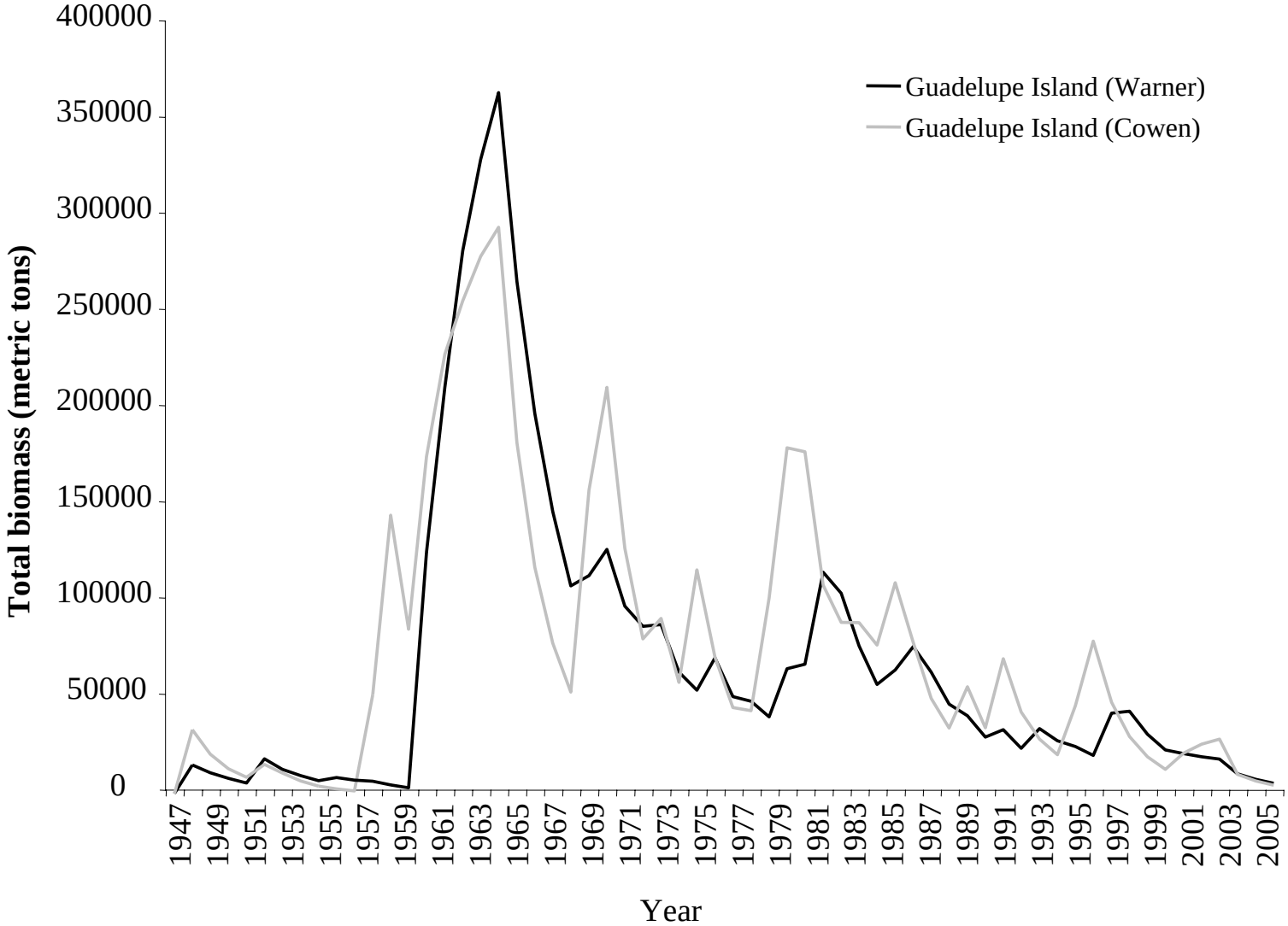


Figure 6.16 The predicted total biomass for the two sets of Guadelupe Island, Mexico life history parameters from Table 3.1. Spawning biomass and recruitment exhibit similar patterns.

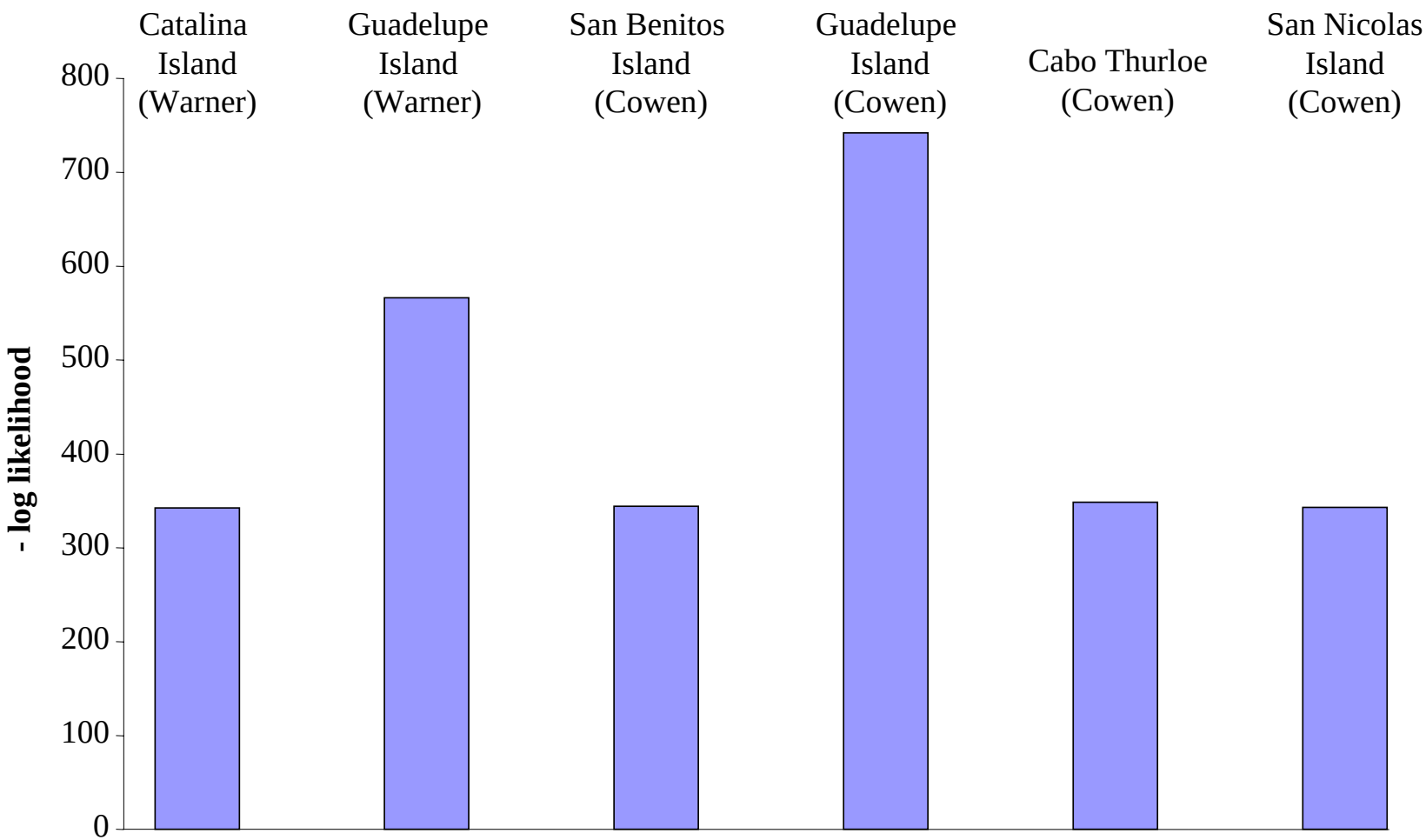


Figure 6.17 The negative log likelihood of the model as the life history parameters are varied. The Guadelupe parameters do not lead to a good fit with the data while the parameters from the four California populations fit the data similarly. The parameters used for the baseline model were based on the Catalina data from Warner (1975) which lead to the best fit between the data and the model.

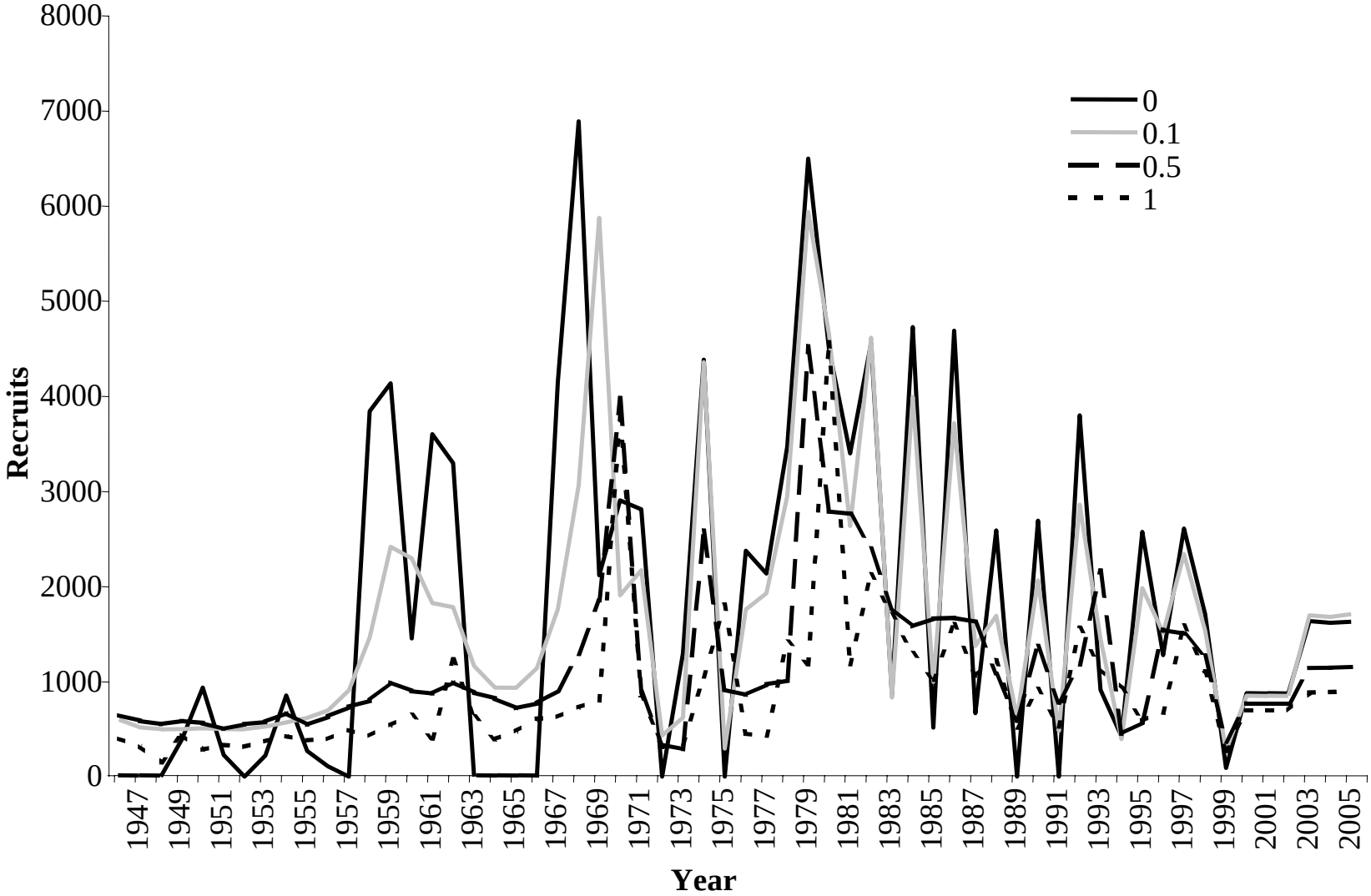


Figure 6.18 The effect of increasing the likelihood weights on the stock recruitment curve from zero to one on the estimated recruitment in the model. The freely estimated values (zero weight on the curve), show greater temporal variation but a similar trend to the other values.

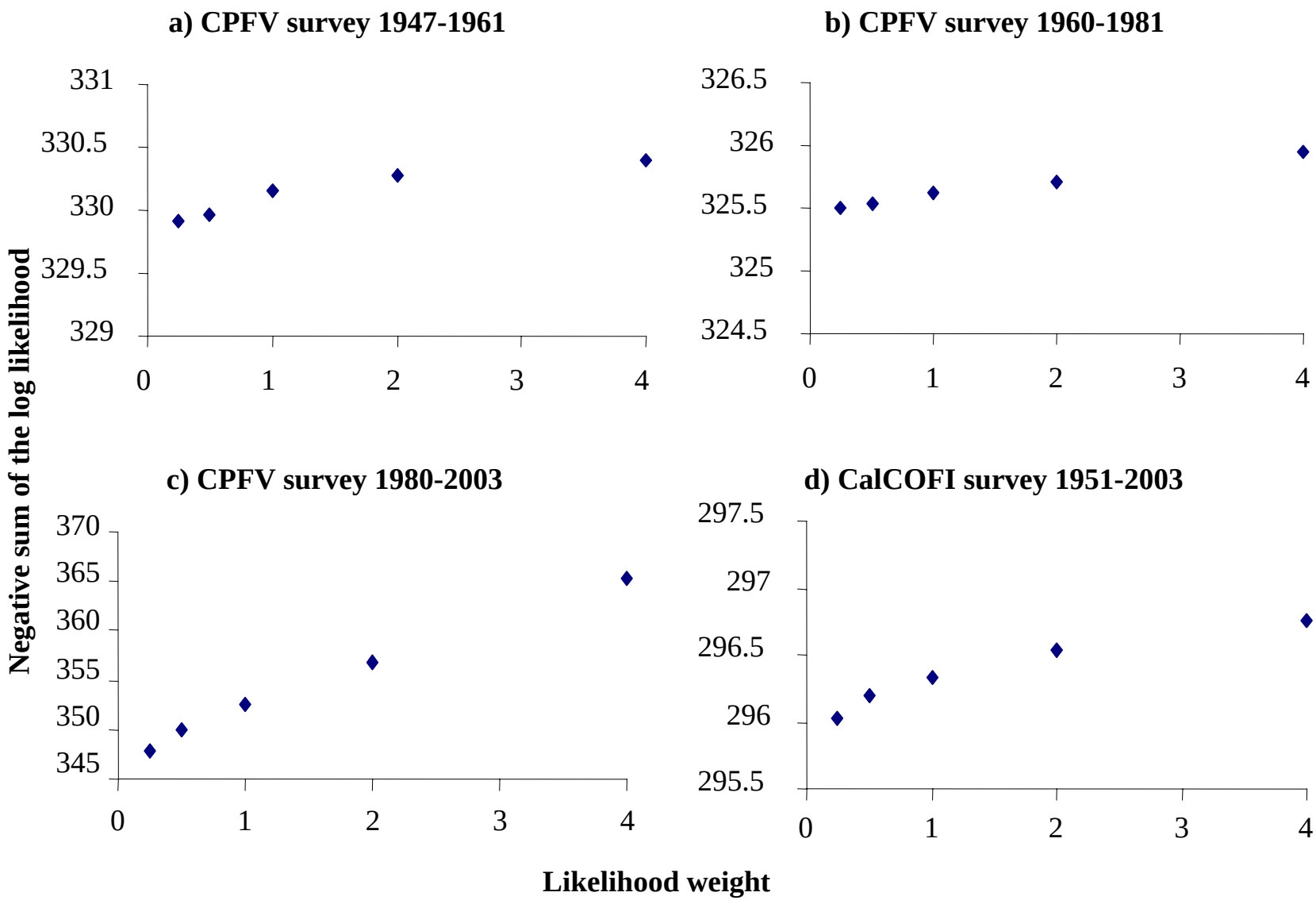


Figure 6.19 a-d A sensitivity analyses on data sources. For each of the four abundance indices we varied the individual likelihood weight from 0.25 to 4 and took the sum of all of the likelihood weights except the survey of interest. The CPFV logbook survey that covers 1980-2003 shows a decrease in the sum of the rest of the negative log likelihood components indicating that it does not necessarily agree with other data sources. However the other three surveys show an increase with the likelihood meaning they are in agreement with the other data sources.

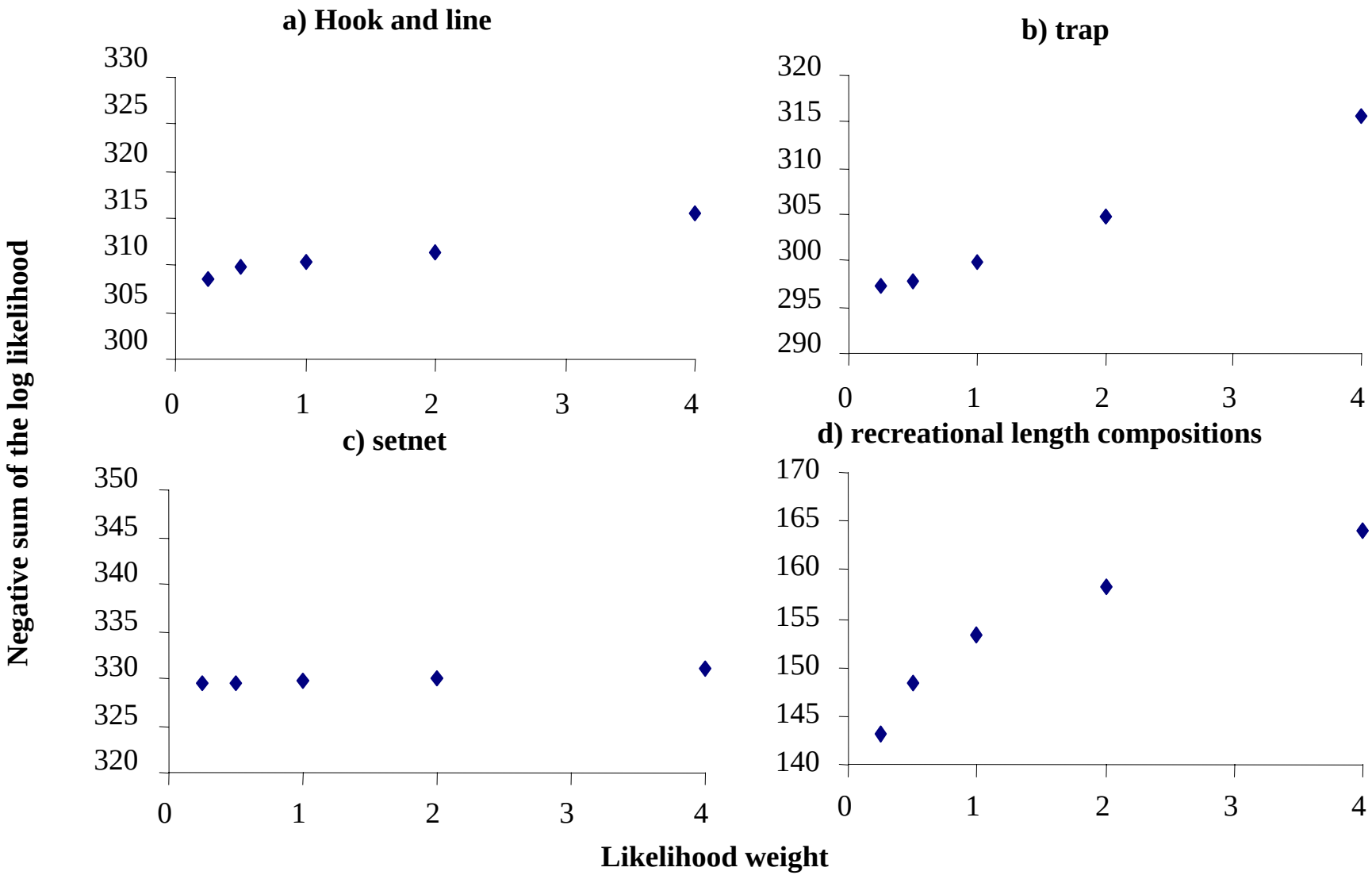


Figure 6.20 a-d A sensitivity analyses on data sources. For each set of length compositions associated with one of the four fisheries, we varied the individual likelihood weight from 0.25 to 4 and took the sum of all of the likelihood components except the length composition being varied. They all tend to increase with the likelihood weight indicating that they tend to be in agreement with the other data sources.

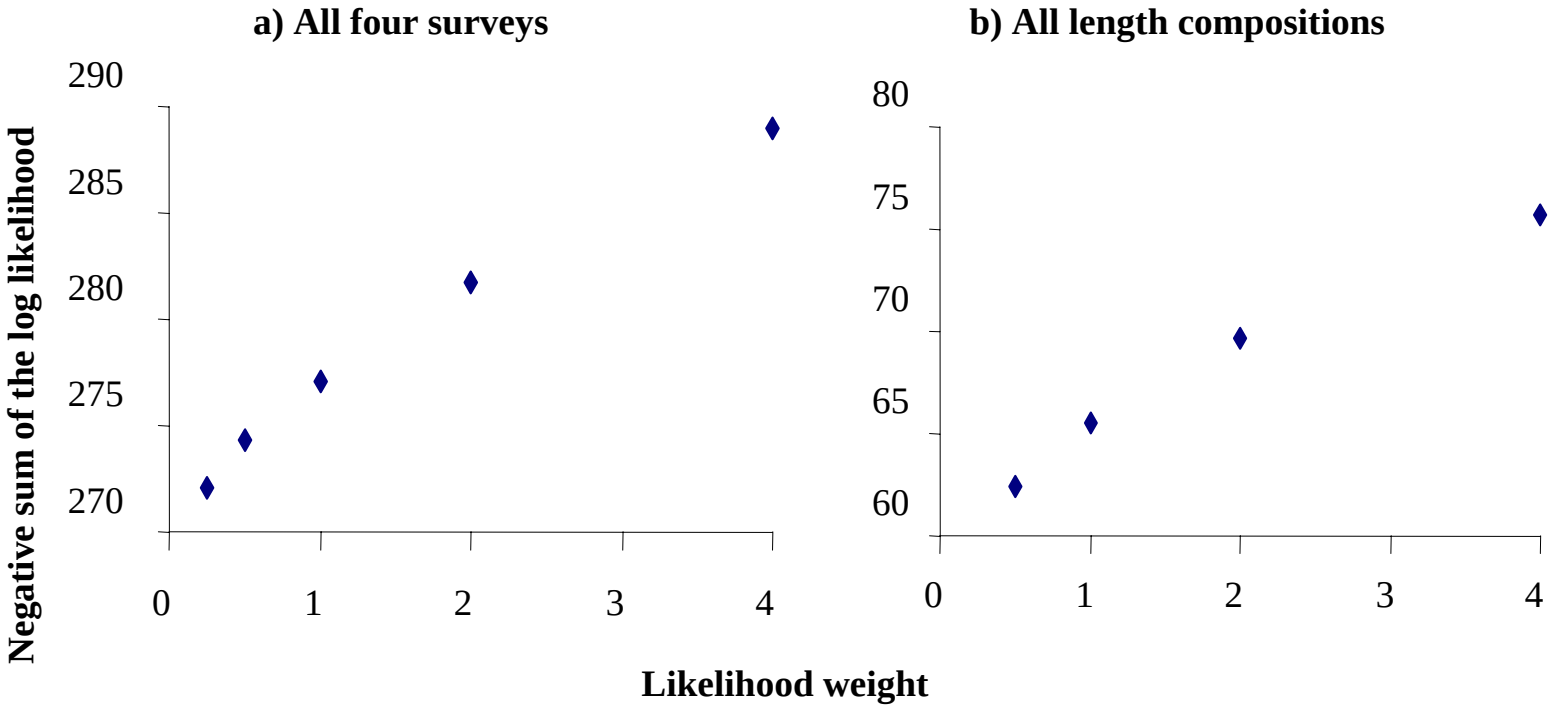


Figure 6.21 Sensitivity analysis on data sources. We give the total log-likelihood of the model when we (a) varied the likelihood weight of all four surveys simultaneously while keeping all other likelihood weights constant (and equal to 1.0) and (b) varied the likelihood weight of all four sets of length compositions while keeping all other likelihood weights constant.

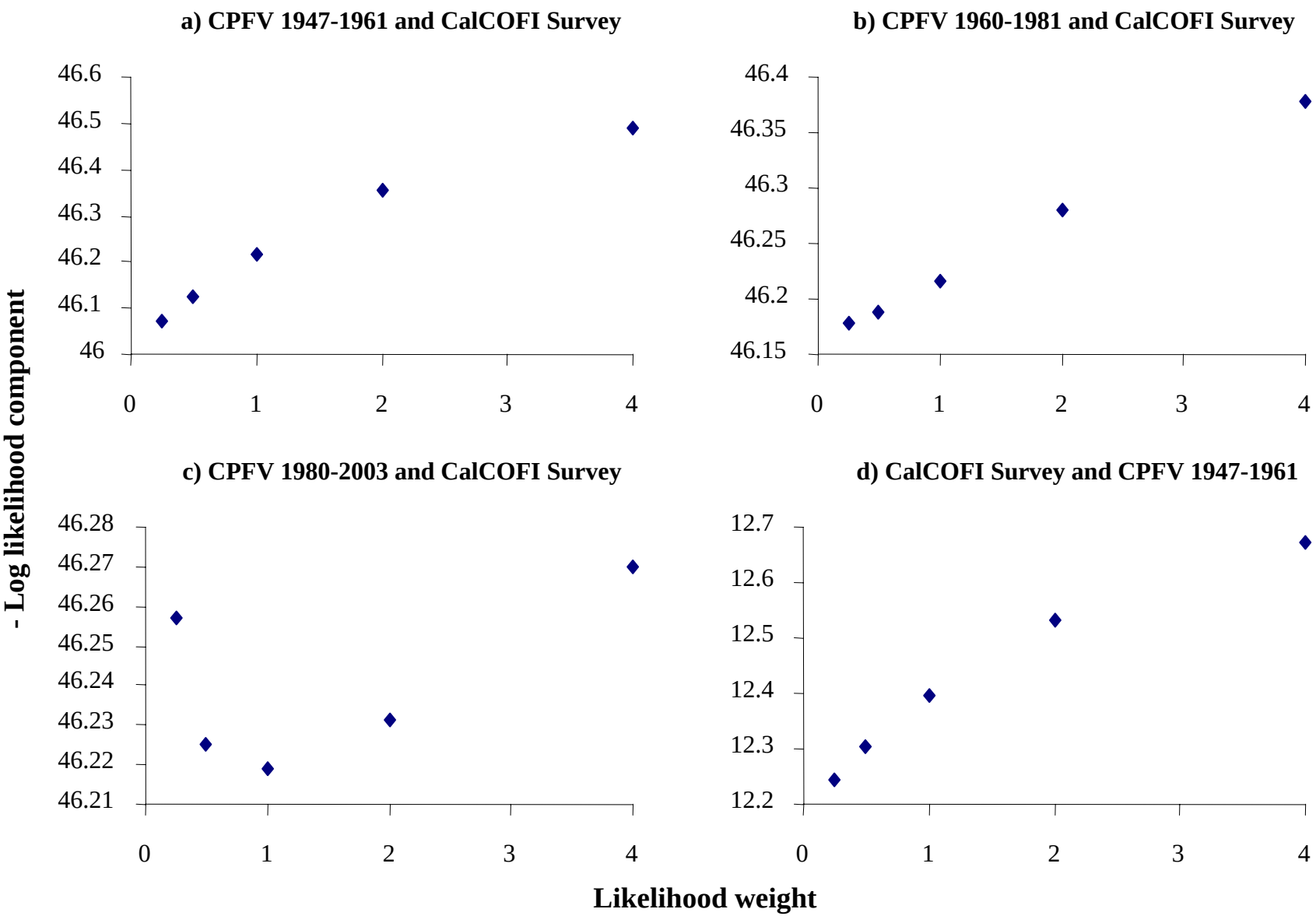


Figure 6.22 a-d We varied the likelihood weight of each of the four surveys individually while holding all other likelihood weights at the baseline level at one. In each panel, the likelihood component of one survey is shown as another survey's likelihood weight is varied. We focus on comparing the CPFV surveys with the CalCOFI survey.

