Introduction

Spot shrimp (Pandalus platyceros) are distributed across the northeast Pacific from Unalaska to Baja California (Lowry, 2007). Adults prefer rocky bottoms and in Prince William Sound are most abundant in depths of 45-140m (Lowry 2007; Trowbridge 1992). Larvae hatch in the spring and spend their first summer in the water column before settling in shallow water eelgrass beds as juveniles in the fall. After approximately 3 yrs the juveniles migrate to deeper rocky areas and mature as males (Kimker and Donaldson 1987). Being prodandric hermaphordites, like most Pandalids, they transition to females after approximately 3-5 years as males (Kruse and Murphy 1989). In Alaska females may live for another 3-5 years and reproduce annually (Trowbridge, 1992; Love and Bishop 2005). Tagging studies in Prince William Sound suggest a maximum age of 7 to 10 years (Kimker et al 1996) substantially longer than the faster growing populations to the south in British Columbia, Washington and California (Butler 1964, Lowry 2007), similar to other pandalids (e.g. *P. borealis* Anderson 1991, Butler 1964). Although larvae are advected by currents, as adults spot shrimp are sedentary with all tags recovered within 1 mi of release over 3 years in Unakwik Inlet. (Kimker et al 1996). The slow growth, limited movement, predictable distribution, and harvest concentrated on the larger saleable female component of the stock predispose spot shrimp to serial depletion and overharvest (Orensanz et al. 1998).

Spot shrimp in Prince William Sound are targeted by both commercial and noncommercial pot fisheries. Commercial harvest was first documented in the 1950’s (Trowbridge 1994). It remained at relatively low levels (< 25,000 lbs) until 1979 when the fishery rapidly expanded, peaking at 290,632 lbs in 1986, with a concurrent dramatic increase in effort (Table 1). Year round seasons with no harvest restrictions were shortened to summer only in 1982 and the first GHR set at 75,000 –145,000 lb. The GHR was increased to 150,000–200,000 lb in 1985 and an experimental harvest area established in Montague Strait with no harvest or season restrictions. Harvest declines in 1988 raised conservation concerns. Harvest well exceeded the GHR every year until 1989 when the Exxon Valdez oil spill limited harvest opportunities. In 1990 gear restrictions were instituted and in 1991 the GHR was reduced to 10,000–40,000 lbs. The commercial fishery was closed from 1992 through 2009.

The noncommercial fishery remained opened during the closure and expanded substantially with opening of road access to the port of Whitter in 2000. Noncommercial harvest was documented on permits from 2002-2006, and since 2009.

In 2010 the commercial fishery was reopened under a new management plan. The management plan established a harvestable surplus threshold of 110,000 lb for opening the commercial fishery. If the estimated harvestable surplus exceeds this threshold, 40% of the harvestable surplus is allocated to the commercial fishery and 60% to the noncommercial fishery. Recognizing the inherent vulnerability of fishery that selectively removes females, the plan also established 3 commercial harvest areas which are to be opened on a rotational basis, such that each area is given a resting period of 2 years to allow newly recruited females a chance to reproduce before being exposed to fishing pressure.

Since reopening under the new management plan, harvest has been relatively stable at around 150,000 lbs, roughly half the peak commercial harvest in 1986. The exceptionally large harvest of 187,495 lb in 2010 was mostly a result of a non commercial harvest exceeding its GHL by nearly factor of 3.

The department has conducted a pot survey for spot shrimp in Prince William Prince annually since 1989. The first three years of the project were conducted as part of study on the effects of the Exxon Valdez oil spill. Valuing the project as an assessment tool, the depart chose to continue the project from 1992 to present. The primary objective of the survey is to provide a relative index of spot shrimp abundance in the Inside District of Prince William Sound. A Shaefer Surplus Produciton model combines this index with the noncommercial and commercial harvest and CPUE to estimate harvestable surplus. GHRs are established from this estimated harvestable surplus as stipulated by the management plan.

