Exxon Valdez Oil Spill
Restoration Project Final Report

Statistically Based Sampling Strategies for Gulf of Alaska Ecosystem Trawl Survey Monitoring

Restoration Project 00493
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Study History: This project was funded in 2000 with subsequent revision in 20002 - 2003. Statistical analysis of the historic trawl survey database (from EVOS APEX Project 00163L) was undertaken in order to design an effective sampling strategy for possible future monitoring.

Abstract: Catch and species composition data collected in the Gulf of Alaska since 1953, by use of small mesh trawl surveys, forms the basis of our understanding of decadal scale change in the marine community structure over large spatial scale. These data indicated large changes in the relative abundance of individual species and in some cases entire species groups occur periodically related to changes in the ocean environment. We have termed these periods as the warm and cool community regimes. A goal of the current project is to examine historical data in order to optimize sampling effort for possible future surveys. The methodology used for this project was to construct a model of species and groups of species abundance and spatial distribution changes over the period of record. This model was then used to assess the level of sampling required to detect species abundance change within the precision limits of various sampling levels in individual bays.

Key Words: Gulf of Alaska, forage fish, marine ecology, population changes, groundfish, shrimp, capelin, randomization tests, Dirichlet tiles, spatial analysis, kernel density estimation, sampling strategy.

Project Data: All of the historical data and meta data used in the analysis to develop a statistically based sampling strategy are available on CD-Rom. The data were extracted from the catch (apx_c.dbf) and haul (apx_h.dbf) FoxPro files provided by the National Marine Fisheries Service (NMFS), Alaska Fisheries Science Center, Kodiak, Alaska. The historical database includes data from both NMFS and ADF&G surveys. The species were individually selected or grouped as necessary (see methods). When combining the catch and haul information, tows with zero catch had records created for all species (or species group). Please contact: P. J. Anderson, Kodiak Fisheries Research Center - NMFS, 301 Research Court, Kodiak, Alaska 99615 for a recent release of the data.

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Objectives:

1. Develop a statistically based sampling strategy based on analysis of past trawl survey data using changes in abundance and composition as parameters.

2. Provide sampling scenarios based on integrating survey logistics and other associated survey costs.

Introduction:

The Gulf of Alaska (GOA) marine ecosystem undergoes extreme changes in trophic structure which have become known as regime shifts (Anderson and Piatt, 1999; Anderson, 2000). This knowledge is the result of over 50 years of small mesh trawl sampling in the GOA and the scientific investment provided by the APEX project to understand the nature of decadal fluctuations in GOA trophic structure. Yet, the state of scientific knowledge is inadequate to explain the mechanisms at work that drive changes in this system. The following report is a compendium of what the data tell us is important in the benthic and epi-benthic portion of the GOA marine ecosystem and offers some possible mechanisms that control trophic structure. Unfortunately the data needed to fully comprehend the dynamics of this abundant system have not been collected consistently in the past and our hope is that we can make a compelling case for collecting this information to benefit future understanding.

Recently there has been information presented that the Gulf of Alaska (GOA) ecosystem has undergone some abrupt and significant changes (Piatt and Anderson, 1996; Anderson et. al., 1997; Anderson and Piatt, 1999). The extent and degree of these changes are documented and will become important in determining future strategies for management of the marine ecosystem. Analysis of the historic data is a first step in gaining an appreciation for the rapid and abrupt changes that have occurred in the marine species complex in the last five decades. The data from small-mesh shrimp trawl cruises provide an opportunity to review changes in the composition of forage species and other epi-benthic fish and invertebrates that occurred through time in the GOA from 1953 to present. These surveys represent the longest continually collected data on species composition and relative abundance in the near shore and bay habitiat of the Gulf of Alaska. This long temporal data perspective is necessary when judging the current species composition

Historically, there is evidence of major abundance changes in the fish/crustacean community in the western GOA. Fluctuation in Pacific cod availability on a generational scale was reported for coastal Aleutian communities by Turner (1886). Similarly, landings from the near-shore Shumagin Islands cod fishery (Cobb, 1927) showed definite periods of high and low catches with the fishery peaking in late 1870s. King crab commercial catches in the GOA show two major peaks of landings, one in the mid 1960s and another in 1978-1980 (Blau, 1986). All of the area was closed to fishing in response to low population levels in 1983 (Blau, 1986) and has yet to reopen. By the 1960s there was evidence of high Pandalid shrimp abundance in these same areas (Ronholt 1963). One of the highest densities of Pandalid shrimp known in the world was to spur the development of a major shrimp fishery (Anderson and Gaffney, 1977). By the late 1970s the

shrimp population density had declined radically and was accompanied by a closure of the shrimp fishery and the return of cod to inshore areas (Albers and Anderson, 1985). Catches of almost all salmon stocks of Alaskan origin suddenly increased to unprecedented levels in the 1980's (Francis and Hare, 1994; Hare and Francis, 1995). These changes, witnessed over the last century, imply dynamic fluctuations in abundance of commercially fished species. Managers, fisherman, and processors should be aware of these dynamics and their impacts on the ecology and economy.

The data supplied for this analysis is mostly drawn from the region around Kodiak Island and the adjacent bays along the south side of the Alaska peninsula. It should be pointed out that this area lies in an ecotone. An ecotone is defined as an area of overlap between different faunal domains. This area is judged to have a mixture of the Arctic and Aleutian faunal assemblages (Hedgepeth, 1953). We also believe that additional fauna from southern faunal domains are also represented in this area. One characteristic of an ecotone is that the areas are significantly more productive than areas that do not have overlap with adjacent faunal domains. The observation that climate drives changes in the relative abundance of one species to another is not surprising given the mixed faunal assemblages that are prevalent in this region. The cold climate phase probably favors increased abundance of species in the Arctic faunal domain, whereas warmer climate probably favors increased abundance of southern species. In addition to examining data drawn from the general Kodiak area we have also included Pavlof Bay because of the extensive data availability for this one bay. This allows comparison of results between areas relative to high sampling effort to those with lesser sampling intensity. The ultimate goal of this study is devoted to optimizing sampling of the small-mesh trawl survey that has proved useful in characterizing the relative state of the GOA ecosystem in the past.

Methods:

Small-mesh trawl surveys for shrimp were conducted by the National Marine Fisheries Service (NMFS) and the Alaska Department of Fish and Game (ADF&G) from 1953 to 2002. Sampling areas were designated by early exploratory surveys that had the purpose of locating commercial quantities of shrimp. Over 90% of survey tows were conducted in May - October. Early surveys had shown that shrimp concentrate in relatively deeper locations in the inshore bays and gullys of the GOA (Ronholt 1963). Consequently, most survey tows were restricted to depths greater than 55 m. After 1971 survey strata were designed for all known major shrimp concentrations in the central and western GOA. Random tow sampling locations within each strata were selected for each survey from 1972 to present. Prior to 1972, trawls were conducted with a variety of small-mesh gear having different catch efficiencies. These data are used here to compare relative (%) catch composition from 1953 to 1999. From 1972 onward, ADF&G and NMFS standardized methods and used “high-opening” trawls with 32 mm stretched-mesh throughout (Anderson 1991, Wathne 1977). Catch per unit effort (CPUE) was calculated as kg caught per km trawled. Between 1953 and 1999, 9108 trawls covering 17,630 km were conducted (Figure 1). Annual effort averaged 259 trawls per year (range: 22-775).

The ability to statistically detect changes in species abundance was analyzed for the shrimp trawl gear for 1972 - 1975 NMFS data, and 1975 - present for NMFS and ADFG (ADFG data do not include complete taxanomic sorting until 1975 and later). Species abundance estimates were analyzed using the historical database from both NMFS and ADFG surveys. The selected species and groups are given below with abbreviations used throughout the remainder of this report.

Individual Species	**Species Groups**
Pandalus borealis (n)	Pandalid Shrimp (gp)
Pandalus goniurus (h)	Flatfish (gf)
Theragra chalcogramma (w)	Roundfish (gr)
Mallotus villosus (c)	Osmerids (go)
Gadus macrocephalus (p)	
Atheresthes stomias (a)	
Hippoglossoides elassodon (f)	
Theragra chalcogramma (Juvenile) (wj)	

The selected species above comprised nearly 90% of the biomass reported by Anderson and Piatt (1999). Seasonal variation in the relative abundance of some species made it necessary to use only the data from the predominant seasonal sampling period (July 16 - October 31). Tows prior to 0600, or on or after 2200 hours were excluded. Tow numbers in the selected sampling areas by year are presented in Table 1. Catches from tows judged to have unsatisfactory performance were also excluded from this analysis. Tows where it was difficult to determine position were also eliminated from the analysis. The species were individually selected or grouped as necessary. When combining the catch and haul information, records were created for tows with a zero catch of any species (or species group).

Abundance estimates were obtained using CPUE spatially expanded to the representative area of each tow. The expansion to the representative area used Dirichlet tessellation (Isaaks and Srivastava, 1989; Okabe et. al., 1992). Each Dirichlet tile is a convex polygon and takes into account the representative area of each tow in each year. To exclude tile overlap with the land mass, the tiles were clipped, with each tile retaining its attribute as a convex polygon. The clipping process began with a semi-rectangular area (example: Figure 2) followed by additional clipping to remove the overlap with the land mass (example: Figure 3). Where some land mass overlap remained, an approximately equal area of ocean was clipped. Tiles that extended too far out into the ocean were also clipped. The final clipped tiles, as far as practicable, covered the historically charted sample areas. When two or more tows within a year had identical locations, only one of the tows was retained, having no affect on the tiles.

The CPUE of each tow was weighted by dividing the Dirichlet tile area associated with that tow by the total tile area in that bay and year. The estimator used for CPUE is the weighted mean CPUE for a selected bay, year and species.

The between-year difference in CPUE estimates was tested for significant differences using randomization tests (Good, 1994; Edgington, 1987). The randomization process used the

observed individual tow CPUE's, and without replacement, randomly assigned them to a tile in each year according to the number of tows in that year. Identically located tows used the average of the observed CPUE of those tows. The obtained *P*-values are the one-tailed probability of getting such a large test statistic (difference in means).

We used graphical analysis to view the relation between the *P*-values, the percentage change in CPUE and the number of tows. The percentage change in CPUE was computed by dividing the absolute difference of the two CPUE values by the larger of the two values. This provides a metric bounded by zero and one. We have termed this percentage change as the "detectability", even though a small detectability is better than a larger detectability.

Criteria for developing a sampling strategy rely on the concept of detecting a change in a given individual species or species group abundance in successive years. The detection range of the models for the individual bays range from very small changes (0.3) to extremely large changes (1.0). When the difference between two CPUE's is a decrease between two years, the detectability is equal to the percentage change (e.g. 70% decrease is equivalent to a 0.70 detectability value). When the difference between two CPUE's is an increase between two years, the detectability is equal to (percentage increase) / (100 + (percentage increase))(e.g. 70% increase is equivalent to a 0.41 detectability value). Table 2 lists detectability values for selected increases and decreases in weighted mean CPUE. When a detectability is evaluated, it can be interpreted for the direction of change. For example, a detectability of 0.7 is a decrease of 30% or an increase of 233%.

Change in historical weighted mean CPUE was analyzed to determine statistical differences between subsequent survey years and all possible pairings of survey years within each bay. The test statistic was the absolute difference of the two weighted mean CPUE values. CPUE estimates were tested for significant differences using randomization with 10,000 permutations for subsequent survey years and 5,000 for all possible pairings. For comparative purposes, we also tested adjacent survey year weighted CPUE distributions using randomization of the Wilcoxon rank sum test (Conover 1980) with adjustment for ties and 10,000 permutations. We graphically present the relation of historical detectability and level of *P*-value of the test of differences of all possible pairs of survey years. In addition, we illustrate the relation between the percentage of survey pairs meeting the $\alpha = 0.05$ and 0.10 significant levels and the detectability.

Sensitivity to reduced or increased sampling intensity in selected geographic areas was evaluated through simulated sampling. In recognition that the community structure had undergone significant change during the historical study period (Anderson and Piatt, 1999; Anderson, 2000), we sampled the data under two distinct community regime conditions. The "warm" regime community structure was assigned the 1981 to present time period in the data series. In turn, the 1972 through 1980 data was assigned the "cold" regime period. These data sets were separated based on our *a priori* understanding of the two phases of the observed community structure evident in the historical trawl survey data.

The sampling simulation models used polygonal sampling areas (example: Figure 4) overlaid

with a NS-EW grid of possible locations, with a distance of 400 m between the intersections of the grid for possible locations of tows. Sampling frequencies of 3,4,...,25 were evaluated by simulating a 20 year survey sampling period by sampling from both warm and cold water regime species mixes and bay-specific probability density functions (pdf) developed using kernel density estimation (Silverman, 1986; Scott, 1992). The CPUE bandwidth for each species was chosen to smooth the pdf, but still retain local modes (is this OK??). The Epanechnikov kernel was used as the smoother (Silverman 1986). Each pdf was estimated at 1000 points. The portion of the estimated pdf associated with a CPUE of less than zero was pivoted into the positive portion of the pdf (Silverman, 1986). The warm and cold water regime pdfs were obtained from identifying the low and high pdfs for the historical data. Samples were randomly located in the sampling area using systematic random sampling and the abundance estimates weighted on tile area were obtained. Randomization tests of absolute difference in CPUE used 1000 permutations. For each simulated sampling frequency, there were 190 possible combinations for the 20 years.

The effect of sample size on the *P*-values was graphically analyzed to determine sensitivity in observing various levels of detectability. We used a moving-window smoother (Isaaks and Srivastava, 1989) on the *P*-values to estimate the surface describing the relation between percentage change (detectability) and sample size. The contour lines for these surfaces were evaluated at $\alpha = 0.01$, 0.05, 0.10, and 0.20. The smoothed estimate used an $\alpha = 0.10$ trimmed mean (Rosenberger and Gasko, 1983) with a window width of 4 (*x*-axis, sample size) and height of 0.125 (*y*-axis, detectability). The overlap was 3/4 of the window, with the *x*-axis mid-point of each window at 2.5, 3.5,..., 26.5. The trimmed mean gives a robust metric of what the *P*-value is "on average" within the window. We also looked at the SE of the *P*-values using the same windowing parameters.

We targetted a detectability of 2/3=0.667 at $\alpha \leq 0.10$, which provides a sensitivity to observing a statistically significant decrease in CPUE of 66.7% (2/3rds the size of the previous year) or increase of 200% (3 times larger than the previous year). Other sampling scenarios can be obtained from the information presented in this report and accompanying appendices.

Analyses of the sensitivity to increased (and decreased) sampling frequency were linked to survey cost. Cost is expressed in terms of number of bays (sampling areas) and number of tows needed to adequately sample within those areas (number of survey days). The cost was directly related to the ability to detect statistically significant changes in species abundance. Distance and logistical cost estimates were then integrated into results obtained above in order to arrive at a final cost for possible sampling scenarios.

In order to aide in the decision making process for determining sample size, a custom program was developed based on project data output matrices from the simulation sampling (Argile, 2002). A complete description of this program can be found in the help file accompaning the program. In order to aide in the interpretation and writing, graphics created by the program and from referenced reports were structured into several computer screen slide series as a “story book” (Johnson, 2002).

The solution for cruise days computed by the software takes the number of full and partial days in each bay, adds the travel time between each bay, and the return trip to port. The value returned is rounded up to 0.1 days. We used the median tows per day from the historical data for the years 1975 to present to estimate days of effort in each bay or sampling area (SA). The days to the first bay and between bays is 1.00, but this can be changed in the software along with the number of tows per day for each bay for a different solution output by the software. The resultant cruise days are calculated. Cruise setup and breakdown are not included in this estimate.

Graphics used the S statistical package (Becker et al., 1998). Kernel density estimation was performed using the S library by Hardel (1991). The estimation of Dirichlet tiles, moving window smoothing and randomization tests used customized S libraries. The random number generator for randomization tests is from Press et al. (1992).

Results:

For the period of record (1953-1999), trawl catch biomass was dominated by three taxonomic groups: shrimp (36%), cod and pollock (33%) and flatfish (15%). Although 435 individual taxa were identified, 10 taxa comprised 90% of the total biomass (in order of abundance): northern shrimp (*Pandalus borealis*), walleye pollock (*Theragra chalcogramma*), flathead sole (*Hippoglossoides elassodon*), Pacific cod (*Gadus macrocephalus*), humpy shrimp (*P. goniurus*), jellyfish (Scyphozoa), arrowtooth flounder (*Atheresthes stomias*), sidestripe shrimp (*Pandalopsis dispar*), yellowfin sole (*Pleuronectes asper*) and capelin (*Mallotus villosus*).

Each bay had its own unique species mix and distribution over time. In recognition of these unique patterns and the necessity of building a separate temporal species/abundance model for each bay, results are presented individually for each bay or SA in the sections below. However, some similar conditions were common to all or most bays studied. These common patterns are presented in the information below. The number of historical trawl tows retained by this analysis for each bay is presented in Table 1.

Historical spatial area estimation - Overview

An example of the initially clipped tiles is shown in Figure 2. From this start, additional clipping removed the tile overlap with the land mass or when a tile extended too far from the historical sampling area. Figure 3 is an example of the final clipped tile. The tiles in all years within each bay were identically clipped with additional clipping unique to a year when tiles extended beyond the historical sampling areas.

In some of the bays, several of the tows were recorded as located on the land mass or outside of the normal locations. These are later discussed in the separate bay sections. Until the dry tows are relocated to their correct locations, it was necessary to drop these from this analysis. Including them would force the tiles onto the land mass and misrepresent resulting abundance estimates.

The initial tile clipping and final clipped tiles for each bay and year are documented in Johnson (2000e, 2000f, 2000g, 2000h, 2001i and 2001j). The total area of the Dirichlet tiles for each year

of historical sampling are given in Appendix I.

Historical detectability - Overview

The historical detectability for all SAs of weighted CPUE as a percentage decrease or increase shows a wide range of maximum and median values (Tables 3, 4, 5 and 6). The percentage change when one of the values is zero were excluded because it can result in a percentage change of zero or infinity when the numerator or denominator is zero.

Historical tests of subsequent year CPUE - Overview

The tests for the difference between years in historical survey weighted CPUE's for each bay and species are documented in Johnson (2000a, 2000b, 2000c, 2000d, 2001g and 2001h). The test results are presented in Appendix II. The CPUE values are rounded to one decimal place, so very small values show up as 0.0. In addition to the *P*-values of the randomization tests between adjacent survey years, the Wilcoxon rank sum test of equallity of distribution "location" is included (Appendix II). The rank sum test does not take into account the spatial aspect of the data. The rank test is provided to show the similarity to the test of differences in weighted mean CPUE, but is only a test of location shift between the two distributions.*(Alan, if the locations are shifted what does it mean)

Historical tests of all possible pairs of survey year CPUE - Overview

Figure 5 is an example of all possible combinations of historical survey years for one species and bay (Johnson 2000a). This is different from adjacent historical survey years. The figure shows the relation between the percentage change in CPUE and the *P*-value from the randomization test of differences in weighted mean CPUE. If both species CPUE in adjacent years are truly zero, there is no test and the pair of years is excluded. In Figure 5 each pair of survey years is plotted as a circle with the radius reflecting the number of tows that is the smaller of the two years. The density of the points is illustrated by the histogram in the box at the right. The histogram is scaled to the box. If one or more of the years had a weighted mean CPUE value of zero, all of the pairs of survey years associated with it have a change of 100%. This is also reflected in the height of the histogram at the 1.0 *y*-axis value. The height at 1.0 is also increased when there are very large and very small CPUE values, making the change in CPUE close to one.

To gain further information from the figures on historical differences, for each bay we plotted the relation between percentage change between any two years and the *P*-value for the α=0.05 and α=0.10 significance levels. These are presented as line plots for each species that show the percentage of all combinations that are within the critical area as they relate to the percentage change between the years as presented by Johnson (2000a, 2000b, 2000c, 2000d, 2001g and 2001h). An example is shown in Figure 6. Given any percentage change, there are values that are within the critical area, or not. The percentage of points that are within the critical area provides a measure of the stability or frequency of how the historical data performed when at or above a given percentage change. The referenced material also graphically shows what happens when changes in CPUE that equal 100% are excluded. This is necessary to restrict tests of significance to only non-zero CPUE.

Simulated sampling to determinating sample size - Overview
We present a possible solution that attempts to achieve a detectability of 0.667 for all species with a 0.1 or less alpha-level. A 0.667 detectability means that on average we can observe a statistically significant difference, at a specified alpha-level, in the change in CPUE between two subsequent years within a bay. The detectability, as previously discussed, is the percentage change based on the ratio of the absolute value of the change in weighted mean CPUE (weighted CPUE is a spatial estimate of CPUE) divided by the larger CPUE of the paired years.

We used the software to determined the detectability of each species for the warm and cold conditions in each bay at an α= 0.01, 0.05 and 0.10 for any given number of tows between 3 and 25. From the graphs and computer printouts, we adjusted the alpha-levels for the species within each bay to target the 0.667 detectability. The *P*-value contour lines in the graphs allowed us to identify problem species. Problem species are represented by broken P-value lines, wraparounds and islands in the contour graphs. In addition, some species cannot achieve the targetted detectability due to these problems and are also classed as problem species.

The low and high pdf's that were sampled for each species in each bay are shown in Johnson (2001a, 2001b, 2001c, 2001d, 2001e, and 2001f). An example (Johnson, 2001a) is displayed in Figure 7. It was determined from the pdf's that the warm water years after 1981 were characterized by low densities of the pandalid shrimp species group, the osmerid species group, northern shrimp, humpy shrimp, and capelin. The other species are at high densities in the warm water years. The opposite holds true for the cold water period prior to 1981. The *y*-axis scale in the pdfs is called the "point probability" which appropriately scales both curves (warm and cold periods) for comparison. The actual probabilities associated with each CPUE take into account the distance between each CPUE value that makes up the curve.*(Alan is there a better way to explain this??, why is the CPUE distance important, also it might be appropriate to point out higher probability of a larger CPUE in years through 1980??)

For each bay, the 20 years of samples yield 190 possible pairs of comparisons for each species or group, sample size and pdf level. For each species pdf level there were 4,370 data points for the moving-widow application, 190 at each sample size. The number of observations used in each moving window are documented in Johnson (2001a, 2001b, 2001c, 2001d, 2001e, and 2001f) as the minimum and maximum of the available observations for the 12 species for each of the pdf levels. An example from Johnson (2001a) of the minimum number of available observations is displayed in Figure 8. Along the edges are smaller numbers due to the decrease in numbers of observations available to the moving window. The data elements for each species at each sample size do not completely span the range 0.0 to 1.0 of the percentage change in weighted CPUE. When the contour lines extend into areas where there is no data, there will be gaps. Figures 22-23 in Johnson (2001a, 2001b, 2001c, 2001d, 2001e, and 2001f) are the maximum values of the weighted CPUE for each species at each sample size. Areas above the limits of the data will not have any contour lines. The contour lines at the edge of the data, or within the range of the data will depend upon the variability of the moving-window SE or *P*-value.

Johnson (2001a, 2001b, 2001d, 2001e, and 2001f) presents the contour lines for each species at

the α-levels, the low and high pdf levels for each species, and a discussion of the SE of the *P*-values. A visual reference at 50% change in weighted CPUE is included in the referenced figures. An example of the *P*-value contour lines (Johnson 2001a) is provided in Figure 9. Sample modeling in this case demonstrates that only four species (or groups) will be adequately sampled to detect the targeted change in CPUE at 21 samples. Increasing samples be yond this point does not bring more species into the targeted range in this example.

In the interpretation of the contour line graphics, a smaller value on the *y*-axis (detectability) is better. A sensitivity to observing small changes in CPUE is desirable. It is also desirable to include as many species (or groups) into the targeted detectability as possible.

In the following sections the figures are for warm and cold water regime solutions. Species that are problem species are presented separately. However, we do leave in the figures any species that has a "stable" *P*-value contour at or above the selected number of tows, even if the detectability is more than our targeted detectability. For most bays we have selected one of the problem species (if any) to present its *P*-value contour lines and SE of the *P*-values.

The following is a narrative explanation of results given by sampling area, frequently referenced to a specific bay.

Alitak Bay
Alitak Bay at the southwestern tip of Kodiak Island (Figure 4) has been sampled well since 1975 almost entirely by ADF&G. There were 6 tows either on land or outside of the area that were dropped from the analysis. In 1985, 1986, 1987, 1988 and 1990 the number of tows (30, 24, 12, 0 and 0) that were only on the bottom were less than the total number of tows of 36, 25, 13, 3, and 2 (Appendix I).

Alitak Bay - Adjacent historical survey years
For the pandalid shrimp species group, only one test (1984-1985) was significant (Appendix II Table 1). The change was a large change (97.6 kg/km), but the early years with larger changes were not significant. For the flatfish species group, the tests were consistent at catching differences for a change of 27 kg/km or greater (except for 1987-1989). With a change of 83 kg/km or greater, we can show significant differences for the roundfish species group. For northern shrimp, the tests were consistent at catching differences for a change of 56 kg/km or greater. For flathead sole, the tests were consistent at catching differences for a change of 13 kg/km or greater.

For the osmerid species group, humpy shrimp, walleye pollock, juvenile walleye pollock, capelin, Pacific cod and arrowtooth flounder, the pattern was erratic with significance sometimes at low changes in CPUE, and sometimes at high changes, but not consistent, showing no evident pattern (Appendix II Table 1).

Alitak Bay - All possible pairs of historical survey years
If we ignore 1-3 tows, the following species appear to show consistency in detecting a change in

CPUE ≥70-80% at the α=0.05 significance level: the flatfish species group (Figure 5) and flathead sole (Figure 10). The other species are more varied. As indicated by the horizontal line of points at 1.0, seven species have trouble with significance for changes in CPUE of 100%, with Figure 11 as an example (Johnson 2000a).

The relation between cumulative percentage of *P*-values in the critical region and percentage change in weighted CPUE provides an additional view. There appear to be three groupings of species in the 0.0-0.5 range of detectability. The groups are (1) northern shrimp, flathead sole, the pandalid shrimp species group, capelin, and the flatfish species group; (2) Pacific cod, walleye pollock, and the osmerid species group; (3) juvenile walleye pollock, the roundfish species group, humpy shrimp and arrowtooth flounder (Figure 12). Within the first two groups, the lines follow each other within the group to approximately a 0.5% percentage change in weighted CPUE. The species in the third group do not follow each other.

Only the flatfish species group and flathead sole have 90% of the tests in the critical region, and only at a percentage change of ≥80% for the α=0.05 level (Figure 12) and ≥60% for the α=0.1 level (Figure 6). The poorest performance is with arrowtooth flounder, humpy shrimp and the roundfish species group (Figures 6 and 12). The approximate horizontal line at the top of the figures is caused by years that had zero CPUE, paired with a non-zero CPUE year, the change in CPUE in these cases is 100%.

Alitak Bay - Simulated sampling area

The historical tows were overlaid with 4-sided polygons yielding a sample area of 446.6 km^2 (Figure 4) with 2807 possible sample locations (Figure 13). The sequence of sample locations runs NS and EW within each polygon.

Alitak Bay - Simulated sampling detectability and number of tows - Warm water

With 11 tows in Alitak Bay for the warm water regime, on average we would achieve a 0.667 or less detectability for 7 species (Figure 14). Except for Pacific cod at 0.05, all alpha-levels are at 0.1 (Table 7). To pick up arrowtooth flounder at a 0.667 detectability, 19 tows would be needed (Figure 14). The problem species are the osmerid species group, humpy shrimp, juvenile walleye polllock, capelin and arrowtooth flounder (Figure 15).

Capelin have *P*-value contour lines with an island of greater than 0.1 (and 0.2) running along the top portion (0.6-0.9) of Figure 16. In this area, we cannot achieve a *P*-value of 0.1. We must use the values associated with the 0.1 contour at the top of the graph, not any lower 0.1 contour. At 12 tows, the detectability of capelin is approximately 0.95 (very poor). The *P*-values in the island area do not have a high SE (0.01-0.05) (Figure 17).

Alitak Bay - Simulated sampling detectability and number of tows - Cold water

With 13 tows in Alitak Bay for the cold water regime, on average we would achieve a 0.667 or less detectability for 8 species (Figure 18). Except for the pandalid species group and northern shrimp at 0.05, all alpha-levels are at 0.1 (Table 7). The detectability for humpy shrimp was 0.73.

The detectability was 0.82 for juvenile walleye pollock and 0.80 for Pacific cod. For humpy shrimp, juvenile walleye pollock and Pacific cod there would be 23, 19 and 20 tows respectively needed to achieve the target detectability (Figure 19). Arrowtooth flounder had a 0.91 detectability if the broken line is ignored.

Arrowtooth flounder had *P*-value contour lines that had a wraparound problem where *P*-values were between than 0.1 and 0.2 (Figure 20). In this area, we cannot achieve a *P*-value of 0.1. We must use the values associated with the 0.1 contour at the top of the graph, not any lower 0.1 contour. The upper 0.1 contour line is broken. Even if it was continuous (and smoother) at 13 tows, the detectability of arrowtooth flounder is more than 0.9 (very poor). The *P*-values in this area do not have a high SE (0.005-0.01) (Figure 21).

Chignik-Castle Bays

There were 12 tows either on land or outside of the area that were dropped from the analysis. In 1985, 1987, 1988 and 1990 the number of tows (8, 11, 0 and 1) that were only on the bottom were less than the total number of tows of 12, 14, 1 and 2 (Appendix I) .

Chignik-Castle Bays - Adjacent historical survey years

For the pandalid shrimp species group and northern shrimp, a change in CPUE of 78 kg/km or greater was significant (Appendix II Table 2). It appears that northern shrimp dominate the composition of the pandalid shrimp species group in historical CPUE estimates. A change in CPUE of 27 kg/km or greater was significant for the flatfish species group. For flathead sole a change of 35 kg/km or greater was significant.

For the osmerid species group, Pacific cod and arrowtooth flounder the performance was poor with significance sometimes at low changes in CPUE, and sometimes at high changes, but not consistent (Appendix II Table 2). Table interpretation is inconclusive for the roundfish species group, humpy shrimp, walleye pollock, juvenile walleye pollock and capelin.

Chignik-Castle Bays - All possible pairs of historical survey years

The following species showed consistency in an α=0.05 significance in detecting a change in CPUE > 75%: the pandalid shrimp species group, the flatfish species group, the roundfish species group, northern shrimp, arrowtooth flounder and flathead sole (pattern as in Figure 10). For the most part the only deviant *(Alan, is there a better term we could use here??) tests were those with a small number of tows, and occasionally several larger tows. At a change in CPUE > 80%, walleye pollock and Pacific cod did show a very large number of values in the critical region, but still have tests outside of the region that are not associated with a small number of tows. Performance was poor for the osmerid species group, humpy shrimp, juvenile walleye pollock and capelin.

The relation between cumulative percentage of *P*-values in the critical region and percentage change in weighted CPUE provides an additional view. The pandalid shrimp species group, the flatfish species group, northern shrimp and flathead sole performed the best and were very similar. At the α=0.05 level, 90% of the *P*-values are significant when the change in CPUE is

approximately 60% or greater (Figure 22). At the α=0.10 level, the change in CPUE needs to be only 40% or greater, and arrowtooth flounder joins the other species (Figure 23). The flatfish species group and walleye pollock lines follow each other. The poorest performance is with humpy shrimp and capelin. The approximately horizontal lines at the top of the figures are caused by the decrease in the proportion in the critical region at the largest change in CPUE. This is usually at a 100% change in CPUE.

Chignik-Castle Bays - Simulated sampling area
The historical tows were overlaid with 4-sided polygons yielding a sample area of 210.6 km^2 (Figure 24) with 1301 possible sample locations (Figure 25). The sequence of sample locations runs EW and NS within each polygon.

Chignik-Castle Bays - Simulated sampling detectability and number of tows - Warm water
With 10 tows in Chignik-Castle Bays for the warm water regime, on average we would achive a 0.667 detectability for all 12 species (Figure 26). Alpha-levels are 0.05, except for the osmerid species group, humpy shrimp, capelin and Pacific cod at 0.1 (Table 8). There were no problem species.

Chignik-Castle Bays - Simulated sampling detectability and number of tows - Cold water
With 13 tows in Chignik-Castle Bays for the cold water regime, on average we would achive a 0.667 detectability for 10 species (Figure 27). With 15 tows, all species have a 0.667 detectability. Alpha-levels are 0.05, except for the osmerid species group, humpy shrimp, capelin and Pacific cod at 0.1 (Table 8). Capelin had a detectability of 0.72. We have no statistically valid tests for juvenile walleye pollock in this sampling model(Figure 28).

Juvenile walleye pollock have *P*-value contour lines that have a wraparound problem where *P*-values are greater than 0.1, but less than 0.2 (15-19 tows) (Figure 29). In this area, we cannot achieve a *P*-value of 0.1. We must use the values associated with the 0.1 contour at the top of the graph, not any lower 0.1 contour. Even with tows of 14 or more, the detectability of juvenile walleye pollock is more than 0.95 (very poor). The *P*-values in this area do not have a high SE (0.01-0.05) (Figure 30).

Kiliuda Bay
There were 5 tows either on land or outside of the area that were dropped from the analysis. In 1985, 1986 and 1987 the number of tows (9, 10 and 0) that were only on the bottom were less than the total number of tows of 12, 13 and 1 (Appendix I).

Kiliuda Bay - Adjacent historical survey years
For the osmerid species group, a change in CPUE greater than 8 kg/km was significant at the α=0.05 level (Appendix II Table 3). All of the test prior to 1985 for walleye pollock are significant, but after 1984 none are significant even when the change in CPUE is large. A change in CPUE of 8 kg/km or greater was significant for arrowtooth flounder prior to 1985, but not significant afterwards.

For the pandalid shrimp species group and northern shrimp the performance was poor with significance sometimes at low changes in CPUE, and sometimes at high changes, but not consistent (Appendix II Tables 3). It appears that the pandalid shrimp species group is mostly composed of northern shrimp. Table interpretation is inconclusive for the flatfish species group, the roundfish species group, humpy shrimp, juvenile walleye pollock, capelin, Pacific cod and flathead sole.

Kiliuda Bay - All possible pairs of historical survey years

The following species show consistency in an α=0.05 significance in detecting a change in CPUE > 60%: the flatfish species group, the roundfish species group, walleye pollock, arrowtooth flounder and flathead sole (pattern as in Figure 10). For the most part the only deviant tests are those with a small number of tows. At a change in CPUE > 70%, the pandalid shrimp species group, northern shrimp and Pacific cod do show a very large number of values in the critical region, but still have tests outside of the region that are not associated with a small number of tows. Performance is poor for the osmerid species group, humpy shrimp, juvenile walleye pollock and capelin.

The relation between cumulative percentage of *P*-values in the critical region and percentage change in weighted CPUE provides an additional view (of what?). At the α=0.05 level, the flatfish species group and flathead sole perform the best (Figure 31). Ninety percent of the *P*-values are significant when the change in CPUE is approximately 50% or greater. With a change in weighted CPUE > 40%, the pandalid shrimp species group, the roundfish species group, northern shrimp, walleye pollock, and arrowtooth flounder perform very similar. The pandalid shrimp species group and northern shrimp are essentially identical lines. The osmerid species group and Pacific cod have very similar performance. Capelin and humpy shrimp show no promise of producing acceptable results in this instance. At the α=0.10 level, and a change in CPUE of 70% or greater, six species show good performance (Figure 32).

The poorest performance *(Alan, in terms of what? In terms of detectability??) is with capelin, humpy shrimp and juvenile walleye pollock. The approximately horizontal lines at the top of the figures are caused by the drastic decrease (or increase) in the proportion in the critical region at the largest change in CPUE. This is usually at a 100% change in CPUE. The vertical line that ends the flatfish species group and flathead sole is caused by the mass of points that are in the critical region at the largest change in CPUE.

Kiliuda Bay - Simulated sampling area

The historical tows were overlaid with 4-sided polygons yielding a sample area of 205.4 km^2 (Figure 33) with 1293 possible sample locations (Figure 34). The sequence of sample locations runs EW and NS within each polygon.

Kiliuda Bay - Simulated sampling detectability and number of tows - Warm water

With 12 tows in Kiliuda Bay for the warm water regime, on average we would achieve a 0.667 detectability for 10 species (Figure 35). Alpha-levels are 0.05, except for the roundfish species group, the osmerid species group, walleye pollock and arrowtooth flounder at 0.1 (Table 9).

At 12 tows, we have no statistically based tests for juvenile walleye pollock with the broken line. Pacific cod has a detectability of 0.82 (Figure 36).

Kiliuda Bay - Simulated sampling detectability and number of tows - Cold water
With 15 tows in Kiliuda Bay for the previous cold water regime, on average we would achive a 0.667 detectability for 7 species (Figure 37). Alpha-levels are 0.05, except for the osmerid species group and juvenile walleye pollock at 0.1 (Table 9). Those close to the target detectability are the osmerid species group at 0.69, northern shrimp at 0.68 and juvenile walleye pollock at 0.69 detectability.

If we accept the jagged contour line for capelin, it has a detectability of 0.78 (Figure 38). We have no statistically based tests for humpy shrimp (Figure 39). More then 18 tows are needed for obtaining any detectability for humpy shrimp, and the detectability is more than 0.95 (very poor). Where humpy shrimp P-values are available, the SE is reasonable (0.01-0.05) however (Figure 40).

Marmot Bay (inshore)
There were 12 tows either on land or outside of the area that were dropped from the analysis. No tile estimate exists for 1990 because there was only one tow. In 1985, 1986, 1987, 1988 and 1990 the number of tows (19, 1, 16, 0 and 0) that were only on the bottom were less than the total number of tows of 25, 7, 22, 3 and 1 (Appendix I).

Marmot Bay (inshore) - Adjacent historical survey years
For the flatfish species group, a change in CPUE of 136 kg/km or greater was significant (Appendix Table 4). For flathead sole a change of 33 kg/km or greater was significant. For the roundfish species group and humpy shrimp, there were no significant differences at the α=0.05 level. Table interpretation is inconclusive for the osmerid species group. For the pandalid shrimp species group, northern shrimp, walleye pollock, juvenile walleye pollock, capelin, Pacific cod and arrowtooth flounder, the performance was poor with significance sometimes at low changes in CPUE, and sometimes at high changes, but not consistent, showing no evident pattern.

Marmot Bay (inshore) - All possible pairs of historical survey years
Both the flatfish species group and flathead sole appear to show consistency in detecting a change in CPUE $\geq$70% and $\geq$65% respectively (pattern as in Figure 10). With at least 10 tows, northern shrimp and the roundfish species group appear consistent for changes in CPUE $\geq$75%, and the pandalid shrimp species group for changes in CPUE $\geq$80%. The other species are more varied. As indicated by the horizontal line of points at 1.0, three to four species have trouble with significance for changes in CPUE of 100%. Most of the changes in CPUE for humpy shrimp are at the 100% level, and there are no *P*-values in the 0.05 critical region.

The relation between cumulative percentage of *P*-values in the critical region and percentage change in weighted CPUE provides an additional view. There appear to be three groupings of species in the 0.0-0.7 range of detectability at the α=0.05 level (Figure 41). The groupings are (1) the flatfish species group and flathead sole; (2) the pandalid shrimp species group, northern

shrimp, Pacific cod, and arrowtooth flounder; and (3) the osmerid species group and capelin. Additionally, the walleye pollock and the roundfish species group lines follow each other in the 0.0-0.6 range. The other species are more varied. At the α=0.1 level the groupings still hold except for a change in flathead sole (Figure 42). As previously discussed, humpy shrimp is not even present in the comparison because it has no values within the α=0.1 level.

The approximately horizontal lines at the top of the figures are caused by small counts at the percentage change and almost all (or almost none) of the *P*-values located in the critical region.

Marmot Bay (inshore) - Simulated sampling area
The historical tows were overlaid with 4-sided polygons yielding a sample area of 351.2 km^2 (Figure 43) with 2211 possible sample locations (Figure 44). The sequence of possible sample locations runs EW and NS within each polygon.

Marmot Bay (inshore) - Simulated sampling detectability and number of tows - Warm water
With 12 tows in Marmot Bay (inshore) for the warm water regime, on average we would achieve a 0.667 detectability for 9 species (Figure 45). Alpha-levels are 0.05, except for the pandalid species group, northern shrimp and Pacific cod at 0.1 (Table 10). Pacific cod does not improve with more tows and remains at approximately a 0.75 detectability.

We have no statistically based tests for arrowtooth flounder. Accepting the top line for humpy shrimp gives a 0.92 detectability (Figure 46).

Humpy shrimp have *P*-value contour lines that have a band of *P*-values greater than 0.2 running along the top portion (0.5-0.9) of the graph (Figure 47). In this area, we cannot achieve a *P*-value of 0.1. We must use the values associated with the 0.1 contour at the top of the graph, not any lower 0.1 contour. The 0.1 contour line at the top of the graph is reasonable, but with poor detectability (0.85 to 0.95). At 12 tows and higher, the detectability of humpy shrimp is approximately 0.92 (very poor). The P-values in this area do not have a high SE (0.01-0.05) (Figure 48).

Marmot Bay (inshore) - Simulated sampling detectability and number of tows - Cold water
With 11 tows in Marmot Bay (inshore) for the cold water regime, on average we would achieve a 0.667 detectability for 7 species (Figure 49). Alpha-levels are 0.05, except for the osmerid species group, humpy shrimp, walleye pollock, juvenile walleye pollock, capelin and Pacific cod at 0.1 (Table 10). The remaining 5 species, the osmerid species group, humpy shrimp, walleye pollock, juvenile walleye pollock, and capelin do not improve with an increase in the number of tows (Figure 50).

The osmerid species group has an island of 0.05-0.1 *P*-values. Because it has a better alpha-level, we can ignore it and use the upper line (Figure 51). The P-values in this area do not have a high SE (less than 0.05) (Figure 52).

Pavlof Bay
While Pavlof Bay is technically out of the proposed monitoring area it is analyzed here in comparison to the other bays under study. Pavlof has the longest continually conducted survey in the GOA and is therefore provided here for comparison. There were 11 tows outside of the area that were dropped from the analysis. In 1987, 1988 and 1990 the number of tows (12, 22 and 23) that were only on the bottom were less than the total number of tows of 17, 25 and 24 (Appendix I).

Pavlof Bay - Adjacent historical survey years
For the pandalid shrimp species group, large and small changes in CPUE were detected (Appendix II Table 5). For northern shrimp, the tests were consistent at catching differences for a change of 5 kg/km or greater. With a change of 45 kg/km or greater, we can show significant differences for the flatfish species group.

For the roundfish species group prior to 1990, changes > 105 kg/km were significant, but after 1990 these same levels of change were not significant (Appendix II Table 5). Differences in CPUE for walleye pollock were detected when the change was > 90 kg/km, but not in all instances, especially in 1997-1999. For arrowtooth flounder, a change ≥ 5 kg/km was usually significant, but this level of change only exists for the most recent survey years.

For the osmerid species group, the performance was poor with significance sometimes at low changes in CPUE, and sometimes at high changes, but not consistent (Appendix II Table 5). There were many years with no catch of juvenile walleye pollock, leading to no conclusions.

Even with large changes in the CPUE of humpy shrimp in the early years, the tests were inconsistent and after 1990, all CPUE values were very low with no significant values (Appendix II Table 5). Table interpretation is inconclusive for capelin, Pacific cod and flathead sole.

Pavlof Bay - All possible pairs of historical survey years
The following species appear to show consistency with 90% in the critical region and a change in CPUE ≥ 50% at the α=0.05 significance level: the pandalid shrimp species group, the flatfish species group, northern shrimp and flathead sole (pattern as in Figure 10). The other species are more varied.

The relation between cumulative percentage of *P*-values in the critical region and percentage change in weighted CPUE provides an additional view. The northern shrimp, the flatfish species group, the pandalid shrimp species group and flathead sole perform the best and are very similar. At the α=0.05 level, 90% of the *P*-values are significant when the change in CPUE is approximately 30% or greater (Figure 53). At the α=0.10 level, the change in CPUE needs to be only 20% or greater (Figure 54). The poorest performance is with capelin, juvenile walleye pollock and the osmerid species group.

The approximately horizontal lines at the top of the figures*(Alan fig. Numbers here ?) are caused by years that had zero CPUE. When paired with a non-zero CPUE year, the change is

100%.

Pavlof Bay - Simulated sampling area
The historical tows were overlaid with 4-sided polygons yielding a sample area of 251.2 km^2 (Figure 55) with 1564 possible sample locations (Figure 56). The sequence of possible sample locations runs NS and EW within each polygon.

Pavlof Bay - Simulated sampling detectability and number of tows - Warm water
With 7 tows in Pavlof Bay for the warm water regime, on average we would achieve a 0.667 detectability for all but 1 species (Figure 57). Alpha-levels are 0.05, except for the roundfish species group and walleye pollock at 0.1 (Table 11). We have no statistically based tests for Pacific cod (Figure 58).

Pacific cod have *P*-value contour lines that have an open-ended island of *P*-values greater than 0.1 (and 0.2) running along the top portion (0.6-0.9) of the graph (Figure 59). In this area, we cannot achieve a *P*-value of 0.1. We must use the values associated with the 0.1 contour at the top of the graph, not any lower 0.1 contour. At 7 tows, the detectability of Pacific cod is between 0.90 and 1.00 (very poor). However, the 0.05 and 0.1 contour lines at the top of the graph are broken. We do not have any support for Pacific cod at *P*-values of 0.1, or less. The P-values in top part of the graph do not have a high SE (0.01-0.05) (Figure 60).

Pavlof Bay - Simulated sampling detectability and number of tows - Cold water
With 14 tows in Pavlof Bay for the cold water regime, on average we would achive a 0.667 detectability for 9 species (Figure 61). Alpha-levels are 0.1, except for the pandalid species group, the flatfish species group, northern shrimp and humpy shrimp at 0.05 (Table 11). However, 2 species, the osmerid species group and capelin, have anomalies when the number of tows is more than 21 (Figure 62). Juvenile walleye pollock and Pacific cod are fairly flat for tows more than 14, and never achieve a 0.667 detectability.

Flathead sole does not have a problem with the wraparound when the tows are more than 12 or 13 (Figure 63). The area in the wraparound has P-values between 0.05 and 0.1, giving us an acceptable P-value. The 0.1 contour supports this. The P-values in this area do not have a high SE (0.005-0.01) (Figure 64).

