Assessment of Relative Abundance and Size of Juvenile Shrimp (*Penaeus* spp.) and Blue Crab (*Callinectes sapidus*) in Texas Coastal Waters, 1977-86

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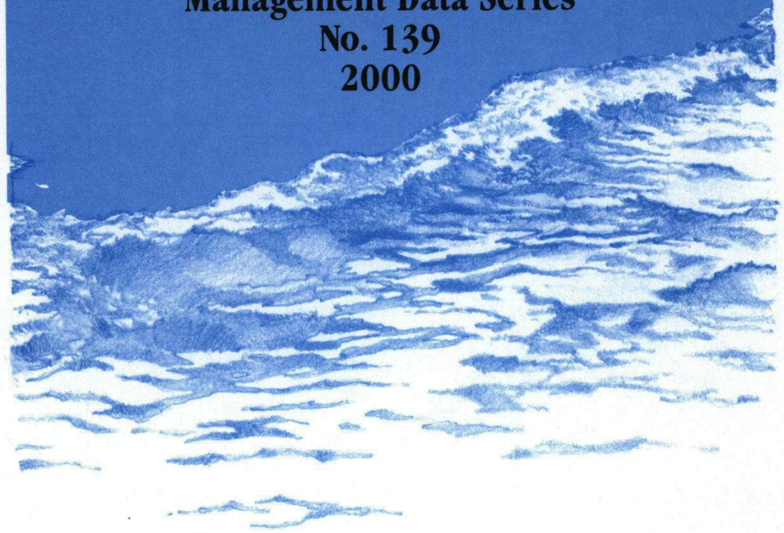
Management Data Series
No. 139
2000



TEXAS
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COASTAL FISHERIES DIVISION
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ABSTRACT

Analyses of peak seasonal abundance and size of juvenile brown shrimp (*Penaeus aztecus*), white shrimp (*P. setiferus*), pink shrimp (*P. duorarum*), and blue crab (*Callinectes sapidus*) collected in Texas coastwide bag seine samples revealed significant differences among years in mean catch rates and mean lengths. Peak seasonal catch rate data were used to develop sample size curves to determine number of seasonal coastwide bag seine samples required to detect a given percent difference in catch rate among years.

INTRODUCTION

Texas commercial fishery landings are dominated by penaeid shrimp followed by blue crab (*Callinectes sapidus*) (Osburn et al. 1987). Texas coastwide annual reported shrimp landings during 1977-86 averaged over 37 million kg worth $164 million (ex-vessel). Of these landings, 74% were brown (*Penaeus aztecus*) and pink (*P. duorarum*) shrimps, 25% were white shrimp (*P. setiferus*), and 1% were "other" species. During the same period, blue crab coastwide annual reported landings averaged 8.4 million kg worth $2.5 million.

Sound management of such a fishery is vital. With adoption of the Texas Shrimp Fishery Management Plan (Cody et al. 1989), and Blue Crab Fishery Management Plan (Cody et al. 1992) the shrimp and blue crab fisheries in Texas are regulated by the Texas Parks and Wildlife Commission (TPWC). Texas Parks and Wildlife (TPW) is responsible for investigating the supply, economic value and other aspects of the fishery to provide information on which to base sound management.

Estimation of recruitment is essential for prediction of abundance of fishery stocks and for effective fisheries management (Cushing 1968, Gulland 1977, Ricker 1978). In 1977, TPW began a standardized year-round fishery independent monitoring program to supply information for fishery management. Fishery independent indices of relative abundance are preferred over fishery dependent indices when using fishery models because biases in gear modifications, species size selection, and inadequacies in reporting commercial landings are reduced (Cushing 1968, Matlock 1982, McEachron and Green 1984). Recruitment data can be obtained through TPW's standardized fishery independent coastwide bag seine monitoring program. Of primary importance to a successful monitoring program is an adequate sample size for detecting significant differences in catch rates when making year-to-year assessments of relative abundance. However, year-round assessment of relative abundance and size of many species of juvenile shellfish present some analytical problems. Because of species specific spawning periods, there will be periods throughout the year when there will be a great number of zero bag seine catches for a specific species. These zero catches provide no useful information on year-to-year recruitment of the specific organisms and tend to hinder analyses through distortion of means and variances. In addition, because abundance and frequency of appearance vary in bag seine samples for various species, the power of year-to-year tests will vary from species to species for a given number of samples in a standard sampling regime.

The objectives of the present study were to:

1. Determine peak seasonal abundance of young-of-the-year (YOY) brown shrimp, white shrimp, pink shrimp, and blue crabs in coastwide bag seines for use as an indicator of annual recruitment.

2. Determine if there are differences among yearly peak seasonal catch rates and size of YOY brown shrimp, white shrimp, pink shrimp, and blue crabs.

3. Determine number of coastwide bag seine samples that need to be collected seasonally, to determine if a given percent difference exists in catch rates of YOY among years.

MATERIALS AND METHODS

Brown shrimp, white shrimp, pink shrimp, and blue crabs were collected with bag seines (18.3 m deep with 1.3-cm stretched nylon multifilament mesh in the central bag) in seven Texas bay systems (Galveston, Matagorda, San Antonio, Aransas, Corpus Christi, and upper and lower Laguna Madre) from January 1978 to December 1986; East Matagorda Bay was added in February 1983 and Sabine Lake was added in January 1986. Six randomly selected samples were collected in each bay system each month from January 1978 to September 1981; 10 samples were collected each month from October 1981 to December 1986 (Rice et al. 1988).

Size Determination for YOY

Total lengths (shrimp: tip of rostrum to tip of telson; crabs: carapace width measured from tip of spine to tip of spine) for each species were obtained from a random selection of no more than 19 individuals of each species in each sample. Because juvenile YOY were used for recruitment, infrequently caught sub-adult and sub-juvenile individuals were excluded from analyses by constructing length-frequency charts (5-mm increments TL) for each species, combining data from all bay systems, all months and all years. Relative frequencies of 5-mm groups derived from the length-frequency charts were used to determine size range of individuals to be used in later analyses. Lengths were deleted from the upper and lower ends of length-frequency distributions wherein the 5-mm length increments accounted for less than 5% of the total number measured. Therefore, organisms used for recruitment analyses ranged from 33-82 mm for both brown shrimp (90% of total measured) and white shrimp (81% of total measured), from 28-77 mm for pink shrimp (89% of total measured), and from 13-42 mm for blue crab (58% of total measured). Size ranges closely represent optimum juvenile growth within a month for the specific species (Cody et al. 1989, Hammerschmidt 1982), therefore, representing monthly recruitment of the specific species to bag seines in Texas' bays.