The objective of this report is to document the survey results from 1992 to 2016 for use in informing management, especially for use in the 2017 BOF meeting. The first three years of the survey are not included here because of substantive differences in methods.

Methods

*Spatial Layout*

The spatial layout of the survey consists of a number of sites, each composed of several stations. One longlined string of pots is fished at each station. The number of sites, the number of stations per site and the number of pots per station have all varied over the history of the survey.

The methods from the first three years of the survey 1989-1991 were different enough from the latter years, that those data are not included in this report. The first three years of the project were designed to study the effects of EVOS, with 3 sites in the unoiled area and 3 sites in the oiled area. Two strata, one shallow (20–70fa) and one deep (70–120fa), were fished at each site. In order to achieve the sampling objective of 500 shrimp per stratum, the most productive depths were sometimes repeatedly fished. Some of these shrimp were retained for toxicological and other histological analysis.

The survey design was modified in 1992, when the primary objective shifted to developing a relative index of abundance. Depth stratification was abandoned and replaced with a single target depth range of 20­–80 fathoms where spot shrimp were concentrated in the initial study and as reported by commercial fisherman. Other changes initiated in 1992 included adding 2 additional sites (Chenega and Prince of Wales) to the original 6 (Unakwik, Golden, Culross, Herring Bay, Junction I, and Green Island). These 8 sites were fished from 1992 until 2009, when Long Bay replaced Green Island. In 2012 Bald Head Chris was added and in 2013 Valdez was added.

In addition to changes in sites, the number of stations per site and pots per station have also varied. From 1992–2015, 4 fixed stations each comprised of a longlined string of 11 pots were fished at each site. In 2016 the project leader doubled the number of stations at each site to 8 and reduced the number of pots per station from 11 to 5. Once established, station locations are fixed.

*Gear and Field Logistics*

One longlined string of pots is set at each station. Except for 2016, each string consisted of 11 pots, spaced 10 fa apart. Each string is buoyed at both ends. Anchors were added to both ends in later years (>2009?). The kite style posts measure 16” x 16” x 36”, and are covered with black woven fabric except for 2 tunnels on opposing ends. The tunnels are made of 1/2” web and have 2.5” openings. Each pot is baited with a 2.5 qt perforated plastic jar of chopped herring. Pots are set in the evening and retrieved the following morning with typical soak times of 20-22 hours. Lost, torn or pots with open doors were excluded from analysis.

The survey was completed over the course of a week in October, aboard the r/v Montague, Pandalus or Solstice.

*Biological Sampling*

Shrimp catch of every pot was sorted to species, counted and weighed in aggregate.

From 1992 through 2004 all spot shrimp were measured and sexed following the methods of Butler(1980)(see SOP in Trowbridge 1992) . In 2005 all female spot shrimp and half the males were measured. Beginning in 2006, spot shrimp were only measured from one randomly selected pot. Also beginning in 2006, individual shrimp weights were also recorded (except 2007, missing?) .

Bycatch of other species was counted prior 2006, and also weighed afterwards.

*Analysis*

Spot shrimp catch and CPUE (kg or cnt per pot) was calculated for both large (>32mm) and all sizes. A carapace length of 32mm was estimated as the approximate minimum saleable size based on questionnaire mailed to 97 commercial fishermen in 1988 (?) (Donaldson and Trowbridge, 1989).

All sizes

Survey-wide catch of all-sizes of spot shrimp was calculated as the total catch in all pots:

where c is survey-wide total catch (count or weight) ,

*ci* is catch in pot i and

n is number of pots successfully fished.

Survey-wide CPUE of all sizes was calculated by dividing the total catch by the number of pots successfully fished:

*Larges*

Catch of large shrimp was estimated as the sum of the products of total catch and proportion large at each site.

where is survey-wide catch of larges (no. or kg),

ch is catch in site h and

h is number of sites and

is proportion larges at site h.

The proportion large is calculated from the measured shrimp pooled by site:

where is the number or weight of large shrimp measured at site h and

is the total number or weight of shrimp measured at site h.

