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Development of a Management and Stock Assessment Program for the Pot Shrimp Fishery for *Pandalus platyceros* in Southeastern Alaska

by

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ABSTRACT

Southeastern Alaska has the last viable pot shrimp fishery in the state. *Pandalus platyceros* comprise 95% of the landed weight; the remainder is primarily *P. hypsinotus*. A 10-fold increase in participating vessels since 1960 has heightened concern for conservation and led to increasing restrictions, including limited entry in 1996.

With increasing effort in this fishery we recognized a need to move towards a harvest rate management strategy, thus we began developing our stock assessment protocol in 1996 and conducted pre-season surveys of a limited area southwest of Prince of Wales Island (district 3) in September of 1997 and 1998 and a post-season survey in February of 1999. Pre- and post fishery length frequency and catch per pot data are modeled using change in ratio techniques to estimate harvest rate, as described by Clark et al. (*these proceedings*). Also in 1997 and 1998 we initiated a port sampling and observer onboard floating processor program to characterize the commercial harvest.

We examined commercial harvest, port sampling, and survey data for indications that serial depletion of spot shrimp populations was occurring in southeastern Alaska. We looked at the harvest and index of abundance on various geographic scales, and analyzed length frequency and sex composition data for temporal trends. Fishing districts have developed sequentially with harvest beginning in the most productive southern districts and subsequently increasing in central and finally northern districts. There is evidence for serial depletion within district 1 where the harvest from several subdistricts has decreased while the number of subdistricts fished continues to increase and overall harvest fluctuates slightly due to inaccuracies in targeting the upper end of the guideline harvest level. Percent female in the commercial catch has decreased for districts 1 and 3. Survey data from district 3 also shows an annual decrease in the percentage of females in the catch from Hetta Inlet for the years 1997, 1998, and 1999 although numbers per pot increased between the 1997 and 1998 September surveys. The harvest rate of 28 – 32.5 percent per fishing season estimated by Clark et al. (*these proceedings*) may be excessive.

We propose a more conservative management strategy be adopted given the current level of capitalization (302 permits as of August, 1999), limited in-season management tools available, and uncertainty in life history parameters, harvest rates, and appropriate harvest level for the species in southeastern Alaska. We are evaluating increased effort restrictions, downward adjustment of the upper limits of the guideline harvest range (GHR), rotation of subdistricts, and perhaps in-season monitoring of an index of escapement such as is used in British Columbia. In addition, we need to continue to accurately characterize the length frequency and size at sex of the species for each major district each year in order to evaluate inter-annual and area trends. We are looking to continue to expand our

survey program to include annual pre-season surveys of each major district and occasional post season surveys to determine harvest rates. We are considering a logbook program that would provide us with location-specific information on the catch per pot of a specific pot type and would allow us to evaluate the effects of commercial harvest on populations on a smaller scale. Finally, we are looking to estimate a stock-recruitment relationship as a potential basis for a harvest model.

Introduction

In this paper we describe the history of the pot fishery for the spot shrimp *Pandalus platyceros* in southeastern Alaska, present an overview of historical harvest, and introduce our recent stock assessment and port sampling protocols and preliminary results. We use this information in a discussion of future management directions.

History of the fishery

Development of the southeastern Alaska pot shrimp fishery (Figure 1) began in 1950 with limited effort and a small harvest from Lituya Bay (Caldwell 1979). During the 1950s and 1960s the Bureau of Commercial Fisheries conducted research on stock distribution and relative abundance, and pot efficiency (Ronholt 1963; Harry 1963). The resulting information assisted fishers in development of the commercial fishery.

Harvest data are limited from the 1960s, but indicate an average seasonal harvest of about 7,938 kg. The highest catch during that period was almost 17,690 kg. Management was completely passive at this time. The market form was either fresh whole shrimp or fresh in the shell tails.

Through the 1960s the only major regulation guiding the fishery was a season from May 1 through March 14, which was established to reduce fishing effort during the spring egg-hatch period for trawl caught shrimp (Hynes 1929) but was also applied to the developing pot fishery.

Interest in the fishery increased and resulted in average seasonal harvests of approximately 9,072 kg during the 1970s. The peak harvest during this 10-season period was 23,406 kg in 1979/80 (Figure 2). Effort varied between a low of 5 vessels to a peak of 124 vessels. Fishers participated in this fishery in order to obtain supplemental income during the off season from the traditional summer salmon or groundfish fisheries.

Beginning in the 1970/71 season, in an attempt to provide fishers with an opportunity to learn more about distribution and other factors, the egg-hatch closure (based on Alaska pink shrimp *Pandalus eous*) was eliminated and fishing occurred throughout the year. As interest, effort, and harvests increased, the department provided basic regulations on buoy marking, pre-fishing vessel registration, biodegradable twine, and a maximum of 150 pots per vessel.

The fishery continued to expand through the 1980s. The average seasonal harvest increased to almost 112,493 kg, with a peak of 170,554 kg by 130 permit holders during the 1988/89 fishing season. By this time the season had been adjusted to October 1 until February 28 in major fishing areas and a minimum legal mesh of 4.45 cm (1-3/4 in) (stretch measure) was established by the Alaska Board of Fisheries at the department's recommendation. Management was still passive at this point in the development of the fishery.

The 1990s saw the greatest growth in the fishery and the addition of major regulations to more properly address resource concerns. The average seasonal harvest increased once again to almost 356,076 kg. The peak harvest of 485,352 kg occurred during the 1994/95 fishing season when 248 permits fished. The first floating-processor participated in the fishery during that season. The 1994/95 season also necessitated active inseason management by the department. Just prior to the 1994/95 season, the department set district guideline harvest ranges by news release. The total seasonal harvest from all districts combined was restricted to a maximum of 371,952 kg. This upper limit of the guideline harvest range represented the average harvest during the previous five seasons plus an increase to allow for some continued development of the fishery in districts where limited harvests had occurred.

