STATISTICAL CONSIDERATIONS IN ASSESSING RECENT ADULT/JUVENILE CENSUS TRENDS OF STELLER SEA LIONS

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Abstract

From June 1985 through June 1992 regular aerial surveys over Southeast Alaska, the Gulf of Alaska, and Aleutian Islands were conducted to monitor the distribution and abundance of Steller sea lions (*Eumetopias jubatus*). Furthermore, during 1992 the use of repetitive aerial surveys was introduced to study survey variability. The purposes of our present study were two-fold: (1) To investigate alternative statistical procedures for estimating population trend rates from aerial survey counts, and (2) to apply these procedures to the 1989-92 counts. We focused on 1989-92 because of the more abundant data for that period and to determine the most recent direction of population abundance relative to the well-documented steep decline prior to 1989. We concluded that parametric bootstrapping was the most appropriate interval estimation procedure. For this procedure the 90% confidence interval for the rate of change between the 1989 and 1992 Kenai-Kiska Recovery Plan trend site counts was (-10.19%, 2.62%). For <u>all</u> rookery and haul-out sites within the Kenai-Kiska region for which counts were made for both 1989 and 1992, the 90% confidence interval was (-6.20%, 6.81%). For sites outside the Kenai-Kiska region, the 90% confidence interval for the rate of change between 1989 and 1992 was (-37.92%, -6.93%). The parametric bootstrap procedure had the weakness of including data from only pairs of years; thus, 1990-91 information was excluded from the above interval estimates. Consequently, we investigated the use of both generalized linear modeling (GLM) and generalized estimating equations (GEE) as tools for analyzing all four years' data together. GLM seemed less appropriate than GEE, and the latter procedure yielded conclusions similar to those of parametric bootstrapping: 1989-92 stability for sea lion abundance in the Kenai-Kiska region, and some likelihood of decline from 1989-1992 considering all sites together.

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1 Introduction

1.1 Background

The Steller sea lion is the largest of the "eared" seals. Gregarious by nature, sea lions tend to use traditional sites on remote offshore islands for resting, breeding, and pupping. Their range extends from Southern California north to the Bering Strait, west to the Okhotsk Sea off Russia's coast, and in northern islands of Japan and along the coast of the Korean Peninsula. In Alaska, the greatest abundance of sea lions occurs in the Gulf of Alaska and Aleutian Islands. Sea lions use specific land sites, *haulouts*, for resting between feeding activities and movements. From May through July, adult sea lions congregate on specific land-based *rookeries* for breeding and pupping. Adult females usually return to the same rookeries where they were born to give birth (Anonymous, 1992).

From 1976 to 1990 a severe population decrease of about 70% (67.3% at trend sites) was noted in Alaska (Merrick, pers. com., 1994). This rapid decline prompted the National Marine Fisheries Service (NMFS) to publish an emergency rule listing the Steller sea lion as a threatened species under provisions for the Endangered Species Act (Recovery Plan 1992). This final listing became effective on December 4, 1990.

To monitor the effectiveness of the Recovery Plan, the Recovery Team suggested that an objective evaluation of whether and how Steller sea lions should be listed under the provisions of the ESA can be made by exploring the most recent data available. Earlier count data is favored less since earlier counts were widely spaced in time and were performed by non-uniform techniques, thus making them more variable and less reliable than modern count data. The Recovery Team also acknowledged the difficulty of examining count data outside of the Kenai-Kiska area since existing sets of data for these regions are of variable quality and completeness (Recovery Plan 1992).

1.2 Study Area and Experimental Methods

Survey and other data from 1929 until 1992 was generously provided by the National Marine Mammal Laboratory, National Marine Fisheries Service. Our study primarily examines data only from 1985–1992. Examining only recent data is motivated by an earlier Recovery Plan Draft (II.1.C(3) 1992) which emphasized that the species might be considered as endangered if the Kenai-Kiska Adult/Juvenile Trend Count has declined by at least 10 percent over 3 or more consecutive survey years. Moreover, NMFS believes that the above classification strategy should "focus on small, short-term changes" (Recovery Plan 1992). The data studied consist of counts of adult and juvenile Steller sea lions counted from photographs taken from an aircraft flying over rookeries and haul-out sites from the southern end of Southeast Alaska to the western Aleutian Islands' end at Attu Island and over a single site in the Bering Sea during this period of interest. The survey area was broken down into several regions or subareas (Merrick 1993):

1. Southeast Alaska (SE AK)

2. Eastern Gulf and Prince William Sound (E GULF)
3. Central Gulf (Kenai to Semidi Islands) (C GULF)
4. Western Gulf (West of Semidi Islands to the end of the Alaska Peninsula at False Pass) (W GULF)
5. Eastern Aleutian (Unimak Island through Samalga Island) (E ALEU)
6. Central Aleutian (Islands of Four Mountains through Kiska Island) (C ALEU)
7. Western Aleutian (Buldir through Attu Islands) (W ALEU)
8. Bering (Round Island) (BERING).

Surveys generally followed standard rationale and methods of Withrow (1982). Some data also included hourly and daily beach surveys conducted on land rather than by plane. Details of survey methods can be found in Sease *et al* (1993).

1992 replicate data were used for primary assessment of survey variability. For this dataset, all aerial data originated from slide photographs that were projected onto a white background. Counters outlined overlap between photographs and marked individual animals on the projected images as they counted. Only adults and juveniles on land or in the surf zone were counted. At least two counters independently counted sea lions in each series of photographs for each site. To control variability, counters repeated the process when their results differed by 10% or more. The development of the "10% rule" was motivated by the belief that differences between counters greater than 10% are mostly due to resolvable error by one of the counters and therefore does not represent true replicate variability in the counting procedure (Laughlin 1993, pers. com.)

1.3 Objectives

The focus of this study is to assess and analyze survey variability and incorporate this variability into estimates of the sea lion percent decline at selected sets of sites and over specific time periods. Of particular interest are Kenai-Kiska trend sites during 1989–1992. These estimates of percent decline are of particular interest for monitoring the progress of the management strategies proposed by the Recovery Plan.

2 Analyses and Results

2.1 Summary of Data

Four datasets were considered in this study:

Primary – This dataset consists of survey counts ranging in time from 1929 until 1992. Records include information regarding site name, location (latitude/longitude), region (e.g. Central Gulf), date, indicator for trend site, and indicator for rookery. Again, this present study primarily focuses on the 1985–1992 portion of these data.

Replicate – This dataset consists of the 1992 replicate data from the study carried out by Sease *et al.* (1993). Records include counts from two or more counters at a particular site on a particular day. Most records have sites surveyed for more than one day. Other information in these records includes site name, region, date, time, and indicator for trend site.

Hourly Data – This dataset consists of land-based hourly beach counts on a particular day. Three sites were included: Rogue Reef in 1982 (early, mid, and late season), Marmot Island in 1983 (early, mid and late season), and Ugamak Island in 1985 (late season) and in 1986 (early, mid, and late season).

Daily Data – This dataset consists of land-based daily beach counts for a series of consecutive days. Sites studied include Rogue Reef in 1982, Marmot Island in 1979 and 1983, Ugamak Island in 1985 and 1986, and Sugarloaf Island in 1978.