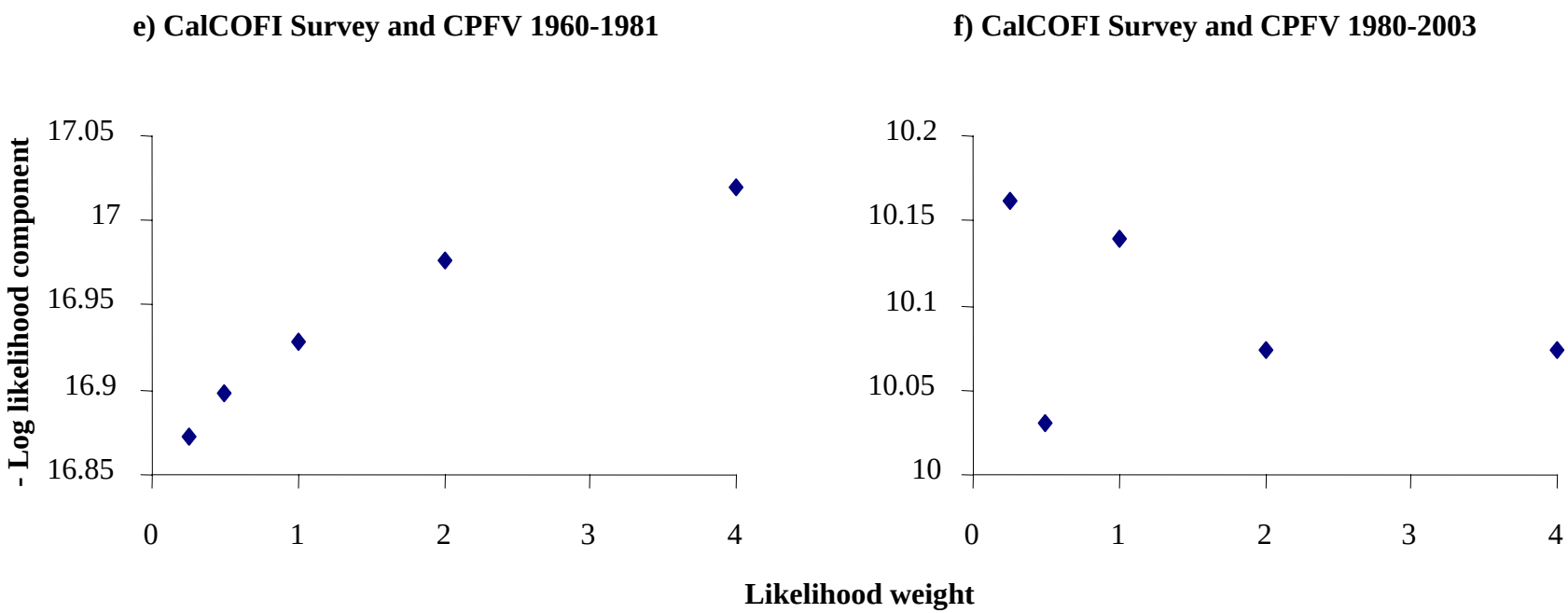


Figure 6.22 e-f Continued. We varied the likelihood weight of each of the four surveys individually while holding all other likelihood weights at the baseline level of one. In each panel, the likelihood component of one survey is shown as another survey's likelihood weight is varied. We focus on comparing the CPFV surveys with the CalCOFI survey.

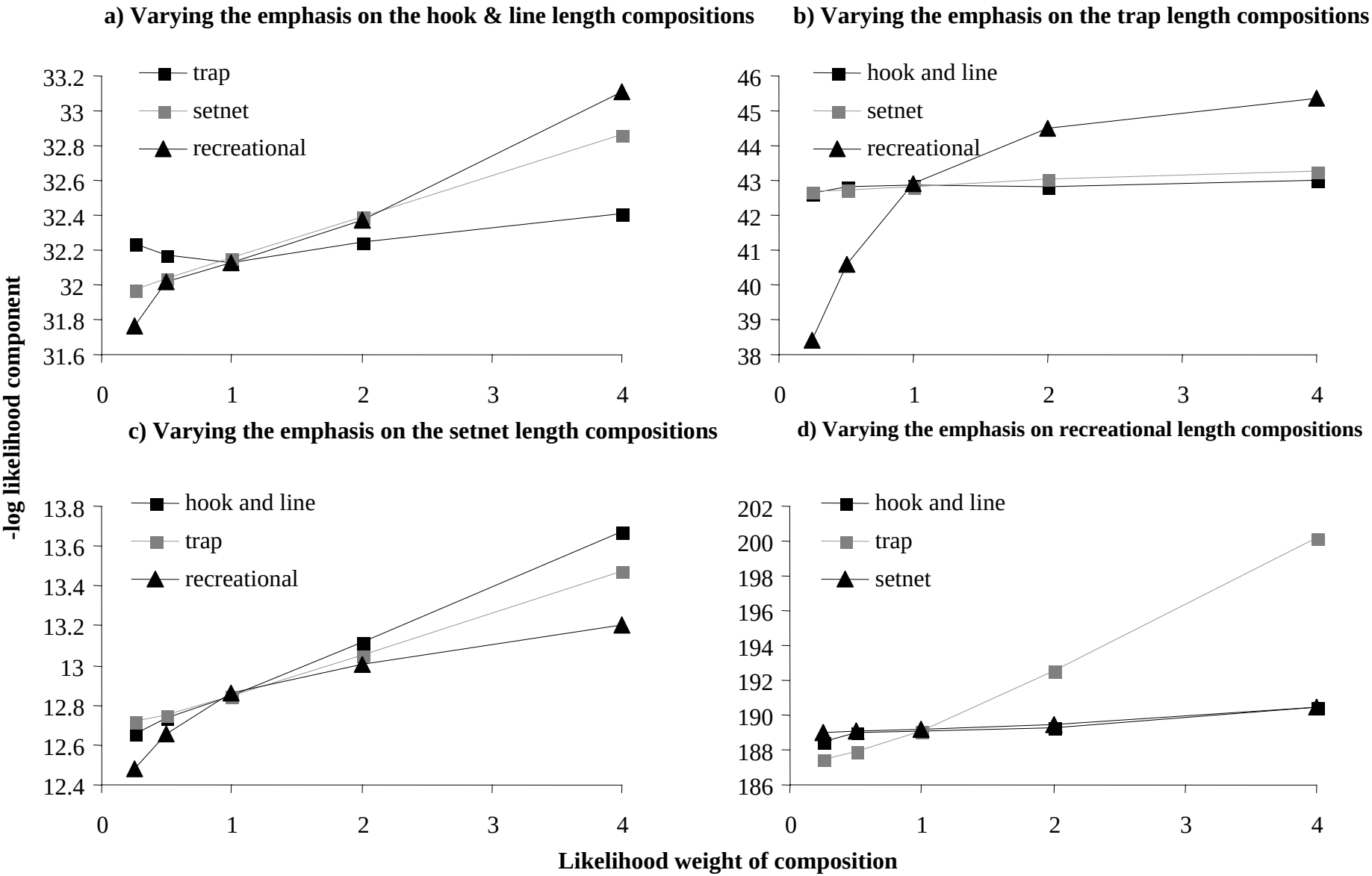


Figure 6.23 a-d Sensitivity analyses on data sources. We varied the individual likelihood weights of each length composition while holding all other likelihood weights at the baseline level of one. Each panel represents the change in the individual likelihood component of the three length compositions while the weight of the fourth set of length compositions is varied.

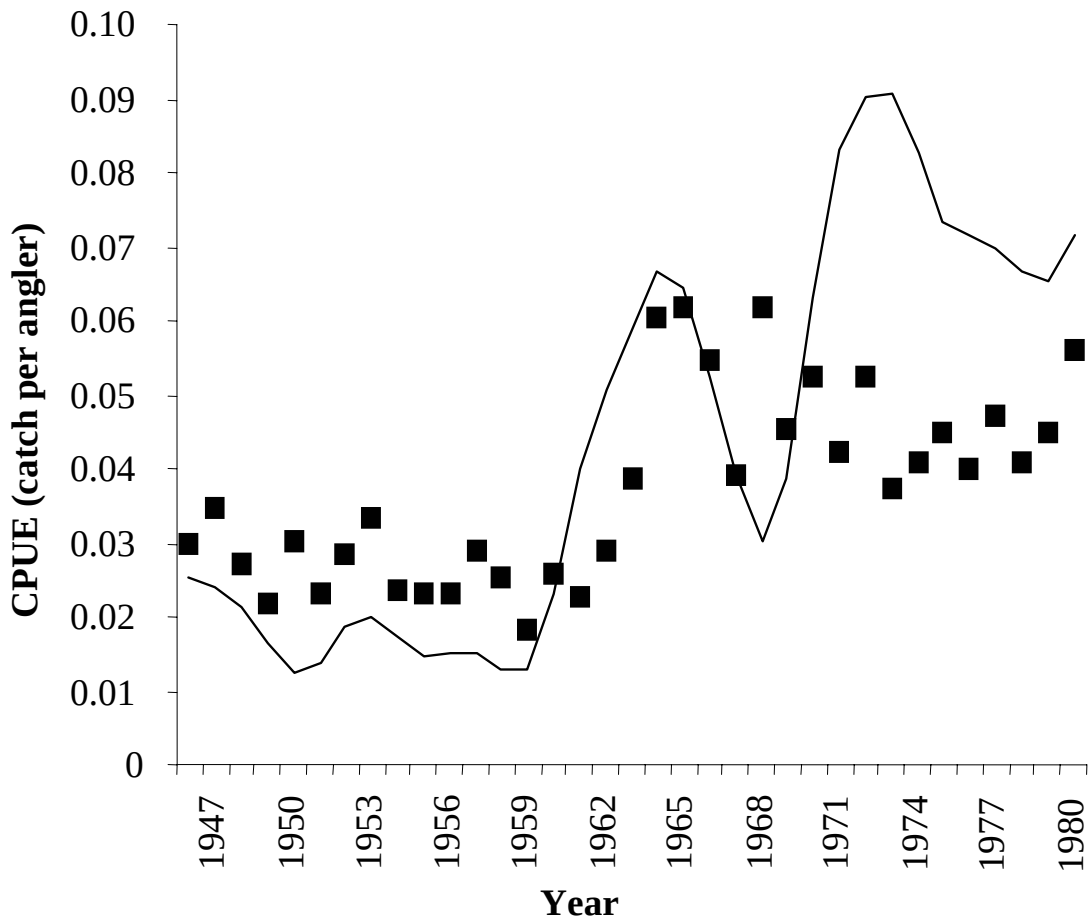


Figure 6.24 Sensitivity analysis on the fit to the combined CPFV (1947-1981) survey. Black squares are the observed values and the solid line is the estimated abundance index.

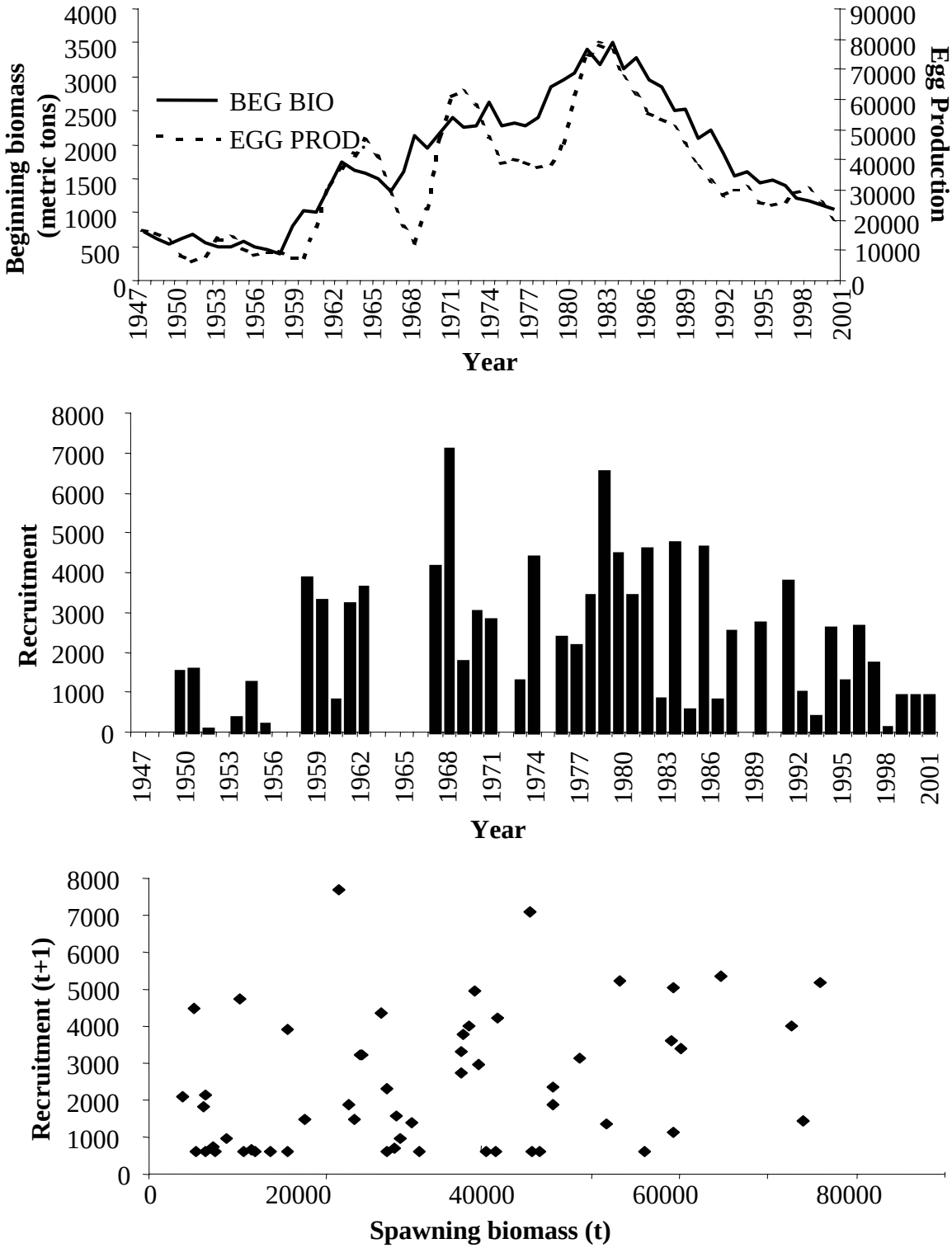


Figure 6.25 Sensitivity analysis on data: The predicted biomass, recruitment and stock/recruitment pattern using the calibrated CPFV survey as one index 1947-2003.

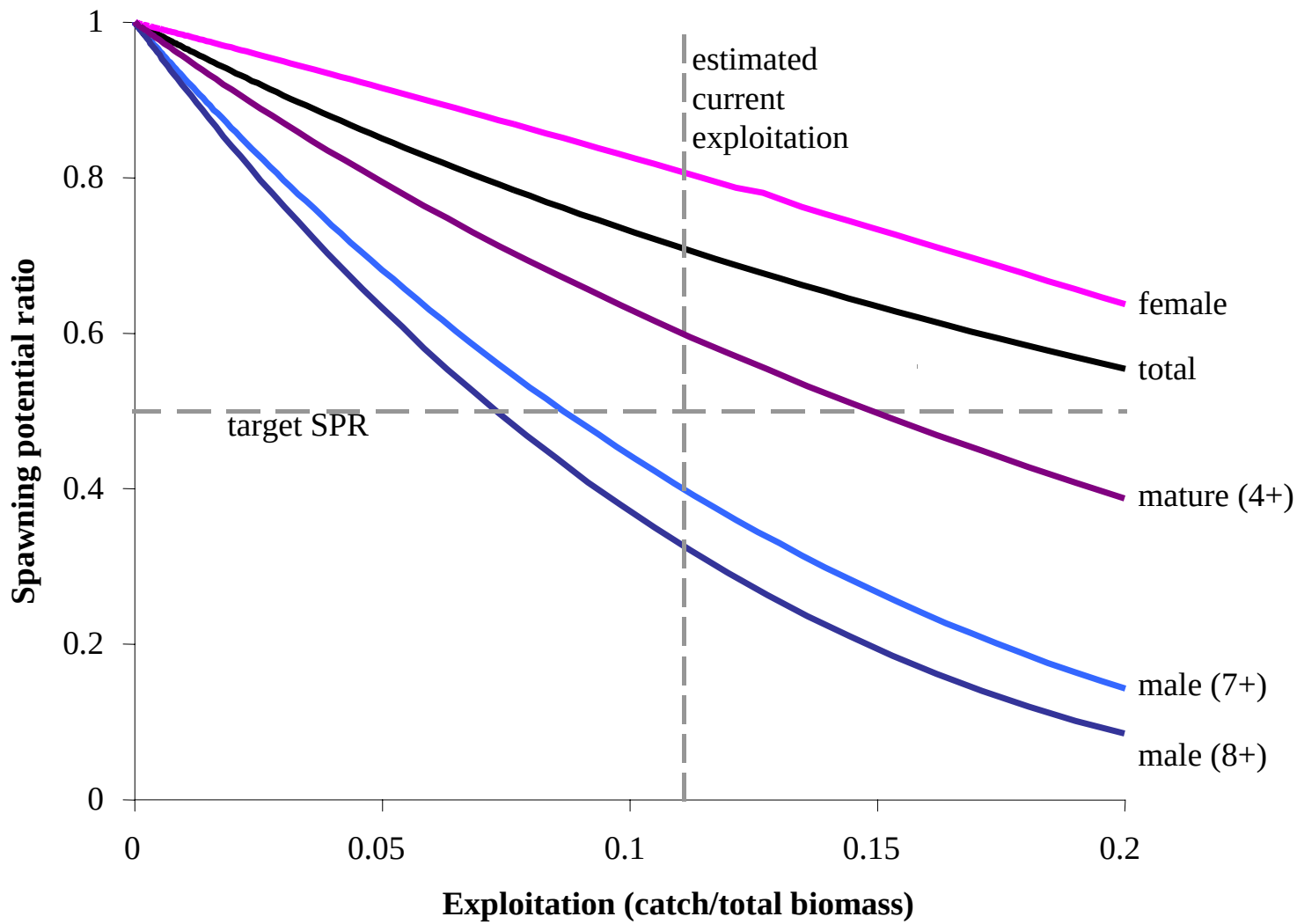


Figure 7.1 Estimated status of the stock as predicted by the baseline model. We give the relative spawning potential ratio (SPR) for female, mature (age 4 and above), male (age 7 and above or age 8 and above) and total biomass. Current exploitation is shown with the dashed vertical line. Female spawning potential ratio is estimated to be reduced to 80% of unfished levels while relative male spawning potential ratio is estimated to be reduced by about 65%. Equilibrium calculations are based on current (2003) fishing mortality associated with each fishery.

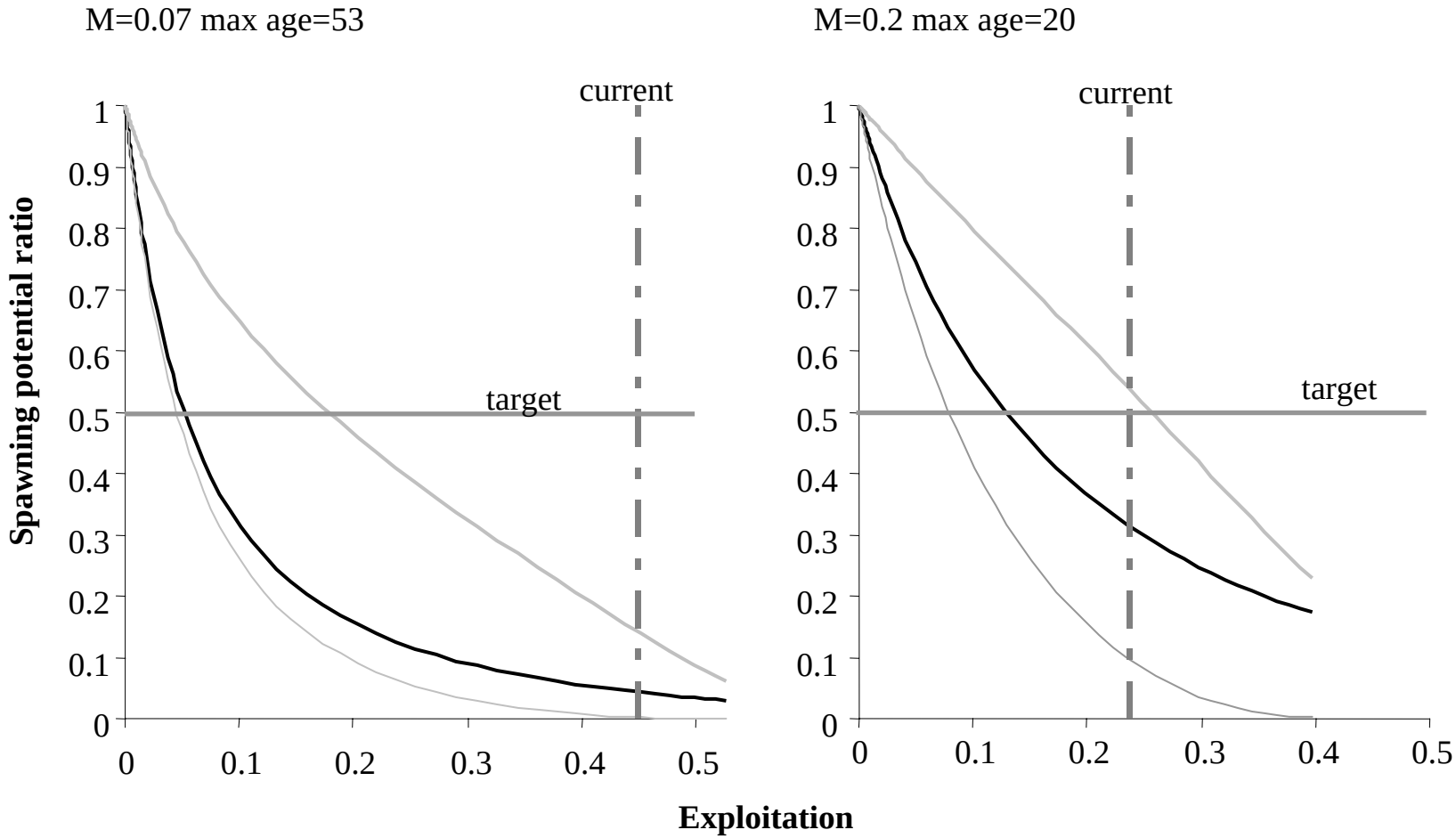


Figure 7.2 Natural mortality affects the estimated status of the stock. We give the relative spawning potential ratio (SPR) for female (thick grey line), male (age 7 and above, thin grey line) and total biomass (black line) for two additional natural mortality values. Natural mortality was estimated using Hoenig (1983) and the observed maximum age of Sheephead from two different sources. For further details see the text. Current estimated exploitation differs between the models as natural mortality changes because the estimated total and spawning biomass are affected by natural mortality. Equilibrium calculations are based on current (2003) fishing mortality associated with each fishery.

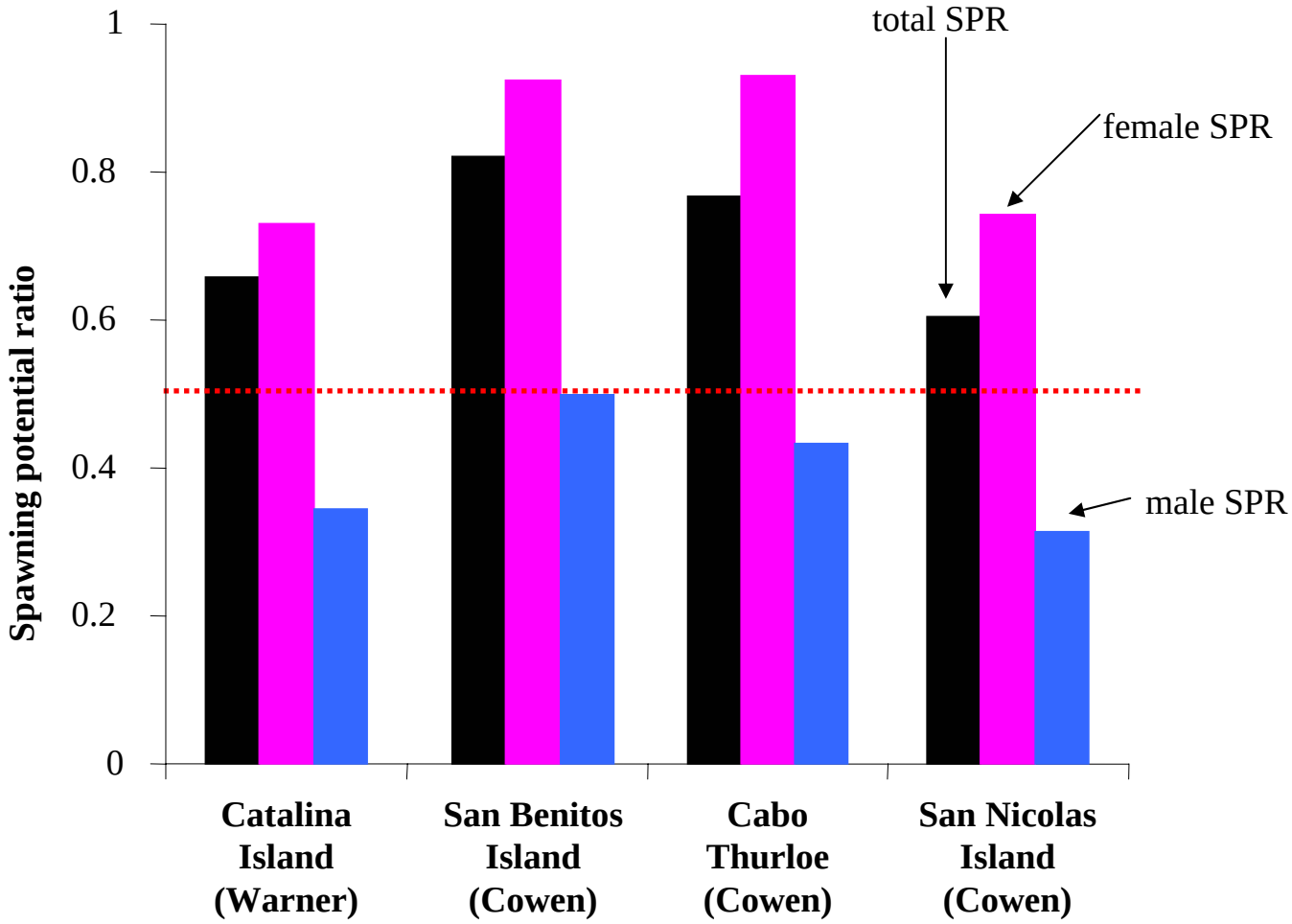


Figure 7.3 The estimated current status of the stock is also affected by the combination of life history parameters used. We ran the model with each of the six sets of parameters given in Table 3.1 and calculated the estimated relative spawning potential ratios (total, female and male) for each model, this figure shows only the four nearshore populations. Equilibrium calculations are based on current (2003) fishing mortality associated with each fishery.

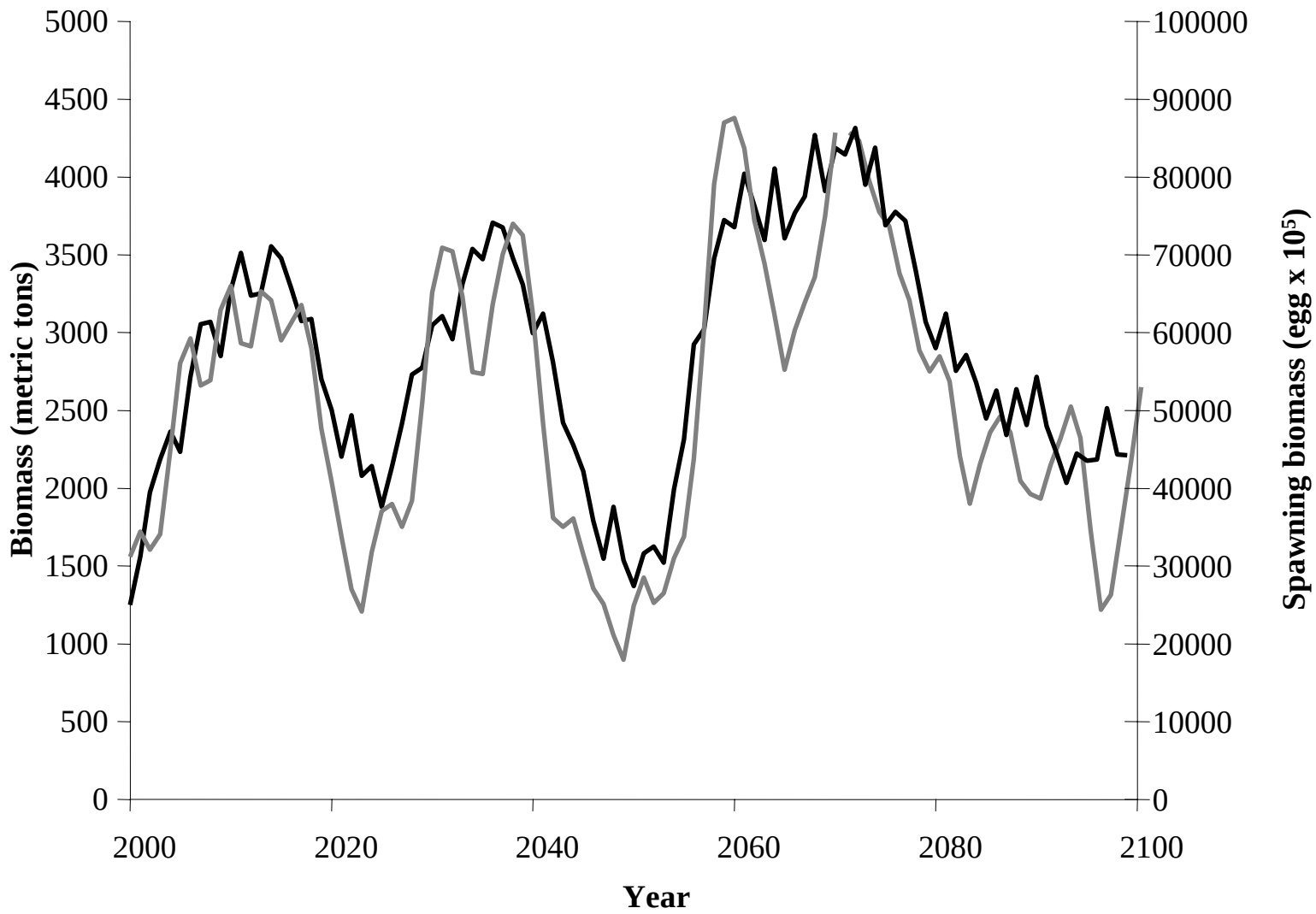


Figure 7.4 Variable recruitment leads to temporal variation in expected total and spawning biomass even in the absence of fishing mortality. The results presented here are based on a single projection showing for total (black line) and female (grey line) spawning biomass in the absence of fishing assuming that recruitment is selected randomly from model estimated recruitment from 1970-1995.