The Alaska Board of Fisheries set the 371,952 kg upper limit of the guideline harvest range in regulation for the 1995/96 fishing season. During that season, five floating-processors participated and additional catcher-processors entered the fishery. By this time, the predominant form was whole, dipped, frozen shrimp that were marketed

primarily in the Orient. Shrimp were purchased by most processors as unsorted, live shrimp. Limited entry was established in 1996, with a maximum of 314 participants. By 1997, a number of important regulations were adopted by the Alaska Board of Fisheries. The most significant included a season of October 1 through February 28 for all districts, a maximum pot size, a reduction in the number of pots per vessel based on pot size (140 pots of maximum bottom perimeter 315-cm, or 100 pots with bottom perimeter > 315-cm and ≤ 389-cm) and the requirement of observers on all floating-processors. When the 1999/2000 fishery begins, the fishery management process will also include on-the-grounds management by district, and survey work in three major fishing districts.

Recent work

We began to develop our survey protocol with gear tests in district 7 in 1996. The survey objective is to obtain baseline catch rate index-of-abundance information. This is particularly important as we have no useful effort data as pot configuration has been evolving too rapidly. In 1997 we conducted our first survey with established protocol in district 3 (Figure 3), gathering preseason catch-rate index of abundance and size composition data. The requirement of 100 percent observer coverage of floating processors since 1997 provided the first catch sampling of the fishery. This was expanded in 1998 to include dockside sampling and some onboard sampling. Also, in the 1998/99 season we expanded our stock assessment survey protocol to include pre and post-season surveys.

Materials and Methods

Species captured in order of abundance were spot, coonstripe, (*P. hypsinotus*), Alaskan pink (*P. eous*), and yellowleg pandalid (*P. tridens*) shrimp. Longlined conical pots were set by a chartered commercial vessel. In 1997 we conducted one 9-day survey from September 15 – 23 in five subdistricts, and in 1998/99 two 5-day surveys from September 14 to 18, 1998, and February 9 to 13, 1999 in two subdistricts of Alaska Department of Fish and Game (ADF&G) statistical district 3 (southwestern Prince of Whales Island) (Figure 3). In each year, two pulling days were spent in each of Hetta (subdistrict 25) and Nutkwa (subdistrict 23) Inlets and these data only will be discussed here.

All shrimp harvested during each survey were kept and sold. Following the February, 1999 survey there was a cost recovery period which paid for most survey expenses.

Gear

Six strings of 10 longlined pots were set daily. Pots were snapped to floating groundline at 18-meter intervals. Each string consisted of five 2.86 cm (1 1/8-inch) (stretch measure) mesh and five 4.45 cm (1 ¾-inch) mesh conical stacking pots snapped alternately onto the groundline. All pots were 107-cm diameter at the base. Spot shrimp habitat in the two subdistricts was identified during 1997 survey work. This same habitat was measured for length along the 91.5-meter isobath by GIS and set start position determined in a systematic random fashion (Thompson 1992) before the survey in September, 1998. For each pot set, a 37-meter depth range of prime spot shrimp habitat was sampled, beginning shallow and ending deep. Pre-selected set start positions were adjusted for depth on the grounds by moving perpendicular to the shore shallow or deep according to the skippers knowledge of each set start location. In general the depth range was 55 – 110 meters at the head of inlets and 91 – 128 meters in other areas. Set beginning and ending locations and depths were recorded by differential geographic positioning system (DGPS) and duplicated precisely in February 1999. Average soak time and 95 percent CI for 1997, 1998, and 1999 respectively was 22.2 ± .5, 21.1 ± .8, and 20.1 ± 2 hours.

Sampling

Shrimp pot contents were sorted by species. All bycatch was counted, recorded and released. The total weight of shrimp in each pot was measured to the nearest 0.01 kg. Three large and 3 small mesh pots were sampled from each set. On each day the pot numbers to be sampled were randomly determined. From each pot a representative subsample of approximately 1 kg was obtained. Subsample rates varied from 1/1 to 1/40. The sub-sampled shrimp were measured for carapace length (CL) to the nearest 0.1-mm, examined for presence or absence of eggs, and parasites, and soft-shell condition noted when present. Daily, a random sample of approximately 100 spot shrimp was frozen for later determination of sexual stage. Frozen spot shrimp were sexed using the methods of Hoffman (1972). These shrimp were also measured to the nearest 0.1 mm CL, and whole and tail weights measured to the

nearest 0.1 g. Also on a daily basis, 10 spot shrimp each from five-mm categories with and without eggs were measured for CL to the nearest 0.1 mm, weighed to the nearest 0.1 g, head removed, and tail weighed also to the nearest 0.1 g.

Observers onboard floating shrimp processors sampled 50 shrimp, measuring CL to the nearest 0.1 mm from each commercial delivery, noting presence or absence of eggs and parasites, and soft-shell condition when present. They also froze samples of 100 shrimp from each subdistrict for later sexing. Port samplers collected this same information from any deliveries of whole shrimp to dockside processors.

Results

Harvest trends

We examined commercial harvest port sampling, and survey data for indication that serial depletion of spot shrimp populations was occurring in southeastern Alaska. We looked at the harvest and index of abundance on various geographic scales, and analyzed length frequency and sex composition data for temporal trends.

We hypothesized that as one district became either fully or over-exploited, harvest in another would begin to increase. A continuing pattern of increases in geographic distribution of the harvest while kg harvested remained static would suggest that serial depletion was occurring. There has been a sequential development of the major fishing districts for *P. platyceros* in southeastern Alaska (Figure 4). Peak harvests have been achieved earlier in the most productive southern districts; 1, 2, and 3, respectively in the 1986-87, 88-89, and 91-92 fishing seasons. (A fishing season runs from October 1 – September 30 spanning two calendar years). Next were districts 6, 7, 10, 12, and 13 in central southeastern Alaska which all achieved peak harvest respectively in the 1994-95 season. In the northern districts 11 and 15 coonstripes are abundant, composing 99 percent of the 1998/99 pot harvest in 15, and 46 percent in 11. The district 14 harvest was100 percent spot shrimp in 1998/99; it peaked in the 1995/96 season. Even at this time it did not reach the upper limit of the GHR of 9,072 kg. Region wide harvest also peaked in the 1994/95 season at 457,033 kg (Figure 2), exceeding the upper limit of the GHR by 85,081 kg due to limitations in our ability to monitor catch rate and determine appropriate closing date in-season. Average kg per landing has remained stable at about 181.