The primary dataset from 1985–1992 contains 200 records for the Eastern Aleutians, 261 for the Central Aleutians, 95 for the Western Gulf of Alaska, and 168 for the Central Gulf of Alaska. These four regions comprise what is known as the Kenai-Kiska region. Outside of the Kenai-Kiska region there are 5 records for the Bering region, 17 for the Western Aleutians, 55 for the Eastern Gulf of Alaska, and 80 for Southeast Alaska. Table 1 and Figure 1 summarize the data. In the table notice that within a given region the mean and total counts generally decrease with time. This apparent trend can also be noticed when studying the boxplots. The boxplots reflect the variability of the counts for a given year within a region. They also suggest a significant drop in counts from 1985. After 1989 the plots seem to stabilize so trends are not as obvious. Keep in mind that these plots do not reflect the percent changes, so a small unnoticeable decline within the resolution of this plot may still be significant. Furthermore, when viewing these plots keep in mind that the number of sites surveyed in a particular region varies from year to year. Thus, we must take caution when comparing these plots from year to year. The best summary to focus on in these plots is the median (white bar). Following the median with time we can see general regional trends. The "box" summarizes the variability in the survey counts for the region for a particular year; counts at half of the sites surveyed in the region fall within the box. A wide box can indicate large variability, but for some regions and times, this apparently large variability is actually a result of sampling few sites. The other extreme occurs when only one site was sampled, showing no apparent variability in the plot.

Appendix F contains exhaustive plots of the counts at each site over time. The plots are organized by region. Be aware that the scales on the plots differ so that what may appear as a dramatic relative change may actually only be a small absolute change in animals on a very fine scale.

2.2 Comparing Survey Seasons

For the purposes of this analysis, a season shall be defined as the middle of the breeding season: June 10th through June 30th during any given year. This interval was selected since

Table 1: *Regional count summaries for June 1985–1992. Only years with counts have been included in the table. When comparing yearly totals and means, keep in mind that different years may contain counts from different sites. The number of sites sampled can be used as a rough guide when comparing years.*

Region	Kenai-Kiska?	Year	Min.	Median	Mean	Max.	Total count for region sampled	# of Sites sampled
SE AK	N	1989	0	7.5	446.8	4648	9830	22
SE AK	N	1991	0	11	333.6	3648	9008	27
SE AK	N	1992	0	1	189.3	1576	5868	31
E GULF	N	1989	0	65	454.5	2159	5909	13
E GULF	N	1991	0	14	258.4	1350	4652	18
E GULF	N	1992	0	8.5	177.5	1005	4260	24
C GULF	Y	1985	0	406	900.7	4983	23417	26
C GULF	Y	1989	0	93	362.6	2467	13418	37
C GULF	Y	1990	0	94	279.5	1766	8943	32
C GULF	Y	1991	0	81	219.8	1459	7692	35
C GULF	Y	1992	0	60.5	192.9	1581	7330	38
W GULF	Y	1985	12	432	625.2	1588	7503	12
W GULF	Y	1989	0	56.5	246.4	1366	4435	18
W GULF	Y	1990	0	134	278.6	1305	5294	19
W GULF	Y	1991	0	148	251.8	1049	5287	21
W GULF	Y	1992	0	112	217.5	1092	5437	25
E ALEU	Y	1985	0	196	342.3	1429	10611	31
E ALEU	Y	1986	527	563	563	599	1126	2
E ALEU	Y	1989	0	0	75.55	682	3173	42
E ALEU	Y	1990	0	26.5	116.1	915	4875	42
E ALEU	Y	1991	0	30	129	1025	5289	41
E ALEU	Y	1992	0	33.5	136	1061	5714	42
C ALEU	Y	1985	0	161.5	425.8	2942	24695	58
C ALEU	Y	1989	0	18.5	136.1	1123	7351	54
C ALEU	Y	1990	0	46.5	169.7	1324	6789	40
C ALEU	Y	1991	0	52.5	166.4	1046	8655	52
C ALEU	Y	1992	0	58	141.5	1059	8065	57
W ALEU	N	1985	3130	3130	3130	3130	3130	1
W ALEU	N	1988	1306	1396	1495	1783	4485	3
W ALEU	N	1989	1058	1772	1772	2486	3544	2
W ALEU	N	1990	429	429	429	429	429	1
W ALEU	N	1991	398	589	983.4	2099	4917	5
W ALEU	N	1992	248	454	906.6	2077	4533	5
BERING	N	1985	74	74	74	74	74	1
BERING	N	1989	0	0	0	0	0	1
BERING	N	1990	30	30	30	30	30	1
BERING	N	1991	38	38	38	38	38	1
BERING	N	1992	45	45	45	45	45	1

