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Alaska Department of Fish & Game
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EXECUTIVE SUMMARY

We applied population estimation models to annual stock assessment, catch sampling, and commercial catch data for red king crabs in Bristol Bay during 1972-1997 and blue king crabs off St. Matthew and Pribilof Islands in the Eastern Bering during 1980-1997. A length-based analysis (LBA) was applied to male and female red king crabs and a catch-survey analysis (CSA) was applied to male blue king crabs.

For Bristol Bay, an above average year class, likely from spawning in 1989-1991 (hereafter termed the 1990 year class), was nearly fully recruited to the surveyed stock of red king crabs during 1997. This recruitment event led to a substantial increase in most segments of the stock, except for legal crabs. Compared to 1996, mature males increased from 8.5 to 10.5 million and legal males were unchanged at 5.9 million. Mature females more than doubled from 10.5 to 23.7 million and effective spawning biomass increased from 21.3 to 31.4 million pounds – both well above threshold needed for a directed commercial fishery. By applying the 10% rebuilding harvest rate times mature male abundance times an average weight of 6.56 pounds per legal crab, a preseason guideline harvest level (GHL) of 7.0 million pounds was set for the November 1, 1997 opening.

For St. Matthew blue king crabs, CSA estimates legal-sized male crabs and area-swept methods provide estimates of prerecruits (sublegal mature males). Compared to 1996, an increase in legal males from 3.1 to 4.1 million and little change in prerecruits from 2.0 to 2.3 million combined as an increase of mature male crabs from 5.1 to 6.4 million. This apparent increase in abundance is tempered by low confidence in the population estimates and relatively poor fishery performance in 1996. Nonetheless, by multiplying the 20% harvest rate times mature male abundance and a mean weight of 3.96 pounds, a GHL of 5.0 million pounds was prescribed.

For Pribilof Islands blue king crabs, changes from last year included a slight decrease in legal males from 0.9 to 0.8 million, and a drop in prerecruits from 0.9 to 0.3 million. Taken together, mature male abundance declined by 41% from 1.8 to 1.1 million. In recent years, trends in survey and fishery performance data for red and blue king crabs at Pribilof Islands have been used to set an aggregate GHL for a combined fishery to avoid bycatch that would occur if each was held separately. For 1997, the GHL was set at 1.5 million pounds for the combined red and blue king crab fishery based on the decline in blue king crab abundance, recent poor fishery performance for red king crabs, and imprecision in abundance estimates. The combined blue and red king crab fisheries at Pribilof Islands are scheduled to open on September 15, 1997.

Beyond 1997, the future outlook for these king crab stocks is mixed. For king crabs at St. Matthew and Pribilof Islands, imprecise abundance estimates and limited biological information make it difficult to predict future stock status. However, based on trends in prerecruits and recruits for blue king crabs, we anticipate continued improvement in the stock at St. Matthew Island and continued decline at Pribilof Islands through 1998 or 1999.

Survey results from 1997 provide some optimism for Pribilof Islands red king crabs, but fishery performance has not yet revealed evidence of an improving stock.

For Bristol Bay red king crabs, a higher level of confidence in abundance estimates and better biological information allow more detailed predictions. In last year's stock status report we speculated that increased recruitment during 1994-1996 could represent the leading edge of a good year class, however we did not anticipate the apparent strength of the 1990 year class that was nearly fully recruited to the surveyed stock in 1997. Juvenile crabs are very difficult to estimate with trawl surveys, so our LBA is limited to larger crabs. As repeated observations are collected on this cohort by future surveys and catch samples, LBA will be able to provide more accurate estimates on the true strength of this year class.

Over the next couple of years, mature male crab abundance and effective spawning biomass should increase as the cohort grows to full maturity. Although total stock abundance (numbers) may actually level off or decline slightly as soon as 1998, total stock biomass (weight) should increase through 1999 or 2000 as growth in body weight exceeds loss in numbers of this cohort due to mortality. Size frequency data from the survey suggest that several weak year classes follow the 1990 year class. If true, the stock will decline early in the 21st Century as this year class senesces. The duration of this decline depends on future recruitment that is a complex function of stock and environmental relationships.

INTRODUCTION

The National Marine Fisheries Service (NMFS) conducts annual trawl surveys of crab abundance in the eastern Bering Sea. For each crab stock, the Alaska Department of Fish and Game (ADF&G), in consultation with NMFS, sets preseason guideline harvest levels (GHLs) or catch levels with an exploitation rate management strategy applied to estimates of mature male crab abundance. For most Bering Sea stocks, abundance is estimated by area-swept methods and reported annually by NMFS (e.g., Otto et al. 1997).

For a few stocks, ADF&G developed population models to minimize the effects of annual survey measurement errors on current-year abundance estimates by incorporating survey and fishery data from prior years into the estimation process. Abundance estimates from these models are used to manage the crab fisheries and to set annual crab bycatch limits in the groundfish fisheries. Because of the high level of interest in these population estimates by the fishing industry, ADF&G began an annual report series on stock status (Zheng et al. 1996a) in 1996 as a public information service. Our goal was to publish this report near the time a news release announced the upcoming Bering Sea king crab fisheries. This provides the industry and public access to the same information used by the agencies to set GHLs.

With these considerations in mind, the purpose of this report is to provide concise and timely information on the status of Eastern Bering Sea king crab stocks as estimated by population models for use in fishery management. In 1996, the status of stocks report was confined to red king crabs *(Paralithodes camtschaticus)* in Bristol Bay (Zheng et al. 1996a).

For 1997, we have extended our status of stocks report to include blue king crabs *(Paralithodes platypus)* off St. Matthew and Pribilof Islands because these stocks are now estimated with population models. In this report we briefly review estimation methods, current stock status, implications for crab fishery management and regulation of crab bycatch in groundfish fisheries, and a speculative outlook for the future. Trawl survey data used in our analyses were provided by Dr. Robert Otto of NMFS, Kodiak, Alaska.

METHODS

Survey Methods

NMFS has performed annual trawl surveys of the eastern Bering Sea since 1968. This multispecies, crab-groundfish survey is conducted during summer by two vessels each equipped with an eastern otter trawl with 83 ft headrope and 112 ft footrope. Stations are sampled in the center of a systematic 20X20 nm grid overlaid in an area of ≈140,000 nm^2. The towed area is estimated, and fish and invertebrate catches from each station are sampled, enumerated, measured and weighed. An update of Otto et al. (1997), to be published in winter 1997-1998, will provide details on the 1997 survey results for: Bristol Bay and Pribilof Islands red king crabs, St. Matthew and Pribilof Islands blue king crabs, and eastern Bering Sea Tanner *(Chionoecetes bairdi)*, snow *(C. opilio)*, and hair crabs *(Erimacrus isenbeckii)*. Status of Bering Sea groundfish stocks also assessed by this survey will be reported in an update to NPFMC (1996a).