A similar pattern to the harvest by district is apparent in harvest by subdistrict for district 1. The harvest from subdistricts 11, 13, 30, 80, and 90 have sequentially peaked followed by declines since the 1988/89 season while the number of subdistricts fished has continued to increase (Figure 5) and district wide harvest remains constant (Figure 4).

Stock assessment and sampling work

The district 3 survey, number per pot data shows an increase in number per pot for Nutkwa Inlet from 102.9 to 111.5 for 42-in diameter large mesh pot between the 1997 and 1998 pre-season surveys and a predictable post-season decrease to 87.2 per pot in February, 1999 (Figure 6). For Hetta Inlet the number per pot was respectively 130.1 to 160.8 to 111.2 for large mesh pots in 1997, 1998, and 1999 surveys.

Finally, we also looked at length frequency and percent female data from port sampling (Tables 1, and 2, and Figures 7, 8, and 9) and survey sampling (Figure 10), hypothesizing that serial depletion would result in a loss of larger shrimp and a decrease in the percentage of females in the harvest. The distribution of sampling effort between 1997 and 1998 limits the comparisons we can make. Between 1997 and 1998 average CL of shrimp in district 1 decreased from 43.8 to 42.6 mm CL. In contrast, the average CL for districts 2 and 3 increased from 38.3 to 39.4 and 37.5 to 38.2 ($p = 3.5 \times 10\text{-}05$, $p = 8.1 \times 10\text{-}19$). Although significant ($p = 2.5\text{x}10\text{-}07$, t-test) this change was small (Figure 7). The percent female in the harvest between 1997 and 1998 from district 1 decreased from 47 to 30 percent. This can be partly accounted for by an increase in L_{50} from 43.2 to 47.0 mm CL (Table 1). For district 3 the percent female also decreased between 1997 and 1998 from 54 to 46 percent. However, unlike district 1, this was associated with a decrease in the L_{50} from 38.6 to 36.6 mm CL. In district 10, females constituted 46 percent in 1997 and the L_{50} increased from 40 to 43 mm CL between 1997 and 1998, and (Table 1). From the survey data the percent female for Hetta Inlet dropped from 56 to 27 percent over the three sampling periods. The L_{50} was very

constant, ranging from 41 – 41.5 mm CL in Hetta Inlet but more variable in Nutkwa Inlet. The percent female for Nutkwa Inlet averaged 29 percent while the L_{50} averaged 36.3 percent.

Discussion

Orensanz et al. (1998) pointed out that for a species with limited geographic distribution such as *P. platyceros* serial depletion could eventually lead to a sudden precipitous decline in population size or biomass. Our work here indicates that serial depletion is occurring in district 1, because harvest in some subdistricts are decreasing while the number of subdistricts fished continues to increase and district wide harvest declines only slightly. The fact that a decline in the percent female was observed for both districts 1 and 3 suggests that the pattern may be more widespread. It is difficult to document in other districts however as district 1 is unique in being divided into numerous small subdistricts whose boundaries are biologically meaningful for spot shrimp.

Dealing with the challenges of managing a fishery on a species with such a limited distribution as the spot shrimp presents two types of problems, detecting when serial depletion is occurring and preventing its occurrence. With regards to detection, logbook data with set location information accurate to latitude/longitude would allow us to group harvest information into smaller more biologically meaningful units for analysis. We currently have difficulty in interpreting carapace length frequency data from the commercial fishery as the sorting rate in the industry is still variable between years and areas as vessel types and product forms vary. This points up the need for catch sampling on the grounds for this fishery. Another difficulty in interpretation of length frequency information is our lack of growth information specific to southeastern Alaska making recruitment events difficult to identify. The problem with relying upon our ability to respond is that it will probably be too late to prevent recruitment failure and given our location at the northern extent of this species' range recovery is less likely.

Garcia (1996) discussed the need to develop recruitment-based 'precautionary' management strategies for the management of penaeid shrimps that give the shrimp resource the benefit of the doubt. He advocated the use of biological reference points for management. The British Columbia (BC) pot fishery for the species uses an escapement index harvest strategy in which escapement is fixed in terms of numbers of spawning females per standard pot type (DFO 1999). Our current management practices in southeastern Alaska are essentially identical to those in place in Prince William Sound at the time of its closure due to stock collapse in 1991 (Trowbridge 1994). Until appropriate guideline harvest levels can be determined we should establish interim measures to assure that our management is sufficiently precautionary. These could take the form of increased effort restrictions, downward adjustment of the upper limits of the guideline harvest range (GHR), rotation of subdistricts, and perhaps in-season monitoring of an index of escapement such as is used in British Columbia. A reduction in fleet size should also be considered for this fishery.

Clark et al. (*these proceedings*) estimated a harvest rate of 28 – 32.5 % per annum for spot shrimp of > 40 mm CL in Nutkwa and Hetta Inlets. In Prince William Sound, Kimker et al. (1996) estimated the maximum age of *P. platyceros* to be over seven years. Butler (1964) estimated the maximum age for the species in British Columbia to be five years. The maximum size of spot shrimp we have measured in southeastern Alaska was 61.5 mm CL from subdistrict 101-80 in 1998. The largest shrimp measured by Trowbridge (1994) in Prince William Sound between the years 1989 and 1993 was approximately 54 mm CL. Given that southeastern Alaska is slightly south of Prince

William Sound, it seems reasonable to assume that the growth rates are similar. This suggest that the maximum age for *P. platyceros* in southeastern Alaska is probably at least that of PWS. Some *P. borealis* in the North Atlantic have a comparable maximum age and considerable effort has been expended to estimate their harvest rate. Teigsmark (1983) estimated the maximum age and total mortality (Z) for several *Pandalus borealis* stocks in the Barents Sea as respectively: 7 and 1.01 (64 % per annum) for the southern part, 8 and 0.76 (53 % per annum) for the central part, and 10 and 0.64 (47 % per annum) for the north and east part. Nilssen (1990) estimated maximum age at 9 and Z = 1.05 (65 % per annum) in Isfjord, Sptisbergen. It is reasonable then to assume that the total mortality for *P. platyceros* is in the range of Z = 47 – 64 % per annum. In this case the Clark et al. (*these proceedings*) F of 28 – 32.5 % per annum means that we are exploiting at either very close or significantly greater than F = M which is probably excessive for this species at the northern limit of its range. This, taken into consideration with the observed serial depletion in district 1 and changes in percent females for districts 1 and 3, suggests that the current upper limits of the guideline harvest levels are too high in some districts.