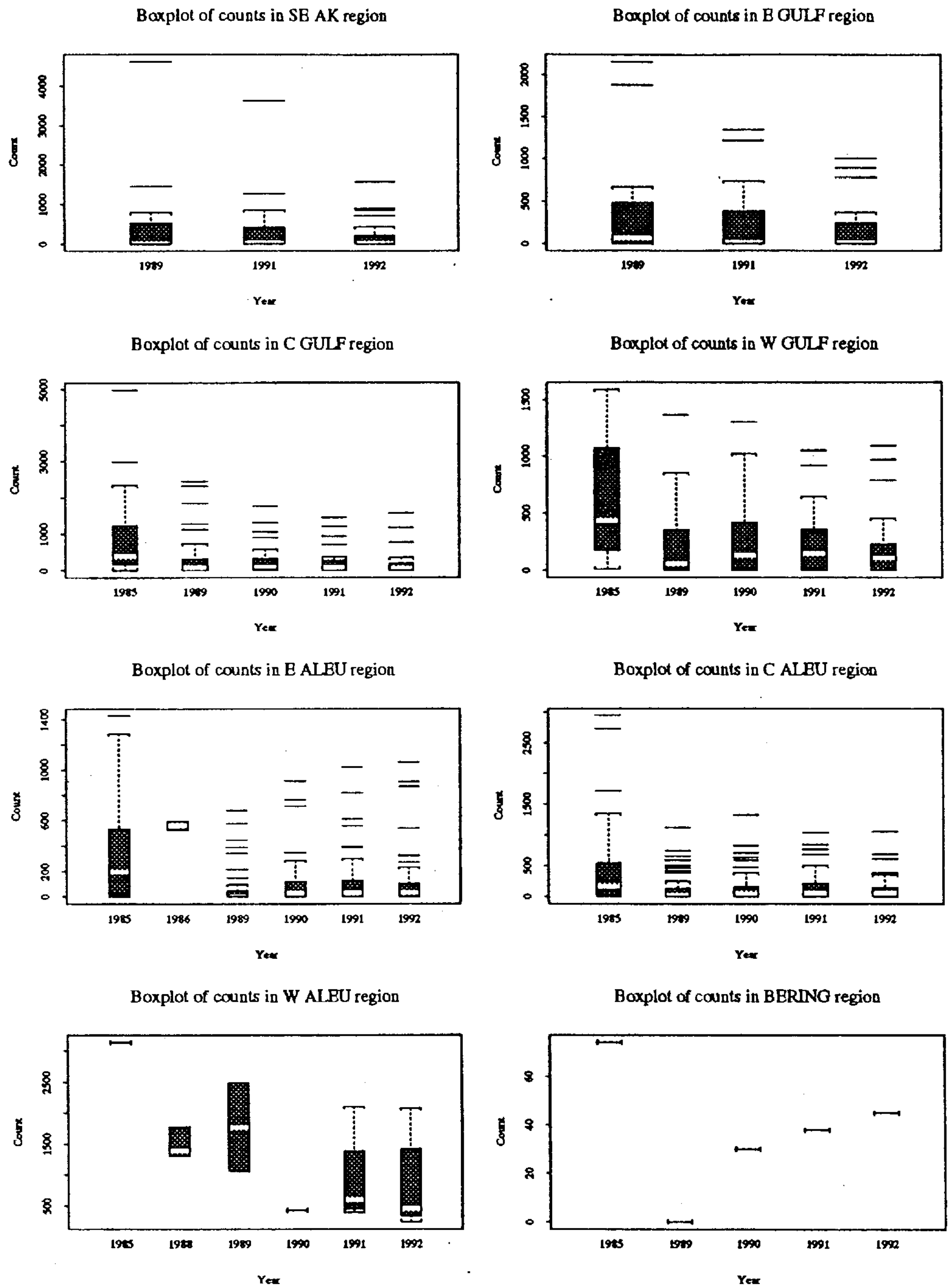

Figure 1: *Boxplots of regional June counts over time. Be aware that for each year different sites may be represented in the region counts. Refer to Table 1 for the number of sites sampled.*

it exhibits higher site counts with less inter-survey (day-to-day and hourly) variability.

Using the primary data we can examine the total sea lion index population for a given season by calculating the total count over all sites surveyed during that season. Unfortunately this value is only useful when compared to other season totals that have the same sites surveyed. For this reason, when comparing two seasons, only sites with data for both seasons will be used. In some earlier years this loss of data is great since surveys were not as thorough, but recent surveys are considerably more complete, allowing for minimal losses in data.

We define the *percent change for a year-pair* as 100 times the difference in index counts for two years divided by a reference year. That is, let y_1 denote the total count during the survey for the first year (t_1) in the year-pair, and let y_2 denote the total count during the survey for the second year (t_2) in the year-pair. Then $p(t_1, t_2) = 100 \times (y_2 - y_1)/y_1$ is defined as the percent change for a year-pair.

Unfortunately this method will only generate point estimates of the percent changes and not exhibit the uncertainty of the estimate. To demonstrate our uncertainty we must generate a confidence interval and consider the endpoints of these intervals as possible scenarios for estimating sea lion population trends.

2.3 Parametric Bootstrap

The parametric bootstrap is a useful tool to simulate data which can in turn be used to generate confidence intervals for statistics of interest (e.g., percent differences). The replicate data set was used to estimate the inter-survey variability of the counts at a particular site. Using this estimate of variability and some distributional assumptions, 1000 sets of data were simulated for the 1989–1992 year pair and the percent change was calculated for each of these simulations. Rationale for this procedure is discussed in Appendix A. Results are tabulated in Table 2. Note that the data have been broken down into three primary categories: Kenai-Kiska trend sites (KKT), Kenai-Kiska non-trend sites (KKNT), and remaining non-Kenai Kiska sites (NKK). For reference, a fourth category of Kenai-Kiska (KK) was also explored. The confidence intervals for KKNT and NKK are especially wide since inter-survey variability at those sites was estimated to be quite large. Several points to notice and consider are

- Both the KKT and NKK sites account for most of the counts for the sites that are common in the 1989–1992 year pair;
- Both the KKT and NKK sites exhibit a likely negative trend with the NKK sites exhibiting a clearly negative trend;
- A positive trend is noted for the KKNT sites, however the number of animals involved in this trend is only about 10% of the total animals surveyed;
- Nearly all KKT sites were surveyed in both 1989 and 1992, while many KKNT and NKK sites were not surveyed in both 1989 and 1992 making these estimates less

reliable than those for the KKT sites. These estimates are still very useful since most of the sites that were not surveyed in 1989 had low counts in 1992. (The apparent missing data is caused by the fact that extensive surveying was performed in 1992 where many more sites were sampled than in previous years).

Table 2: *Confidence intervals for percent change for the 1989–1992 year-pair using the parametric bootstrap. The average total count is the average total between the two years.*

Sites	Point Estimate	90% Confidence Interval	No. of Sites Included	Total Sites	Ave. Total Count
KK	-0.1107	(-6.2012, 6.8183)	124	190	23477
KKT	-4.0832	(-10.1981, 2.6213)	67	69	19504.5
KKNT	21.9894	(4.3876, 43.1337)	57	121	3972.5
NKK	-25.5142	(-37.9184, -6.9275)	37	62	12768

While carrying out this analysis it became apparent that the variability due to the counters is a great deal less than the inter-survey variability (day-to-day and hourly combined). In the worst case (KKT), the counter variability accounted for about 2.5% of the total variability; for KKNT, 0.42%; and for NKK, 0.34%. This result suggests that current counting techniques are sufficiently precise and do not contribute much to the uncertainty of estimation. Since the primary source of uncertainty is apparently inter-survey variability, it is this source of uncertainty that primarily drives the simulation models above. (Our analysis of variability does not discount the possibility of bias in the counting procedures – any consistent tendency to undercount or overcount animals present. Bias is discussed in more detail later.)

The simulation analysis was repeated on the 1991–1992 year-pair to examine if and how the most recent year trends have changed from those estimated for the 1989–1992 pair. While the KKT site percent changes appear to be similar (Table 3), one must consider that the 1991–1992 time interval is only over one year, while 1989–1992 considers 3 year time intervals. For this reason, the similar confidence interval suggests an accelerated decline. That is, the decline appears to be greater in the more recent years (1991–1992) when compared to 1989–1992. Within the 1991–1992 year pair, every KKT site was sampled making this estimate the most reliable estimate for recent trends.

The KKNT sites have shown a large shift (Table 3). Instead of showing continued growth, they are showing possible signs of a recent decline. Such a shift suggests that while an overall 1989–1992 increase has occurred, 1991–1992 recent trends indicate a decline. Similarly the KK sites (trend and non-trend sites) also show signs of a shift towards a recent decline in the 1991–1992 pair. This shift can be interpreted in the same way as the KKNT sites.

Table 3: *Confidence intervals for percent change for the 1991–1992 year-pair using the parametric bootstrap. The average total count is the average total between the two years.*

Sites	Point Estimate	90% Confidence Interval	No. of Sites Included	Total Sites	Ave. Total Count
KK	-4.6725	(-9.8043, 0.8518)	141	190	26294
KKT	-4.6004	(-9.9616, 1.2241)	69	69	21003.5
KKNT	-4.9585	(-16.4774, 9.5226)	72	121	5290.5
NKK	-4.4431	(-20.8327, 15.0412)	50	62	14634.5

2.4 Alternate Analyses: Generalized Linear Models (GLM)

Another strategy used to study the regional trends is to explore the coefficients of a generalized linear model. This approach was pursued in the Steller Sea Lion Workshop Report (1992). The model analyzed was log(adult/juvenile count) = Year + Site + Region * Year using the Gaussian family. By selecting a reference year of 1985, the coefficients of these models can be used to estimate the effect on the counts of a particular year (year/region) of interest when compared to the year 1985. At an even finer level one can analyze particular site trends.