Since individual shrimp were not weighted prior to 2006, those weights were estimated using the length-weight relationship fit to shrimp sampled in 2006–2010:

where *w* = weight in grams and

*l* = carapace length in mm.

Large cpue was estimated by dividing the estimated survey-wide catch of larges by the total number of pots successfully fished in the survey:

The Valdez site was not included in survey-wide statistics because it is outside the commercial fishing area.

Size at 50% female was estimated using logistic regression.

**Results**

**Survey-wide**

*Raw effort and catch*

A total of 264 to 395 pots were fished each year with a mean of 350 (Table 2). The total catch of spot shrimp ranged from 76 lb and 2,252 shrimp in 1998 to 838 lb and 24,152 shrimp in 2007 with a mean of 474 lb and 10,802 shrimp.

*Catch Rate*

The survey-wide CPUE of all sizes ranged from 0.29 to 2.75 lb/pot with a mean of 1.32(Table 2). The CPUE of larges ranged from 0.14 to 1.98 lb/pot with a mean of 0.86 . Both large and all CPUE generally decreased from 1992 to record lows in 1998 with a minor peak in 1995 (Figure 2). Over the next decade the CPUE of both size classes increased with CPUE of alls peaking at nearly record highs in 2008 and CPUE of larges peaking in 2009. Both catch rates declined in 2010, then increased again in 2011. From 2012 to 2015 the catch rates of both declined, before surging to all time highs in 2016.

*Size Comp*

The survey-wide mean carapace length was 30.8mm(ins exct), and ranged from 28.2mm to 33.8mm (Figure 3). Similar to CPUE, mean length declined from 1992 to 1994, increased in 1995, then decreased again through 1998. Avg size increased from 1998 to 2001, then decreased through 2007. Avg size reached a record high in 2011, then generally declined over the remainder of the time series. In 2016 the average size was near the long average.

Dominant size classes are apparent in the length frequency histograms(Figure 4). Growth in some of these modes can be tracked over time. For example the recruitment pulse at ~ 25 mm in 2005 progressively shifts larger to ~ 37mm in 2011. This particular recruitment pulse coincides, and may be responsible for the increase in CPUE from 2005 to 2011, appearing first mostly as an increase in CPUE alls, then later as an incrase in CPUE of larges. (in disc mention relative to kimker 3mm/yr). The smallest recorded female was 34mm. The length at 50% female ranged from 38 to 42 mm with a mean over years of 40 mm (15 and 16 not included) **.**

**Area 1**

*CPUE*

In Area 1 the 1992–2016 average CPUE of all sizes was 1.6 and larges 1.4. The catch rate increased dramatically in 2004. Prior to 2004 the CPUE of larges fluctuated around .5 lb.pot and never exceeded 1.1. From 2004 to 2016 CPUE of larges never droped below 1.2 lb/pot and averaged 2.0 lb/pot. Some the interannual variation apparent in the survey-wide values area also apparent in the area-1 CPUE. For example, the local minima observed in 1994 and 1998, and local maxima in 2008, 2012 and 2016 paralleled those in the survey-wide values.

*Size Comp*

The long term average size in area 1 was 33.7mm with a range of 29 to 37mm. The mean size decreased slightly following near record highs in 2010–2012, however the 2016 value was near the long term average.

In the size frequency distributions, a single dominant mode tracks progressively larger from 2004 to 2012. Prior to and after this time period the distribution was multimodal. In 2016 modes were observed at 24, 34, and 44 mm.

**Area 2**

*CPUE*

In Area 2, the long term average CPUE of larges was 1.6, nearly identical to that in Area 1. The CPUE of larges was intermediate the two other areas at 1.0 lb/pot. Catch rates have generally increased in Area 2 over the history of the survey, with dips in 1994 and 1998 and peaks in 2008 and 2016.

*Size Comp*

Mean size in area 2 was 29mm with a range of 27 to 32, substantially less than area 1 and similar to area 3. After record highs in 2010 and 2011, mean size has generally declined to near the long term average in 2016.