We need to determine appropriate harvest rates for southeastern Alaska. This will entail expanding our stock assessment program to all major districts and perhaps developing a stock/recruit relationship for the species. Once appropriate harvest rates are determined, they will need to be translated to changes in the upper limit of the GHR.

Acknowledgements

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Table 1. Size at 50 percent female (L_{50}) for *P. platyceros* from 11 districts of southeastern Alaska 1997, and 1998.

	Percent female		L_{50}, mm CL		Number sexed		Number CL measured	
District	1997	1998	1997	1998	1997	1998	1997	1998
1	47	30	43.2	47.0	694	650	1266	1085
2	44		40.5		494	0	3251	500
3	54	46	38.6	36.6	1631	250	6043	2500
6		53		42.6	0	150	0	600
7		35		45.2	0	317	0	948
8		10		45.0	0	52	0	137
9		38		43.0	0	145	0	600
10	46		40.0	43.0	96	50	100	0
11	65		46.0		106	0	110	0
13		21		45.7	0	150	0	451
14		18		45.0	0	200	0	100

Table 2. Percent female in large mesh pots, L_{50} and number sexed for two subdistricts of district 3 from survey work in September 1997 and 1998 and February 1999.

	Percent female			L_{50}, mm CL			Number sexed			Number CL measured		
Subdistrict	1997	1998	1999	1997	1998	1999	1997	1998	1999	1997	1998	1999
Nutkwa (103-23)	12	52	23	35	36	38	105	304	195	737	2399	2006
Hetta (103-25)	56	36	27	41	41	41.5	66	356	208	1175	2063	1756

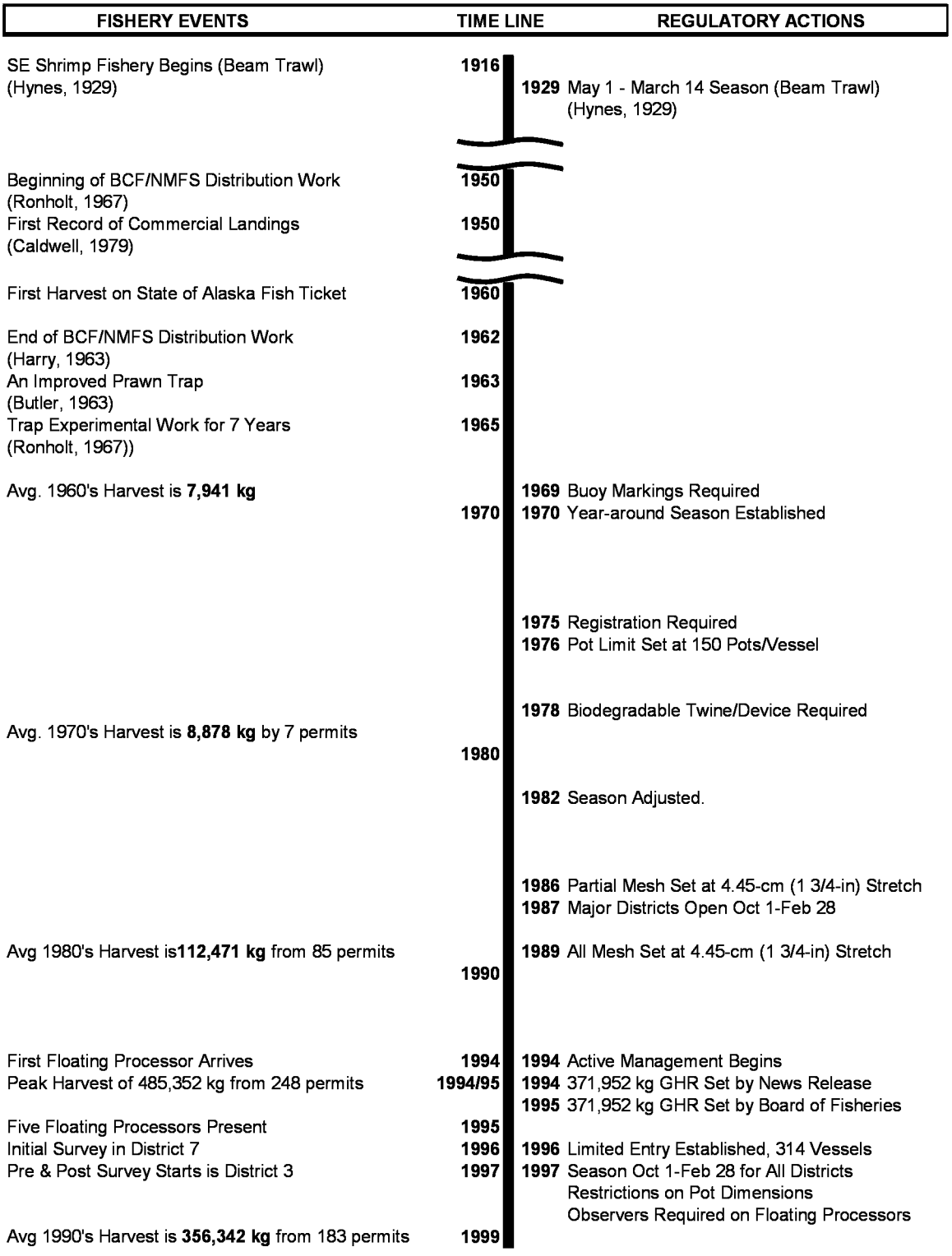

Figure 1. A time-line for development of the pot shrimp fishery for *P. platyceros* and *P. hypsinotus* in southeastern Alaska.