We pursued a similar model and were able to duplicate the results found in the Workshop Report (Appendix D). The parameter estimates of this model are in agreement with the point estimates of the simulation analysis proposed above; however, under this scheme there is no reliable way to assess the variability of these estimates. The standard errors of the parameters may be biased by the non-normality of the data. Diagnostic plots of the residuals of this model suggest that the data is non-Gaussian, and variance is non-constant.

Since we were dealing with count data we also pursued a log-linear model with Poisson errors — a standard approach to analyzing count data. Building this model in a similar fashion to the one above we find again that parameter estimates are consistent with the earlier point estimates, but again the standard errors are unreliable. Under this modeling scenario the standard error estimates are unreliable because of the overdispersion of the data. That is, the variance of the dataset exceeds what is expected for Poisson modeling. Unfortunately when this sort of problem arises it is uncertain as to whether the overdispersion is caused by a poor fit of the model, true overdispersion of the data (perhaps latent variables), or both (McCullagh and Nelder 1989).

A final model using a square root transformation was explored. We have shown in Appendix A that under this transformation the variance is indeed stabilized. Fitting a linear model similar to the Workshop model (sqrt(adult/juvenile count) = Year + Site + Region * Year) we find that residual diagnostics are reasonable (residual variance is constant and residuals are approximately Gaussian). One could use this model in conjunction with the delta method, or use simulation (as above), to study confidence intervals for the percent change for various year-pairs, $p(t_1, t_2)$. The parametric bootstrap method was favored over

Table 4: *Estimated annual rates of change for all sites stratified by site size (mean count over 1989–1992). Rates greater than 100% indicate growth while rates less than 100% indicate decline. Also tabulated are total counts over 1989–1992 for all sites in each strata.*

Strata	number of sites	estimated rate (in %)	90% Confidence Interval	total count for 1989–1992	% of total
0–50	66	129.5	(109.2, 153.6)	4270	2.7
51–200	48	138.0	(112.8, 168.7)	18650	11.9
201–400	20	114.2	(90.2, 144.5)	21440	13.7
401–600	12	93.9	(80.5, 109.5)	20201	12.9
601–1000	12	103.5	(97.3, 110.0)	33914	21.6
1001–5000	12	86.7	(82.3, 91.4)	58553	37.3

the square root transformed linear model approach for simplicity.

2.5 Alternate Analyses: Generalized Estimating Equations

Generalized estimating equations (GEE) is yet another modeling approach to this trend estimation problem. The GEE approach exploits the time correlation structure within each site, a structure which GLM's do not account for. In addition, GEE provides robust and consistent estimates of model parameters and standard errors even if model assumptions are only weakly satisfied (Liang and Zeger, 1986). Although this GEE analysis incorporates all the primary data for 1989–1992, the replicate data are not utilized. In contrast, the parametric bootstrap approach utilizes the replicate data and overlooks some of the primary data (recall it only uses two years of data for each site, whereas here all four are used when available).

As with our GLM analysis, it was necessary to find a stable transformation of the count data in order to both satisfy model assumptions and to yield an interpretable model. The square-root transformation was quickly seen to be one appropriate transform as we have already discovered many times earlier. Unlike the parametric bootstrap where we can easily back transform to get estimates of rates, there is no such clear way to transform parameter estimates that GEE produces into interpretable rates. However, a log transform will allow for such an interpretation. More details of this analysis can be found in Appendix E.

To utilize a log transformation, the sites were classified into categories according to their size (mean counts over 1989–1992). The classes chosen are as follows: 0–50, 51–200, 201–400, 401–600, 601–1000, 1001–5000. When focusing on these narrow ranges of sites, the GEE model assumptions are more reasonably satisfied. Also, examining the sites by size allows us to investigate what sizes of sites are undergoing the most rapid population changes over 1989–1992. Table 4 summarizes the estimated rates when focusing on all sites and Table 5 displays a similar summary for KKT sites.

The 90% confidence intervals in Tables 4 and 5 immediately indicate that there is still

Table 5: *Estimated rates of change for KKT sites stratified by site size (mean count over 1989–1992). Rates greater than 100% indicate growth while rates less than 100% indicate decline. Also tabulated are total counts over 1989–1992 for all sites in each strata.*

Strata	number of sites	estimated rate (in %)	90% Confidence Interval	total count for 1989–1992	% of total
0–50	15	133.1	(99.6, 177.8)	1489	1.7
51–200	21	106.9	(84.6, 135.0)	8670	10.2
201–400	9	93.0	(88.9, 97.3)	10617	12.5
401–600	6	103.9	(83.7, 129.0)	10986	12.9
601–1000	9	105.6	(99.9, 111.5)	27008	31.7
1001–5000	5	88.4	(85.0, 91.9)	26439	31.0

a great deal of unexplained variability as also noted in the parametric bootstrap model and variance components analysis.

When considering all sites, one should be concerned about trends of the largest sites (i.e., those with highest number of individuals) since about 37% of the total counts are observed in this strata. Note that the estimated decline is between 9 and 18% per year. Furthermore, all but the smallest two strata (i.e., those with fewer individuals) are showing no significant signs of increase. The increase of the small strata, though statistically significant, may not account for the apparent large decline in the largest stratum. These findings are parallel to the parametric bootstrap model findings indicating that the NKK sites were showing a large significant decline from 1989–1992.

Focusing on the KKT sites, the largest sites (1001–5000) are shown to have a significant decline of at least 8% per year. However, the next largest sites (601–1000) are likely to be increasing by as much as about 12%. Each of these strata accounts for about 30% of the total counts observed from 1989–1992. One hypothesis is that the animals are relocating from the largest sites into smaller ones explaining both the apparent decline and increase in the various strata of the KKT sites. Ideally a pooled estimate would be generated that would summarize the trend rate over all strata, but this is not possible in the framework of this model as such an estimate would involve violating modeling assumptions.

It should be noted that the stratified analysis produced above could also be pursued in the GLM framework; however, GEE standard error estimates are known to be robust even when model assumptions are somewhat violated. This robustness is not characteristic of GLMs, hence the GEE analysis is preferred.

3 Discussion

For the parametric bootstrapping procedure, 90% confidence interval estimates for the 1989–1992 percent decline suggest as much as a 10% decline in the KKT sites (the point estimate suggesting a 4% decline) or as much as a 2% growth. This interval estimate is believed to be very reliable since nearly every KKT site was included in the analysis and a large proportion of the total animals surveyed (55%) are included in the KKT sites. The KKNT sites have shown some signs of growth (at least 4%) during the 1989–1992 year pair; however, the number of animals involved is few (10% of the total number surveyed) and the number of sites sampled during both of these times is incomplete. Thus, this estimate is rather unreliable. Finally, the NKK sites show fairly clear signs of decline during 1989–1992. Although many sites were not represented in both years, nearly 35% of the total animals surveyed occurred in the NKK sites. The interval estimate suggests at least a 6.9% decline in the population between 1989 and 1992 for the NKK sites.