Analytical Methods

<u>Overview.</u> The annual trawl survey is an essential data-gathering tool on the status of crab stocks in the eastern Bering Sea. Yet, year-to-year variation in oceanographic conditions lead to changes in species distributions and availability to survey gear. These changes may cause measurement errors that lead to unexpected shifts in area-swept abundance estimates unrelated to true changes in population size. Estimates from previous years' surveys and commercial catches provide valuable auxiliary information to help decipher real population changes from survey measurement errors. We developed population estimation models that incorporate detailed size, sex, and shell condition data from annual surveys, catch samples, and commercial catches. Model estimates based on multiple years of data and multiple data sources are generally more accurate than area-swept estimates from current-year survey data alone. Accordingly, for stocks in which these models have been implemented, ADF&G uses such estimates for fishery management.

Because the quantity and quality of data vary among crab stocks, no single analytical model is ideally suited for all situations. Therefore, we developed the following approaches that are tailored to differing levels of information: ***length-based analysis (LBA)*** for stocks with abundant, high-quality size composition data for which estimates of survey catchability coefficient exist, ***catch-survey analysis (CSA)*** for stocks lacking detailed size composition data or where survey catchability coefficient is unknown, and ***catch-length analysis (CLA)*** for stocks lacking annual assessment surveys (Zheng et al. 1996b). A brief description of these methods and their application to king crab stocks in the Eastern Bering Sea follows.

Length-based Analysis. Zheng et al. (1995a) developed a LBA for Bristol Bay red king crabs, and Zheng et al. (1995b) revised and updated the approach with more recent data. A less technical description of the approach appears in Zheng et al. (1996c). In summary, the LBA is an analytical procedure to estimate annual abundance of crab stocks for which extensive high-quality data are available, such as Bristol Bay red king crabs. The LBA makes use of detailed annual data on size, sex, and shell condition from trawl surveys, onboard and dockside catch samples, and annual commercial harvests. Males and females are modeled separately by 5 mm carapace length (CL) intervals as newshell (i.e., those that molted within the past year) and oldshell crabs (i.e., those that have not molted within the past year). The annual abundance of crabs at each length group is a combined result of recruitment, growth, natural mortality, and harvest. Kruse and Collie (1991) and Collie and Kruse (1997) estimated the trawl survey catchability coefficient *(q)* to be near unity for red king crabs in Bristol Bay, and $q = 1$ is assumed for area-swept and LBA methods (see Zheng et al. 1995a).

Benefits of the LBA are that it provides more precise abundance estimates for male and female crabs for fishery management, yields information needed to estimate stock-recruitment relationships, and allows us to analyze alternative harvest strategies. A drawback is that LBA requires extensive data not available for all crab stocks.

Catch-survey analysis. Collie and Kruse (1997) provided a detailed description of CSA. In summary, CSA can be thought of as a simpler version of LBA: the model is less complex and it requires less detailed data. As with LBA, CSA estimates survey measurement errors and “true” stock abundance. However, instead of tracking multiple 5 mm size groups as the LBA does, CSA considers only two age-size groups of crabs: recruits (i.e., crabs that molted to legal size within the past year) and post-recruits (i.e., crabs that have been legal for more than one year). Thus, CSA is suitable for crab stocks lacking detailed size composition data. If an estimate of natural mortality is available, then an additional advantage of CSA is that *q* can be estimated rather than assumed. Thus, CSA is particularly suited for crab stocks that occupy untrawlable areas where *q* is uncertain or stocks that are assessed by pot surveys where area-swept methods cannot be applied.

The two-stage (recruit, post-recruit) CSA has some disadvantages: (1) it cannot be applied to females because they are not harvested and commercial catch data are needed to estimate *q* for correct scaling of abundance estimates; (2) measurement error of recruits cannot be estimated in the last year; and (3) it provides estimates of legal male abundance but not mature males that are used in the exploitation rate strategy. Thus, CSA results for legal males are combined with area-swept results on sublegal crabs to estimate total mature male crab abundance.

Development of CSA preceded LBA. The first application to crabs was by Kruse (1986, 1987) who modified Collie and Sissenwine's (1983) analytical method for groundfish and developed a CSA application to historical pot surveys for red king crabs off Kodiak Island. Kruse and Collie (1991) refined the method and applied it to trawl surveys for red king crabs in Bristol Bay, and Collie and Kruse (1997) made further refinements of the approach in applications to Kodiak and Bristol Bay stocks. CSA is routinely applied in Southeast Alaska where red king crabs are assessed by pot surveys due to untrawlable bottom topography (Woodby 1994). In the Bering Sea, CSA is well-suited to blue king crab stocks near Pribilof and St. Matthew Islands where concerns exist about measurement errors and estimates of q are somewhat questionable. Zheng et al. (1997) first applied CSA to these blue king crab stocks in 1996, and we updated this application with survey data from 1997 in this report. As with Bristol Bay red king crabs, $q = 1$ is assumed for blue king crabs.

Catch-length analysis. Zheng et al. (1996d) developed CLA for application to crab stocks lacking annual assessment surveys. The analysis uses commercial catch data and dockside and onboard samples of shell condition and size composition. CLA was successfully tested on red king crab stocks in Bristol Bay and off Kodiak Island where abundance is already well-known from LBA, CSA and area-swept applications. However, because NMFS surveys crab stocks in the Eastern Bering Sea, CLA is not the preferred method for stock assessment in this region and results are not reported here.

CURRENT STOCK STATUS

Bristol Bay Red King Crabs

LBA estimates of Bristol Bay red king crab abundance and 95% bootstrap confidence limits for 1997 are shown in Table 1. Historical changes in legal male and mature female abundance are graphed in Figure 1. An above average 1990 year class, apparently the 7th largest since 1973, was nearly fully recruited to the surveyed stock during 1997. This recruitment event led to a substantial increase in most segments of the stock, except for legal crabs. Compared to 1996, mature males increased from 8.5 to 10.5 million and legal males were unchanged at 5.9 million. Mature females more than doubled from 10.5 to 23.7 million and effective spawning biomass[1] (ESB) increased from 21.3 to 31.4 million pounds.

In last year's report (Zheng et al. 1996a), we noted an increasing trend in the abundance of small males (<115 mm CL) and females (<105 mm CL) during 1994-1996. In 1997, the increase in abundance included males up to 130 mm CL and females up to 110 mm as the crabs in the 1990 year class grew in size and became more fully recruited to the survey gear and to the stock modeled by LBA (Figure 2). Changes in abundance of males >130 mm CL and females >125 mm CL were negligible.

[1] ***Effective spawning biomass*** is the estimated biomass of mature female crabs that the population of mature male crabs successfully mate in a given year.