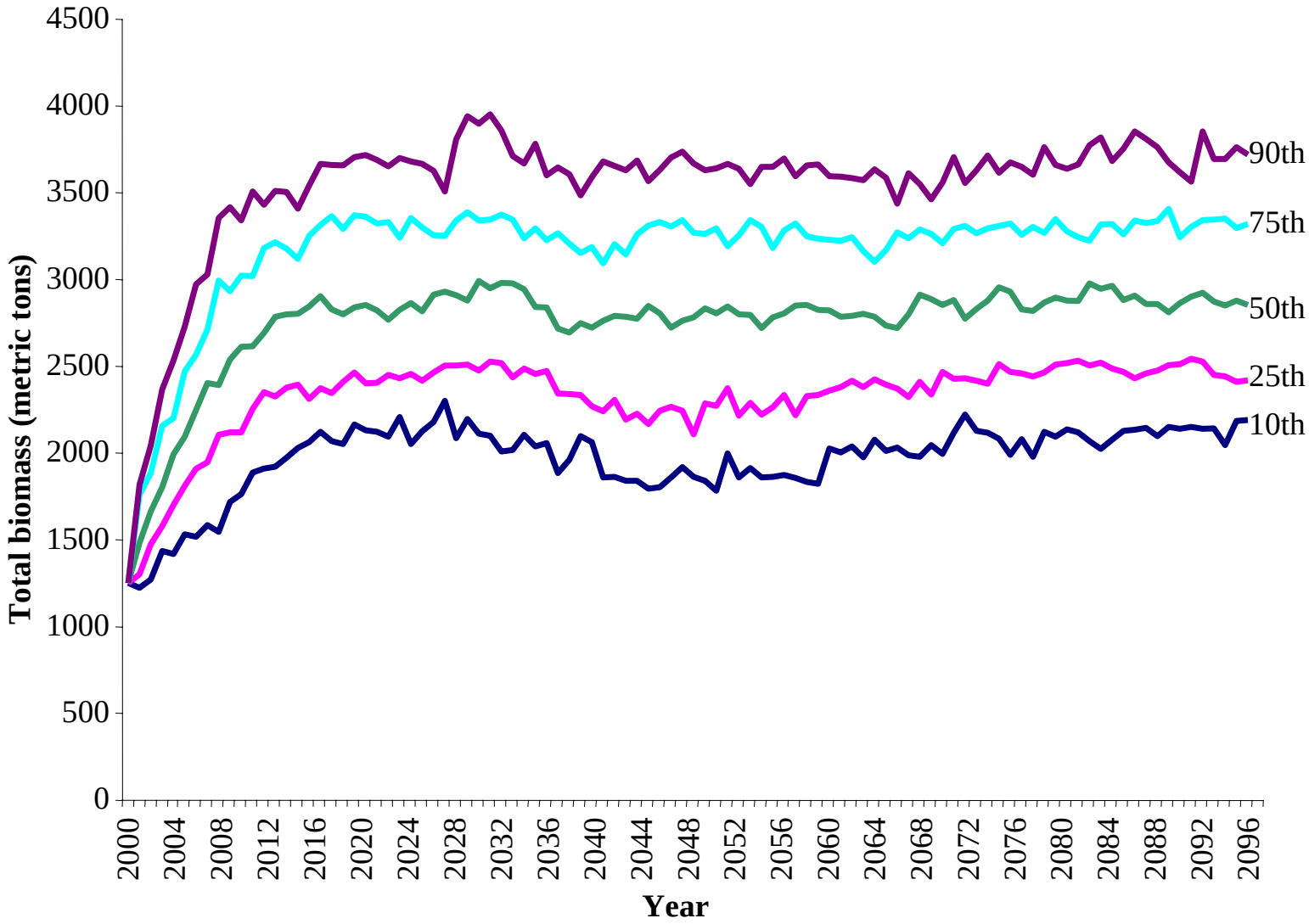


Figure 7.5 Projections of the 10th, 25th, 50th and 90th percentiles for projected total biomass when fishing mortality is zero. The results presented here are based on 100 projections for 100 years in the absence of fishing assuming that recruitment is selected randomly from model estimated recruitment from 1970-1995.

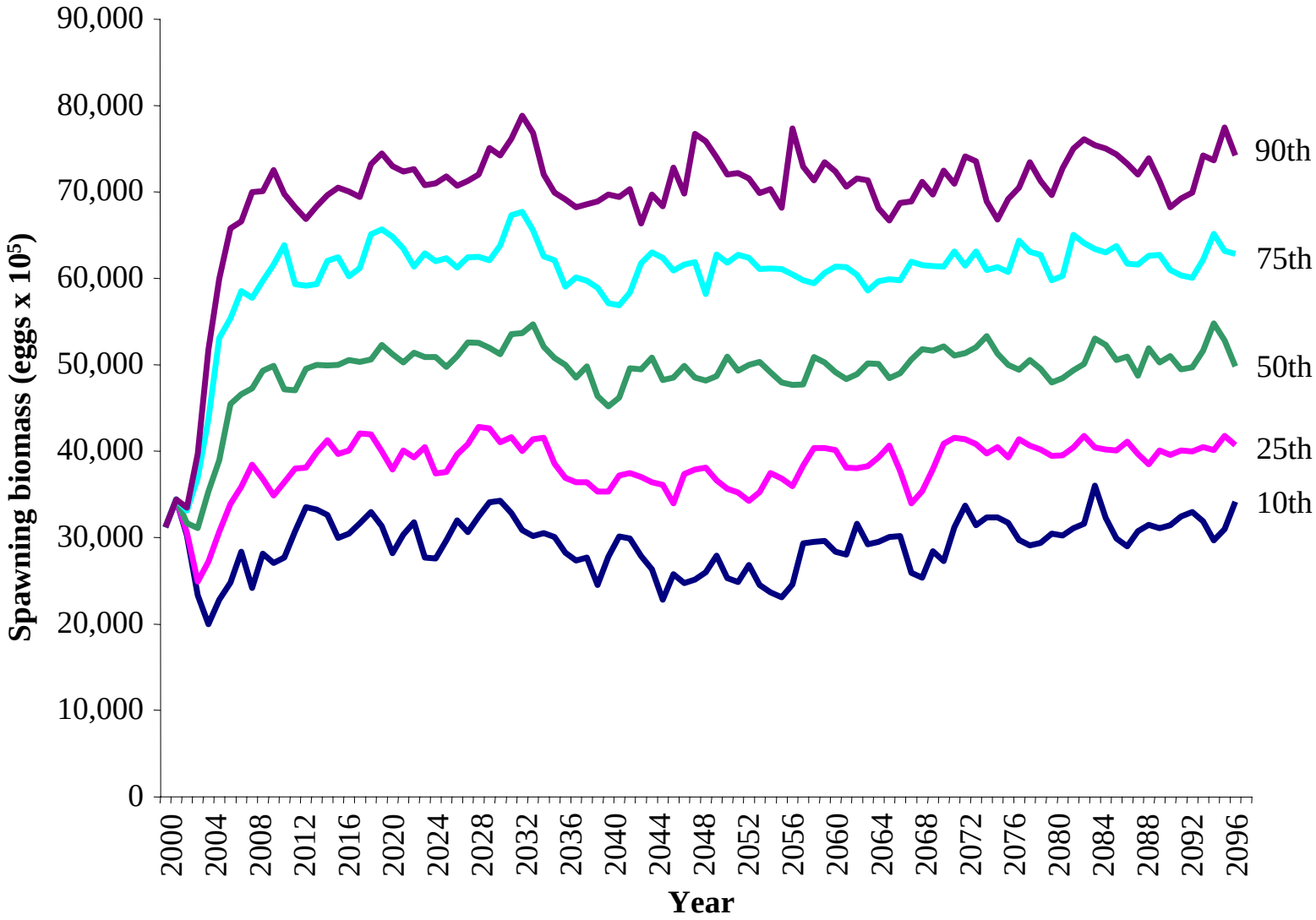


Figure 7.6 Projections of the 10th, 25th, 50th and 90th percentiles for projected spawning biomass when fishing mortality is zero. The results presented here are based on 100 projections for 100 years in the absence of fishing assuming that recruitment is selected randomly from model estimated recruitment from 1970-1995.

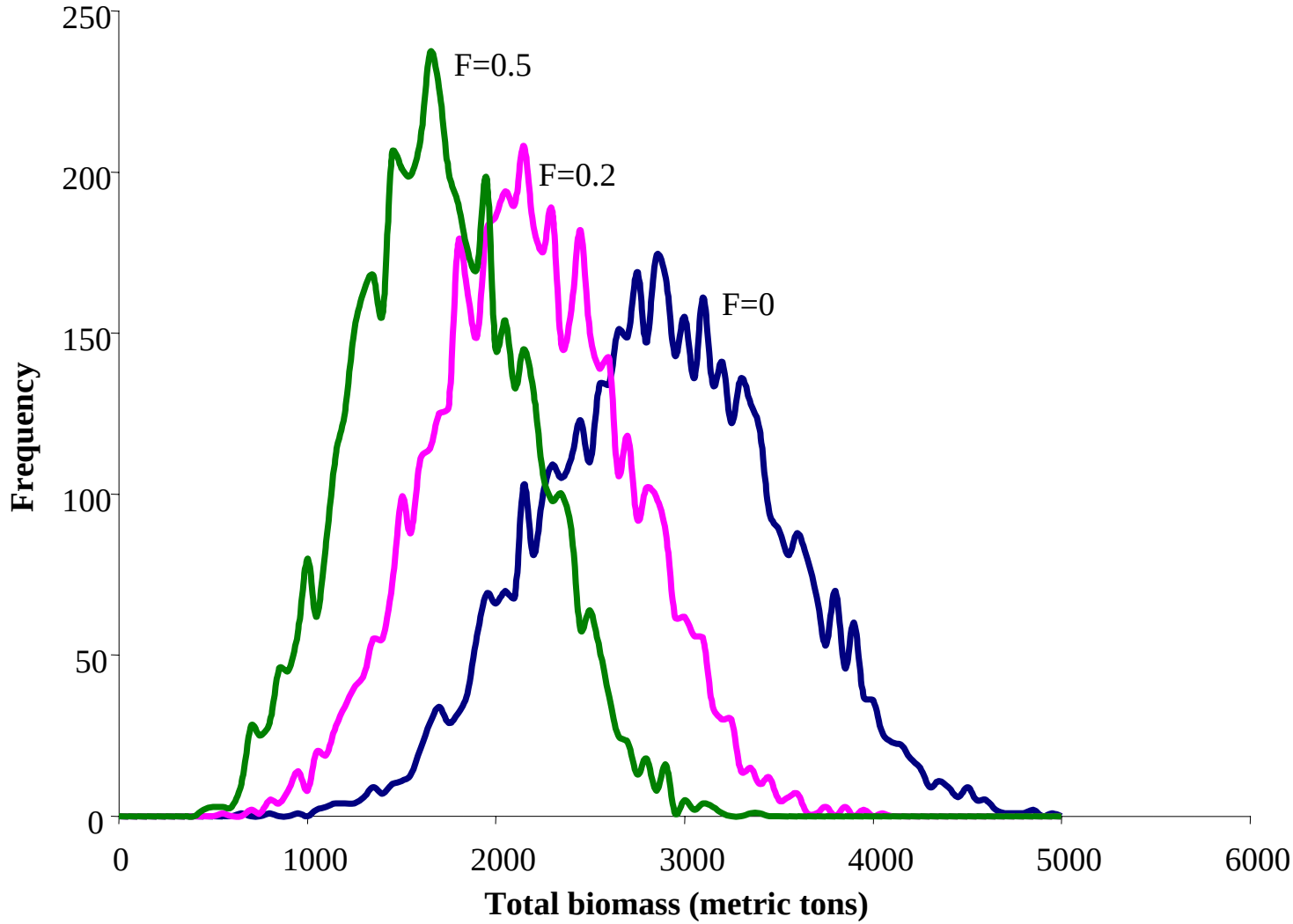


Figure 7.7 Frequency distributions of projected total biomass in the future (of the baseline model) when future fishing mortality is fixed at 0, 0.2 and 0.5. The distribution of total biomass is based on projections over 50 years after having allowed the projections to stabilize. The results presented here are based on 100 projections for 100 years assuming that recruitment is selected randomly from model estimated recruitment from 1970-1995.

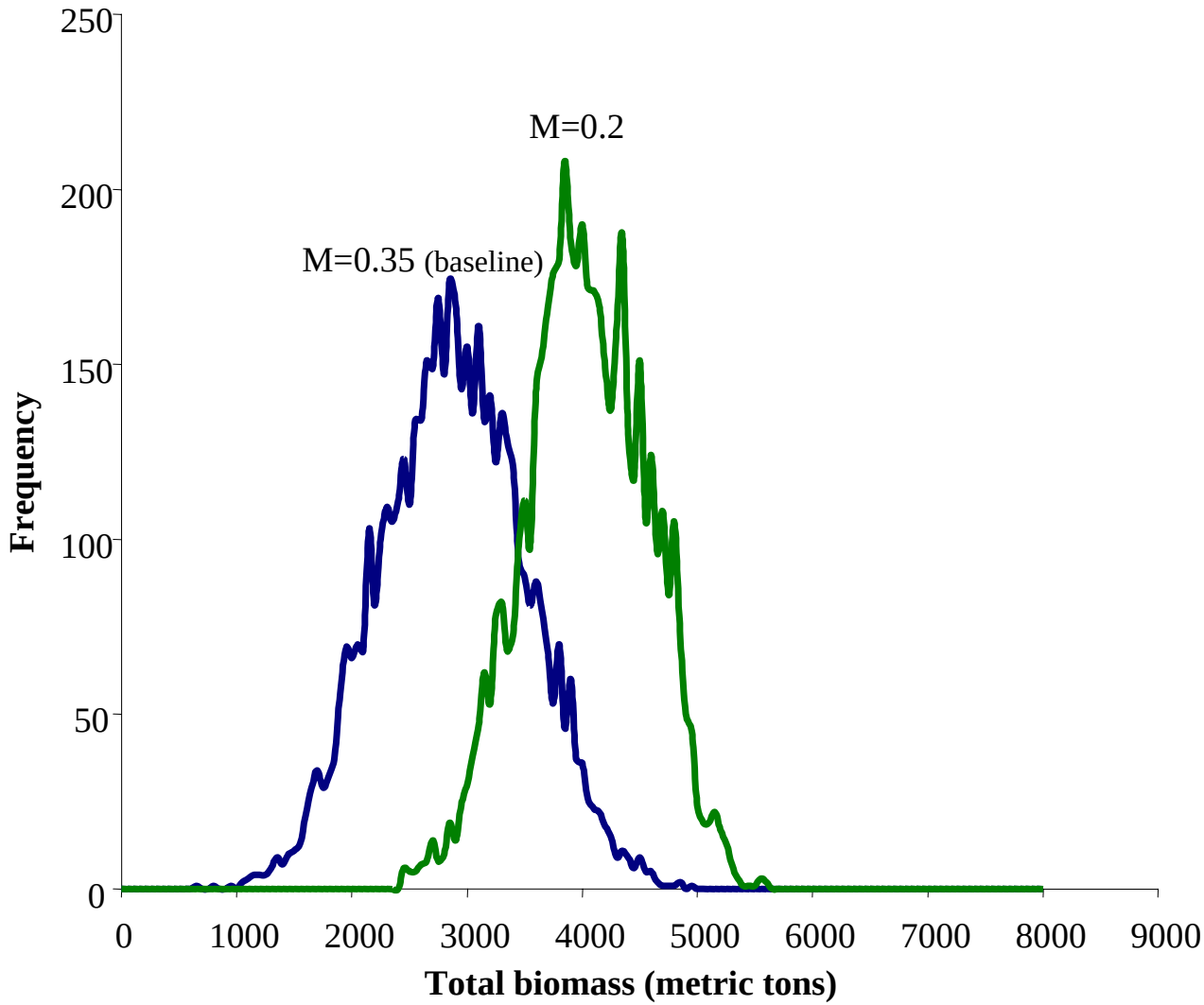


Figure 7.8 Frequency distributions of projected total biomass in the future (of the baseline model) when fishing mortality is zero (F=0) and natural mortality is 0.35 (baseline case) and 0.2. The distribution of total biomass is based on projections over 50 years after having allowed the projections to stabilize. The results presented here are based on 100 projections for 100 years assuming that recruitment is selected randomly from model estimated recruitment from 1970-1995.

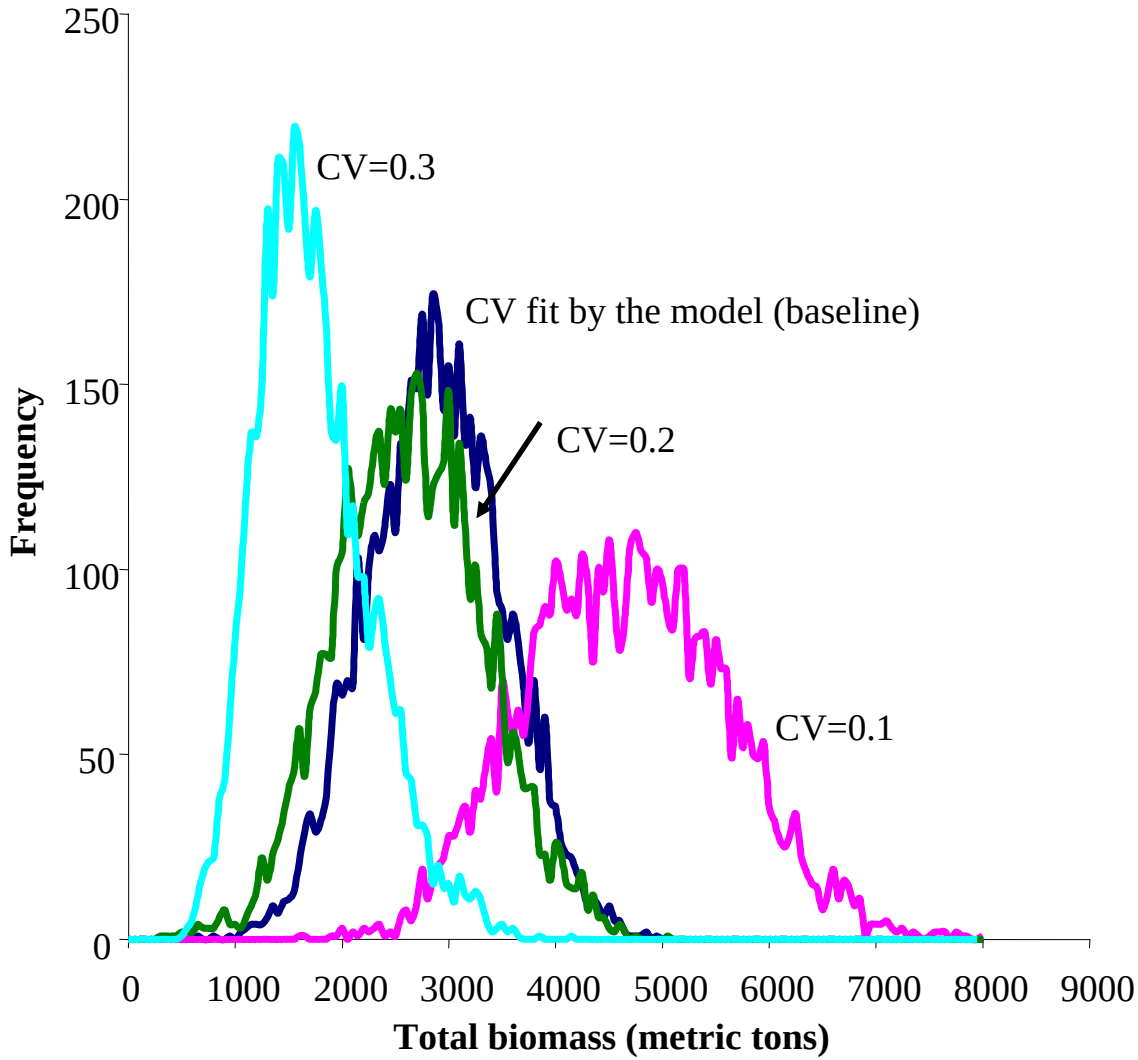


Figure 7.9 Frequency distributions of projected total biomass in the future (of the baseline model) when fishing mortality is zero and the coefficient of variation is estimated by the model (baseline case), 0.1, 0.2 and 0.3. The distribution of total biomass is based on projections over 50 years after having allowed the projections to stabilize. The results presented here are based on 100 projections for 100 years assuming that recruitment is selected randomly from model estimated recruitment from 1970-1995.

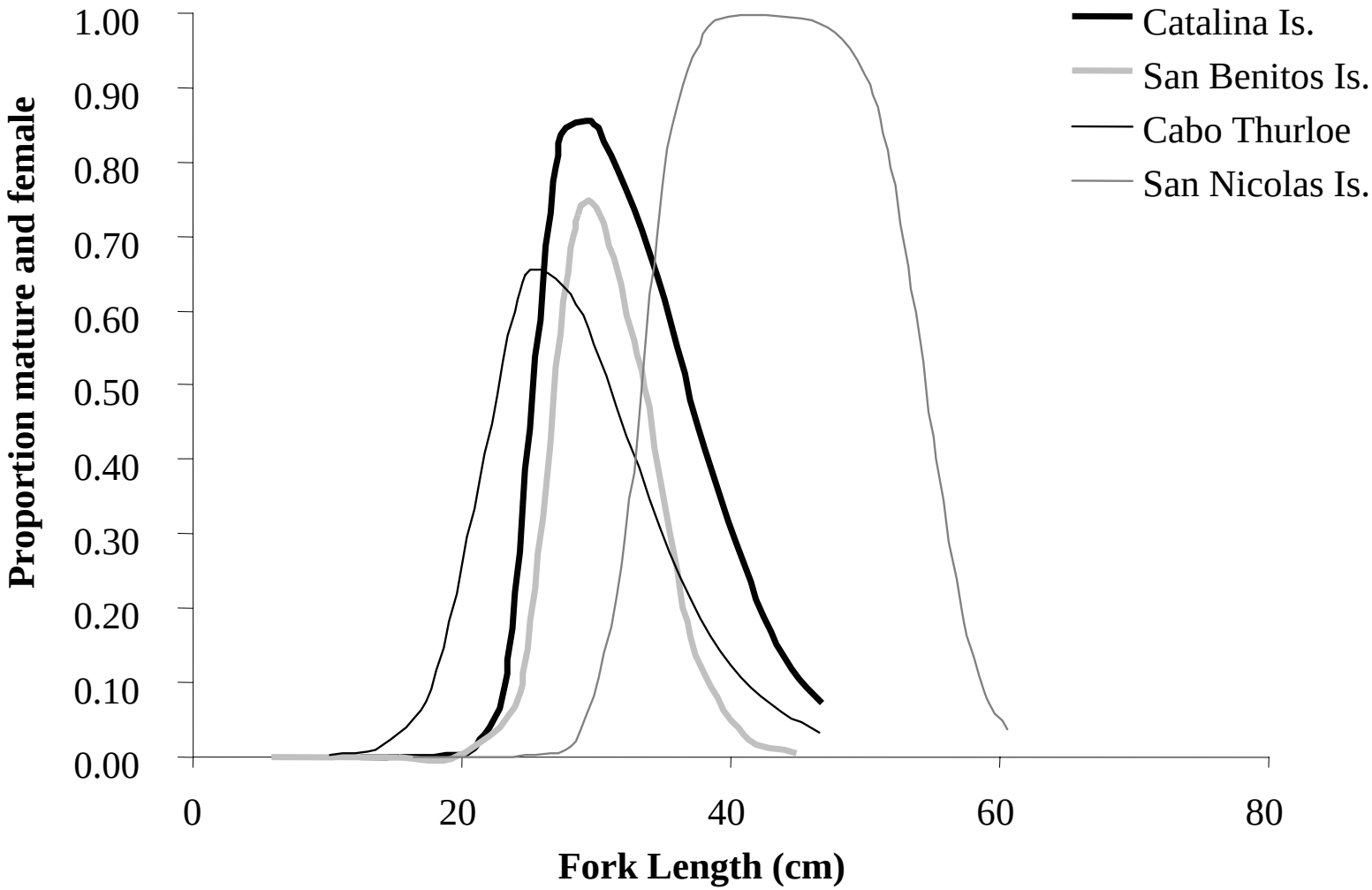


Figure 8.1 The maturity and sex change combined function for each of the refitted length and maturity data for the four nearshore populations.

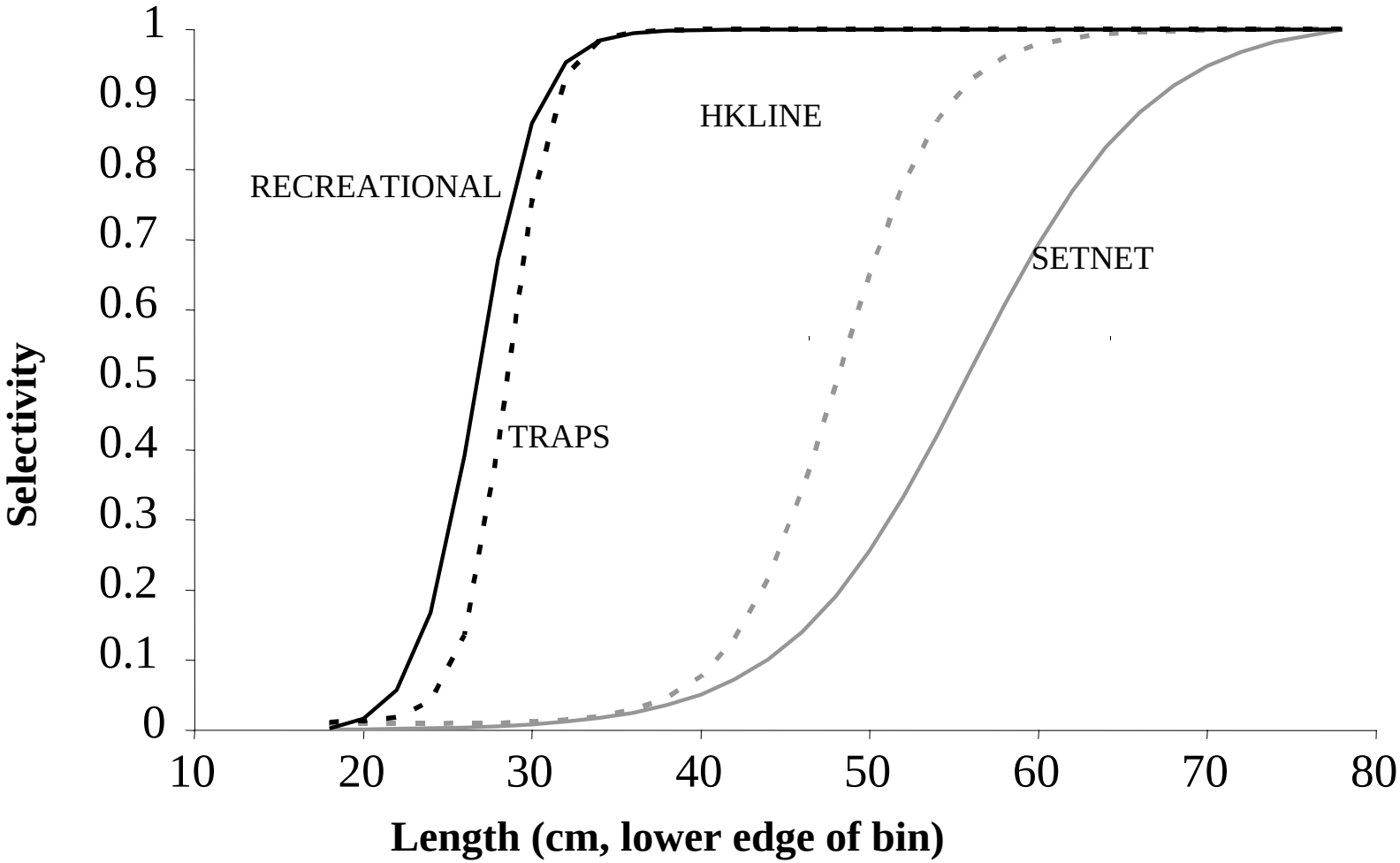


Figure 8.2 Estimated selectivities for each of the four fisheries in the final Synthesis model. Results are shown for the case where M=0.2. However, alternative natural mortality values (M=0.15 and M=0.3) lead to the same pattern.