Ugak Bay
There were 4 tows either on land or outside of the area that were dropped from the analysis. In 1986 the number of tows (11) that were only on the bottom were less than the number of total tows of 13 (Appendix I).

Ugak Bay - Adjacent historical survey years
At the α=0.05 level, a change in weighted mean CPUE for the flatfish species group greater than 35 kg/km and flathead sole greater than 23 kg/km were significant, except for the 1982 versus 1984 tests (Appendix II Table 6). A change in CPUE greater than 56 kg/km for walleye pollock was significant, except for the 1985 versus 1986 test. For arrowtooth flounder, a change in CPUE

greater than 7 kg/km was significant. A change greater than 14 kg/km for Pacific cod was significant, but there was only one test at this amount.

There were no tests significant at the α=0.05 level for the pandalid shrimp species group, the osmerid species group, northern shrimp, humpy shrimp and capelin (Appendix II Table 6). It appears that northern shrimp dominates the pandalid shrimp species group. Table interpretation is inconclusive for the roundfish species group and juvenile walleye pollock.

Ugak Bay - All possible pairs of historical survey years
The flatfish species group and flathead sole show consistency in an α=0.05 significance in detecting a change in CPUE ≥60% (pattern as in Figure 10). For the most part the only deviant tests are those with a small number of tows. Performance is poor for the pandalid shrimp species group, the roundfish species group, northern shrimp, walleye pollock, Pacific cod, and arrowtooth flounder. The pandalid shrimp species group and northern shrimp figures are very similar. Performance is the worst for the osmerid species group, humpy shrimp, juvenile walleye pollock and capelin.

The relation between cumulative percentage of *P*-values in the critical region and percentage change in weighted CPUE provides an additional view. At the α=0.05 level, the flatfish species group and flathead sole perform the best, but a change in weighted mean CPUE of greater than 80% is needed to have approximately 90% of the *P*-values in the critical region (Figure 65). The lines for the pandalid shrimp species group and northern shrimp follow each other. The poorest performance is with the osmerid species group, capelin and humpy shrimp.

At the α=0.1 level there is a band of five species that perform well at an 80-90% change in CPUE (Figure 66). The pandalid species group and northern shrimp are almost identical lines. The approximately horizontal lines at the top of the figures are caused by the drastic decrease (or increase) in the proportion in the critical region at the largest change in CPUE. This is usually at a 100% change in CPUE.

Ugak Bay - Simulated sampling area
The historical tows were overlaid with 4-sided polygons yielding a sample area of 123.02 km^2 (Figure 67) with 773 possible sample locations (Figure 68). The sequence of sample locations runs NS and WE within each polygon.

Ugak Bay - Simulated sampling detectability and number of tows - Warm water
With 12 tows in Ugak Bay for the warm water regime, on average we would achieve a 0.667 detectability for 10 species (Figure 69). Alpha-levels are 0.05, except for the pandalid species group, northern shrimp, walleye pollock and juvenile walleye pollock at 0.1 (Table 12). Juvenile walleye pollock never attains a 0.667 detectability. Taking the peak into account, Pacific cod has a 0.84 detectability (Figure 70).

Pacific cod have *P*-value contour lines that have a band of *P*-values greater than 0.2 extending into the upper portion of the graph (Figure 71). The 0.1 contour has an island. In the areas

between the 0.1 and 0.2 contour lines, we cannot achieve a *P*-value of 0.1. We must use the values not any lower than the 0.1 contour at the top of the graph. The 0.1 contour line at the top of the graph is reasonable, but mostly with a detectability greater than 0.667, except when tows numbers are greater than 21. The P-values in top of the graph do not have a high SE (0.01-0.05) (Figure 72).

Ugak Bay - Simulated sampling detectability and number of tows - Cold water
With 12 tows in Ugak Bay for the cold water regime, on average we would achieve a 0.667 detectability for 8 species (Figure 73). Alpha-levels are 0.1, except for the pandalid species group, the flatfish species group, the roundfish species group, northern shrimp and Pacific cod at 0.05 (Table 12). Capelin approaches the 0.667 detectability (0.68). With 17 or more tows, humpy shrimp is close to the 0.667 detectability. Juvenile walleye pollock cannot maintain a 0.667 detectability. Taking into account the peak, walleye pollock has a 0.86 detectability (Figure 74).

Walleye pollock have *P*-value contour lines that have an island of *P*-values greater than 0.1, but less than 0.2) running diagonally along the top portion (0.6-0.9) of the graph (Figure 75). In this area, we cannot achieve a *P*-value of 0.1 We must use the values associated with the 0.1 contour at the top of the graph, not any lower 0.1 contour. At 12 tows, the detectability of walleye pollock is approximately 0.9 (very poor). The *P*-values in this area do not have a high SE (0.005-0.01) (Figure 76).

Problem species
A summary of the problem species is presented in Table 13. Problem species are those that exhibit erratic contour lines of P-value. These are the lines that form islands and odd wraparounds that become difficult to interpret. In the cold water regime we cannot achieve a 0.667 detectabilty for juvenile walleye pollock in any of the bays. We come the closest at 0.69 in Kiliuda Bay. The detectability that we can achieve for other problem species is given in Table 14.

Species achieving 0.667 detectability
We present the species that achieve a 0.667 or better detectability in Table 15. Included with these species are those species that are close (0.69) to the target detectability. When two species have similar detectability, the bay with a 0.05 alpha-level is better than the bay with a 0.1 alpha level. For example, in the warm water regime, the roundfish species group in Marmot and Pavlof Bays have detectability of 0.55 and 0.54 respectively, but Marmot Bay is at the 0.05 alpha-level. The differences in the detectability is small (55% and 54% decrease; 122.2% and 117.4% increase).

Discussion:

The data which has been examined for this report has demonstrated useful description on the qualitative changes in the GOA marine benthic and epi-benthic community structure over long time periods relative to other available data sets. The principle reason for this is there has been a long-term commitment to the collection of information to support fishery development and management goals. While in transition from a territorial to a state jurisdiction the collection

methods have remained remarkably similar over the time span of 1953 to the present. It is this consistency of data collection approach from both a spatial and temporal perspective that has proved most beneficial from the analytical viewpoint. Also, the sampling gear and methodology used in the historic surveys has remained similar over the time span. Since 1972 both the ADF&G and the NMFS have used the same sampling gear design (Wathne, 1977). The authors believe that this sampling consistency must be maintained to provide a useful relative index for future monitoring of the marine community structure in the GOA. With the above premise as our guide we have undertaken the development of sampling strategies based on the retention of the basic sampling method as outlined above. We have used the historic data to model species change detectability for a given sampling level and area in order to design possible future data collection scenarios.

There is really only one community structure for the region under consideration in this study. The Kodiak Island region of the Gulf of Alaska is in an area of overlap between the Arctic and Aleutian faunal domains. This overlap or ecotone is defined in the classic marine ecology literature (Hedgepeth, 1953). When conditions are relatively cold members of the Arctic domain proliferate while Aleutian and other southern fauna diminish. Conversely, during warmer periods Aleutian and more southern fauna will dominate the species assemblage. This interplay of dominance leads to a region that becomes exceedingly rich in overall abundance when compared with single faunal domain regions. This data set measures the change in species assemblage dominance by assessing the relative abundance of the major species in this region possibly driven by periodic changes in ocean conditions.

This historical trawl survey data series was iniated in 1953 in response to developing needs of fishery development in Alaska. The major target species has been members of several species of pandalid shrimp (Ronholt, 1963). Pandalid shrimp are considered a keystone species in boreal ecosystems. They consume benthic and zooplankton prey depending on their life stage or location in the water column. Prey even included other shrimps and each other. Pandalid shrimp have the ability to integrate changes that occur throughout the water column owing to their diel vertical migration traits and these are expressed in population abundance. Inshore species react to changes in shallow water, often very rapidly. While offshore pandalid species change distribution patterns and species mixes in reaction to changing oceanic conditions It can be strongly argued that monitoring changing relative abundance of pandalid shrimp in the Gulf of Alaska should be a central component of any long term monitoring program as they are prime indicators of ecosystem regime shift (Anderson, 2000).

The primary objective for this monitoring survey series is to detect community structure changes over time as expressed in varying species and group abundance. The following criteria are suggested by the authors in the design of future monitoring using small-mesh trawl surveys: (1) Maintenance of a stabile sampling protocol over a long time period at equal intervals. (2) Spatial and temporal stability in collection of biotic and environmental variables (abiotic) that will be used to describe and predict changes in species community structure in the GOA. (3) Sampling at

a reasonable precision and cost. (4) Relevance at detecting composition changes at a sensitivity that is important for understanding ecosystem dynamics. (5) A sampling program that has some relation to economic and aesthetic aspects of the GOA ecosystem.

In many marine environmental monitoring cases it is preferable to consider benthic over other species groups because of their inherent stability in the marine ecosystem (Green, 1979), but in this study we have found that relatively stable epi-benthic species provides the best sense of change in the ecosystem. These species characterized by the pandalid shrimp taxa and pleuronectid fishes react very quickly to changes that propagate through the entire water column. Pandalid shrimps owing to their diel vertical migrations and relatively low trophic level seem to be candidates for indicator species in the GOA ecosystem (Anderson, 2000). Their rapid population declines and recruitment failure in apparent reaction to water column conditions in the GOA after the climatic regime shift is well documented in this survey series (Anderson et al. 1997; Anderson and Piatt, 1999; Anderson, 2000).

In order to arrive at a sampling strategy for the bays considered in this study involves juggling a complex array of factors to arrive at the best balanced approach. First, the biologist might have some *a priori* knowledge of the state of the ecosystem. Whether the ecosystem reflects either the cold or warm regime species mix will determine strategy to some extent. Sampling models have been constructed using species mix conditions that represent both regimes (warm and cold regime probability density functions). However if there is uncertainty concerning the prevailing ecosystem structure then a blend of results using both base models of species mix may need to be used .to arrive at an optimal sampling strategy. One approach is to use the greater number of the cold/warm water tows for each bay as determined by the sample modeling. The second goal in strategy design is to maximize the detectability of absolute change while simultaneously minimizing the number of trawl tows that are required for a given alpha level. We have developed a software program that integrates the matrixes of detectability value, alpha level, and sample size by each species and group in order to arrive at a decision matrix for determining the best sampling intensity. This software allows graphic interpretation of the *P*-value contour lines. The summary of our analysis based on the models of each bay or SA has been presented. The software is enclosed on a floppy disk with this report, so additional strategies can be examined by a future researcher.

One of the main weaknesses in the current effort is that there is no way to evaluate for sample design purposes CPUE changes of 100%. This frequently occurs with only a few species when adjacent survey years have zero abundance next to years when the animal is present. This happens frequently with species such as capelin or juvenile pollock, which exhibit highly variable recruitment through time in this region of the Gulf of Alaska. Clearly some better method of evaluating sampling needs for these species needs to examined. However it is clear that when these species are abundant within the sampling areas this survey series has historically captured them in relative high abundance.*(Alan do we have some examples of this in the tables ??)

The SE contours indicate that the *P*-values are not highly variable except for small sample sizes

at high percentage change in weighted mean CPUE, or at the very edge of data support. The use of 0.667 as a target detectability seems reasonable. A small detectability is the most desirable, but might not be the same for all species. Any percentage change can be selected and the figures used to see what species meet the selection. Alternatively, a decision could be made on a selected list of species, and at different alpha-levels. The following discussion uses the selected 0.05 and 0.1 alpha-levels and a detectability of 0.667 (a 66.7% decrease or 200% increase) in weighted CPUE as reference points. We also interpret islands and wraparound on the "G" reports (see above bay discussions) differently when resolving for sample size. The top line (highest detectability) is always chosen in these cases.

Not all species are similarly represented in the detectability values across all sampling areas. An example is Chignik-Castle SA has overall better detectability for the pandalid shrimp species group as compared to other sampling areas during cold regime community structure (Figure 77). All species alpha-levels are 0.05. At the simulated sampling intensity, Chignik-Castle SA has a 0.34 detectability (Table 15). The other bays follow a similar pattern for this species group but at higher (not as good) detectability. The reason for this pattern are unknown. The pleuronectid species group under the same community structure regime showed Chignik-Castle SA and Marmot SA with very similar patterns (Figure 78). All but Alitak Bay are at the 0.05 alpha-level. At the simulated sampling intensity, Chignik-Castle SA has a 0.49 detectability. The other bays have a higher detectability ($\geq$0.54), but still under the target value (Table 15).

Under the warm community structure condition pandalids, Kiliuda SA and Pavlof SA have very similiar detectability (Figure 79) . Chignik-Castle, Kiliuda and Pavlof SAs are at 0.05 alpha-levels. At the simulated sampling intensity, Kiliuda and Pavlof SAs have 0.42 and 0.50 detectability, respectively (Table 15). In turn, the pleuronectids also show a tight band of detectability values for all bays and reach the target detectability (Figure 80). All but Alitak Bay has 0.05 alpha-levels. At the simulated sampling intensity, Kiliuda SA with a 0.42 detectability is the best.

Comparing pandalid and pleuronectid species groups across bays, some similarities become obvious. Both species groups achieve the target detectablity in all SAs (Table 15). The cold regime species structure required more tows perhaps due to higher variability for this regime structure (Table 15). The suggested number of tows per SA is adequate for determining changes in pandalid species which may constitute one of the most important indicator groups in the epi-benthic community structure under either community structure condition that has been identified in the historical data.

The osmerid group abundance changes are noted at relatively high detectability values 0.8 at α=0.05. All of the bays we analyze would be adequately sampled at less than 24 tows per SA under these criteria under cold community structure. Tow requirements for the same criteria would be less under the warm regime community structure all would be sampled at less than 13 tows per SA to meet the 0.667 target detectability, except for Alitak Bay (Table 15, Figures 81 and 82). Alitak Bay has no detectability in the warm water regime for this important species group. In the cold water regime, Marmot (0.83) and Pavlof (0.79) Bays have relatively poor

detectability (Table 14), detecting a 488% and 376% respective increase at a 0.1 alpha-level.

Some overall general conclusions were drawn from simulation of sampling intensity data analysis. For the warm species community structure we will have a chance of sampling all species at reasonable detectability except humpy shrimp in Marmot Bay (inshore) and walleye pollock juveniles in Kiluda Bay at 20 tows per SA (at α=0.05, and detectability of 0.9 or lower). Even increasing sampling to 24 tows per SA still does not allow humpy shrimp and juvenile pollock in those areas to be adequately sampled under the same criteria. Marmot Bay is not known as an area of major historical abundance of humpy shrimp so under current warm conditions this cool water adapted species is probably not important in the sampling mix. The results for juvenile pollock in Kiluda Bay may also indicate this area is not a preferred habitat under warm regime conditions. Under cool regime community structure many of the groundfish, pandalid shrimps, and roundish species are sampled adequately at modest sampling rates. Even at the highest level of sampling (24 tows per SA) considered in our analysis humpy shrimp in Kiluda Bay and juvenile pollock in both Chignik and Castle Bays and Pavlof Bay will not perform at reasonable detectability (at α=0.05, and detectability of 0.9 or lower). We conclude that the best sampling strategy lies between 20 and 24 tow per sampling area to get the best fix on true abundance changes in the ecosystem structure.

Further, in recognition of the uneven response to detectability at a given sampling rate for each bay we believe it is important to consider sampling all five bays in the Kodiak area. Recent small-mesh trawl surveys in 2001 and 2002 showed significant changes in recent species composition (Ruccio, 2003). Two sections in the Kodiak district closed to directed shrimp fishing for over 20 years attained a high enough level of shrimp biomass to allow for the opening of a shrimp fishery, under current management guidelines. Overall, recent surveys show declining fish abundance and increasing shrimp abundance. These changes are not uniform throughout the Kodiak region. Some bays or sampling areas show reversion to a cold regime structure while other areas, principally along the southeastern side of Kodiak show no significant changes. Until the mechanisms that control these community structures are fully understood we feel it is necessary to sample as many of the sampling areas as possible in any proposed monitoring program. Only with this data can we properly associate the abiotic observations with the observed population response. We believe this approach will produce the necessary data to understand and model ecosystem community dynamics.

Cruise days

To arrive at the total cruise days for a sampling senario we used historic median tows per day from the SAs (Table 16). In this way we use past performance as our best guide to determining a reasonable sampling plan. Sampling at the number of tows from this study gives 20.6 days for the warm water regime and 23.7 days for the cold water regime (Table 16). If we select the larger number of tows from each bay of either “warm” or “cold” species assemblage than the number of cruise days required would be approximately 24 days.

Future number of tows and sample locations

Since an apparent transition from the warm water condition to a colder water condition is occurring, the larger of the warm and cold water number of tows should be selected until the cold water community is evident in all sampling areas. At that time, it would then be appropriate to reduce sampling effort in line with the conclusions of this study.

After a decision is made on the number of tows, the locations of future tows need to follow the same sampling scheme as used in past surveys and this analysis. The general design of sampling location selection is systematic random as described by Anderson (1991). The sampling grids must be the same size within a bay and not extend beyond the specified sampling area (where the historical tows have occurred). Tows outside the historic sampling area would not be appropriate for the relative species abundance indexing, but may have other uses in an integrated sampling program.

Conclusion:

1. Maintenance of a stable sampling protocol will enable the best data for analyzing species change in the future.

2. Concentrate monitoring trawl surveys on epi-benthic species such as pandalid shrimps and some inshore species of pleuronetids as possible indicator species.

3. A reasonable level of detectability in abundance can be obtained for most of these species at relatively low cost (number of tows within SAs and total number of cruise days). A total of 20 to 24 total cruise days would adequately sample most of the species and groups for all SAs considered in this report.

4. Some SAs render relatively small detectability values (better) than others for the same species group. The reason for this needs to be analized. This result seems to indicate that sampling a number of discrete bays (SA) is a better strategy than using just one SA for a proxy of change in the ecosystem, especially inlight of recent survey results.

6. This analysis could probably be improved by combining pdfs from several SAs, and running simulations that span 30 years. This might improve useful in the development of a sampling strategy for problem species that have highly variable recruitment (osmerids, juvenile pollock).

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Tables

Table 1. Total number of historical tows for each of the selected bays. The counts include off-bottom tows.

Year	Alitak	Chignik-Castle	Kiliuda	Marmot (inshore)	Pavlof	Ugak
1972	0	0	10	0	10	10
1973	0	3	17	0	2	0
1974	0	8	18	0	13	16
1975	20	12	27	0	12	18
1976	0	12	31	15	12	19
1977	10	12	10	22	13	7
1978	10	23	36	19	15	7
1979	12	12	27	12	22	14
1980	18	13	10	12	26	11
1981	57	13	20	34	12	24
1982	0	9	0	0	13	2
1983	9	11	0	0	12	0
1984	12	7	10	16	13	5
1985	37	15	12	27	12	9
1986	25	3	15	8	12	13
1987	18	14	2	23	18	0
1988	3	3	0	5	26	0
1989	9	11	10	16	28	10
1990	2	5	0	1	24	0
1991	0	0	0	0	22	0
1992	7	11	10	14	22	0
1993	0	0	0	0	22	0
1994	0	0	0	0	22	0
1995	9	9	6	16	23	0
1996	0	0	0	0	22	0
1997	0	0	0	0	22	0
1998	11	0	6	15	22	0
1999	0	0	0	0	22	0

Table 2 . Percentage decrease and increase (expressed in decimals) in weighted CPUE at selected detectability values.

Detectability	Percentage decrease	Percentage increase
0.90	90	900
0.85	85	567
0.80	80	400
0.75	75	300
0.70	70	233
0.65	65	186
0.60	60	150
0.55	55	122
0.50	50	100
0.45	45	82
0.40	40	67
0.35	35	54
0.30	30	43
0.25	25	33
0.20	20	25
0.15	15	18
0.10	10	11

Table 3. Calculated maximum percentage decrease of adjacent survey year weighted CPUE for historical species or group abundance survey data with zero CPUE removed as a basis for the percentage difference. NA = not available to calculate.

	gp	gf	gr	go	n	h	w	wj	c	p	a	f
Alitak Bay	92	85	94	96	91	100	89	100	87	100	95	79
Chignik-Castle Bays	94	68	100	87	94	93	100	NA	99	81	44	61
Kiliuda Bay	89	48	81	93	89	NA	91	97	96	73	95	51
Marmot Bay (inshore)	71	69	56	98	73	100	78	94	100	99	82	67
Pavlof Bay	91	49	89	96	91	98	100	97	98	82	65	79
Ugak Bay	50	82	74	94	50	89	100	94	96	30	84	85

Table 4. Calculated values for median percentage decrease of adjacent survey year weighted CPUE species or group abundance for historical survey data with zero CPUE removed as a basis for the percentage difference. NA = not available to calculate.

	gp	gf	gr	go	n	h	w	wj	c	p	a	f
Alitak Bay	43	62	26	86	60	87	55	74	82	55	92	61
Chignik-Castle Bays	28	29	37	40	28	91	51	NA	94	44	24	29
Kiliuda Bay	53	18	38	91	53	NA	60	54	83	54	45	32
Marmot Bay (inshore)	53	57	39	90	53	31	34	51	81	57	49	52
Pavlof Bay	58	22	41	54	63	79	46	97	77	48	30	24
Ugak Bay	22	44	74	53	29	72	40	93	85	24	66	56

Table 5. Calculated maximum percentage increase of adjacent survey year weighted CPUE for historical species or group abundance survey data with zero CPUE removed as a basis for the percentage difference. NA = not available to calculate.

	gp	gf	gr	go	n	h	w	wj	c	p	a	f
Alitak Bay	903	1084	2081	747	960	5227	1882	307	990	95136	1406	710
Chignik-Castle Bays	3663	842	44633	11692	4248	1081	82333	8677	1329	1678	12184	1134
Kiliuda Bay	370	1648	1204	608	363	NA	2912	555	2253	927	666	255
Marmot Bay (inshore)	276	385	611	1051	270	341	702	NA	690	23779	1065	239
Pavlof Bay	1663	450	2417	1267	1688	725	1580	4143	88292	4317	669	4099
Ugak Bay	319	6066	462	1288	320	213	3192	1309	1288	1908	740	1090

Table 6. Calculated values for median percentage increase of adjacent survey year weighted CPUE species or group abundance for historical survey data with zero CPUE removed as a basis for the percentage difference. NA = not available to calculate.

	gp	gf	gr	go	n	h	w	wj	c	p	a	f
Alitak Bay	144	354	171	141	153	228	215	244	159	1139	1077	381
Chignik-Castle Bays	134	187	253	1082	138	367	525	4419	608	312	172	167
Kiliuda Bay	197	209	161	314	190	NA	273	555	1225	185	215	125
Marmot Bay (inshore)	201	158	182	198	218	129	374	NA	358	400	502	180
Pavlof Bay	224	148	153	227	280	172	227	1562	427	132	226	144
Ugak Bay	135	586	177	457	119	213	830	1039	607	1099	600	819

Table 7. Alitak Bay species detectabilities and alpha-levels for the warm and cold water regimes. Number of tows were 11 for warm water and 13 for cold water.

Species	Alpha-level		Detectability	
	Warm	Cold	Warm	Cold
Pandalid shrimp species group	0.10	0.05	0.65	0.50
Flatfish species group	0.10	0.10	0.54	0.61
Roundfish species group	0.10	0.10	0.51	0.55
Osmerid species group	0.10	0.10	1.00**	0.66
Northern shrimp	0.10	0.05	0.58	0.56
Humpy shrimp	0.10	0.10	1.00**	0.73
Walleye pollock	0.10	0.10	0.65	0.61
Juvenile walleye pollock	0.10	0.10	0.79**	0.82(a)**
Capelin	0.10	0.10	1.00**	0.60
Pacific cod	0.05	0.10	0.50	0.80
Arrowtooth flounder	0.10	0.10	0.95**	0.91(b)**
Flathead sole	0.10	0.10	0.63	0.64

** problem species
(a) interpreted from graph ignoring wraparound at top
(b) broken line and wraparound

Table 8. Chignik-Castle Bays species detectabilities and alpha-levels for the warm and cold water regimes. Number of tows were 10 for warm water and 13 for cold water.

Species	Alpha-level		Detectability	
	Warm	Cold	Warm	Cold
Pandalid shrimp species group	0.05	0.05	0.62	0.34
Flatfish species group	0.05	0.05	0.52	0.49
Roundfish species group	0.10	0.05	0.59	0.61
Osmerid species group	0.10	0.10	0.56	0.60
Northern shrimp	0.05	0.05	0.62	0.34
Humpy shrimp	0.05	0.10	0.42	0.66
Walleye pollock	0.10	0.05	0.68	0.66
Juvenile walleye pollock	0.05	0.10	0.42	0.94**
Capelin	0.05	0.10	0.42	0.72
Pacific cod	0.10	0.10	0.66	0.65
Arrowtooth flounder	0.05	0.05	0.64	0.58
Flathead sole	0.05	0.05	0.58	0.53

** problem species

Table 9. Kiliuda Bay species detectabilities and alpha-levels for the warm and cold water regimes. Number of tows were 12 for warm water and 15 for cold water.

Species	Alpha-level		Detectability	
	Warm	Cold	Warm	Cold
Pandalid shrimp species group	0.05	0.05	0.42	0.66
Flatfish species group	0.05	0.05	0.42	0.58
Roundfish species group	0.10	0.05	0.51	0.55
Osmerid species group	0.10	0.10	0.57	0.69
Northern shrimp	0.05	0.05	0.44	0.68
Humpy shrimp	0.05	0.10	0.41	1.00**
Walleye pollock	0.10	0.05	0.57	0.61
Juvenile walleye pollock	0.10	0.10	1.00**	0.69
Capelin	0.05	0.10	0.41	0.78
Pacific cod	0.10	0.05	0.82**	0.65
Arrowtooth flounder	0.10	0.05	0.53	0.66
Flathead sole	0.05	0.05	0.48	0.62

** problem species

Table 10. Marmot Bay (inshore) species detectabilities and alpha-levels for the warm and cold water regimes. Number of tows were 12 for warm water and 11 for cold water.

Species	Alpha-level		Detectability	
	Warm	Cold	Warm	Cold
Pandalid shrimp species group	0.10	0.05	0.63	0.65
Flatfish species group	0.05	0.05	0.60	0.54
Roundfish species group	0.05	0.05	0.55	0.66
Osmerid species group	0.05	0.10	0.46	0.83
Northern shrimp	0.10	0.05	0.59	0.64
Humpy shrimp	0.10	0.10	0.92(b)**	0.86
Walleye pollock	0.05	0.10	0.64	0.78
Juvenile walleye pollock	0.05	0.10	0.51(a)	0.77
Capelin	0.05	0.10	0.42	0.89
Pacific cod	0.10	0.10	0.76	0.65
Arrowtooth flounder	0.10	0.05	0.83**	0.62
Flathead sole	0.05	0.05	0.57	0.55

** problem species
(a) interpreted from graph with short line at right ignored
(b) interpreted from graph with lower islands and upper short line ignored

Table 11. Pavlof Bay species detectabilities and alpha-levels for the warm and cold water regimes. Number of tows were 12.

Species	Alpha-level		Detectability	
	Warm	Cold	Warm	Cold
Pandalid shrimp species group	0.05	0.05	0.50	0.56
Flatfish species group	0.05	0.05	0.53	0.66
Roundfish species group	0.10	0.10	0.54(a)	0.65
Osmerid species group	0.05	0.10	0.48	0.79(a)**
Northern shrimp	0.05	0.05	0.57	0.56
Humpy shrimp	0.05	0.05	0.48	0.66
Walleye pollock	0.10	0.10	0.57(a)	0.70(a)**
Juvenile walleye pollock	0.05	0.10	0.48	0.89
Capelin	0.05	0.10	0.48	0.78(a)**
Pacific cod	0.10	0.10	0.96**	0.79
Arrowtooth flounder	0.05	0.10	0.67	0.65
Flathead sole	0.05	0.10	0.63	0.67**

** problem species
(a) interpreted from graph and ignoring short upper lines and islands

Table 12. Ugak Bay species detectabilities and alpha-levels for the warm and cold water regimes. Number of tows were 11 for warm water and 13 for cold water.

Species	Alpha-level		Detectability	
	Warm	Cold	Warm	Cold
Pandalid shrimp species group	0.10	0.05	0.65	0.61
Flatfish species group	0.05	0.05	0.52	0.60
Roundfish species group	0.05	0.05	0.55	0.67
Osmerid species group	0.05	0.10	0.45	0.66
Northern shrimp	0.10	0.05	0.66	0.64
Humpy shrimp	0.05	0.10	0.61	0.79
Walleye pollock	0.10	0.10	0.63	0.86(a)
Juvenile walleye pollock	0.10	0.10	0.81	0.84
Capelin	0.05	0.10	0.44	0.68
Pacific cod	0.10	0.05	0.84(a)**	0.64
Arrowtooth flounder	0.05	0.10	0.67	0.60
Flathead sole	0.05	0.10	0.55	0.62

** problem species
(a) interpreted from graph and taking the peak into account

Table 13. Species that do not achieve a 0.667 detectability. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

	Tows	gr	go	n	h	w	wj	c	p	a	f
Warm water condition											
Alitak Bay	11		*		*		*	*		*	
Chignik-Castle Bays	10					(0.68)					
Kiliuda Bay	12						*		*		
Marmot Bay (inshore)	12				*				*	*	
Pavlof Bay	7								*		
Ugak Bay	12						*		*	0.67	
Cold water condition											
Alitak Bay	13				*		*		*	*	
Chignik-Castle Bays	13						*	*			
Kiliuda Bay	15		0.69	0.68	*		0.69	*			
Marmot Bay (inshore)	11		*		*	*	*	*			
Pavlof Bay	14		*			*	*	*	*		0.67
Ugak Bay	12	0.67			*	*	*	0.68			

* above targeted detectability

(0.68) meets targeted detectability when the number of tows for warm and cold conditions for each bay are the larger of the two

Table 14. Detectability of problem species without a 0.667 detectability (or close). Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

	go	h	w	wj	c	p	a	f
Warm water condition								
Alitak Bay	*	*		0.79	*		*	
Chignik-Castle Bays								
Kiliuda Bay				*		0.82		
Marmot Bay (inshore)		0.92				0.76	*	
Pavlof Bay						*		
Ugak Bay				0.81		0.84		
Cold water condition								
Alitak Bay		0.73		*		0.80	*	
Chignik-Castle Bays				0.94	0.72			
Kiliuda Bay		*			0.78			
Marmot Bay (inshore)	0.83	0.86	0.78	0.77	0.89			
Pavlof Bay	0.79		0.70	0.89	0.78	0.79		*
Ugak Bay		0.79	0.86	0.84				

* no detectability; or a detectability of 0.95 or larger

Table 15. Species achieving a 0.667 detectability (or close). Alpha-levels are 0.05 (*) and 0.1 (unmarked). Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Bay (tows)	gp	gf	gr	go	n	h	w	wj	c	p	a	f
Warm water condition												
Alitak Bay(11)	0.65	0.54	0.51		0.58		0.65			0.50*		0.63
Chignik-Castle Bays(10)	0.62*	0.52*	0.59	0.56	0.62*	0.42*	0.68	0.42*	0.42*	0.66	0.64*	0.58*
Kiliuda Bay(12)	0.42*	0.42*	0.51	0.57	0.44*	0.41*	0.57		0.41*		0.53	0.48*
Marmot Bay (inshore)(12)	0.63	0.60*	0.55*	0.46*	0.59		0.64*	0.51*	0.42*			0.57*
Pavlof Bay(7)	0.50*	0.53*	0.54	0.48*	0.57*	0.48*	0.57	0.48*	0.48*		0.67*	0.63*
Ugak Bay(12)	0.65	0.52*	0.55*	0.45*	0.66	0.61*	0.63		0.44*		0.67*	0.55*
Cold water condition												
Alitak Bay(13)	0.50*	0.61	0.55	0.66	0.56*		0.61		0.60			0.64
Chignik-Castle Bays(13)	0.34*	0.49*	0.61*	0.60	0.34*	0.66	0.66*			0.65	0.58*	0.53*
Kiliuda Bay(15)	0.66*	0.58*	0.55*	0.69	0.68*		0.61*	0.69		0.65*	0.66*	0.62*
Marmot Bay (inshore)(11)	0.65*	0.54*	0.66*		0.64*					0.65	0.62*	0.55*
Pavlof Bay(14)	0.56*	0.66*	0.65		0.56*	0.66*					0.65	0.67
Ugak Bay(12)	0.61*	0.60*	0.67*	0.66	0.64*				0.68	0.64*	0.60	0.62

Table 16. Cruise days based on median number of historical tows per day, 1 day travel between bays, and 1 day travel at the geginning and end of the cruise.

	Number of tows			
	Per day	Warm water	Cold water	Larger of warm/cold
Alitak Bay	6	11	13	13
Chignik-Castle Bays	4	10	13	13
Kiliuda Bay	5	12	15	15
Marmot Bay (inshore)	4	12	11	12
Pavlof Bay	5	7	14	14
Ugak Bay	5	12	12	12
Cruise days		20.6	23.4	23.7
Without Pavlof Bay		18.2	19.6	19.9

Figures

Figure 1. Location of small-mesh trawl surveys in bays around Kodiak Island and the Alaskan Peninsula.

Figure 2. Example of the initial clipping step to obtain Dirichlet tiles in Alitak Bay.

Figure 3. Example of final Dirichlet tiles for 1985 in Alitak Bay.

Figure 4. Historical sampling locations in Alitak Bay and selected 4-sided polygonal areas used for random sampling at 400 m intervals. The larger dot is the starting location of a tow.

Figure 5. Randomization tests of differences in the flatfish species group weighted mean CPUE (kg/km) for all possible pairs (105) of survey years (1975-1998) in Alitak Bay. CPUE was weighted by Dirichlet tile area. Percentage change is $|CPUE_1-CPUE_2|/\max(CPUE_2,CPUE_2)$. The dotted vertical line is $\alpha=0.05$. Number of permutations for the randomization was 5000. The size of a circle is based on $\min(n_1,n_2)$.

Figure 6. Relation between percentage of P-values in the $\alpha=0.05$ critical region and percentage change in CPUE between sample years, based on randomization tests of differences in mean weighted CPUE (kg/km) for all possible pairs of survey years in Alitak Bay. Weighting was based on Dirichlet tiles. Number of permutations for the randomization was 5000. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 7. Probability density functions for northern shrimp (*Pandalus goniurus*) unweighted CPUE (kg/km) for low and high density survey years in Alitak Bay using kernel density estimation with h=15 and an Epinechnikov kernel.

Figure 8. Minimum number of observations for the 12 species (or species groups) within each moving-window for low probability density functions.

Figure 9. $\alpha=0.05$ contours for high CPUE probability density function. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 10. Randomization tests of differences in flathead sole weighted mean CPUE (kg/km) for all possible pairs (105) of survey years (1975-1998) in Alitak Bay. CPUE was weighted by Dirichlet tile area. Percentage change is $|CPUE_1-CPUE_2|/\max(CPUE_2,CPUE_2)$. The dotted vertical line is $\alpha=0.05$. Number of permutations for the randomization was 5000. The size of a circle is based on $\min(n_1,n_2)$.

Figure 11. Randomization tests of differences in juvenile walleye pollock weighted mean CPUE (kg/km) for all possible pairs (105) of survey years (1975-1998) in Alitak Bay. CPUE was weighted by Dirichlet tile area. Percentage change is $|CPUE_1-CPUE_2|/\max(CPUE_2,CPUE_2)$. The dotted vertical line is $\alpha=0.05$. Number of permutations for the randomization was 5000. The size of a circle is based on $\min(n_1,n_2)$.

Figure 12. Relation between percentage of P-values in the $\alpha=0.1$ critical region and percentage change in CPUE between sample years, based on randomization tests of differences in mean weighted CPUE (kg/km) for all possible pairs of survey years in Alitak Bay. Weighting was based on Dirichlet tiles. Number of permutations for the randomization was 5000. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 13. Location of the midpoint of possible tows placed at 400 m in Alitak Bay.

Figure 14. Sampling the warm water regime at 11 tows, Alitak bay had 0.667 detectability or less for 7 species. To pick up arrowtooth flounder at the same detectability, 19 tows would be needed. Alpha-levels are 0.1, except for Pacific cod at 0.05. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (n) northern shrimp, (w) walleye pollock, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 15. Sampling the warm water regime at 11 tows, Alitak Bay had no statistically based tests for the osmerid species group, humpy shrimp, and capelin. Juvenile walleye pollock had a detectability of 0.79. Alpha-levels are 0.1. Species are (go) the osmerid species group, (h) humpy shrimp, (wj) juvenile walleye pollock, (c) capelin and (a) arrowtooth flounder .

Figure 16. Capelin *P*-value contour lines in Alitak Bay warm water regime.

Figure 17. Capelin *P*-value SE contour lines in Alitak Bay warm water regime.

Figure 18. Sampling the cold water regime at 13 tows, Alitak Bay achieved a 0.667 detectability or less for 8 species. All alpha-levels are 0.1, except for the pandalid species group and northern shrimp (0.05). Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod and (f) flathead sole.

Figure 19. Sampling the Alitak Bay cold water regime at 13 tows, the detectability was 0.82 for juvenile walleye pollock and 0.80 for Pacific cod. For humpy shrimp, juvenile walleye pollock and Pacific cod there would be 23, 19 and 20 tows respectively needed to achieve the target detectability. Arrowtooth flounder has a 0.91 detectability if the broken line is ignored. Alpha-levels are 0.1. Species are (h) humpy shrimp, (wj) juvenile walleye pollock, (p) Pacific cod and (a) arrowtooth flounder.

Figure 20. Arrowtooth flounder *P*-value contour lines in Alitak Bay cold water regime.

Figure 21. Arrowtooth flounder *P*-value SE contour lines in Alitak Bay cold water regime.

Figure 22. Relation between percentage of P-values in the α=0.05 critical region and percentage change in CPUE between sample years, based on randomization tests of differences in mean weighted CPUE (kg/km) for all possible pairs of survey years in Chignik-Castle Bays. Weighting was based on Dirichlet tiles. Number of permutations for the randomization was 5000. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 23. Relation between percentage of P-values in the α=0.1 critical region and percentage change in CPUE between sample years, based on randomization tests of differences in mean weighted CPUE (kg/km) for all possible pairs of survey years in Chignik-Castle Bays. Weighting was based on Dirichlet tiles. Number of permutations for the randomization was 5000. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 24. Historical sampling locations in Chignik-Castle Bays and selected 4-sided polygonal areas used for random sampling at 400 m intervals. The larger dot is the starting location of a tow.

Figure 25. Location of the midpoint of possible tows placed at 400 m in Chignik-Castle Bays.

Figure 26. Sampling the warm water regime and 10 tows, Chignik-Castle Bays had a 0.667 detectability for all species. Alpha-levels are 0.05, except for the roundfish species group, the osmerid species group, walleye pollock and Pacific cod at 0.1. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 27. Sampling the cold water regime at 13 tows, Chignik-Castle Bays had a 0.667 detectability for 10 species. Capelin has a detectability of 0.72. Alpha-levels are 0.05, except for the osmerid species group, humpy shrimp, capelin and Pacific cod at 0.1. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 28. Sampling the cold water regime at 13 tows, Chignik-Castle Bays had no statistically based tests for juvenile walleye pollock. Both alpha levels are 0.1. Species are (wj) juvenile walleye pollock and (c) capelin.

Figure 29. Juvenile walleye pollock *P*-value contour lines in Chignik-Castle Bays cold water regime.

Figure 30. Juvenile walleye pollock *P*-value SE contour lines in Chignik-Castle Bays cold water regime.

Figure 31. Relation between percentage of P-values in the α=0.05 critical region and percentage change in CPUE between sample years, based on randomization tests of differences in mean weighted CPUE (kg/km) for all possible pairs of survey years in Kiliuda Bay. Weighting was based on Dirichlet tiles. Number of permutations for the randomization was 5000. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 32. Relation between percentage of P-values in the α=0.1 critical region and percentage change in CPUE between sample years, based on randomization tests of differences in mean weighted CPUE (kg/km) for all possible pairs of survey years in Kiliuda Bay. Weighting was based on Dirichlet tiles. Number of permutations for the randomization was 5000. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 33. Historical sampling locations in Kiliuda Bay and selected 4-sided polygonal areas used for random sampling at 400 m intervals. The larger dot is the starting location of a tow.

Figure 34. Location of the midpoint of possible tows placed at 400 m in Kiliuda Bay.

Figure 35. Sampling the warm water regime at 12 tows, Kiliuda Bay had a 0.667 detectability for 10 species. Alpha-levels are 0.05, except for the roundfish species group, the osmerid species group, walleye pollock and arrowtooth flounder at 0.1. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (c) capelin, (a) arrowtooth flounder and (f) flathead sole.

Figure 36. Sampling the warm water regime at 12 tows, Kiliuda Bay had no statistically based tests for juvenile walleye pollock with the broken line. Pacific cod has a detectability of 0.82. Both alpha-levels are 0.1. Species are (wj) juvenile walleye pollock and (p) Pacific cod.

Figure 37. Sampling the cold water regime at 15 tows, Kiliuda Bay has a 0.667 detectability for 7 species. Those close to the target detectability are the osmerid species group at 0.69, northern shrimp at 0.68 and juvenile walleye pollock at 0.69 detectability. Alpha-levels are 0.05, except for the osmerid species group and juvenile walleye pollock at 0.1. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 38. Sampling the cold water regime at 15 tows, Kiliuda Bay had no statistically based tests for humpy shrimp. If we accept the jagged contour line for capelin, it has a detectability of 0.78. Alpha-levels are 0.1. Species are (go) the osmerid species group, (h) humpy shrimp, (wj) juvenile walleye pollock and (c) capelin.

Figure 39. Humpy shrimp *P*-value contour lines in Kiliuda Bay cold water regime.

Figure 40. Humpy shrimp *P*-value SE contour lines in Kiliuda Bay cold water regime.

Figure 41. Relation between percentage of P-values in the α=0.05 critical region and percentage change in CPUE between sample years, based on randomization tests of differences in mean weighted CPUE (kg/km) for all possible pairs of survey years inMarmot Bay (inshore). Weighting was based on Dirichlet tiles. Number of permutations for the randomization was 5000. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 42. Relation between percentage of P-values in the α=0.1 critical region and percentage change in CPUE between sample years, based on randomization tests of differences in mean weighted CPUE (kg/km) for all possible pairs of survey years inMarmot Bay (inshore). Weighting was based on Dirichlet tiles. Number of permutations for the randomization was 5000. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 43. Historical sampling locations inMarmot Bay (inshore) and selected 4-sided polygonal areas used for random sampling at 400 m intervals. The larger dot is the starting location of a tow.

Figure 44. Location of the midpoint of possible tows placed at 400 m inMarmot Bay (inshore).

Figure 45. Sampling the warm water regime at 12 tows,Marmot Bay (inshore) had a 0.667 detectability for 9 species. Pacific cod did not improve with more tows and remains at approximately a 0.75 detectability. Alpha-levels are 0.05, except for the pandalid species group, northern shrimp and Pacific cod at 0.1. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod and (f) flathead sole.

Figure 46. Sampling the warm water regime at 12 tows,Marmot Bay (inshore) had no statistically based tests for arrowtooth flounder. Accepting the top line for humpy shrimp gives a 0.92 detectability. Alpha-levels are 0.1. Species are (h) humpy shrimp, (p) Pacific cod and (a) arrowtooth flounder.

Figure 47. Humpy shrimp *P*-value contour lines inMarmot Bay (inshore) warm water regime.

Figure 48. Humpy shrimp *P*-value SE contour lines inMarmot Bay (inshore) warm water regime.

Figure 49. Sampling the cold water regime at 11 tows,Marmot Bay (inshore) had a 0.667 detectability for 7 species. Alpha-levels are 0.05, except for the osmerid species group, humpy shrimp, walleye pollock, juvenile walleye pollock, capelin and Pacific cod at 0.1. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 50. Sampling the cold water regime at 11 tows,Marmot Bay (inshore) had 5 species, the osmerid species group, humpy shrimp, walleye pollock, juvenile walleye pollock, and capelin do not improve with an increase in the number of tows. Alpha-levels are 0.1. Species are (go) the osmerid species group, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock and (c) capelin.

Figure 51. Osmerid species group *P*-value contour lines inMarmot Bay (inshore) cold water regime.

Figure 52. Osmerid species group *P*-value SE contour lines inMarmot Bay (inshore) cold water regime.

Figure 53. Relation between percentage of P-values in the α=0.05 critical region and percentage change in CPUE between sample years, based on randomization tests of differences in mean weighted CPUE (kg/km) for all possible pairs of survey years in Pavlof Bay. Weighting was based on Dirichlet tiles. Number of permutations for the randomization was 5000. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 54. Relation between percentage of P-values in the α=0.1 critical region and percentage change in CPUE between sample years, based on randomization tests of differences in mean weighted CPUE (kg/km) for all possible pairs of survey years in Pavlof Bay. Weighting was based on Dirichlet tiles. Number of permutations for the randomization was 5000. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 55. Historical sampling locations in Pavlof Bay and selected 4-sided polygonal areas used for random sampling at 400 m intervals. The larger dot is the starting location of a tow.

Figure 56. Location of the midpoint of possible tows placed at 400 m in Pavlof Bay.

Figure 57. Sampling the warm water regime at 7 tows, Pavlof Bay has a 0.667 detectability for all but 1 species. Alpha-levels are 0.05, except for the roundfish species group and walleye pollock at 0.1. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (a) arrowtooth flounder and (f) flathead sole.

Figure 58. Sampling the warm water regime at 7 tows, Pavlof Bay had no statistically based tests for species Pacific cod. Alpha-level is 0.1.

Figure 59. Pacific cod *P*-value contour lines in Pavlof Bay warm water regime.

Figure 60. Pacific cod *P*-value SE contour lines in Pavlof Bay warm water regime.

Figure 61. Sampling the cold water regime at 14 tows, Pavlof Bay had a 0.667 detectability for 9 species. Alpha-levels are 0.1, except for the pandalid species group, the flatfish species group, northern shrimp and humpy shrimp at 0.05. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 62. Sampling the cold water regime at 14 tows, Pavlof Bay had 2 species, the osmerid species group and capelin, with anomalies when the number of tows is more than 21. Juvenile walleye pollock and Pacific cod are fairly flat for tows more than 14, and never achieve a 0.667 detectability. Alpha-levels are 0.1. Species are (go) the osmerid species group, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod and (f) flathead sole.