Examination of size frequency distributions from NMFS surveys provides much insight into the recent changes in this stock (Figure 3). Although abundance estimates of juvenile males <95 mm CL and females < 90 mm CL are unreliable and are not included in LBA analysis, recent size frequency modes of juvenile crabs during 1994-1997 appear to track the strong year class that is now nearly fully recruited to the modeled stock. Although the dual modes in 1996 are not evident in 1997, the principal modes seem to increase in abundance and CL each year. The increase in CL is explained by growth in size, whereas the increase in apparent abundance is explained by increased catchability by survey gear as the crabs get larger. This year class is most likely the progeny of parental mating during early spring 1990, though it may contain a combination of 1989-1991 year classes.

LBA estimates of abundance compare favorably with area-swept methods over the history of the survey (Figure 1). Yet, in 1997 there are some notable differences. LBA estimates of legal and mature males were 5.9 and 10.5 million compared to preliminary area-swept estimates of 9.4 and 12.7, respectively. In 1997, the difference between LBA and area-swept estimates of legal males was the largest since the middle to late 1970s (Figure 1). On the other hand, mature females estimated by LBA (23.7 million) and area-swept methods (25.4 million) were very similar.

The reasons for the differences in abundance estimates for large male crabs between the two methods is evident by comparing size frequency distributions (Figures 2 and 3). Size frequencies from area-swept estimates show a slight decline in abundance of males >120 mm CL from 1994 to 1996 (Figure 3). Yet, in 1997, the abundance of males >140 mm CL nearly doubled over 1994-1996 levels. This increase in 1997 is not consistent with the previous years' data. Note that the 1990 year class is primarily 85-125 mm CL in 1997 — too small in size to have contributed to a real increase in males >140 mm CL (Figure 3). These are exactly the types of inconsistencies that the LBA is intended to address. Note that the size frequencies of these large crabs over 1995-1997 from the LBA (Figure 2) show a more consistent trend of abundance that is compatible with the weak levels of recruitment of this stock for the past decade prior to 1997 (Table 1).

Just as historical survey results enter into the LBA and modify the interpretation of data from 1997, the 1997 survey results also provide additional information about reconstructed stock size in recent years. Thus, historical abundance estimates generated with data from 1972-1997 (Table 1) differ slightly from estimates generated with data from 1972-1996 (see Table 1 in Zheng et al. 1996a). Likewise, in the future, reconstructed abundance estimates will change with the addition of new data.

It should also be noted that the abundance of the 1990 year class is quite uncertain at this time, because it has just been recruited to the surveyed and modeled stock. As crabs in this year class grow in size with age, we will be able to follow them over time. Repeated observations will allow us to refine our estimates of year class strength. Nonetheless, we updated the stock-recruitment results from last year (Zheng et al. 1996a) with the new data point for the 1990 year class (Figure 4). The position of this data point will undoubtedly change up or down as we learn more about this year class.

Clearly, the apparent size of the 1990 year class is good news for this stock. This stock is recovering, though the 31.4 million pounds of ESB is well short of our target rebuilding level of 55 million pounds (Table 1). Later in this report, we speculate on the future prospects for this stock.

Blue King Crabs

St. Matthew Island. CSA estimates of St. Matthew Island blue king crab abundance and 95% bootstrap confidence limits for 1997 are shown in Table 2. Historical changes in legal male abundance are graphed in Figure 5. Compared to 1996, an increase in legal males from 3.1 to 4.1 million and little change in prerecruits from 2.0 to 2.3 million combined to result in an increase of mature male crabs from 5.1 to 6.4 million. Most of the increase in legal male crabs was due to an apparent increase in recruitment (Table 2). As the two-stage CSA is not capable of estimating measurement errors (and confidence intervals) of recruits in the final year (1997), recruits are primarily determined by survey results that have not been filtered to remove measurement errors. Thus, this apparent increase in mature male and legal abundance is tempered by relatively low confidence in the population estimates and by fishery performance in 1996 that fell short of expectations. We are currently developing a three-stage CSA for use with stock assessment data in 1998. This three-stage assessment will include prerecruits. Thus, measurement errors (and confidence limits) for recruits, postrecruits, and legal crabs should be available next year.

Pribilof Islands. For the Pribilof Islands, changes from last year included a slight decrease in legal male abundance from 0.9 to 0.8 million. This change is attributable to a slight increase in recruits and a slightly larger decrease in postrecruits. More significantly, prerecruits dropped from 0.9 to 0.3 million. Taken together, mature male abundance declined by 41% from 1.8 to 1.1 million.

FISHERY MANAGEMENT IMPLICATIONS

Bristol Bay Red King Crabs

Directed Crab Fishery. In March 1996 the Alaska Board of Fisheries adopted a new fishery management strategy to promote stock rebuilding and optimal harvest of the Bristol Bay red king crabs (Zheng et al. 1996c). The strategy sets an annual guideline harvest level (GHL) by harvest rate coupled to a fishery threshold. When the stock is at or below threshold of 8.4 million mature females (>90 mm CL) or 14.5 million pounds of ESB, the fishery is closed. When the stock is above both of these criteria, GHL is determined by the abundance of mature and legal-sized males. A mature male harvest rate of 10% is applied to promote stock rebuilding when ESB is below the target rebuilding level of 55 million pounds. Once the stock is rebuilt (at or above 55 million pounds of ESB) a 15% harvest rate is applied to mature male abundance. To prevent a disproportionate harvest of large male crabs, the GHL is capped so that no more than 50% of the legal male crabs may be harvested in any one year.

In 1997 the estimates of mature female abundance and ESB were 23.7 million and 31.4 million pounds, respectively — both well above the thresholds needed to conduct a directed commercial fishery. Because ESB remains below the target rebuilding level of 55 million pounds, a 10% rebuilding harvest rate is applied. Applying this harvest rate times mature male abundance of 10.5 million results in a harvest of 1.05 million crabs. Because 1.05 million is only 18% of the legals, the 50% cap is not required. By multiplying 1.05 million crabs times an average weight of 6.56 pounds per legal crab, a preseason guideline harvest level (GHL) of 7.0 million pounds is prescribed for the November 1, 1997 opening.

Implications on the Eastern Bering Sea Tanner Crab Fishery. The status of the Bristol Bay red king crab stock has implications on the eastern Bering Sea Tanner crab fishery. In years, such as 1994 and 1995, when the red king crab fishery was closed, the waters of the eastern Bering Sea east of 163^{o} West longitude do not open for Tanner crab fishing by regulation 5 AAC 35.519. This area closure, coupled to regulation 5 AAC 35.525 that restricts vertical tunnel entrances to 3 inches, reduces potential impacts of the Tanner crab fishery on king crab stocks. Because the red king crab fishery will open in 1997, the Tanner crab fishery will not be restricted to areas west of 163^{o} W by this regulation. In 1997, the Tanner crab season in waters east of 168^{o} W will open and close concurrent with the red king crab fishery. This promotes efficiency in these crab fisheries while reducing handling and bycatch. However, this Tanner crab stock has declined to depressed levels in recent years, and much concern exists for conservation. Management actions concerning a directed fishery for Tanner crabs in the Eastern Bering Sea will be carefully evaluated and announced in the near future.