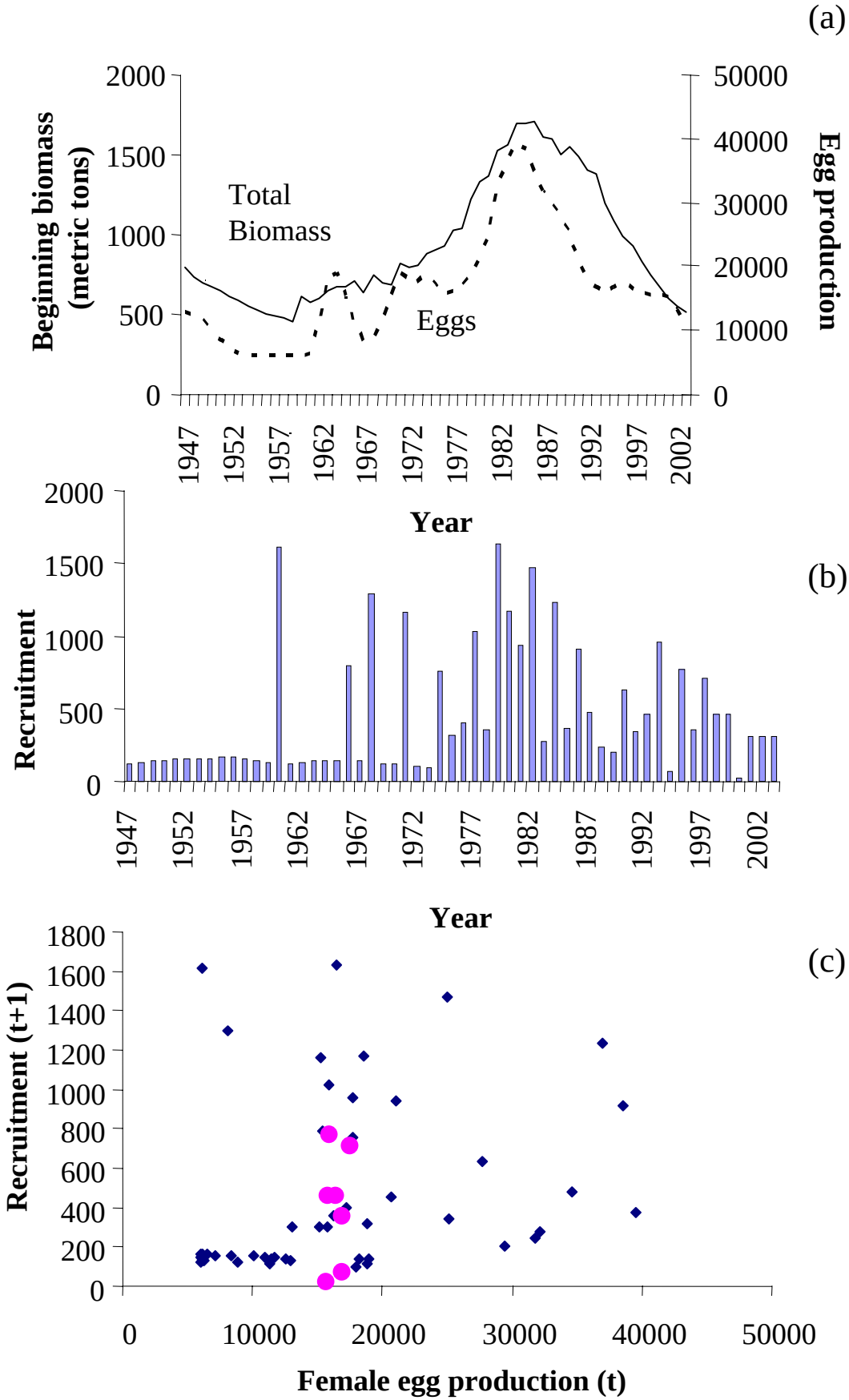


Figure 8.3 (a) The historical total biomass and spawning biomass (b) recruitment, and (c) the relationship between recruitment and spawning output estimated by the final Synthesis model when M=0.2. The round markers indicate recruitment between 1993-2000.

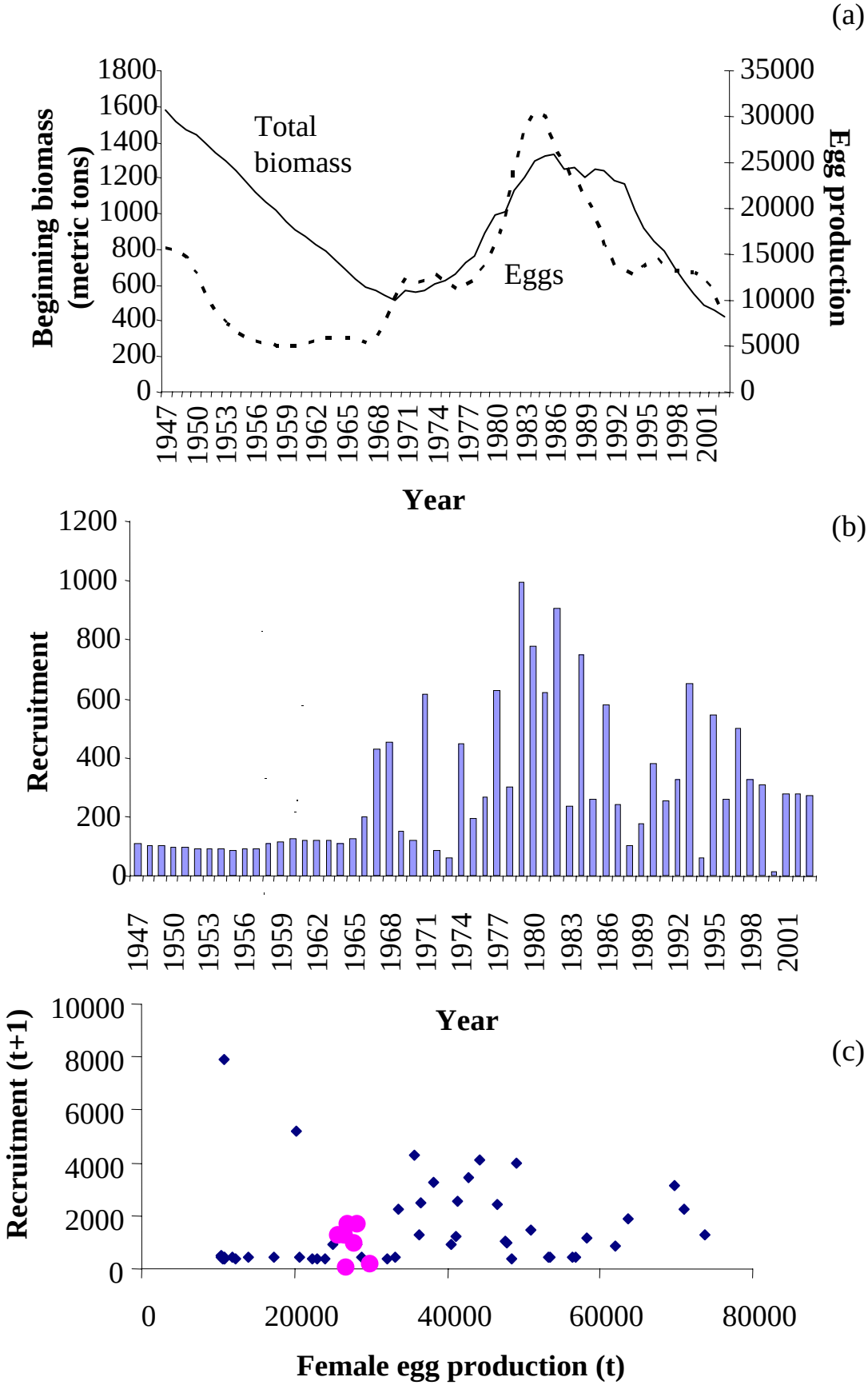


Figure 8.4 (a) The historical total biomass and spawning biomass (b) recruitment, and (c) the relationship between recruitment and spawning output estimated by the final Synthesis model when M=0.15the round markers indicate recruitment between 1993-2000.

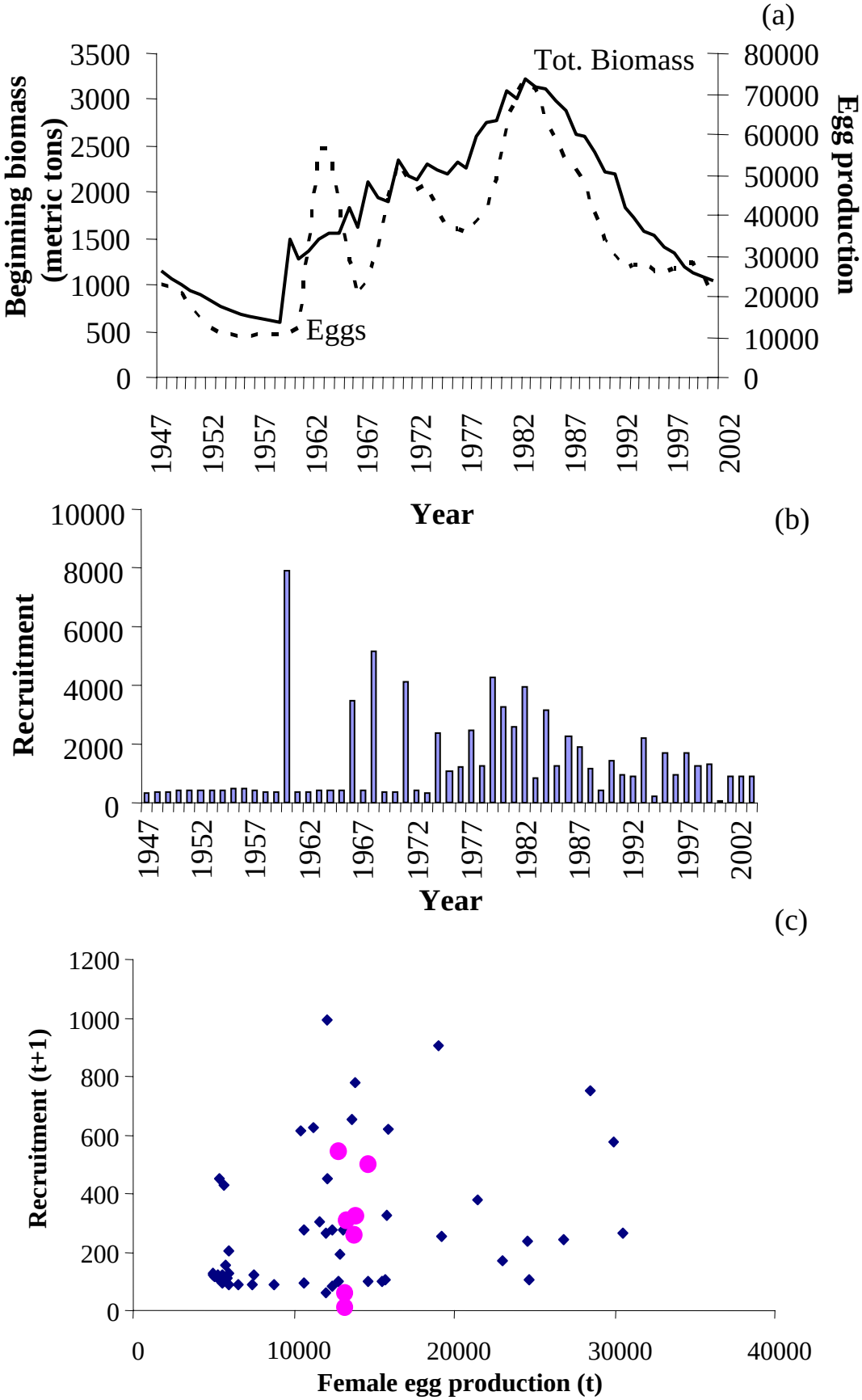


Figure 8.5 (a) The historical total biomass and spawning biomass (b) recruitment, and (c) the relationship between recruitment and spawning output estimated by the final Synthesis model when M=0.3 the round markers indicate recruitment between 1993-2000.

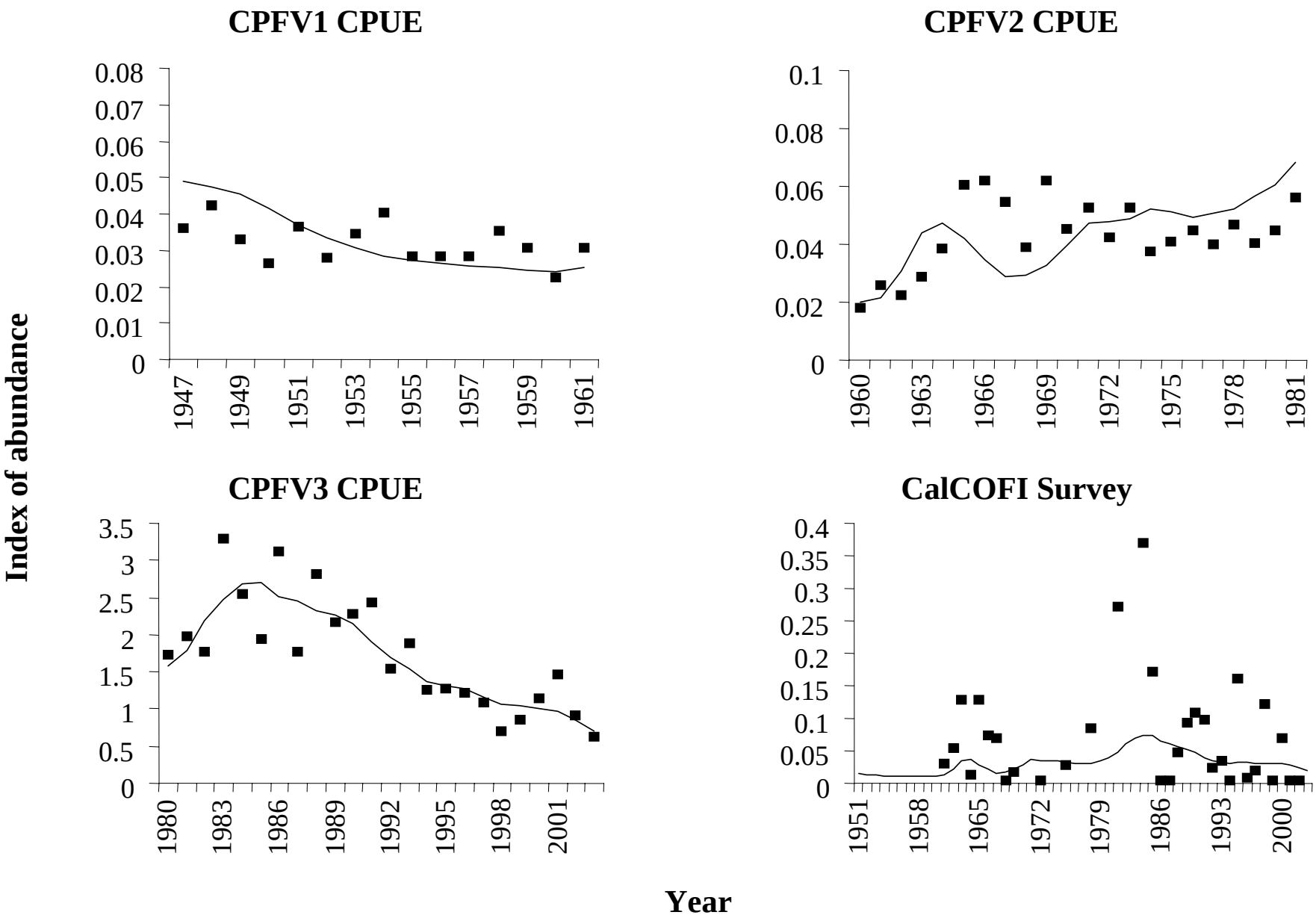


Figure 8.6 The estimated (solid line) and observed (black squares) abundance indices for the final Synthesis model when M=0.2.

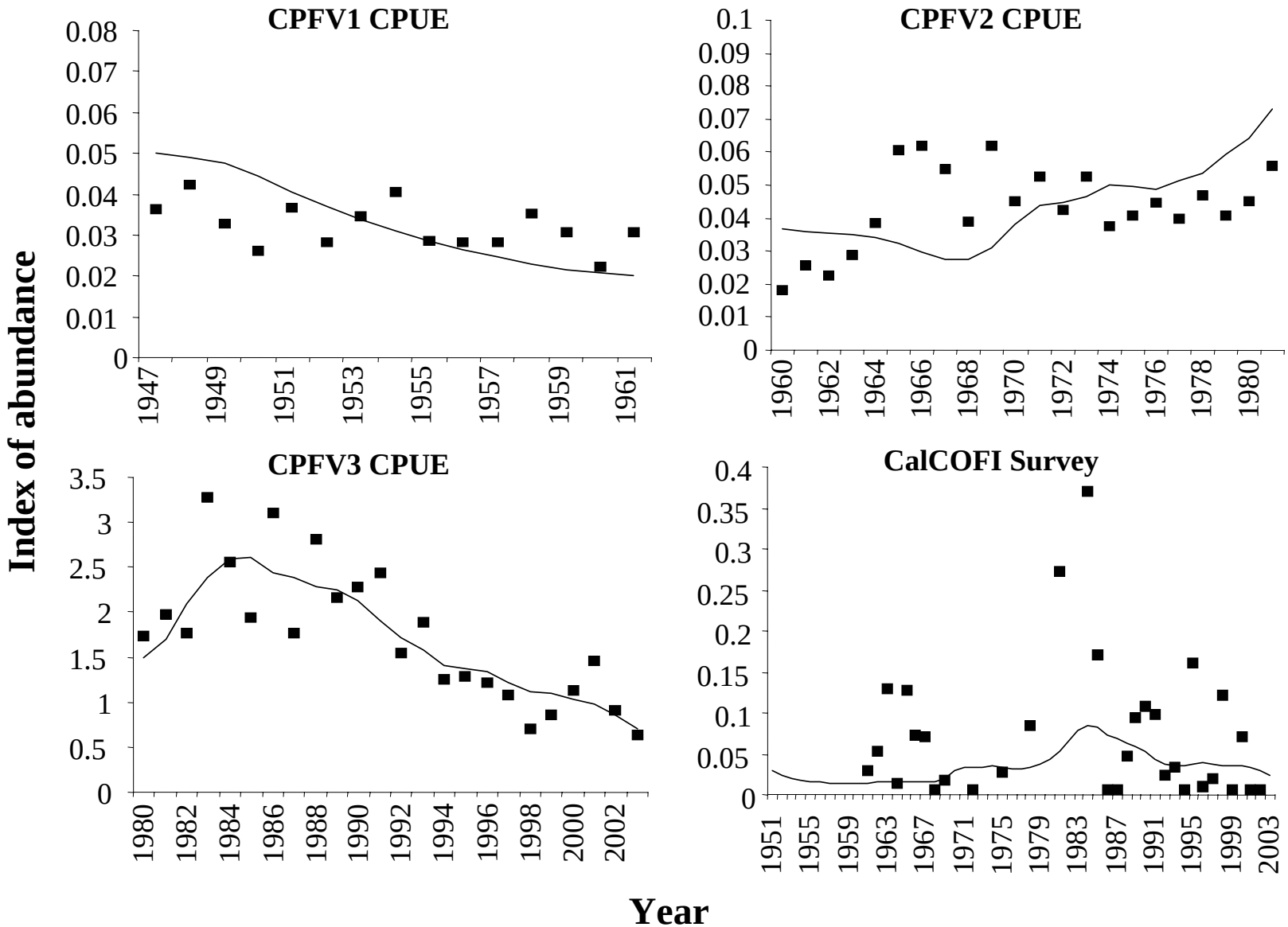


Figure 8.7 The estimated (solid line) and observed (black squares) abundance indices for the final Synthesis model when M=0.15.

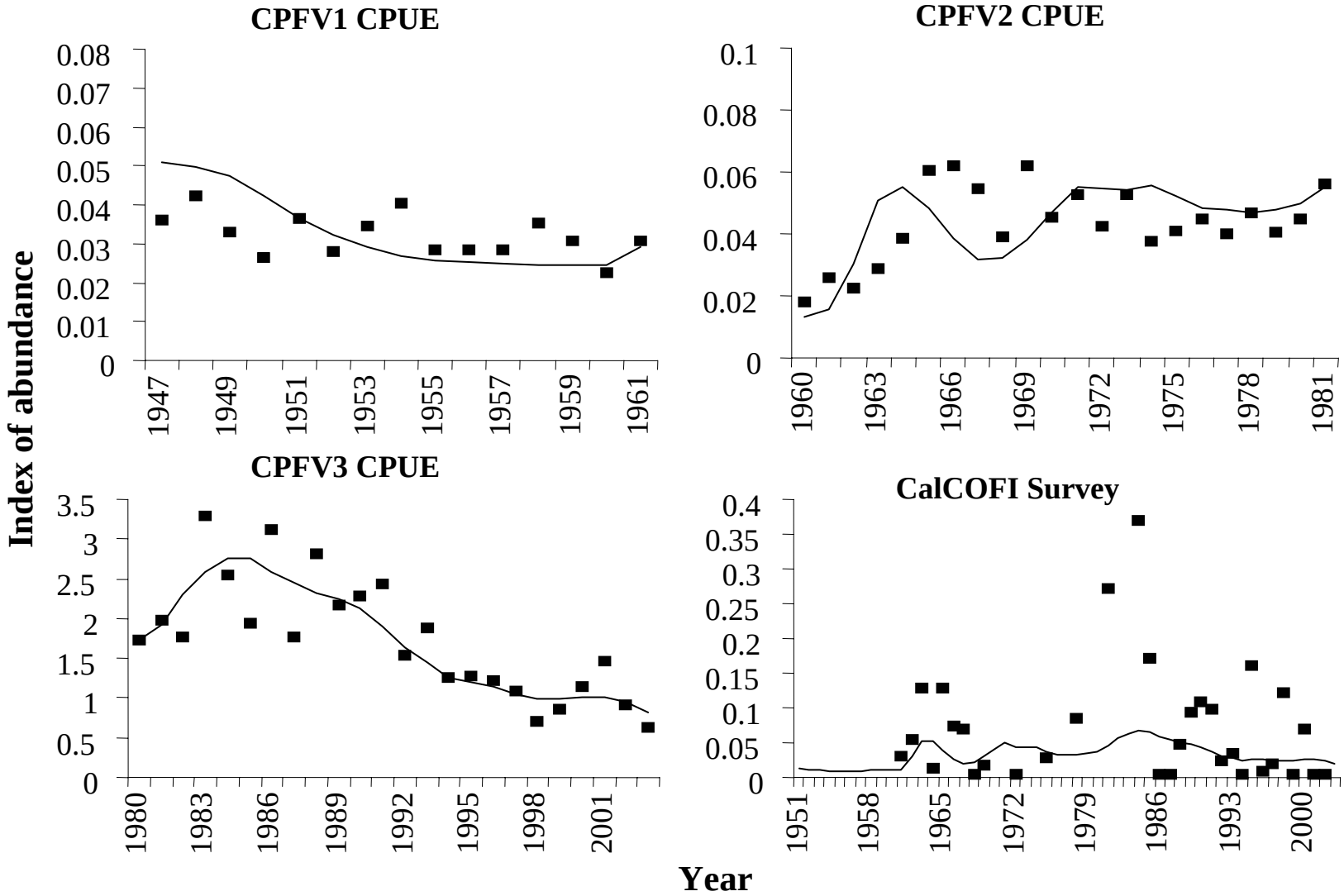


Figure 8.8 The estimated (solid line) and observed (black squares) abundance indices for the final Synthesis model when M=0.3.

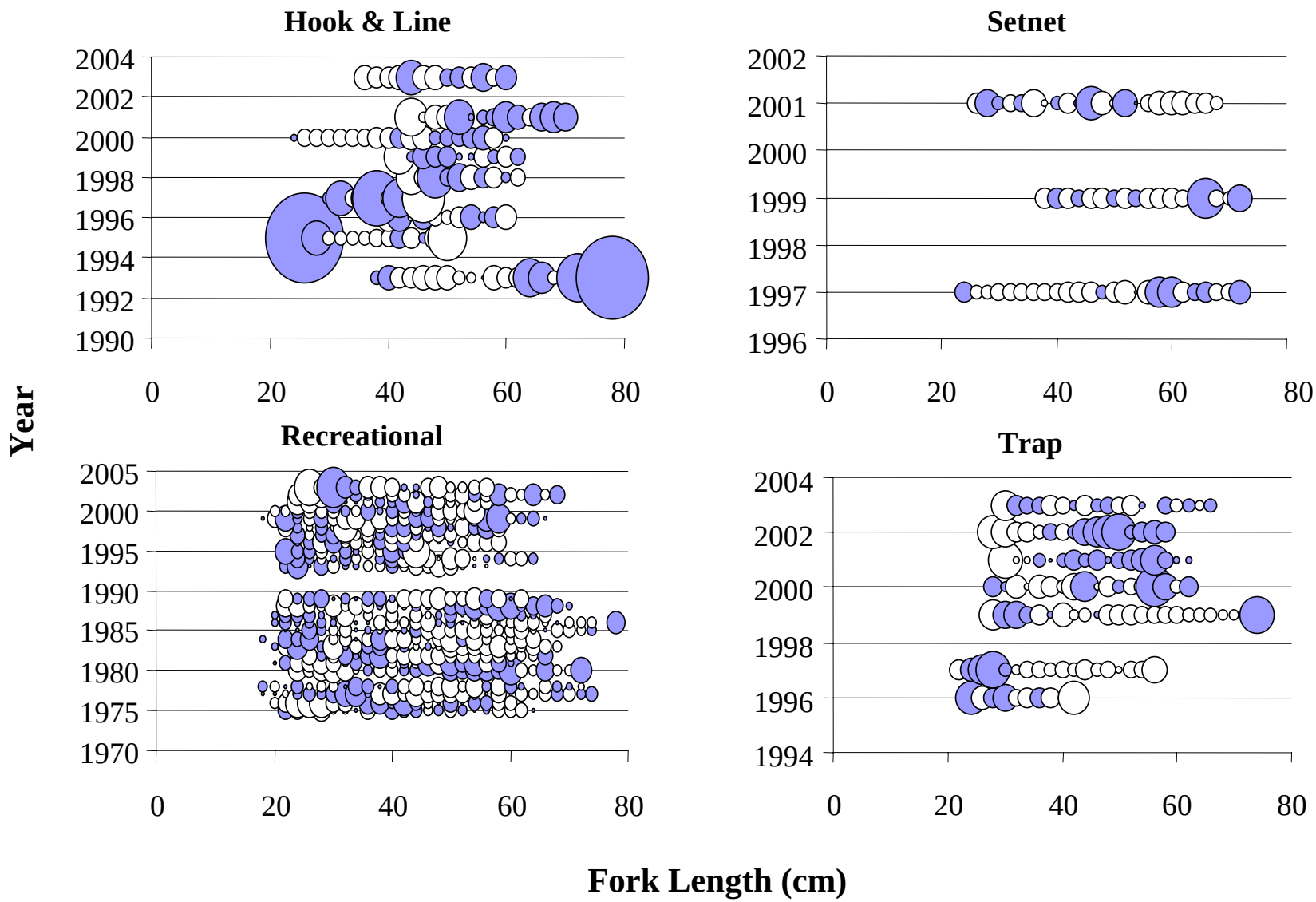


Figure 8.9 Bubble plots representing the fit between the observed and estimated length compositions for the final Synthesis model when M=0.2. However, alternative estimates of natural mortality (M=0.15 and 0.3) lead to identical patterns. The area of the circle indicates the deviation between the observed and estimated values. Filled circles represent a positive deviation and empty circles represent a negative deviation.