Data Weighting

The area sampled by a single bag seine tow was expressed to the nearest 0.01 ha. Catch rate for each species in a sample within specified size ranges was weighted to No./ha for analyses. Individual lengths for each species were weighted to No./ha for bag seine samples with all individuals measured ($\leq$19). For samples with >19 individuals of each species, individual lengths were weighted for number not measured (number of individuals in sample/number of individuals measured) and No./ha.

Peak Seasonal Abundance Determination

Specific peak seasons for analyses among years for each species were determined by conducting Duncan's multiple-range test (Steel and Torrie 1960) for comparisons among monthly mean catch rates, and by graphing catch rate by month (using combined data from all bay systems and all years). A specific season for maximum recruitment of each species was then determined by selecting peak periods (months) of abundance consulting graphs and Duncan's multiple comparisons; giving some consideration to possible early or late recruitment to bag seines in relation to knowledge of the specific species.

Data Analyses

SAS (SAS Institute Inc. 1985) software programs were used for all analyses. Catch rates for each species were found to be heteroscedastic based on F_{max} test (Sokal and Rohlf 1981): brown shrimp and blue crab were the least heteroscedastic; white shrimp and pink shrimp the most. Length data for pink shrimp were found to be moderately heteroscedastic, whereas length data for brown shrimp, white shrimp and blue crab were not heteroscedastic. Sokal and Rohlf (1981) state moderate heterogeneity of variances is not too serious for overall test of significance.

Using the SAS UNIVARIATE procedure, it was determined that catch rate and length data for each species were not normally distributed. Catch rate data were found to exhibit great skewness and kurtosis. Therefore, data were analyzed non-parametrically by ranking data and then testing for significant differences ($P \leq 0.05$) among years using the SAS procedure GLM (with ranked data, equivalent to Kruskal-Wallis test) for a one-way analysis of variance (AOV) with unequal sample size (SAS Institute Inc. 1985, Sokal and Rohlf 1981). Because length data were graphically found to be only slightly skewed (close to a normal distribution) data were not transformed or ranked and normal parametric procedures (SAS GLM) were used to analyze the data. The GT2-method for a one-way AOV with unequal sample size (SAS GLM MEANS option) was used to determine which years were different for both ranked mean catch rates and untransformed mean lengths (Sokal and Rohlf 1981).

Sample Size Determination

Sample size selection curves to determine the number of samples required to significantly detect a specific percent difference among years for catch rate were calculated using the following equation (Sokal and Rohlf 1981):

$$n \geq 2(CV/d)^2(t_{\alpha[v]} + t_{2(1-P)[v]})^2$$

where

n	=	number of samples required;
CV	=	coefficient of variation (%);
d	=	smallest difference that is desired to be detected (% of mean);
α	=	significance level (precision);
P	=	probability a true difference as small as d will be found significant;

and

$t_{\alpha[v]}$ and $t_{2(1-P)[v]}$ = values from a 2-tailed t-table with v degrees of freedom and corresponding to probabilities of α and 2 (1-P), respectively.

The sample size selection method is a parametric procedure with all normal assumptions. Because catch data in the present study were not normally distributed, and nonparametric ranked data were not appropriate for use in the sample size selection method, catch rates were log transformed [$\log_{10}$ (catch rate + 1)], bringing data distributions closer to normality.

Sample size requirements for a detectable percent difference in catch rate data (significance level = 0.05; P = 80%) are presented in relation to the standard number of coastwide samples collected during 1986 within each species specific peak seasonal period for YOY (brown shrimp-360 samples; white shrimp-450 samples; pink shrimp-540 samples; blue crab-360 samples). TPWD would like to detect $\leq$50% difference in catch rates of YOY among years at a significant level $\leq$0.05 and P $\geq$80%.

RESULTS

Brown Shrimp

Peak seasonal abundance for YOY brown shrimp (33-82 mm TL) occurs during April-July (Table 1, Figure 1). Significant differences were found among years for both mean catch rate and mean length (Tables 2 and 3). Multiple comparison tests revealed mean catch rate in 1979 differed significantly from all other years except 1980 and 1983; years 1980-86 were similar to each other (Table 4). Analysis of mean length revealed each year differed significantly from all other years (Table 5). Untransformed mean catch rate and mean length fluctuated throughout the period, with highest catch rate during 1981, 1982 and 1985 and greatest mean length during 1984 and 1986 (Figures 2 and 3).

A 16% difference in mean coastwide catch rates of brown shrimp among years (CV = 74) could be detected with 360 samples at a significance level of 0.05 with P = 80%, and with 637 samples at a significance level of 0.01 with P = 90% (Figure 4).

White Shrimp

Peak seasonal abundance for YOY white shrimp (33-82 mm TL) occurred during July-November (Table 1, Figure 1). Significant differences were found among years for both mean catch rate and mean length (Tables 2 and 3). Multiple comparison tests revealed mean catch rate within grouped years 81/82/83/84, 81/82/83, and 78/79/80/81/83/85/86 were similar among years within each group but differed among years outside each group (Table 4). Analysis of mean length revealed grouped years 79/84 and 84/81 were similar among years within each group, but differed among other years (Table 5). Untransformed mean catch rate and mean length fluctuated throughout the period, with highest catch during 1982 and greatest mean length during 1986 (Figures 2 and 3).

A 19% difference in mean coastwide catch rate of white shrimp among years (CV = 103) could be detected with 450 samples at a significance level of 0.05 with P = 80%, and with 875 samples at a significance level of 0.01 with P = 90% (Figure 5).

Pink Shrimp

Two peaks in seasonal abundance were defined for YOY pink shrimp (28-77 mm TL), but were considered as one for data analyses. Peak abundance was March-April and August-November (Table 1, Figure 1). Significant differences were found among years for both mean catch rates and mean lengths (Tables 2 and 3). Multiple comparison tests revealed mean catch rates within grouped years 80/81/82, 79/80/81/83/84/86, and 78/79/83/84/85/86 were similar among years within each group, but differed among years outside each group (Table 4). Analysis of mean length revealed grouped years 79/84 and 84/81 were similar among years within each group, but differed among other years (Table 5). Untransformed mean catch rate and mean length fluctuated throughout the period, with highest catch rate during 1981 and 1982 and greatest mean length during 1978, 1980 and 1985.