Implications on the Bering Sea Groundfish Trawl Fisheries. In June 1996, the North Pacific Fishery Management Council (NPFMC 1996b) adopted new guidelines for setting annual prohibited species catch (PSC) limits for red king crabs caught during groundfish trawl fisheries as a function of estimated ESB of Bristol Bay red king crabs in the prior year (see Figure 3 in Zheng et al. 1996a). When ESB exceeds 14.5 million pounds but is less than 55 million pounds, the PSC is 100,000 crabs. Given the estimate of 31.4 million pounds of ESB for 1997, the PSC limit for groundfish trawl fisheries in the Bering Sea will be set at 100,000 crabs for 1998.

Also in June 1996, the NPFMC established a year-round closure to non-pelagic trawling in the Red King Crab Savings Area (162^{o} to 164^{o} W, 56^{o} to 57^{o} N) to protect adult red king crabs and their habitat (NPFMC 1996b). In years in which there is a red king crab fishery in Bristol Bay, such as 1997, the portion of the Red King Crab Savings Area bounded by 56^{o} to 56^{o} 10' N latitude will remain open to the rock sole fishery in 1998. A separate bycatch limit is established for this area not to exceed 35% of the red king crab prohibited species catch (PSC) limits apportioned to the rock sole fishery by the NPFMC.

Blue King Crabs

For St. Matthew Island, the fishery management plan specifies a 20% harvest rate when the stock is above the threshold of 0.6 million mature males. (Pengilly and Schmidt 1995). For 1997, the 6.42 million mature male abundance was well above threshold. Thus, we established the GHL at 5 million pounds based on mature male abundance, the 20% harvest rate, and a mean weight of 3.96 pounds per legal crab. The blue king crab fishery at St. Matthew Island is scheduled to open on September 15, 1997.

For the Pribilof Islands, the fishery management plan specifies a threshold of 0.77 million mature male blue king crabs; no threshold is specified for red king crabs (Pengilly and Schmidt 1995). In recent years, trends in survey and fishery performance data have been used to set an aggregate GHL for a combined blue and red king crab fishery to avoid bycatch problems that would occur if each fishery was managed separately. From 1996 to 1997, the abundance of mature male blue king crabs declined by 41% to 1.1 million — slightly above fishery threshold. Although abundance estimates of mature male red king crabs appeared to increase from 1996 to 1997, precision of abundance estimates is low for both stocks. Another consideration is that the fishery performed below expectations during 1995 and 1996[2]. Given the uncertainty of the population estimates, the decline in blue king crab abundance and the poor performance of recent fisheries for red king crabs, GHL is set at 1.5 million pounds for the combined fisheries at Pribilof Islands. This red and blue king crab fishery at Pribilof Islands is scheduled to open on September 15, 1997.

FUTURE OUTLOOK

The future outlook for these king crab stocks is mixed. For St. Matthew and Pribilof Islands, wide confidence intervals in the abundance estimates and limited biological information render predictions difficult. However, based on trends in prerecruits and recruits for blue king crabs, we anticipate continued decline at the Pribilof Islands and some further improvement at St. Matthew Island through 1998 or 1999. Survey results from 1997 provide some optimism for Pribilof Islands red king crabs, but fishery performance has not yet revealed evidence of an improving stock.

Regarding Bristol Bay red king crabs, last year we speculated that slight improvement in recruitment from 1994 to 1996 could represent the leading edge (e.g., the fastest growing segment) of a year class that had not fully recruited to the survey gear (Zheng et al. 1996a). We further inferred that the stock could experience increased recruitment in the ensuing

[2] In 1995 the combined GHL was 2.5 million pounds and the fishery caught 2.2 (0.9 red and 1.3 blue king crabs) million pounds. In 1996 the combined GHL was 1.8 million pounds and the fishery caught 1.1 (0.2 red and 0.9 blue king crabs) million pounds.

year or two. The most recently completed survey during summer 1997 shows that this forecast was basically correct. However, we had no idea that the 1990 year class would be nearly as large as it now appears. Accurate predictions of recruitment are difficult because juvenile abundance estimates are imprecise and sometimes misleading.

What do we predict for 1998 and beyond? There are reasons to be optimistic about the future status of the Bristol Bay stock of red king crabs, at least over the short term. Recruitment of the 1990 year class should sustain the adult population for a number of years. It is conceivable that total stock abundance may show some slight continued increase into 1998 as the remainder of this year class is recruited. However, it may be more likely that the stock will show little change or a slight decrease in numbers in 1998. Total stock biomass (weight) should continue to increase through 1999 or 2000 as growth in body weight exceeds loss in numbers of this cohort due to mortality.

Over the intermediate term, there is some cause for concern. After the full recruitment of the 1990 year class, we suspect that the spawning stock will decline thereafter for three or more years into the 21st Century. Although abundance estimates on juvenile red king crabs <90 mm CL are imprecise, the same size frequency data that gave hints of the 1990 year class as early as 1994, imply that several very weak year classes follow the 1990 year class based on data from 1997 (Figure 3). The duration of the ensuing downturn in the stock will depend on future recruitment from year classes that are not yet observed by trawl survey gear.

Our recent investigations on stock-recruitment relationships (Zheng et al. 1995a,b) and potential environmental effects (Tyler and Kruse 1996) offer some additional insights beyond those that can be made from recent survey results alone. We fitted a stock-recruit curve to data on ESB and recruitment that incorporates both stock (density-dependent) and environmental (autocorrelated) effects (Figure 4). Implications of the density-dependent component are that low recruitment results from low spawning stocks and moderate recruitment results from high spawning stocks. When stocks are intermediate, the probability of strong recruitment is greatest.

However, note that there are differences between the recruitment predicted from the curve and the recruitment observed as data points (Figure 4). Whereas the curve in Figure 4 explains the effect of spawning biomass on recruitment, deviations from the curve, such as occurred for the 1990 year class, are most likely due to environmental factors.

A number of hypotheses have been proposed about causes of these “environmental” effects including predation, food, and physical oceanographic conditions on king crab recruitment (Tyler and Kruse 1996). Unfortunately, the general decline of crab recruitment during the 1970s and 1980s in Bristol Bay corresponds to similar broad trends in many physical and ecological factors, and it is not yet possible to draw definitive conclusions about cause and effect. Turnarounds in recruitment, such as occurred with the 1990 year class, should assist our investigations.