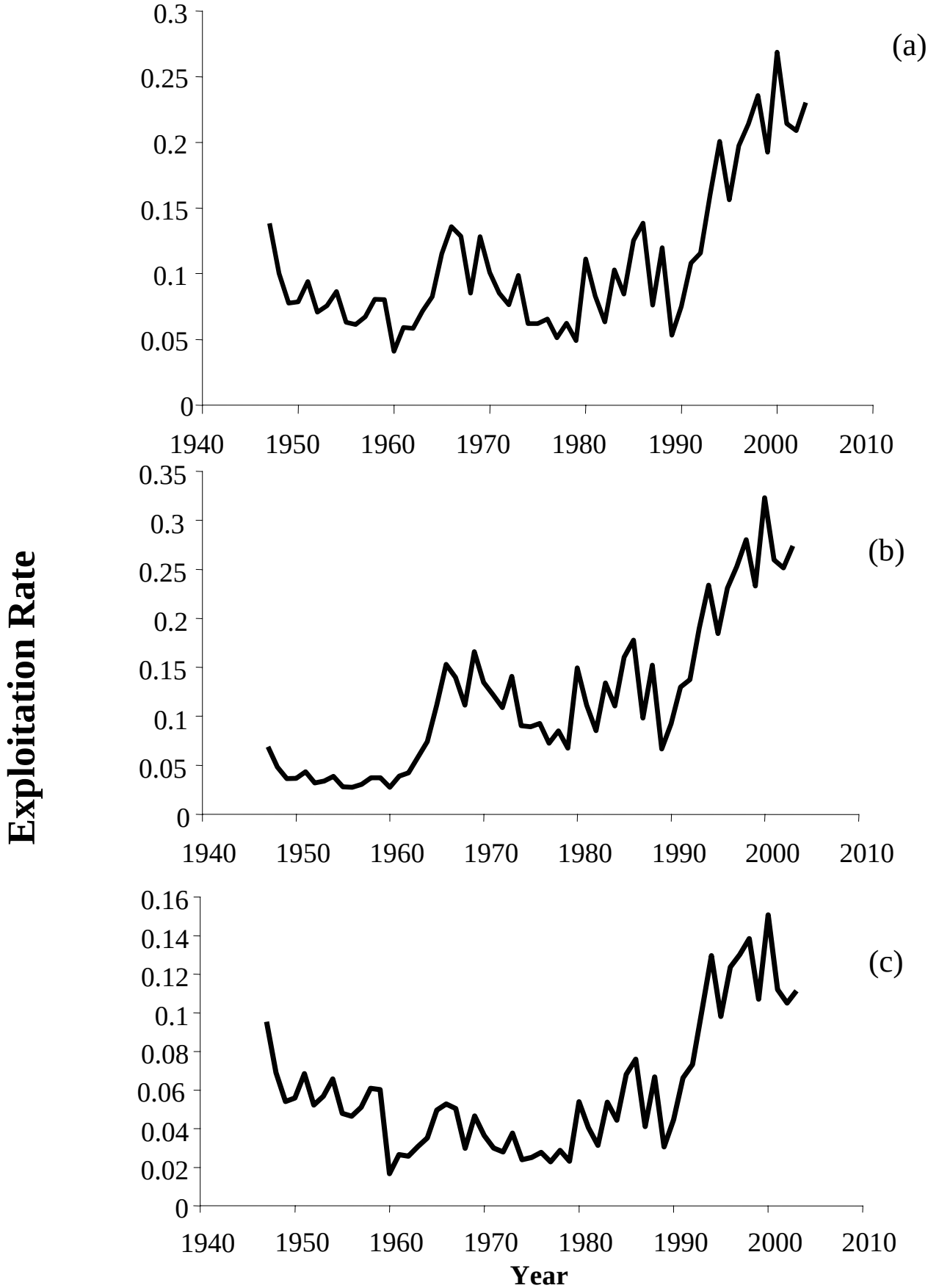


Figure 8.10 Exploitation rate of Sheephead as estimated by the final Synthesis model when M=0.20 (a), M=0.15 (b), and M=0.30 (c).

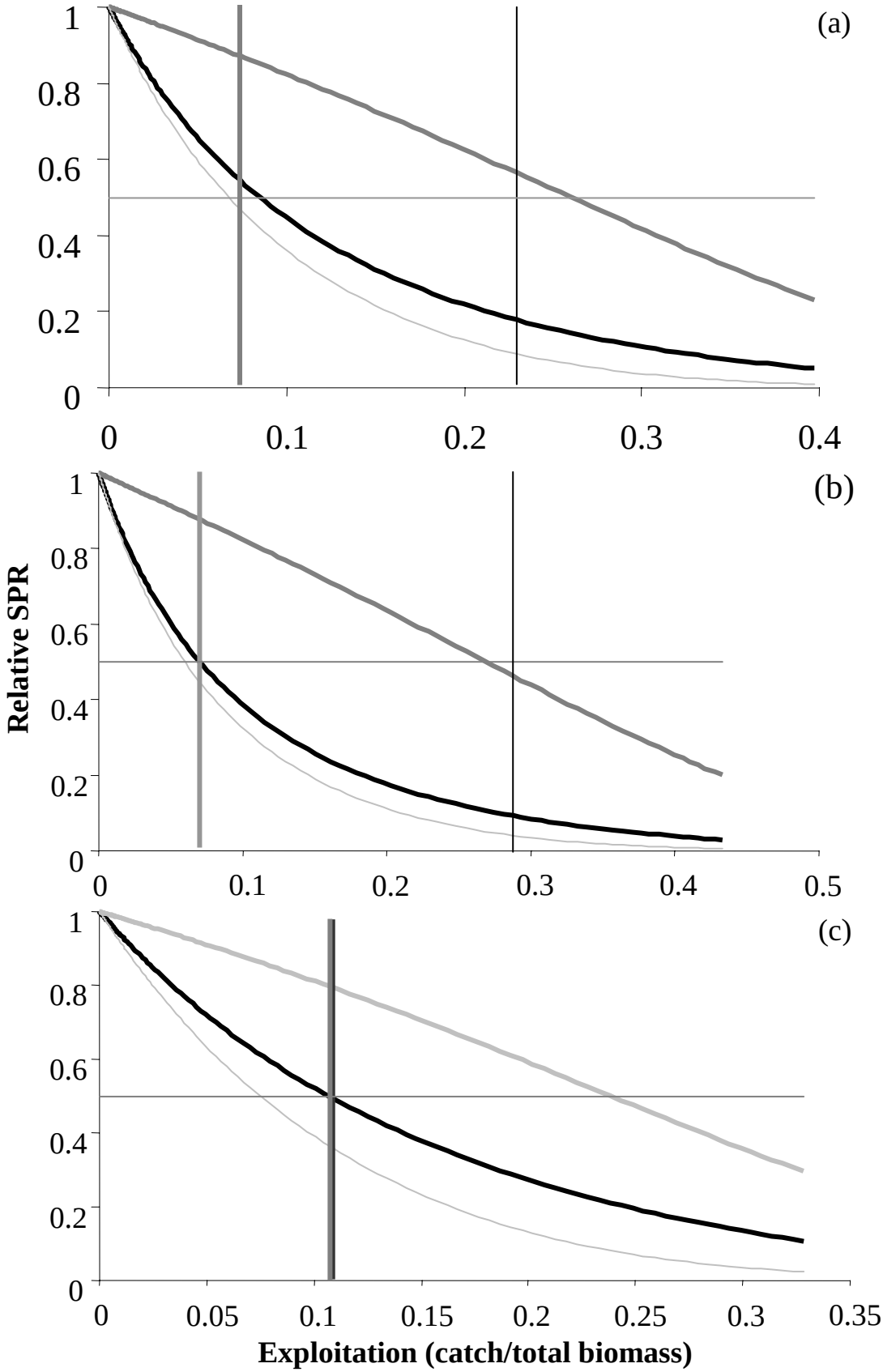


Figure 8.11 Relative spawning potential ratio (SPR) for female (upper curve), mature (middle curve), and male (lower curve) biomass based on the final model when M=0.2 (a), M=0.15 (b), and M=0.30 (c). Current exploitations are shown with the vertical thin black line, target exploitations are shown with the vertical solid grey line, and target levels are shown by the horizontal grey line.

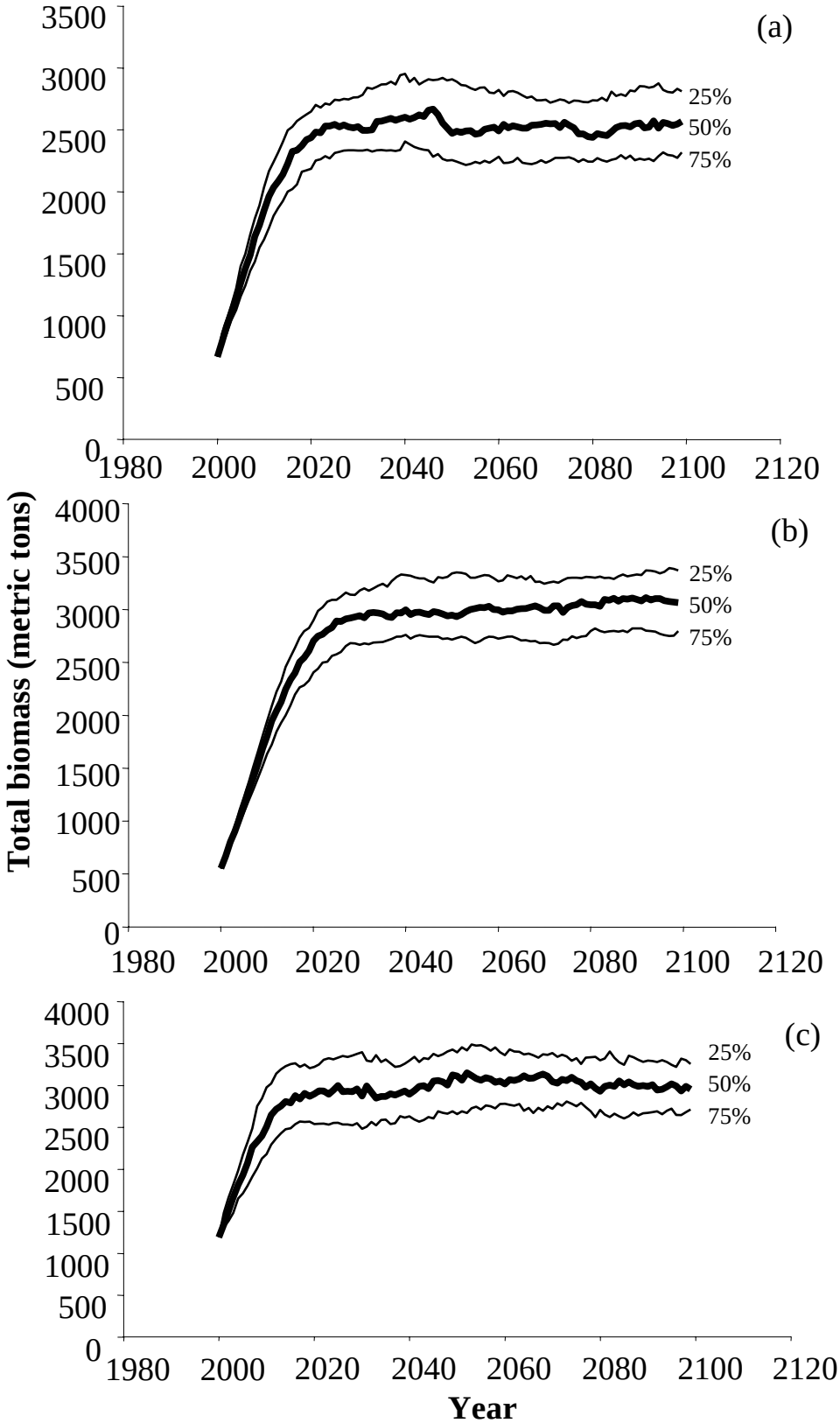


Figure 8.12 Projections of the 25th, 50th and 75th percentiles for projected total biomass when fishing mortality is zero for M=0.20 (a), M=0.15 (b), and M=0.30 (c). The results presented here are based on 100 projections for 100 years in the absence of fishing assuming that recruitment is selected randomly from model estimated recruitment from 1970-1995.

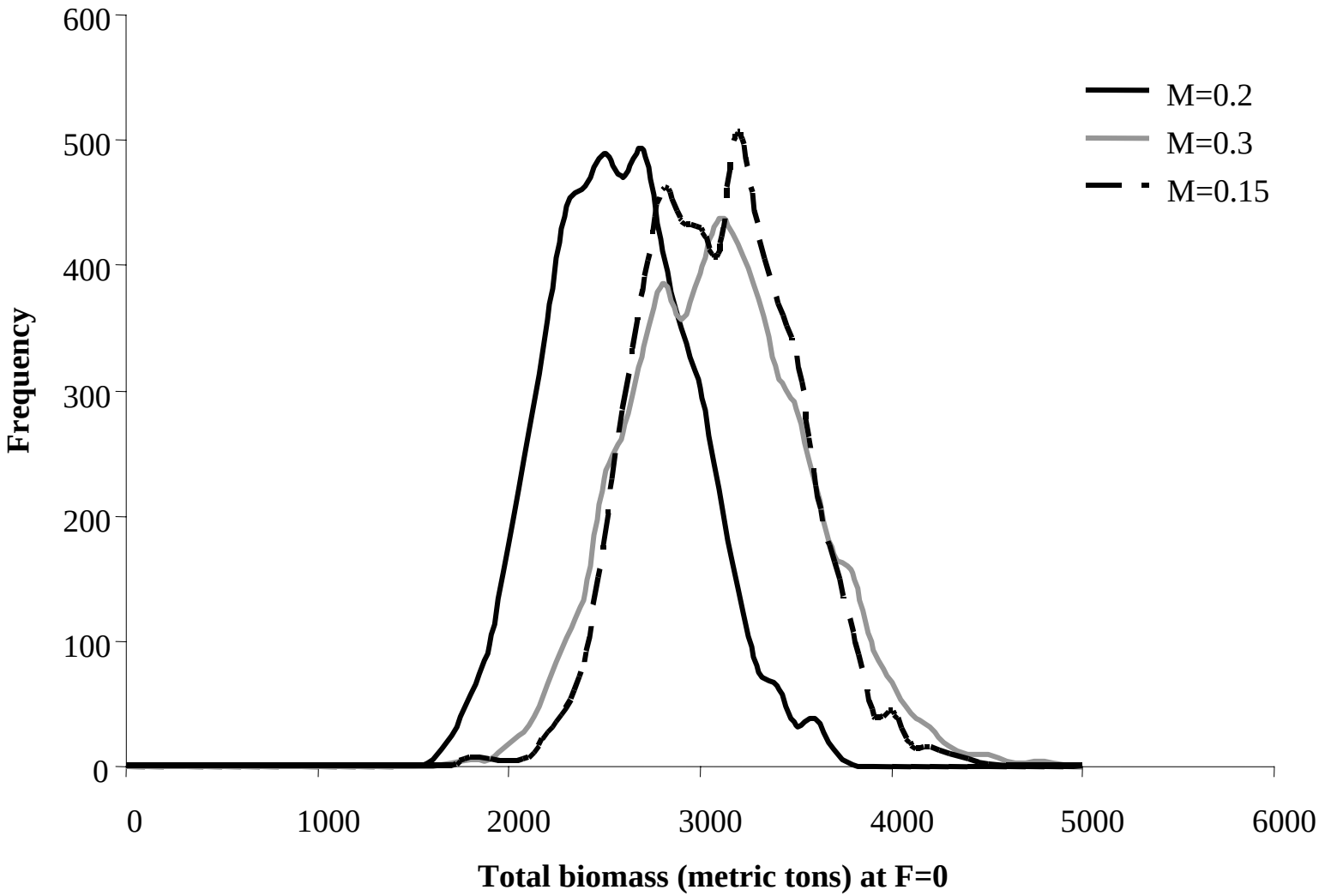


Figure 8.13 Expected frequency distributions of future total biomass (for the final model) in the absence of fishing if M=0.2. The distribution of total biomass is based on projections over 50 years after having allowed the projections to stabilize for 50 years. The results presented here are based on 100 projections for 100 years assuming that recruitment is selected randomly from model estimated recruitment from 1970-1995.

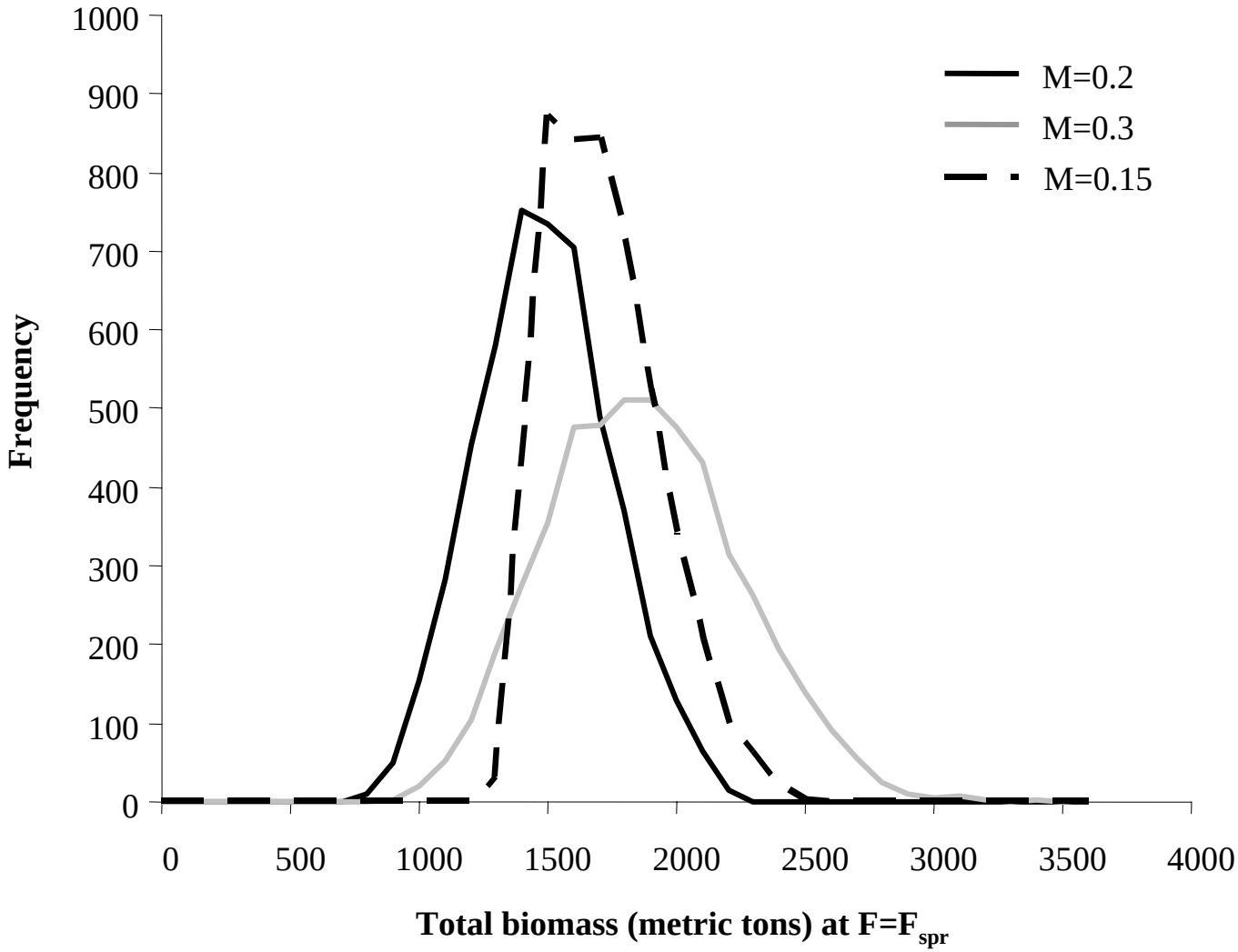


Figure 8.14 Expected frequency distributions of future total biomass (for the final model) when future fishing mortality adopts the 60/20 plan outlined by the NFMP and is set at the target level which allows the spawning potential ratio based on mature biomass to be reduced to 50% of the estimated unfished situation (CDFG 2002). The distribution of total biomass is based on projections over 50 years after having allowed the projections to stabilize for 50 years. The results presented here are based on 100 projections for 100 years assuming that recruitment is selected randomly from model estimated recruitment from 1970-1995.

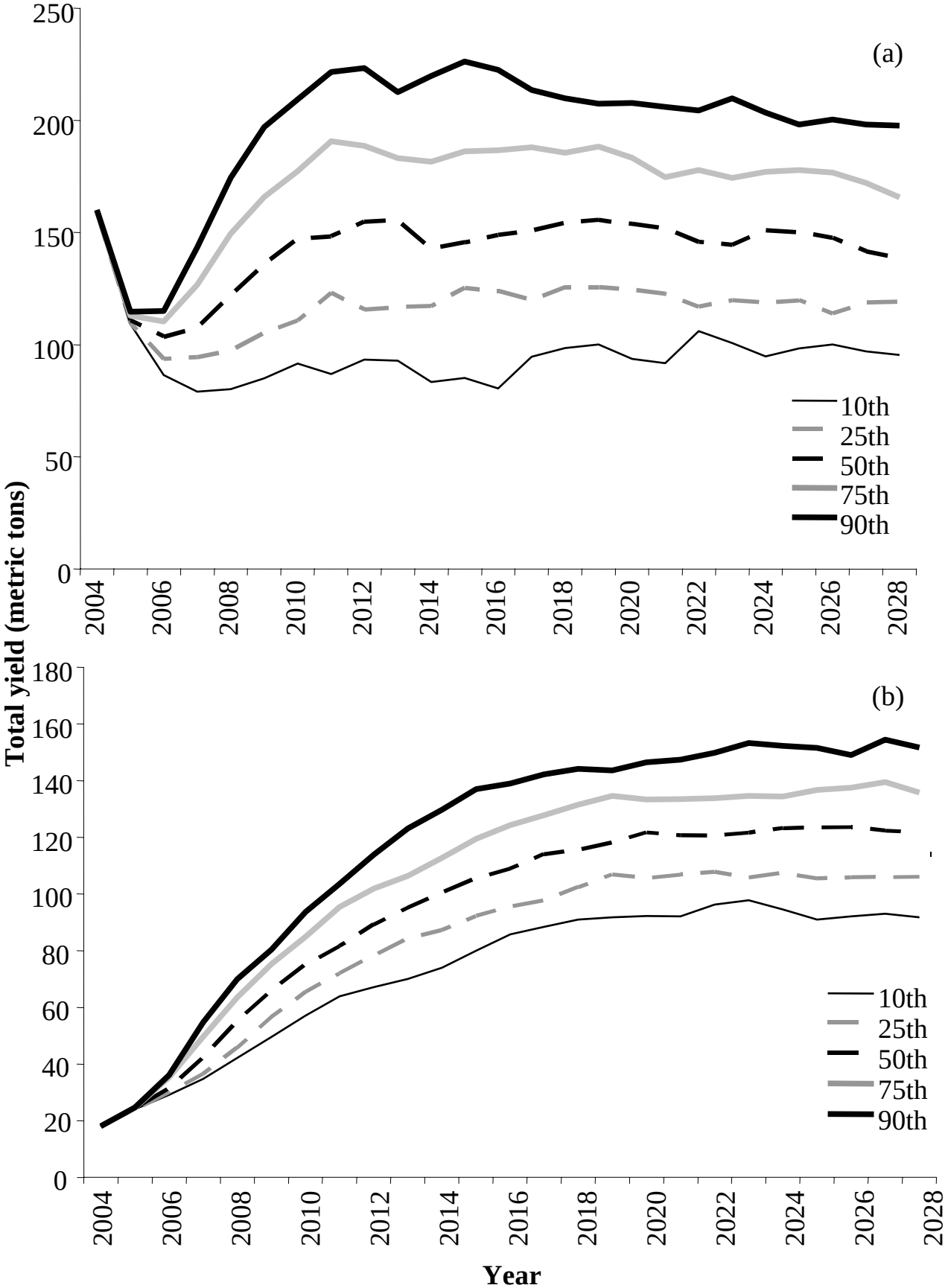


Figure 8.15 Allowable catch under NFMP 60/20 policy (CDFG 2002) for California Sheephead for the final model when M=0.2 for females only (a) and the total mature population (b). Projection assumptions are the same as described in Figure 8.13.

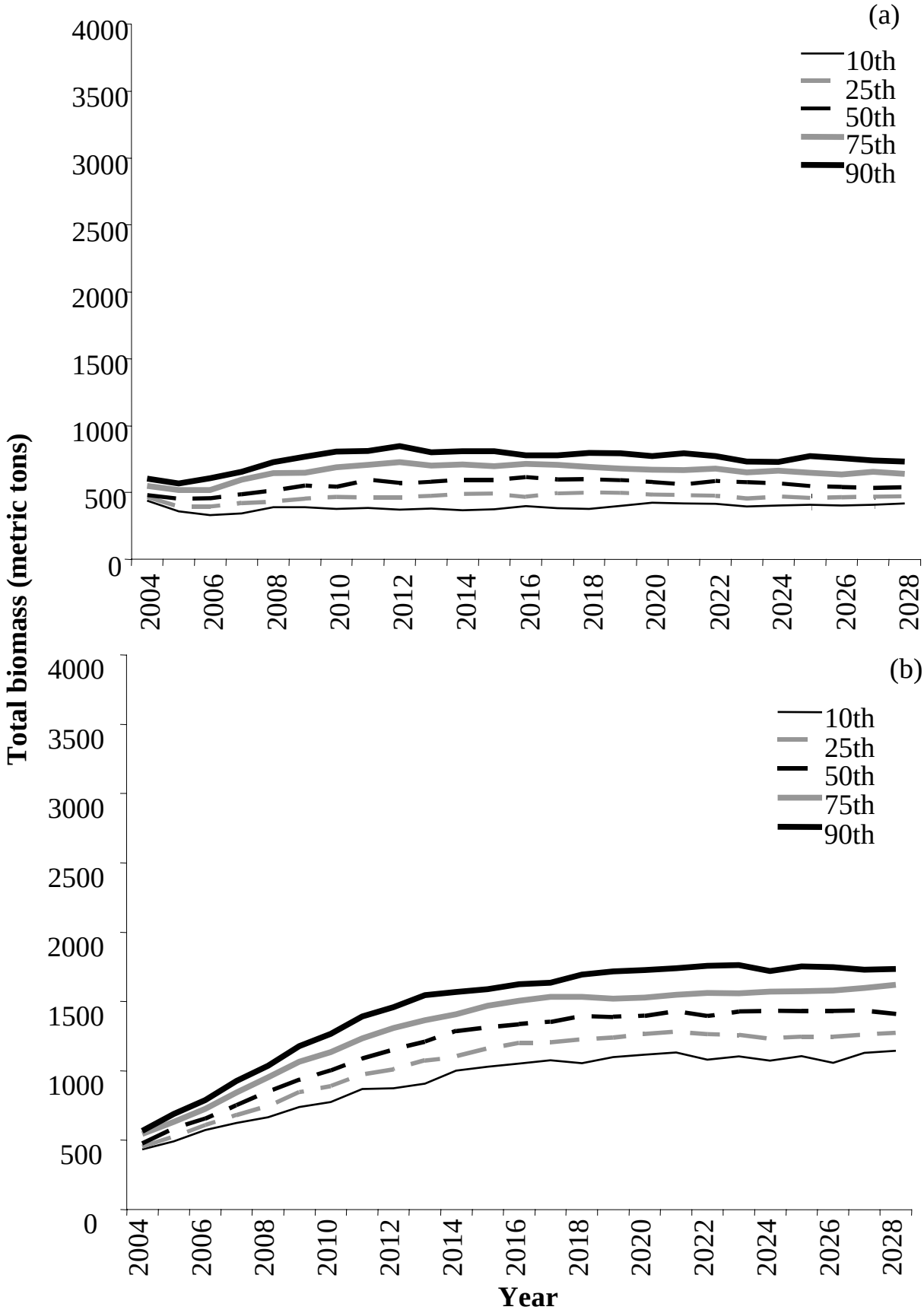
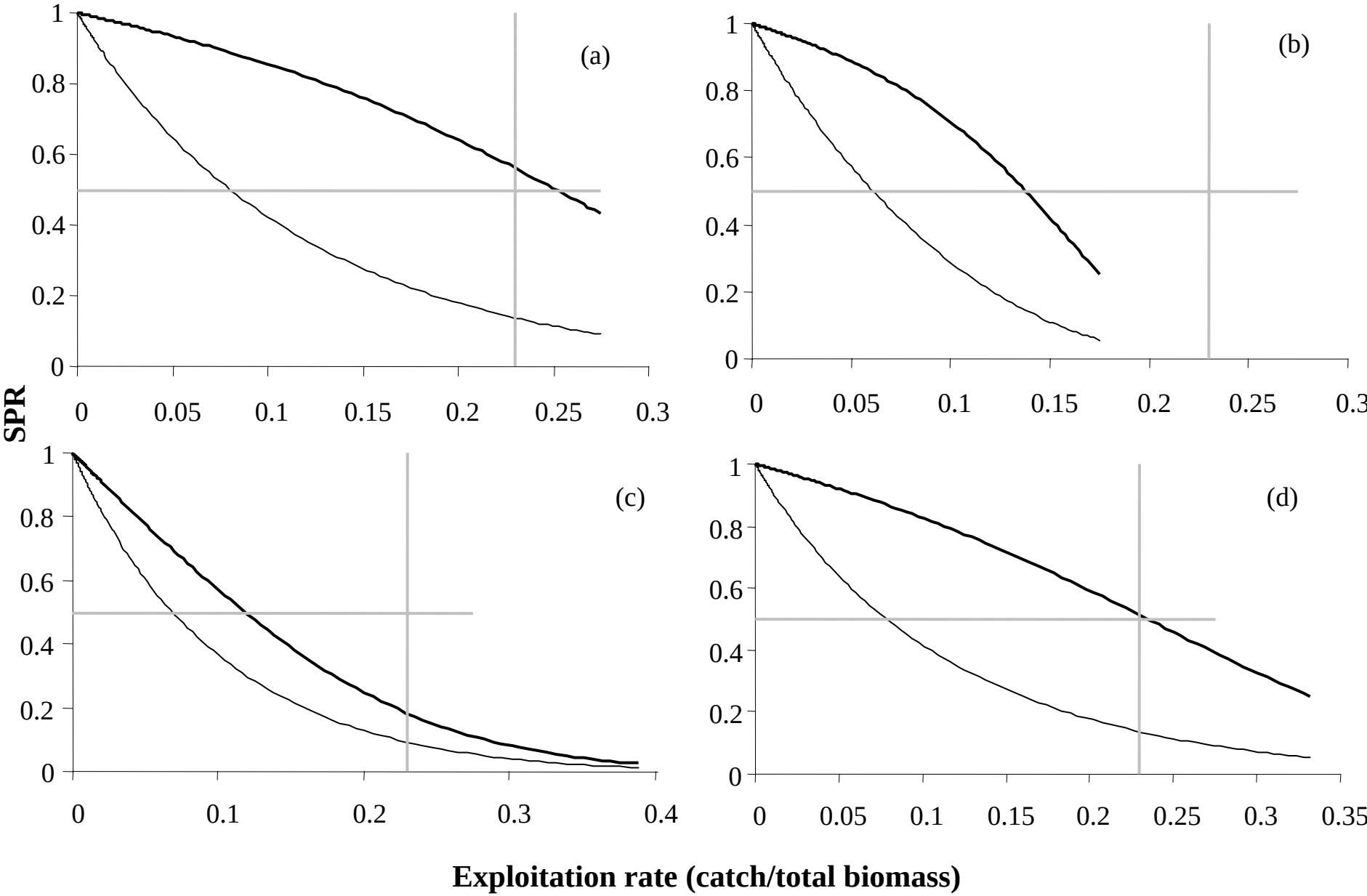


Figure 8.16 Projected population bioamass under NFMP 60/20 policy (CDFG 2002) for California Sheephead for the final model when M=0.2 for females only (a) and the total mature population (b). Projection assumptions are the same as described in Figure 8.13.