A 62% difference in mean coastwide catch rate of pink shrimp among years (CV = 363) could be detected with 540 samples at a significance level of 0.05 with P = 80%, and with 1,020 samples at a significance level of 0.01 with P = 90% (Figure 6).

Blue Crab

Peak seasonal abundance for YOY blue crab (13-42 mm TL) was during March-June (Table 1, Figure1). Significant differences were found among years for both mean catch rate and mean length (Tables 2 and 3). Multiple comparison tests revealed mean catch rate within grouped years 79/82/83/85, 79/80/81/82/83/84, and 79/80/81/83/84/86 were similar among years within each group, but differed among years outside each group (Table 4). Analysis of mean length revealed grouped years 80/82 and 79/82 were similar among years within each group, but differed among all other years (Table 5).

Untransformed mean catch rate and mean length fluctuated throughout the period, with highest catch rate during 1985 and greatest mean length during 1986 (Figures 2 and 3).

A 24% difference in mean coastwide catch rate of blue crab among years (CV = 113) could be detected with 360 samples at a significance level of 0.05 with P = 80%, and with 660 samples at a significance level of 0.01 with P = 90% (Figure 7).

DISCUSSION

Magnitude of recruitment of organisms to an ecosystem, and subsequently to a fishery, is of prime importance to fishery managers. Findings in the present study reveal bag seines can be used by fishery managers to assess recruitment of juvenile shellfish populations with a reasonable level of precision. Such bag seine information can be used in developing spawner-recruit relationships, as well as for other population dynamics information. Required sample sizes are not unreasonably large if a seasonal approach to recruitment is utilized. Key elements are that a bag seine program be standardized and that it be conducted routinely. The TPW has been sampling with bag seines since 1978; these long-term data are providing vital information in the management of fishery resources.

In general, seasonal year to year high and low coastwide juvenile mean catch rates and mean lengths for the four species in the present study correspond to total annual mean catch rates and mean lengths for TPW coastwide sampling (Meador et al. 1988, Cody et al. 1989). In most cases high seasonal coastwide juvenile mean catch rate for the four species in the present study correspond to total annual Texas landings (by weight) and total annual value (Osburn et al. 1987) for the specific species analyzed.

The major problem with normality of catch rate data in the present study appears to be due to the large number of samples that produced zero catches of a target species. By defining seasonal periods of abundance for use in analyses, the number of zero catches within a year are greatly reduced, but those remaining still resulted in data not being normally distributed. The authors used ranked data for analyses; however, log-transformed and untransformed data produced parallel results.

Mean length of juvenile pink shrimp in the present study may be biased due to the uncertainty about identification of pink shrimp in the field, resulting from the identification of only larger more recognizable pink shrimp in bag seines during 1978 and possibly other years. The factor of ability to recognize small pink shrimp from small brown shrimp may have also been a limiting factor in coastal bag seine catch rates of pink shrimp throughout the study.

Since 1986 TPW increased the number of bag seine samples collected in each of the nine bay systems along the Texas coast from 10/mo during 1986, to 12/mo beginning March 1988, to 16/mo beginning January 1990, and finally, to 20/mo beginning January 1992. These increases result in greater precision for detectablility of yearly changes in juvenile abundance and size. With 20 bag seine samples/mo the detectablility for a change in mean seasonal coastwide catch rate (using the same CV's in the present study), at the 0.05 significance level with P = 80%, would be 11% for brown shrimp, 14% for white shrimp, 45% for pink shrimp, and 17% for blue crab. These are better than the 50% target levels.

The present report indicates that fishery independent measures of annual season abundance and size of juvenile brown shrimp, white shrimp, pink shrimp, and blue crab caught in TPWD's random bag seine sampling program can be used to develop management techniques with quantified precision levels in relation to recruitment of a specific species to a fishery and subsequent parental stock.

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Table 1. Mean catch rates (No./ha) by month for brown shrimp, white shrimp, pink shrimp, and blue crab in TPW coastwide bag seine collections (combined years 1978-86). Means followed by the same letter in a column are not significantly different (P <0.05).

Brown shrimp		White shrimp		Pink shrimp		Blue crab	
Month	Mean	Month	Mean	Month	Mean	Month	Mean
May	1,495 A	Oct	1,440 A	Oct	30 A	Mar	121 A
Jun	1,018 B	Sep	760 B	Nov	22 A,B	Apr	95 B
Apr	615 C	Nov	723 B	Sep	18 A,B,C	May	66 C
Jul	313 D	Aug	603 B	Apr	16 A, B,C,D	Jun	44 C,D
Aug	182 D,E	Jul	581 B	Aug	16 A,B,C,D	Jul	41 D
Oct	153 E,F	Jun	244 C	Dec	11 B,C,D	Feb	39 D
Sep	150 E,F	Dec	131 C	Mar	10 B,C,D	Dec	35 D
Nov	114 E,F	Jan	4 C	Jun	4 C,D	Aug	32 D
Mar	30 F	Apr	2 C	Jul	2 D	Nov	30 D
Dec	19 F	Mar	1 C	Feb	2 D	Jan	28 D
Jan	8 F	Feb	<1 C	May	2 D	Oct	26 D
Feb	7 F	May	<1 C	Jan	1 D	Sep	21 D

Table 2. Summary of AOV of ranked seasonal catch rates (No./ha) for brown shrimp, white shrimp, pink shrimp, and blue crab in TPW coastwide bag seine collections during 1978-86.

Species	Source of variation	df	Sum of squares	F
Brown shrimp[1]	Total	2,099	841783230	
	Among years	7	13039656	4.70***
	Error	2,092	828743574	
White shrimp	Total	2,894	1946321795	
	Among years	8	40875983	7.74***
	Error	2,886	1905445812	
Pink shrimp	Total	3,460	759556011	
	Among years	8	16550184	9.61***
	Error	3,452	743005828	
Blue crab[1]	Total	2,100	738132912	
	Among years	7	14867290	6.5***
	Error	2,093	723265622	

[1]Only years 1979-86
***P <0.001

Table 3. Summary of AOV of seasonal mean length [TL (mm)) for brown shrimp, white shrimp, pink shrimp, and blue crab in TPW coastwide bag seine collections during 1978-86.