Figure 63. Flathead sole *P*-value contour lines in Pavlof Bay cold water regime.

Figure 64. Flathead sole *P*-value SE contour lines in Pavlof Bay cold water regime.

Figure 65. Relation between percentage of P-values in the α=0.05 critical region and percentage change in CPUE between sample years, based on randomization tests of differences in mean weighted CPUE (kg/km) for all possible pairs of survey years in Ugak Bay. Weighting was based on Dirichlet tiles. Number of permutations for the randomization was 5000. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 66. Relation between percentage of P-values in the α=0.1 critical region and percentage change in CPUE between sample years, based on randomization tests of differences in mean weighted CPUE (kg/km) for all possible pairs of survey years in Ugak Bay. Weighting was based on Dirichlet tiles. Number of permutations for the randomization was 5000. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 67. Historical sampling locations in Ugak Bay and selected 4-sided polygonal areas used for random sampling at 400 m intervals. The larger dot is the starting location of a tow.

Figure 68. Location of the midpoint of possible tows placed at 400 m in Ugak Bay.

Figure 69. Sampling the warm water regime at 12 tows, Ugak Bay had a 0.667 detectability for 10 species. Alpha-levels are 0.05, except for the pandalid species group, northern shrimp, walleye pollock and juvenile walleye pollock at 0.1. Juvenile walleye pollock never attains a 0.667 detectability. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (n) northern shrimp, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (a) arrowtooth flounder and (f) flathead sole.

Figure 70. Sampling the warm water regime at 12 tows, Ugak Bay had Pacific cod with a 0.84 detectability when taking the peak into account. Both alpha-levels are 0.1. Species are (wj) juvenile walleye pollock and (p) Pacific cod.

Figure 71. Pacific cod *P*-value contour lines in Pavlof Bay warm water regime.

Figure 72. Pacific cod *P*-value SE contour lines in Pavlof Bay warm water regime.

Figure 73. Sampling the cold water regime at 12 tows, Ugak Bay had a 0.667 detectability for 8 species. Capelin approaches the 0.667 detectability (0.68). With 17 or more tows, humpy shrimp is close to the 0.667 detectability. Juvenile walleye pollock cannot maintain a 0.667 detectability. Alpha-levels are 0.1, except for the pandalid species group, the flatfish species group, the roundfish species group, northern shrimp and Pacific cod at 0.05. Species are (gp) the pandalid shrimp species group, (gf) the flatfish species group, (gr) the roundfish species group, (go) the osmerid species group, (h) humpy shrimp, (w) walleye pollock, (wj) juvenile walleye pollock, (c) capelin, (p) Pacific cod, (a) arrowtooth flounder and (f) flathead sole.

Figure 74. Sampling the cold water regime at 12 tows, Ugak Bay walleye pollock had a 0.86 detectability when taking the peak into account. Alpha-levels are 0.1. Species are (h) humpy shrimp, (w) walleye pollock and (wj) juvenile walleye pollock.

Figure 75. Walleye pollock *P*-value contour lines in Ugak Bay cold water regime.

Figure 76. Walleye pollock *P*-value SE contour lines in Ugak Bay cold water regime.

Figure 77. Pandalid shrimp species group detectability for a given sampling rate accross all bays in the cold water regime. Alpha-level is 0.05.

Figure 78. Pleuronectid species group detectability for a given sampling rate accross all bays in the cold water regime. Alpha-levels are 0.05, except for Alitak Bay.

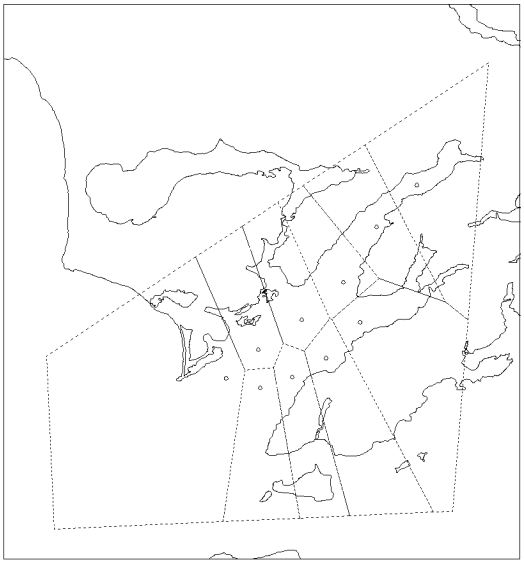
Figure 79. Pandalid shrimp species group detectability for a given sampling rate accross all bays in the warm water regime. Alpha-levels are 0.05, except for Alitak, Marmot and Ugak Bays.

Figure 80. Pleuronectid species group detectability for a given sampling rate accross all bays in the warm water regime. Alpha-levels are 0.05, except for Alitak Bay.

Figure 81. Osmerid species group detectability for a given sampling rate accross all bays in the cold water regime. Alpha-levels are 0.1.

Figure 82. Osmerid species group detectability for a given sampling rate accross all bays in the warm water regime. Alpha-levels are 0.05, except for Alitak, Chignik-Castle and Kiliuda Bays.

Figure 2.



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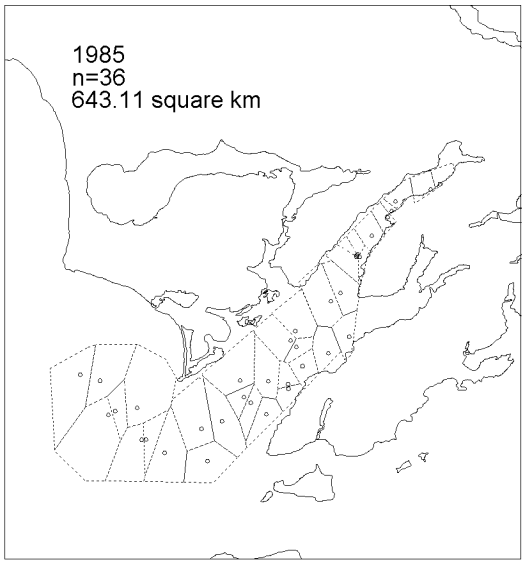

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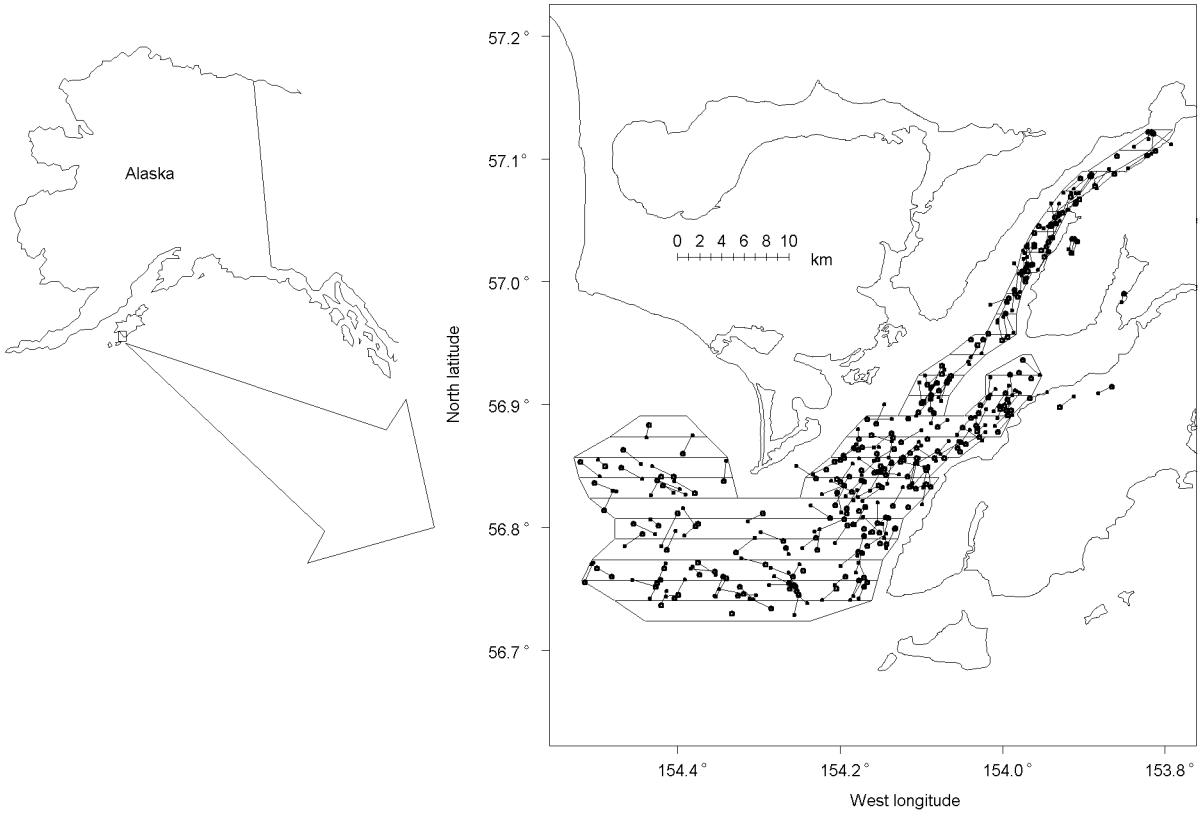
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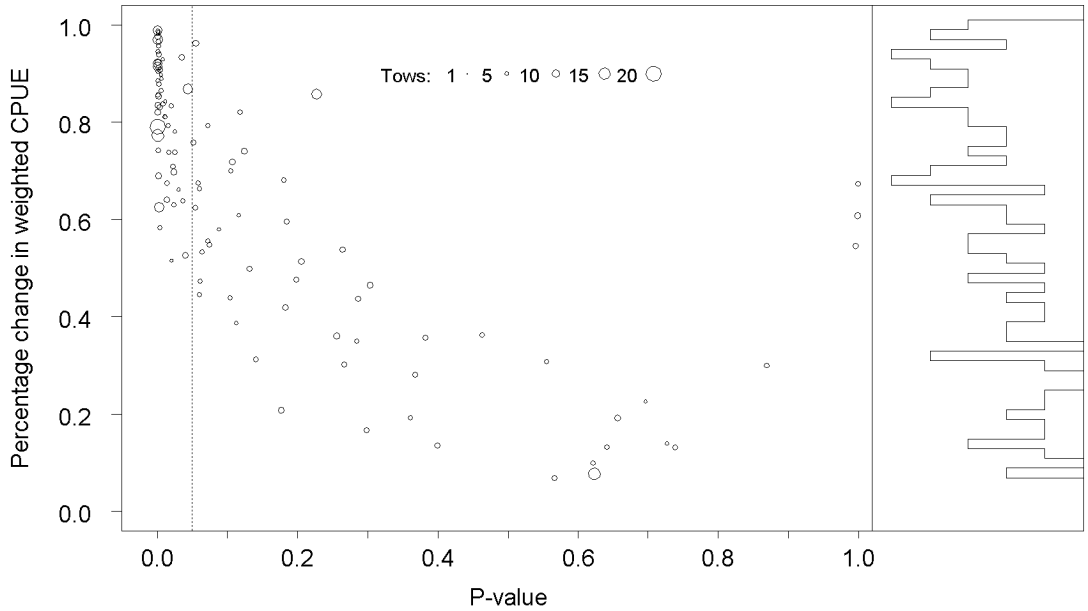
Figure 5.



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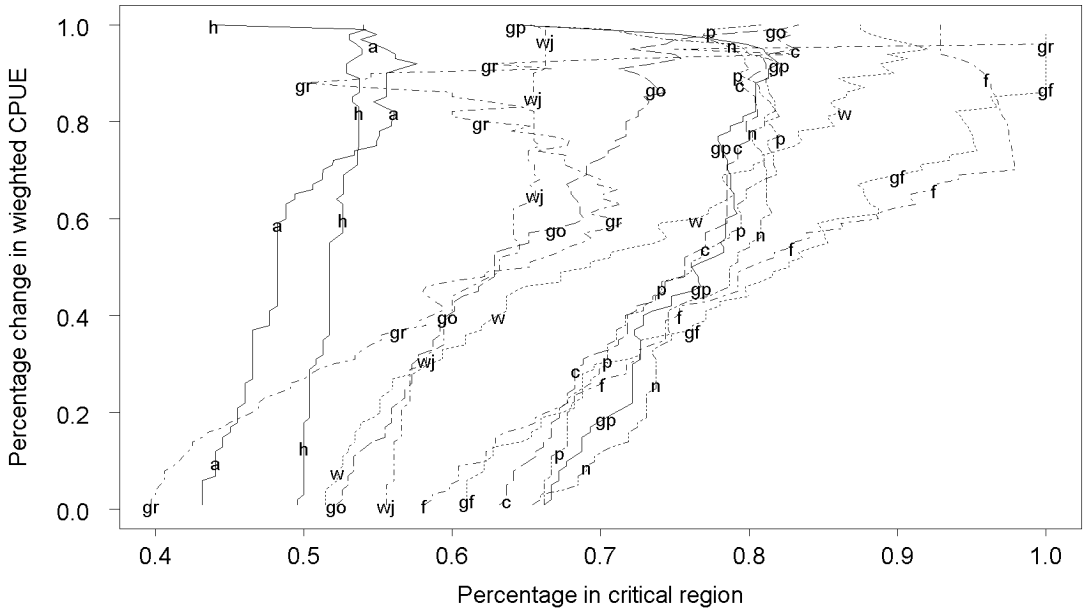

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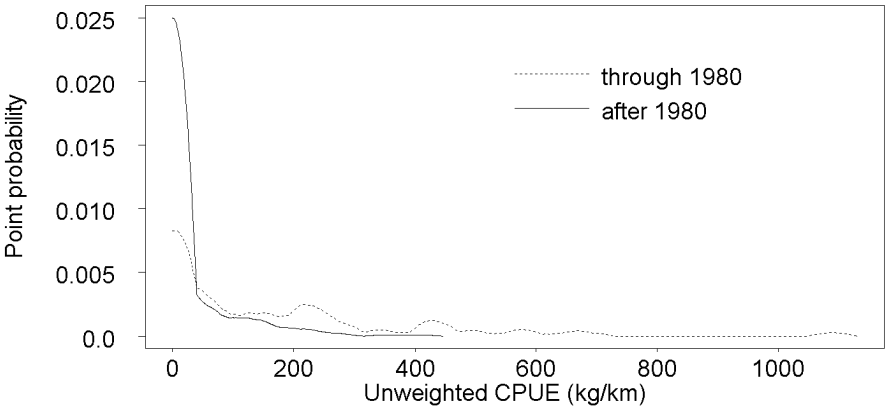

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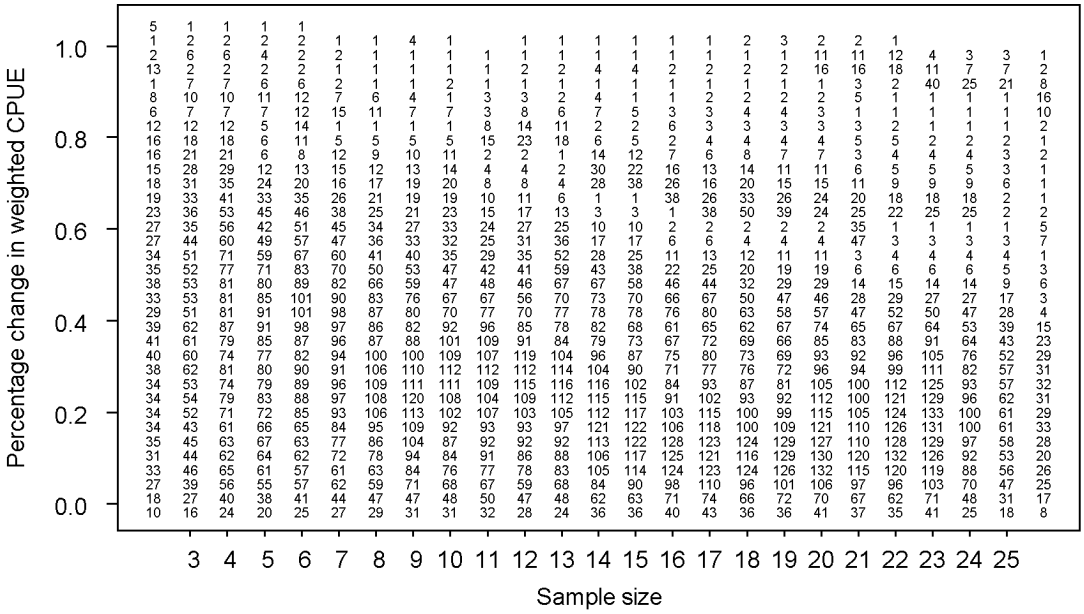

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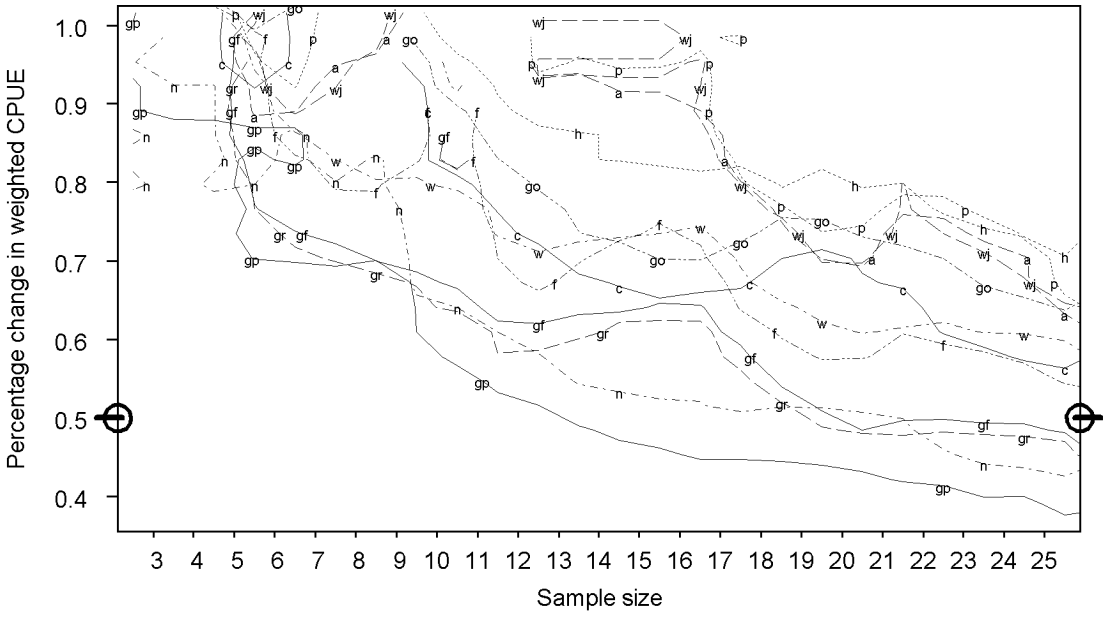

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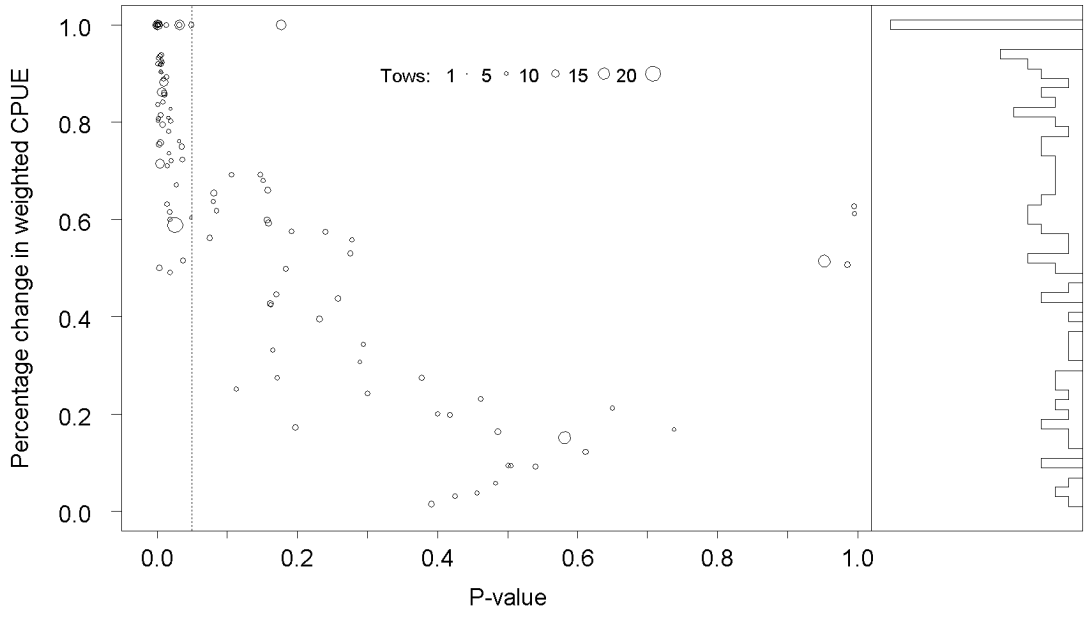

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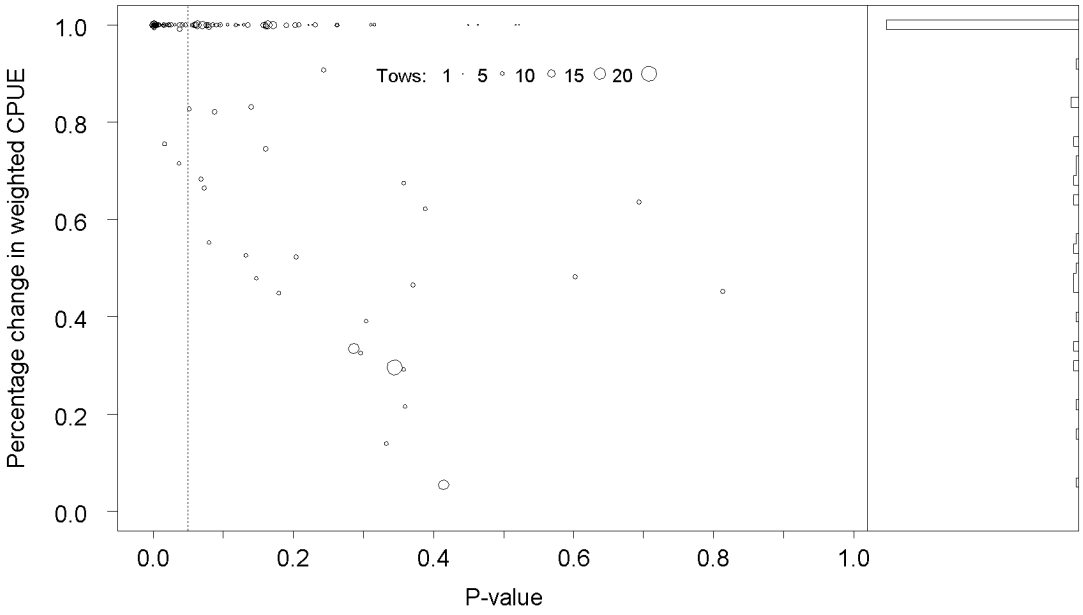

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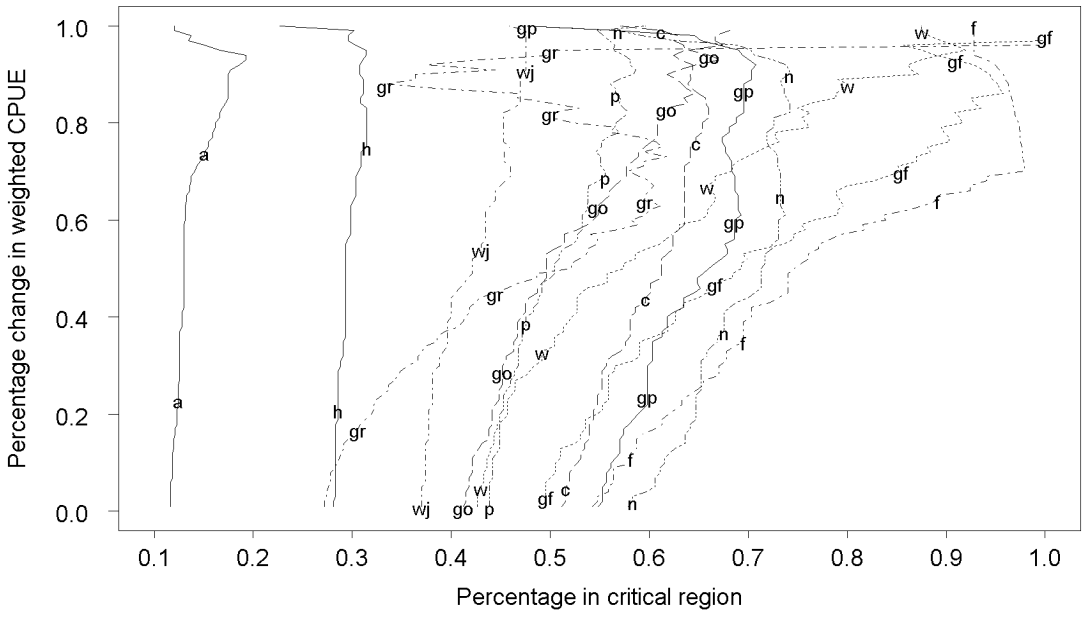

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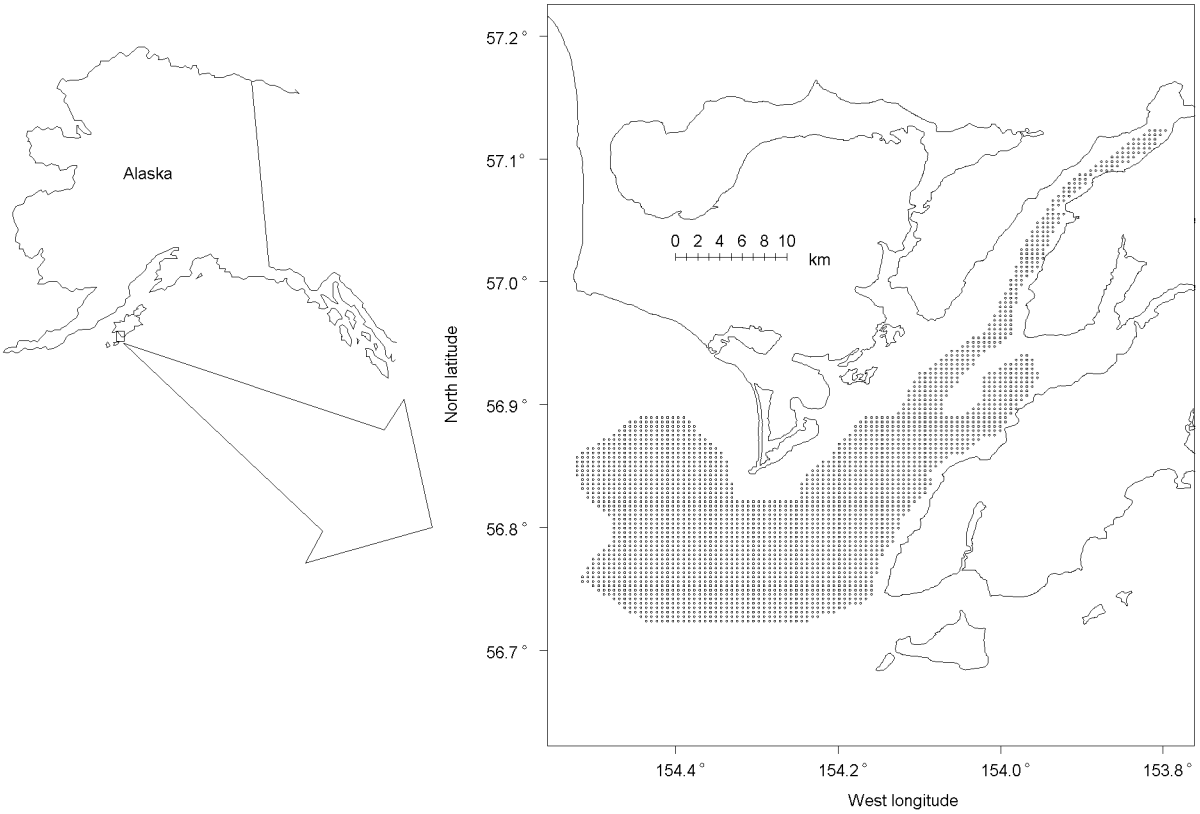
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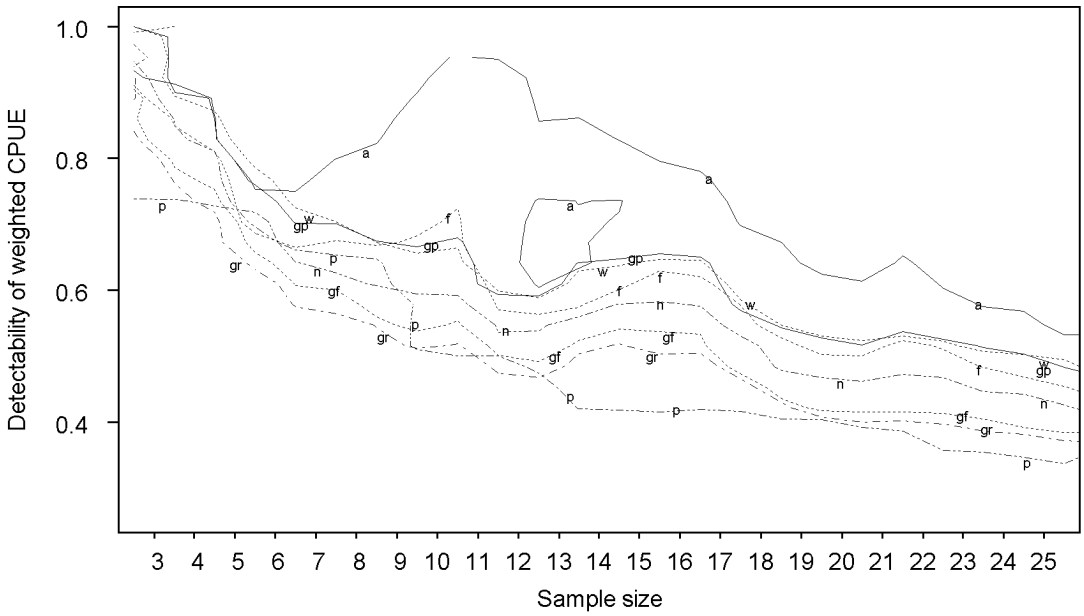

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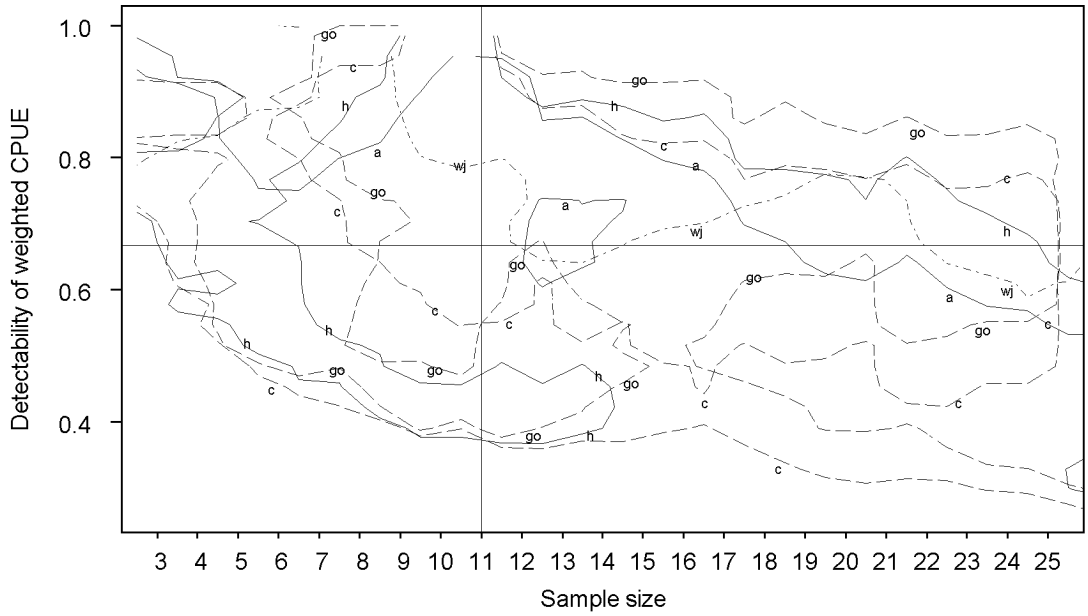

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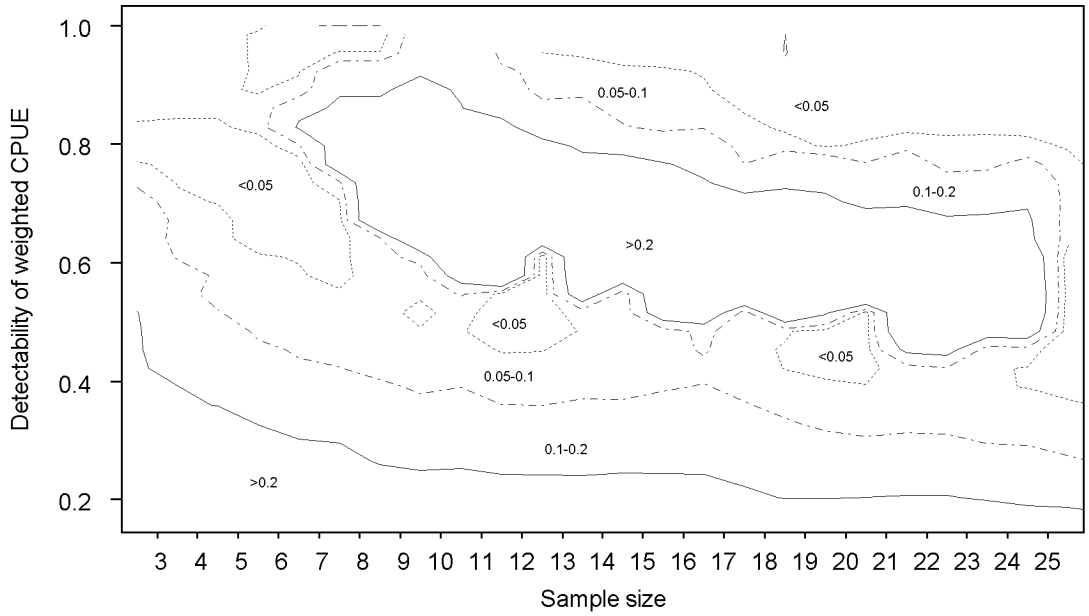

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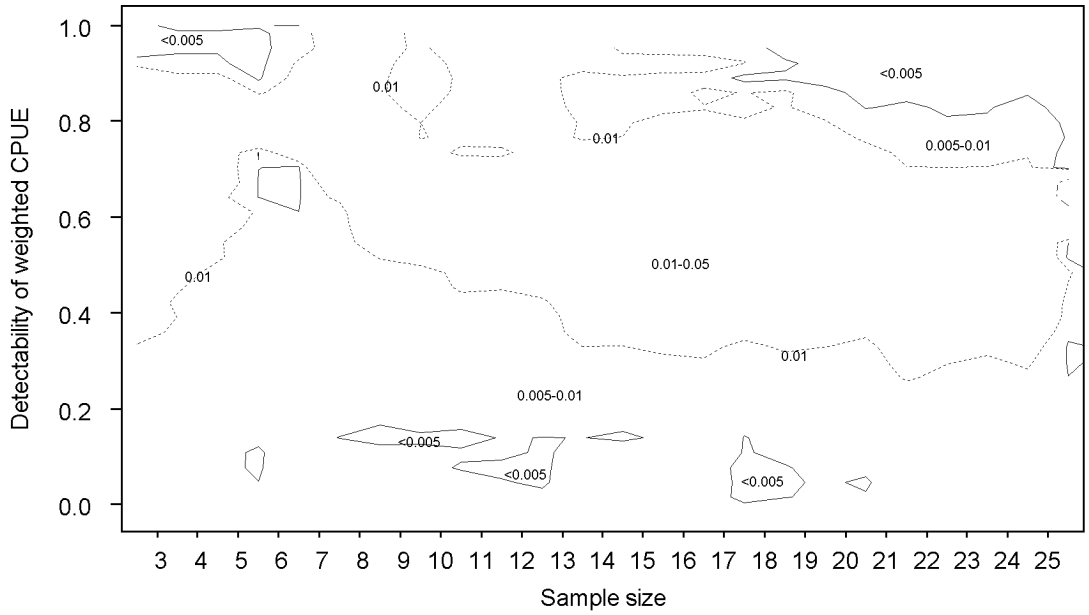

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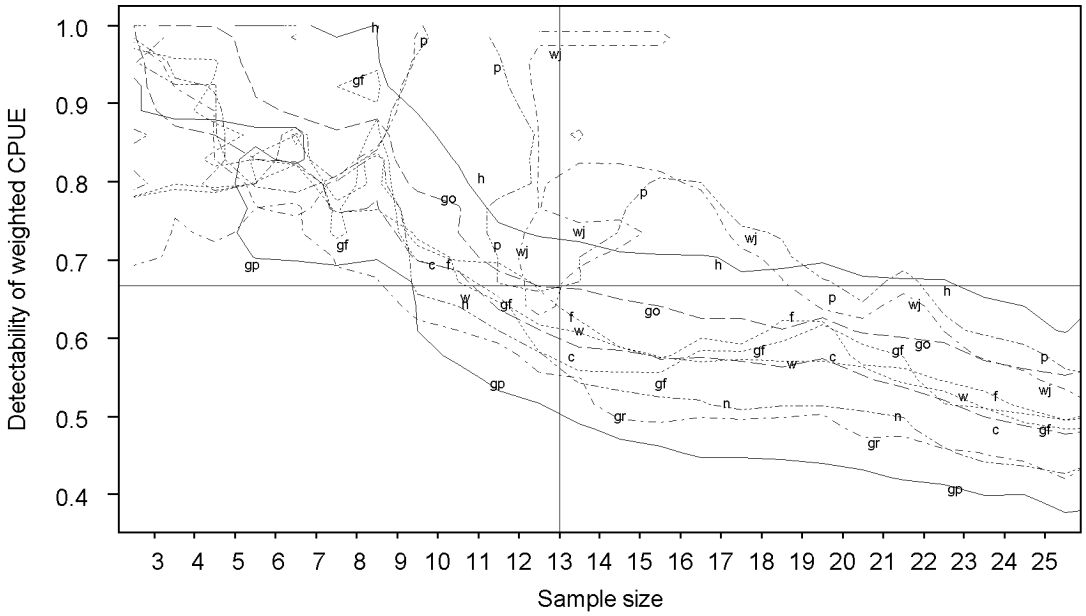

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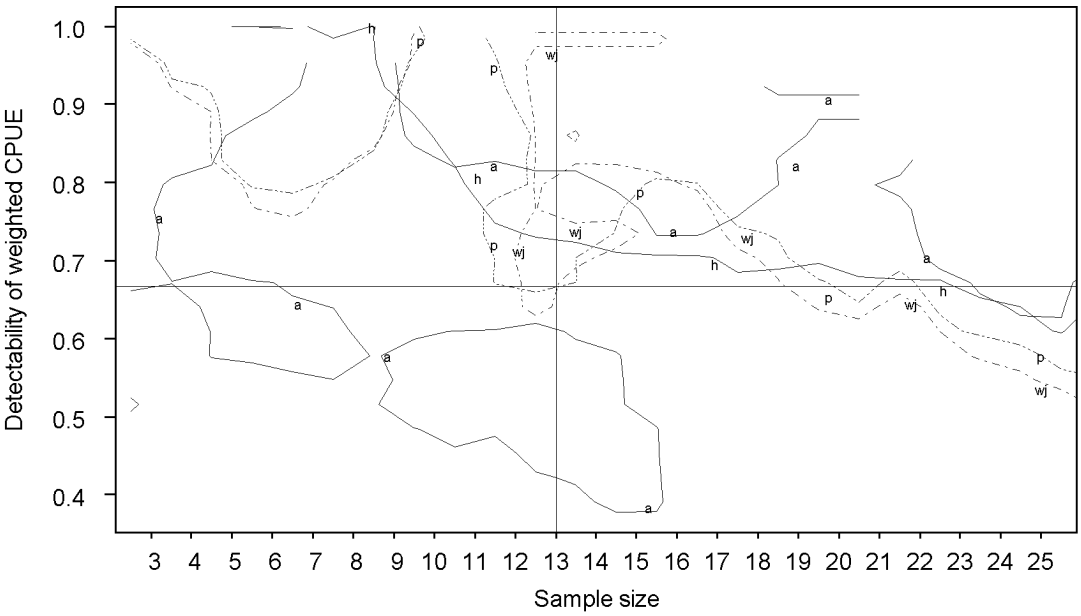

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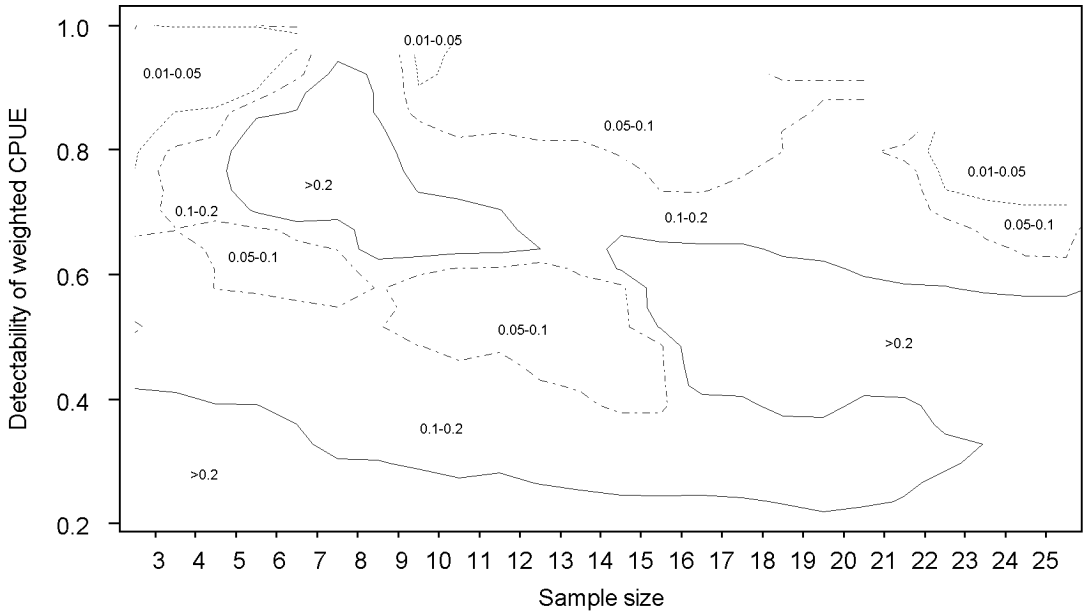


Figure 21.