8.17 Relative SPR with life history characteristics for Cabo Thurloe (a), San Benitos Island (b), San Nicolas Island (c), and Catalina Island (d). The upper curve is female biomass, the lower curve is mature biomass, the vertical line is an estimate for current exploitation and the horizontal line is 0.50 relative SPR.

12. APPENDICIES

APPENDIX 1: The parameter file for the baseline Sheephead model in Synthesis

```
spbase.d13        LOOP1:  8  LIKE:  -342.57294  DELTA LIKE:      .00025 ENDBIO:     1037.
spbase.r01
spbase.p34
Baseline best-fit Sheephead model for the 2004 assessment
     100.000000        .001000     BEGIN AND END DELTA F PER LOOP1
   3   .95               FIRST LOOP1 FOR LAMBDA & VALUE
   1.500                 MAX VALUE FOR CROSS DERIVATIVE
   1 READ HESSIAN
spbase.hes
   1 WRITE HESSIAN
spbase.hes
    .001                 MIN SAMPLE FRAC. PER AGE
   1  20   1  20         MINAGE, MAXAGE,  SUMMARY AGE RANGE
  1947  2003             BEGIN YEAR, END YEAR
  1       12  0  0  0    NPER, MON/PER
  6.00                   SPAWNMONTH
  4  4 NFISHERY, NSURVEY
  1 N SEXES
    1000.  REF RECR LEVEL
  0 MORTOPT
     .350000     .001000    3.000000 'NATMORT         '   0     1  0     .000000   .0000 !   1 NO PICK    .000          -.01      .0000000
 HKLINE     TYPE:  1
  8 SELECTIVITY PATTERN
   0   0   0   2   0   0   0  AGE TYPES USED
     1.00000       .20 ' HKLINE CATCH       '  ! # =  1 VALUE:        -.05724
     1.00000       .20 ' HKLINE SIZECOMP    '  ! # =  2 VALUE:      -32.06566
  1  0  0  0  0  0  SEL. COMPONENTS
     .005793     .000100    1.000000 'HKLINE INITIAL S'   2     1  0     .000000   .0000 !   2 OK         .000    -127453.15      .0000099
     .999978     .000100    1.000000 'HKLINE INFLECT  '   2     1  0     .000000   .0000 !   3 OK         .000**************      .0000000
     .308123     .000100    5.000000 'HKLINE SLOPE    '   2     1  0     .000000   .0000 !   4 OK        -.001       -678.28      .0019460
 TRAPS      TYPE:  2
  8 SELECTIVITY PATTERN
   0   0   0   4   0   0   0  AGE TYPES USED
     1.00000       .20 ' TRAP CATCH         '  ! # =  3 VALUE:         .00000
     1.00000       .20 ' TRAP SIZECOMP      '  ! # =  4 VALUE:      -42.90195
  1  0  0  0  0  0  SEL. COMPONENTS
     .005481     .000100    1.000000 'TRAPS INITIAL SE'   2     1  0     .000000   .0000 !   5 OK         .000     -56403.75      .0000261
     .350618     .000100    1.000000 'TRAP INFLECT    '   2     1  0     .000000   .0000 !   6 OK         .000      -5741.37      .0003282
     .689538     .000100    5.000000 'TRAP SLOPE      '   2     1  0     .000000   .0000 !   7 OK         .000        -79.50      .0268074
 SETNET     TYPE:  3
  8 SELECTIVITY PATTERN
   0   0   0   6   0   0   0  AGE TYPES USED
     1.00000       .20 ' SETNET CATCH       '  ! # =  5 VALUE:         .00000
     1.00000       .20 ' SETNET SIZECOMP    '  ! # =  6 VALUE:      -12.87307
  1  0  0  0  0  0  SEL. COMPONENTS
     .001891     .000100    1.000000 'SETNET INITIAL S'   2     1  0     .000000   .0000 !   8 OK         .000    -245098.78      .0000049
     .999995     .000100    1.000000 'SETNET INFLECT  '   2     1  0     .000000   .0000 !   9 OK         .000**************      .0000000
     .254941     .000100    5.000000 'SETNET SLOPE    '   2     1  0     .000000   .0000 !  10 OK         .000      -1056.43      .0013201
```

```
RECREA     TYPE:  4
 8 SELECTIVITY PATTERN
  0   0   0   8   0   0   0  AGE TYPES USED
    1.00000       .20 ' RECREA CATCH       '  ! # =  7 VALUE:        -.05724
    1.00000       .20 ' RECREA SIZECOMP    '  ! # =  8 VALUE:     -189.16699
 1  0  0  0  0  0  SEL. COMPONENTS
    .001230     .000100    1.000000 'RECREA INITIAL S'   2     1  0     .000000   .0000 !  11 OK         .000   -3000281.69      .0000004
    .308864     .010000    1.000000 'RECREA INFLECT  '   2     1  0     .000000   .0000 !  12 OK         .000     -63814.08      .0000950
    .536938     .010000    5.000000 'RECREA SLOPE    '   2     1  0     .000000   .0000 !  13 OK         .000      -2673.40      .0010982
CPFV1      TYPE:  5
 2 SELECTIVITY PATTERN
  0   0   0   0   0   0   0  AGE TYPES USED
    .000121  0  1  2 Q, QUANT, LOGERROR=1, BIO=1 or NUM=2
    1.00000       .20 'CPFV1   Q           '  ! # =  9 VALUE:      -12.39961
   4.000000    -.200000    1.000000 'CPFV1 SELTYPE   '   0 -1947  0     .000000   .0000 !  14 NO PICK    .000          -.01      .0000000
  10.000000     .010000   10.000000 'CPFV1 MINSIZE   '   0 -1947  0     .000000   .0000 !  15 NO PICK    .000          -.01      .0000000
 100.000000     .001000  100.000000 'CPFV1 MAXSIZE   '   0 -1947  0     .000000   .0000 !  16 NO PICK    .000          -.01      .0000000
CPFV2      TYPE:  6
 2 SELECTIVITY PATTERN
  0   0   0   0   0   0   0  AGE TYPES USED
    .000035  0  1  2 Q, QUANT, LOGERROR=1, BIO=1 or NUM=2
    1.00000       .20 'CPFV2   Q           '  ! # = 10 VALUE:      -16.93212
   4.000000    -.200000    1.000000 'CPFV2 SELTYPE   '   0 -1960  0     .000000   .0000 !  17 NO PICK    .000          -.01      .0000000
  10.000000     .010000   10.000000 'CPFV2 MINSIZE   '   0 -1960  0     .000000   .0000 !  18 NO PICK    .000          -.01      .0000000
 100.000000     .001000  100.000000 'CPFV2 MAXSIZE   '   0 -1960  0     .000000   .0000 !  19 NO PICK    .000          -.01      .0000000
CPFV3      TYPE:  7
 2 SELECTIVITY PATTERN
  0   0   0   0   0   0   0  AGE TYPES USED
    .001145  0  1  2 Q, QUANT, LOGERROR=1, BIO=1 or NUM=2
    1.00000       .20 'CPFV3   Q           '  ! # = 11 VALUE:       10.09611
   4.000000    -.200000    1.000000 'CPFV3 SELTYPE   '   0 -1980  0     .000000   .0000 !  20 NO PICK    .000          -.01      .0000000
  10.000000     .010000   10.000000 'CPFV3 MINSIZE   '   0 -1980  0     .000000   .0000 !  21 NO PICK    .000          -.01      .0000000
 100.000000     .001000  100.000000 'CPFV3 MAXSIZE   '   0 -1980  0     .000000   .0000 !  22 NO PICK    .000          -.01      .0000000
 CalCOFI   TYPE:  8
 4 SELECTIVITY PATTERN
  0   0   0   0   0   0   0  AGE TYPES USED
    .000001  0  1  2 Q, QUANT, LOGERROR=1, BIO=1 or NUM=2
    1.00000       .20 'CalCOFI SPB         '  ! # = 12 VALUE:      -46.21517
 1 AGEERR: 1: MULTINOMIAL,  0: S(LOG(P))=CONSTANT,  -1: S=P*Q/N
200.000 : MAX N FOR MULTINOMIAL
 3 1=%CORRECT, 2=C.V., 3=%AGREE, 4=READ %AGREE @AGE
    .800000     .300000     .950000 '%AGREE @ MIN    '   0 -1980  0     .000000   .0000 !  23 NO PICK    .000          -.01      .0000000
    .050000     .000000     .900000 '%AGREE @ MAX    '   0 -1980  0     .000000   .0000 !  24 NO PICK    .000          -.01      .0000000
   1.000000     .001000    2.000000 '%AGREE POWER    '   0 -1980  0     .000000   .0000 !  25 NO PICK    .000          -.01      .0000000
    .150000     .010000     .300000 'OLD DISCOUNT    '   0 -1980  0     .000000   .0000 !  26 NO PICK    .000          -.01      .0000000
    .000000     .001000     .100000 '%MIS_SEXED      '   0 -1980  0     .000000   .0000 !  27 NO PICK    .000          -.01      .0000000
 0 END OF EFFORT
 0 FIX n FMORTs
```

```
 2  MATURITY
  25.240000   10.000000  100.000000 'MATURITY INFL   '   0     1  0     .000000   .0000 !  28 NO PICK    .000          -.01      .0000000
   1.060000     .001000    5.000000 'MATURITY SLOPE  '   0     1  0     .000000   .0000 !  29 NO PICK    .000          -.01      .0000000
    .000000     .000000    5.000000 'MATURITY - DD   '   0     1  0     .000000   .0000 !  30 NO PICK    .000          -.01      .0000000
  36.700000   10.000000  100.000000 'MATURITY - INFL2'   0     1  0     .000000   .0000 !  31 NO PICK    .000          -.01      .0000000
    .320000     .001000    5.000000 'MATURITY - SLP2 '   0     1  0     .000000   .0000 !  32 NO PICK    .000          -.01      .0000000
 1  GROWTH: 1=CONSTANT, 2=MORT. INFLUENCE
 1.0000 13.0000  AGE AT WHICH L1 AND L2 OCCUR
 1 1=NORMAL, 2=LOGNORMAL
  12.920000    1.000000  100.000000 'L1             '   0     1  0     .000000   .0000 !  33 NO PICK    .000          -.01      .0000000
  52.600000   10.000000  100.000000 'LINF           '   0     1  0     .000000   .0000 !  34 NO PICK    .000          -.01      .0000000
    .068000     .000100    4.000000 'K              '   0     1  0     .000000   .0000 !  35 NO PICK    .000          -.01      .0000000
    .144787     .001000     .290000 'CV1            '   2     1  0     .000000   .0000 !  36 OK         .000     -16525.43      .0027558
    .260825     .001000     .290000 'CV1            '   2     1  0     .000000   .0000 !  37 OK        -.001      -2272.83      .0140529
          0  DEFINE MARKET CATEGORIES
 0 ENVIRONMENTAL FXN:    [-INDEX]  [FXN TYPE(1-4)]  [ENVVAR USED]
 0 ESTIMATE N ENVIRON VALUES
 0 PENALTIES
 0 ENVIRONMENT EFFECT ON EXP(RECR)
13  STOCK-RECR
 3 1=B-H, 2=RICKER, 3=new B-H, 4=HOCKEY
 0 0=recr is mult x averecr, 1=log(DEV) from S-R
     .00000      -.61 ' SPAWN-RECR-IND     '  ! # = 13 VALUE:    -2450.28137
     .00000      -.30 ' SPAWN-RECR-MEAN    '  ! # = 14 VALUE:  -267579.98097
   1.392113     .200000   15.000000 'VIRGIN RECR MULT'   2     1  0     .000000   .0000 !  38 OK         .000         -1.01      .0000000
    .700000     .100000     .990000 'B/H  S/R PARAM  '   2     1  0     .000000   .0000 !  39 OK         .000         -1.01      .0000000
    .879565     .100000 1000.000000 'BACK. RECRUIT   '   2     1  0     .000000   .0000 !  40 OK         .000       -573.49      .0023595
    .610740     .100000     .990000 'S/R STD.DEV.    '   2     1  0     .000000   .0000 !  41 OK         .000         -1.01      .0000000
    .000000    -.100000     .100000 'RECR TREND      '   0     1  0     .000000   .0000 !  42 NO PICK    .000          -.01      .0000000
   1.000000     .010000   10.000000 'RECR-MULT       '   0     1  0     .000000   .0000 !  43 NO PICK    .000          -.01      .0000000
-2 INIT AGE COMP
 .10000E-04  .10000E-04  .10000E+04 'RECR 1947       '   2  1947  0  .00000E+00   .0000 !  44 BOUND      .000          -.01      .0000000
 .10000E-04  .10000E-04  .10000E+04 'RECR 1948       '   2  1948  0  .00000E+00   .0000 !  45 BOUND      .000          -.01      .0000000
 .10000E-04  .10000E-04  .10000E+04 'RECR 1949       '   2  1949  0  .00000E+00   .0000 !  46 BOUND      .000          -.01      .0000000
    .379973     .000010 1000.000000 'RECR 1950       '   2  1950  0     .000000   .0000 !  47 OK         .013          -.32     7.0221005
    .908167     .000010 1000.000000 'RECR 1951       '   2  1951  0     .000000   .0000 !  48 OK         .014          -.33    11.6044858
    .258704     .000010 1000.000000 'RECR 1952       '   2  1952  0     .000000   .0000 !  49 OK         .001          -.37     9.7869974
 .10000E-04  .10000E-04  .10000E+04 'RECR 1953       '   2  1953  0  .00000E+00   .0000 !  50 BOUND      .000          -.01      .0000000
    .209285     .000010 1000.000000 'RECR 1954       '   2  1954  0     .000000   .0000 !  51 OK         .001          -.40     8.9602294
    .868467     .000010 1000.000000 'RECR 1955       '   2  1955  0     .000000   .0000 !  52 OK        -.005          -.38    10.5169026
    .256415     .000010 1000.000000 'RECR 1956       '   2  1956  0     .000000   .0000 !  53 OK        -.003          -.36    13.5930758
    .114372     .000010 1000.000000 'RECR 1957       '   2  1957  0     .000000   .0000 !  54 OK        -.007          -.26    15.0761416
 .10000E-04  .10000E-04  .10000E+04 'RECR 1958       '   2  1958  0  .00000E+00   .0000 !  55 BOUND      .000          -.01   127.7874979
   3.843077     .000010 1000.000000 'RECR 1959       '   2  1959  0     .000000   .0000 !  56 BIG DX    -.052          -.03    81.8756818
   3.961665     .000010 1000.000000 'RECR 1960       '   2  1960  0     .000000   .0000 !  57 OK        -.049          -.02   187.5174318
   1.639433     .000010 1000.000000 'RECR 1961       '   2  1961  0     .000000   .0000 !  58 BIG DX    -.084          -.03   198.3726438
   3.557151     .000010 1000.000000 'RECR 1962       '   2  1962  0     .000000   .0000 !  59 OK        -.045          -.05   116.1409925
   3.167107     .000010 1000.000000 'RECR 1963       '   2  1963  0     .000000   .0000 !  60 OK        -.016          -.08    65.2935513
 .10000E-04  .10000E-04  .10000E+04 'RECR 1964       '   2  1964  0  .00000E+00   .0000 !  61 BOUND      .000          -.01      .0000000
 .10000E-04  .10000E-04  .10000E+04 'RECR 1965       '   2  1965  0  .00000E+00   .0000 !  62 BOUND      .000          -.01      .0000000
 .10000E-04  .10000E-04  .10000E+04 'RECR 1966       '   2  1966  0  .00000E+00   .0000 !  63 BOUND      .000          -.01      .0000000
```

.10000E-04	.10000E-04	.10000E+04	'RECR 1967	'	2	1967	0	.00000E+00	.0000	!	64	BOUND	.000	-.01	.0000000
4.058199	.000010	1000.000000	'RECR 1968	'	2	1968	0	.000000	.0000	!	65	OK	-.004	-.38	15.1548928
6.746247	.000010	1000.000000	'RECR 1969	'	2	1969	0	.000000	.0000	!	66	OK	.009	-.43	17.9949524
2.263120	.000010	1000.000000	'RECR 1970	'	2	1970	0	.000000	.0000	!	67	OK	-.039	-.50	12.3161679
2.819827	.000010	1000.000000	'RECR 1971	'	2	1971	0	.000000	.0000	!	68	OK	.004	-.84	6.2505783
2.811472	.000010	1000.000000	'RECR 1972	'	2	1972	0	.000000	.0000	!	69	OK	-.007	-1.81	2.2175872
.10000E-04	.10000E-04	.10000E+04	'RECR 1973	'	2	1973	0	.00000E+00	.0000	!	70	BOUND	.000	-.01	.0000000
1.281670	.000010	1000.000000	'RECR 1974	'	2	1974	0	.000000	.0000	!	71	OK	.004	-3.60	1.5302221
4.359793	.000010	1000.000000	'RECR 1975	'	2	1975	0	.000000	.0000	!	72	OK	.000	-3.14	.8295523
.10000E-04	.10000E-04	.10000E+04	'RECR 1976	'	2	1976	0	.00000E+00	.0000	!	73	BOUND	.000	-.01	.0000000
2.345187	.000010	1000.000000	'RECR 1977	'	2	1977	0	.000000	.0000	!	74	OK	-.003	-2.84	8.8355504
2.139460	.000010	1000.000000	'RECR 1978	'	2	1978	0	.000000	.0000	!	75	OK	-.010	-2.48	9.2595675
3.442073	.000010	1000.000000	'RECR 1979	'	2	1979	0	.000000	.0000	!	76	OK	-.004	-1.98	2.6593930
6.434604	.000010	1000.000000	'RECR 1980	'	2	1980	0	.000000	.0000	!	77	OK	.005	-1.75	3.6192893
4.488103	.000010	1000.000000	'RECR 1981	'	2	1981	0	.000000	.0000	!	78	OK	.003	-1.70	3.8544547
3.369834	.000010	1000.000000	'RECR 1982	'	2	1982	0	.000000	.0000	!	79	OK	.011	-1.96	2.9144829
4.526783	.000010	1000.000000	'RECR 1983	'	2	1983	0	.000000	.0000	!	80	OK	.006	-2.31	2.1294228
.878214	.000010	1000.000000	'RECR 1984	'	2	1984	0	.000000	.0000	!	81	OK	.010	-2.73	2.5683371
4.654983	.000010	1000.000000	'RECR 1985	'	2	1985	0	.000000	.0000	!	82	OK	.018	-3.02	3.0108088
.538834	.000010	1000.000000	'RECR 1986	'	2	1986	0	.000000	.0000	!	83	OK	.004	-3.17	2.6616016
4.618527	.000010	1000.000000	'RECR 1987	'	2	1987	0	.000000	.0000	!	84	OK	.009	-3.19	2.5481074
.705957	.000010	1000.000000	'RECR 1988	'	2	1988	0	.000000	.0000	!	85	OK	-.006	-3.45	2.5707334
2.543166	.000010	1000.000000	'RECR 1989	'	2	1989	0	.000000	.0000	!	86	OK	-.001	-4.36	1.2442657
.10000E-04	.10000E-04	.10000E+04	'RECR 1990	'	2	1990	0	.00000E+00	.0000	!	87	BOUND	.000	-.01	.0000000
2.689334	.000010	1000.000000	'RECR 1991	'	2	1991	0	.000000	.0000	!	88	OK	-.003	-7.08	.7294157
.10000E-04	.10000E-04	.10000E+04	'RECR 1992	'	2	1992	0	.00000E+00	.0000	!	89	BOUND	.000	-.01	.0000000
3.813868	.000010	1000.000000	'RECR 1993	'	2	1993	0	.000000	.0000	!	90	OK	-.007	-9.09	.4811933
.875257	.000010	1000.000000	'RECR 1994	'	2	1994	0	.000000	.0000	!	91	OK	.009	-10.01	.5349557
.429165	.000010	1000.000000	'RECR 1995	'	2	1995	0	.000000	.0000	!	92	OK	.005	-10.17	.7489634
2.545830	.000010	1000.000000	'RECR 1996	'	2	1996	0	.000000	.0000	!	93	OK	.009	-9.40	2.0086865
1.288574	.000010	1000.000000	'RECR 1997	'	2	1997	0	.000000	.0000	!	94	OK	.003	-7.95	1.2004215
2.577891	.000010	1000.000000	'RECR 1998	'	2	1998	0	.000000	.0000	!	95	OK	.006	-5.82	.8848554
1.696037	.000010	1000.000000	'RECR 1999	'	2	1999	0	.000000	.0000	!	96	OK	-.005	-6.42	.7654103
.107711	.000010	1000.000000	'RECR 2000	'	2	2000	0	.000000	.0000	!	97	OK	-.008	-8.36	.3551433
-999.000000	.000010	1000.000000	'RECR 2001	'	0	2001	0	.000000	.0000	!	98	NO PICK	.000	-.01	.0000000
-999.000000	.000010	1000.000000	'RECR 2002	'	0	2002	0	.000000	.0000	!	99	NO PICK	.000	-.01	.0000000
-999.000000	.000010	1000.000000	'RECR 2003	'	0	2003	0	.000000	.0000	!	100	NO PICK	.000	-.01	.0000000

sheephead data file for 2004 assessment assembled by Meisha Key & Suzanne Alonzo

55.47	1	hkline	trap	setnet	recrea
1947	1	87.77	0	0	21.03
1948	1	45.46	0	0	27.91
1949	1	28.81	0	0	24.97
1950	1	30.03	0	0	23.09
1951	1	27.86	0	0	33.01
1952	1	16.43	0	0	26.65
1953	1	16.07	0	0	28.05
1954	1	13.24	0	0	34.77
1955	1	5.97	0	0	26.64
1956	1	2.98	0	0	27.75
1957	1	5	0	0	28.26
1958	1	5.16	0	0	33.14
1959	1	4.64	0	0	31.56
1960	1	2.15	0	0	22.5
1961	1	5.72	0	0	28.43
1962	1	9.22	0	0	25.65
1963	1	12.71	0	0	33.66
1964	1	8.13	0	0	47.21
1965	1	5.51	0	0	71.19
1966	1	7.25	0	0	89.49
1967	1	8.9	0	0	72.85
1968	1	5.78	0	0	57.32
1969	1	6.03	0	0	84.09
1970	1	1.73	0	0	67.65
1971	1	4.02	0	0	65.77
1972	1	3.21	0	0	58.08
1973	1	1.39	0	0	78.6
1974	1	1.69	0	0	52.96
1975	1	2.74	0	0	53.15
1976	1	3.78	0	0	57.08
1977	1	2.91	0	0	49.94
1978	1	0.94	0.49	3.63	59.48
1979	1	0.23	0.45	3.32	55.58
1980	1	0.85	1.08	2.2	143.57
1981	1	0.36	0.36	5.13	106.97
1982	1	0.44	0.82	4.08	92.03
1983	1	0.88	0.34	4.5	155.35
1984	1	1.96	0.28	9.15	131.2
1985	1	0.17	0.08	12.67	200.2
1986	1	0.39	0	12.88	223.3
1987	1	2.76	0	12.16	108.09

1988	1	2.84	0	10.47	178.84		
1989	1	7.84	0	7.25	64.64		
1990	1	49.6	0	6.54	60		
1991	1	80.43	0	6.66	73.63		
1992	1	111.2	0	6.14	45.5		
1993	1	127.11	11.88	4.33	78.24		
1994	1	27.06	89.92	0.72	121.12		
1995	1	26.4	88.2	0.47	54.52		
1996	1	20.89	92.83	0.68	81.22		
1997	1	22.02	115.69	1.28	59.81		
1998	1	24.79	93.32	0.94	76.51		
1999	1	11.24	46.68	0.9	84.94		
2000	1	15.16	62.31	1.21	100.09		
2001	1	10.96	55.78	1.39	58.85		
2002	1	10.34	43.71	0.66	60.26		
2003	1	10.87	36.98	0.15	68.51		
-1	1	1	1	1	1	1	END OF CATCH DATA
-1	1	1	1				END OF EFFORT AND CPUE DATA
1947	1	8	5	0.0362	0.4		CPFV Logbook CPUE ang
1948	1	8	5	0.0423	0.4		CPFV Logbook CPUE ang
1949	1	8	5	0.0329	0.4		CPFV Logbook CPUE angler days
1950	1	8	5	0.0262	0.4		CPFV Logbook CPUE angler days
1951	1	8	5	0.0367	0.4		CPFV Logbook CPUE ang
1952	1	8	5	0.028	0.4		CPFV Logbook CPUE ang
1953	1	8	5	0.0345	0.4		CPFV Logbook CPUE ang
1954	1	8	5	0.0404	0.4		CPFV Logbook CPUE angler days
1955	1	8	5	0.0284	0.4		CPFV Logbook CPUE angler days
1956	1	8	5	0.0283	0.4		CPFV Logbook CPUE angler days
1957	1	8	5	0.0282	0.4		CPFV Logbook CPUE angler days
1958	1	8	5	0.0352	0.4		CPFV Logbook CPUE angler days
1959	1	8	5	0.0308	0.4		CPFV Logbook CPUE angler days
1960	1	8	5	0.0224	0.4		CPFV Logbook CPUE angler days
1961	1	8	5	0.0307	0.4		CPFV Logbook CPUE ang
1960	1	8	6	0.0181	0.4		CPFV Logbook CPUE per angler
1961	1	8	6	0.0256	0.4		CPFV Logbook CPUE per angler
1962	1	8	6	0.0226	0.4		CPFV Logbook CPUE per angler
1963	1	8	6	0.0287	0.4		CPFV Logbook CPUE per angler
1964	1	8	6	0.0386	0.4		CPFV Logbook CPUE per angler
1965	1	8	6	0.0605	0.4		CPFV Logbook CPUE per angler
1966	1	8	6	0.0618	0.4		CPFV Logbook CPUE per angler
1967	1	8	6	0.0547	0.4		CPFV Logbook CPUE per angler
1968	1	8	6	0.0389	0.4		CPFV Logbook CPUE per
1969	1	8	6	0.0618	0.4		CPFV Logbook CPUE per