Species	Source of variation	df	Sum of squares	F
Brown shrimp[1]	Total	1814050	267190334	
	Among years	7	4799648	4,740.4***
	Error	1814043	262390686	
White shrimp	Total	2360556	402498513	
	Among years	8	12167993	9,198.3***
	Error	2360548	390330520	
Pink shrimp	Total	64512	10383776	
	Among years	8	707377	589.4***
	Error	64504	9676399	
Blue crab[1]	Total	174591	10537818	
	Among years	7	217043	524.5***
	Error	174584	10320774	

[1]Only years 1979-86
***P <0.001

Table 4. Ranked seasonal mean catch rates (No./ha) by year for brown shrimp, white shrimp, pink shrimp, and blue crab in TPW coastwide bag seine collections during 1978-86. Means followed by the same letter in a column are not significantly different (P <0.05).

Brown shrimp			White shrimp			Pink shrimp			Blue crab		
Year	Ranked Mean		Year	Ranked Mean		Year	Ranked Mean		Year	Ranked Mean	
1981	1,208	A	1984	1,712	A	1982	1,936	A	1985	1,265	A
1985	1,199	A	19082	1,669	A,B	1980	1,843	A,B	1982	1,226	A,B
1982	1,167	A	1981	1,536	A,B,C	1981	1,842	A,B	1983	1,114	A,B,C
1984	1,152	A	1983	1,501	A,B,C	1983	1,791	B,C	1979	1,110	A,B,C
1986	1,127	A	1978	1,475	B,C	1984	1,766	B,C	1980	1,079	B,C
1983	1,074	A,B	1979	1,437	C	1979	1,761	B,C	1984	1,075	B,C
1980	1,038	A,B	1986	1,418	C	1986	1,747	B,C	1981	1,064	B,C
1979	916	B	1980	1,395	C	1985	1,718	C	1986	1,021	C
			1985	1,374	C	1978	1,696	C			

Table 5. Seasonal mean length (TL) by year for brown shrimp, white shrimp, pink shrimp, and blue crab in TPW coastwide bag seine collections during 1978-86. Means followed by the same letter in a column are not significantly different (P <0.05).

Brown shrimp			White shrimp			Pink shrimp			Blue crab		
Year	Ranked Mean		Year	Ranked Mean		Year	Ranked Mean		Year	Ranked Mean	
1984	62.2	A	1986	59.6	A	1978	67.1	A	1986	29.1	A
1986	61.8	B	1978	57.5	B	1980	55.5	B	1980	27.6	B
1982	59.6	C	1984	57.0	C	1985	54.5	C	1982	27.3	B,C
1979	59.2	D	1981	56.8	D	1983	51.8	D	1979	27.2	C
1981	58.9	E	1980	56.3	E	1979	50.7	E	1985	26.9	D
1985	58.8	F	1979	56.2	E	1984	50.0	E,F	1984	26.6	D
1980	57.6	G	1985	55.4	F	1981	49.4	F	1981	25.6	E
1983	57.4	H	1982	53.1	G	1982	47.4	G	1983	25.2	F
			1983	53.1	G	1986	45.4	H			

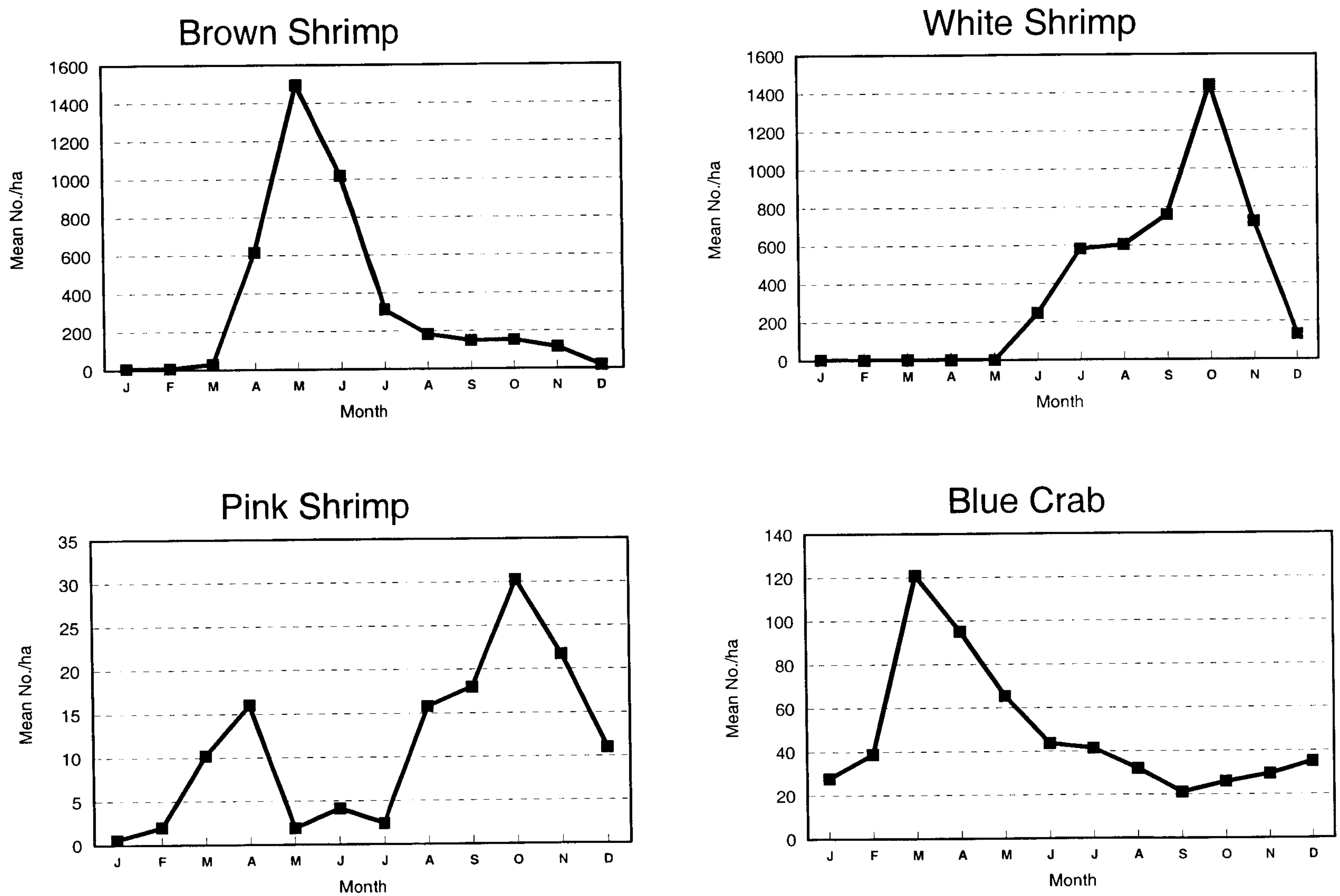

Figure 1. Monthly mean catch rate of brown shrimp, white shrimp, pink shrimp, and blue crab in TPW coastwide bag seine collections during the combined years 1978-86.