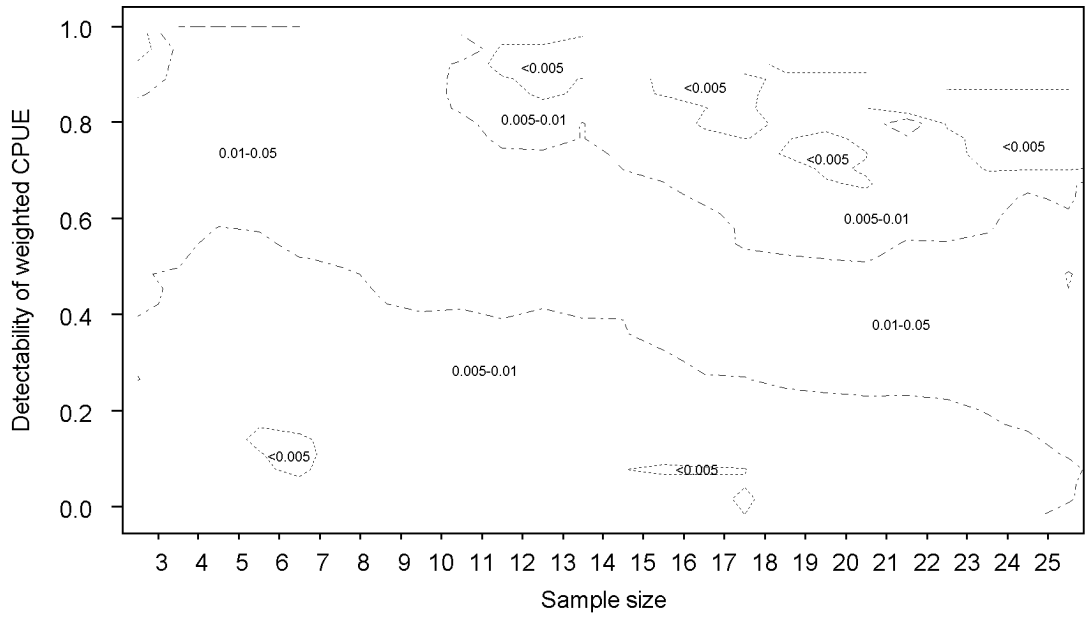


Figure 22

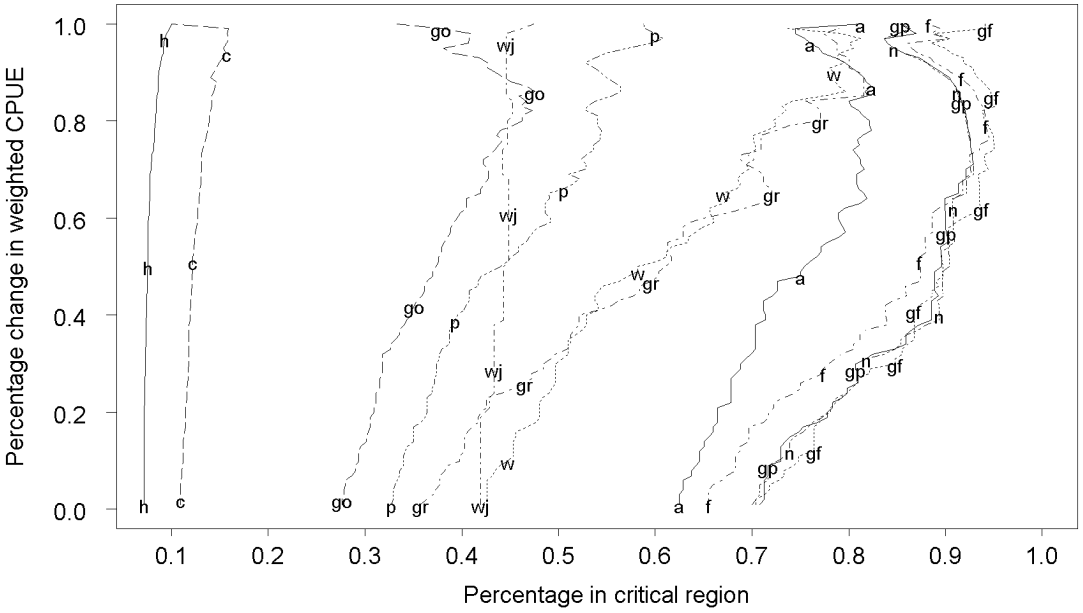


Figure 23

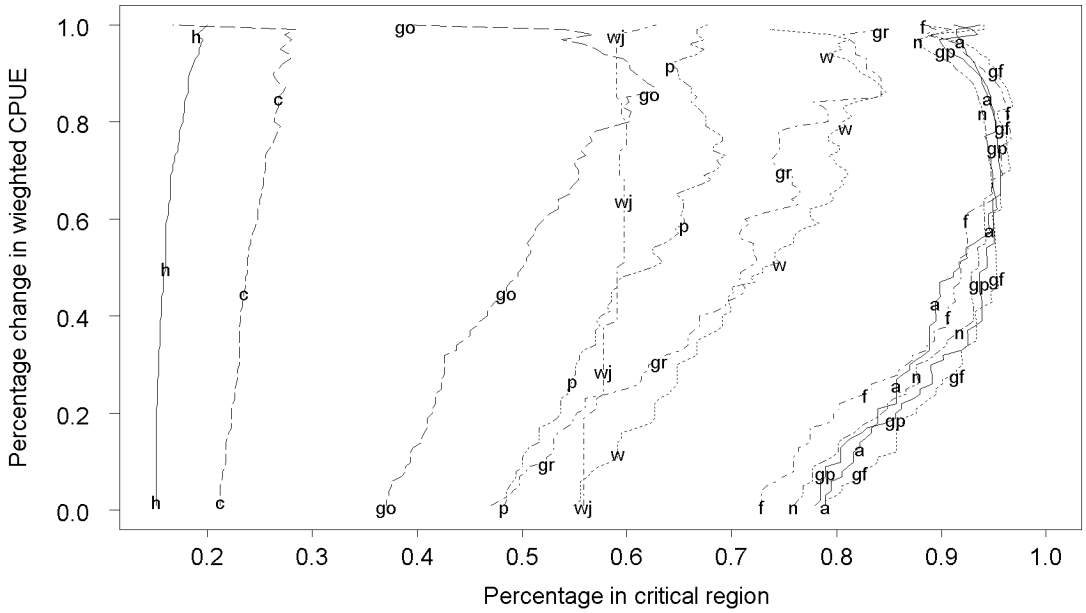


Figure 24

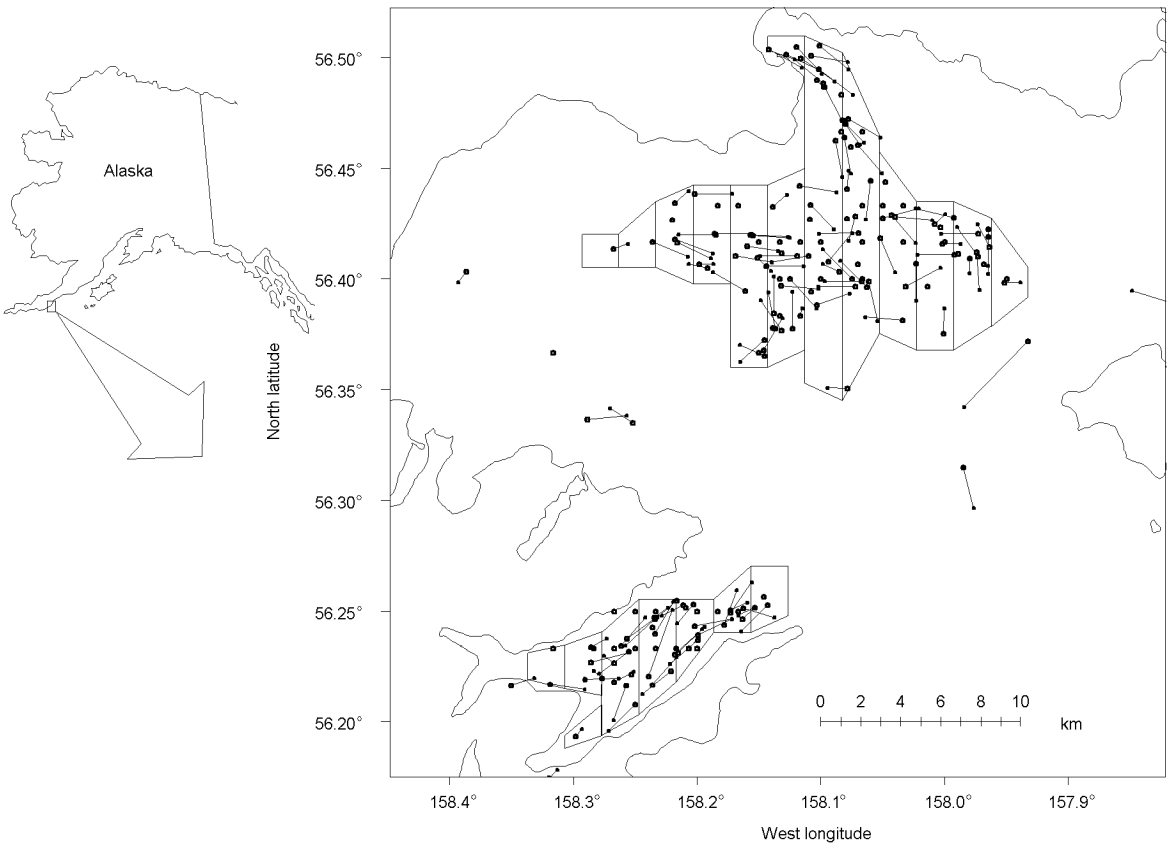

Alaska
56.50°
56.45°
56.40°
56.35°
56.30°
56.25°
56.20°
North latitude
0 2 4 6 8 10
km
158.4°
158.3°
158.2°
158.1°
158.0°
157.9°
West longitude

Figure 25

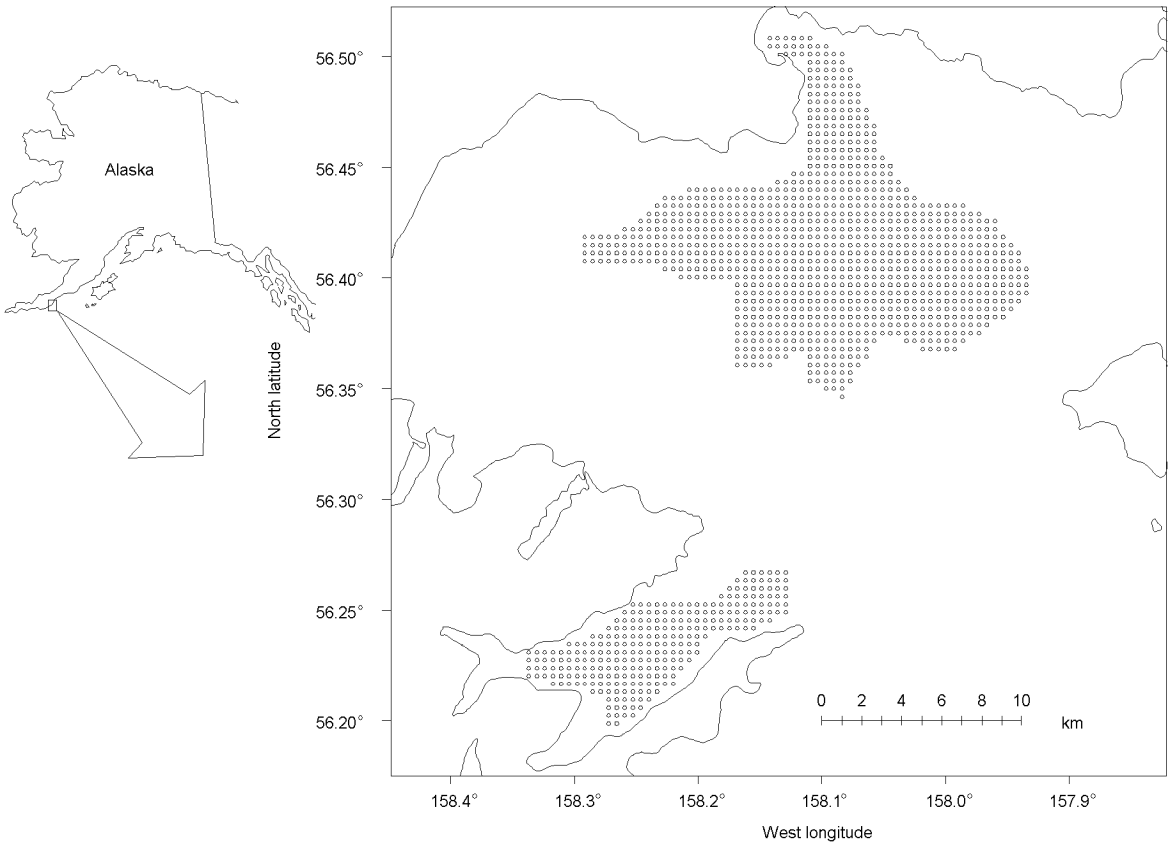

Alaska
56.50°
56.45°
56.40°
56.35°
56.30°
56.25°
56.20°
North latitude
0 2 4 6 8 10
km
158.4°
158.3°
158.2°
158.1°
158.0°
157.9°
West longitude

Figure 26

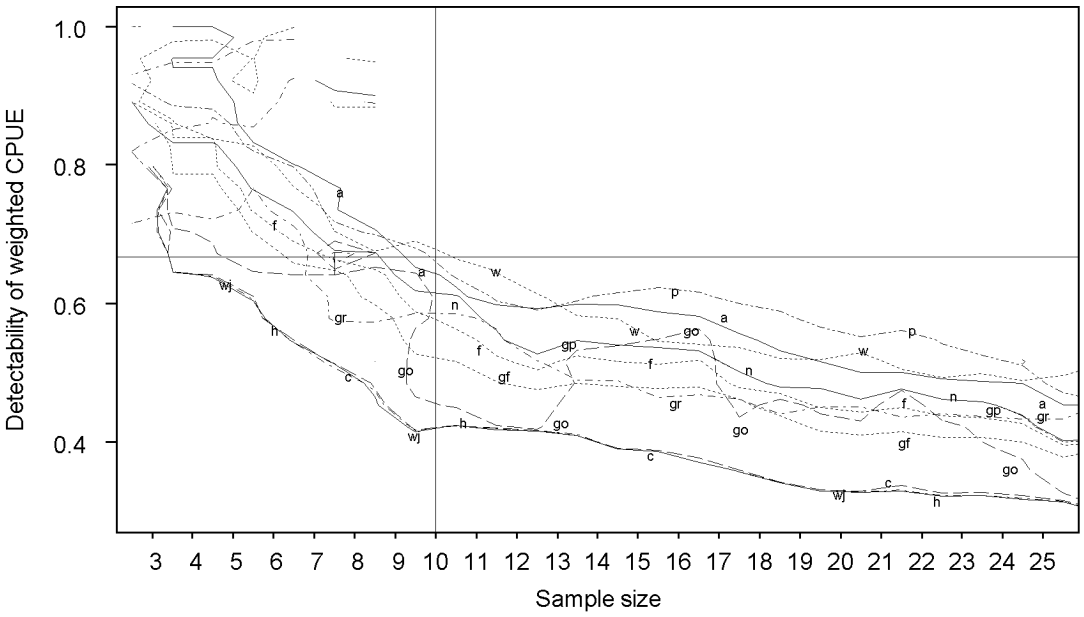


Figure 27

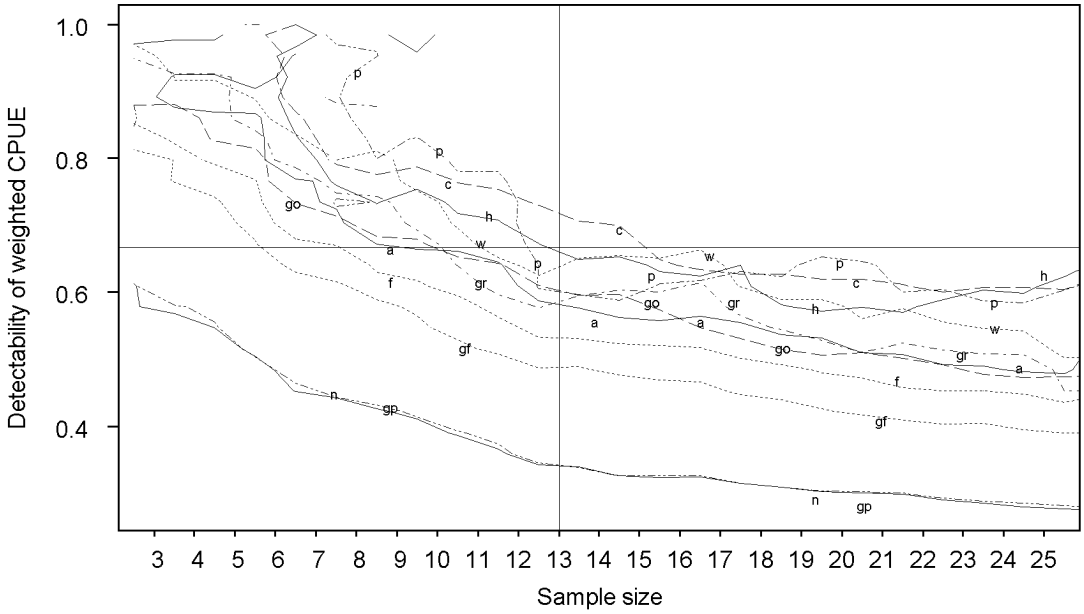


Figure 28

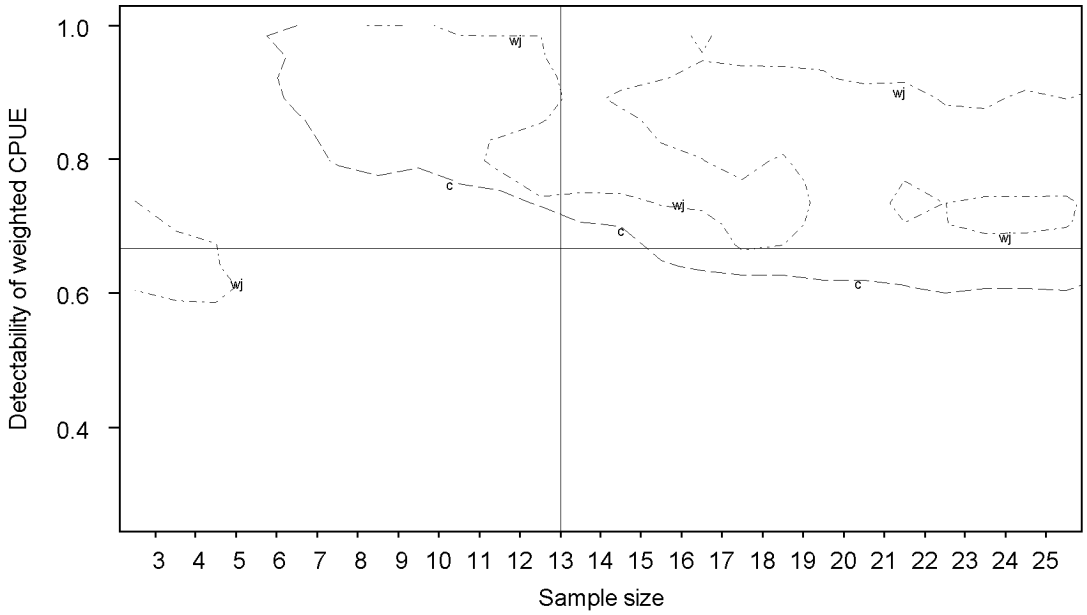


Figure 29

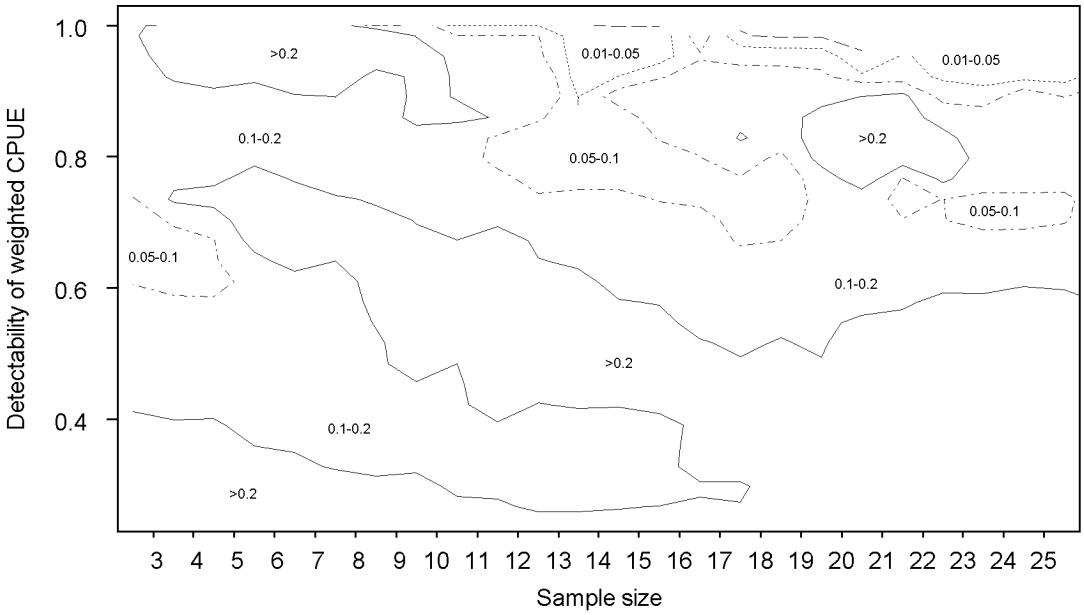


Figure 30

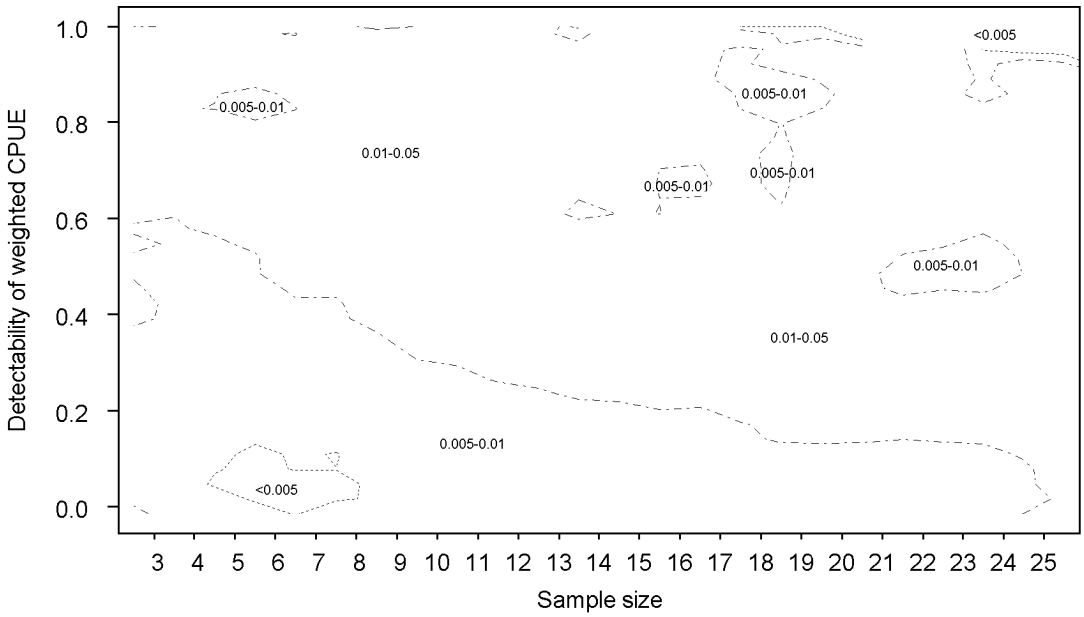

Detectability of weighted CPUE
1.0
0.8
0.6
0.4
0.2
0.0
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Sample size
<0.005
0.005-0.01
0.01-0.05
0.005-0.01
0.005-0.01
0.005-0.01
0.005-0.01
0.01-0.05
0.005-0.01
<0.005

Figure 31

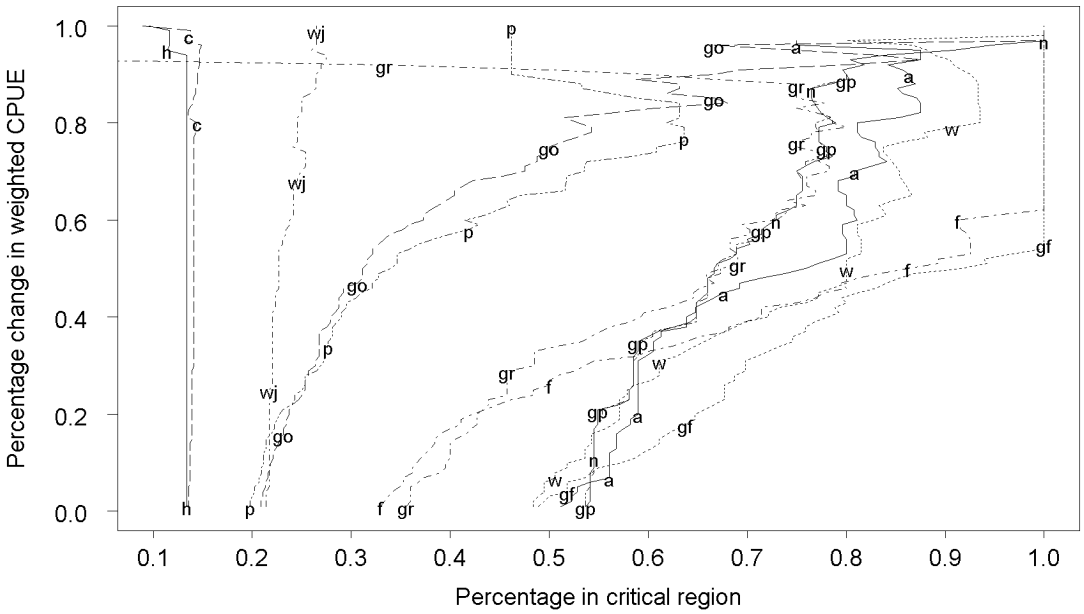


Figure 32

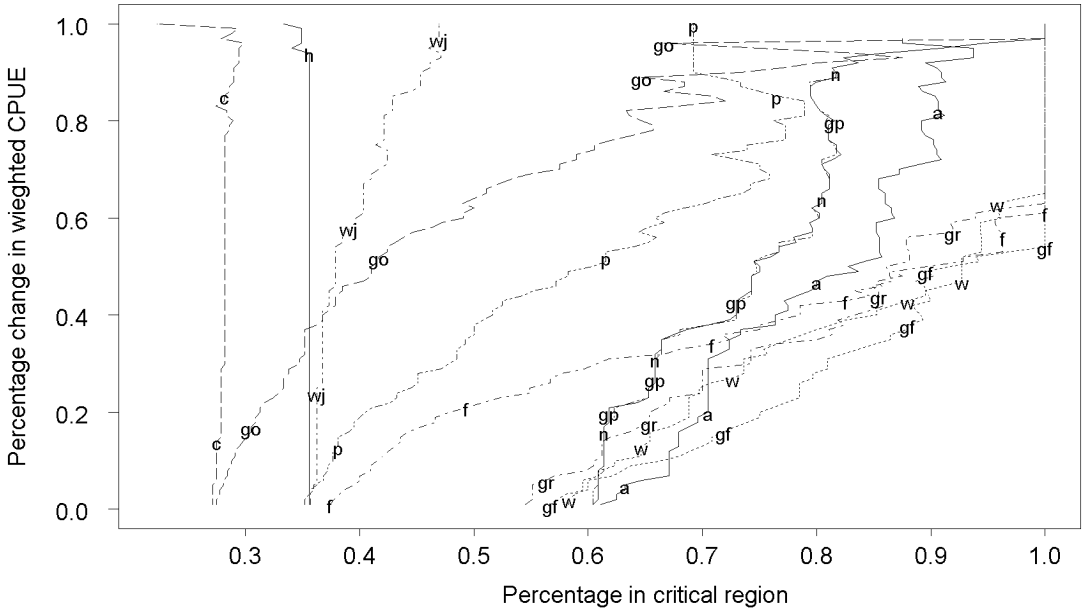


Figure 33

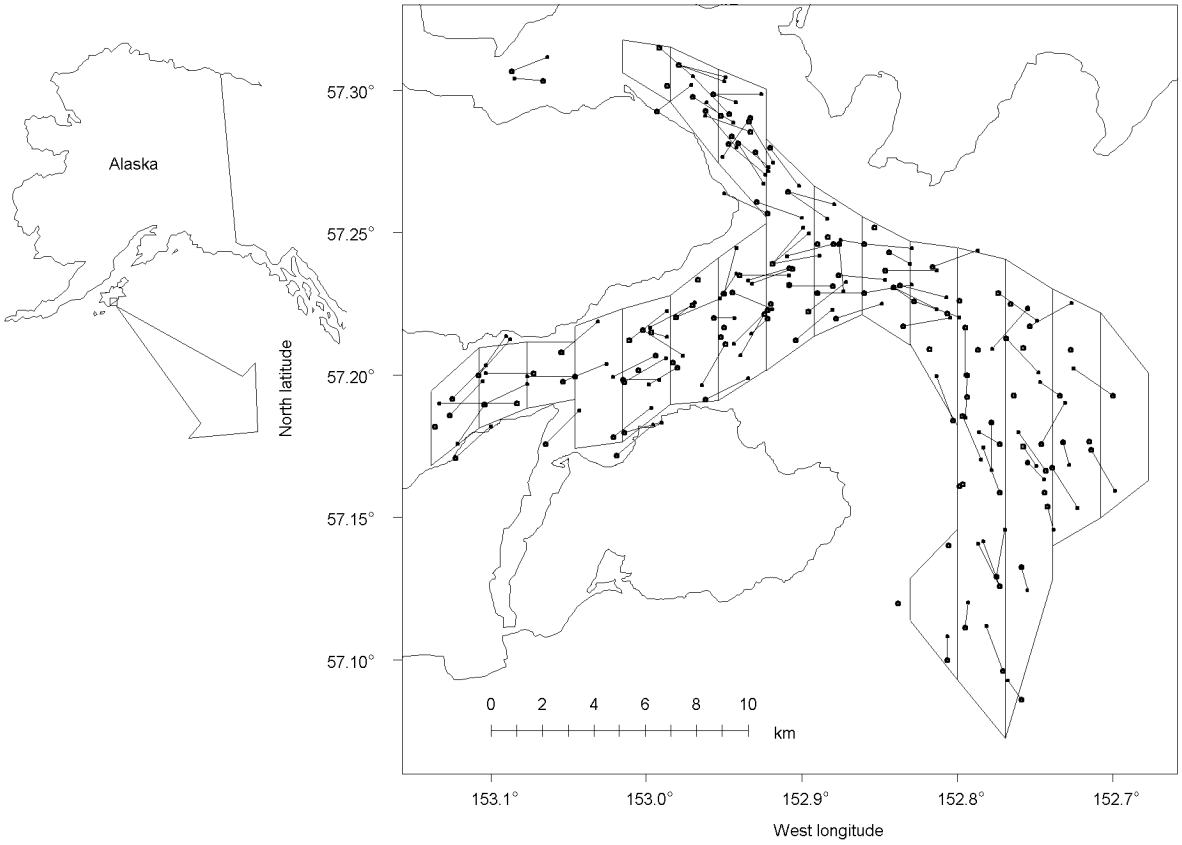

Alaska
57.30°
57.25°
57.20°
57.15°
57.10°
North latitude
0 2 4 6 8 10
km
153.1°
153.0°
152.9°
152.8°
152.7°
West longitude