The 1991–1992 year-pair differed dramatically from the 1989–1992 pair in two regards: for the KKNT sites where intervals shifted negatively; for the NKK sites the 1989–1992 comparison is strongly negative whereas the 1991–1992 comparision is less negative.

The main strength of the above parametric bootstrap analysis is also its weakness. The final interval estimates can be somewhat inconclusive. It is important to consider that two scenarios are supported by some of these confidence intervals. For example, when the uncertainty of the percent change estimate is considered, we find that there may be as much as a 2% growth in the KKT sites or as much as a 10% decline. Unfortunately there does not seem to be an easy way around this estimation problem. Current survey techniques are not able to control the day to day and hourly variability of the sea lions. The 1992 replicate survey is a major advancement. Prior to this survey there was no reliable source to estimate the intrinsic variability of the data. In the future, even more thorough surveys focusing on perhaps a selected set of sites may help to further our knowledge of the daily variability. Currently, within the time frame of interest, we were forced to use variance estimates based on only two observations per site. Having more observations with which to estimate variance we could possibly improve the interval estimation.

The GEE analyses offer a complimentary view to the parametric bootstrap. The dominating decline of the large KKT sites and the apparent growth of the smaller KKT sites indicates that it is likely the population is undergoing a sort of redistribution over the KKT sites. This movement acts as "noise" in any trend estimation procedure, therefore the observed wide confidence intervals throughout all analyses are not surprising. Viewing the sites together as a whole, a decline of of between 9 and 18% is noted for the largest sites which comprise about 37% of the total number of animals counted from 1989–1992. The smaller sites ($<$ 200 animals) are showing signs of growth, while the intermediate sites (between 200 and 1000) animals indicate stability. If there is any trend as a whole for the 1989-1992 period it is likely downward because the growth of the smaller sites may not counteract the decline of the larger. Both the parametric bootstrap and GEE analyses hint that further investigation into the NKK sites is warranted.

Some items were not considered in this report:

- Weather effects.
- How to utilize information outside the "season".

• Counter bias.

Current data do not indicate weather conditions during surveys. We have found that weather could significantly influence the sea lion count. For example, while exploring the hourly dataset we noticed that one site on a particular day had variability that was an order of magnitude higher than previous and later days. Further investigation revealed that on this day a severe storm passed through (Merrick, R. 1993, pers. comm.).

This report only considers data within a season (June 10 to June 30). These dates were chosen based on sealion breeding behavior, leading to higher and more stable counts. Although there is not a surplus of data, it could be beneficial to construct methods to incorporate counting information outside the June 10-30 period into a model.

Because counter variability was found to be negligible relative to inter-survey variability, if a bias were present it would not dramatically affect variance estimates. A bias could, however, change the interval's location somewhat, shifting it positive or negative. The difficulty of examining for bias arises when the counters differ by more than 10% and a third counter is introduced. For example, if counter one is biased negatively, counter two is unbiased, and counter three is biased positively, the net result may be nearly unbiased. Examining the data actually used in our analysis (replacing the "faulty count" with a third counter's count), a sign test on the resulting counts does not suggest any bias (p-value = 0.18). Again, each counter may have a bias, but as mentioned above, it is undetectable. It is our opinion, from examining samples of aerial still photos and aerial videos, that counting bias is not an important factor. The process of enumerating sea lions on rookeries using airplanes is straightforward and has been scientifically developed and refined over many years.

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Appendices

A Parametric Bootstrap

The parametric bootstrap was used to simulate data for the individual sites in a given year-pair. These simulations were in turn used to create a reference distribution for the statistic of interest: the percent change, $p(t_1, t_2)$. In order to use the parametric bootstrap two main assumptions were made:

1. Under the square root transformation, the day-to-day and counter variability from site to site is approximately constant.

2. The underlying distribution of the square root of counts at a particular site is approximately Gaussian.

Using variance components analysis on the 1992 replicate data we found that the day-to-day variability considerably outweighed the counter variability (Tables 6 – 8). Performing this analysis and analyzing the residuals all under a square root transform helps validate our first assumption of constant variance at least when considering similar sites (i.e. KKT, KKNT, or NKK). Log transformations were considered, but the square root seemed to stabilize the variance better. The upper plots in Figure 2 are residuals from the variance components analysis of the Kenai-Kiska trend sites. Neither plot is desirable; however the square root plot seems to be in general more stable with the exception of a few points. The residual plot under the log transform seems to increase in variance with the fitted values. The second (bottom) set of plots is more informative. These plots are perhaps more standard as they demonstrate the estimates of variance (standard deviation) relative to the mean. Here we see that perhaps the log transform is a bit too strong: the estimates clearly decrease with the mean. The square root does not show this tendency. Both plots appear distorted due to the large number of observations with small means, but this is not an artifact of the transformations, it reflects the nature of the data.

Simulations were carried out under both transformations. Point estimates under both transformations were consistent with the data; however, confidence intervals generated under the log transformation were unreasonably wide and incongruent with the data. Again, the square root transformation is favored.

Although considerably older, outside the time frame of interest, and from land based surveys, not aerial counts, variance estimates from the daily and hourly datasets do not contradict the variance estimates found below using the square root transformation.

Let σ_ϵ^2 denote the counter variance, σ_t^2 denote the survey variance, and $\sigma^2 = \sigma_\epsilon^2/2 + \sigma_t^2$ denote the estimated variance for a particular class of sites (KKT, KKNT, or NKK) from the replicate dataset. Finally, let $x_i(t)$ denote the count at site i at time t obtained from the primary dataset. Then for time t, to generate a parametric bootstrap sample of size 1000 for the total yearly count the following steps are taken:

1. Randomly sample 1000 observations from a Gaussian distribution with mean $\sqrt{x_i(t)}$ and variance σ^2.

2. Square the simulated values.
3. Repeat 1 and 2 for each site.
4. Sum over sites.

(Note: in essence we are generating a non-central Chi-squared distribution which is reasonable since the mean of a chi-squared distribution is proportional to its variance)

For any year-pair we can perform this procedure to simulate a reference distribution for $p(t_1, t_2)$, the percent change for the year pair t_1, t_2. Using this reference distribution we can use the upper and lower 5% quantiles as estimates for the endpoints of a 90% confidence interval. The 50% quantile (median) will be similar to the point estimate for $p(t_1, t_2)$ using the original (un-simulated) data.

Estimated variances based on a balanced design[1] are calculated by computing

$$\hat{\sigma_t^2} = \frac{1}{2}(MS_{survey} - MS_{counter})$$

for inter-survey variability, and

$$\hat{\sigma_\epsilon^2} = MS_{counter}$$

for counter variability.

Table 6: *Variance components analysis of the square root of counts at KKT sites.*

Source	Df	Sum of Sq.	Mean Sq.	EMS
site	79	33867.43	428.7016	$\sigma_\epsilon^2 + 2\sigma_t^2 + 4\sigma_s^2$
survey nested in site	80	590.62	7.3827	$\sigma_\epsilon^2 + 2\sigma_t^2$
counter	160	16.50	0.1031	σ_ϵ^2

Estimated survey variance = $\hat{\sigma_t^2} \approx 3.64$
Estimated counter variance = $\hat{\sigma_\epsilon^2} \approx 0.10$
site variance = σ_s^2

[1]These formulas and the expected mean squares as given in Table 6 are for a balanced design (2 surveys and 2 counts at each site). The actual data have a few missing values; the formulas for EMS with missing data are too complicated to include here.