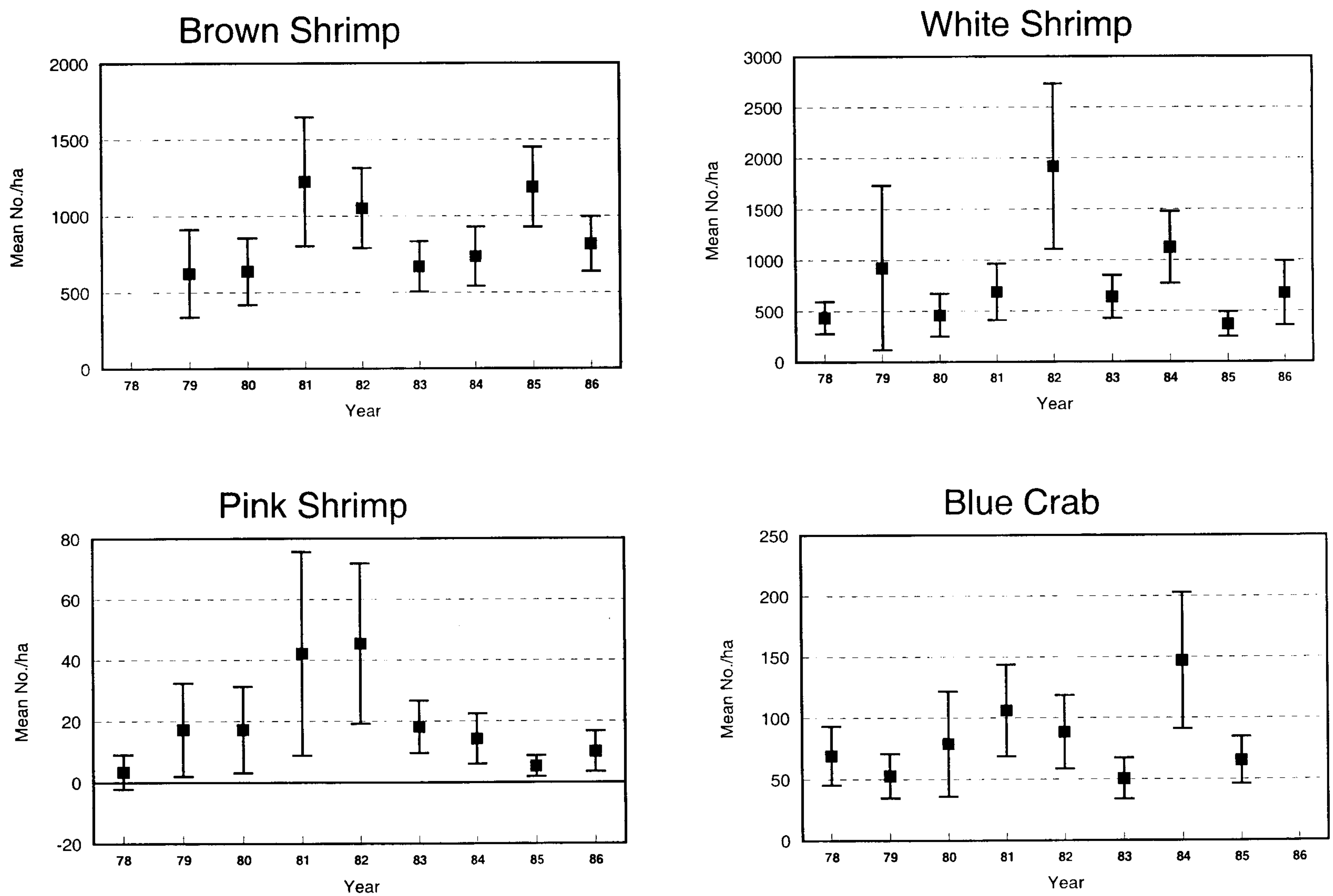

Figure 2. Seasonal mean catch rate (untransformed data $\pm$ 2 SE) of brown shrimp, white shrimp, pink shrimp, and blue crab in TPW coastwide bag seine collections during 1978-86.