Figure 34

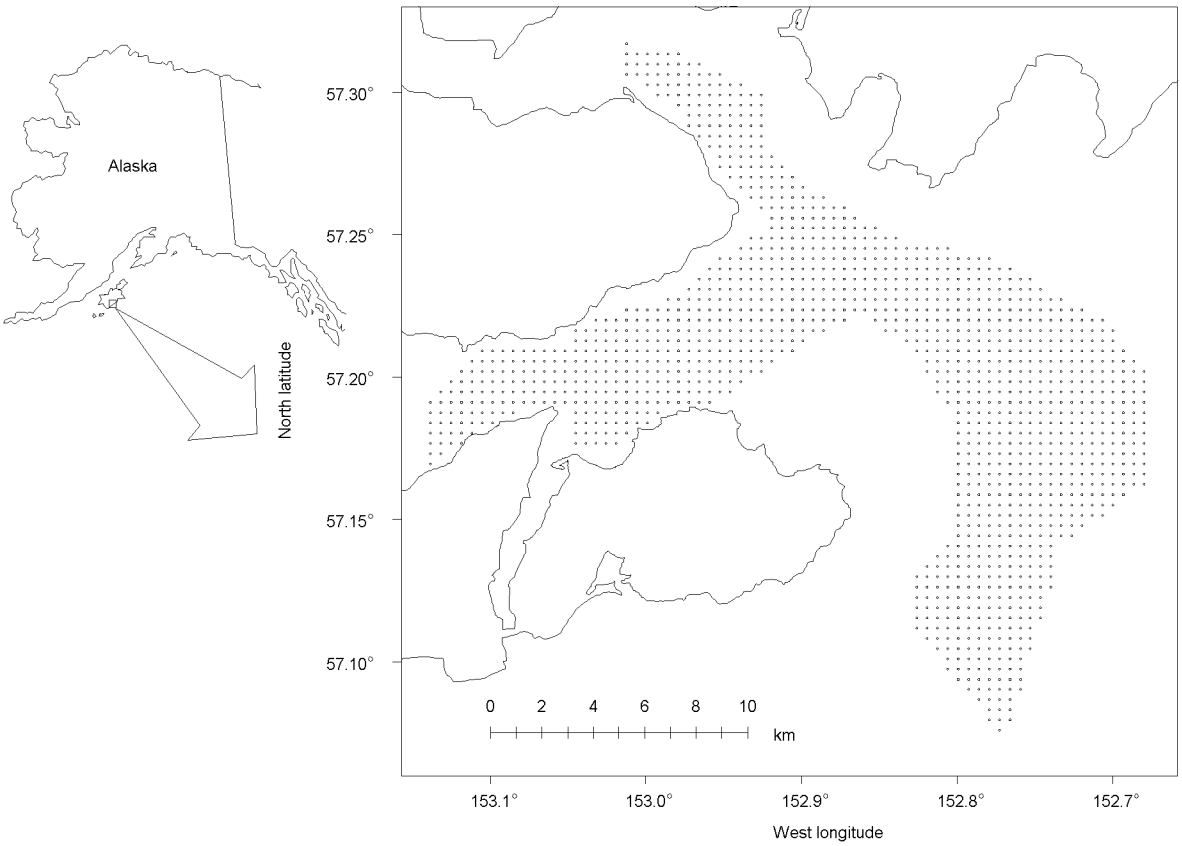


Figure 35

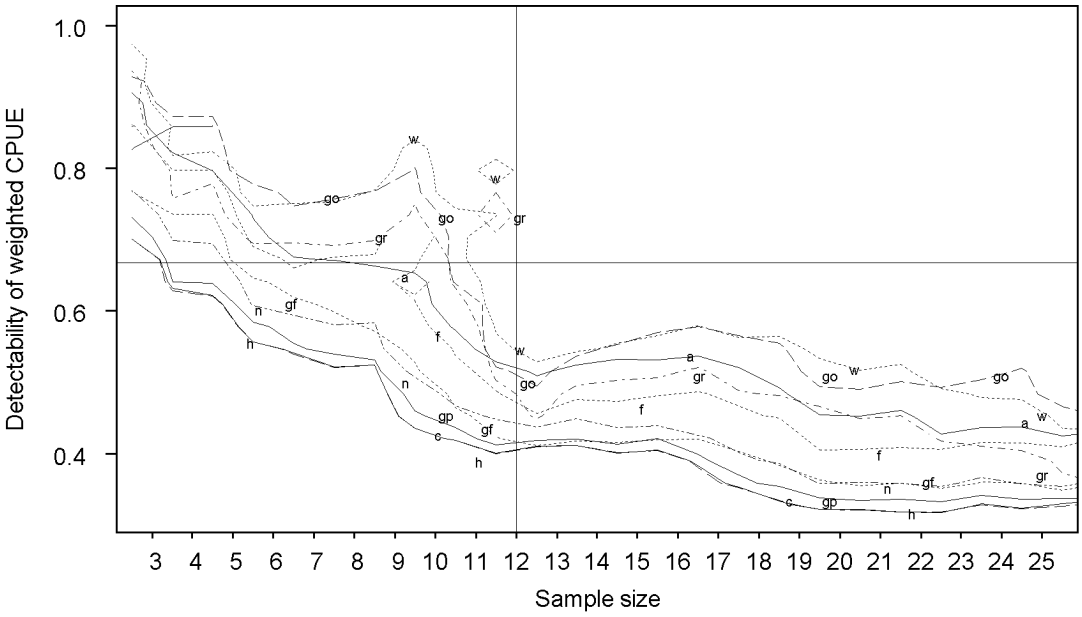


Figure 36

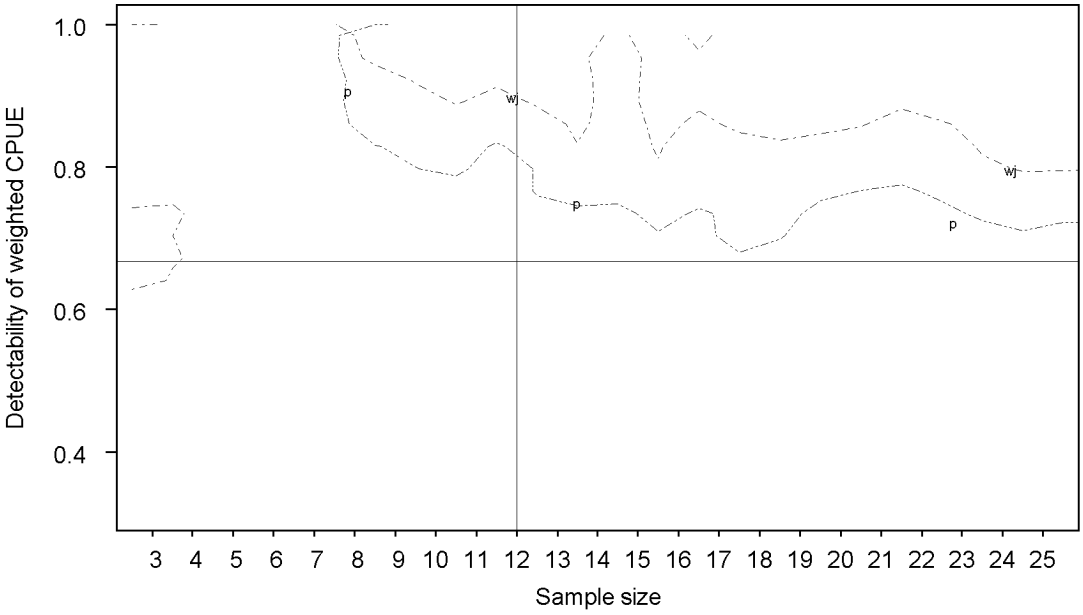


Figure 37

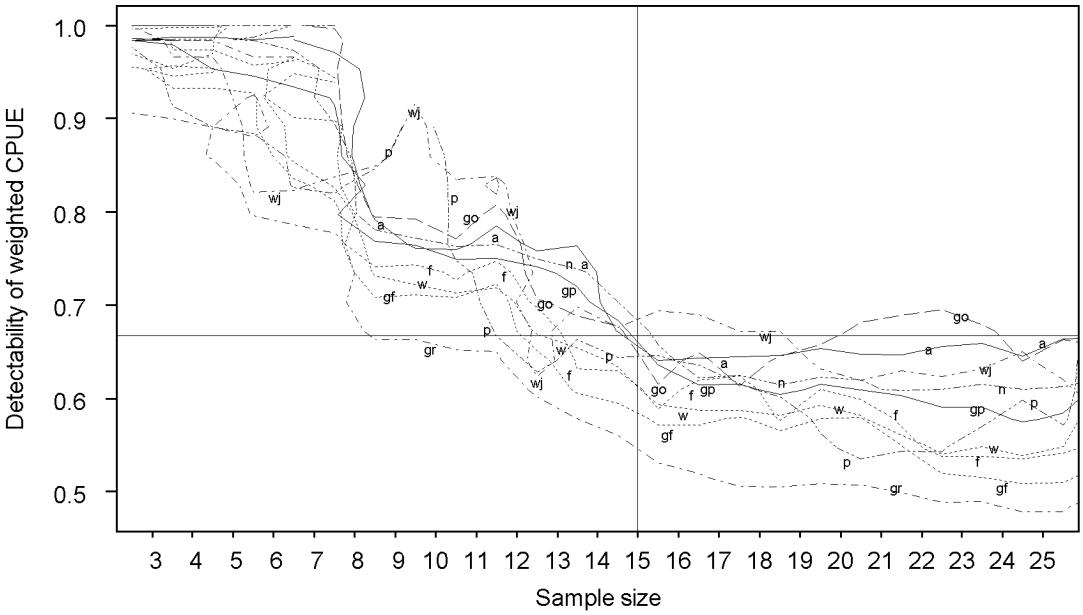


Figure 38

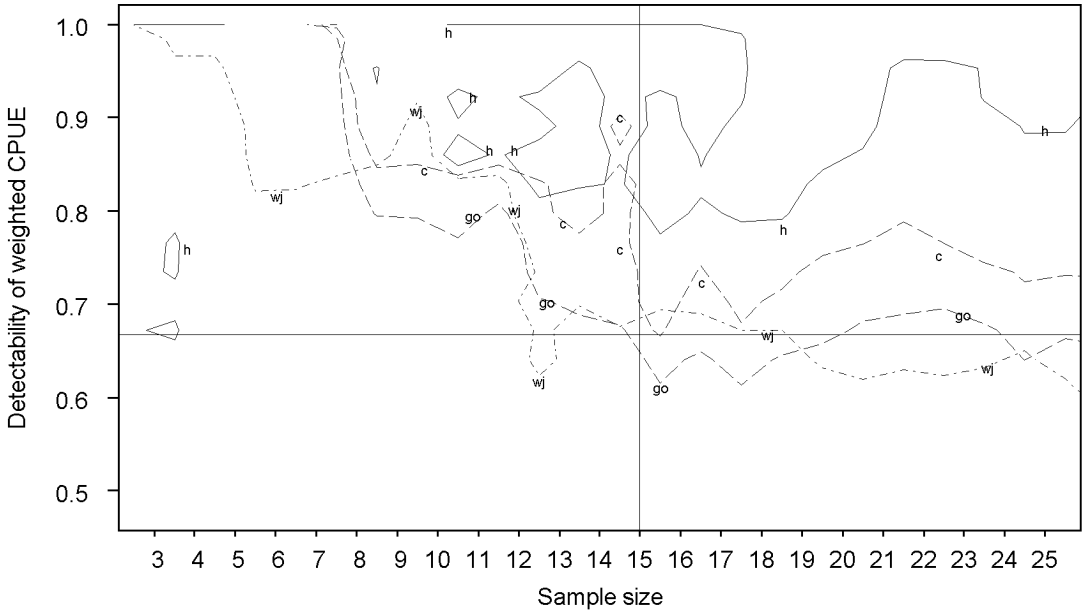


Figure 39

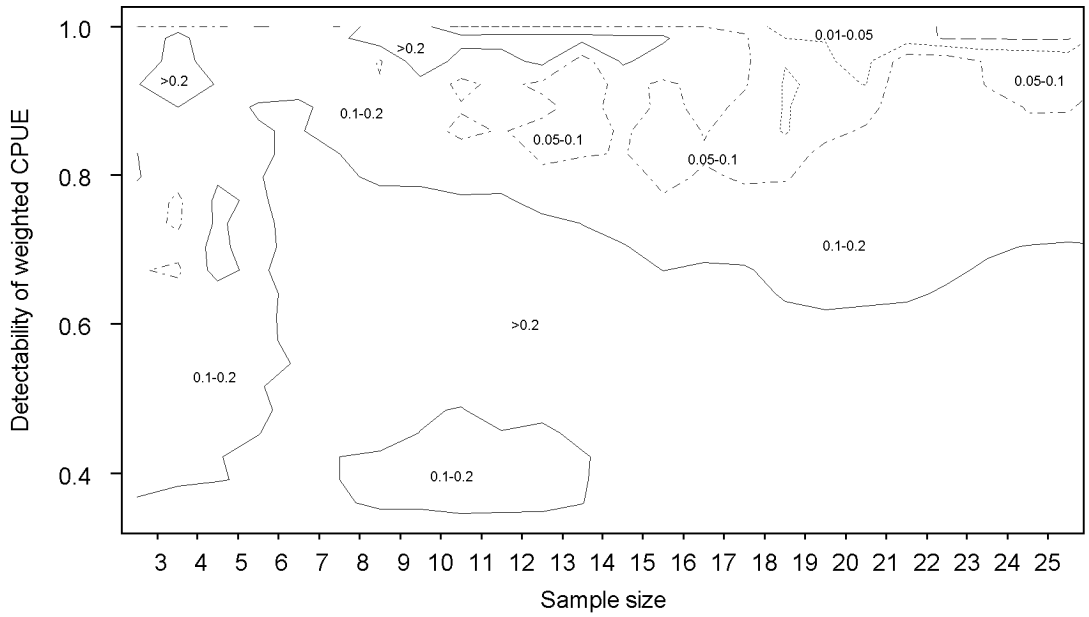


Figure 40

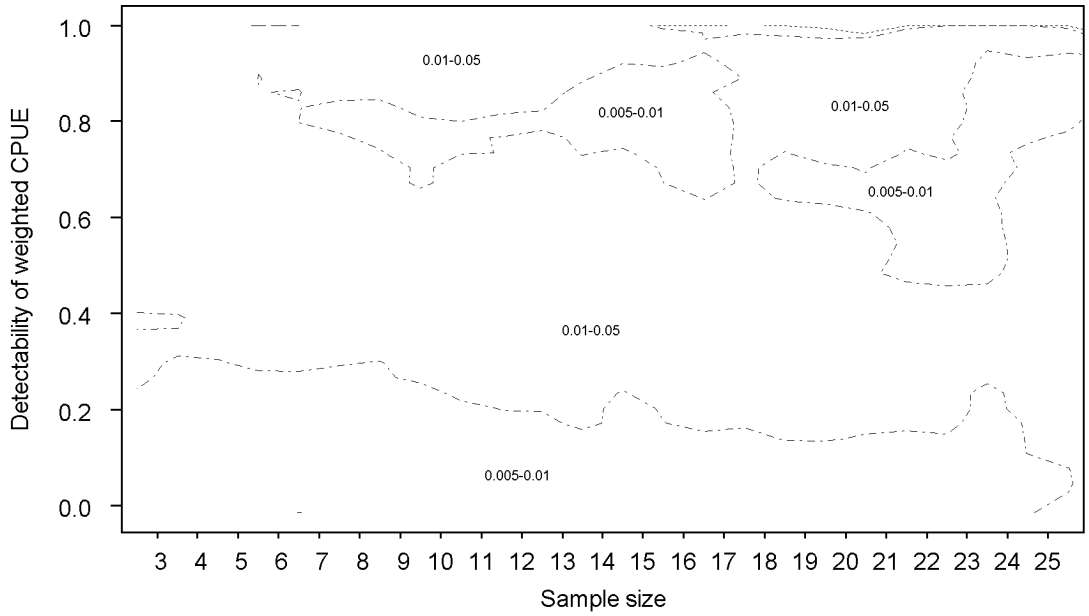


Figure 41

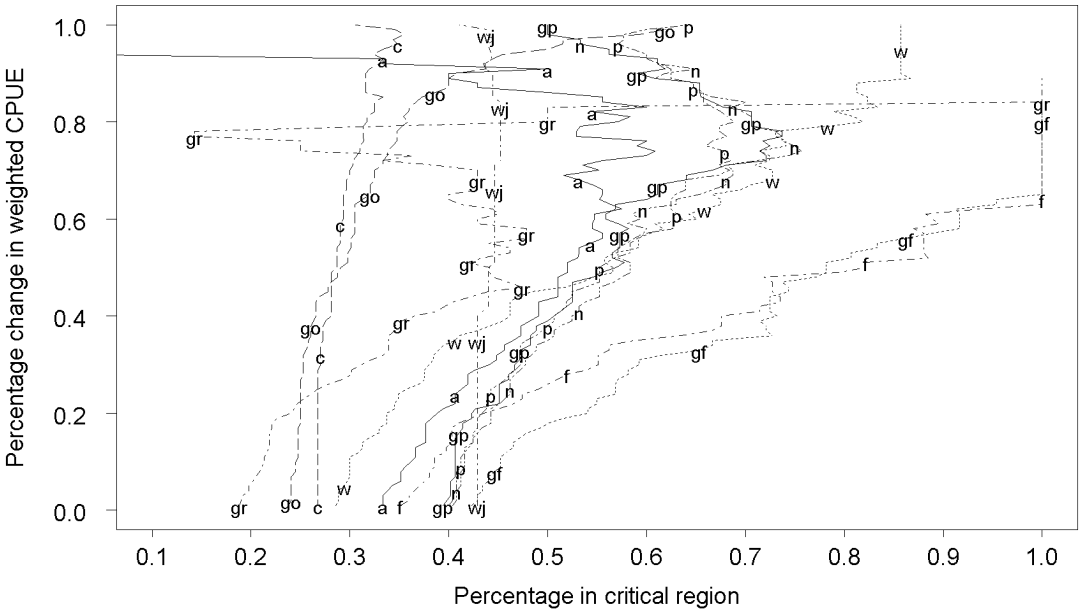


Figure 42

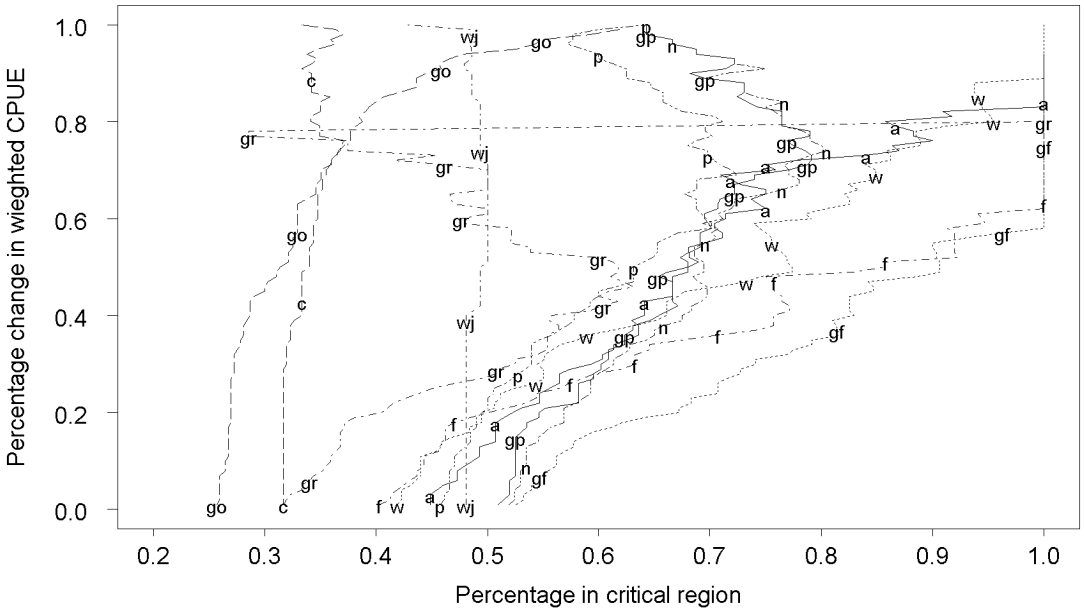


Figure 43

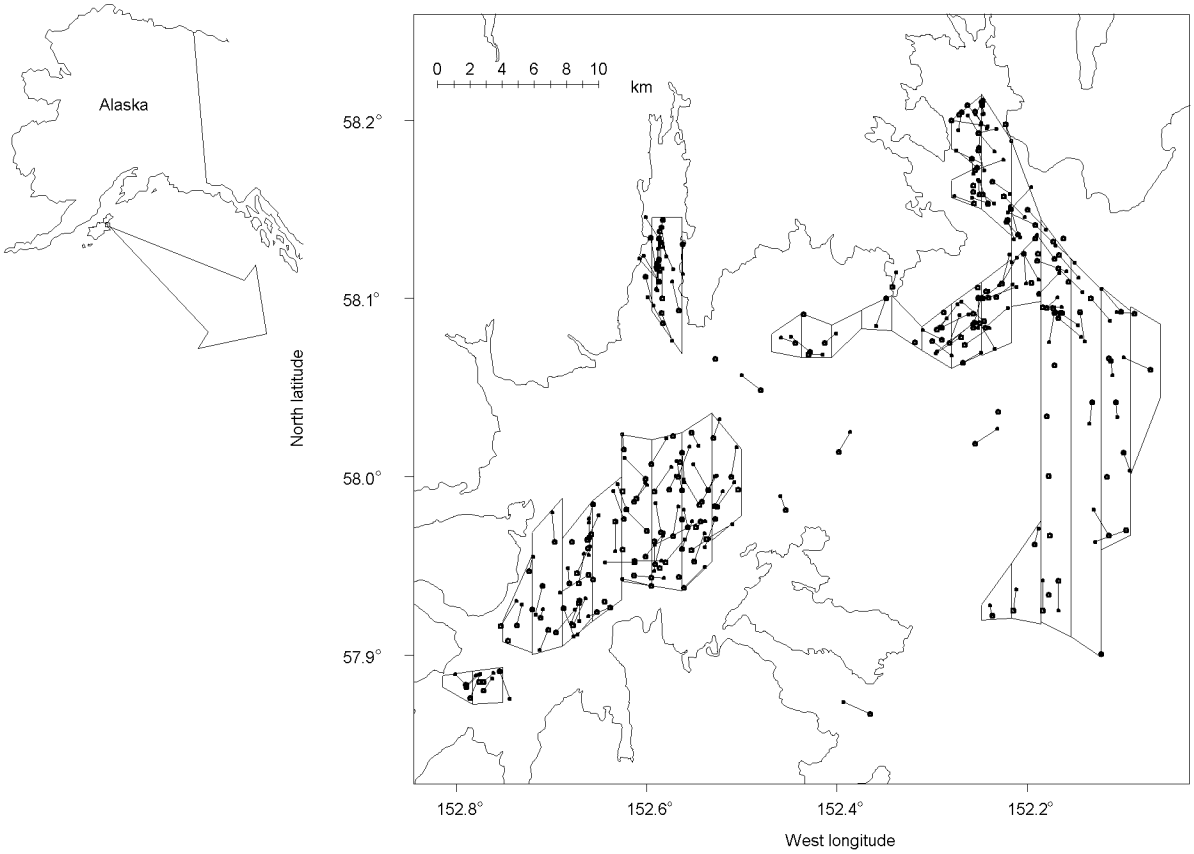


Figure 44

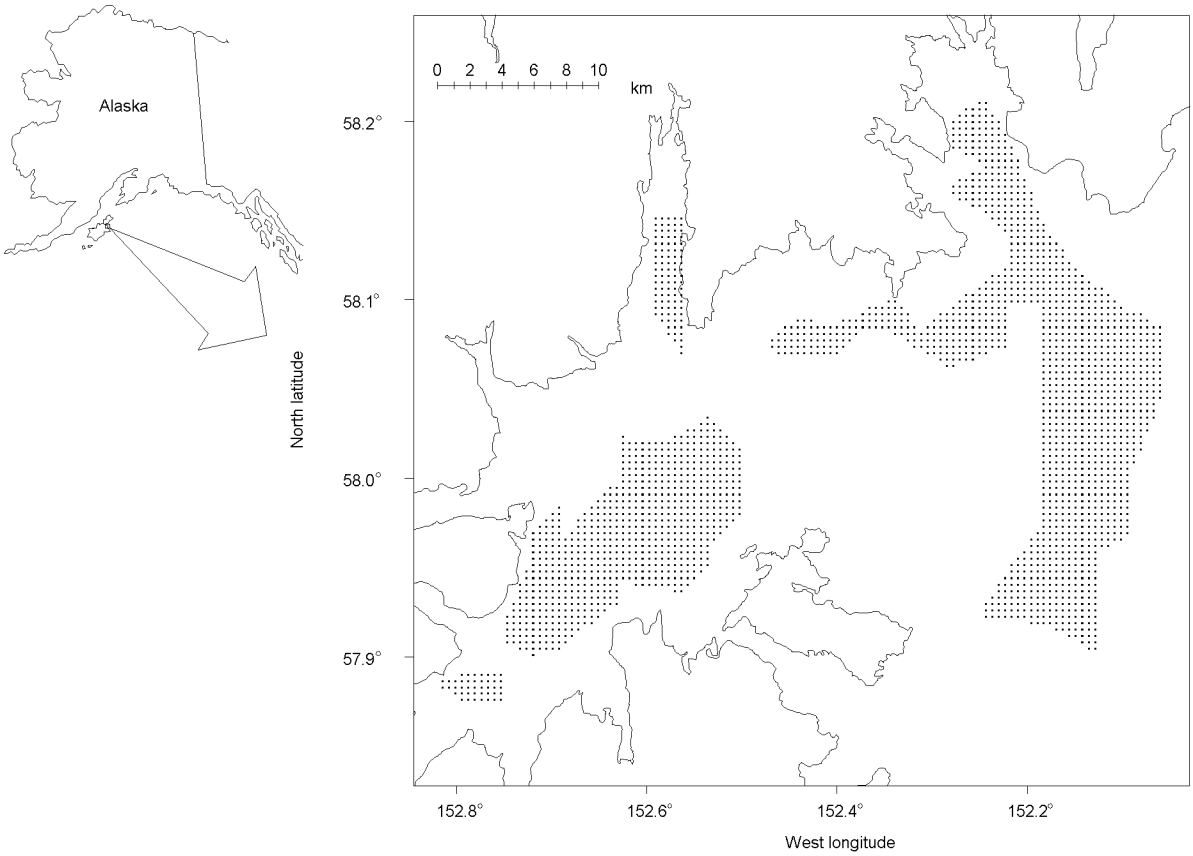


Figure 45

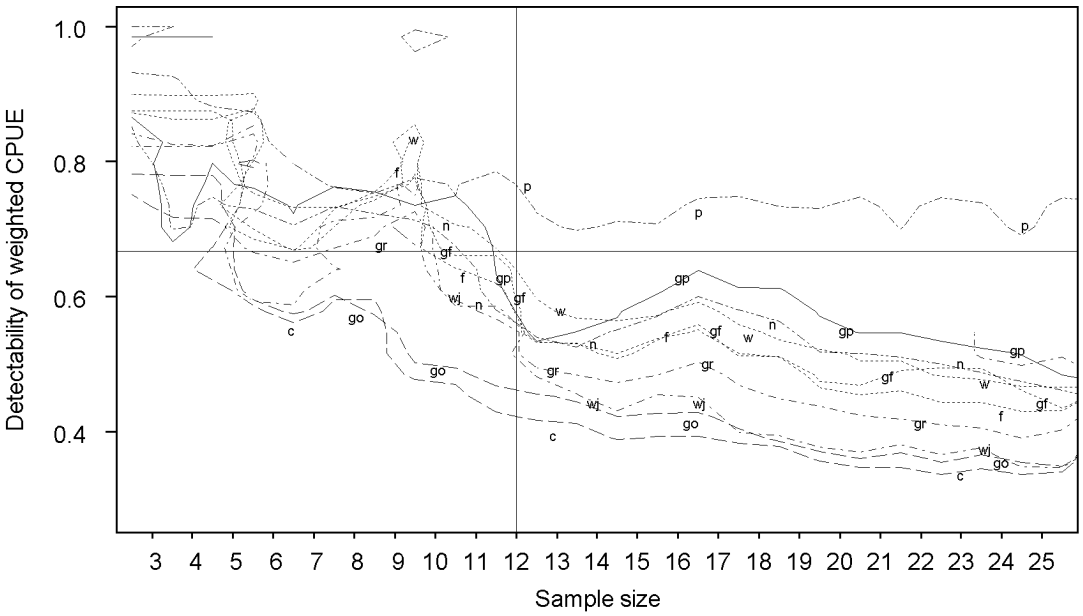
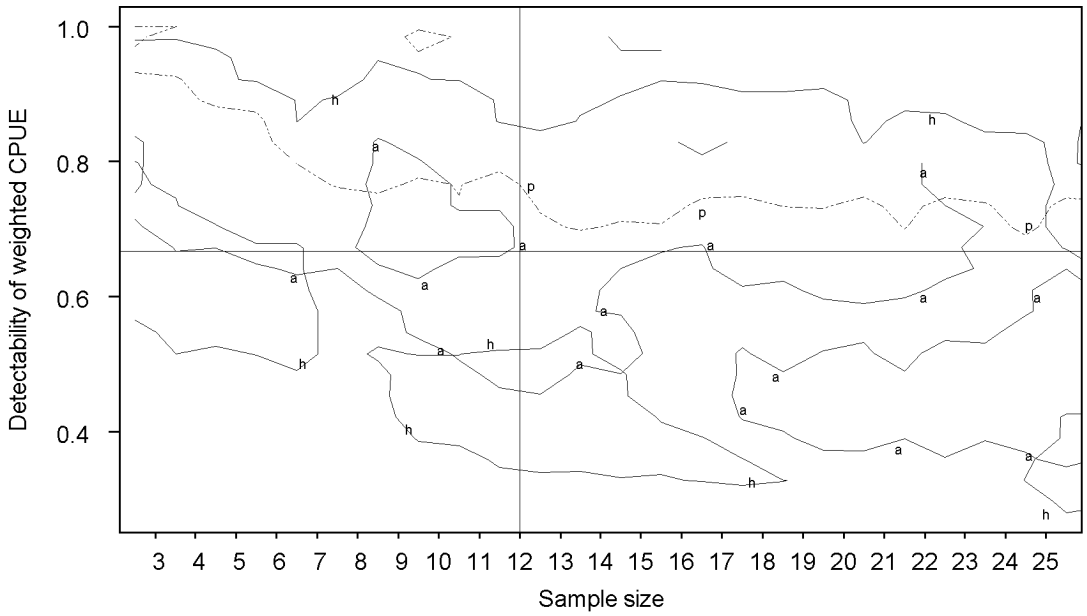


Figure 46



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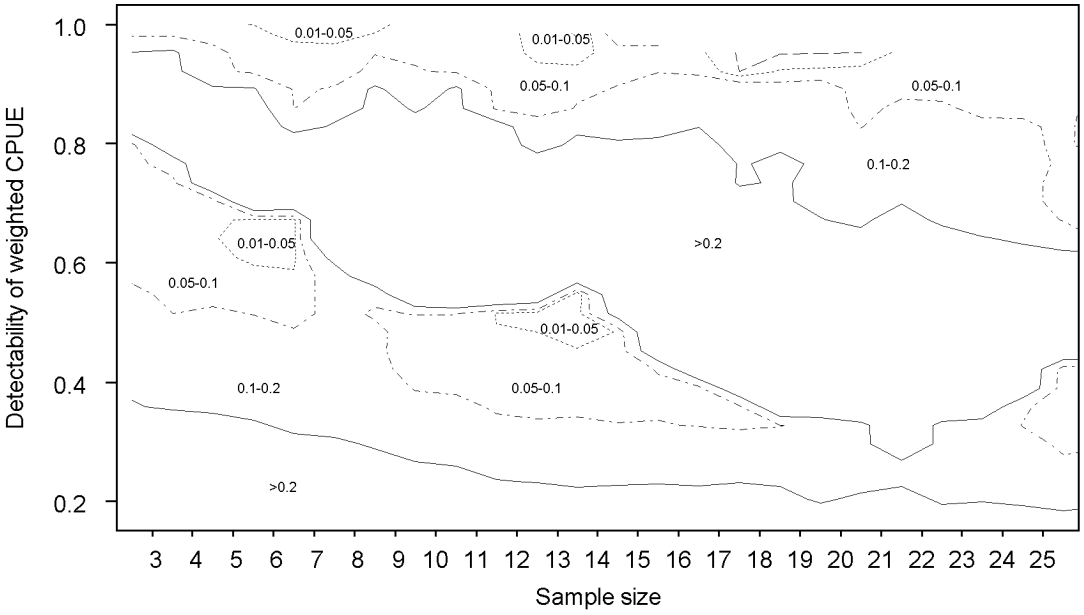
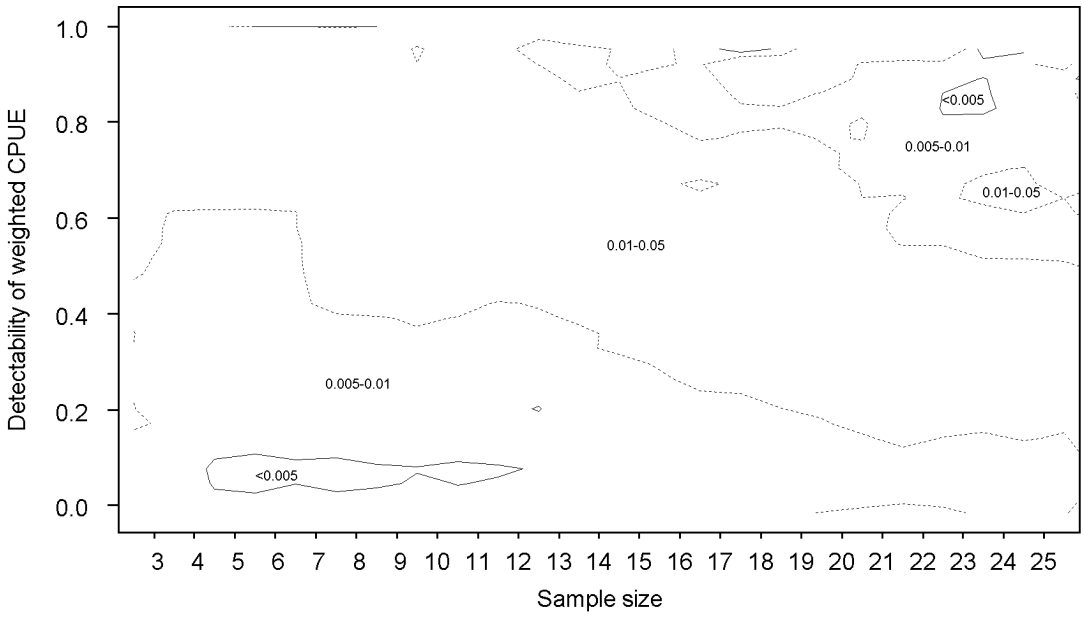


Figure 48



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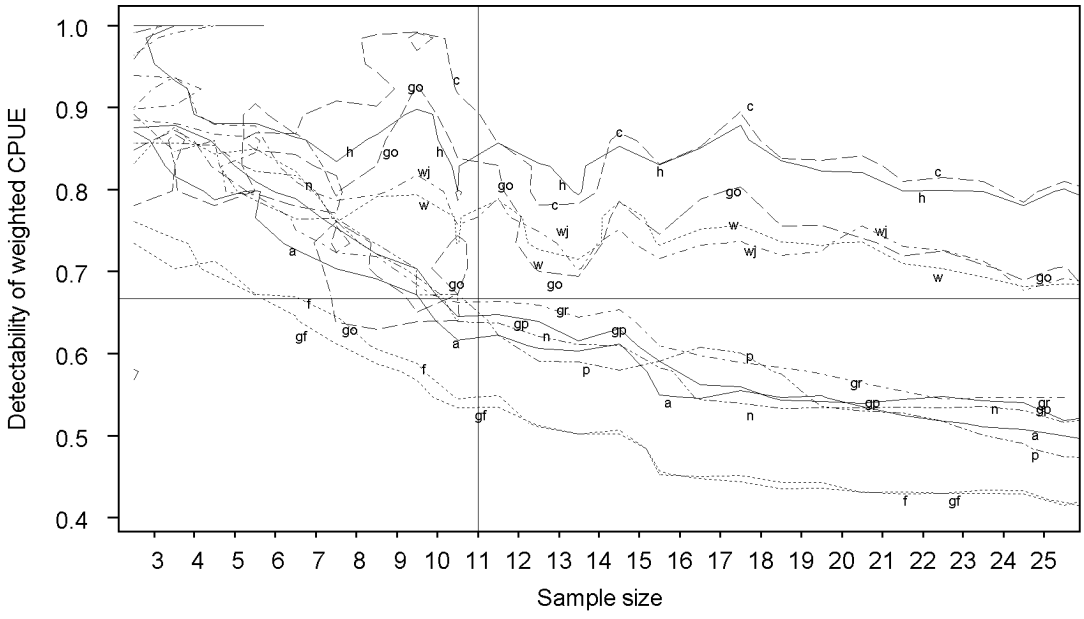


Figure 50

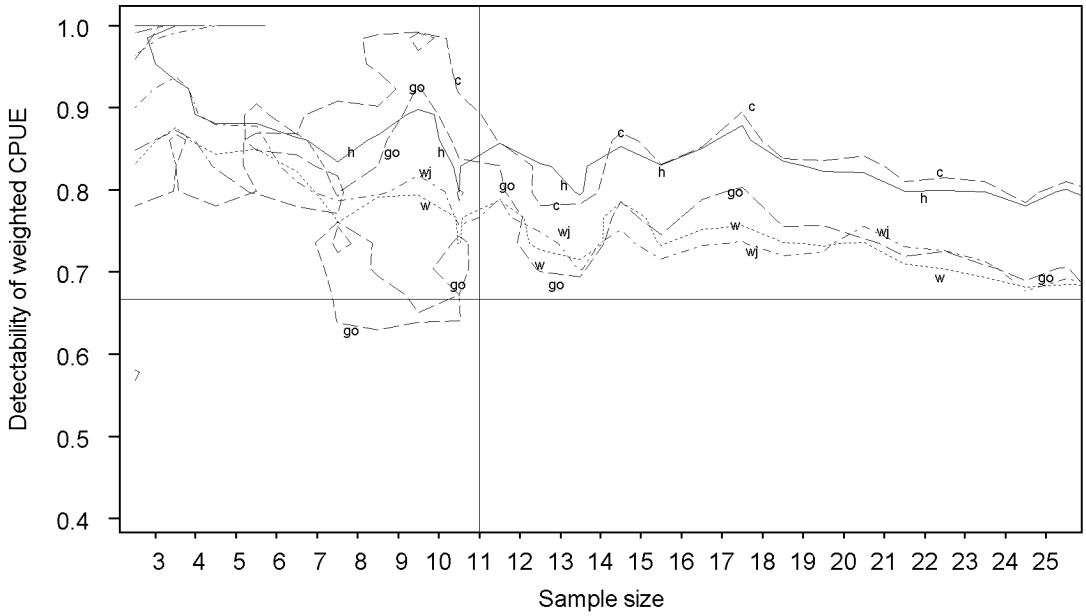
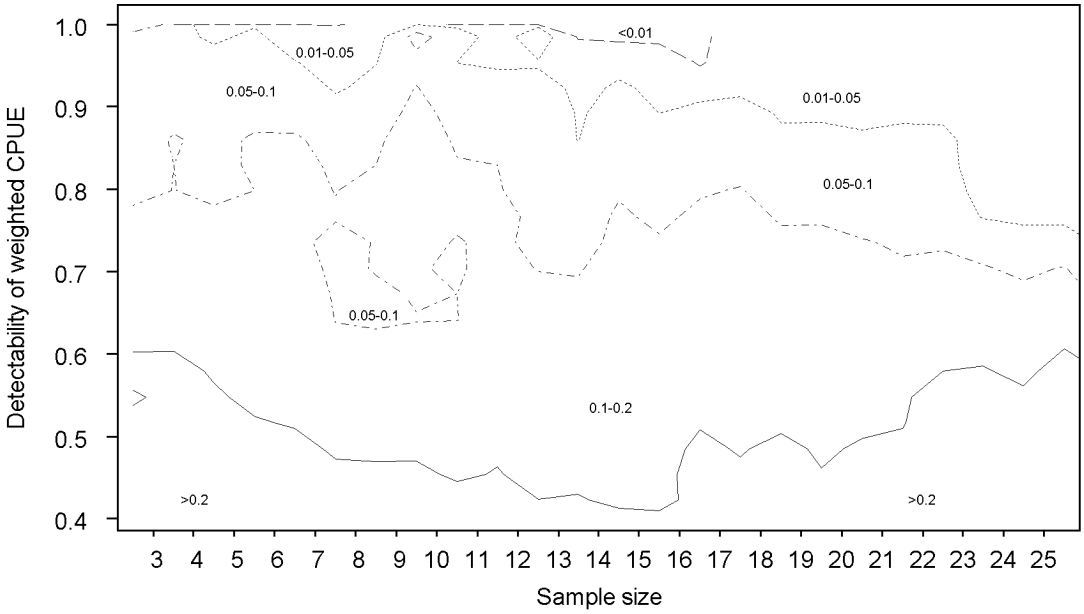


Figure 51



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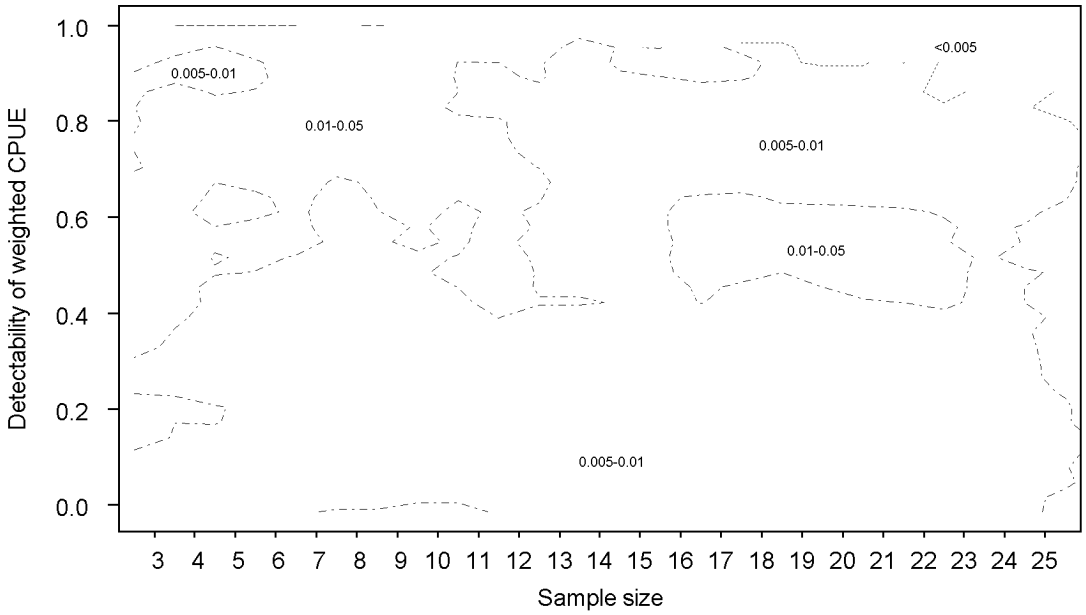

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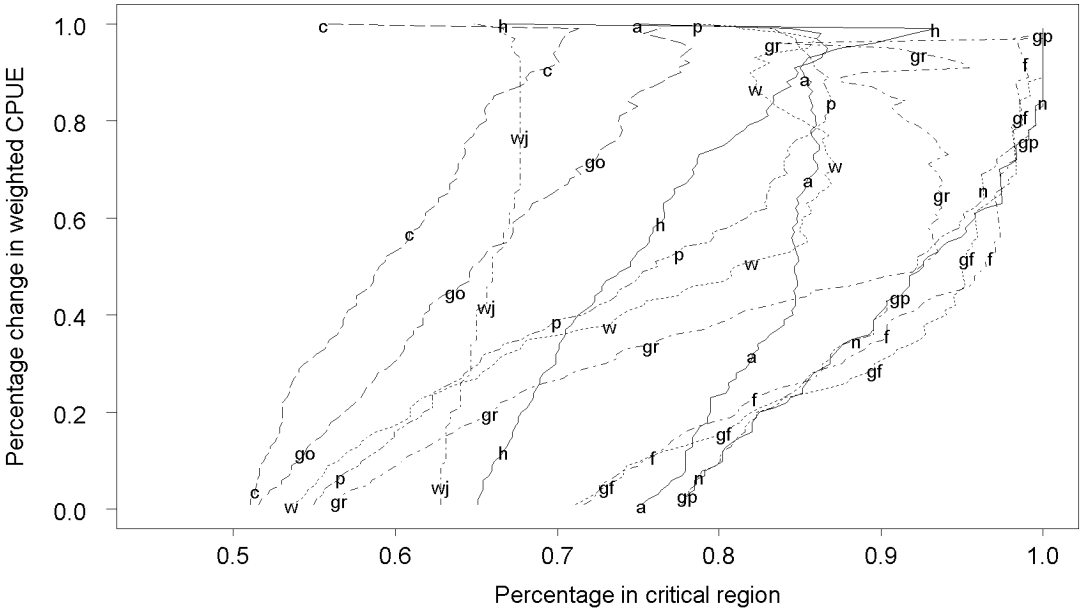


Figure 54

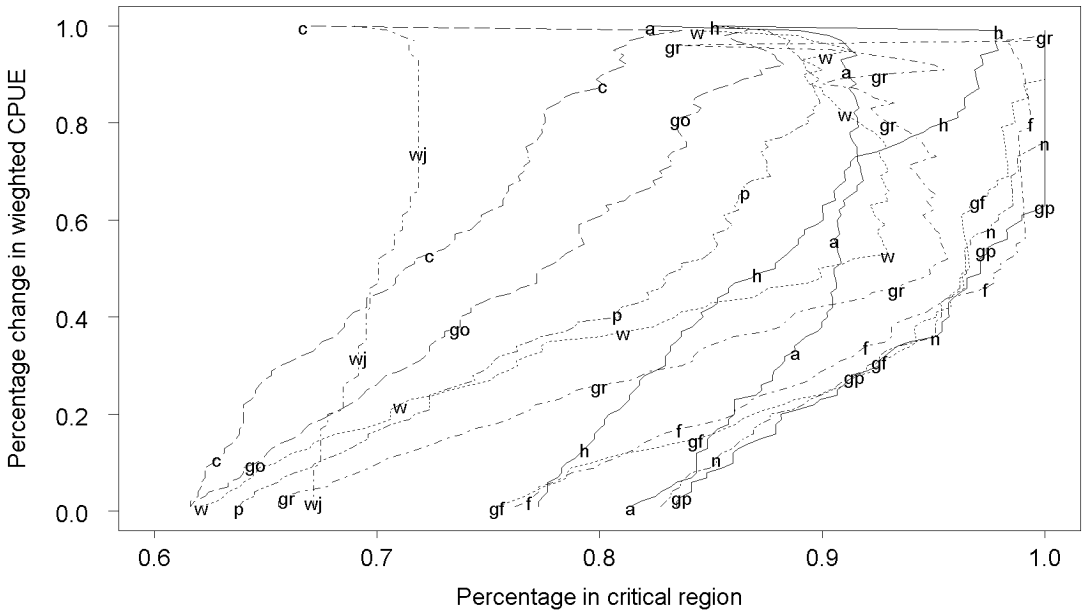
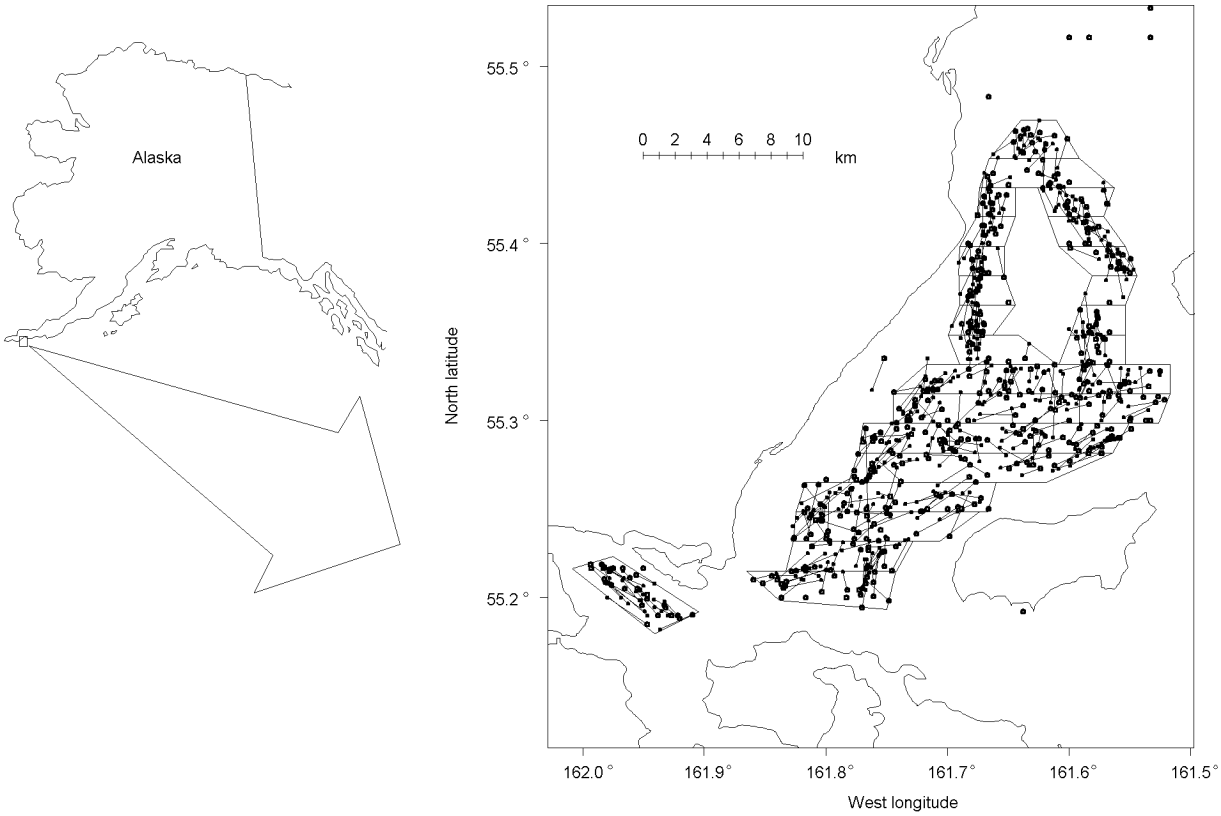


Figure 55



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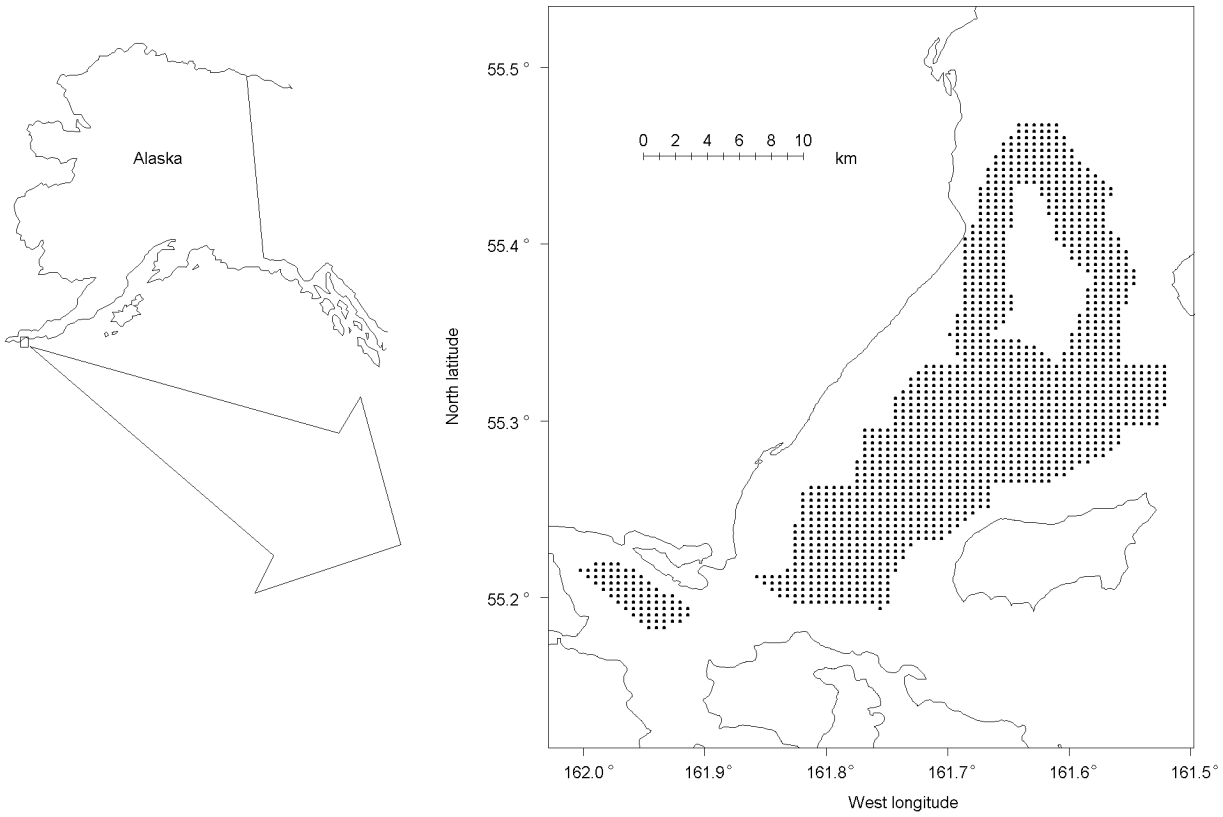

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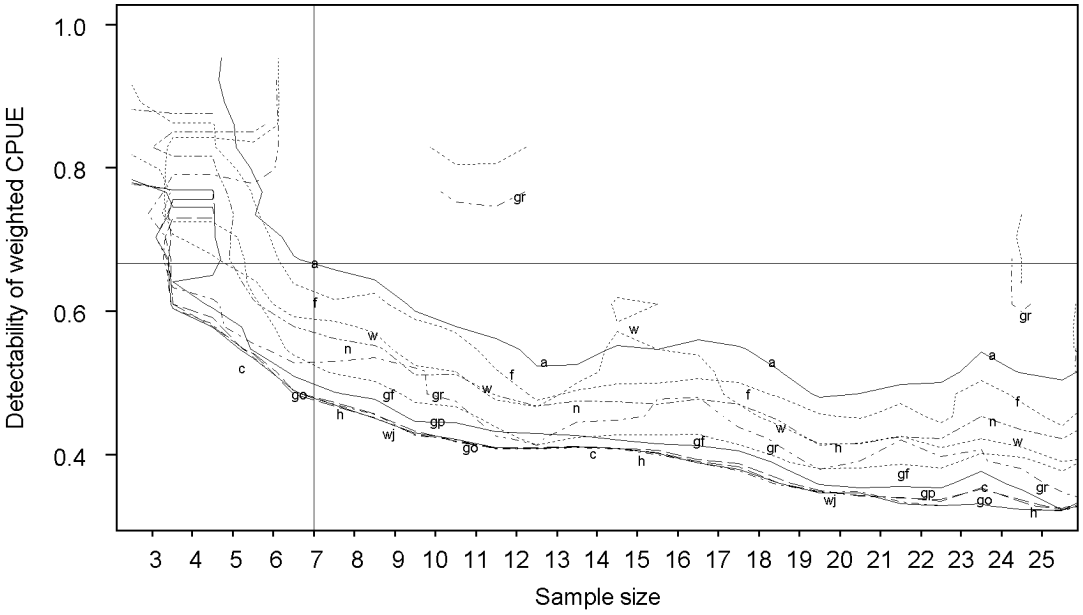

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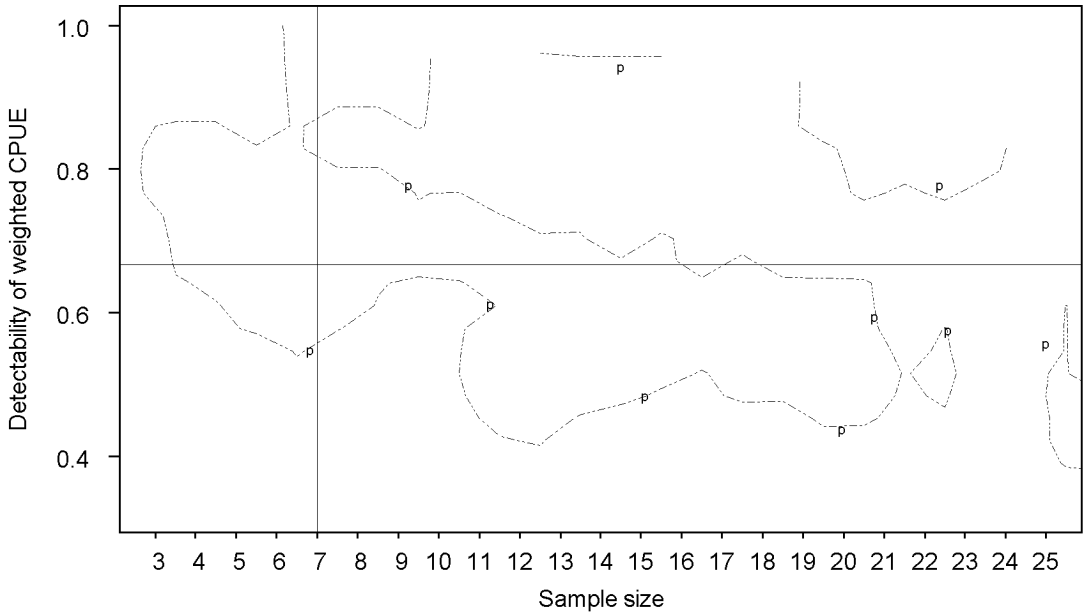

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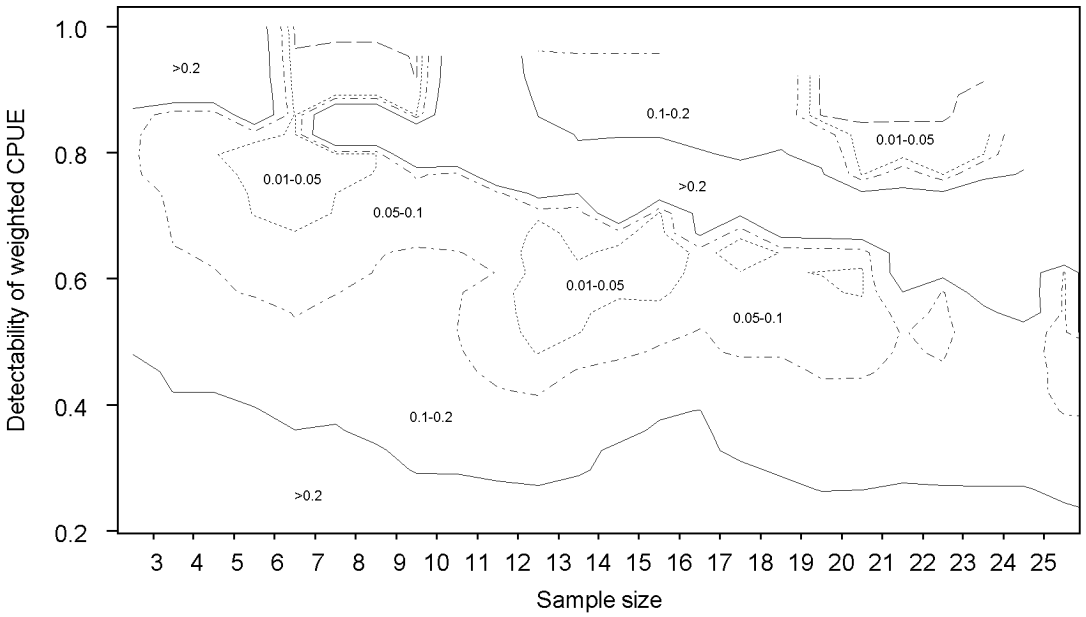

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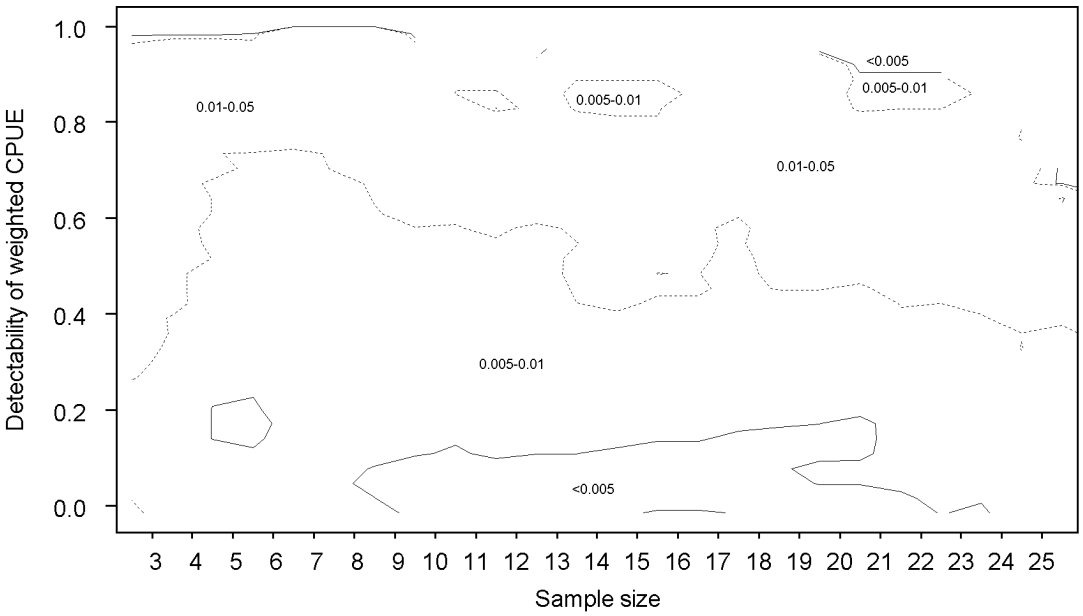
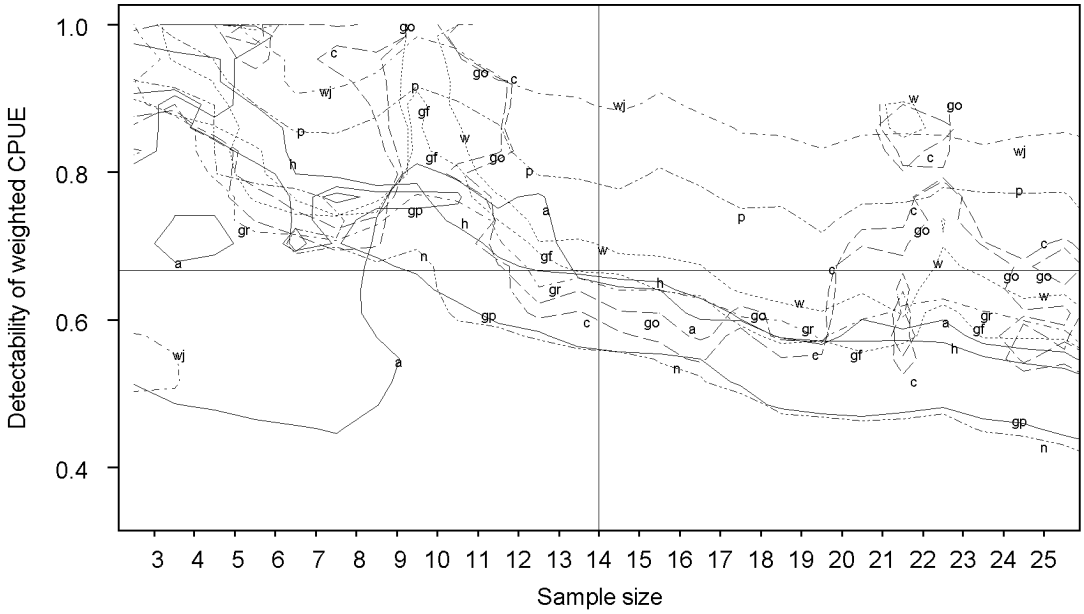