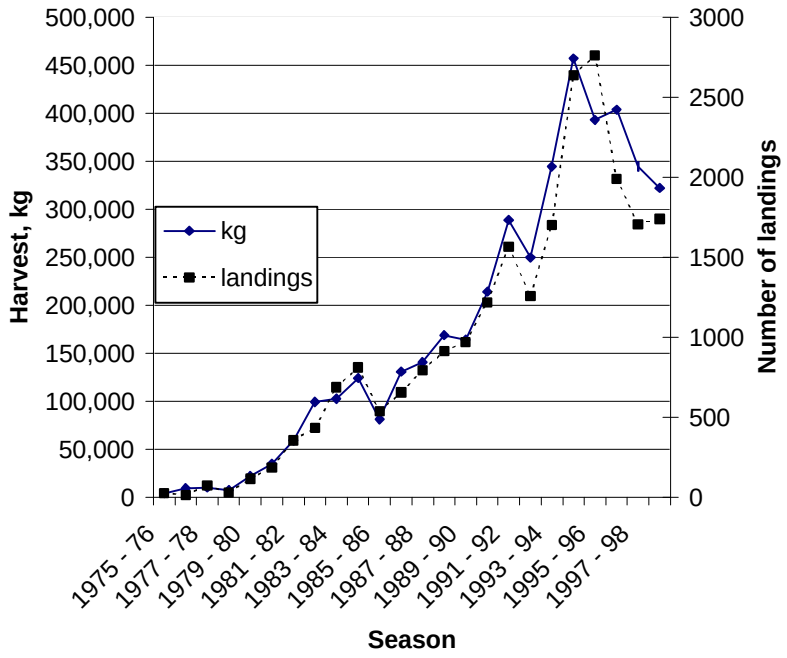

Figure 2. **Harvest and landings of *P. platyceros* by the pot fishery in southeastern Alaska for the period October 1975 – September, 1999.**

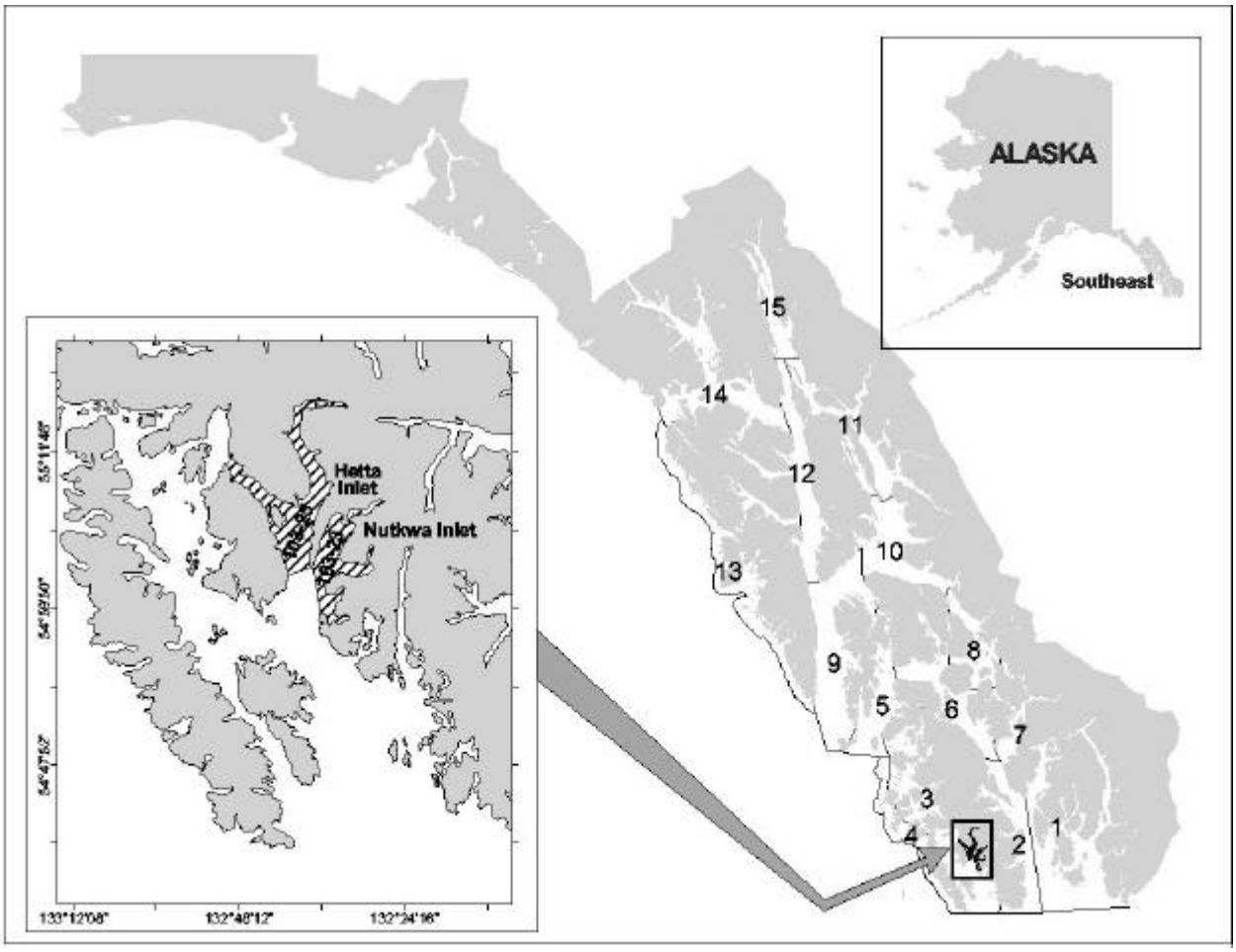

Figure 3. Location of fishing districts and the 1997, 1998, and 1999 stock assessment surveys for *P. platyceros* in district 3 of southeastern Alaska.