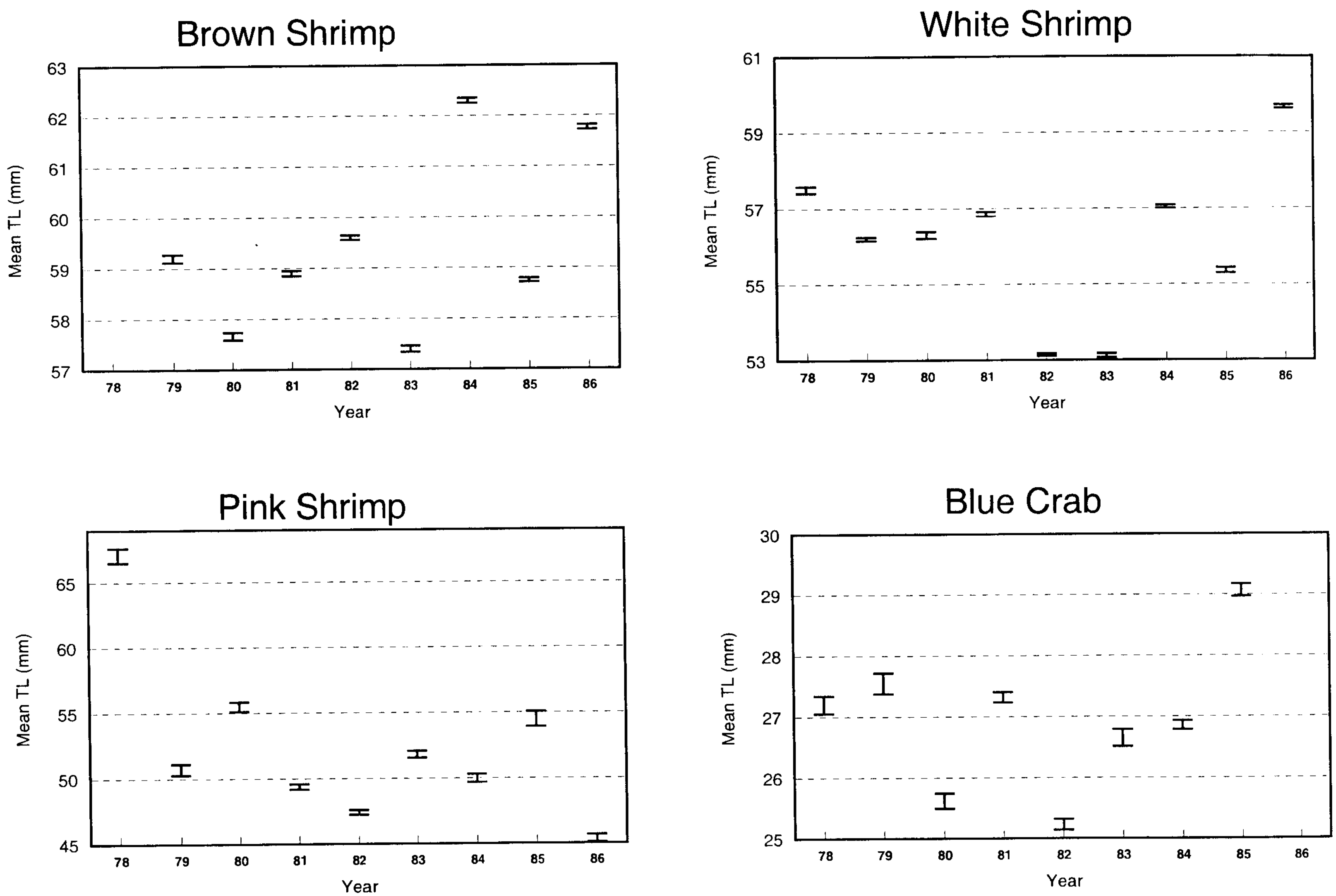

Figure 3. Seasonal mean length ($\pm$ 2 SE) of brown shrimp, white shrimp, pink shrimp, and blue crab in TPW coastwide bag seine collections during 1978-86.

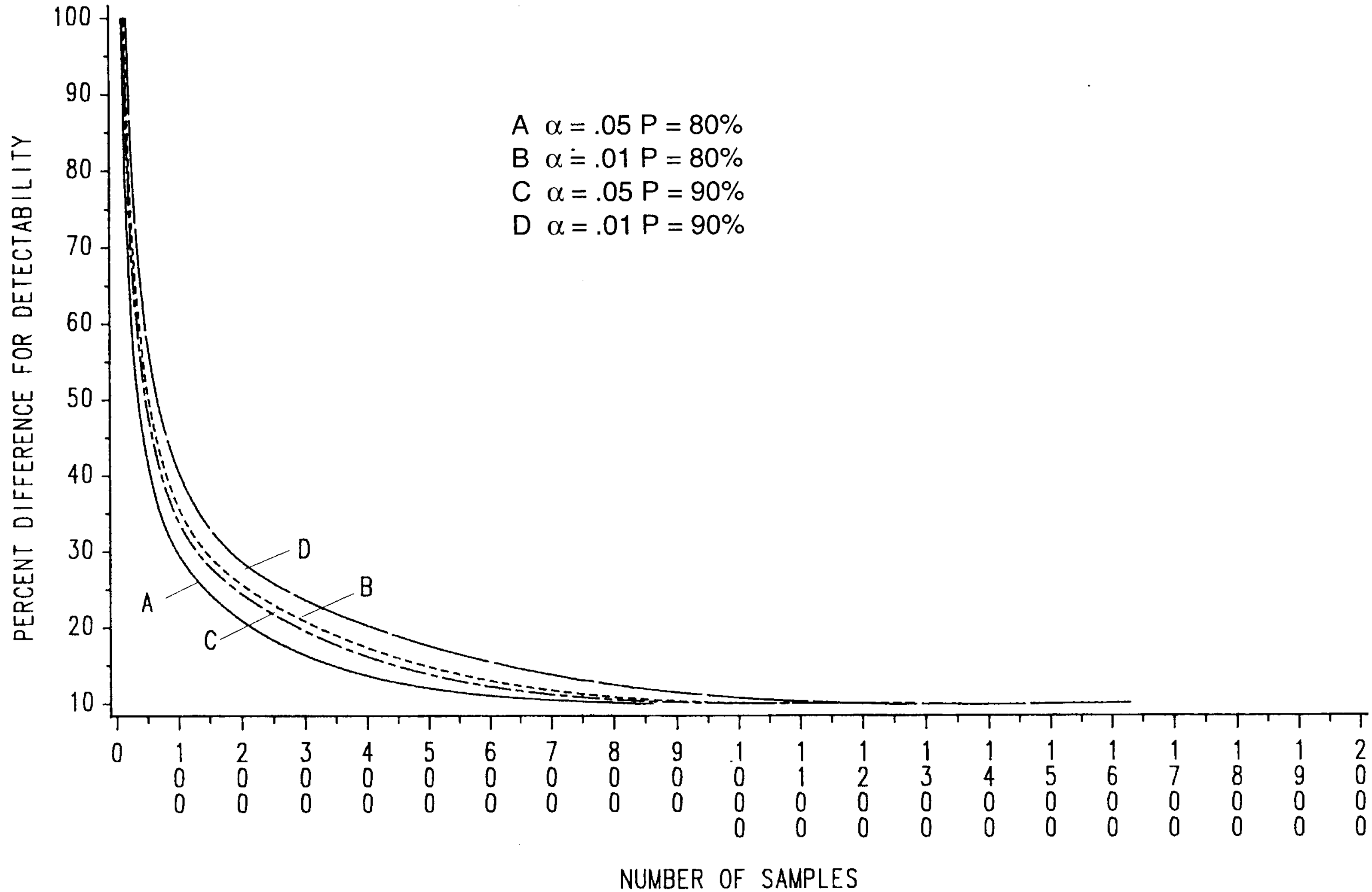

Figure 4. Sample size selection curves for number of seasonal coastwide TPW bag seine sample collections needed to detect a desired percent difference among years for mean catch rates of brown shrimp, at each precision level using a CV = 74.