Shifts in some physical oceanographic and ecological conditions of the Bering Sea and Gulf of Alaska seem related to the Aleutian Low Pressure System. Yearly trends in atmospheric pressure for January reveal a deepening of the Aleutian Low during the late 1960s through mid-1970s and a weakening of the Aleutian Low during the late 1970s through the late 1980s (Tyler and Kruse 1996). An intense Aleutian Low in winter increases upwelling of deep nutrients in the Alaska Gyre and is associated with higher phytoplankton and zooplankton production the following summer. The strength of the Aleutian Low, as indexed by the mean pressure in the North Pacific over the area 20^o N 60^0 N during January, explains about 36% of the variability in red king crab recruitment in Bristol Bay (Tyler and Kruse 1996). During 1989-1994, the Aleutian Low deepened again reminiscent of the late 1960s to mid-1970s perhaps causing environmental conditions that favor the 1989-1994 year classes. On the other hand, another widely used measure of the Aleutian Low, the North Pacific Index (Trenberth and Hurrell 1994), revealed a deepening of the Aleutian Low during 1989-1991 only and a reversal to weakened low pressure conditions through 1996 with exception of 1994. In any case, the relationship between king crab recruitment and barometric pressure is weak and more years of data are required to know whether it really holds. New research is needed to identify the underlying causes.

The key to continued stock rebuilding will be to patiently accumulate good year classes, such as the 1990 year class, regardless of whether improved recruitment results from increased ESB, higher survival associated with more favorable environmental conditions, or a combination of both. The current harvest strategy for Bristol Bay red king crabs is designed to promote stock rebuilding so that ESB can achieve the 55 million pound target level in the not-so-distant future. It is unlikely that the 1990 year class alone will rebuild the stock by itself, but hopefully subsequent progeny from this increased spawning stock and the next turnaround in environmental conditions will provide for another burst of recruitment toward the end of the first decade of the next century.

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Table 1. Annual abundance estimates (millions of crabs), effective spawning biomass (millions of pounds), and 95% confidence intervals for red king crabs in Bristol Bay estimated by length-based analysis. Size measurements are mm CL.

	Males					Females		
Year	Recruits	Small	Prerec.	Mature	Legal	Recruits	Mature	Effective Spawning Biomass
mm→		(95-109)	(110-134)	(>119)	(>134)		(>89)	
a. Abundance Estimates and Spawning Biomass								
1972	NA	13.464	14.991	18.433	9.961	NA	59.707	55.245
1973	29.811	20.650	26.089	22.472	10.748	33.008	69.927	63.239
1974	20.597	14.965	34.825	34.019	14.765	28.116	71.392	93.396
1975	31.872	22.002	35.960	41.038	20.529	21.843	66.061	116.536
1976	43.370	30.094	45.295	48.753	25.389	34.445	75.388	129.274
1977	50.127	35.085	59.024	61.512	30.187	71.964	118.627	163.650
1978	19.138	14.940	57.518	74.237	39.244	46.214	119.529	199.305
1979	12.362	9.073	36.303	72.408	46.642	18.774	92.812	166.543
1980	23.364	16.003	25.500	58.568	43.446	35.932	93.529	166.120
1981	17.187	12.397	17.016	18.025	9.415	13.544	71.479	58.281
1982	22.985	15.986	16.028	10.018	2.917	17.362	29.972	23.567
1983	13.101	9.698	13.690	8.857	2.433	4.784	10.050	16.759
1984	18.503	12.849	12.908	8.082	2.337	11.729	13.497	16.337
1985	8.951	6.752	10.460	6.799	1.787	4.585	6.950	10.411
1986	5.865	4.416	12.250	11.434	4.236	3.787	8.911	14.180
1987	6.170	4.424	10.793	13.273	6.433	8.446	15.031	23.792
1988	5.834	4.209	9.806	13.868	7.898	5.475	16.567	27.787
1989	4.739	3.468	8.998	14.891	9.340	5.342	17.596	30.800
1990	1.377	1.187	6.912	14.554	9.867	0.891	13.910	26.946
1991	4.058	2.769	4.999	11.709	8.403	3.758	14.075	27.401
1992	5.355	3.765	5.914	9.859	6.739	3.532	13.949	27.396
1993	1.958	1.841	6.636	9.935	6.014	2.268	12.594	25.596
1994	0.934	0.879	5.224	8.517	4.839	0.430	9.760	21.457
1995	2.419	1.722	4.111	8.476	5.643	1.793	9.034	19.783
1996	3.336	2.453	4.457	8.530	5.925	3.844	10.535	21.258
1997	23.113	15.459	11.674	10.495	5.858	15.910	23.699	31.415
b. 95% Confidence Limits in 1997								
Lower	20.544	NA	9.848	8.726	4.838	12.013	19.111	NA
Upper	26.649	NA	12.629	11.143	6.511	21.329	29.459	NA

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Table 2.Annual abundance estimates (millions of crabs) and 95% confidence intervals for male blue king crabs off St. Matthew and Pribilof Islands. Prerecruits are estimated by area-swept methods from NMFS surveys. Recruits, postrecruits and legals are estimated by catch-survey analysis. St. Matthew Island recruits are newshell males of size 120-133 mm CL and Pribilof Island recruits are newshell males of size 135-148 mm CL. All other legal males are postrecruits. Mature crabs include prerecruits plus legals. Size measurements are mm CL.

	St. Matthew Island					Pribilof Islands				
Year mm→	Prerec. (105-119)	Mature (≥105)	Recruit	Post.	Legal (≥120)	Prerec. (120-134)	Mature (≥120)	Recruit	Post.	Legal (≥135)
a. Abundance Estimates										
1980	2.59	5.48	1.70	1.20	2.90	1.28	6.60	1.40	3.92	5.32
1981	1.48	5.25	1.48	2.30	3.78	0.72	3.92	0.64	2.56	3.20
1982	2.62	7.59	2.98	2.00	4.98	0.31	2.09	0.51	1.26	1.77
1983	1.64	5.05	1.31	2.10	3.41	0.62	1.66	0.28	0.76	1.04
1984	0.50	2.20	0.84	0.86	1.70	0.23	0.94	0.20	0.51	0.71
1985	0.43	1.42	0.45	0.54	0.99	0.16	0.81	0.16	0.49	0.65
1986	0.42	0.97	0.22	0.33	0.54	0.02	0.53	0.11	0.41	0.51
1987	0.76	1.60	0.62	0.22	0.84	0.07	0.48	0.06	0.35	0.41
1988	0.70	1.80	0.64	0.45	1.09	0.00	0.25	0.03	0.22	0.25
1989	1.24	2.76	0.94	0.59	1.53	0.00	0.19	0.00	0.19	0.19
1990	0.96	2.77	0.83	0.99	1.82	0.66	1.15	0.35	0.14	0.49
1991	1.64	4.02	1.30	1.08	2.39	0.79	1.79	0.64	0.36	1.00
1992	1.58	4.05	1.25	1.22	2.47	0.73	1.86	0.39	0.74	1.13
1993	1.99	4.60	1.15	1.46	2.61	0.64	1.85	0.37	0.84	1.21
1994	1.35	3.89	1.05	1.49	2.54	0.31	1.43	0.22	0.90	1.12
1995	1.32	3.62	1.06	1.25	2.30	0.84	2.06	0.38	0.83	1.22
1996	1.97	5.10	1.92	1.21	3.13	0.94	1.82	0.14	0.74	0.88
1997	2.32	6.42	2.21	1.88	4.10	0.26	1.08	0.28	0.54	0.82
b. 95% Confidence Limits in 1997										
Lower	NA	NA	NA	NA	2.87	NA	NA	NA	NA	0.58
Upper	NA	NA	NA	NA	5.32	NA	NA	NA	NA	1.06