Figure 61



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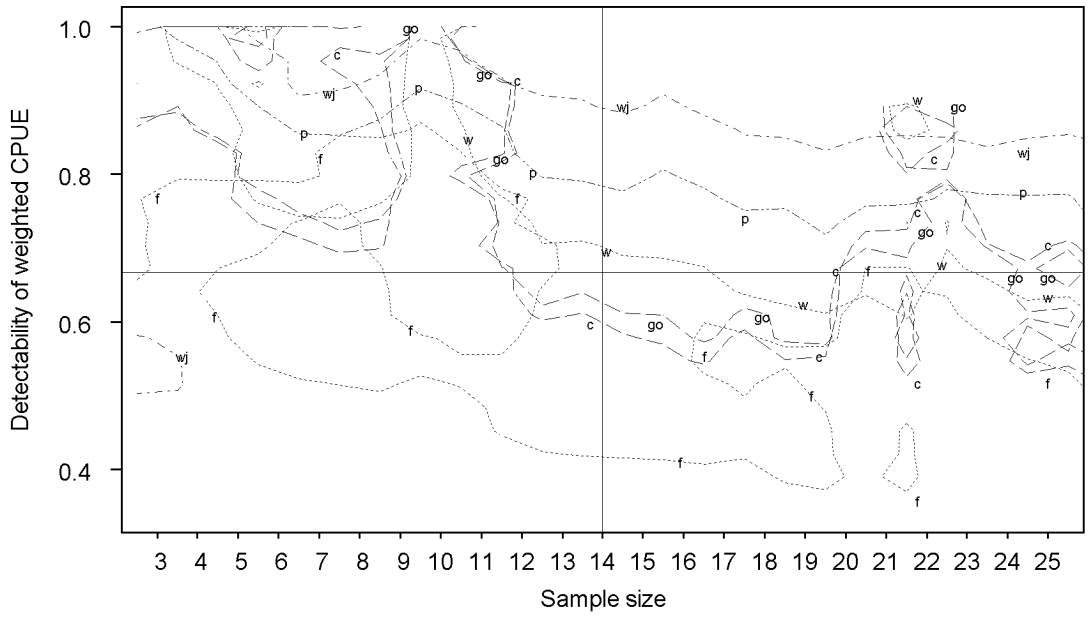
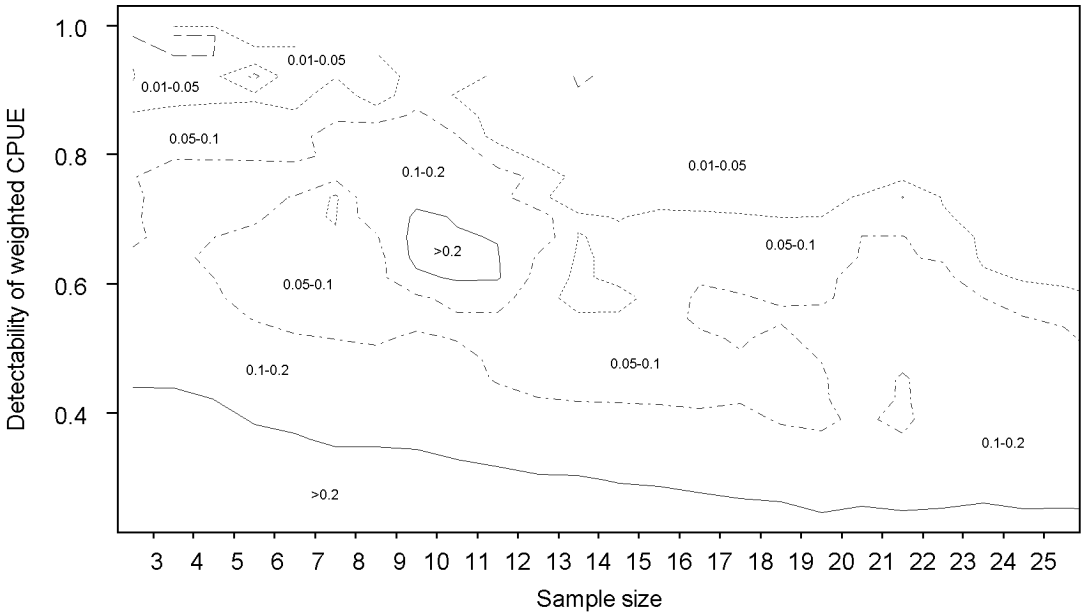


Figure 63



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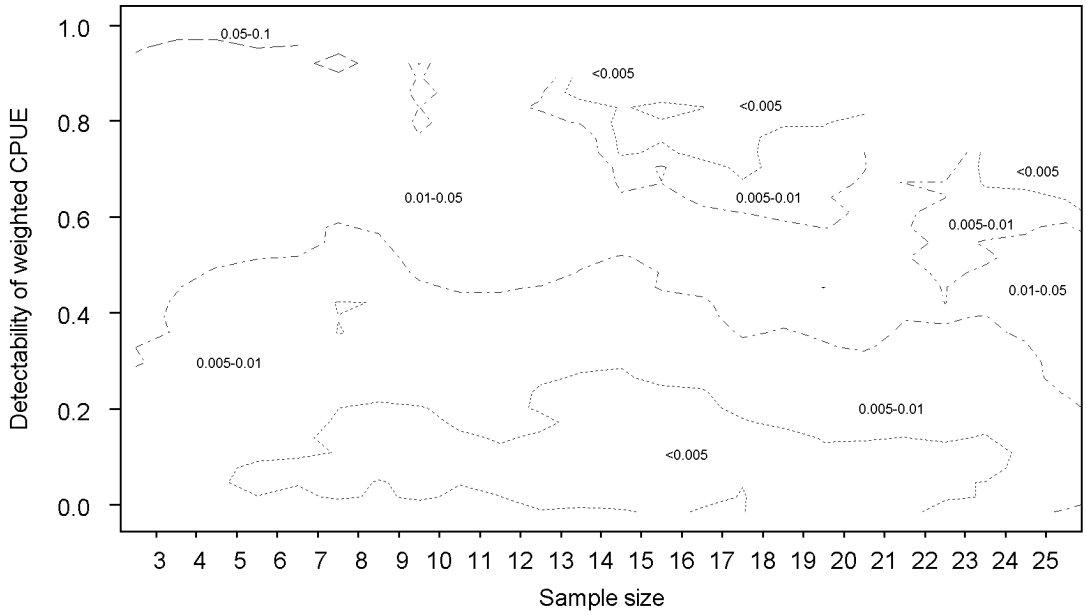

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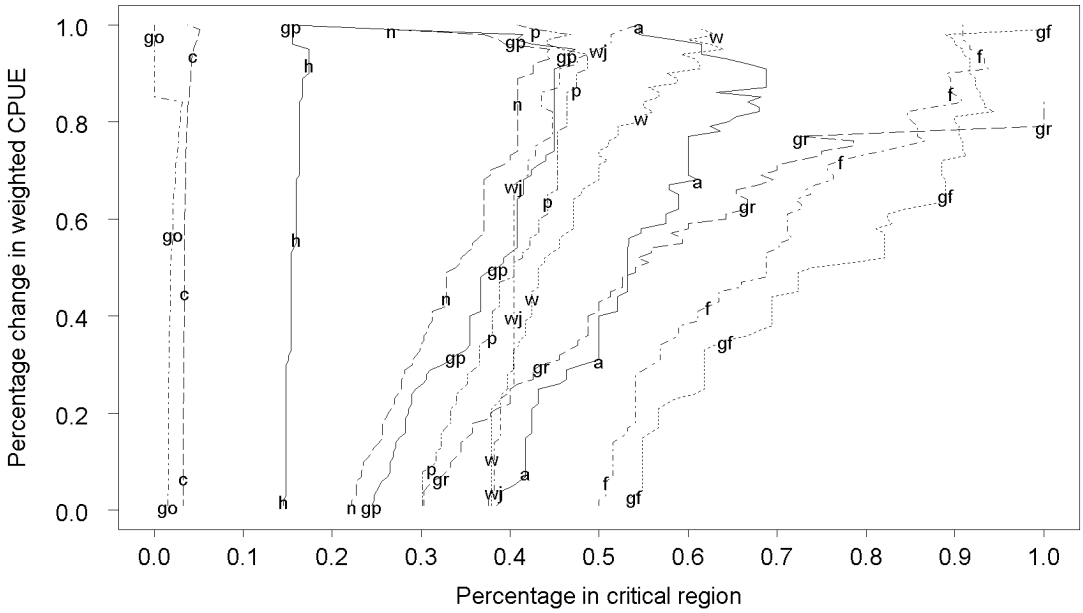

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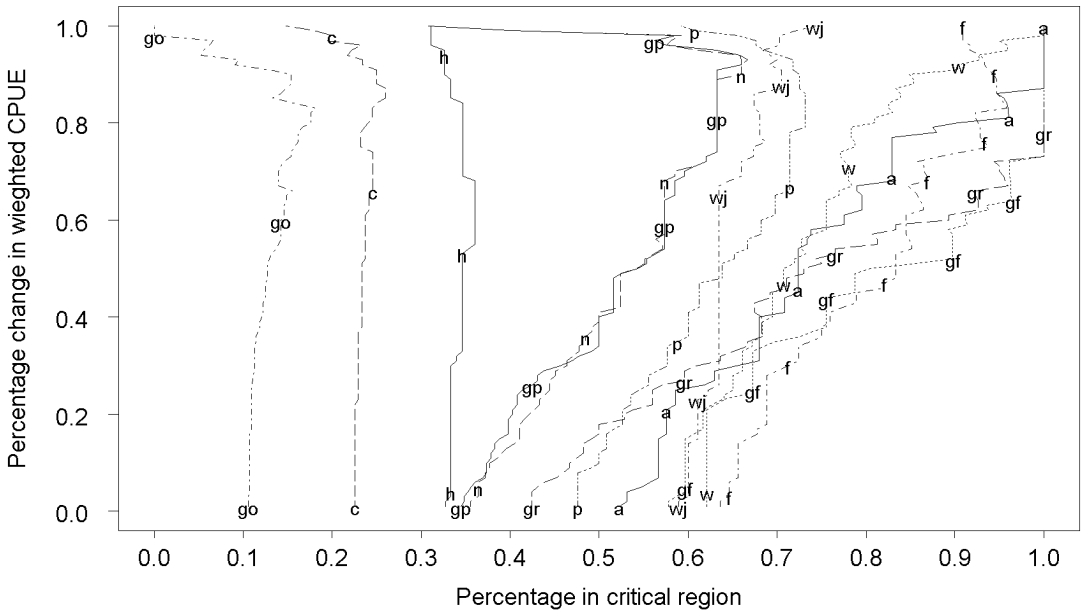


Figure 67

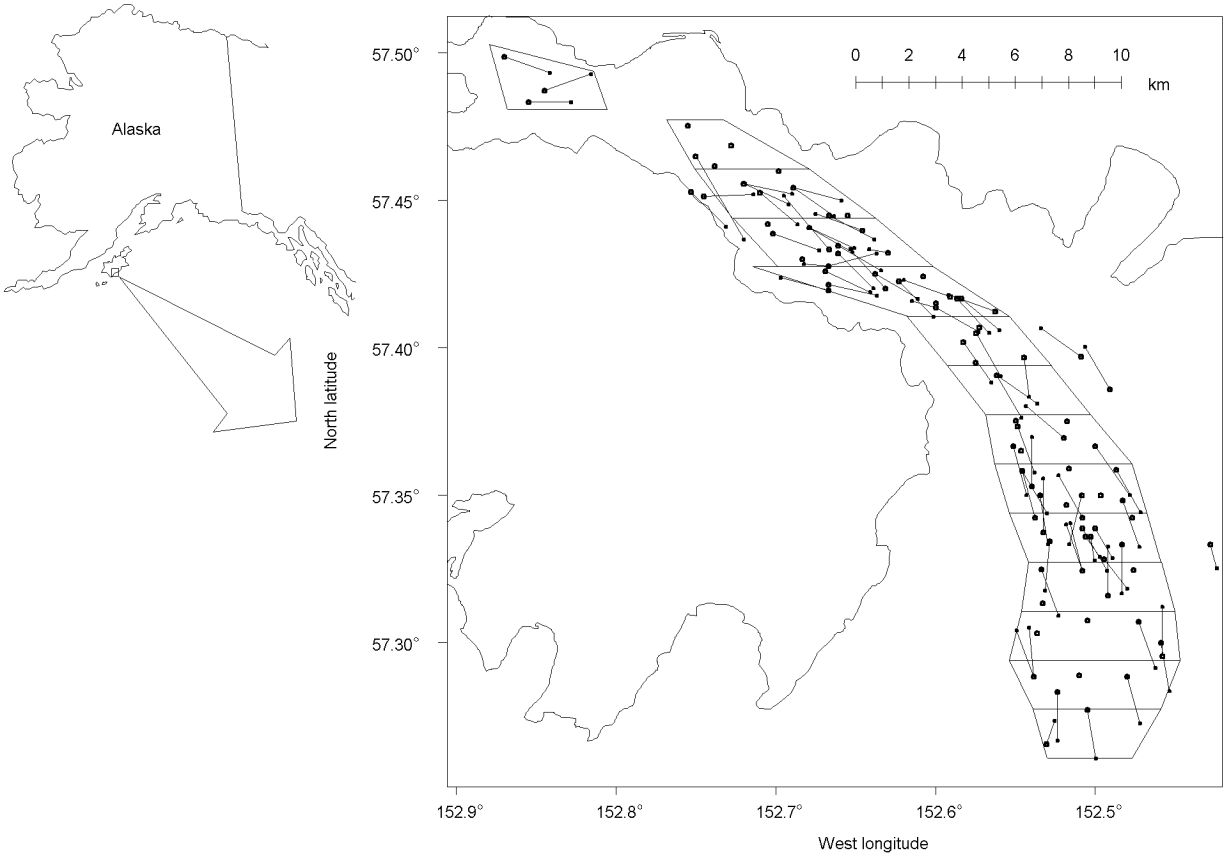
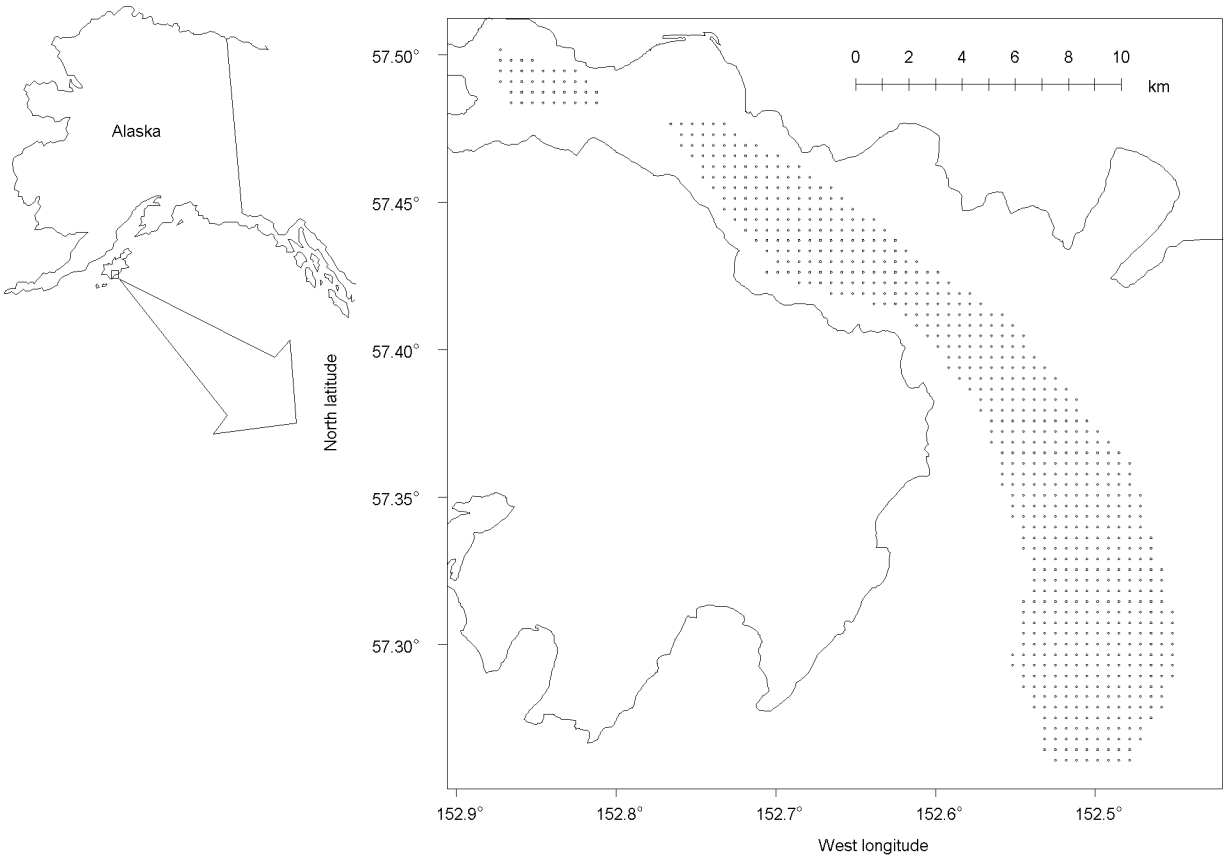


Figure 68



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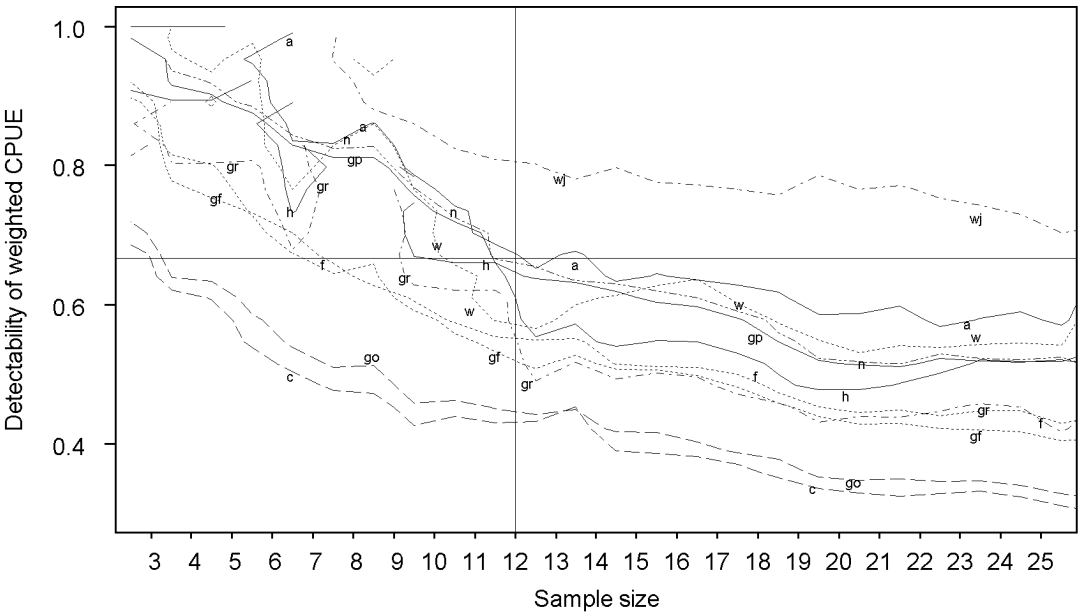
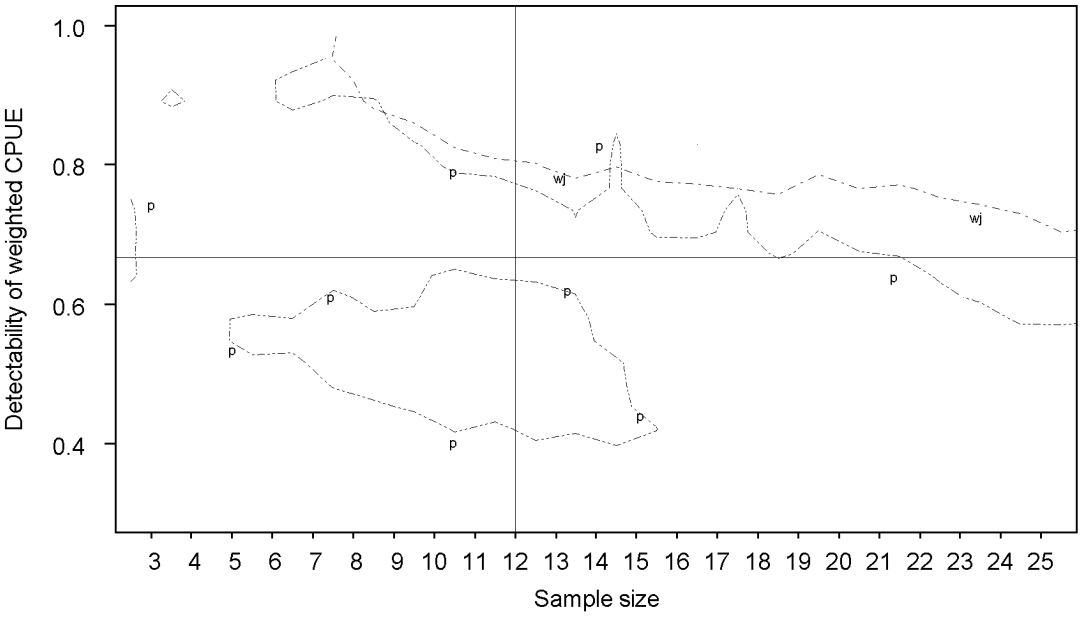


Figure 70



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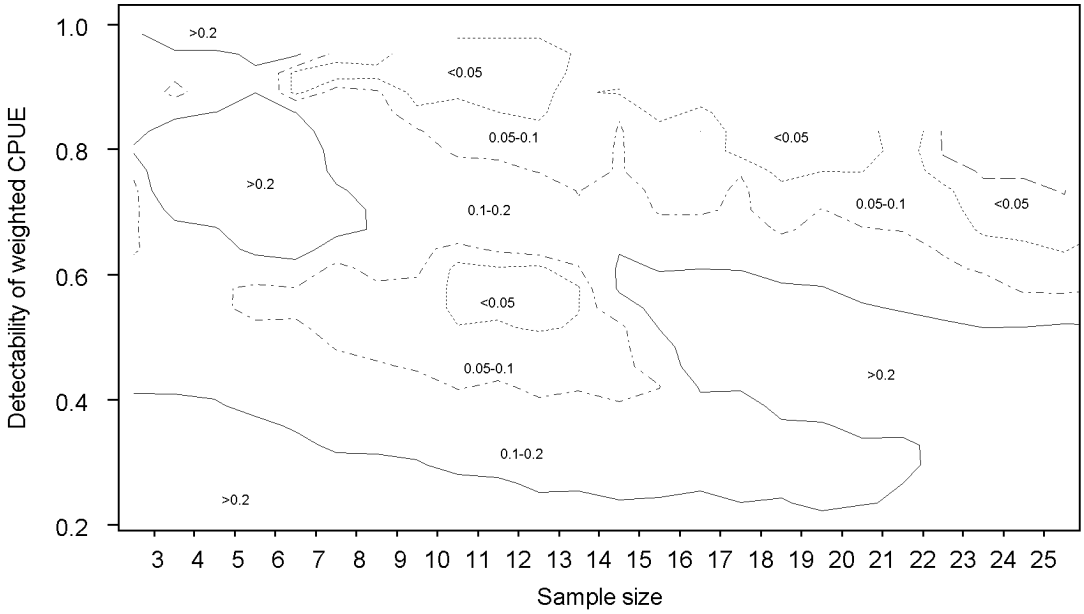
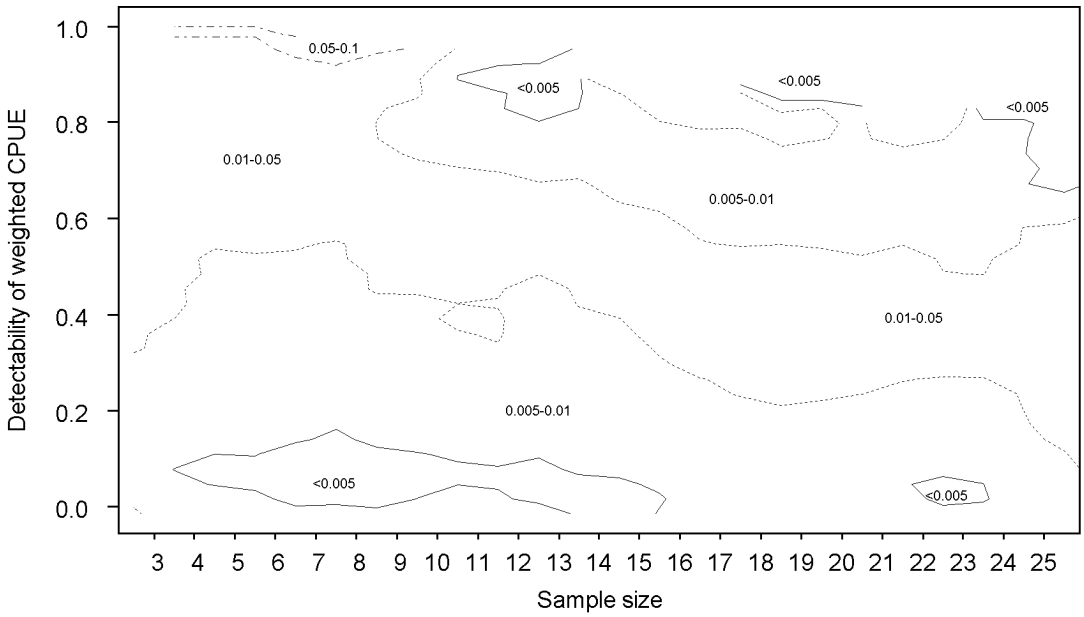


Figure 72



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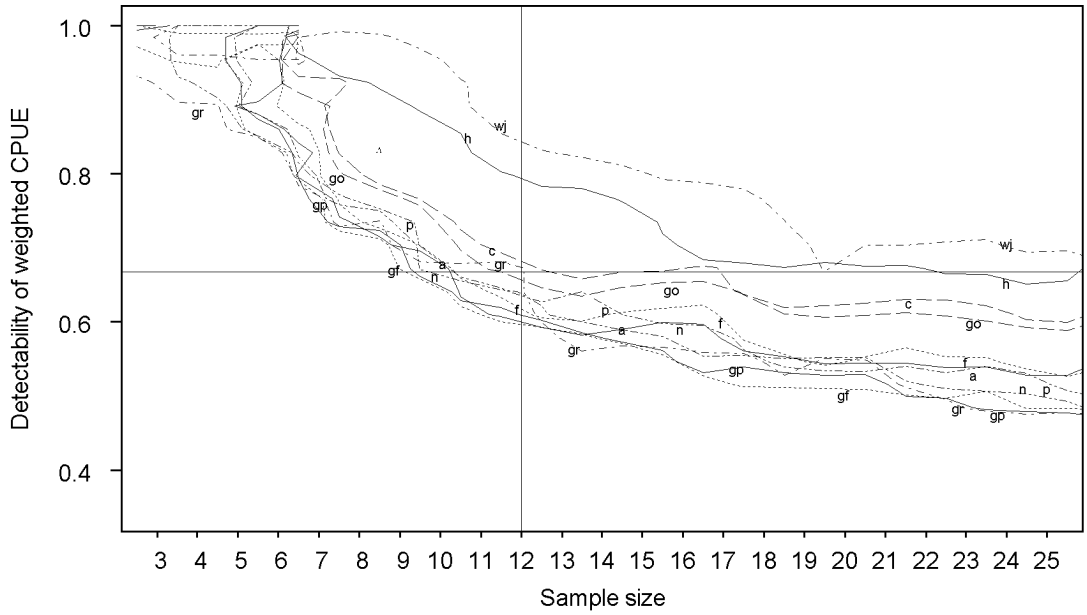


Figure 74

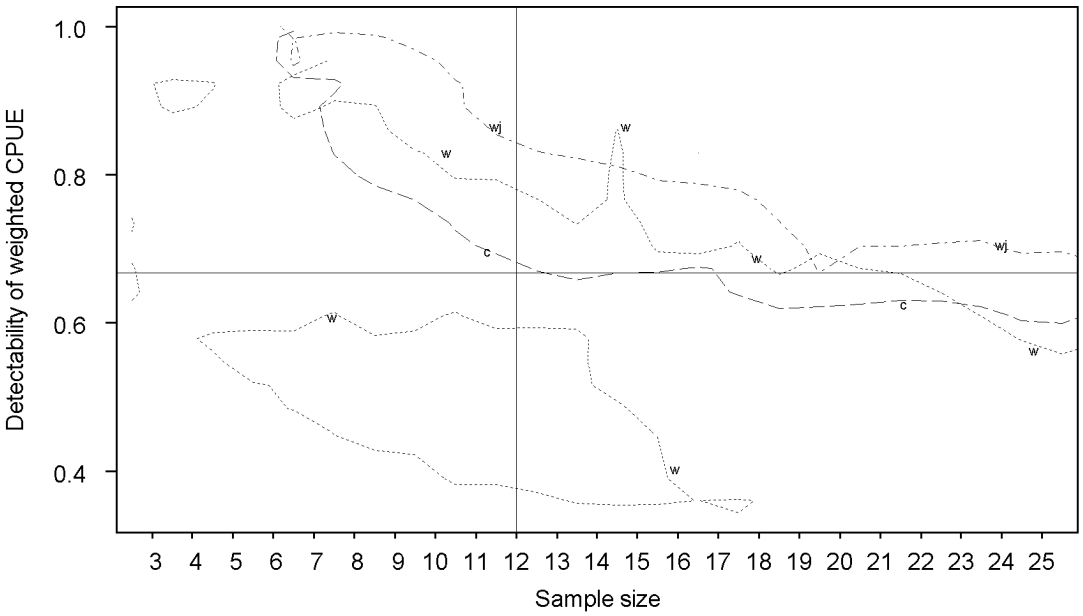
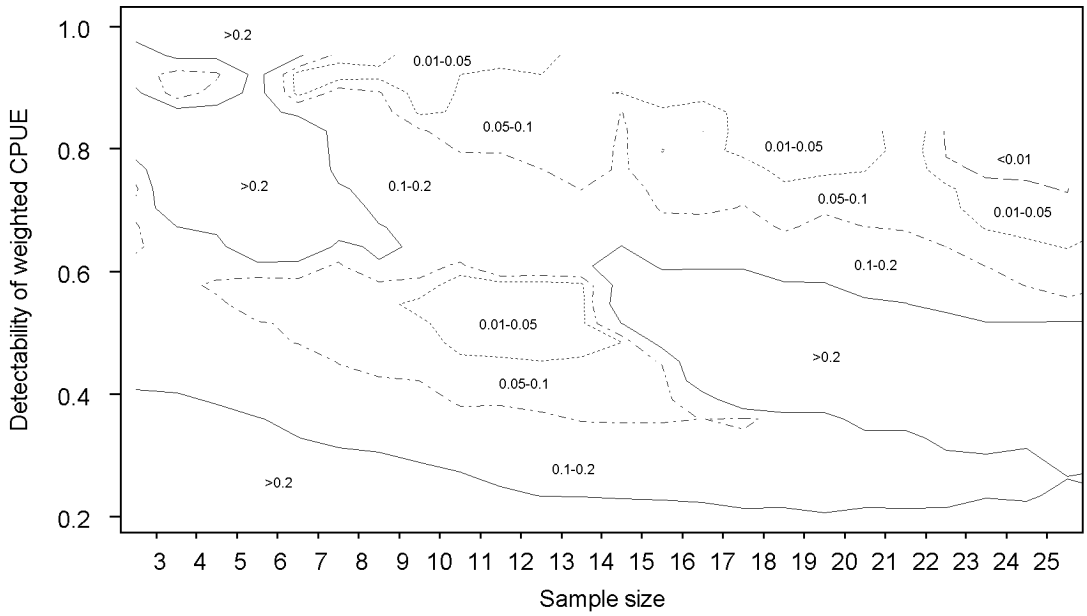


Figure 75



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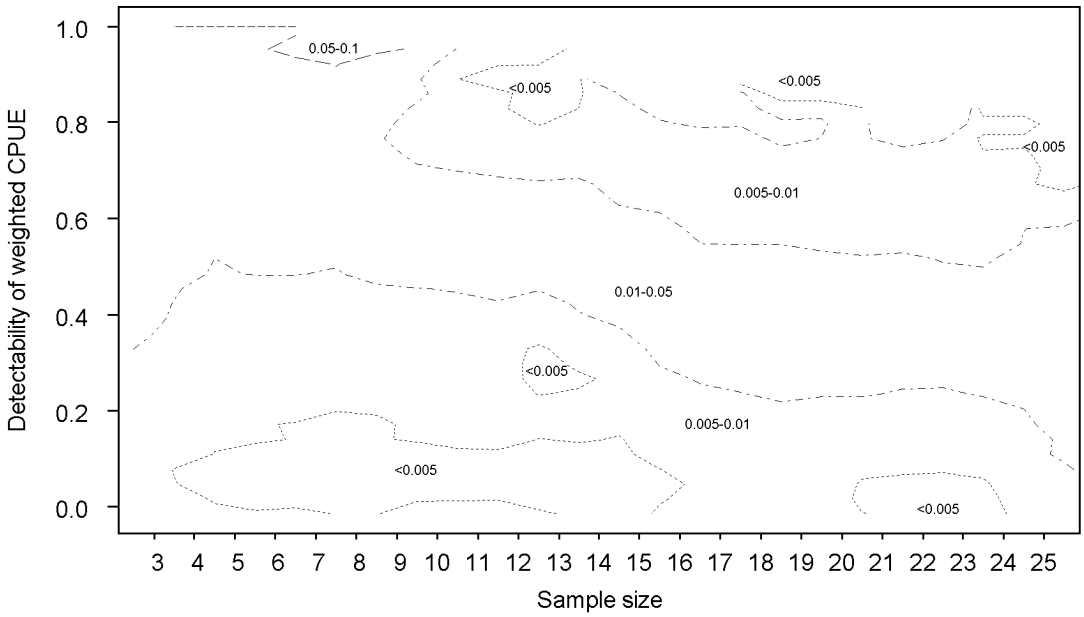


Figure 77

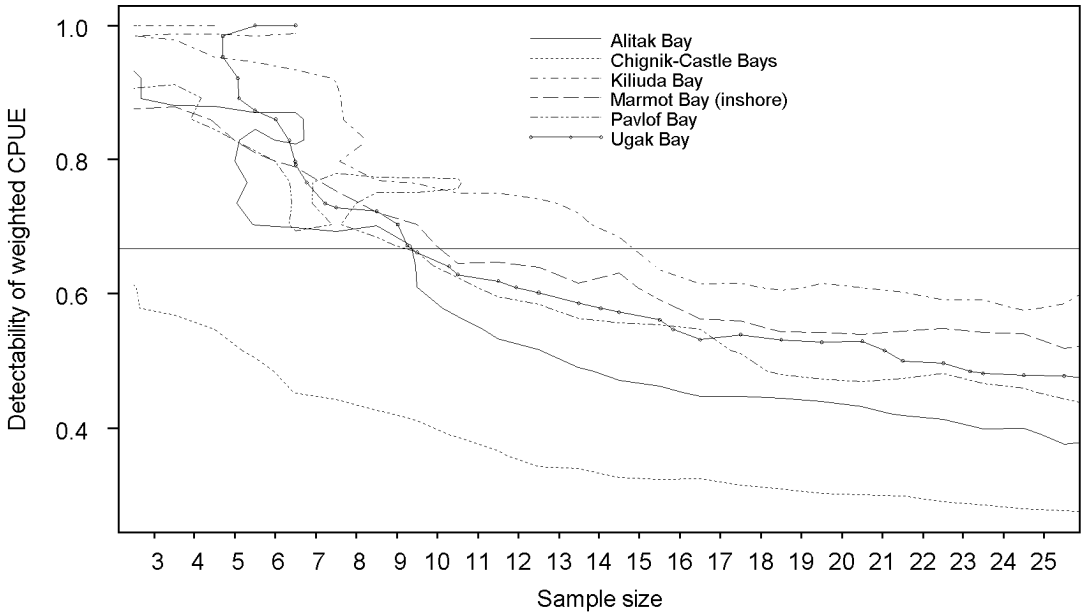


Figure 78

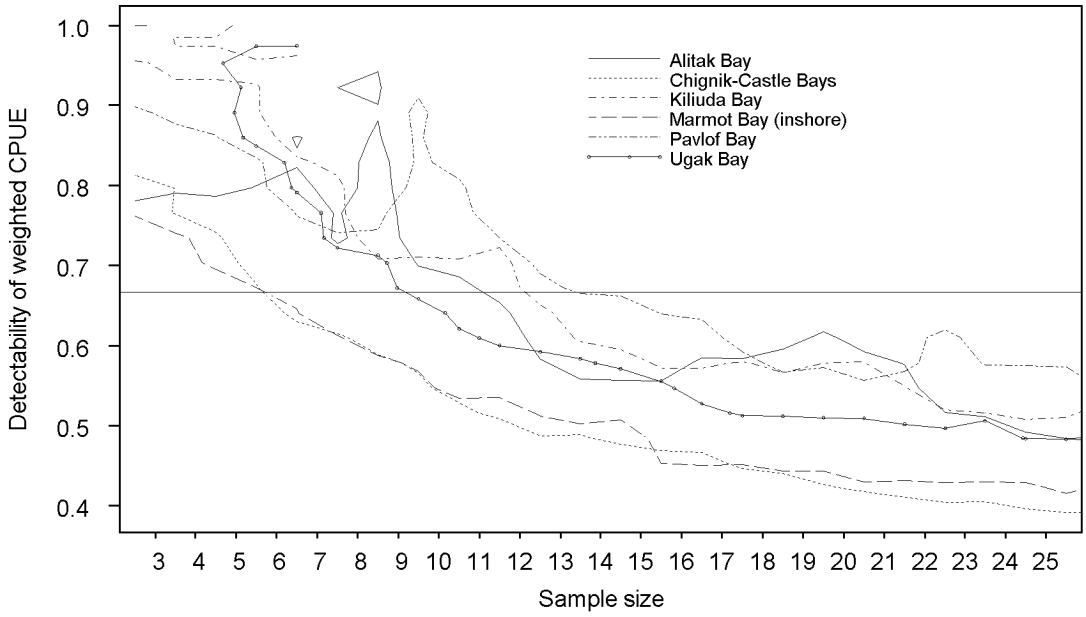


Figure 79

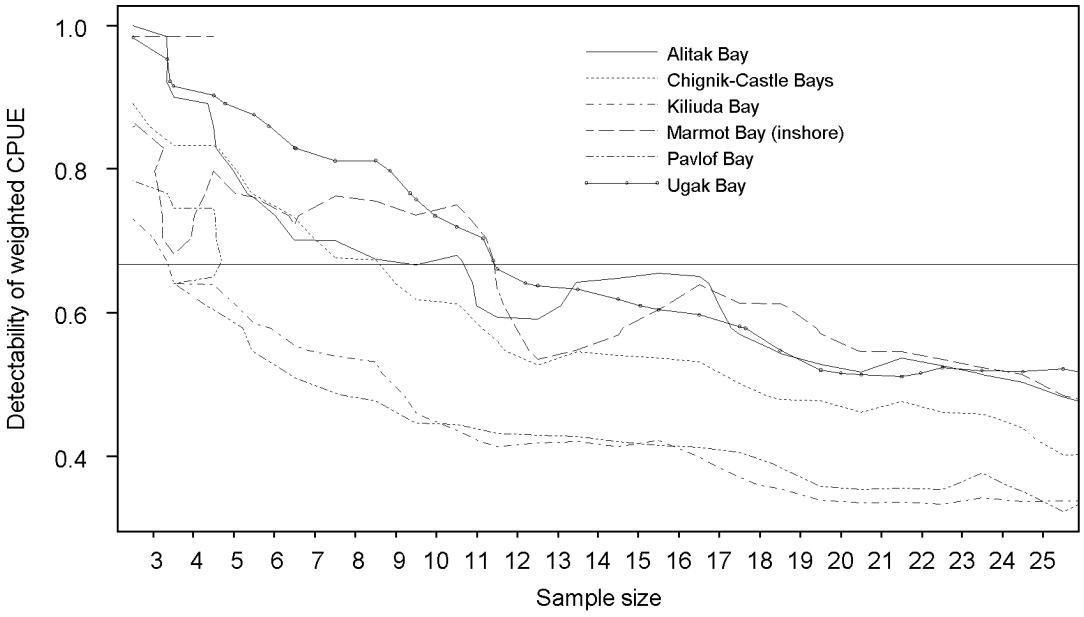


Figure 80

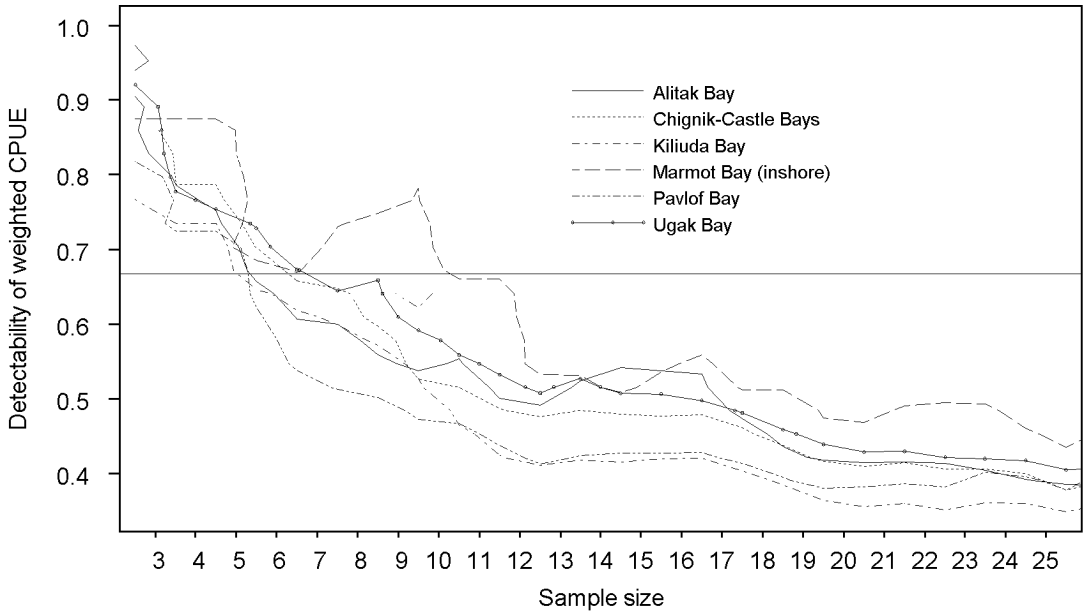


Figure 81

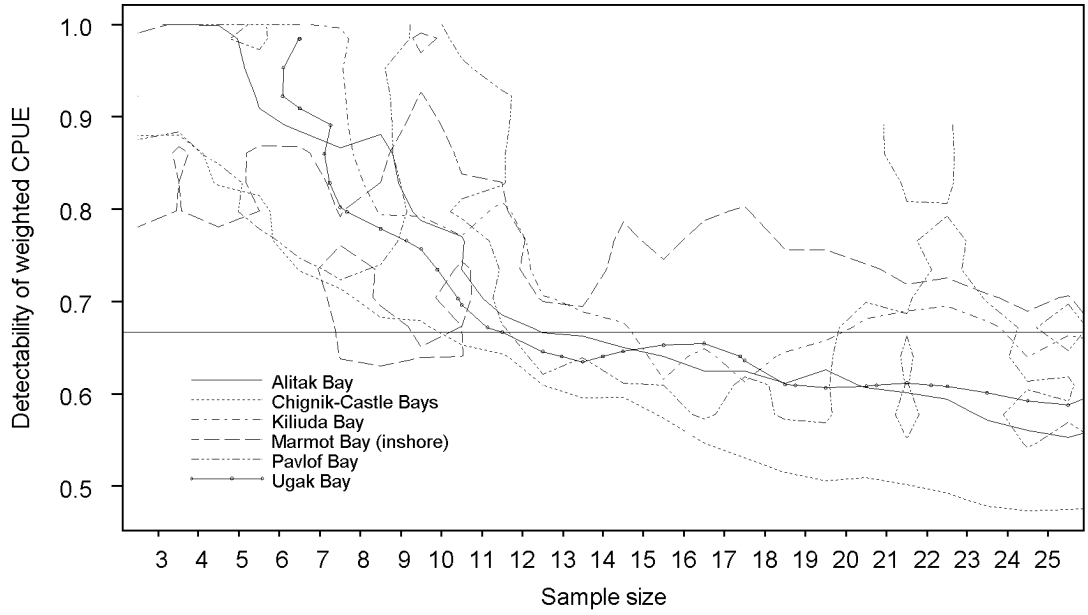
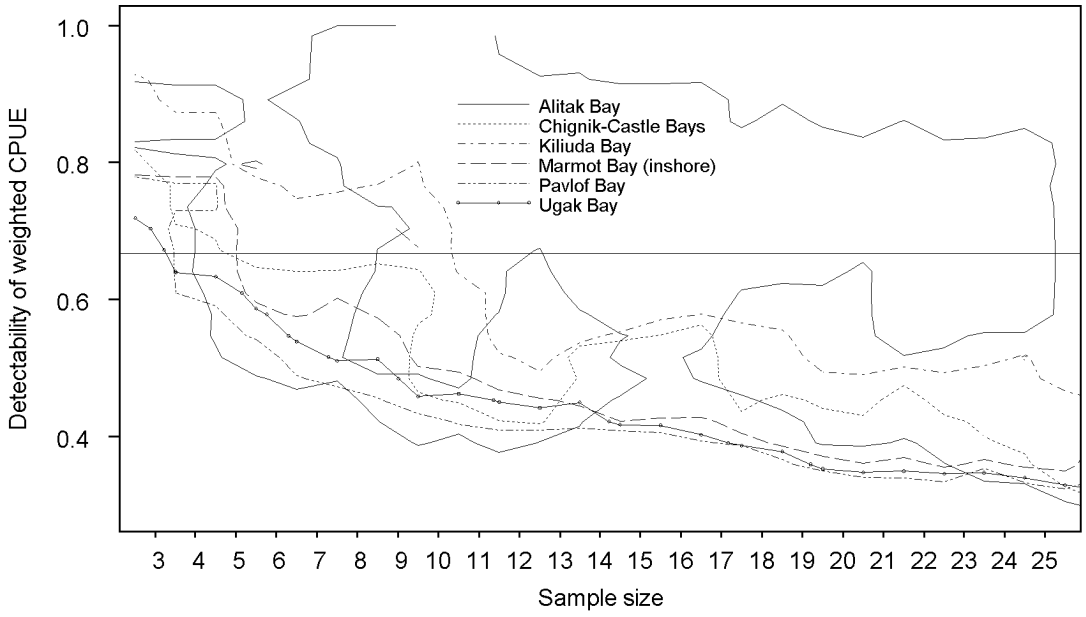


Figure 82


Detectability of weighted CPUE
1.0
0.8
0.6
0.4
Alitak Bay
Chignik-Castle Bays
Kiliuda Bay
Marmot Bay (inshore)
Pavlof Bay
Ugak Bay
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Sample size

Appendix I. Dirichlet tile areas; n_1 is the number of actual tows, and n_2 is the number of tows used to estimate the tiles. Source: Johnson (2000e, 2000f, 2000g, 2000h, 2001i and 2001j).