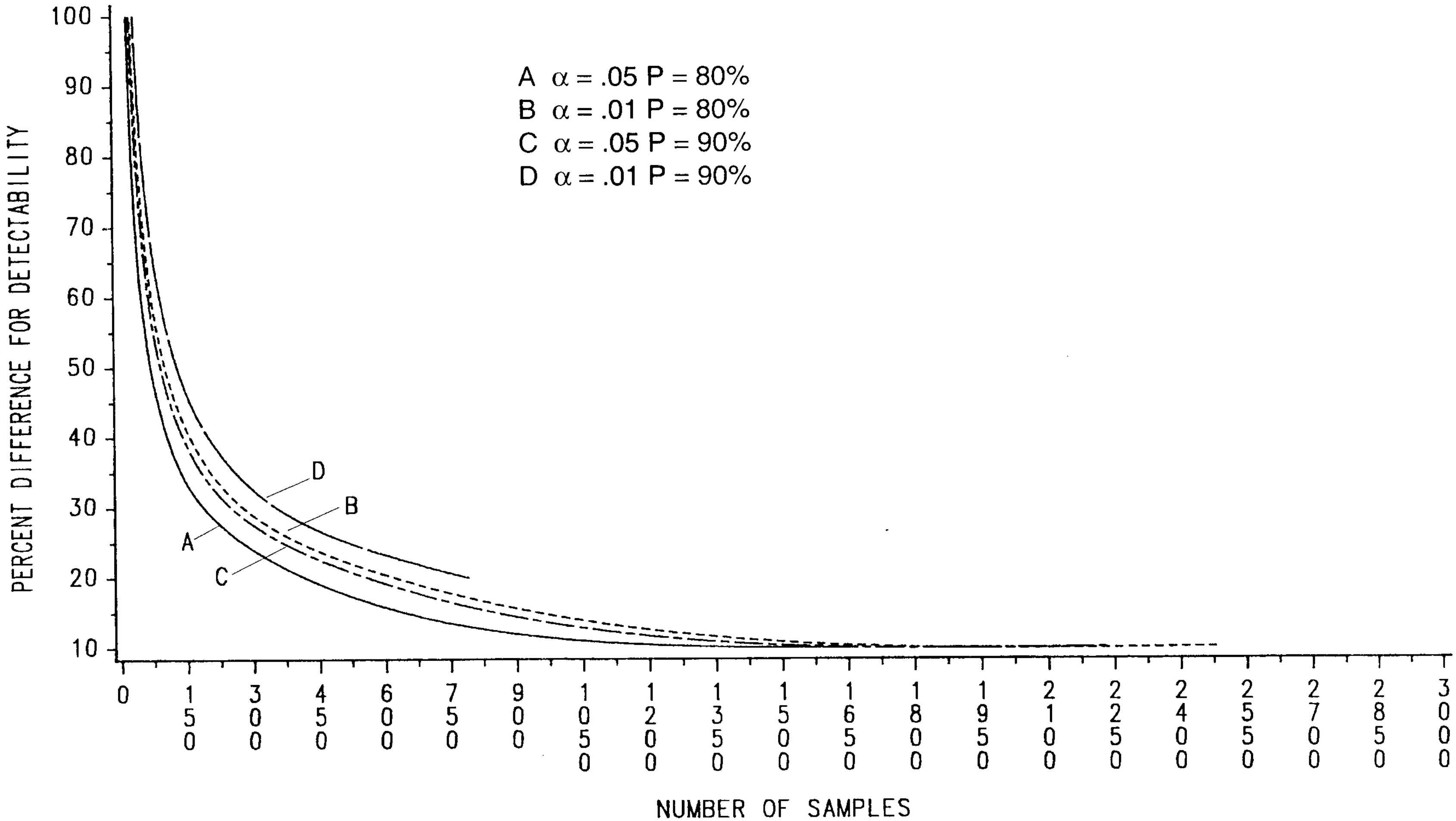

Figure 5. Sample size selection curves for number of seasonal coastwide TPW bag seine sample collections needed to detect a desired percent difference among years for mean catch rates of white shrimp, at each precision level using a CV = 103.