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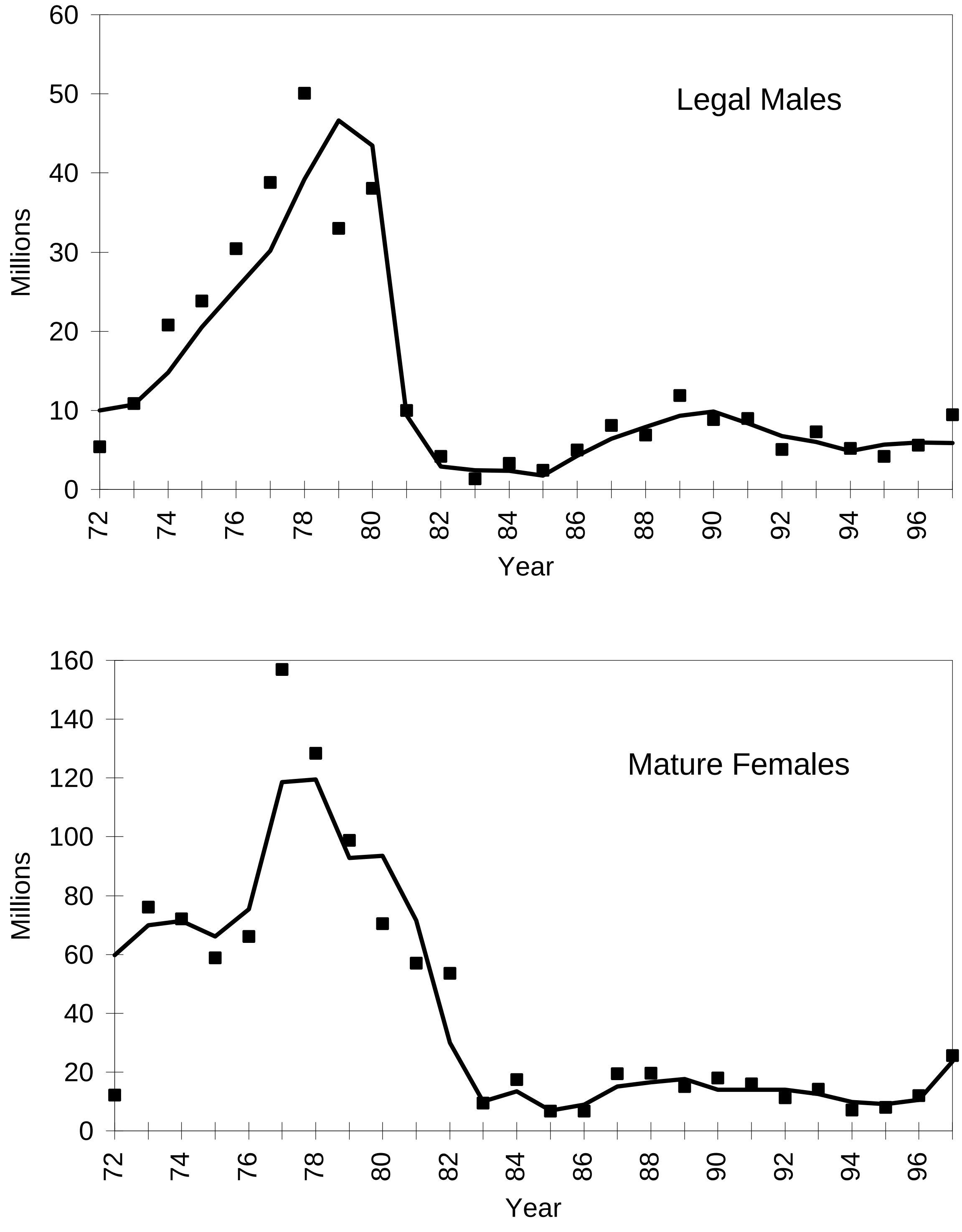

Figure 1. Comparison of abundance estimates (millions of crabs) of Bristol Bay red king crabs from area-swept estimates (dots) and length-based analysis (line) for legal males (top panel) and mature females (bottom panel).

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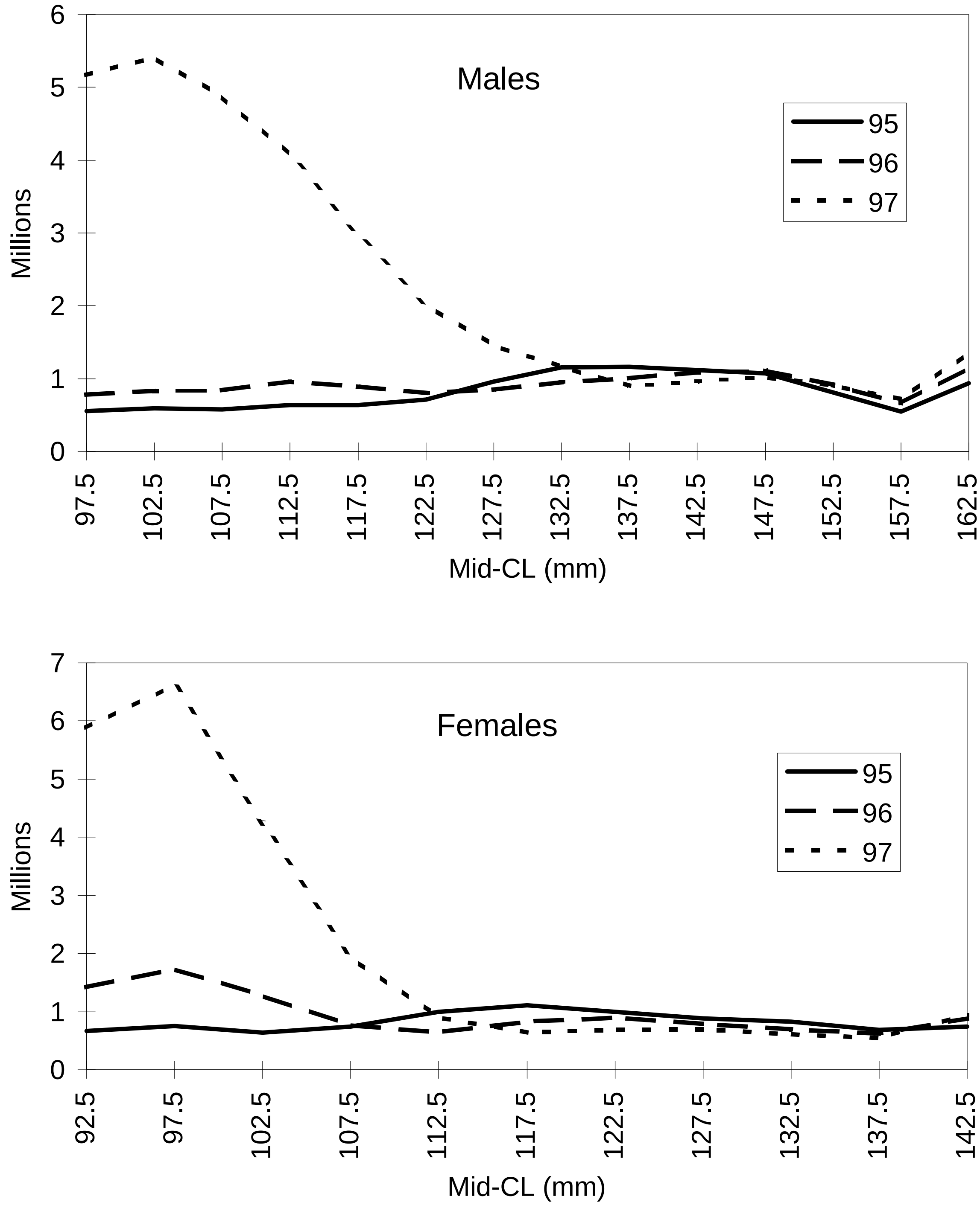