1970	1	8	6	0.0452	0.4	CPFV Logbook CPUE per angler
1971	1	8	6	0.0526	0.4	CPFV Logbook CPUE per
1972	1	8	6	0.0423	0.4	CPFV Logbook CPUE per
1973	1	8	6	0.0525	0.4	CPFV Logbook CPUE per angler
1974	1	8	6	0.0375	0.4	CPFV Logbook CPUE per angler
1975	1	8	6	0.0408	0.4	CPFV Logbook CPUE per
1976	1	8	6	0.0448	0.4	CPFV Logbook CPUE per angler
1977	1	8	6	0.0398	0.4	CPFV Logbook CPUE per angler
1978	1	8	6	0.047	0.4	CPFV Logbook CPUE per angler
1979	1	8	6	0.0407	0.4	CPFV Logbook CPUE per angler
1980	1	8	6	0.0451	0.4	CPFV Logbook CPUE per angler
1981	1	8	6	0.056	0.4	CPFV Logbook CPUE per angler
1980	1	8	7	1.7322	0.2	CPFV logbook by DFG block
1981	1	8	7	1.9716	0.2	CPFV logbook by DFG block
1982	1	8	7	1.7744	0.2	CPFV logbook by DFG block
1983	1	8	7	3.2815	0.2	CPFV logbook by DFG block
1984	1	8	7	2.5572	0.2	CPFV logbook by DFG block
1985	1	8	7	1.9315	0.2	CPFV logbook by DFG bl
1986	1	8	7	3.1116	0.2	CPFV logbook by DFG bl
1987	1	8	7	1.7721	0.2	CPFV logbook by DFG block
1988	1	8	7	2.8178	0.2	CPFV logbook by DFG block
1989	1	8	7	2.1687	0.2	CPFV logbook by DFG block
1990	1	8	7	2.2795	0.2	CPFV logbook by DFG block
1991	1	8	7	2.4404	0.2	CPFV logbook by DFG block
1992	1	8	7	1.5472	0.2	CPFV logbook by DFG block
1993	1	8	7	1.89	0.2	CPFV logbook by DFG block
1994	1	8	7	1.2557	0.2	CPFV logbook by DFG block
1995	1	8	7	1.2804	0.2	CPFV logbook by DFG block
1996	1	8	7	1.2231	0.2	CPFV logbook by DFG block
1997	1	8	7	1.0815	0.2	CPFV logbook by DFG block
1998	1	8	7	0.7118	0.2	CPFV logbook by DFG block
1999	1	8	7	0.8609	0.2	CPFV logbook by DFG block
2000	1	8	7	1.1381	0.2	CPFV logbook by DFG block
2001	1	8	7	1.4589	0.2	CPFV logbook by DFG block
2002	1	8	7	0.9112	0.2	CPFV logbook by DFG block
2003	1	8	7	0.6342	0.2	CPFV logbook by DFG block
1951	1	8	8	0.005	1.1	CalCOFI
1952	1	8	8	0.005	1.1	CalCOFI
1953	1	8	8	0.005	1.1	CalCOFI
1954	1	8	8	0.005	1.1	CalCOFI
1955	1	8	8	0.005	1.1	CalCOFI
1956	1	8	8	0.005	1.1	CalCOFI
1957	1	8	8	0.005	1.1	CalCOFI

1958	1	8	8	0.005	1.1	CalCOFI
1959	1	8	8	0.005	1.1	CalCOFI
1960	1	8	8	0.005	1.1	CalCOFI
1961	1	8	8	0.03	1.1	CalCOFI
1962	1	8	8	0.0536	1.1	CalCOFI
1963	1	8	8	0.1286	1.1	CalCOFI
1964	1	8	8	0.0135	1.1	CalCOFI
1965	1	8	8	0.1277	1.1	CalCOFI
1966	1	8	8	0.073	1.1	CalCOFI
1967	1	8	8	0.07	1.1	CalCOFI
1968	1	8	8	0.005	1.1	CalCOFI
1969	1	8	8	0.0173	1.1	CalCOFI
1970	1	8	8	-1	1.1	placeholder
1971	1	8	8	-1	1.1	placeholder
1972	1	8	8	0.005	1.1	CalCOFI
1973	1	8	8	-1	1.1	placeholder
1974	1	8	8	-1	1.1	CalCOFI
1975	1	8	8	0.0279	1.1	CalCOFI
1976	1	8	8	-1	1.1	placeholder
1977	1	8	8	-1	1.1	CalCOFI
1978	1	8	8	0.0848	1.1	CalCOFI
1979	1	8	8	-1	1.1	CalCOFI
1980	1	8	8	-1	1.1	CalCOFI
1981	1	8	8	0.2721	1.1	CalCOFI
1982	1	8	8	-1	1.1	CalCOFI
1983	1	8	8	-1	1.1	CalCOFI
1984	1	8	8	0.3701	1.1	CalCOFI
1985	1	8	8	0.171	1.1	CalCOFI
1986	1	8	8	0.005	1.1	CalCOFI
1987	1	8	8	0.005	1.1	CalCOFI
1988	1	8	8	0.048	1.1	CalCOFI
1989	1	8	8	0.0939	1.1	CalCOFI
1990	1	8	8	0.1078	1.1	CalCOFI
1991	1	8	8	0.0983	1.1	CalCOFI
1992	1	8	8	0.0229	1.1	CalCOFI
1993	1	8	8	0.0342	1.1	CalCOFI
1994	1	8	8	0.005	1.1	CalCOFI
1995	1	8	8	0.1605	1.1	CalCOFI
1996	1	8	8	0.0094	1.1	CalCOFI
1997	1	8	8	0.0188	1.1	CalCOFI
1998	1	8	8	0.1215	1.1	CalCOFI
1999	1	8	8	0.005	1.1	CalCOFI
2000	1	8	8	0.0699	1.1	CalCOFI

2001	1	8	8	0.005	1.1	CalCOFI											
2002	1	8	8	0.005	1.1	CalCOFI											
2003	1	8	8	-1	1.1	CalCOFI											
-1	1	1	1	1	1	END	OF	SURVEY	ABUND, DATA								
-1	-1	(no bins defined for perfect ages)															
-1	-1	(no bins for imprecise ages)															
-1	-1	(no bins defined for biased ages)															
17	17	(17 2-cm length bins [18-50 cm])															
18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	83.86
25.2	1.06	length@50%mature, slope (Warner 1975) (could use Cowen 1990 for other estimates)															
3E-05	2.857	both sexes length-weight (alpha & beta) from deMartini et al. 1994															
129	0	eggs/kg on weight (intercept & slope) from deMartini et al. 1994 (could use Warner 1975 instead)															
3E-05	2.857	both sexes length-weight (alpha & beta) from deMartini et al. 1994															
Length compositi																	
1975	1	4	4	1	79	1	1	17	17	0							
0	0	0.0268	0	0.0446	0.0446	0.1339	0.1339	0.1071	0.0625	0.0714	0.0982	0.0804	0.0714	0.0357	0.0357	0.0536	
1976	1	4	4	1	186	1	1	17	17	0							
0	0.0038	0.0038	0.0038	0.0113	0.0113	0.0679	0.0792	0.117	0.1434	0.1245	0.0792	0.0981	0.0679	0.0415	0.0415	0.1057	
1977	1	4	4	1	431	1	1	17	17	0							
0.0049	0.0016	0.0081	0.0326	0.0765	0.1059	0.1238	0.1238	0.1173	0.0961	0.0586	0.0489	0.0537	0.0244	0.0293	0.0228	0.0717	
1978	1	4	4	1	486	1	1	17	17	0							
0.0043	0.0043	0.013	0.0332	0.0506	0.0838	0.1084	0.1084	0.1185	0.0882	0.0607	0.0795	0.0535	0.0419	0.0419	0.0231	0.0867	
1980	1	4	4	1	44	1	1	17	17	0							
0	0	0	0.0159	0.0476	0.0635	0.0476	0.0476	0.0794	0.0952	0.0476	0.0317	0.0635	0.0635	0.0476	0.0317	0.3175	
1981	1	4	4	1	58	1	1	17	17	0							
0	0.0122	0.0366	0.0244	0.061	0.0488	0.0732	0.122	0.122	0.0732	0.0488	0.0366	0.0488	0.0244	0.0732	0	0.1951	
1982	1	4	4	1	27	1	1	17	17	0							
0	0	0	0	0.1026	0.1795	0.1026	0.1795	0.1026	0.1282	0.1538	0.0256	0	0	0	0	0.0256	
1983	1	4	4	1	273	1	1	17	17	0							
0	0.0077	0.0077	0.0617	0.0848	0.144	0.1105	0.1465	0.0925	0.0951	0.0771	0.0463	0.0411	0.0257	0.0231	0.0154	0.0206	
1984	1	4	4	1	283	1	1	17	17	0							
0.0025	0.0025	0.0223	0.0496	0.1042	0.1117	0.1266	0.1216	0.1216	0.0819	0.1017	0.0397	0.0248	0.0248	0.0223	0.0124	0.0298	
1985	1	4	4	1	381	1	1	17	17	0							
0	0	0.0129	0.0221	0.0812	0.1255	0.1255	0.1144	0.1162	0.107	0.0812	0.0664	0.0498	0.0443	0.0148	0.0092	0.0295	
1986	1	4	4	1	534	1	1	17	17	0							
0	0.0053	0.0171	0.0315	0.0618	0.0933	0.117	0.1261	0.1209	0.1038	0.0775	0.0631	0.0512	0.0329	0.0184	0.025	0.0552	
1987	1	4	4	1	478	1	1	17	17	0							
0	0.0059	0.0132	0.0309	0.0691	0.1	0.1118	0.0765	0.1029	0.0926	0.0897	0.0647	0.0618	0.0397	0.0353	0.0309	0.075	
1988	1	4	4	1	491	1	1	17	17	0							
0	0	0.0029	0.0129	0.0415	0.073	0.073	0.1016	0.0801	0.0801	0.0873	0.0658	0.0644	0.0629	0.0472	0.0372	0.1702	
1989	1	4	4	1	272	1	1	17	17	0							
0	0	0.0026	0.0258	0.0672	0.1085	0.1034	0.1085	0.0982	0.1034	0.0982	0.0749	0.0491	0.0388	0.0336	0.0181	0.0698	
1993	1	1	4	1	5	1	1	17	17	0							

0	0	0	0	0	0	0	0	0	0	0.1667	0.0833	0	0	0	0	0.75
1993	1	4	4	1	25	1	1	17	17	0						
0	0	0.0286	0.0857	0.0571	0.1429	0.0571	0.0857	0.0857	0.0571	0.0571	0.1143	0.0571	0.0286	0.0286	0	0.1143
1994	1	4	4	1	32	1	1	17	17	0						
0	0	0	0.0889	0.0667	0.0667	0.1111	0.1333	0.0667	0.0667	0.0889	0.1111	0.0222	0.0222	0.0222	0.0444	0.0889
1995	1	1	4	1	5	1	1	17	17	0						
0	0	0.0833	0.0833	0.5	0.0833	0	0	0	0	0	0	0.0833	0	0.0833	0	0.0833
1995	1	4	4	1	29	1	1	17	17	0						
0	0	0.0732	0.0732	0.122	0.0732	0.0976	0.1463	0.0976	0.0488	0.0488	0.122	0.0732	0.0244	0	0	0
1996	1	1	4	1	5	1	1	17	17	0						
0	0	0	0	0	0	0	0	0	0	0	0.037	0.1111	0.037	0.1481	0.037	0.6296
1996	1	2	4	1	31	1	1	17	17	0						
0	0	0	0.1	0	0.1333	0.2333	0.1	0.0667	0.1333	0.0333	0.0667	0.1333	0	0	0	0
1996	1	4	4	1	47	1	1	17	17	0						
0	0	0.0149	0.0299	0.1045	0.0746	0.2388	0.1045	0.0597	0.0597	0.0896	0.0149	0.0746	0.0149	0.0299	0.0299	0.0597
1997	1	1	4	1	5	1	1	17	17	0						
0	0	0	0	0	0	0.2	0.1	0	0.1	0.3	0	0.2	0	0.1	0	0
1997	1	2	4	1	31	1	1	17	17	0						
0	0	0.0081	0.0323	0.0806	0.1935	0.1452	0.1411	0.1048	0.0726	0.0605	0.0403	0.0363	0.0161	0.0202	0.0121	0.0363
1997	1	3	4	1	8	1	1	17	17	0						
0	0	0	0.0833	0	0	0	0	0	0	0	0	0	0	0	0.0833	0.8333
1997	1	4	4	1	14	1	1	17	17	0						
0	0	0	0.15	0.05	0.15	0.25	0.05	0.1	0.05	0.1	0	0	0.05	0	0	0.05
1998	1	1	4	1	5	1	1	17	17	0						
0	0	0	0	0	0	0	0	0	0	0	0	0	0.0667	0	0.3333	0.6
1998	1	4	4	1	74	1	1	17	17	0						
0	0	0.0094	0.0472	0.0755	0.1604	0.1226	0.0283	0.1038	0.066	0.066	0.0943	0.066	0.0189	0.0283	0.0377	0.0755
1999	1	1	4	1	5	1	1	17	17	0						
0	0	0	0	0	0	0	0	0	0	0	0	0.0769	0.0769	0.1538	0.1538	0.5385
1999	1	2	4	1	31	1	1	17	17	0						
0	0	0	0	0	0.0588	0.2353	0.25	0.1618	0.0588	0.0882	0.0294	0.0441	0.0294	0.0294	0	0.0147
1999	1	3	4	1	6	1	1	17	17	0						
0	0	0	0	0	0	0	0	0	0	0.125	0.125	0	0.125	0	0	0.625
1999	1	4	4	1	272	1	1	17	17	0						
0.0026	0	0.0388	0.0517	0.0749	0.1447	0.124	0.093	0.0749	0.0827	0.0439	0.0465	0.0362	0.0491	0.0362	0.0103	0.0904
2000	1	1	4	1	5	1	1	17	17	0						
0	0	0	0.125	0	0	0	0	0	0	0	0	0.125	0	0	0.125	0.625
2000	1	2	4	1	31	1	1	17	17	0						
0	0	0	0	0	0.2195	0.1707	0.0976	0.122	0.0488	0.0488	0.0488	0	0.0976	0.0244	0	0.122
2000	1	4	4	1	183	1	1	17	17	0						
0	0.0038	0.0115	0.0538	0.0769	0.1269	0.1346	0.1385	0.0962	0.1115	0.0692	0.0654	0.0308	0.0346	0.0269	0.0077	0.0115
2001	1	1	4	1	5	1	1	17	17	0						
0	0	0	0	0	0	0	0	0	0	0	0	0	0.0667	0.0667	0	0.8667

2001	1	2	4	1	31	1	1	17	17	0						
0	0	0	0	0	0	0.1018	0.1614	0.1333	0.1228	0.0807	0.0772	0.0772	0.0491	0.0526	0.0211	0.1228
2001	1	3	4	1	26	1	1	17	17	0						
0	0	0	0	0.0263	0.0789	0.0526	0.0263	0.0789	0	0.0526	0.0789	0.0263	0.0789	0.1842	0.0263	0.2895
2001	1	4	4	1	101	1	1	17	17	0						
0	0	0	0.0069	0.0417	0.125	0.2153	0.1458	0.1181	0.0764	0.0764	0.0625	0.0694	0.0069	0.0278	0.0069	0.0208
2002	1	2	4	1	31	1	1	17	17	0						
0	0	0	0	0	0.0058	0.0526	0.117	0.1053	0.0994	0.1228	0.0409	0.0643	0.0877	0.0819	0.076	0.1462
2002	1	4	4	1	129	1	1	17	17	0						
0	0	0	0.0109	0.0326	0.0707	0.1848	0.1522	0.1522	0.1196	0.087	0.0489	0.0326	0.0326	0.0217	0.0163	0.038
2003	1	1	4	1	5	1	1	17	17	0						
0	0	0	0	0	0	0	0	0	0.1429	0	0	0	0.2857	0	0	0.5714
2003	1	2	4	1	31	1	1	17	17	0						
0	0	0	0	0	0	0.0814	0.2127	0.1991	0.1719	0.0633	0.0633	0.0724	0.0181	0.0452	0.0362	0.0362
2003	1	4	4	1	195	1	1	17	17	0						
0	0	0	0	0.0072	0.0578	0.2383	0.1805	0.1552	0.083	0.0686	0.0578	0.0578	0.0433	0.0181	0.0072	0.0253

APPENDIX 3: The parameter file for the Review Panel baseline Sheephead model in Synthesis

```
panel.d02        LOOP1:  7  LIKE:  -423.56754  DELTA LIKE:      .00020 ENDBIO:      239.
panel.r01
panel.p11
stage 2 changes requested by panel- virgin recruits, new baseline model search ascending only fir
    100.000000        .001000     BEGIN AND END DELTA F PER LOOP1
   3   .95               FIRST LOOP1 FOR LAMBDA & VALUE
   1.500                 MAX VALUE FOR CROSS DERIVATIVE
   1 READ HESSIAN
spbase.hes
   1 WRITE HESSIAN
spbase.hes
    .001                 MIN SAMPLE FRAC. PER AGE
   1  20   7  20         MINAGE, MAXAGE,  SUMMARY AGE RANGE
  1947  2003             BEGIN YEAR, END YEAR
  1       12  0  0  0    NPER, MON/PER
  6.00                   SPAWNMONTH
  4  4 NFISHERY, NSURVEY
  1 N SEXES
    1000.  REF RECR LEVEL
  0 MORTOPT
    .20000     .001000    3.000000 'NATMORT         '   0     1  0     .000000   .0000 !   1 NO PICK    .000          -.01      .0000000
 HKLINE     TYPE:  1
  8 SELECTIVITY PATTERN
   0   0   0   2   0   0   0  AGE TYPES USED
    1.00000       .20 ' HKLINE CATCH       '  ! # =  1 VALUE:         .00000
    1.00000       .20 ' HKLINE SIZECOMP    '  ! # =  2 VALUE:      -46.77540
  1  0  0  0  0  0  SEL. COMPONENTS
    .007365     .000100    1.000000 'HKLINE INITIAL S'   2     1  0     .000000   .0000 !   2 OK         .000     -88714.10      .0000164
    .520713     .000100    1.000000 'HKLINE INFLECT  '   2     1  0     .000000   .0000 !   3 OK         .000      -1274.55      .0018583
    .302354     .000100    5.000000 'HKLINE SLOPE    '   2     1  0     .000000   .0000 !   4 OK         .000       -317.86      .0069934
 TRAPS      TYPE:  2
  8 SELECTIVITY PATTERN
   0   0   0   4   0   0   0  AGE TYPES USED
    1.00000       .20 ' TRAP CATCH         '  ! # =  3 VALUE:         .00000
    1.00000       .20 ' TRAP SIZECOMP      '  ! # =  4 VALUE:      -50.68638
  1  0  0  0  0  0  SEL. COMPONENTS
    .011185     .000100    1.000000 'TRAPS INITIAL SE'   2     1  0     .000000   .0000 !   5 OK         .000     -17408.33      .0000846
    .178000     .000100    1.000000 'TRAP INFLECT    '   2     1  0     .000000   .0000 !   6 OK         .000     -19389.62      .0000787
    .752285     .000100    5.000000 'TRAP SLOPE      '   2     1  0     .000000   .0000 !   7 OK         .000        -39.55      .0476835
 SETNET     TYPE:  3
  8 SELECTIVITY PATTERN
   0   0   0   6   0   0   0  AGE TYPES USED
    1.00000       .20 ' SETNET CATCH       '  ! # =  5 VALUE:         .00000
    1.00000       .20 ' SETNET SIZECOMP    '  ! # =  6 VALUE:      -24.76985
  1  0  0  0  0  0  SEL. COMPONENTS
    .000612     .000100    1.000000 'SETNET INITIAL S'   2     1  0     .000000   .0000 !   8 OK         .000   -1067543.78      .0000012
    .656452     .000100    1.000000 'SETNET INFLECT  '   2     1  0     .000000   .0000 !   9 OK         .000       -296.55      .0091487
    .179861     .000100    5.000000 'SETNET SLOPE    '   2     1  0     .000000   .0000 !  10 OK         .000      -2802.16      .0010298
 RECREA     TYPE:  4
  8 SELECTIVITY PATTERN
   0   0   0   8   0   0   0  AGE TYPES USED
    1.00000       .20 ' RECREA CATCH       '  ! # =  7 VALUE:         .00000
    1.00000       .20 ' RECREA SIZECOMP    '  ! # =  8 VALUE:     -238.95360
  1  0  0  0  0  0  SEL. COMPONENTS
    .002149     .000100    1.000000 'RECREA INITIAL S'   2     1  0     .000000   .0000 !  11 OK         .000    -846539.13      .0000013
    .148960     .010000    1.000000 'RECREA INFLECT  '   2     1  0     .000000   .0000 !  12 OK         .000    -216535.95      .0000100
    .562873     .010000    5.000000 'RECREA SLOPE    '   2     1  0     .000000   .0000 !  13 OK         .000      -1521.75      .0012841
 CPFV1      TYPE:  5
```

```
 2 SELECTIVITY PATTERN
  0   0   0   0   0   0   0  AGE TYPES USED
    .000083  0  1  2 Q, QUANT, LOGERROR=1, BIO=1 or NUM=2
    1.00000       .20 'CPFV1   Q           '  ! # =  9 VALUE:      -12.25646
   4.000000    -.200000    1.000000 'CPFV1 SELTYPE   '   0 -1947  0     .000000   .0000 !  14 NO PICK    .000          -.01      .0000000
  10.000000     .010000   10.000000 'CPFV1 MINSIZE   '   0 -1947  0     .000000   .0000 !  15 NO PICK    .000          -.01      .0000000
 100.000000     .001000  100.000000 'CPFV1 MAXSIZE   '   0 -1947  0     .000000   .0000 !  16 NO PICK    .000          -.01      .0000000
CPFV2      TYPE:  6
 2 SELECTIVITY PATTERN
  0   0   0   0   0   0   0  AGE TYPES USED
    .000069  0  1  2 Q, QUANT, LOGERROR=1, BIO=1 or NUM=2
    1.00000       .20 'CPFV2   Q           '  ! # = 10 VALUE:      -16.82161
   4.000000    -.200000    1.000000 'CPFV2 SELTYPE   '   0 -1960  0     .000000   .0000 !  17 NO PICK    .000          -.01      .0000000
  10.000000     .010000   10.000000 'CPFV2 MINSIZE   '   0 -1960  0     .000000   .0000 !  18 NO PICK    .000          -.01      .0000000
 100.000000     .001000  100.000000 'CPFV2 MAXSIZE   '   0 -1960  0     .000000   .0000 !  19 NO PICK    .000          -.01      .0000000
CPFV3      TYPE:  7
 2 SELECTIVITY PATTERN
  0   0   0   0   0   0   0  AGE TYPES USED
    .001813  0  1  2 Q, QUANT, LOGERROR=1, BIO=1 or NUM=2
    1.00000       .20 'CPFV3   Q           '  ! # = 11 VALUE:        4.56110
   4.000000    -.200000    1.000000 'CPFV3 SELTYPE   '   0 -1980  0     .000000   .0000 !  20 NO PICK    .000          -.01      .0000000
  10.000000     .010000   10.000000 'CPFV3 MINSIZE   '   0 -1980  0     .000000   .0000 !  21 NO PICK    .000          -.01      .0000000
 100.000000     .001000  100.000000 'CPFV3 MAXSIZE   '   0 -1980  0     .000000   .0000 !  22 NO PICK    .000          -.01      .0000000
 CalCOFI   TYPE:  8
 4 SELECTIVITY PATTERN
  0   0   0   0   0   0   0  AGE TYPES USED
    .000002  0  1  2 Q, QUANT, LOGERROR=1, BIO=1 or NUM=2
    1.00000       .20 'CalCOFI SPB         '  ! # = 12 VALUE:      -34.43127
 1 AGEERR: 1: MULTINOMIAL,  0: S(LOG(P))=CONSTANT,  -1: S=P*Q/N
200.000 : MAX N FOR MULTINOMIAL
 3 1=%CORRECT, 2=C.V., 3=%AGREE, 4=READ %AGREE @AGE
    .800000     .300000     .950000 '%AGREE @ MIN    '   0 -1980  0     .000000   .0000 !  23 NO PICK    .000          -.01      .0000000
    .050000     .000000     .900000 '%AGREE @ MAX    '   0 -1980  0     .000000   .0000 !  24 NO PICK    .000          -.01      .0000000
   1.000000     .001000    2.000000 '%AGREE POWER    '   0 -1980  0     .000000   .0000 !  25 NO PICK    .000          -.01      .0000000
    .150000     .010000     .300000 'OLD DISCOUNT    '   0 -1980  0     .000000   .0000 !  26 NO PICK    .000          -.01      .0000000
    .000000     .001000     .100000 '%MIS_SEXED      '   0 -1980  0     .000000   .0000 !  27 NO PICK    .000          -.01      .0000000
 0 END OF EFFORT
 0 FIX n FMORTs
 2  MATURITY
  25.240000   10.000000  100.000000 'MATURITY INFL   '   0     1  0     .000000   .0000 !  28 NO PICK    .000          -.01      .0000000
   1.060000     .001000    5.000000 'MATURITY SLOPE  '   0     1  0     .000000   .0000 !  29 NO PICK    .000          -.01      .0000000
    .000000     .000000    5.000000 'MATURITY - DD   '   0     1  0     .000000   .0000 !  30 NO PICK    .000          -.01      .0000000
  36.700000   10.000000  100.000000 'MATURITY - INFL2'   0     1  0     .000000   .0000 !  31 NO PICK    .000          -.01      .0000000
    .320000     .001000    5.000000 'MATURITY - SLP2 '   0     1  0     .000000   .0000 !  32 NO PICK    .000          -.01      .0000000
 1  GROWTH: 1=CONSTANT, 2=MORT. INFLUENCE
 1.0000 13.0000  AGE AT WHICH L1 AND L2 OCCUR
 1 1=NORMAL, 2=LOGNORMAL
  12.920000    1.000000  100.000000 'L1             '   0     1  0     .000000   .0000 !  33 NO PICK    .000          -.01      .0000000
  52.600000   10.000000  100.000000 'LINF           '   0     1  0     .000000   .0000 !  34 NO PICK    .000          -.01      .0000000
    .068000     .000100    4.000000 'K              '   0     1  0     .000000   .0000 !  35 NO PICK    .000          -.01      .0000000
    .110000     .001000     .290000 'CV1            '   0     1  0     .000000   .0000 !  36 NO PICK    .000          -.01      .0000000
    .110000     .001000     .290000 'CV1            '   0     1  0     .000000   .0000 !  37 NO PICK    .000          -.01      .0000000
          0  DEFINE MARKET CATEGORIES
 0 ENVIRONMENTAL FXN:    [-INDEX]  [FXN TYPE(1-4)]  [ENVVAR USED]
 0 ESTIMATE N ENVIRON VALUES
 0 PENALTIES
 0 ENVIRONMENT EFFECT ON EXP(RECR)
13  STOCK-RECR
 3 1=B-H, 2=RICKER, 3=new B-H, 4=HOCKEY
 0 0=recr is mult x averecr, 1=log(DEV) from S-R
```

```
     .01000      -.80 ' SPAWN-RECR-IND     '  ! # = 13 VALUE:      -31.05687
     .01000      -.30 ' SPAWN-RECR-MEAN    '  ! # = 14 VALUE:     -312.34996
    .219875     .200000   15.000000 'VIRGIN RECR MULT'   2     1  0     .000000   .0000 !  38 OK         .000      -1476.24      .0011552
    .990000     .100000     .990000 'B/H  S/R PARAM  '   0     1  0     .000000   .0000 !  39 NO PICK    .000          -.01      .0000000
   1.163816     .100000 1000.000000 'BACK. RECRUIT   '   0     1  0     .000000   .0000 !  40 NO PICK    .000          -.01      .0000000
    .800000     .100000     .990000 'S/R STD.DEV.    '   0     1  0     .000000   .0000 !  41 NO PICK    .000          -.01      .0000000
    .000000    -.100000     .100000 'RECR TREND      '   0     1  0     .000000   .0000 !  42 NO PICK    .000          -.01      .0000000
   1.000000     .010000   10.000000 'RECR-MULT       '   0     1  0     .000000   .0000 !  43 NO PICK    .000          -.01      .0000000
-1 INIT AGE COMP
    .122439     .000010 1000.000000 'RECR 1947       '   2  1947  0     .000000   .0000 !  44 OK         .000        -17.97      .0682950
    .130241     .000010 1000.000000 'RECR 1948       '   2  1948  0     .000000   .0000 !  45 OK         .000        -15.57      .0804081
    .138544     .000010 1000.000000 'RECR 1949       '   2  1949  0     .000000   .0000 !  46 OK         .000        -13.68      .0986575
    .146323     .000010 1000.000000 'RECR 1950       '   2  1950  0     .000000   .0000 !  47 OK         .000        -12.53      .1149593
    .151967     .000010 1000.000000 'RECR 1951       '   2  1951  0     .000000   .0000 !  48 OK         .000        -12.15      .1289720
    .151368     .000010 1000.000000 'RECR 1952       '   2  1952  0     .000000   .0000 !  49 OK         .000        -13.03      .1300624
    .153277     .000010 1000.000000 'RECR 1953       '   2  1953  0     .000000   .0000 !  50 OK         .000        -13.72      .1376645
    .159185     .000010 1000.000000 'RECR 1954       '   2  1954  0     .000000   .0000 !  51 OK         .000        -14.19      .1471341
    .164010     .000010 1000.000000 'RECR 1955       '   2  1955  0     .000000   .0000 !  52 OK         .000        -14.89      .1624994
    .160454     .000010 1000.000000 'RECR 1956       '   2  1956  0     .000000   .0000 !  53 OK         .000        -17.30      .1438551
    .147861     .000010 1000.000000 'RECR 1957       '   2  1957  0     .000000   .0000 !  54 OK         .000        -21.13      .1134823
    .139406     .000010 1000.000000 'RECR 1958       '   2  1958  0     .000000   .0000 !  55 OK         .000        -24.91      .0953660
    .129684     .000010 1000.000000 'RECR 1959       '   2  1959  0     .000000   .0000 !  56 OK         .000        -29.29      .0827939
   1.612239     .000010 1000.000000 'RECR 1960       '   2  1960  0     .000000   .0000 !  57 OK        -.001        -18.21      .3101900
    .123475     .000010 1000.000000 'RECR 1961       '   2  1961  0     .000000   .0000 !  58 OK         .000        -35.81      .0669103
    .128971     .000010 1000.000000 'RECR 1962       '   2  1962  0     .000000   .0000 !  59 OK         .000        -36.28      .0714022
    .139058     .000010 1000.000000 'RECR 1963       '   2  1963  0     .000000   .0000 !  60 OK         .000        -36.64      .0813681
    .136999     .000010 1000.000000 'RECR 1964       '   2  1964  0     .000000   .0000 !  61 OK         .000        -40.45      .0731628
    .138859     .000010 1000.000000 'RECR 1965       '   2  1965  0     .000000   .0000 !  62 OK         .000        -43.54      .0700242
    .790001     .000010 1000.000000 'RECR 1966       '   2  1966  0     .000000   .0000 !  63 OK         .000        -36.85      .1508386
    .145598     .000010 1000.000000 'RECR 1967       '   2  1967  0     .000000   .0000 !  64 OK         .000        -49.97      .0688721
   1.294809     .000010 1000.000000 'RECR 1968       '   2  1968  0     .000000   .0000 !  65 OK         .000        -45.76      .1019342
    .123705     .000010 1000.000000 'RECR 1969       '   2  1969  0     .000000   .0000 !  66 OK         .000        -66.29      .0422911
    .116657     .000010 1000.000000 'RECR 1970       '   2  1970  0     .000000   .0000 !  67 OK         .000        -75.24      .0356947
   1.158491     .000010 1000.000000 'RECR 1971       '   2  1971  0     .000000   .0000 !  68 OK         .000        -73.55      .0404156
    .111973     .000010 1000.000000 'RECR 1972       '   2  1972  0     .000000   .0000 !  69 OK         .000       -146.43      .0183111
    .097487     .000010 1000.000000 'RECR 1973       '   2  1973  0     .000000   .0000 !  70 OK         .000       -185.07      .0134824
    .754900     .000010 1000.000000 'RECR 1974       '   2  1974  0     .000000   .0000 !  71 OK         .000       -124.66      .0216837
    .315519     .000010 1000.000000 'RECR 1975       '   2  1975  0     .000000   .0000 !  72 OK         .000       -108.62      .0272001
    .397883     .000010 1000.000000 'RECR 1976       '   2  1976  0     .000000   .0000 !  73 OK         .000        -81.65      .0388832
   1.023903     .000010 1000.000000 'RECR 1977       '   2  1977  0     .000000   .0000 !  74 OK         .000        -62.89      .0644968
    .353467     .000010 1000.000000 'RECR 1978       '   2  1978  0     .000000   .0000 !  75 OK        -.001        -59.83      .0736734
   1.631827     .000010 1000.000000 'RECR 1979       '   2  1979  0     .000000   .0000 !  76 OK         .000        -56.98      .0757378
   1.168362     .000010 1000.000000 'RECR 1980       '   2  1980  0     .000000   .0000 !  77 OK        -.001        -60.83      .0687749
    .939448     .000010 1000.000000 'RECR 1981       '   2  1981  0     .000000   .0000 !  78 OK         .000        -68.60      .0569848
   1.467415     .000010 1000.000000 'RECR 1982       '   2  1982  0     .000000   .0000 !  79 OK         .000        -82.06      .0470863
    .276011     .000010 1000.000000 'RECR 1983       '   2  1983  0     .000000   .0000 !  80 OK         .000        -98.92      .0394011
   1.230623     .000010 1000.000000 'RECR 1984       '   2  1984  0     .000000   .0000 !  81 OK         .000       -113.38      .0364135
    .370393     .000010 1000.000000 'RECR 1985       '   2  1985  0     .000000   .0000 !  82 OK         .000       -132.94      .0321506
    .916670     .000010 1000.000000 'RECR 1986       '   2  1986  0     .000000   .0000 !  83 OK         .000       -143.72      .0339520
    .475524     .000010 1000.000000 'RECR 1987       '   2  1987  0     .000000   .0000 !  84 OK         .000       -154.02      .0375689
    .240262     .000010 1000.000000 'RECR 1988       '   2  1988  0     .000000   .0000 !  85 OK         .000       -166.74      .0363572
    .199216     .000010 1000.000000 'RECR 1989       '   2  1989  0     .000000   .0000 !  86 OK         .000       -183.44      .0317055
    .631694     .000010 1000.000000 'RECR 1990       '   2  1990  0     .000000   .0000 !  87 OK         .000       -191.65      .0305949
    .341172     .000010 1000.000000 'RECR 1991       '   2  1991  0     .000000   .0000 !  88 OK         .000       -199.47      .0272552
    .456879     .000010 1000.000000 'RECR 1992       '   2  1992  0     .000000   .0000 !  89 OK         .000       -200.63      .0255811
    .952528     .000010 1000.000000 'RECR 1993       '   2  1993  0     .000000   .0000 !  90 OK         .000       -196.20      .0214115
    .070550     .000010 1000.000000 'RECR 1994       '   2  1994  0     .000000   .0000 !  91 OK         .000       -273.20      .0091046
    .768997     .000010 1000.000000 'RECR 1995       '   2  1995  0     .000000   .0000 !  92 OK         .000       -178.19      .0175815
    .360388     .000010 1000.000000 'RECR 1996       '   2  1996  0     .000000   .0000 !  93 OK         .000       -163.99      .0208137
    .713896     .000010 1000.000000 'RECR 1997       '   2  1997  0     .000000   .0000 !  94 OK         .000       -128.97      .0245946
```