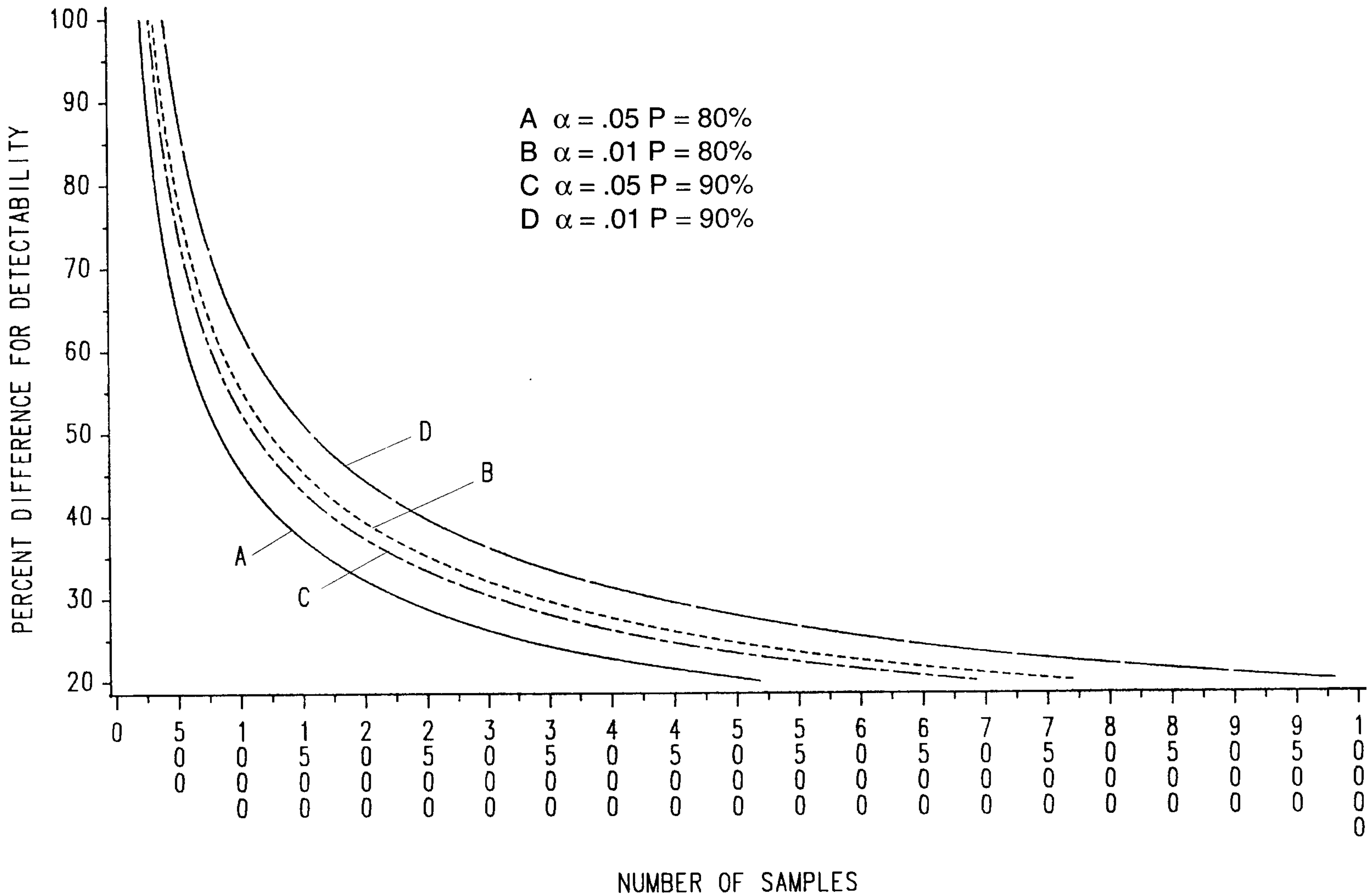

Figure 6. Sample size selection curves for number of seasonal coastwide TPW bag seine sample collections needed to detect a desired percent difference among years for mean catch rates of pink shrimp, at each precision level using a CV = 363.

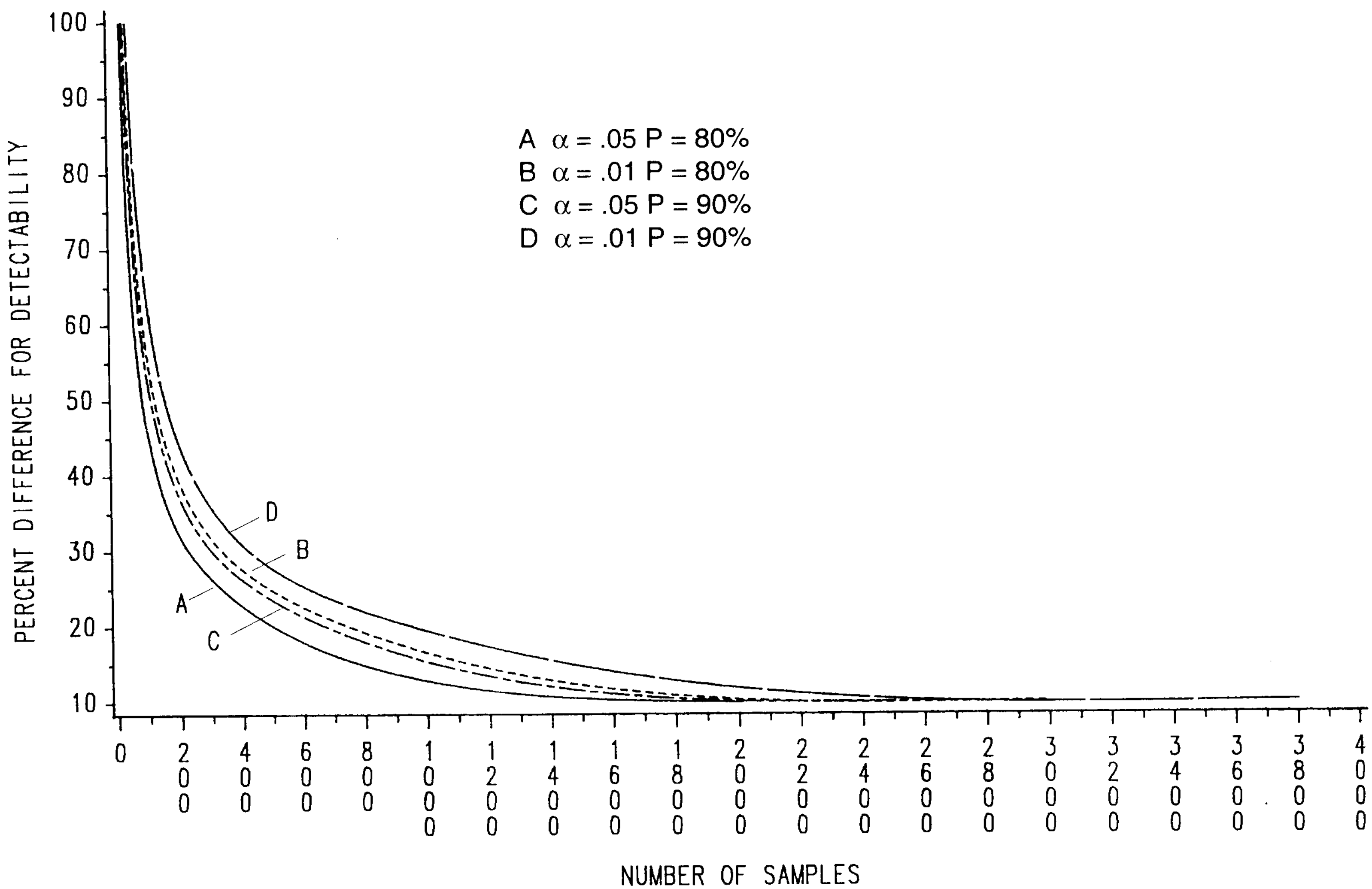

Figure 7. Sample size selection curves for number of seasonal coastwide TPW bag seine sample collections needed to detect a desired percent difference among years for mean catch rates of blue crab, at each precision level using a CV = 113.

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