Figure 2. Size-frequency distributions of male (top panel) and female (bottom panel) red king crabs in Bristol Bay as estimated by length-based analysis for 1995-1997.

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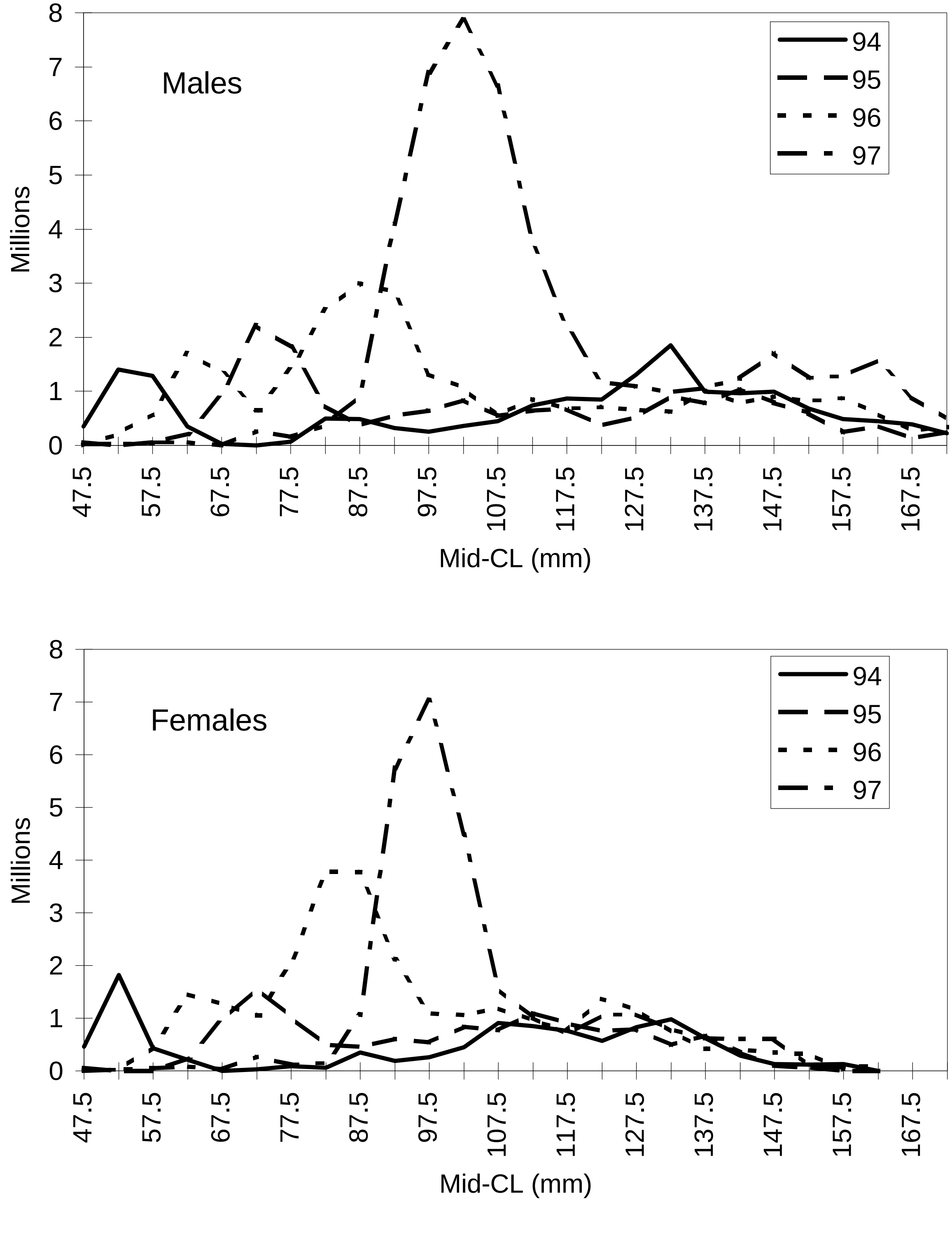

Figure 3. Size frequency distributions of male (top panel) and female (bottom panel) red king crabs in Bristol Bay from NMFS trawl surveys during 1994-1997. Abundance estimates are based on area-swept methods not LBA.