.462676	.000010	1000.000000	'RECR 1998 '	2	1998	0	.000000	.0000	!	95	OK	.000	-100.76	.0234682
.459330	.000010	1000.000000	'RECR 1999 '	2	1999	0	.000000	.0000	!	96	OK	.000	-142.47	.0110084
.021097	.000010	1000.000000	'RECR 2000 '	2	2000	0	.000000	.0000	!	97	OK	.000	-1983.01	.0005914
-.302796	.000010	1000.000000	'RECR 2001 '	0	2001	0	.000000	.0000	!	98	NO PICK	.000	-.01	.0000000
-.302796	.000010	1000.000000	'RECR 2002 '	0	2002	0	.000000	.0000	!	99	NO PICK	.000	-.01	.0000000
-.302796	.000010	1000.000000	'RECR 2003 '	0	2003	0	.000000	.0000	!	100	NO PICK	.000	-.01	.0000000

APPENDIX 4: The data file for the Review Panel baseline Sheephead model in Synthesis

"sheephead data file for 2004 assessment, assembled by Meisha Key & Suzanne Alonzo"

55.47	1	hkline	trap	setnet	recrea
1947	1	87.77	0	0	21.03
1948	1	45.46	0	0	27.91
1949	1	28.81	0	0	24.97
1950	1	30.03	0	0	23.09
1951	1	27.86	0	0	33.01
1952	1	16.43	0	0	26.65
1953	1	16.07	0	0	28.05
1954	1	13.24	0	0	34.77
1955	1	5.97	0	0	26.64
1956	1	2.98	0	0	27.75
1957	1	5	0	0	28.26
1958	1	5.16	0	0	33.14
1959	1	4.64	0	0	31.56
1960	1	2.15	0	0	22.5
1961	1	5.72	0	0	28.43
1962	1	9.22	0	0	25.65
1963	1	12.71	0	0	33.66
1964	1	8.13	0	0	47.21
1965	1	5.51	0	0	71.19
1966	1	7.25	0	0	89.49
1967	1	8.9	0	0	72.85
1968	1	5.78	0	0	57.32
1969	1	6.03	0	0	84.09
1970	1	1.73	0	0	67.65
1971	1	4.02	0	0	65.77
1972	1	3.21	0	0	58.08
1973	1	1.39	0	0	78.6
1974	1	1.69	0	0	52.96
1975	1	2.74	0	0	53.15
1976	1	3.78	0	0	57.08
1977	1	2.91	0	0	49.94
1978	1	0.94	0.49	3.63	59.48
1979	1	0.23	0.45	3.32	55.58
1980	1	0.85	1.08	2.2	143.57
1981	1	0.36	0.36	5.13	106.97
1982	1	0.44	0.82	4.08	92.03
1983	1	0.88	0.34	4.5	155.35
1984	1	1.96	0.28	9.15	131.2
1985	1	0.17	0.08	12.67	200.2
1986	1	0.39	0	12.88	223.3
1987	1	2.76	0	12.16	108.09
1988	1	2.84	0	10.47	178.84
1989	1	7.84	0	7.25	64.64
1990	1	49.6	0	6.54	60
1991	1	80.43	0	6.66	73.63
1992	1	111.2	0	6.14	45.5
1993	1	127.11	11.88	4.33	78.24
1994	1	27.06	89.92	0.72	121.12
1995	1	26.4	88.2	0.47	54.52
1996	1	20.89	92.83	0.68	81.22
1997	1	22.02	115.69	1.28	59.81
1998	1	24.79	93.32	0.94	76.51
1999	1	11.24	46.68	0.9	84.94
2000	1	15.16	62.31	1.21	100.09
2001	1	10.96	55.78	1.39	58.85
2002	1	10.34	43.71	0.66	60.26

NEW VERSION OF THE DATA FILE FOR THE PANEL
SAME AS SPBASE.D13 EXCEPT LENGTH COMPOSITION
ARE NOT BINNED ABOVE 50CM

2003	1	10.87	36.98	0.15	68.51						
-1	1	1	1	1	1	1	OF	CATCH	DATA		
-1	1	1	1				OF	EFFORT	AND	CPUE	DATA
1947	1	8	5	0.036178903	0.4						
1948	1	8	5	0.042331585	0.4						
1949	1	8	5	0.032857006	0.4						
1950	1	8	5	0.026239105	0.4						
1951	1	8	5	0.036656857	0.4						
1952	1	8	5	0.028024765	0.4						
1953	1	8	5	0.034549713	0.4						
1954	1	8	5	0.040397227	0.4						
1955	1	8	5	0.028415067	0.4						
1956	1	8	5	0.028273841	0.4						
1957	1	8	5	0.028171772	0.4						
1958	1	8	5	0.035174085	0.4						
1959	1	8	5	0.030774256	0.4						
1960	1	8	5	0.022355231	0.4						
1961	1	8	5	0.030677383	0.4						
1960	1	8	6	0.018103586	0.4						
1961	1	8	6	0.025609682	0.4						
1962	1	8	6	0.022635962	0.4						
1963	1	8	6	0.028675825	0.4						
1964	1	8	6	0.038568111	0.4						
1965	1	8	6	0.060530182	0.4						
1966	1	8	6	0.061805134	0.4						
1967	1	8	6	0.054705667	0.4						
1968	1	8	6	0.038927611	0.4						
1969	1	8	6	0.061815297	0.4						
1970	1	8	6	0.045188114	0.4						
1971	1	8	6	0.052600786	0.4						
1972	1	8	6	0.042316728	0.4						
1973	1	8	6	0.052532667	0.4						
1974	1	8	6	0.037546657	0.4						
1975	1	8	6	0.040767219	0.4						
1976	1	8	6	0.044756237	0.4						
1977	1	8	6	0.039791441	0.4						
1978	1	8	6	0.046977309	0.4						
1979	1	8	6	0.040688144	0.4						
1980	1	8	6	0.045104848	0.4						
1981	1	8	6	0.055954773	0.4						
1980	1	8	7	1.732179064	0.2						
1981	1	8	7	1.971613638	0.2						
1982	1	8	7	1.774373126	0.2						
1983	1	8	7	3.281535519	0.2						
1984	1	8	7	2.557200197	0.2						
1985	1	8	7	1.931451602	0.2						
1986	1	8	7	3.111646369	0.2						
1987	1	8	7	1.772070442	0.2						
1988	1	8	7	2.817807005	0.2						
1989	1	8	7	2.168732715	0.2						
1990	1	8	7	2.279456015	0.2						
1991	1	8	7	2.440362891	0.2						
1992	1	8	7	1.547237147	0.2						
1993	1	8	7	1.890015687	0.2						
1994	1	8	7	1.255741401	0.2						
1995	1	8	7	1.280379067	0.2						
1996	1	8	7	1.223139248	0.2						
1997	1	8	7	1.081495203	0.2						
1998	1	8	7	0.71177501	0.2						
1999	1	8	7	0.860862578	0.2						

2000	1	8	7	1.138076258	0.2				
2001	1	8	7	1.45894012	0.2				
2002	1	8	7	0.911182492	0.2				
2003	1	8	7	0.634184694	0.2				
1951	1	8	8	-1	1.1				
1952	1	8	8	-1	1.1				
1953	1	8	8	-1	1.1				
1954	1	8	8	-1	1.1				
1955	1	8	8	-1	1.1				
1956	1	8	8	-1	1.1				
1957	1	8	8	-1	1.1				
1958	1	8	8	-1	1.1				
1959	1	8	8	-1	1.1				
1960	1	8	8	-1	1.1				
1961	1	8	8	0.02997	1.1				
1962	1	8	8	0.05363	1.1				
1963	1	8	8	0.12863	1.1				
1964	1	8	8	0.01345	1.1				
1965	1	8	8	0.12768	1.1				
1966	1	8	8	0.073	1.1				
1967	1	8	8	0.07004	1.1				
1968	1	8	8	0.005	1.1				
1969	1	8	8	0.01733	1.1				
1970	1	8	8	-1	1.1				
1971	1	8	8	-1	1.1				
1972	1	8	8	0.005	1.1				
1973	1	8	8	-1	1.1				
1974	1	8	8	-1	1.1				
1975	1	8	8	0.02788	1.1				
1976	1	8	8	-1	1.1				
1977	1	8	8	-1	1.1				
1978	1	8	8	0.08477	1.1				
1979	1	8	8	-1	1.1				
1980	1	8	8	-1	1.1				
1981	1	8	8	0.27208	1.1				
1982	1	8	8	-1	1.1				
1983	1	8	8	-1	1.1				
1984	1	8	8	0.37014	1.1				
1985	1	8	8	0.17095	1.1				
1986	1	8	8	0.005	1.1				
1987	1	8	8	0.005	1.1				
1988	1	8	8	0.04798	1.1				
1989	1	8	8	0.09385	1.1				
1990	1	8	8	0.10783	1.1				
1991	1	8	8	0.09826	1.1				
1992	1	8	8	0.02285	1.1				
1993	1	8	8	0.03417	1.1				
1994	1	8	8	0.005	1.1				
1995	1	8	8	0.16048	1.1				
1996	1	8	8	0.00941	1.1				
1997	1	8	8	0.01878	1.1				
1998	1	8	8	0.12147	1.1				
1999	1	8	8	0.005	1.1				
2000	1	8	8	0.06988	1.1				
2001	1	8	8	0.005	1.1				
2002	1	8	8	0.005	1.1				
2003	1	8	8	-1	1.1				
-1	1	1	1	1	1	OF	SURVEY	ABUNDANCE	DATA
-1	-1	(no bins defined for perfect ages)							

```
-1      -1      (no bins for imprecise ages)

-1      -1      (no bins defined for biased ages)

30      30      (30 2-cm length bins [18-50 cm])

18      20      22      24      26      28      30      34      36      38      40      42      44      46      48      50      52      54
        56      58      60      62      64      66      68      70      72      74      78      83.86
25.2    -1.06           "length@50%mature, slope  (Warner 1975) (could use Cowen 1990 for other estimates)"


0.000026935     2.857           both sexes length-weight (alpha & beta) from deMartini et al. 1994


129     0               eggs/kg on weight (intercept & slope) from deMartini et al. 1994 (could use Warner 1975 instead)


0.000026935     2.857           both sexes length-weight (alpha & beta) from deMartini et al. 1994


BEGINNING       OF      SIZE    AND     AGE     COMPOSITION

1975    1       4       4       1       79      1       30      30      0

0       0       0.026785714     0       0.044642857     0.044642857     0.125   0.116071429     0.0625  0.071428571     0.098214286
        0.080357143     0.071428571     0.035714286     0.035714286     0.008928571     0.017857143     0.008928571     0.008928571     0
        0       0       0.008928571     0       0       0       0       0       0
1976    1       4       4       1       186     1       30      30      0

0       0.003773585     0.003773585     0.003773585     0.011320755     0.011320755     0.056603774     0.113207547     0.150943396
        0.124528302     0.079245283     0.098113208     0.067924528     0.041509434     0.037735849     0.041509434     0.018867925
        0.018867925     0.01509434      0.003773585     0.011320755     0       0       0       0       0       0       0       0
1977    1       4       4       1       431     1       30      30      0

0.003257329     0.003257329     0.008143322     0.03257329      0.076547231     0.105863192     0.118892508     0.117263844     0.091205212
        0.063517915     0.048859935     0.053745928     0.024429967     0.029315961     0.022801303     0.016286645     0.013029316
        0.013029316     0.011400651     0.001628664     0.004885993     0.001628664     0.001628664     0       0.003257329     0
        0.001628664     0.003257329     0
1978    1       4       4       1       486     1       30      30      0

0.00433526      0.00433526      0.01300578      0.033236994     0.050578035     0.083815029     0.105491329     0.115606936     0.086705202
        0.067919075     0.079479769     0.053468208     0.041907514     0.041907514     0.023121387     0.01300578      0.020231214
        0.007225434     0.01734104      0.00433526      0.010115607     0.005780347     0.002890173     0       0.002890173     0.001445087
        0.001445087     0       0
1980    1       4       4       1       44      1       30      30      0

0       0       0       0.015873016     0.047619048     0.063492063     0.047619048     0.079365079     0.095238095     0.047619048
        0.031746032     0.063492063     0.063492063     0.047619048     0.031746032     0.063492063     0.047619048     0.047619048
        0.047619048     0.031746032     0.047619048     0       0       0.015873016     0       0       0.015873016     0       0
1981    1       4       4       1       58      1       30      30      0

0       0.012195122     0.036585366     0.024390244     0.06097561      0.048780488     0.073170732     0.12195122      0.073170732
        0.048780488     0.036585366     0.048780488     0.024390244     0.073170732     0       0.06097561      0.036585366     0.048780488
        0       0.024390244     0.024390244     0       0       0       0       0       0       0       0
1982    1       4       4       1       27      1       30      30      0

0       0       0       0       0.102564103     0.179487179     0.102564103     0.102564103     0.128205128     0.153846154     0.025641026
        0       0       0       0       0       0       0       0       0       0       0       0       0.025641026     0       0       0
        0       0
```

1983 1 4 4 1 273 1 30 30 0

0 0.007712082 0.007712082 0.061696658 0.084832905 0.143958869 0.110539846 0.092544987 0.095115681
0.077120823 0.046272494 0.041131105 0.025706941 0.023136247 0.015424165 0.002570694 0.005141388
0.002570694 0.002570694 0 0.002570694 0.002570694 0 0 0.002570694 0 0 0 0
1984 1 4 4 1 283 1 30 30 0

0.00248139 0.00248139 0.022332506 0.049627792 0.104218362 0.111662531 0.126550868 0.121588089 0.081885856
0.101736973 0.039702233 0.024813896 0.024813896 0.022332506 0.012406948 0 0.014888337 0
0.004962779 0.004962779 0.00248139 0 0.00248139 0 0 0 0 0 0
1985 1 4 4 1 381 1 30 30 0

0 0 0.012915129 0.022140221 0.081180812 0.125461255 0.125461255 0.116236162 0.10701107 0.081180812
0.066420664 0.049815498 0.044280443 0.014760148 0.009225092 0.009225092 0.003690037 0.001845018
0.003690037 0.003690037 0.001845018 0 0.001845018 0.001845018 0 0 0 0.001845018 0
1986 1 4 4 1 534 1 30 30 0

0 0.005256242 0.017082786 0.031537451 0.061760841 0.093298292 0.11695138 0.120893561 0.103810775
0.077529566 0.063074901 0.051248357 0.032851511 0.018396846 0.024967148 0.019710907 0.011826544
0.006570302 0.003942181 0.005256242 0.002628121 0 0 0.00131406 0.00131406 0 0 0
0.002628121
1987 1 4 4 1 478 1 30 30 0

0 0.005882353 0.013235294 0.030882353 0.069117647 0.1 0.111764706 0.102941176 0.092647059 0.089705882
0.064705882 0.061764706 0.039705882 0.035294118 0.030882353 0.027941176 0.013235294 0.013235294
0.001470588 0.005882353 0.004411765 0.004411765 0.002941176 0.001470588 0 0 0 0 0
1988 1 4 4 1 491 1 30 30 0

0 0 0.00286123 0.012875536 0.04148784 0.072961373 0.072961373 0.080114449 0.080114449 0.087267525
0.065808298 0.064377682 0.062947067 0.0472103 0.037195994 0.038626609 0.030042918 0.028612303
0.015736767 0.021459227 0.014306152 0.004291845 0.005722461 0.005722461 0.00286123 0.00286123 0
0 0
1989 1 4 4 1 272 1 30 30 0

0 0 0.002583979 0.025839793 0.067183463 0.108527132 0.103359173 0.098191214 0.103359173 0.098191214
0.074935401 0.049095607 0.03875969 0.033591731 0.018087855 0.020671835 0.015503876 0.005167959
0.018087855 0.002583979 0.005167959 0.002583979 0 0 0 0 0 0 0
1993 1 1 4 1 5 1 30 30 0

0 0 0 0 0 0 0 0 0 0.166666667 0.083333333 0 0 0 0 0
0.083333333 0.083333333 0.083333333 0 0 0 0.166666667 0.083333333 0 0 0.083333333
0 0.166666667
1993 1 4 4 1 25 1 30 30 0

0 0 0.028571429 0.085714286 0.057142857 0.142857143 0.057142857 0.085714286 0.057142857 0.057142857
0.114285714 0.057142857 0.028571429 0.028571429 0 0 0.028571429 0.028571429 0.057142857 0
0 0 0 0 0 0 0 0 0
1994 1 4 4 1 32 1 30 30 0

0 0 0 0.088888889 0.066666667 0.066666667 0.111111111 0.066666667 0.066666667 0.088888889
0.111111111 0.022222222 0.022222222 0.022222222 0.044444444 0 0 0.022222222 0.022222222
0.022222222 0 0 0.022222222 0 0 0 0 0 0
1995 1 1 4 1 5 1 30 30 0

0 0 0.083333333 0.083333333 0.5 0.083333333 0 0 0 0 0 0.083333333 0
0.083333333 0 0.083333333 0 0 0 0 0 0 0 0 0 0 0 0
0
1995 1 4 4 1 29 1 30 30 0

0 0 0.073170732 0.073170732 0.12195122 0.073170732 0.097560976 0.097560976 0.048780488 0.048780488
0.12195122 0.073170732 0.024390244 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0
1996 1 2 4 1 31 1 30 30 0

0 0 0 0.1 0 0.133333333 0.233333333 0.066666667 0.133333333 0.033333333 0.066666667
0.133333333 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0
1996 1 1 4 1 5 1 30 30 0

0 0 0 0 0 0 0 0 0 0 0.037037037 0.111111111 0.037037037 0.148148148
0.037037037 0.074074074 0.037037037 0.222222222 0.111111111 0.148148148 0.037037037 0 0 0
0 0 0 0 0
1996 1 4 4 1 47 1 30 30 0

0 0 0.014925373 0.029850746 0.104477612 0.074626866 0.23880597 0.059701493 0.059701493 0.089552239
0.014925373 0.074626866 0.014925373 0.029850746 0.029850746 0.029850746 0.014925373 0 0
0.014925373 0 0 0 0 0 0 0 0 0
1997 1 3 4 1 8 1 30 30 0

0 0 0 0.083333333 0 0 0 0 0 0 0 0 0 0 0.083333333 0
0 0.083333333 0 0.25 0.25 0 0.083333333 0.083333333 0 0 0.083333333 0 0
1997 1 2 4 1 31 1 30 30 0

0 0 0.008064516 0.032258065 0.080645161 0.193548387 0.14516129 0.10483871 0.072580645 0.060483871
0.040322581 0.036290323 0.016129032 0.02016129 0.012096774 0.02016129 0.008064516 0.004032258
0.004032258 0 0 0 0 0 0 0 0 0 0
1997 1 1 4 1 5 1 30 30 0

0 0 0 0 0 0 0.2 0 0.1 0.3 0 0.2 0 0.1 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0
1997 1 4 4 1 14 1 30 30 0

0 0 0 0.15 0.05 0.15 0.25 0.1 0.05 0.1 0 0 0.05 0 0 0.05 0 0
0 0 0 0 0 0 0 0 0 0 0
1998 1 1 4 1 5 1 30 30 0

0 0 0 0 0 0 0 0 0 0 0 0 0.066666667 0 0.333333333
0.133333333 0.2 0 0.133333333 0 0.066666667 0.066666667 0 0 0 0 0 0
0
1998 1 4 4 1 74 1 30 30 0

0 0 0.009433962 0.047169811 0.075471698 0.160377358 0.122641509 0.103773585 0.066037736 0.066037736
0.094339623 0.066037736 0.018867925 0.028301887 0.037735849 0.018867925 0 0.018867925 0.028301887
0.009433962 0 0 0 0 0 0 0 0 0
1999 1 3 4 1 6 1 30 30 0

0 0 0 0 0 0 0 0 0 0.125 0.125 0 0.125 0 0 0.125 0 0.125
0 0 0 0 0 0.25 0 0 0.125 0 0
1999 1 2 4 1 31 1 30 30 0

0 0 0 0 0 0.058823529 0.235294118 0.161764706 0.058823529 0.088235294 0.029411765
0.044117647 0.029411765 0.029411765 0 0 0 0 0 0 0 0 0 0 0
0 0 0.014705882 0
1999 1 1 4 1 5 1 30 30 0

0 0 0 0 0 0 0 0 0 0 0 0.076923077 0.076923077 0.153846154
0.153846154 0.153846154 0.076923077 0.076923077 0 0.076923077 0 0.153846154 0 0 0
0 0 0 0

1999 1 4 4 1 272 1 30 30 0

0.002583979 0 0.03875969 0.051679587 0.074935401 0.144702842 0.124031008 0.074935401 0.082687339
0.043927649 0.046511628 0.036175711 0.049095607 0.036175711 0.010335917 0.010335917 0.010335917
0.012919897 0.018087855 0.020671835 0.002583979 0.005167959 0.005167959 0.005167959 0 0 0
0 0
2000 1 2 4 1 31 1 30 30 0

0 0 0 0 0 0.219512195 0.170731707 0.12195122 0.048780488 0.048780488 0.048780488 0
0.097560976 0.024390244 0 0.024390244 0 0 0.048780488 0.024390244 0 0.024390244 0
0 0 0 0 0 0
2000 1 1 4 1 5 1 30 30 0

0 0 0 0.125 0 0 0 0 0 0 0 0.125 0 0 0.125 0.125 0.125 0.125
0.125 0 0.125 0 0 0 0 0 0 0 0
2000 1 4 4 1 183 1 30 30 0

0 0.003846154 0.011538462 0.053846154 0.076923077 0.126923077 0.134615385 0.096153846 0.111538462
0.069230769 0.065384615 0.030769231 0.034615385 0.026923077 0.007692308 0.003846154 0.003846154
0.003846154 0 0 0 0 0 0 0 0 0 0 0
2001 1 3 4 1 26 1 30 30 0

0 0 0 0 0.026315789 0.078947368 0.052631579 0.078947368 0 0.052631579 0.078947368
0.026315789 0.078947368 0.184210526 0.026315789 0.052631579 0.131578947 0.052631579 0.026315789 0
0 0 0 0 0.026315789 0 0 0 0
2001 1 2 4 1 31 1 30 30 0

0 0 0 0 0 0 0.101754386 0.133333333 0.122807018 0.080701754 0.077192982 0.077192982
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0.003508772 0.007017544 0 0 0 0 0 0 0
2001 1 1 4 1 5 1 30 30 0

0 0 0 0 0 0 0 0 0 0 0 0.066666667 0.066666667 0 0
0.266666667 0.066666667 0.066666667 0.066666667 0.133333333 0.066666667 0 0.066666667 0.066666667
0.066666667 0 0 0
2001 1 4 4 1 101 1 30 30 0

0 0 0 0.006944444 0.041666667 0.125 0.215277778 0.118055556 0.076388889 0.076388889 0.0625
0.069444444 0.006944444 0.027777778 0.006944444 0.006944444 0.006944444 0 0.006944444 0 0
0 0 0 0 0 0 0
2002 1 2 4 1 31 1 30 30 0

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2002 1 4 4 1 129 1 30 30 0

0 0 0 0.010869565 0.032608696 0.070652174 0.184782609 0.152173913 0.119565217 0.086956522
0.048913043 0.032608696 0.032608696 0.02173913 0.016304348 0.005434783 0 0.010869565 0
0.010869565 0 0 0.005434783 0 0.005434783 0 0 0 0
2003 1 2 4 1 31 1 30 30 0

0 0 0 0 0 0 0.081447964 0.199095023 0.171945701 0.063348416 0.063348416 0.07239819
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0.004524887 0 0.004524887 0 0 0 0 0
2003 1 1 4 1 5 1 30 30 0

0 0 0 0 0 0 0 0 0.142857143 0 0 0 0.285714286 0 0
0.142857143 0.142857143 0 0.142857143 0 0.142857143 0 0 0 0 0 0 0
0

2003 1 4 4 1 195 1 30 30 0

0 0 0 0 0.007220217 0.057761733 0.238267148 0.155234657 0.083032491 0.068592058 0.057761733
0.057761733 0.0433213 0.018050542 0.007220217 0.010830325 0.007220217 0.003610108 0.003610108 0
0 0 0 0 0 0 0 0 0