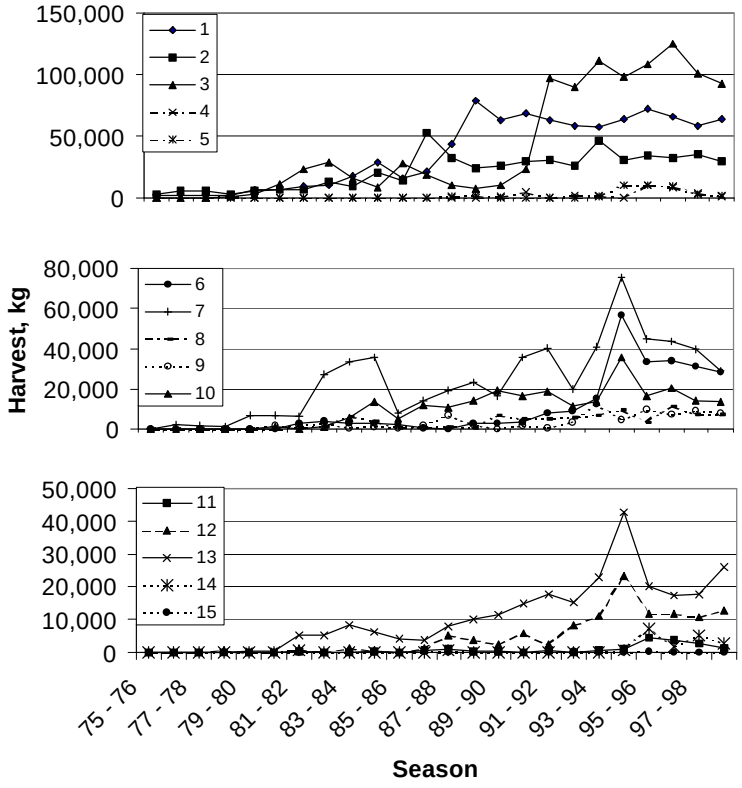

Figure 4. **Harvest by district of *P. platyceros* by the pot fishery in southeastern Alaska for the period October 1975 – September, 1999.**

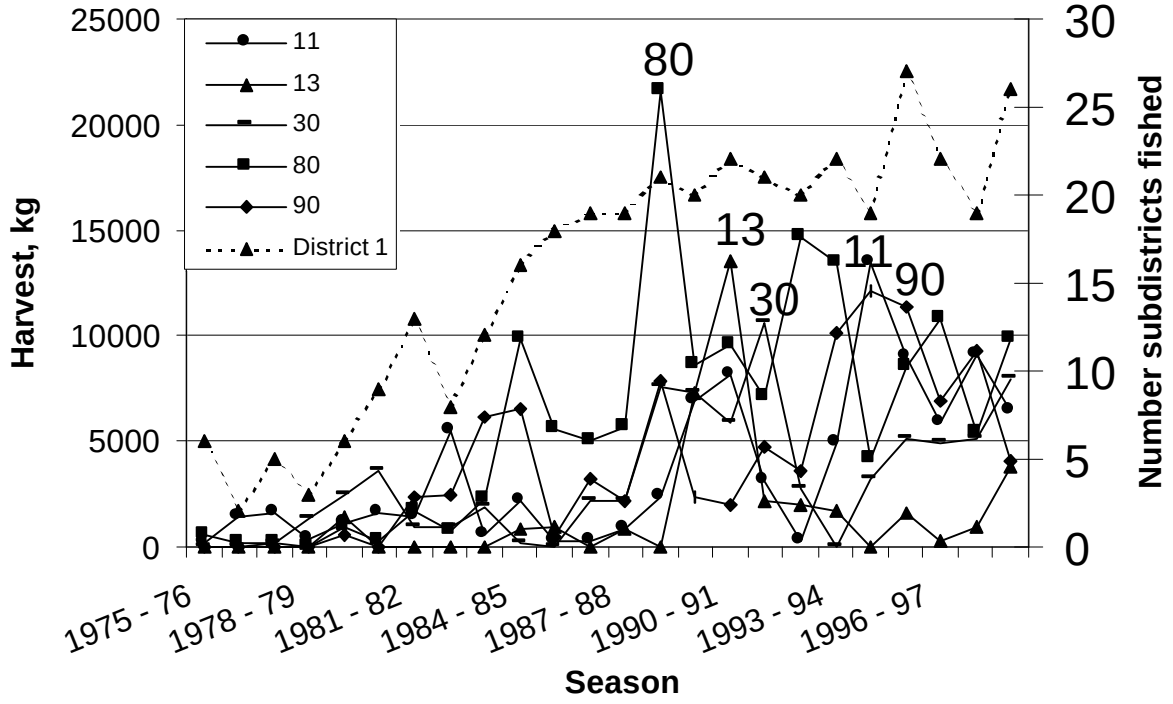

Figure 5. Harvest by subdistrict of spot shrimp for five subdistricts of district 1 and total number of district 1 subdistricts fished for the period September 1975 – October 1998.