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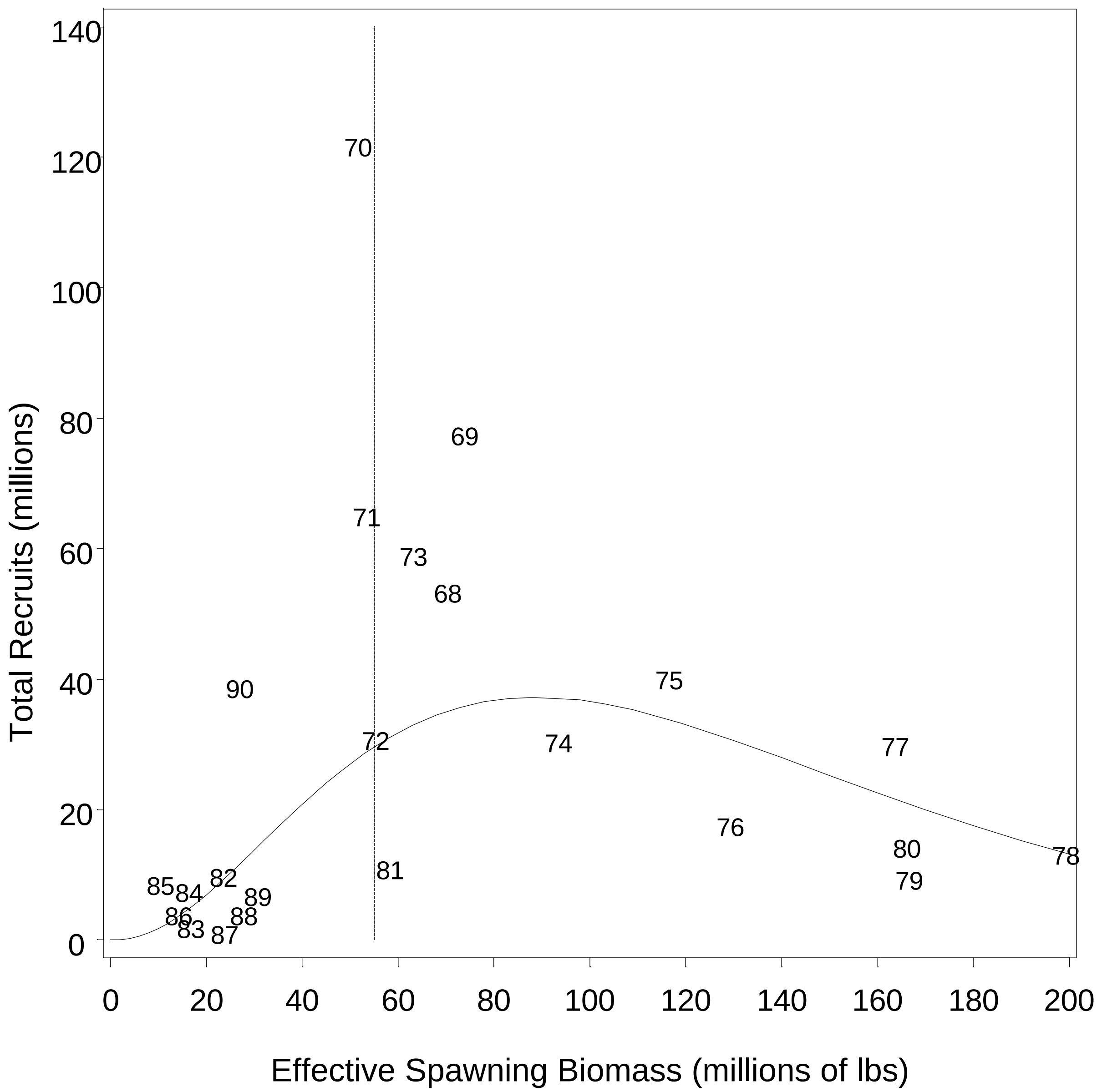

Figure 4. Stock-recruit relationship for Bristol Bay red king crabs from LBA abundance estimates. Recruits are age 6.2 from date of hatching corresponding to a 7-year lag from spawning to recruitment. Numbers refer to brood year (year of spawning). Effective spawning biomass is defined in the text. The vertical dotted line indicates the target rebuilding level of 55 million pounds of effective spawning biomass.

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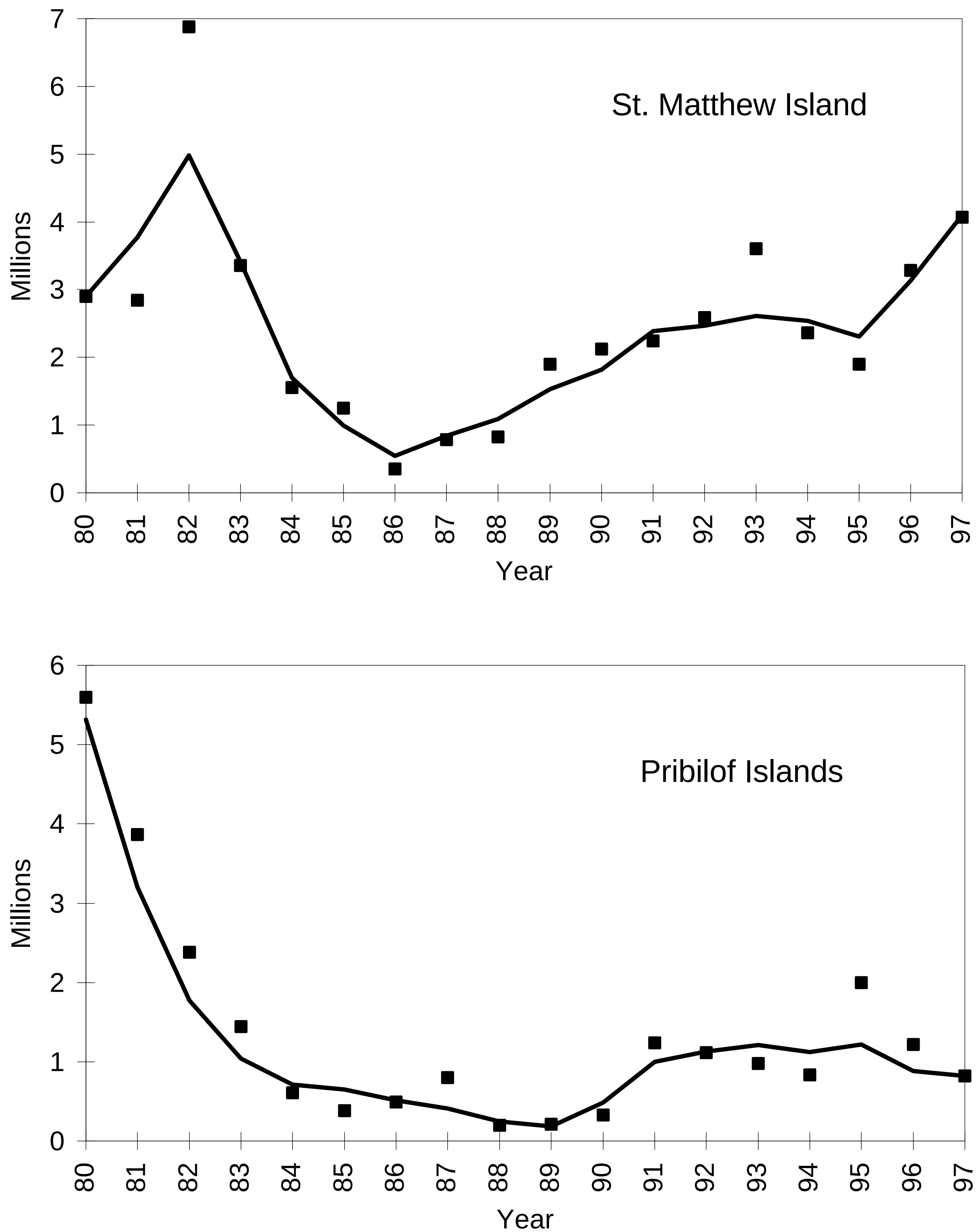

Figure 5. Comparison of abundance estimates (millions of crabs) of legal-sized male blue king crabs from area-swept estimates (dots) and catch-survey analysis (line) for St. Matthew (top panel) and Pribilof Islands stocks (bottom panel).

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