Table 7: *Variance components analysis of the square root of counts at KKNT sites.*

Source	Df	Sum of Sq.	Mean Sq.	EMS
site	15	1854.175	123.6117	$\sigma_\epsilon^2 + 2\sigma_t^2 + 4\sigma_s^2$
survey nested in site	16	152.881	9.5551	$\sigma_\epsilon^2 + 2\sigma_t^2$
counter	32	0.684	0.0214	σ_ϵ^2

Estimated survey variance = $\hat{\sigma}_t^2 \approx 4.78$
Estimated counter variance = $\hat{\sigma}_\epsilon^2 \approx 0.02$
site variance = σ_s^2

Table 8: *Variance components analysis of the square root of counts at NKK sites.*

Source	Df	Sum of Sq.	Mean Sq.	EMS
site	6	3463.604	577.2673	$\sigma_\epsilon^2 + 2\sigma_t^2 + 4\sigma_s^2$
survey nested in site	7	364.147	52.0210	$\sigma_\epsilon^2 + 2\sigma_t^2$
counter	14	1.194	0.0853	σ_ϵ^2

Estimated survey variance = $\hat{\sigma}_t^2 \approx 26.0$
Estimated counter variance = $\hat{\sigma}_\epsilon^2 \approx 0.09$
site variance = σ_s^2

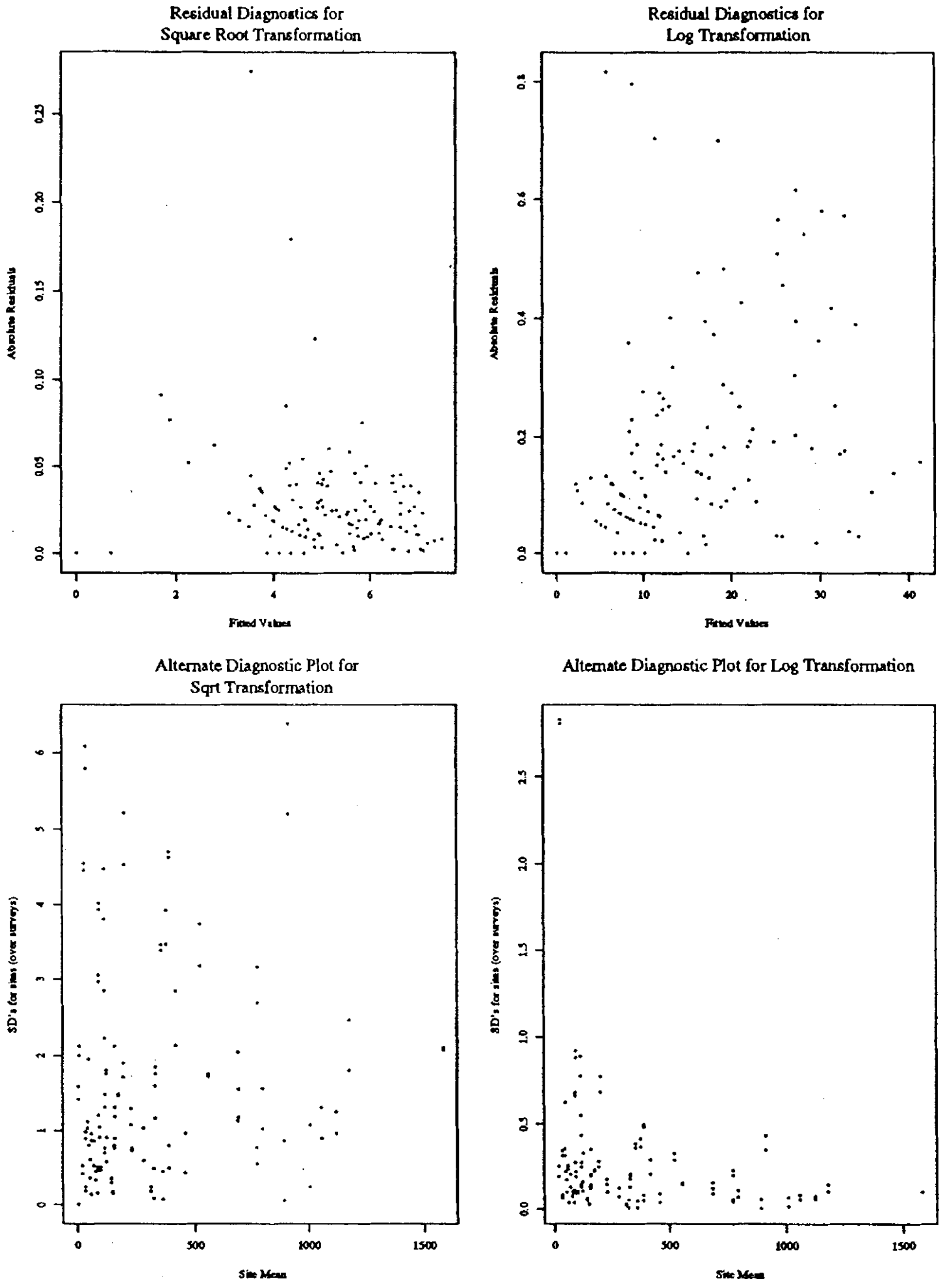


Figure 2: *Diagnostic plots motivating the use of the square root transformation versus logarithm. The upper plots are residuals from the variance components analysis of KKT sites. The lower plots compare standard deviation estimates against site means of KKT sites.*

B CV Plots

A standard practice when analyzing count data is to study the coefficient of variation. It is often the case that the CV will be constant with the mean. That is, the increase in variability (standard deviation) is proportional to the mean. Here, plots suggest that this is not the case (Figure 3). Analyzing the slope of the least squares line we find that it is significantly negative suggesting that the CV does indeed significantly decrease with the mean.

This relationship further supports our choice to not use the log transform as discussed in Appendix A. Log transforms are used when CV is believed to be constant with mean. We have shown earlier that this transformation would be too strong.