A dominant size class can be tracked from 20mm in 2003 to 46 mm in 2013. In 2016 modes were apparent at 27,33 and 45mm.

***Area 3***

*CPUE*

Long term average catch rates in area 3 were 1.0 lb of all sizes and .5 lb of larges, substantially less than the other two areas. During the early years of the time series catch rates in Area 3 were similar to the other two areas, however area 3 did not rebound as rapidly or as substantially from the 1998 record low as the other two areas. Also, following the 2008 peak, area 3 has not performed as well as the other two areas with catch rates generally trending slightly downward.

*Size Comp*

Mean size in area 3 was 30.5 and ranged from 27 to 35, similar to area 2 and smaller than area 1. A maximum size was observed in 2010. In 2016, mean size was near the long term average.

As in the other two areas, a strong size class grew from 25mm in 2004 to 44mm in 2012. In 2016 modes were present at 27, 34, and 47mm.

**Discussion**

*CPUE survey-wide*

Survey-wide CPUE of both large and alls has generally increased over the 1992 to 2016 time series. When the CPUE of all sizes from first three years of the survey (1989–1991) are considered - 1.3, 0.9, and 1.3 lbs/pot - a general decline in CPUE is evident from 89 to 1998, followed by a general increase from 1998 to2016. Those first three years are not included in this report because of substantive differences in methods, and should only be compared results from later years with caution.

Ideally CPUE from the virgin unexploited biomass would be available as a baseline comparison for the current survey results. Unfortunately, this suvey only began immediately following the collapse of the commercial fishery in the 1980’s, thus it is difficult to ascertain where the current abundance stands relative to the unexploited abundance or even to the abundance during the height of the commercial fishery in the 1980’s. Never the less, 1.3 lb/pot has been tentatively suggested as a target threshold necessary for a commercial fishery. This threshold is the 1989 and 1991 survey value and near the 1992 to 2016 longterm average. The survey CPUE has been above this threshold every year since 2004.

*Trends since reopening Com Fishery*

The decline in CPUE larges, mean size, and proportion of females observed from 2011–2015 may be cause for some concern. Viewed by themselves, the decrease in mean size and proportion female could be caused by either an increased abundance of small shrimp or a decrease abundance of large shrimp. However the decline in CPUE large indicates the latter was operative. This downward trend coincided with the reopening of the current commercial fishery in 2010. The non-commercial harvest appears to have substantially increased around the same time as well. Non-commercial harvest is unknown for 2006–2008, however the 2009 documented harvest was nearly twice that documented in earlier years (2002­–2005). The 2016 survey ally these concerns somewhat when the downward trend in all 3 metrics reversed. In particular, the 2016 survey-wide CPUE was the highest on record.

*Size-Freq distributions*

The progression in modes seen the size frequency distributions, suggest a mean growth rate of approximately 2 to 3mm/ yr for the size range 25 to 45 mm. This is growth rate is roughly consistent with the 3mm/yr reported for tagged shrimp in Prince William Sound (Kimker et al. 1996).

*Comparison Between Areas*

Surveyed CPUE of large shrimp decreased across the 3 areas from north to south. Most of the differences can be attributed to varying recoveries from the 1998 low. While the CPUE of all 3 areas was roughly similar prior to 1998, in the following years saw a large increase in CPUE in area 1, a moderate increase in area 2 and only a minor increase in Area 3. Of the 3, Area 3 is cause for most conservation concern with a mostly flat trend in CPUE over the survey’s history as compared to the general upward trend in the other two areas. Shrimp surveyed in Area 1 were slightly larger (~3mm) than those in the other two areas.

Differences in commercial fishery performance between the 3 areas mirrored those seen in the survey, with CPUE averaged over years decreasing from north to south at 2.0, 1.7 and 1.0 lb/pot for Areas 1,2 and 3 respectively. No clear interannual trends in CPUE are evident in the commercial data, however sample sizes are limited. Since reopening in 2010 the fishery has been prosecuted 3 years in Area 1 and only two years in each of areas 2 and 3.