Year	n_1	n_2	km^2	Year	n_1	n_2	km^2
Alitak Bay							
1975	20	20	294.93	1986	25	25	660.45
1977	10	10	331.03	1987	13	13	414.98
1978	10	10	294.59	1988	3	3	115.43
1979	12	12	305.45	1989	9	9	289.51
1980	18	18	549.99	1990	2	2	616.44
1981	57	57	643.07	1992	7	7	286.37
1983	9	9	274.77	1995	9	9	265.74
1984	12	12	313.70	1998	11	11	359.08
1985	36	36	643.11				
Chignik-Castle Bays							
1973	3	3	237.29	1983	11	11	340.73
1974	8	8	345.73	1984	7	7	270.41
1975	11	11	343.64	1985	12	12	333.08
1976	12	12	334.92	1986	2	2	62.72
1977	12	11	325.16	1987	14	14	339.87
1978	23	21	342.53	1988	1	1	0.00
1979	12	12	329.72	1989	11	11	343.50
1980	13	13	338.60	1990	2	2	325.22
1981	12	12	335.97	1992	11	11	327.19
1982	9	9	341.95	1995	9	9	324.40
Kiliuda Bay							
1972	10	10	240.30	1981	19	19	308.33
1973	17	17	269.46	1984	10	10	311.58
1974	18	14	273.35	1985	12	12	297.96
1975	27	23	262.40	1986	13	13	307.11
1976	31	24	281.49	1987	1	1	0.00
1977	10	10	166.66	1989	9	9	268.91
1978	36	26	310.67	1992	10	10	310.97
1979	27	27	309.26	1995	6	6	176.79
1980	10	10	306.15	1998	6	6	237.85
Inshore Marmot Bay							
1976	15	15	403.49	1986	7	7	563.70
1977	22	22	614.11	1987	22	22	498.76
1978	18	18	577.12	1988	3	3	201.44
1979	12	12	352.85	1989	15	15	438.19
1980	11	11	380.56	1990	1	1	0.00
1981	33	33	610.09	1992	14	14	403.17
1984	15	15	421.71	1995	16	16	446.20

Appendix I (cont.). Dirichlet tile areas; n_1 is the number of actual tows, and n_2 is the number of tows used to estimate the tiles.

Year	n_1	n_2	km^2	Year	n_1	n_2	km^2
1985	25	25	502.26	1998	14	14	458.07
Pavlof Bay							
1972	10	10	415.49	1986	12	12	425.69
1973	2	2	274.37	1987	17	17	421.84
1974	12	12	416.06	1988	25	25	424.94
1975	12	12	420.72	1989	28	28	418.16
1976	12	12	420.77	1990	24	24	423.01
1977	11	10	420.09	1991	22	22	423.34
1978	12	11	381.83	1992	22	22	425.11
1979	22	22	419.35	1993	22	22	419.25
1980	24	24	417.28	1994	22	22	422.62
1981	12	12	420.73	1995	23	23	424.54
1982	13	13	418.08	1996	22	22	416.02
1983	12	12	423.13	1997	22	22	420.50
1984	12	12	404.23	1998	22	22	422.86
1985	12	12	421.22	1999	22	22	417.34
Ugak Bay							
1972	10	10	189.08	1980	11	11	191.39
1974	16	16	205.09	1981	23	23	205.24
1975	18	17	189.23	1982	2	2	149.18
1976	19	17	189.88	1984	5	5	190.61
1977	7	7	191.81	1985	7	7	190.64
1978	7	7	188.48	1986	13	13	209.82
1979	14	14	189.18	1989	9	9	189.99

Appendix II.

Tables 1-6 are tables consolidated from Johnson (2000a, 2000b, 2000c, 2000d, 2000g and 2001h) testing differences in weighted CPUE for historical survey data.

Table	
1	Alitak Bay
2	Chignik-Castle Bays
3	Kiliuda Bay
4	Inshore Marmot Bay
5	Pavlof Bay
6	Ugak Bay

Appendix II - Table 1. Tests for significant differences in weighted CPUE between adjacent survey years in Alitak Bay group on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
Pandalid shrimp species group											
75-77	384.3(20)	208.8(10)	175.5	0.962	0.991	84-85	106.0(12)	8.4(36)	97.6	<0.001*	0.002*
77-78	208.8(10)	351.8(10)	143.0	0.123	0.493	85-86	8.4(36)	3.3(25)	5.0	0.264	0.605
78-79	351.8(10)	206.6(12)	145.3	0.114	0.359	86-87	3.3(25)	4.0(13)	0.6	0.394	0.094
79-80	206.6(12)	169.9(18)	36.7	0.423	0.279	87-88	4.0(13)	0.0(3)	4.0	0.286	0.221
80-81	169.9(18)	133.9(57)	36.0	0.302	0.129	90-92	0.0(2)	3.7(7)	3.7	0.217	0.277
81-83	133.9(57)	93.6(9)	40.3	0.768	0.070	92-95	3.7(7)	0.8(9)	3.0	0.101	0.198
83-84	93.6(9)	106.0(12)	12.4	0.651	0.226	95-98	0.8(9)	6.8(11)	6.0	0.139	0.419
Flatfish species group											
75-77	1.0(20)	10.3(10)	9.4	0.002*	<0.001*	84-85	39.9(12)	6.6(30)	33.3	<0.001*	<0.001*
77-78	10.3(10)	27.4(10)	17.1	0.060	0.006*	85-86	6.6(30)	7.2(24)	0.6	0.615	0.086
78-79	27.4(10)	12.4(12)	15.0	0.078	0.009*	86-87	7.2(24)	25.5(12)	18.3	0.110	0.305
79-80	12.4(12)	84.2(18)	71.8	<0.001*	<0.001*	87-89	25.5(12)	75.7(9)	50.3	0.061	0.010*
80-81	84.2(18)	31.6(57)	52.6	0.002*	<0.001*	89-92	75.7(9)	65.1(7)	10.6	0.727	0.530
81-83	31.6(57)	4.6(9)	27.0	<0.001*	<0.001*	92-95	65.1(7)	22.1(9)	43.0	0.034*	0.018*
83-84	4.6(9)	39.9(12)	35.3	<0.001*	<0.001*	95-98	22.1(9)	14.3(11)	7.7	0.284	0.124
Roundfish species group											
75-77	23.6(20)	21.2(10)	2.5	0.657	0.328	85-86	29.4(36)	53.6(25)	24.2	0.191	0.006*
77-78	21.2(10)	58.4(10)	37.2	0.022*	0.015*	86-87	53.6(25)	55.2(13)	1.6	0.543	0.564
78-79	58.4(10)	38.4(12)	20.0	0.086	0.073	87-88	55.2(13)	71.0(3)	15.8	0.342	0.812
79-80	38.4(12)	140.4(18)	102.0	0.021*	<0.001*	88-89	71.0(3)	88.4(9)	17.3	0.706	0.068
80-81	140.4(18)	119.5(57)	21.0	0.232	0.052	89-90	88.4(9)	5.1(2)	83.3	0.065	0.001*

Appendix II - Table 1 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Alitak Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
81-83	119.5(57)	97.1(9)	22.3	0.706	0.345	90-92	5.1(2)	105.9(7)	100.8	0.105	0.012*
83-84	97.1(9)	84.5(12)	12.6	0.478	0.047*	92-95	105.9(7)	169.0(9)	63.0	0.303	0.069
84-85	84.5(12)	29.4(36)	55.1	0.105	0.011*	95-98	169.0(9)	44.9(11)	124.0	0.017*	0.219
Osmerid species group											
75-77	13.8(20)	1.0(10)	12.8	0.104	0.249	85-86	0.1(36)	0.7(25)	0.6	<0.001*	0.016*
77-78	1.0(10)	1.2(10)	0.2	0.449	0.177	86-87	0.7(25)	0.1(13)	0.6	0.003*	0.002*
78-79	1.2(10)	8.8(12)	7.6	0.011*	0.090	87-88	0.1(13)	0.0(3)	0.1	0.100	0.293
79-80	8.8(12)	13.1(18)	4.3	0.831	0.091	88-89	0.0(3)	0.0(9)	0.0	0.338	0.453
80-81	13.1(18)	15.9(57)	2.8	0.367	<0.001*	89-90	0.0(9)	0.0(2)	0.0	0.207	0.056
81-83	15.9(57)	0.6(9)	15.3	0.017*	0.073	90-92	0.0(2)	0.3(7)	0.2	0.213	0.055
83-84	0.6(9)	0.8(12)	0.2	0.572	0.436	92-95	0.3(7)	0.3(9)	0.0	0.478	0.049*
84-85	0.8(12)	0.1(36)	0.7	<0.001*	0.066	95-98	0.3(9)	0.0(11)	0.3	0.150	0.037*
Northern shrimp											
75-77	384.3(20)	96.7(10)	287.7	<0.001*	<0.001*	84-85	97.8(12)	8.4(36)	89.4	0.002*	0.003*
77-78	96.7(10)	147.8(10)	51.2	0.148	0.224	85-86	8.4(36)	3.3(25)	5.0	0.269	0.579
78-79	147.8(10)	111.7(12)	36.1	0.202	0.324	86-87	3.3(25)	3.9(13)	0.5	0.408	0.038*
79-80	111.7(12)	55.0(18)	56.8	0.031*	0.226	87-88	3.9(13)	0.0(3)	3.9	0.311	0.287
80-81	55.0(18)	101.2(57)	46.2	0.981	0.581	90-92	0.0(2)	3.7(7)	3.7	0.219	0.283
81-83	101.2(57)	93.2(9)	8.0	0.534	0.016*	92-95	3.7(7)	0.7(9)	3.0	0.097	0.202
83-84	93.2(9)	97.8(12)	4.6	0.605	0.113	95-98	0.7(9)	6.8(11)	6.1	0.144	0.398
Humpy shrimp											
75-77	0.0(20)	75.3(10)	75.3	<0.001*	<0.001*	83-84	0.2(9)	8.1(12)	7.9	0.193	0.050*
77-78	75.3(10)	171.8(10)	96.5	0.167	0.309	84-85	8.1(12)	0.0(36)	8.1	0.074	<0.001*
78-79	171.8(10)	77.2(12)	94.7	0.162	0.375	85-86	0.0(36)	0.0(25)	0.0	0.441	0.486
79-80	77.2(12)	110.1(18)	33.0	0.594	0.358	86-87	0.0(25)	0.0(13)	0.0	0.424	0.650
80-81	110.1(18)	27.6(57)	82.5	0.100	<0.001*	92-95	0.0(7)	0.0(9)	0.0	0.253	0.570

Appendix II - Table 1 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Alitak Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
81-83	27.6(57)	0.2(9)	27.4	0.083	0.110	95-98	0.0(9)	0.0(11)	0.0	0.219	0.449
Walleye pollock											
75-77	0.0(20)	6.1(10)	6.1	0.033*	0.001*	85-86	9.1(36)	37.6(25)	28.5	0.040*	0.002*
77-78	6.1(10)	2.3(10)	3.8	0.215	0.057	86-87	37.6(25)	49.4(13)	11.8	0.379	0.237
78-79	2.3(10)	3.6(12)	1.3	0.289	0.026*	87-88	49.4(13)	70.5(3)	21.1	0.321	0.759
79-80	3.6(12)	22.6(18)	19.1	0.056	0.003*	88-89	70.5(3)	46.9(9)	23.7	0.295	0.746
80-81	22.6(18)	16.4(57)	6.2	0.259	0.010*	89-90	46.9(9)	4.9(2)	41.9	0.115	0.028*
81-83	16.4(57)	45.0(9)	28.5	0.043*	0.005*	90-92	4.9(2)	93.1(7)	88.2	0.148	0.006*
83-84	45.0(9)	20.1(12)	24.9	0.111	0.004*	92-95	93.1(7)	131.1(9)	38.0	0.458	0.069
84-85	20.1(12)	9.1(36)	11.0	0.180	0.508	95-98	131.1(9)	32.7(11)	98.4	0.019*	0.202
Juvenile walleye pollock											
77-78	0.0(10)	22.3(10)	22.3	0.020*	0.002*	85-86	10.6(36)	7.1(25)	3.6	0.292	0.095
78-79	22.3(10)	0.0(12)	22.3	0.015*	<0.001*	86-87	7.1(25)	0.0(13)	7.0	<0.001*	<0.001*
80-81	0.0(18)	7.5(57)	7.5	0.067	<0.001*	87-88	0.0(13)	0.0(3)	0.0	0.123	0.809
81-83	7.5(57)	13.6(9)	6.1	0.190	<0.001*	88-89	0.0(3)	15.8(9)	15.8	0.012*	0.004*
83-84	13.6(9)	41.7(12)	28.1	0.368	0.053	89-90	15.8(9)	0.0(2)	15.8	0.014*	0.018*
84-85	41.7(12)	10.6(36)	31.1	0.154	0.468	95-98	0.0(9)	3.9(11)	3.9	0.056	0.002*
Capelin											
75-77	13.8(20)	0.0(10)	13.8	0.087	0.178	85-86	0.1(36)	0.7(25)	0.6	<0.001*	0.006*
77-78	0.0(10)	0.9(10)	0.9	0.236	0.014*	86-87	0.7(25)	0.1(13)	0.6	0.006*	0.004*
78-79	0.9(10)	8.8(12)	7.9	0.010*	0.039*	87-88	0.1(13)	0.0(3)	0.1	0.080	0.205
79-80	8.8(12)	9.3(18)	0.5	0.613	0.213	88-89	0.0(3)	0.0(9)	0.0	0.083	0.253
80-81	9.3(18)	15.8(57)	6.4	0.415	0.004*	89-90	0.0(9)	0.0(2)	0.0	0.020*	0.019*
81-83	15.8(57)	0.0(9)	15.8	0.014*	<0.001*	90-92	0.0(2)	0.1(7)	0.0	0.250	0.085
83-84	0.0(9)	0.6(12)	0.6	<0.001*	0.007*	92-95	0.1(7)	0.1(9)	0.0	0.273	0.122
84-85	0.6(12)	0.1(36)	0.5	<0.001*	0.014*	95-98	0.1(9)	0.0(11)	0.1	0.260	0.114

Appendix II - Table 1 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Alitak Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
Pacific cod											
77-78	0.0(10)	0.6(10)	0.6	0.048*	0.511	86-87	5.7(25)	4.0(13)	1.7	0.599	0.537
78-79	0.6(10)	0.0(12)	0.6	0.045*	0.449	87-88	4.0(13)	0.0(3)	4.0	0.080	0.098
79-80	0.0(12)	1.3(18)	1.3	0.046*	0.107	88-89	0.0(3)	19.0(9)	19.0	0.064	0.005*
80-81	1.3(18)	25.3(57)	24.0	0.036*	<0.001*	89-90	19.0(9)	0.0(2)	19.0	0.067	0.020*
81-83	25.3(57)	31.9(9)	6.7	0.272	<0.001*	90-92	0.0(2)	10.9(7)	10.9	0.003*	0.092
83-84	31.9(9)	12.4(12)	19.6	0.067	0.013*	92-95	10.9(7)	34.1(9)	23.2	0.118	0.346
84-85	12.4(12)	6.4(36)	5.9	0.313	0.072	95-98	34.1(9)	2.9(11)	31.2	0.058	0.046*
85-86	6.4(36)	5.7(25)	0.8	0.566	0.128						
Arrowtooth flounder											
79-80	0.0(12)	2.8(18)	2.8	0.058	0.063	86-87	0.8(24)	11.0(12)	10.2	0.070	0.062
80-81	2.8(18)	0.1(57)	2.6	0.034*	0.018*	87-89	11.0(12)	0.9(9)	10.1	0.110	0.227
81-83	0.1(57)	0.0(9)	0.1	0.127	0.468	89-92	0.9(9)	4.4(7)	3.6	0.150	0.411
83-84	0.0(9)	3.3(12)	3.3	0.025*	<0.001*	92-95	4.4(7)	0.2(9)	4.2	0.127	0.306
84-85	3.3(12)	0.9(30)	2.3	0.161	<0.001*	95-98	0.2(9)	2.6(11)	2.3	0.137	0.034*
85-86	0.9(30)	0.8(24)	0.2	0.681	0.368						
Flathead sole											
75-77	0.0(20)	4.4(10)	4.4	0.011*	0.002*	84-85	23.7(12)	4.9(30)	18.8	0.006*	<0.001*
77-78	4.4(10)	11.5(10)	7.0	0.021*	0.025*	85-86	4.9(30)	5.7(24)	0.9	0.577	0.164
78-79	11.5(10)	5.8(12)	5.6	0.020*	0.057	86-87	5.7(24)	14.3(12)	8.6	0.156	0.411
79-80	5.8(12)	41.4(18)	35.5	0.009*	<0.001*	87-89	14.3(12)	71.9(9)	57.6	0.018*	0.010*
80-81	41.4(18)	11.8(57)	29.5	0.004*	<0.001*	89-92	71.9(9)	59.7(7)	12.2	0.740	0.476
81-83	11.8(57)	4.6(9)	7.2	0.992	0.999	92-95	59.7(7)	15.8(9)	43.9	0.019*	0.008*
83-84	4.6(9)	23.7(12)	19.1	0.002*	0.014*	95-98	15.8(9)	10.4(11)	5.4	0.302	0.166

Appendix II - Table 2. Tests for significant differences in weighted CPUE between adjacent survey years in Chignisk-Castle Bays group on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
Pandalid shrimp species group											
73-74	267.1(3)	328.8(8)	61.6	0.581	0.632	82-83	27.6(9)	39.7(11)	12.1	0.158	0.228
74-75	328.8(8)	262.7(11)	66.1	0.240	0.550	83-84	39.7(11)	78.3(7)	38.6	0.133	0.218
75-76	262.7(11)	307.8(12)	45.1	0.276	0.159	84-85	78.3(7)	0.0(12)	78.3	0.027*	<0.001*
76-77	307.8(12)	221.1(11)	86.7	0.031*	0.026*	85-86	0.0(12)	0.6(2)	0.6	0.081	0.011*
77-78	221.1(11)	221.2(21)	0.0	0.438	0.677	86-87	0.6(2)	22.5(14)	21.9	0.115	0.120
78-79	221.2(21)	395.0(12)	173.8	0.009*	0.183	87-89	22.5(14)	16.8(11)	5.7	0.230	0.398
79-80	395.0(12)	397.1(13)	2.1	0.523	0.368	89-90	16.8(11)	0.0(2)	16.8	0.004*	0.014*
80-81	397.1(13)	25.1(12)	372.0	<0.001*	<0.001*	90-92	0.0(2)	58.2(11)	58.2	0.003*	0.014*
81-82	25.1(12)	27.6(9)	2.5	0.486	0.586	92-95	58.2(11)	35.9(9)	22.3	0.058	0.111
Flatfish species group											
73-74	2.8(3)	10.4(8)	7.6	0.064	0.235	82-83	77.2(9)	103.5(11)	26.3	0.201	0.552
74-75	10.4(8)	17.3(11)	6.9	0.045*	0.171	83-84	103.5(11)	196.6(7)	93.1	0.090	0.049*
75-76	17.3(11)	9.2(12)	8.1	0.015*	0.410	84-85	196.6(7)	0.0(8)	196.6	0.015*	<0.001*
76-77	9.2(12)	22.5(11)	13.3	0.056	0.044*	85-86	0.0(8)	75.4(2)	75.4	0.012*	0.024*
77-78	22.5(11)	15.8(21)	6.7	0.158	0.227	86-87	75.4(2)	60.6(11)	14.9	0.332	0.688
78-79	15.8(21)	5.1(12)	10.8	0.025*	<0.001*	87-89	60.6(11)	75.4(11)	14.8	0.214	0.063
79-80	5.1(12)	42.7(13)	37.6	<0.001*	<0.001*	89-92	75.4(11)	85.4(11)	10.0	0.289	0.310
80-81	42.7(13)	79.9(12)	37.3	0.003*	0.069	92-95	85.4(11)	112.9(9)	27.5	0.044*	0.003*
81-82	79.9(12)	77.2(9)	2.7	0.512	0.578						
Roundfish species group											
73-74	43.9(3)	31.5(8)	12.4	0.277	0.151	82-83	105.9(9)	87.0(11)	19.0	0.333	0.319
74-75	31.5(8)	114.4(11)	82.9	0.007*	<0.001*	83-84	87.0(11)	116.7(7)	29.8	0.304	0.221
75-76	114.4(11)	197.4(12)	83.0	0.068	0.084	84-85	116.7(7)	1.2(12)	115.5	0.039*	<0.001*
76-77	197.4(12)	103.8(11)	93.6	0.055	0.079	85-86	1.2(12)	17.8(2)	16.6	0.011*	0.032*
77-78	103.8(11)	79.7(21)	24.1	0.188	0.255	86-87	17.8(2)	66.3(14)	48.5	0.857	0.634

Appendix II - Table 2 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Chignik-Castle Bays based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
78-79	79.7(21)	114.8(12)	35.1	0.372	0.578	87-89	66.3(14)	87.9(11)	21.6	0.381	0.228
79-80	114.8(12)	290.9(13)	176.1	0.151	0.003*	89-90	87.9(11)	0.2(2)	87.7	0.212	0.014*
80-81	290.9(13)	196.7(12)	94.2	0.214	0.050*	90-92	0.2(2)	83.9(11)	83.7	0.008*	0.014*
81-82	196.7(12)	105.9(9)	90.8	0.086	0.536	92-95	83.9(11)	117.4(9)	33.5	0.094	0.178
Osmerid species group											
73-74	5.8(3)	6.2(8)	0.5	0.396	0.167	82-83	0.8(9)	1.0(11)	0.2	0.346	0.524
74-75	6.2(8)	0.8(11)	5.4	0.014*	0.076	83-84	1.0(11)	0.0(7)	1.0	0.002*	0.058
75-76	0.8(11)	5.4(12)	4.6	0.149	0.019*	84-85	0.0(7)	0.0(12)	0.0	0.403	0.225
76-77	5.4(12)	3.6(11)	1.8	0.345	0.408	85-86	0.0(12)	1.2(2)	1.1	0.128	0.284
77-78	3.6(11)	0.8(21)	2.8	0.127	<0.001*	86-87	1.2(2)	0.7(14)	0.4	0.314	0.558
78-79	0.8(21)	12.3(12)	11.4	<0.001*	0.006*	87-89	0.7(14)	0.0(11)	0.7	0.064	0.079
79-80	12.3(12)	5.6(13)	6.6	0.060	0.174	89-90	0.0(11)	0.0(2)	0.0	0.427	0.427
80-81	5.6(13)	1.3(12)	4.3	0.048*	0.180	90-92	0.0(2)	2.2(11)	2.2	0.174	0.014*
81-82	1.3(12)	0.8(9)	0.5	0.182	0.072	92-95	2.2(11)	1.5(9)	0.7	0.354	0.004*
Northern shrimp											
73-74	246.7(3)	323.3(8)	76.6	0.614	0.661	82-83	27.6(9)	39.7(11)	12.1	0.158	0.228
74-75	323.3(8)	261.1(11)	62.1	0.254	0.601	83-84	39.7(11)	78.3(7)	38.6	0.133	0.218
75-76	261.1(11)	304.3(12)	43.1	0.287	0.164	84-85	78.3(7)	0.0(12)	78.3	0.027*	<0.001*
76-77	304.3(12)	220.6(11)	83.6	0.034*	0.049*	85-86	0.0(12)	0.5(2)	0.5	0.148	0.148
77-78	220.6(11)	217.9(21)	2.7	0.418	0.634	86-87	0.5(2)	22.5(14)	22.0	0.115	0.112
78-79	217.9(21)	381.5(12)	163.6	0.011*	0.199	87-89	22.5(14)	16.8(11)	5.7	0.231	0.402
79-80	381.5(12)	391.0(13)	9.5	0.544	0.356	89-90	16.8(11)	0.0(2)	16.8	0.004*	0.014*
80-81	391.0(13)	25.0(12)	365.9	<0.001*	<0.001*	90-92	0.0(2)	58.2(11)	58.2	0.003*	0.014*
81-82	25.0(12)	27.6(9)	2.5	0.486	0.586	92-95	58.2(11)	35.9(9)	22.3	0.058	0.111
Humpy shrimp											
73-74	9.3(3)	0.8(8)	8.5	0.148	0.197	78-79	2.7(21)	12.8(12)	10.1	0.146	0.053

Appendix II - Table 2 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Chignik-Castle Bays based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
74-75	0.8(8)	1.3(11)	0.5	0.430	0.441	79-80	12.8(12)	5.1(13)	7.7	0.275	0.238
75-76	1.3(11)	3.4(12)	2.0	0.379	0.342	80-81	5.1(13)	0.0(12)	5.1	0.088	0.009*
76-77	3.4(12)	0.2(11)	3.1	0.300	0.317	85-86	0.0(12)	0.1(2)	0.1	0.006*	0.011*
77-78	0.2(11)	2.7(21)	2.4	0.278	0.357	86-87	0.1(2)	0.0(14)	0.1	0.005*	0.008*
Walleye pollock											
73-74	31.6(3)	16.9(8)	14.7	0.156	0.288	82-83	69.3(9)	68.3(11)	0.9	0.498	0.542
74-75	16.9(8)	83.3(11)	66.3	0.019*	<0.001*	83-84	68.3(11)	34.0(7)	34.3	0.118	0.202
75-76	83.3(11)	172.0(12)	88.7	0.056	0.157	84-85	34.0(7)	1.2(12)	32.8	0.029*	0.014*
76-77	172.0(12)	74.2(11)	97.8	0.051	0.052	85-86	1.2(12)	10.8(2)	9.6	0.081	0.056
77-78	74.2(11)	20.2(21)	54.0	0.009*	0.008*	86-87	10.8(2)	56.9(14)	46.1	0.900	0.890
78-79	20.2(21)	2.3(12)	17.9	0.007*	0.001*	87-89	56.9(14)	75.3(11)	18.5	0.393	0.224
79-80	2.3(12)	201.3(13)	199.0	0.023*	<0.001*	89-90	75.3(11)	0.1(2)	75.3	0.301	0.014*
80-81	201.3(13)	140.9(12)	60.4	0.326	0.275	90-92	0.1(2)	61.9(11)	61.8	0.012*	0.014*
81-82	140.9(12)	69.3(9)	71.6	0.075	0.645	92-95	61.9(11)	108.0(9)	46.1	0.038*	0.097
Juvenile walleye pollock											
77-78	0.0(11)	1.0(21)	1.0	0.246	0.100	84-85	1.3(7)	0.0(12)	1.3	0.075	0.119
78-79	1.0(21)	84.0(12)	83.0	0.195	<0.001*	86-87	0.0(2)	1.6(14)	1.6	0.077	0.122
79-80	84.0(12)	0.0(13)	84.0	0.267	<0.001*	87-89	1.6(14)	0.2(11)	1.3	0.016*	0.021*
82-83	0.0(9)	0.8(11)	0.8	0.003*	<0.001*	89-90	0.2(11)	0.0(2)	0.2	0.015*	0.133
83-84	0.8(11)	1.3(7)	0.5	0.248	0.084						
Capelin											
73-74	5.3(3)	6.2(8)	0.9	0.404	0.167	82-83	0.0(9)	0.0(11)	0.0	0.454	0.483
74-75	6.2(8)	0.4(11)	5.8	0.010*	0.016*	83-84	0.0(11)	0.0(7)	0.0	0.448	0.612
75-76	0.4(11)	4.8(12)	4.5	0.158	0.010*	84-85	0.0(7)	0.0(12)	0.0	0.054	0.225
76-77	4.8(12)	0.1(11)	4.8	0.144	0.002*	85-86	0.0(12)	0.1(2)	0.0	0.134	0.505
77-78	0.1(11)	0.7(21)	0.6	0.298	0.148	86-87	0.1(2)	0.0(14)	0.1	0.078	0.364

Appendix II - Table 2 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Chignik-Castle Bays based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
78-79	0.7(21)	5.8(12)	5.1	0.048*	0.117	87-89	0.0(14)	0.0(11)	0.0	0.220	0.276
79-80	5.8(12)	0.0(13)	5.8	0.058	0.014*	89-90	0.0(11)	0.0(2)	0.0	0.588	0.695
80-81	0.0(13)	0.0(12)	0.0	0.278	0.223	90-92	0.0(2)	0.2(11)	0.2	0.458	0.710
81-82	0.0(12)	0.0(9)	0.0	0.252	0.377	92-95	0.2(11)	0.0(9)	0.2	0.189	0.284
Pacific cod											
73-74	0.2(3)	3.6(8)	3.4	0.099	0.190	82-83	28.5(9)	14.4(11)	14.1	0.119	0.004*
74-75	3.6(8)	16.4(11)	12.9	0.016*	0.210	83-84	14.4(11)	62.7(7)	48.3	0.080	0.003*
75-76	16.4(11)	10.1(12)	6.4	0.094	0.454	84-85	62.7(7)	0.0(12)	62.7	0.050*	<0.001*
76-77	10.1(12)	13.6(11)	3.5	0.151	0.401	85-86	0.0(12)	4.9(2)	4.9	0.006*	0.011*
77-78	13.6(11)	32.9(21)	19.3	0.235	0.174	86-87	4.9(2)	6.0(14)	1.1	0.543	0.289
78-79	32.9(21)	11.0(12)	21.9	0.282	0.003*	87-89	6.0(14)	11.0(11)	5.0	0.082	0.076
79-80	11.0(12)	34.5(13)	23.4	0.163	0.005*	89-90	11.0(11)	0.0(2)	11.0	0.002*	0.014*
80-81	34.5(13)	32.2(12)	2.2	0.493	0.125	90-92	0.0(2)	16.6(11)	16.6	0.004*	0.040*
81-82	32.2(12)	28.5(9)	3.7	0.563	0.088	92-95	16.6(11)	3.1(9)	13.5	0.016*	0.001*
Arrowtooth flounder											
73-74	0.0(3)	1.7(8)	1.7	0.191	0.072	82-83	21.0(9)	20.3(11)	0.7	0.522	0.424
74-75	1.7(8)	2.5(11)	0.8	0.219	0.191	83-84	20.3(11)	57.5(7)	37.1	0.044*	0.046*
75-76	2.5(11)	1.4(12)	1.1	0.049*	0.252	84-85	57.5(7)	0.0(8)	57.5	0.011*	<0.001*
76-77	1.4(12)	4.1(11)	2.7	0.004*	0.020*	85-86	0.0(8)	9.2(2)	9.2	0.012*	0.024*
77-78	4.1(11)	5.6(21)	1.5	0.671	0.196	86-87	9.2(2)	10.7(11)	1.5	0.576	0.550
78-79	5.6(21)	0.0(12)	5.6	0.018*	<0.001*	87-89	10.7(11)	19.0(11)	8.3	0.181	0.097
79-80	0.0(12)	7.2(13)	7.2	<0.001*	<0.001*	89-92	19.0(11)	24.0(11)	5.0	0.209	0.310
80-81	7.2(13)	10.1(12)	2.9	0.168	0.242	92-95	24.0(11)	40.1(9)	16.1	0.034*	0.060
81-82	10.1(12)	21.0(9)	11.0	0.064	0.280						
Flathead sole											
73-74	1.8(3)	0.7(8)	1.1	0.233	0.052	82-83	46.9(9)	75.1(11)	28.3	0.122	0.617

Appendix II - Table 2 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Chignik-Castle Bays based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
74-75	0.7(8)	8.0(11)	7.3	0.002*	0.049*	83-84	75.1(11)	130.9(7)	55.8	0.140	0.056
75-76	8.0(11)	5.8(12)	2.1	0.156	0.150	84-85	130.9(7)	0.0(8)	130.9	0.029*	<0.001*
76-77	5.8(12)	8.0(11)	2.2	0.130	0.295	85-86	0.0(8)	49.3(2)	49.3	0.012*	0.024*
77-78	8.0(11)	7.5(21)	0.5	0.345	0.140	86-87	49.3(2)	34.4(11)	14.9	0.271	0.690
78-79	7.5(21)	5.0(12)	2.5	0.735	0.771	87-89	34.4(11)	47.3(11)	12.9	0.210	0.222
79-80	5.0(12)	26.5(13)	21.5	<0.001*	<0.001*	89-92	47.3(11)	57.2(11)	9.9	0.261	0.148
80-81	26.5(13)	61.8(12)	35.3	0.002*	0.060	92-95	57.2(11)	69.5(9)	12.4	0.154	0.029*
81-82	61.8(12)	46.9(9)	14.9	0.804	0.761						

Table 3. Tests for significant differences in weighted CPUE between adjacent survey years in Kiliuda Bay group on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
Pandalid shrimp species group											
72-73	113.2(10)	180.4(17)	67.3	0.808	0.052	80-81	51.6(10)	23.0(19)	28.6	0.010*	0.104
73-74	180.4(17)	596.6(14)	416.1	0.001*	0.002*	81-84	23.0(19)	12.7(10)	10.2	0.938	0.040*
74-75	596.6(14)	294.8(23)	301.7	0.018*	0.020*	84-85	12.7(10)	3.8(12)	8.9	0.053	0.005*
75-76	294.8(23)	591.8(24)	296.9	0.060	0.118	85-86	3.8(12)	6.1(13)	2.3	0.404	0.312
76-77	591.8(24)	464.2(10)	127.6	0.632	0.804	86-89	6.1(13)	9.4(9)	3.3	0.444	0.042*
77-78	464.2(10)	114.6(26)	349.6	0.038*	<0.001*	89-92	9.4(9)	7.8(10)	1.6	0.458	0.120
78-79	114.6(26)	13.9(27)	100.6	0.140	0.184	92-95	7.8(10)	4.8(6)	3.0	0.640	0.182
79-80	13.9(27)	51.6(10)	37.7	0.080	0.001*	95-98	4.8(6)	6.1(6)	1.3	0.450	0.458
Flatfish species group											
75-76	2.5(23)	53.6(24)	51.1	<0.001*	<0.001*	84-85	115.1(10)	99.4(9)	15.7	0.203	0.524
76-77	53.6(24)	48.1(10)	5.5	0.639	0.548	85-86	99.4(9)	90.4(10)	9.0	0.392	0.246
77-78	48.1(10)	96.4(26)	48.4	0.928	0.954	86-89	90.4(10)	221.2(9)	130.8	0.024*	0.003*
78-79	96.4(26)	52.5(27)	43.9	0.061	0.006*	89-92	221.2(9)	157.6(10)	63.6	0.163	0.048*
79-80	52.5(27)	48.4(10)	4.1	0.620	0.472	92-95	157.6(10)	102.6(6)	55.0	0.748	0.131
80-81	48.4(10)	93.3(19)	44.9	<0.001*	0.948	95-98	102.6(6)	79.3(6)	23.4	0.358	0.414
81-84	93.3(19)	115.1(10)	21.8	0.107	0.315						
Roundfish species group											
75-76	58.9(23)	96.4(24)	37.5	0.052	<0.001*	84-85	161.4(10)	190.3(12)	28.9	0.461	0.147
76-77	96.4(24)	18.1(10)	78.3	<0.001*	<0.001*	85-86	190.3(12)	163.4(13)	26.9	0.308	0.392
77-78	18.1(10)	206.5(26)	188.4	<0.001*	<0.001*	86-89	163.4(13)	101.9(9)	61.5	0.173	0.323
78-79	206.5(26)	41.6(27)	165.0	<0.001*	<0.001*	89-92	101.9(9)	248.8(10)	146.9	0.235	0.141
79-80	41.6(27)	175.3(10)	133.7	0.006*	0.307	92-95	248.8(10)	269.1(6)	20.3	0.387	0.444
80-81	175.3(10)	108.0(19)	67.2	0.103	0.846	95-98	269.1(6)	247.5(6)	21.7	0.455	0.385

Appendix II - Table 3 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Kiliuda Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
81-84	108.0(19)	161.4(10)	53.4	0.093	0.236						
Osmerid species group											
75-76	1.4(23)	14.1(24)	12.7	0.015*	0.101	84-85	1.6(10)	0.3(12)	1.3	0.190	0.153
76-77	14.1(24)	0.8(10)	13.3	0.025*	0.014*	85-86	0.3(12)	0.7(13)	0.5	0.211	0.291
77-78	0.8(10)	2.0(26)	1.2	0.831	0.108	86-89	0.7(13)	1.6(9)	0.9	0.285	0.351
78-79	2.0(26)	8.7(27)	6.6	0.166	0.027*	89-92	1.6(9)	9.9(10)	8.3	0.071	0.008*
79-80	8.7(27)	0.6(10)	8.0	0.192	0.038*	92-95	9.9(10)	0.9(6)	9.0	0.072	0.007*
80-81	0.6(10)	2.0(19)	1.3	0.064	0.370	95-98	0.9(6)	2.6(6)	1.7	0.291	0.148
81-84	2.0(19)	1.6(10)	0.4	0.524	0.219						
Northern shrimp											
72-73	113.2(10)	180.4(17)	67.3	0.808	0.052	80-81	50.3(10)	22.6(19)	27.7	0.010*	0.103
73-74	180.4(17)	596.6(14)	416.1	0.001*	0.002*	81-84	22.6(19)	12.7(10)	9.8	0.930	0.043*
74-75	596.6(14)	294.8(23)	301.7	0.018*	0.020*	84-85	12.7(10)	3.8(12)	8.9	0.053	0.005*
75-76	294.8(23)	567.3(24)	272.4	0.071	0.122	85-86	3.8(12)	6.1(13)	2.3	0.404	0.312
76-77	567.3(24)	460.6(10)	106.7	0.615	0.812	86-89	6.1(13)	9.4(9)	3.3	0.444	0.042*
77-78	460.6(10)	113.3(26)	347.4	0.038*	<0.001*	89-92	9.4(9)	7.8(10)	1.6	0.458	0.120
78-79	113.3(26)	13.8(27)	99.4	0.141	0.184	92-95	7.8(10)	4.8(6)	3.0	0.640	0.182
79-80	13.8(27)	50.3(10)	36.4	0.084	0.001*	95-98	4.8(6)	6.1(6)	1.3	0.451	0.458
Humpy shrimp											
75-76	0.0(23)	21.2(24)	21.2	0.039*	0.005*	78-79	1.2(26)	0.0(27)	1.1	0.198	0.368
76-77	21.2(24)	0.0(10)	21.2	0.052	0.067	79-80	0.0(27)	0.0(10)	0.0	0.454	0.522
77-78	0.0(10)	1.2(26)	1.2	0.318	0.524						
Walleye pollock											
75-76	4.0(23)	47.7(24)	43.7	0.004*	<0.001*	84-85	143.4(10)	172.3(12)	29.0	0.309	0.125
76-77	47.7(24)	5.6(10)	42.2	0.015*	0.026*	85-86	172.3(12)	127.7(13)	44.7	0.249	0.307
77-78	5.6(10)	153.4(26)	147.9	<0.001*	<0.001*	86-89	127.7(13)	82.6(9)	45.1	0.250	0.211

Appendix II - Table 3 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Kiliuda Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
78-79	153.4(26)	13.8(27)	139.6	<0.001*	<0.001*	89-92	82.6(9)	225.6(10)	143.1	0.235	0.172
79-80	13.8(27)	140.3(10)	126.4	0.011*	0.002*	92-95	225.6(10)	233.7(6)	8.1	0.404	0.339
80-81	140.3(10)	55.4(19)	84.9	0.046*	0.671	95-98	233.7(6)	209.9(6)	23.8	0.448	0.195
81-84	55.4(19)	143.4(10)	87.9	0.008*	0.046*						
Juvenile walleye pollock											
77-78	0.0(10)	9.8(26)	9.8	0.216	0.051	84-85	2.9(10)	1.3(12)	1.5	0.188	0.139
78-79	9.8(26)	0.4(27)	9.4	0.132	0.014*	85-86	1.3(12)	7.3(13)	6.0	0.135	0.161
79-80	0.4(27)	0.0(10)	0.4	0.572	0.525	86-89	7.3(13)	0.7(9)	6.6	0.109	0.284
80-81	0.0(10)	3.0(19)	3.0	0.312	0.055	89-92	0.7(9)	0.0(10)	0.7	0.054	0.002*
81-84	3.0(19)	2.9(10)	0.1	0.535	0.008*						
Capelin											
75-76	1.4(23)	8.2(24)	6.8	0.056	0.243	80-81	0.3(10)	0.1(19)	0.3	0.111	0.023*
76-77	8.2(24)	0.0(10)	8.2	0.050*	0.026*	81-84	0.1(19)	0.0(10)	0.0	0.245	0.138
77-78	0.0(10)	0.3(26)	0.3	0.178	0.258	84-85	0.0(10)	0.0(12)	0.0	0.562	0.323
78-79	0.3(26)	8.7(27)	8.4	0.119	<0.001*	85-86	0.0(12)	0.0(13)	0.0	0.318	0.292
79-80	8.7(27)	0.3(10)	8.3	0.180	0.018*	86-89	0.0(13)	0.0(9)	0.0	0.602	0.602
Pacific cod											
75-76	15.7(23)	5.4(24)	10.3	0.319	0.429	84-85	9.8(10)	14.6(12)	4.8	0.350	0.212
76-77	5.4(24)	0.0(10)	5.4	0.103	0.154	85-86	14.6(12)	26.9(13)	12.3	0.316	0.205
77-78	0.0(10)	19.3(26)	19.3	0.054	0.002*	86-89	26.9(13)	13.7(9)	13.2	0.209	0.294
78-79	19.3(26)	11.7(27)	7.6	0.270	0.078	89-92	13.7(9)	12.4(10)	1.3	0.419	0.355
79-80	11.7(27)	3.8(10)	7.8	0.149	0.543	92-95	12.4(10)	27.7(6)	15.3	0.093	0.081
80-81	3.8(10)	35.5(19)	31.7	0.026*	0.145	95-98	27.7(6)	34.3(6)	6.6	0.306	0.039*
81-84	35.5(19)	9.8(10)	25.8	0.071	0.319						
Arrowtooth flounder											
75-76	1.1(23)	9.7(24)	8.6	0.007*	0.001*	84-85	26.3(10)	41.9(9)	15.6	0.120	0.377

Appendix II - Table 3 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Kiliuda Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
76-77	9.7(24)	3.9(10)	5.8	0.129	0.040*	85-86	41.9(9)	24.7(10)	17.1	0.110	0.172
77-78	3.9(10)	26.3(26)	22.4	0.014*	<0.001*	86-89	24.7(10)	50.1(9)	25.3	0.129	0.054
78-79	26.3(26)	1.2(27)	25.1	<0.001*	<0.001*	89-92	50.1(9)	51.8(10)	1.7	0.507	0.445
79-80	1.2(27)	6.3(10)	5.1	0.052	0.585	92-95	51.8(10)	50.9(6)	0.9	0.379	0.658
80-81	6.3(10)	14.3(19)	8.0	0.028*	0.003*	95-98	50.9(6)	28.2(6)	22.7	0.386	0.362
81-84	14.3(19)	26.3(10)	12.0	0.042*	0.809						
Flathead sole											
(1)-(2)	x1(n1)	x2(n2)	d	Pd	Wd	(1)-(2)	x1(n1)	x2(n2)	d	Pd	Wd
75-76	0.0(23)	32.7(24)	32.7	<0.001*	<0.001*	84-85	76.6(10)	54.3(9)	22.3	0.159	0.392
76-77	32.7(24)	40.5(10)	7.8	0.289	0.132	85-86	54.3(9)	58.9(10)	4.6	0.619	0.616
77-78	40.5(10)	63.9(26)	23.4	0.812	0.890	86-89	58.9(10)	150.0(9)	91.1	0.026*	0.004*
78-79	63.9(26)	49.1(27)	14.8	0.300	0.192	89-92	150.0(9)	85.6(10)	64.3	0.130	0.008*
79-80	49.1(27)	33.5(10)	15.6	0.843	0.914	92-95	85.6(10)	42.3(6)	43.3	0.171	0.013*
80-81	33.5(10)	61.5(19)	28.1	0.939	0.844	95-98	42.3(6)	42.8(6)	0.5	0.458	0.078
81-84	61.5(19)	76.6(10)	15.1	0.117	0.053						