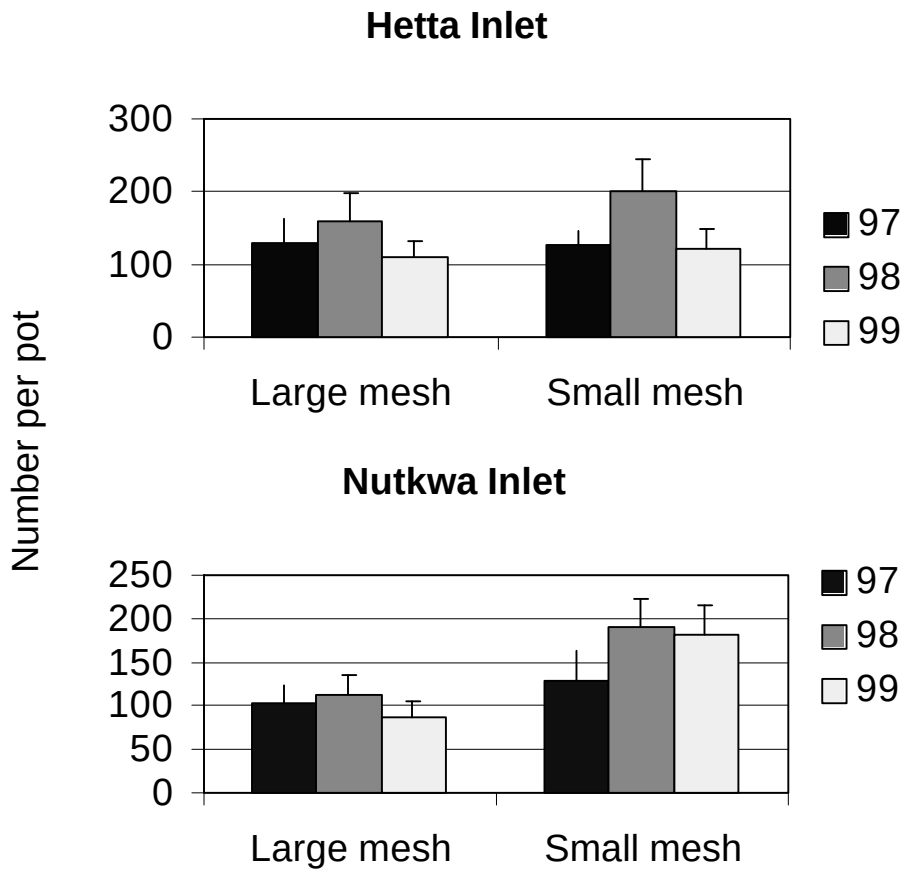

Figure 6. **Catch per pot of *P. platyceros* for subdistricts of district 3; Nutkwa (23) and Hetta (25) Inlets surveyed prior to the fishery in September, 1997 and 1998 and after the fishery in February, 1999.**

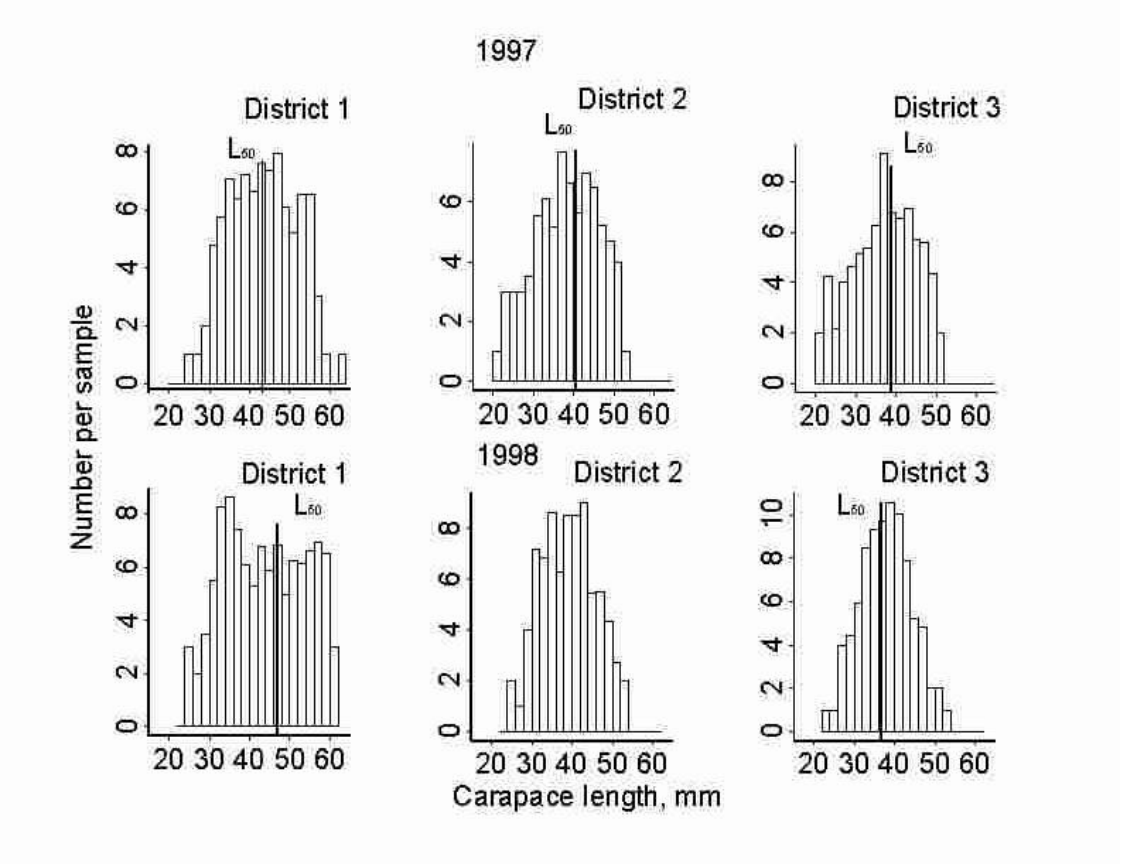

Figure 7. **Carapace length frequency and L_{50} of *P. platyceros* for districts 1, 2, and 3 sampled from the commercial pot fishery harvest of southeastern Alaska for 1997 and 1998.**

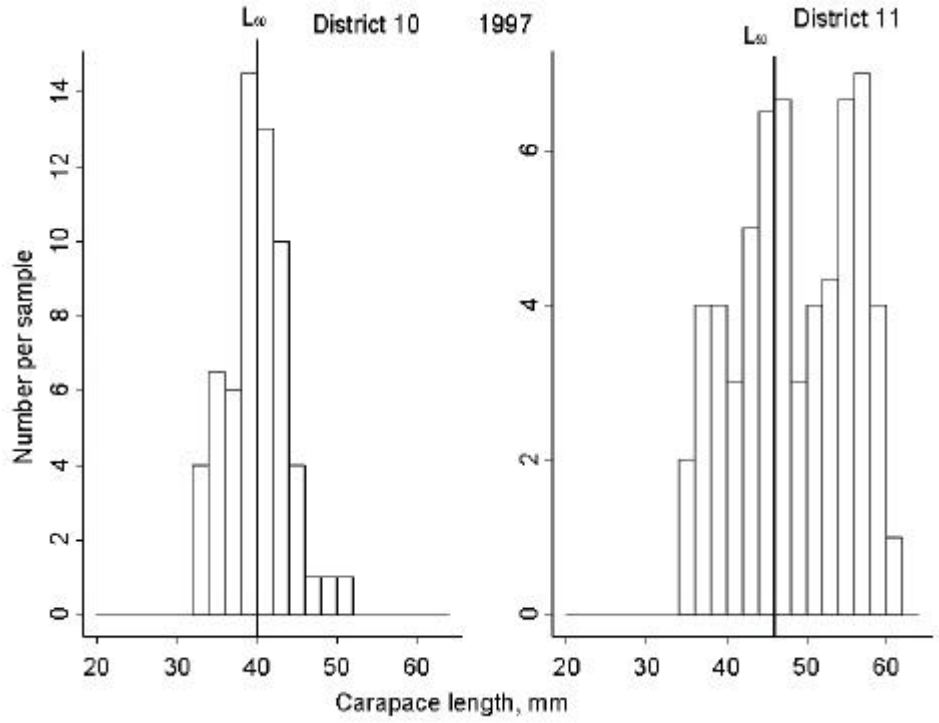

Figure 8. Length frequencies and L_{50} of *P. platyceros* for districts 10 and 11 of southeastern Alaska sampled from the commercial pot fishery harvest for 1997.