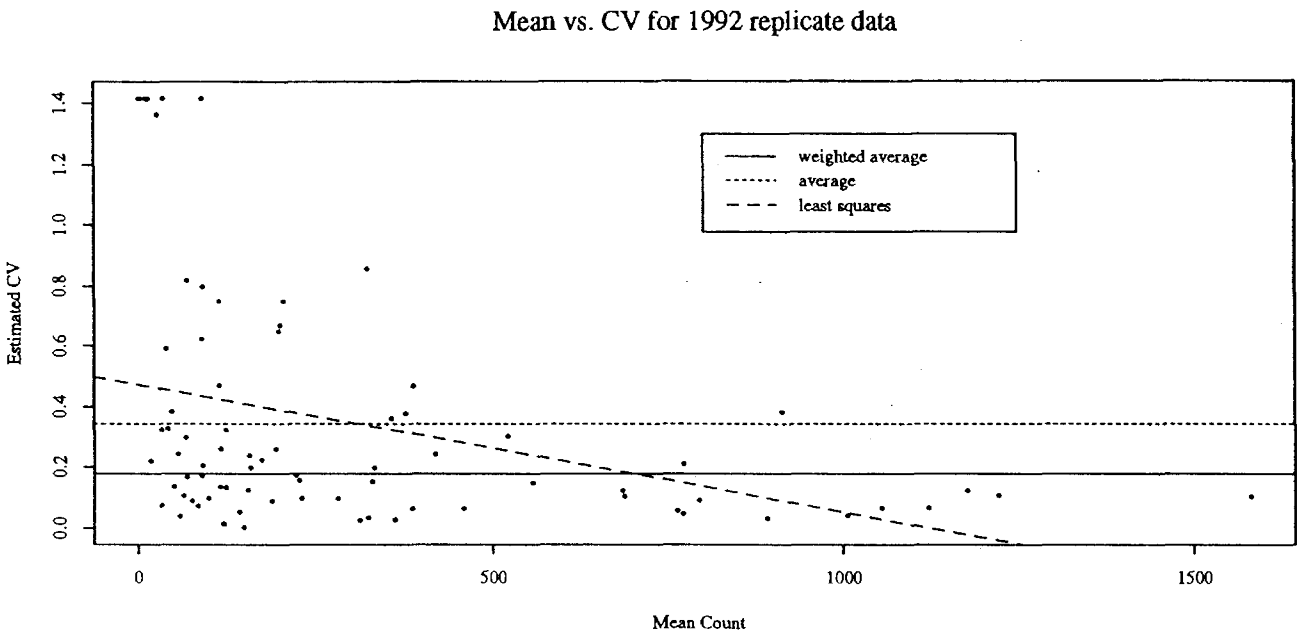


Figure 3: *Plot of the inter-survey coefficient of variation against the mean counts for the 1992 replicate dataset. The three lines suggest possible summaries of the estimated CV: average, average weighed by mean counts and a regression line.*

C Daily Data

To support our variance estimates found using variance components analysis we examined the daily dataset. Figure 4 displays plots for the most recent data for three of the four of the sites surveyed in that study (Sugarloaf Island had two sub-areas surveyed). Rouge Reef was omitted as it is not in Alaska, but in Oregon. The plots of Ugamak and Sugarloaf suggest why the timing of the survey is critical. The critical period of interest (June 10 - June 30) clearly shows both higher and more stable counts. Marmot Island demonstrates that even during times that we expect stability, there can still be a considerable amount of instability.

Using the time interval of interest, we computed variances for counts (under square root transform) taken at one week intervals. That is, the variance for square root of counts for day 1 and 7, 2 and 8 and so on. Of the sites mentioned above, only Marmot Island and Ugamak Island had sufficient data for any meaningful analysis. Sugarloaf was missing several days during the interval of interest. Table 9 lists the estimates. These values should be compared to the estimated inter-survey variance from the variance components analysis $\hat{\sigma}_t^2 \approx 3.9$.

Table 9: *Inter-Survey variance estimates (one week intervals) at Ugamak Island 1986 and Marmot Island 1983.*

Ugamak Island 1986	Marmot Island 1983
0.439	28.275
0.042	4.110
0.008	1.098
0.550	2.339
0.529	5.369
3.804	3.883
NA	13.549

We immediately notice that our inter-survey variance estimate of 3.9 seems very large when compared to Ugamak. We should not be surprised by this difference, since our estimate is based on many sites and we are comparing it to only one. Furthermore, we have observed that there does seem to be a relationship between variance and counts. Couple this relationship with the likely downward trend in KKT sites, and we would almost expect these estimates to differ. The inter-survey variance estimates at Marmot seem to support our variance components estimates. In any event, we find that our estimates of inter-survey variability do not seem to be unreasonable.

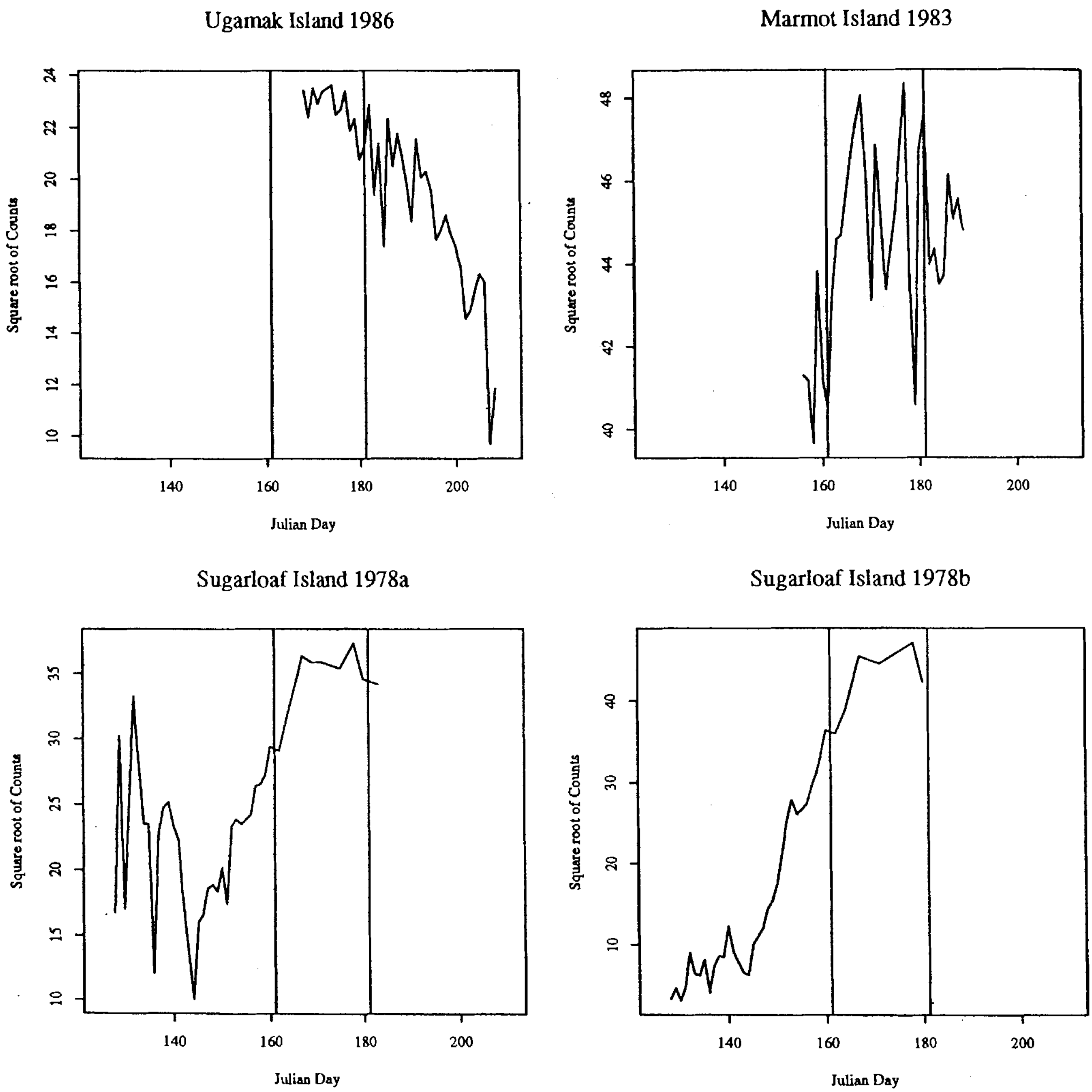


Figure 4: *Daily counts (on square root scale) plotted against time at Ugamak Island 1986, Marmot Island 1983, and Sugarloaf Island 1978. The dates of interest are from Julian Day 161 (June 10) until Julian Day 181 (June 30).*