Appendix II - Table 4. Tests for significant differences in weighted CPUE between adjacent survey years inMarmot Bay (inshore) group on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
Pandalid shrimp species group											
76-77	285.2(15)	115.2(22)	170.0	<0.001*	<0.001*	85-86	24.6(25)	7.1(7)	17.5	0.923	0.040*
77-78	115.2(22)	81.9(18)	33.3	0.224	0.021*	86-87	7.1(7)	19.6(22)	12.5	0.389	0.072
78-79	81.9(18)	164.7(12)	82.8	0.172	0.030*	87-88	19.6(22)	0.0(3)	19.6	0.462	0.131
79-80	164.7(12)	48.9(11)	115.7	0.193	0.052	88-89	0.0(3)	29.4(15)	29.4	0.012*	0.002*
80-81	48.9(11)	76.9(33)	27.9	0.449	0.001*	89-92	29.4(15)	60.4(14)	31.0	0.036*	0.384
81-84	76.9(33)	47.6(15)	29.3	0.788	0.933	92-95	60.4(14)	60.2(16)	0.2	0.480	0.302
84-85	47.6(15)	24.6(25)	22.9	0.160	0.016*	95-98	60.2(16)	24.9(14)	35.3	0.011*	0.133
Flatfish species group											
76-77	43.5(15)	50.0(22)	6.5	0.752	0.668	84-85	238.8(15)	102.5(19)	136.2	0.013*	0.003*
77-78	50.0(22)	83.9(18)	33.9	0.012*	0.013*	85-87	102.5(19)	53.8(16)	48.7	0.126	0.075
78-79	83.9(18)	36.4(12)	47.5	0.004*	0.006*	87-89	53.8(16)	56.7(15)	2.9	0.495	0.244
79-80	36.4(12)	82.9(11)	46.5	0.121	0.047*	89-92	56.7(15)	218.2(14)	161.5	0.016*	<0.001*
80-81	82.9(11)	160.0(33)	77.2	0.983	0.988	92-95	218.2(14)	68.3(16)	149.9	0.021*	0.002*
81-84	160.0(33)	238.8(15)	78.7	0.056	0.073	95-98	68.3(16)	70.5(14)	2.2	0.383	0.148
Roundfish species group											
76-77	95.1(15)	200.5(22)	105.4	0.094	0.044*	85-86	53.4(25)	69.8(7)	16.4	0.234	0.230
77-78	200.5(22)	95.7(18)	104.8	0.083	0.048*	86-87	69.8(7)	46.8(22)	23.0	0.183	0.263
78-79	95.7(18)	53.2(12)	42.5	0.162	0.051	87-88	46.8(22)	20.8(3)	26.0	0.777	0.715
79-80	53.2(12)	56.3(11)	3.1	0.427	0.054	88-89	20.8(3)	127.3(15)	106.5	0.059	0.025*
80-81	56.3(11)	102.5(33)	46.2	0.765	0.989	89-92	127.3(15)	95.1(14)	32.2	0.200	0.403
81-84	102.5(33)	98.5(15)	4.0	0.543	0.200	92-95	95.1(14)	77.3(16)	17.8	0.252	0.302
84-85	98.5(15)	53.4(25)	45.1	0.057	0.010*	95-98	77.3(16)	76.1(14)	1.2	0.459	0.569
Osmerid species group											
76-77	19.9(15)	3.6(22)	16.3	0.004*	0.002*	85-86	0.1(25)	0.2(7)	0.1	0.306	0.218
77-78	3.6(22)	1.8(18)	1.8	0.333	0.032*	86-87	0.2(7)	0.4(22)	0.2	0.804	0.449

Appendix II - Table 4 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years inMarmot Bay (inshore) based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
78-79	1.8(18)	18.5(12)	16.7	<0.001*	<0.001*	87-88	0.4(22)	0.0(3)	0.3	0.266	0.037*
79-80	18.5(12)	27.4(11)	8.9	0.397	0.084	88-89	0.0(3)	0.1(15)	0.1	0.442	0.024*
80-81	27.4(11)	0.6(33)	26.8	0.105	0.020*	89-92	0.1(15)	0.0(14)	0.0	0.328	0.426
81-84	0.6(33)	1.0(15)	0.3	0.304	0.052	92-95	0.0(14)	0.2(16)	0.1	0.198	0.271
84-85	1.0(15)	0.1(25)	0.9	0.220	0.071	95-98	0.2(16)	0.2(14)	0.0	0.399	0.239
Northern shrimp											
76-77	282.0(15)	112.6(22)	169.5	<0.001*	<0.001*	85-86	24.6(25)	7.1(7)	17.5	0.923	0.040*
77-78	112.6(22)	73.3(18)	39.3	0.155	0.020*	86-87	7.1(7)	19.2(22)	12.0	0.385	0.186
78-79	73.3(18)	159.6(12)	86.3	0.137	0.026*	87-88	19.2(22)	0.0(3)	19.2	0.475	0.249
79-80	159.6(12)	43.4(11)	116.2	0.146	0.032*	88-89	0.0(3)	29.4(15)	29.4	0.013*	0.002*
80-81	43.4(11)	69.8(33)	26.4	0.449	<0.001*	89-92	29.4(15)	60.4(14)	31.0	0.036*	0.383
81-84	69.8(33)	47.4(15)	22.3	0.797	0.908	92-95	60.4(14)	60.1(16)	0.3	0.477	0.302
84-85	47.4(15)	24.6(25)	22.8	0.160	0.016*	95-98	60.1(16)	24.9(14)	35.1	0.012*	0.132
Humpy shrimp											
76-77	2.5(15)	2.1(22)	0.5	0.396	0.280	81-84	6.4(33)	0.0(15)	6.4	0.481	0.038*
77-78	2.1(22)	7.0(18)	5.0	0.322	0.324	84-85	0.0(15)	0.0(25)	0.0	0.352	0.379
78-79	7.0(18)	4.8(12)	2.2	0.436	0.105	92-95	0.0(14)	0.1(16)	0.1	0.138	0.542
79-80	4.8(12)	5.0(11)	0.1	0.473	0.368	95-98	0.1(16)	0.0(14)	0.1	0.138	0.542
80-81	5.0(11)	6.4(33)	1.4	0.424	0.415						
Walleye pollock											
76-77	52.8(15)	97.5(22)	44.7	0.344	0.411	85-86	33.6(25)	60.2(7)	26.7	0.122	0.040*
77-78	97.5(22)	21.3(18)	76.2	0.144	0.035*	86-87	60.2(7)	39.7(22)	20.5	0.197	0.195
78-79	21.3(18)	0.0(12)	21.3	0.015*	0.033*	87-88	39.7(22)	20.3(3)	19.4	0.707	0.606
79-80	0.0(12)	11.5(11)	11.5	0.042*	<0.001*	88-89	20.3(3)	114.3(15)	94.0	0.086	0.902
80-81	11.5(11)	80.7(33)	69.2	<0.001*	<0.001*	89-92	114.3(15)	71.3(14)	43.1	0.141	0.184
81-84	80.7(33)	49.8(15)	30.8	0.942	0.692	92-95	71.3(14)	62.8(16)	8.4	0.395	0.610

Appendix II - Table 4 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years inMarmot Bay (inshore) based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
84-85	49.8(15)	33.6(25)	16.3	0.255	0.134	95-98	62.8(16)	53.5(14)	9.3	0.323	0.191
Juvenile walleye pollock											
76-77	0.0(15)	77.2(22)	77.2	0.006*	0.003*	85-86	0.1(25)	0.0(7)	0.1	0.330	0.352
77-78	77.2(22)	45.3(18)	31.9	0.250	0.200	86-87	0.0(7)	0.0(22)	0.0	0.563	0.764
78-79	45.3(18)	22.3(12)	23.0	0.330	0.299	87-88	0.0(22)	0.0(3)	0.0	0.646	0.884
79-80	22.3(12)	0.0(11)	22.3	<0.001*	<0.001*	88-89	0.0(3)	3.5(15)	3.5	0.464	0.555
81-84	0.0(33)	2.1(15)	2.1	0.006*	<0.001*	89-92	3.5(15)	0.0(14)	3.5	0.293	0.128
84-85	2.1(15)	0.1(25)	2.0	0.026*	<0.001*						
Capelin											
76-77	6.2(15)	2.1(22)	4.1	0.145	0.410	85-86	0.0(25)	0.0(7)	0.0	0.468	0.609
77-78	2.1(22)	1.5(18)	0.6	0.426	0.510	86-87	0.0(7)	0.0(22)	0.0	0.384	0.575
78-79	1.5(18)	10.3(12)	8.8	0.038*	0.107	87-88	0.0(22)	0.0(3)	0.0	0.123	0.004*
79-80	10.3(12)	25.2(11)	14.9	0.356	0.095	88-89	0.0(3)	0.0(15)	0.0	0.011*	<0.001*
80-81	25.2(11)	0.1(33)	25.0	0.106	<0.001*	89-92	0.0(15)	0.0(14)	0.0	0.243	0.226
81-84	0.1(33)	0.4(15)	0.3	0.232	0.340	92-95	0.0(14)	0.1(16)	0.1	0.093	0.401
84-85	0.4(15)	0.0(25)	0.4	0.251	0.080	95-98	0.1(16)	0.0(14)	0.1	0.007*	0.275
Pacific cod											
76-77	0.9(15)	6.9(22)	6.0	0.145	0.028*	85-86	15.8(25)	6.8(7)	9.1	0.890	0.088
77-78	6.9(22)	2.2(18)	4.7	0.244	0.240	86-87	6.8(7)	4.5(22)	2.3	0.268	0.405
78-79	2.2(18)	0.0(12)	2.2	0.139	0.111	87-88	4.5(22)	0.0(3)	4.4	0.338	0.357
79-80	0.0(12)	3.7(11)	3.7	0.154	0.037*	88-89	0.0(3)	7.9(15)	7.8	0.005*	0.099
80-81	3.7(11)	4.9(33)	1.1	0.721	0.221	89-92	7.9(15)	5.0(14)	2.8	0.197	0.492
81-84	4.9(33)	26.6(15)	21.8	<0.001*	<0.001*	92-95	5.0(14)	12.6(16)	7.6	0.040*	0.045*
84-85	26.6(15)	15.8(25)	10.8	0.179	0.020*	95-98	12.6(16)	19.6(14)	6.9	0.178	0.004*
Arrowtooth flounder											
76-77	12.1(15)	6.8(22)	5.3	0.153	0.402	84-85	41.4(15)	27.0(19)	14.4	0.196	0.076

Appendix II - Table 4 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years inMarmot Bay (inshore) based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
77-78	6.8(22)	29.7(18)	22.9	<0.001*	<0.001*	85-87	27.0(19)	20.1(16)	6.9	0.292	0.129
78-79	29.7(18)	5.5(12)	24.2	0.003*	<0.001*	87-89	20.1(16)	9.7(15)	10.5	0.198	0.404
79-80	5.5(12)	31.3(11)	25.8	0.119	0.014*	89-92	9.7(15)	103.0(14)	93.3	0.091	0.031*
80-81	31.3(11)	81.0(33)	49.8	0.995	<0.001*	92-95	103.0(14)	28.7(16)	74.2	0.153	0.298
81-84	81.0(33)	41.4(15)	39.7	0.999	<0.001*	95-98	28.7(16)	25.6(14)	3.1	0.564	0.564
Flathead sole											
(1)-(2)	x1(n1)	x2(n2)	d	Pd	Wd	(1)-(2)	x1(n1)	x2(n2)	d	Pd	Wd
76-77	28.5(15)	27.4(22)	1.1	0.450	0.749	84-85	161.3(15)	68.9(19)	92.4	0.018*	0.002*
77-78	27.4(22)	49.4(18)	22.0	0.019*	0.022*	85-87	68.9(19)	33.1(16)	35.8	0.105	0.056
78-79	49.4(18)	26.0(12)	23.4	0.041*	0.042*	87-89	33.1(16)	43.9(15)	10.8	0.206	0.088
79-80	26.0(12)	35.3(11)	9.4	0.266	0.105	89-92	43.9(15)	104.7(14)	60.8	0.005*	0.003*
80-81	35.3(11)	67.9(33)	32.6	0.961	0.854	92-95	104.7(14)	34.8(16)	69.9	0.002*	0.001*
81-84	67.9(33)	161.3(15)	93.3	0.002*	<0.001*	95-98	34.8(16)	43.6(14)	8.8	0.254	0.115

Appendix II - Table 5. Tests for significant differences in weighted CPUE between adjacent survey years in Pavlof Bay group on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
Pandalid shrimp species group											
72-73	649.1(10)	308.3(2)	340.8	0.972	0.828	86-87	15.7(12)	7.2(17)	8.5	0.021*	0.004*
73-74	308.3(2)	691.1(12)	382.8	1.000	0.989	87-88	7.2(17)	1.5(25)	5.7	0.007*	0.304
74-75	691.1(12)	596.4(12)	94.6	0.256	0.108	88-89	1.5(25)	4.7(28)	3.2	0.017*	0.017*
75-76	596.4(12)	808.5(12)	212.0	0.036*	0.077	89-90	4.7(28)	6.7(24)	2.0	0.164	0.149
76-77	808.5(12)	814.6(10)	6.1	0.482	0.578	90-91	6.7(24)	10.1(22)	3.3	0.157	0.022*
77-78	814.6(10)	170.7(11)	643.9	<0.001*	<0.001*	91-92	10.1(22)	5.1(22)	4.9	0.076	0.006*
78-79	170.7(11)	24.6(22)	146.1	<0.001*	<0.001*	92-93	5.1(22)	1.9(22)	3.2	0.002*	<0.001*
79-80	24.6(22)	23.8(24)	0.8	0.492	0.027*	93-94	1.9(22)	0.6(22)	1.3	0.049*	<0.001*
80-81	23.8(24)	21.4(12)	2.4	0.607	0.409	94-95	0.6(22)	0.5(23)	0.0	0.503	0.418
81-82	21.4(12)	5.2(13)	16.2	0.001*	<0.001*	95-96	0.5(23)	9.1(22)	8.6	<0.001*	<0.001*
82-83	5.2(13)	16.8(12)	11.6	0.002*	<0.001*	96-97	9.1(22)	1.2(22)	7.9	<0.001*	<0.001*
83-84	16.8(12)	1.5(12)	15.4	<0.001*	<0.001*	97-98	1.2(22)	2.3(22)	1.0	0.252	0.412
84-85	1.5(12)	4.1(12)	2.6	0.026*	0.020*	98-99	2.3(22)	1.9(22)	0.3	0.460	0.002*
85-86	4.1(12)	15.7(12)	11.6	0.004*	<0.001*						
Flatfish species group											
72-73	2.4(10)	6.1(2)	3.7	0.185	0.231	86-87	188.0(12)	208.3(12)	20.3	0.312	0.323
73-74	6.1(2)	6.6(12)	0.5	0.420	0.264	87-88	208.3(12)	135.9(22)	72.4	0.002*	0.027*
74-75	6.6(12)	4.3(12)	2.2	0.241	0.445	88-89	135.9(22)	119.8(28)	16.1	0.290	0.037*
75-76	4.3(12)	19.5(12)	15.2	<0.001*	<0.001*	89-90	119.8(28)	116.8(23)	3.0	0.628	0.213
76-77	19.5(12)	17.4(10)	2.1	0.652	0.263	90-91	116.8(23)	102.7(22)	14.1	0.242	0.083
77-78	17.4(10)	18.2(11)	0.9	0.600	0.181	91-92	102.7(22)	179.6(22)	76.9	0.004*	<0.001*
78-79	18.2(11)	38.8(22)	20.6	0.080	0.270	92-93	179.6(22)	123.1(22)	56.5	0.026*	0.001*
79-80	38.8(22)	54.2(24)	15.4	0.161	0.020*	93-94	123.1(22)	260.2(22)	137.1	0.003*	0.001*
80-81	54.2(24)	50.9(12)	3.2	0.503	0.060	94-95	260.2(22)	229.5(23)	30.8	0.270	0.070

Appendix II - Table 5 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Pavlof Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
81-82	50.9(12)	29.8(13)	21.1	0.030*	0.018*	95-96	229.5(23)	155.1(22)	74.4	0.044*	0.358
82-83	29.8(13)	93.8(12)	63.9	<0.001*	<0.001*	96-97	155.1(22)	182.9(22)	27.8	0.156	0.353
83-84	93.8(12)	138.7(12)	44.9	0.142	0.698	97-98	182.9(22)	275.0(22)	92.1	0.010*	0.004*
84-85	138.7(12)	159.9(12)	21.3	0.188	0.217	98-99	275.0(22)	140.8(22)	134.2	<0.001*	<0.001*
85-86	159.9(12)	188.0(12)	28.1	0.333	0.053						
Roundfish species group											
72-73	117.6(10)	13.1(2)	104.4	0.098	0.008*	86-87	87.0(12)	142.6(17)	55.5	0.046*	0.171
73-74	13.1(2)	37.1(12)	24.0	0.899	0.773	87-88	142.6(17)	131.3(25)	11.3	0.368	0.659
74-75	37.1(12)	48.5(12)	11.4	0.247	0.390	88-89	131.3(25)	137.2(28)	5.9	0.522	0.536
75-76	48.5(12)	165.1(12)	116.6	<0.001*	0.004*	89-90	137.2(28)	287.7(24)	150.4	0.003*	0.002*
76-77	165.1(12)	115.2(10)	49.9	0.164	0.234	90-91	287.7(24)	308.0(22)	20.3	0.400	0.386
77-78	115.2(10)	45.4(11)	69.8	0.020*	0.002*	91-92	308.0(22)	238.5(22)	69.4	0.122	0.312
78-79	45.4(11)	1091.1(22)	1045.7	0.002*	<0.001*	92-93	238.5(22)	206.1(22)	32.4	0.232	0.160
79-80	1091.1(22)	409.8(24)	681.3	0.012*	0.012*	93-94	206.1(22)	224.0(22)	17.9	0.371	0.241
80-81	409.8(24)	137.0(12)	272.8	0.039*	0.889	94-95	224.0(22)	183.3(23)	40.7	0.272	0.274
81-82	137.0(12)	120.8(13)	16.2	0.371	0.351	95-96	183.3(23)	215.8(22)	32.5	0.201	0.276
82-83	120.8(13)	332.1(12)	211.3	0.002*	0.004*	96-97	215.8(22)	393.3(22)	177.5	0.072	0.044*
83-84	332.1(12)	130.9(12)	201.1	0.002*	0.003*	97-98	393.3(22)	560.2(22)	166.9	0.200	0.386
84-85	130.9(12)	77.4(12)	53.5	0.078	0.146	98-99	560.2(22)	290.3(22)	269.9	0.080	0.117
85-86	77.4(12)	87.0(12)	9.6	0.361	0.291						
Osmerid species group											
72-73	16.2(10)	2.1(2)	14.0	0.379	0.772	86-87	0.2(12)	0.1(17)	0.1	0.335	0.004*
73-74	2.1(2)	25.7(12)	23.6	0.009*	0.106	87-88	0.1(17)	0.0(25)	0.1	0.079	0.163
74-75	25.7(12)	16.6(12)	9.1	0.169	0.102	88-89	0.0(25)	0.1(28)	0.0	0.023*	0.032*
75-76	16.6(12)	14.3(12)	2.4	0.381	0.227	89-90	0.1(28)	0.1(24)	0.0	0.242	0.380
76-77	14.3(12)	24.0(10)	9.8	0.167	0.052	90-91	0.1(24)	0.1(22)	0.0	0.340	0.441

Appendix II - Table 5 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Pavlof Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
77-78	24.0(10)	1.0(11)	23.1	0.009*	<0.001*	91-92	0.1(22)	0.0(22)	0.1	0.028*	0.018*
78-79	1.0(11)	11.6(22)	10.6	0.154	0.244	92-93	0.0(22)	0.0(22)	0.0	0.336	0.124
79-80	11.6(22)	12.0(24)	0.5	0.496	0.109	93-94	0.0(22)	0.0(22)	0.0	0.445	0.303
80-81	12.0(24)	4.0(12)	8.0	0.590	0.074	94-95	0.0(22)	0.0(23)	0.0	0.355	0.506
81-82	4.0(12)	0.2(13)	3.8	<0.001*	<0.001*	95-96	0.0(23)	0.0(22)	0.0	0.431	0.383
82-83	0.2(13)	0.1(12)	0.1	0.105	0.033*	96-97	0.0(22)	0.1(22)	0.1	0.115	0.315
83-84	0.1(12)	0.0(12)	0.1	0.032*	0.019*	97-98	0.1(22)	0.1(22)	0.0	0.208	0.032*
84-85	0.0(12)	0.0(12)	0.0	0.042*	0.202	98-99	0.1(22)	0.1(22)	0.1	0.155	0.477
85-86	0.0(12)	0.2(12)	0.1	0.386	0.004*						
Northern shrimp											
72-73	269.5(10)	99.8(2)	169.7	0.992	1.000	86-87	15.4(12)	7.2(17)	8.2	0.025*	0.004*
73-74	99.8(2)	378.1(12)	278.3	0.995	1.000	87-88	7.2(17)	1.5(25)	5.7	0.006*	0.292
74-75	378.1(12)	236.8(12)	141.3	0.001*	0.001*	88-89	1.5(25)	4.7(28)	3.2	0.016*	0.015*
75-76	236.8(12)	329.1(12)	92.4	0.050	0.003*	89-90	4.7(28)	6.7(24)	2.0	0.159	0.135
76-77	329.1(12)	415.0(10)	85.8	0.179	0.570	90-91	6.7(24)	10.1(22)	3.3	0.161	0.022*
77-78	415.0(10)	122.2(11)	292.7	0.001*	0.001*	91-92	10.1(22)	5.1(22)	4.9	0.079	0.007*
78-79	122.2(11)	23.8(22)	98.4	<0.001*	<0.001*	92-93	5.1(22)	1.9(22)	3.2	0.002*	<0.001*
79-80	23.8(22)	22.8(24)	1.0	0.475	0.027*	93-94	1.9(22)	0.6(22)	1.3	0.046*	<0.001*
80-81	22.8(24)	20.9(12)	1.9	0.588	0.373	94-95	0.6(22)	0.5(23)	0.0	0.490	0.524
81-82	20.9(12)	5.2(13)	15.8	<0.001*	<0.001*	95-96	0.5(23)	9.1(22)	8.5	<0.001*	<0.001*
82-83	5.2(13)	16.6(12)	11.4	0.002*	<0.001*	96-97	9.1(22)	1.2(22)	7.8	<0.001*	<0.001*
83-84	16.6(12)	1.5(12)	15.1	<0.001*	<0.001*	97-98	1.2(22)	2.2(22)	1.0	0.258	0.445
84-85	1.5(12)	4.1(12)	2.6	0.028*	0.017*	98-99	2.2(22)	1.9(22)	0.3	0.467	0.002*
85-86	4.1(12)	15.4(12)	11.3	0.003*	0.001*						
Humpy shrimp											
72-73	333.0(10)	162.1(2)	170.9	0.913	0.789	86-87	0.2(12)	0.0(17)	0.2	0.086	<0.001*

Appendix II - Table 5 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Pavlof Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
73-74	162.1(2)	263.1(12)	101.0	0.623	0.322	87-88	0.0(17)	0.0(25)	0.0	0.084	0.080
74-75	263.1(12)	320.3(12)	57.2	0.369	0.388	88-89	0.0(25)	0.0(28)	0.0	0.058	0.022*
75-76	320.3(12)	445.7(12)	125.4	0.134	0.125	89-90	0.0(28)	0.0(24)	0.0	0.668	0.576
76-77	445.7(12)	371.9(10)	73.8	0.719	0.658	90-91	0.0(24)	0.0(22)	0.0	0.264	0.323
77-78	371.9(10)	40.2(11)	331.7	<0.001*	0.002*	91-92	0.0(22)	0.0(22)	0.0	0.205	0.210
78-79	40.2(11)	0.6(22)	39.6	0.005*	0.161	92-93	0.0(22)	0.0(22)	0.0	0.302	0.269
79-80	0.6(22)	0.7(24)	0.2	0.342	0.143	93-94	0.0(22)	0.0(22)	0.0	0.060	0.119
80-81	0.7(24)	0.1(12)	0.6	0.055	0.009*	94-95	0.0(22)	0.0(23)	0.0	0.153	0.491
81-82	0.1(12)	0.0(13)	0.1	0.126	0.094	95-96	0.0(23)	0.0(22)	0.0	0.197	0.003*
82-83	0.0(13)	0.0(12)	0.0	0.080	0.309	96-97	0.0(22)	0.0(22)	0.0	0.461	0.134
83-84	0.0(12)	0.0(12)	0.0	0.017*	0.023*	97-98	0.0(22)	0.0(22)	0.0	0.436	0.234
84-85	0.0(12)	0.0(12)	0.0	0.012*	0.117	98-99	0.0(22)	0.0(22)	0.0	0.463	0.492
85-86	0.0(12)	0.2(12)	0.2	0.152	0.002*						
Walleye pollock											
72-73	72.0(10)	0.2(2)	71.8	0.171	0.011*	86-87	53.2(12)	101.1(17)	47.9	0.034*	0.176
73-74	0.2(2)	2.1(12)	1.9	0.460	0.424	87-88	101.1(17)	106.9(25)	5.8	0.573	0.786
74-75	2.1(12)	21.7(12)	19.6	0.003*	<0.001*	88-89	106.9(25)	111.4(28)	4.5	0.505	0.606
75-76	21.7(12)	112.2(12)	90.5	0.013*	0.084	89-90	111.4(28)	258.2(24)	146.9	0.002*	0.003*
76-77	112.2(12)	63.0(10)	49.3	0.207	0.116	90-91	258.2(24)	285.2(22)	27.0	0.368	0.431
77-78	63.0(10)	3.8(11)	59.2	<0.001*	<0.001*	91-92	285.2(22)	175.2(22)	110.0	0.047*	0.115
78-79	3.8(11)	59.9(22)	56.1	0.167	0.307	92-93	175.2(22)	172.5(22)	2.8	0.528	0.454
79-80	59.9(22)	174.0(24)	114.0	0.161	0.005*	93-94	172.5(22)	177.3(22)	4.8	0.447	0.407
80-81	174.0(24)	93.4(12)	80.6	0.653	0.138	94-95	177.3(22)	146.2(23)	31.1	0.316	0.402
81-82	93.4(12)	82.2(13)	11.2	0.385	0.382	95-96	146.2(23)	130.8(22)	15.4	0.376	0.258
82-83	82.2(13)	277.4(12)	195.2	0.002*	0.002*	96-97	130.8(22)	296.5(22)	165.7	0.010*	0.015*
83-84	277.4(12)	92.3(12)	185.1	0.002*	0.008*	97-98	296.5(22)	506.6(22)	210.1	0.139	0.336

Appendix II - Table 5 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Pavlof Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
84-85	92.3(12)	44.3(12)	48.0	0.053	0.056	98-99	506.6(22)	232.9(22)	273.8	0.080	0.117
85-86	44.3(12)	53.2(12)	8.8	0.351	0.273						
Juvenile walleye pollock											
78-79	0.0(11)	94.6(22)	94.6	0.013*	0.007*	92-93	0.0(22)	0.0(22)	0.0	0.275	0.408
79-80	94.6(22)	0.0(24)	94.6	0.002*	<0.001*	93-94	0.0(22)	0.0(22)	0.0	<0.001*	0.002*
88-89	0.0(25)	0.0(28)	0.0	0.080	0.033*	95-96	0.0(23)	0.0(22)	0.0	0.135	0.482
89-90	0.0(28)	0.0(24)	0.0	0.387	0.513	96-97	0.0(22)	0.0(22)	0.0	0.135	0.499
90-91	0.0(24)	0.0(22)	0.0	0.026*	0.030*	97-98	0.0(22)	0.5(22)	0.5	0.028*	0.004*
91-92	0.0(22)	0.0(22)	0.0	0.004*	<0.001*	98-99	0.5(22)	0.0(22)	0.5	0.023*	0.066
Capelin											
72-73	16.2(10)	2.1(2)	14.0	0.381	0.775	86-87	0.1(12)	0.0(17)	0.1	0.321	0.002*
73-74	2.1(2)	25.7(12)	23.6	0.008*	0.103	87-88	0.0(17)	0.0(25)	0.0	0.016*	0.005*
74-75	25.7(12)	16.6(12)	9.1	0.164	0.094	88-89	0.0(25)	0.0(28)	0.0	0.398	0.117
75-76	16.6(12)	14.3(12)	2.4	0.381	0.221	89-90	0.0(28)	0.1(24)	0.0	0.180	0.511
76-77	14.3(12)	24.0(10)	9.7	0.173	0.047*	90-91	0.1(24)	0.1(22)	0.0	0.452	0.331
77-78	24.0(10)	1.0(11)	23.0	0.011*	<0.001*	91-92	0.1(22)	0.0(22)	0.1	0.016*	0.033*
78-79	1.0(11)	5.8(22)	4.8	0.251	0.371	92-93	0.0(22)	0.0(22)	0.0	0.276	0.237
79-80	5.8(22)	12.0(24)	6.3	0.489	0.017*	93-94	0.0(22)	0.0(22)	0.0	0.216	0.497
80-81	12.0(24)	4.0(12)	8.1	0.588	0.081	94-95	0.0(22)	0.0(23)	0.0	0.269	0.458
81-82	4.0(12)	0.1(13)	3.9	<0.001*	<0.001*	95-96	0.0(23)	0.0(22)	0.0	0.262	0.510
82-83	0.1(13)	0.0(12)	0.0	0.164	0.027*	96-97	0.0(22)	0.1(22)	0.1	0.029*	0.050
83-84	0.0(12)	0.0(12)	0.0	0.192	0.094	97-98	0.1(22)	0.0(22)	0.0	0.277	0.307
84-85	0.0(12)	0.0(12)	0.0	0.131	0.284	98-99	0.0(22)	0.0(22)	0.0	0.029*	0.246
85-86	0.0(12)	0.1(12)	0.1	0.431	0.025*						
Pacific cod											
72-73	0.0(10)	0.0(2)	0.0	0.457	0.551	87-88	31.5(17)	17.3(25)	14.2	0.059	0.419

Appendix II - Table 5 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Pavlof Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
75-76	0.0(12)	0.1(12)	0.1	0.239	0.238	88-89	17.3(25)	19.8(28)	2.5	0.397	0.596
76-77	0.1(12)	3.4(10)	3.4	0.007*	<0.001*	89-90	19.8(28)	23.7(24)	3.9	0.201	0.119
77-78	3.4(10)	21.4(11)	17.9	0.260	0.163	90-91	23.7(24)	20.7(22)	3.0	0.280	0.187
78-79	21.4(11)	911.7(22)	890.3	0.002*	<0.001*	91-92	20.7(22)	51.3(22)	30.5	0.005*	<0.001*
79-80	911.7(22)	191.4(24)	720.2	0.004*	0.001*	92-93	51.3(22)	28.7(22)	22.6	0.019*	0.030*
80-81	191.4(24)	35.1(12)	156.3	0.025*	0.007*	93-94	28.7(22)	29.2(22)	0.6	0.408	0.498
81-82	35.1(12)	35.5(13)	0.3	0.594	0.128	94-95	29.2(22)	33.7(23)	4.5	0.258	0.191
82-83	35.5(13)	46.9(12)	11.4	0.341	0.351	95-96	33.7(23)	77.8(22)	44.1	0.029*	0.170
83-84	46.9(12)	18.9(12)	28.0	0.064	0.010*	96-97	77.8(22)	91.3(22)	13.5	0.481	0.217
84-85	18.9(12)	10.9(12)	8.0	0.175	0.233	97-98	91.3(22)	44.4(22)	46.9	0.392	0.121
85-86	10.9(12)	21.3(12)	10.5	0.126	0.068	98-99	44.4(22)	49.7(22)	5.3	0.304	0.186
86-87	21.3(12)	31.5(17)	10.1	0.145	0.593						
Arrowtooth flounder											
73-74	0.0(2)	0.0(12)	0.0	0.574	0.726	86-87	5.0(12)	11.9(12)	6.8	0.003*	<0.001*
74-75	0.0(12)	0.1(12)	0.1	0.257	0.231	87-88	11.9(12)	11.3(22)	0.5	0.375	0.133
75-76	0.1(12)	0.3(12)	0.2	0.067	0.082	88-89	11.3(22)	8.5(28)	2.8	0.122	0.062
76-77	0.3(12)	0.1(10)	0.2	0.124	0.105	89-90	8.5(28)	11.8(23)	3.3	0.048*	0.016*
77-78	0.1(10)	0.1(11)	0.0	0.542	0.165	90-91	11.8(23)	11.1(22)	0.8	0.378	0.221
78-79	0.1(11)	0.0(22)	0.1	0.106	0.002*	91-92	11.1(22)	17.6(22)	6.6	0.097	0.020*
79-80	0.0(22)	1.6(24)	1.6	0.033*	0.134	92-93	17.6(22)	11.5(22)	6.1	0.080	0.028*
80-81	1.6(24)	0.0(12)	1.6	0.066	0.290	93-94	11.5(22)	24.8(22)	13.3	<0.001*	<0.001*
81-82	0.0(12)	0.2(13)	0.2	0.002*	0.003*	94-95	24.8(22)	30.2(23)	5.3	0.177	0.603
82-83	0.2(13)	1.3(12)	1.1	0.081	0.014*	95-96	30.2(23)	29.8(22)	0.4	0.477	0.145
83-84	1.3(12)	2.1(12)	0.8	0.318	0.298	96-97	29.8(22)	15.5(22)	14.3	0.009*	<0.001*
84-85	2.1(12)	7.2(12)	5.1	0.010*	0.014*	97-98	15.5(22)	47.7(22)	32.2	<0.001*	<0.001*
85-86	7.2(12)	5.0(12)	2.2	0.224	0.484	98-99	47.7(22)	16.7(22)	31.1	<0.001*	<0.001*

Appendix II - Table 5 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Pavlof Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
Flathead sole											
(1)-(2)	x1(n1)	x2(n2)	d	Pd	Wd	(1)-(2)	x1(n1)	x2(n2)	d	Pd	Wd
72-73	0.5(10)	0.1(2)	0.4	0.711	0.694	86-87	66.3(12)	71.0(12)	4.7	0.461	0.084
73-74	0.1(2)	4.4(12)	4.3	0.244	0.248	87-88	71.0(12)	54.1(22)	16.9	0.043*	0.138
74-75	4.4(12)	1.9(12)	2.4	0.202	0.456	88-89	54.1(22)	54.6(28)	0.5	0.526	0.153
75-76	1.9(12)	8.9(12)	7.0	0.023*	0.003*	89-90	54.6(28)	57.7(23)	3.1	0.434	0.157
76-77	8.9(12)	8.0(10)	0.9	0.569	0.259	90-91	57.7(23)	54.3(22)	3.4	0.351	0.588
77-78	8.0(10)	7.3(11)	0.7	0.464	0.290	91-92	54.3(22)	98.7(22)	44.4	0.003*	0.016*
78-79	7.3(11)	26.0(22)	18.6	0.059	0.054	92-93	98.7(22)	73.4(22)	25.3	0.082	0.014*
79-80	26.0(22)	20.1(24)	5.8	0.322	<0.001*	93-94	73.4(22)	128.6(22)	55.2	0.047*	0.007*
80-81	20.1(24)	26.0(12)	5.9	0.101	0.030*	94-95	128.6(22)	120.9(23)	7.6	0.338	0.092
81-82	26.0(12)	13.1(13)	12.9	0.036*	0.001*	95-96	120.9(23)	83.9(22)	37.0	0.104	0.441
82-83	13.1(13)	40.4(12)	27.3	<0.001*	<0.001*	96-97	83.9(22)	119.3(22)	35.3	0.089	0.597
83-84	40.4(12)	59.3(12)	18.9	0.150	0.295	97-98	119.3(22)	140.3(22)	21.1	0.265	0.012*
84-85	59.3(12)	48.2(12)	11.1	0.297	0.189	98-99	140.3(22)	72.1(22)	68.2	0.006*	0.002*
85-86	48.2(12)	66.3(12)	18.1	0.255	0.258						

Appendix II - Table 6. Tests for significant differences in weighted CPUE between adjacent survey years in Ugak Bay group on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
Pandalid shrimp species group											
72-74	277.5(10)	138.3(16)	139.3	0.150	0.109	80-81	131.7(11)	129.4(23)	2.3	0.575	0.632
74-75	138.3(16)	139.6(17)	1.4	0.442	0.090	81-82	129.4(23)	0.0(2)	129.4	0.202	0.022*
75-76	139.6(17)	188.2(17)	48.6	0.246	0.031*	82-84	0.0(2)	2.3(5)	2.3	0.160	0.044*
76-77	188.2(17)	163.9(7)	24.3	0.525	0.970	84-85	2.3(5)	2.6(7)	0.3	0.549	0.239
77-78	163.9(7)	97.6(7)	66.3	0.373	0.187	85-86	2.6(7)	8.1(13)	5.6	0.209	0.251
78-79	97.6(7)	195.1(14)	97.5	0.667	0.130	86-89	8.1(13)	8.7(9)	0.6	0.529	0.137
79-80	195.1(14)	131.7(11)	63.4	0.370	0.371						
Flatfish species group											
75-76	0.5(17)	27.8(17)	27.3	<0.001*	<0.001*	81-82	55.8(23)	28.0(2)	27.8	0.720	0.719
76-77	27.8(17)	21.2(7)	6.5	0.735	0.824	82-84	28.0(2)	101.2(5)	73.2	0.131	0.083
77-78	21.2(7)	56.2(7)	34.9	0.078	0.025*	84-85	101.2(5)	43.0(7)	58.2	0.047*	0.002*
78-79	56.2(7)	10.3(14)	45.9	0.012*	<0.001*	85-86	43.0(7)	27.0(11)	16.0	0.256	0.204
79-80	10.3(14)	66.9(11)	56.6	0.004*	0.010*	86-89	27.0(11)	158.2(9)	131.2	<0.001*	<0.001*
80-81	66.9(11)	55.8(23)	11.1	0.308	0.694						
Roundfish species group											
75-76	24.6(17)	111.1(17)	86.5	0.057	<0.001*	81-82	77.8(23)	103.9(2)	26.1	0.401	0.843
76-77	111.1(17)	30.0(7)	81.1	0.113	0.004*	82-84	103.9(2)	31.4(5)	72.5	0.024*	0.070
77-78	30.0(7)	131.2(7)	101.2	0.008*	0.053	84-85	31.4(5)	36.6(7)	5.2	0.681	0.679
78-79	131.2(7)	33.6(14)	97.6	0.004*	0.078	85-86	36.6(7)	142.1(13)	105.5	0.056	0.005*
79-80	33.6(14)	73.7(11)	40.2	0.124	0.021*	86-89	142.1(13)	160.9(9)	18.8	0.458	0.352
80-81	73.7(11)	77.8(23)	4.0	0.554	0.748						
Osmerid species group											
75-76	5.9(17)	72.9(17)	67.0	0.093	<0.001*	81-82	1.7(23)	0.0(2)	1.7	0.116	0.022*
76-77	72.9(17)	17.7(7)	55.3	0.240	0.006*	82-84	0.0(2)	0.8(5)	0.8	0.357	0.136
77-78	17.7(7)	10.4(7)	7.2	0.301	0.317	84-85	0.8(5)	2.6(7)	1.8	0.348	0.336

Appendix II - Table 6 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Ugak Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
78-79	10.4(7)	4.9(14)	5.5	0.184	0.262	85-86	2.6(7)	3.6(13)	0.9	0.609	0.329
79-80	4.9(14)	28.5(11)	23.5	0.154	0.004*	86-89	3.6(13)	1.7(9)	1.8	0.307	0.223
80-81	28.5(11)	1.7(23)	26.8	0.129	<0.001*						
Northern shrimp											
72-74	277.5(10)	138.3(16)	139.3	0.150	0.109	80-81	120.9(11)	123.9(23)	3.0	0.597	0.614
74-75	138.3(16)	139.6(17)	1.4	0.442	0.090	81-82	123.9(23)	0.0(2)	123.9	0.221	0.022*
75-76	139.6(17)	176.1(17)	36.4	0.308	0.060	82-84	0.0(2)	2.3(5)	2.3	0.160	0.044*
76-77	176.1(17)	161.0(7)	15.1	0.477	0.941	84-85	2.3(5)	2.5(7)	0.3	0.550	0.243
77-78	161.0(7)	81.2(7)	79.8	0.333	0.131	85-86	2.5(7)	8.1(13)	5.6	0.208	0.250
78-79	81.2(7)	171.4(14)	90.3	0.265	0.089	86-89	8.1(13)	8.7(9)	0.6	0.529	0.137
79-80	171.4(14)	120.9(11)	50.6	0.398	0.384						
Humpy shrimp											
75-76	0.0(17)	6.2(17)	6.2	0.070	0.002*	79-80	19.6(14)	8.9(11)	10.7	0.274	0.435
76-77	6.2(17)	0.0(7)	6.2	0.137	0.033*	80-81	8.9(11)	0.9(23)	8.0	0.144	0.013*
77-78	0.0(7)	9.2(7)	9.2	0.136	0.237	81-82	0.9(23)	0.0(2)	0.9	0.458	0.709
78-79	9.2(7)	19.6(14)	10.4	0.238	0.228						
Walleye pollock											
75-76	0.0(17)	2.7(17)	2.7	0.078	0.003*	81-82	21.2(23)	28.2(2)	7.0	0.325	0.809
76-77	2.7(17)	2.1(7)	0.6	0.615	0.342	82-84	28.2(2)	15.2(5)	13.0	0.295	0.435
77-78	2.1(7)	65.4(7)	63.3	0.015*	0.329	84-85	15.2(5)	10.1(7)	5.1	0.283	0.261
78-79	65.4(7)	0.2(14)	65.2	0.001*	0.110	85-86	10.1(7)	83.7(13)	73.6	0.136	0.009*
79-80	0.2(14)	4.3(11)	4.1	0.082	<0.001*	86-89	83.7(13)	139.4(9)	55.7	0.284	0.068
80-81	4.3(11)	21.2(23)	16.9	0.161	0.039*						
Juvenile walleye pollock											
77-78	0.0(7)	32.4(7)	32.4	0.082	0.102	82-84	0.0(2)	0.4(5)	0.4	0.036*	0.044*
78-79	32.4(7)	2.8(14)	29.6	0.078	0.522	84-85	0.4(5)	2.9(7)	2.5	0.151	0.022*

Appendix II - Table 6 (cont.). Tests for significant differences in weighted CPUE between adjacent survey years in Ugak Bay based on randomization tests with permutations of 10,000. Sampling is at historical frequencies. CPUE was weighted by the Dirichlet tile area. δ is $|CPUE_1-CPUE_2|$, P_δ is the P-value for the difference in weighted mean CPUE and P_W is the Wilcoxon rank sum test of distributional differences. The asterisk (*) indicates significance at the α=0.05 level.

(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W	(1)-(2)	$x_1(n_1)$	$x_2(n_2)$	δ	P_δ	P_W
79-80	2.8(14)	0.0(11)	2.8	0.077	0.001*	85-86	2.9(7)	38.0(13)	35.1	0.120	0.226
80-81	0.0(11)	9.0(23)	9.0	0.233	0.076	86-89	38.0(13)	2.2(9)	35.8	0.069	0.322
81-82	9.0(23)	0.0(2)	9.0	0.426	0.566						
Capelin											
75-76	5.9(17)	72.9(17)	67.0	0.093	<0.001*	81-82	1.2(23)	0.0(2)	1.2	0.205	0.074
76-77	72.9(17)	0.0(7)	72.9	0.162	<0.001*	82-84	0.0(2)	0.2(5)	0.2	0.289	0.277
77-78	0.0(7)	9.5(7)	9.5	0.107	0.102	84-85	0.2(5)	0.0(7)	0.2	0.160	0.091
78-79	9.5(7)	4.6(14)	4.9	0.224	0.486	85-86	0.0(7)	0.0(13)	0.0	0.433	0.389
79-80	4.6(14)	27.8(11)	23.2	0.156	0.009*	86-89	0.0(13)	0.0(9)	0.0	0.294	0.340
80-81	27.8(11)	1.2(23)	26.6	0.132	<0.001*						
Pacific cod											
75-76	0.0(17)	0.2(17)	0.2	0.206	0.499	81-82	13.3(23)	9.3(2)	4.0	0.422	0.703
76-77	0.2(17)	0.0(7)	0.2	0.291	0.708	82-84	9.3(2)	6.9(5)	2.3	0.403	0.712
78-79	0.0(7)	0.9(14)	0.9	0.194	0.271	84-85	6.9(5)	20.1(7)	13.2	0.204	0.112
79-80	0.9(14)	17.5(11)	16.6	0.002*	0.322	85-86	20.1(7)	15.8(13)	4.3	0.338	0.398
80-81	17.5(11)	13.3(23)	4.3	0.281	0.012*	86-89	15.8(13)	14.4(9)	1.3	0.544	0.706
Arrowtooth flounder											
75-76	0.0(17)	2.3(17)	2.3	0.079	0.056	81-82	3.9(23)	5.5(2)	1.6	0.278	0.257
76-77	2.3(17)	0.7(7)	1.5	0.284	0.438	82-84	5.5(2)	12.0(5)	6.5	0.850	0.786
77-78	0.7(7)	5.5(7)	4.7	0.058	0.088	84-85	12.0(5)	4.1(7)	7.9	0.005*	0.066
78-79	5.5(7)	0.9(14)	4.6	0.032*	0.065	85-86	4.1(7)	3.8(11)	0.3	0.546	0.277
79-80	0.9(14)	5.2(11)	4.4	0.017*	0.042*	86-89	3.8(11)	27.4(9)	23.6	0.005*	0.001*
80-81	5.2(11)	3.9(23)	1.4	0.311	0.394						
Flathead sole											
(1)-(2)	x1(n1)	x2(n2)	d	Pd	Wd	(1)-(2)	x1(n1)	x2(n2)	d	Pd	Wd
75-76	0.0(17)	11.7(17)	11.7	<0.001*	<0.001*	81-82	22.3(23)	7.2(2)	15.1	0.895	0.964

76-77	11.7(17)	6.8(7)	4.9	0.785	0.233	82-84	7.2(2)	78.6(5)	71.4	0.102	0.018*
77-78	6.8(7)	26.3(7)	19.6	0.138	0.012*	84-85	78.6(5)	27.1(7)	51.5	0.032*	<0.001*
78-79	26.3(7)	4.0(14)	22.4	0.050	<0.001*	85-86	27.1(7)	19.0(11)	8.1	0.350	0.178
79-80	4.0(14)	41.2(11)	37.2	0.027*	0.025*	86-89	19.0(11)	113.2(9)	94.2	<0.001*	<0.001*
80-81	41.2(11)	22.3(23)	18.8	0.101	0.658						

Appendix III