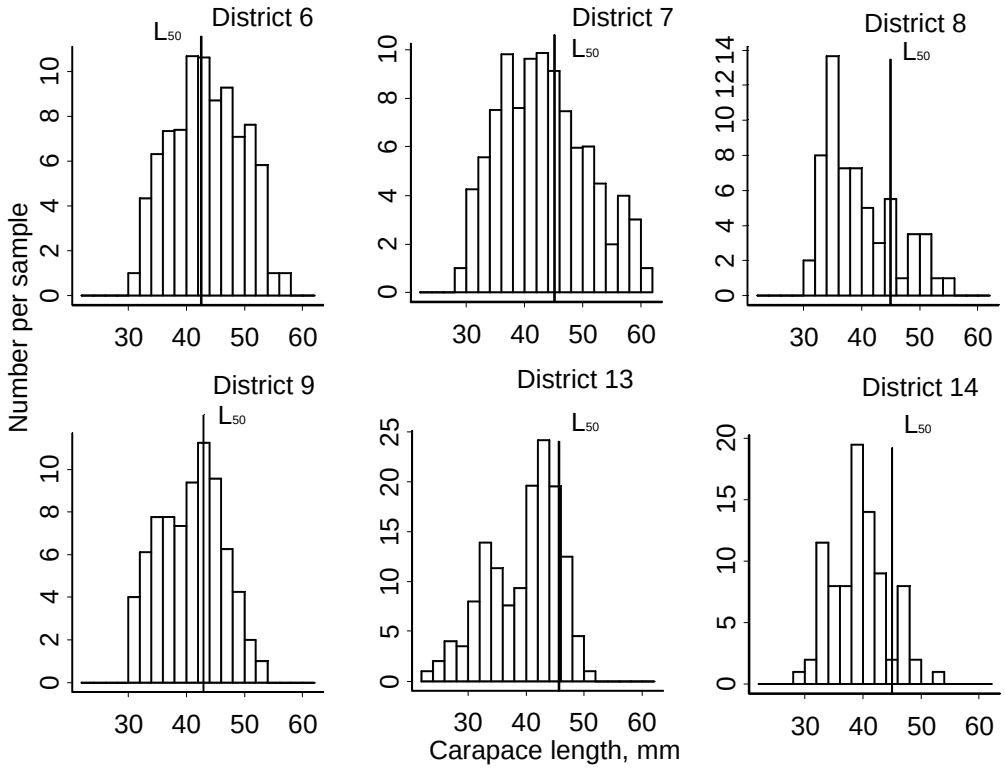

Figure 9. Length frequencies and L_{50} of *P. platyceros* for other districts of southeastern Alaska sampled from the commercial pot fishery harvest for 1998.

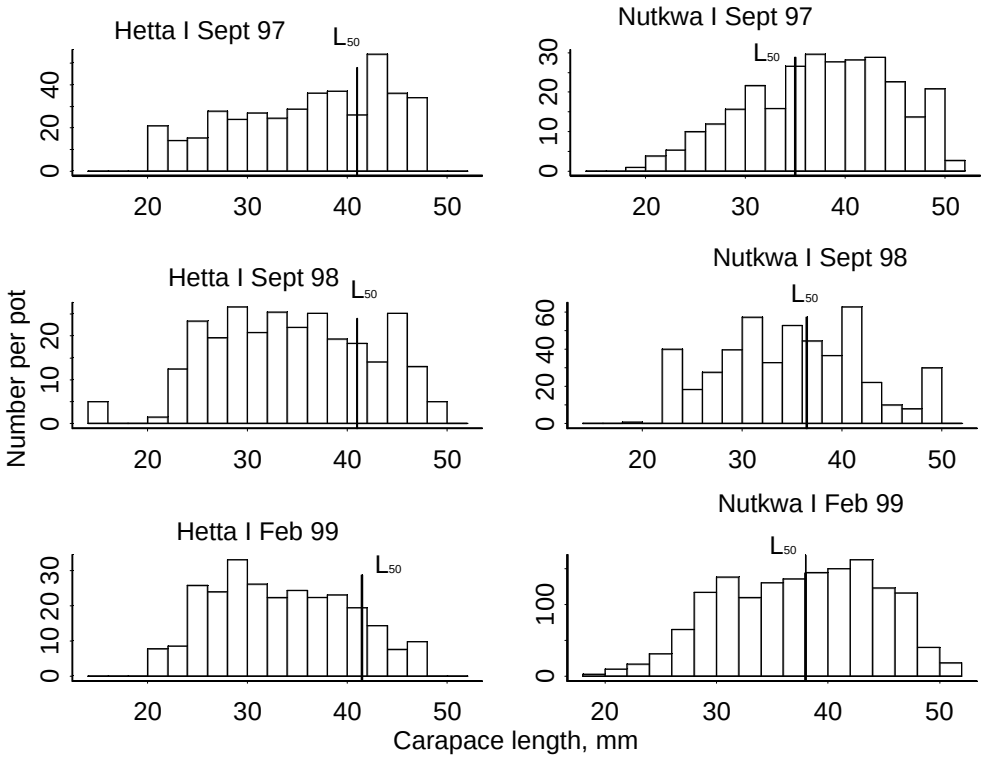

Figure 10. Length frequencies and L_{50} of *P. platyceros* for subdistricts of district 3; Nutkwa (23) and Hetta (25) Inlets surveyed before and after the commercial pot fishery for the 1989/99 season.