D GLM analysis

An attempt to replicate the GLM model found in the Workshop report can be found in Table 10. This model considered only Kenai-Kiska trend sites which were rookeries during 1985, 1989-1991. A general Gaussian linear model was fit to predict the natural logarithm of the counts as a function of the site, year and region. Diagnostics for this particular model were unreasonable. Figure 5 displays residual plots and Gaussian quantile plots. The absolute residuals seem to decrease with the predicted value and the curvature in the quantile-quantile plot suggests a departure from normality suggesting that the log transform is too strong. The Workshop model was also fit to the entire KKT 1895–1992 dataset in both a Gaussian and Poisson framework. Residual plots for these models can be found in Figure 6. Parameter estimates for these models are not included as these models did not satisfy the modeling assumptions.

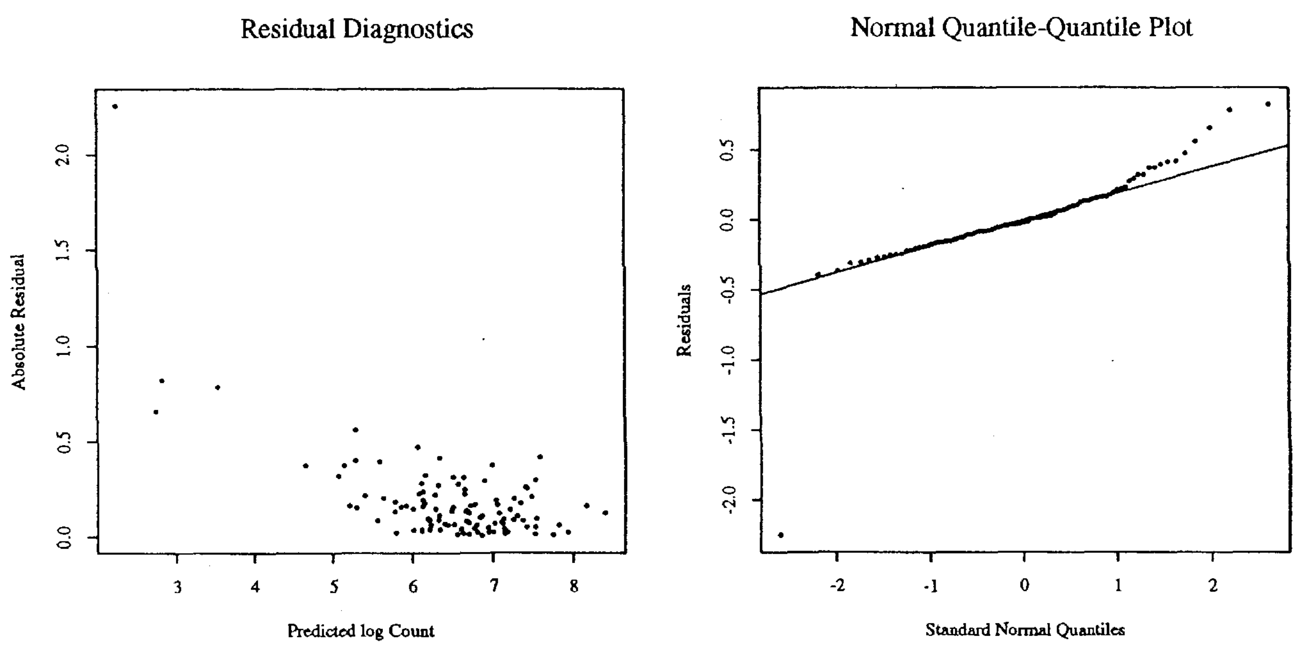


Figure 5: *Residual Diagnostics for the Workshop model. Notice the potential non-constant variance of the residuals (first plot) and the non-linearity of the quantile-quantile plot (second plot).*

Finally, a normal linear model using a square root transformation was fit: sqrt(count) = Year + Site + Region*Year. Under this model, the modeling assumptions appear to be better satisfied than the above model. Diagnostic plots (Figure 7) demonstrate that the constant variance assumption is reasonable. We do notice that there is a departure from the normality assumption in the tails. The distribution of the residuals seems to have heavier

Table 10: *GLM Gaussian parameter estimates for survey count data during 1985, 1989-1991 at Kenai-Kiska trend rookeries. The reference year is 1985 and the reference region is C GULF. The parameter estimates are factor effects relative to the aforementioned reference levels. The fitted model is log(count) = Year + Site + Region*Year. This model is the same as the model described in the Workshop report.*

	Value	Std. Error	t value
(Intercept)	7.2484	0.2237	32.4027
year1989	-0.6442	0.2668	-2.4147
year1990	-0.8701	0.2792	-3.1167
year1991	-1.0232	0.2792	-3.6651
site.num4	-1.0390	0.2792	-3.7217
site.num17	-0.5330	0.3042	-1.7521
site.num23	0.1651	0.2792	0.5913
site.num33	-0.0435	0.2792	-0.1557
site.num35	0.0036	0.3042	0.0118
site.num36	-0.2029	0.3042	-0.6669
site.num51	0.3259	0.2792	1.1673
site.num56	-0.2125	0.2792	-0.7611
site.num62	0.6850	0.2792	2.4537
site.num65	-0.3152	0.2792	-1.1291
site.num66	-0.3917	0.3219	-1.2170
site.num69	-1.3326	0.3219	-4.1396
site.num71	0.1539	0.3219	0.4780
site.num75	-0.6871	0.3219	-2.1346
site.num77	0.0855	0.3219	0.2657
site.num82	-0.9095	0.3219	-2.8254
site.num87	-3.7235	0.3219	-11.5670
site.num93	0.2221	0.3219	0.6901
site.num109	-0.2643	0.3439	-0.7686
site.num114	-0.7489	0.3439	-2.1779
site.num115	-0.1036	0.3439	-0.3011
site.num120	0.1671	0.3439	0.4859
site.num139	0.5692	0.3432	1.6582
site.num140	0.2873	0.3432	0.8371
site.num146	1.1434	0.3432	3.3313
site.num157	0.9141	0.3383	2.7024
year1989:W GULF	0.3576	0.3861	0.9260
year1990:W GULF	0.5552	0.3948	1.4061
year1991:W GULF	0.6823	0.3948	1.7281
year1989:E ALEU	-0.6318	0.3319	-1.9039
year1990:E ALEU	0.0939	0.3419	0.2747
year1991:E ALEU	0.3186	0.3419	0.9319
year1989:C ALEU	-0.2868	0.3154	-0.9091
year1990:C ALEU	0.0609	0.3367	0.1810
year1991:C ALEU	0.1063	0.3260	0.3261

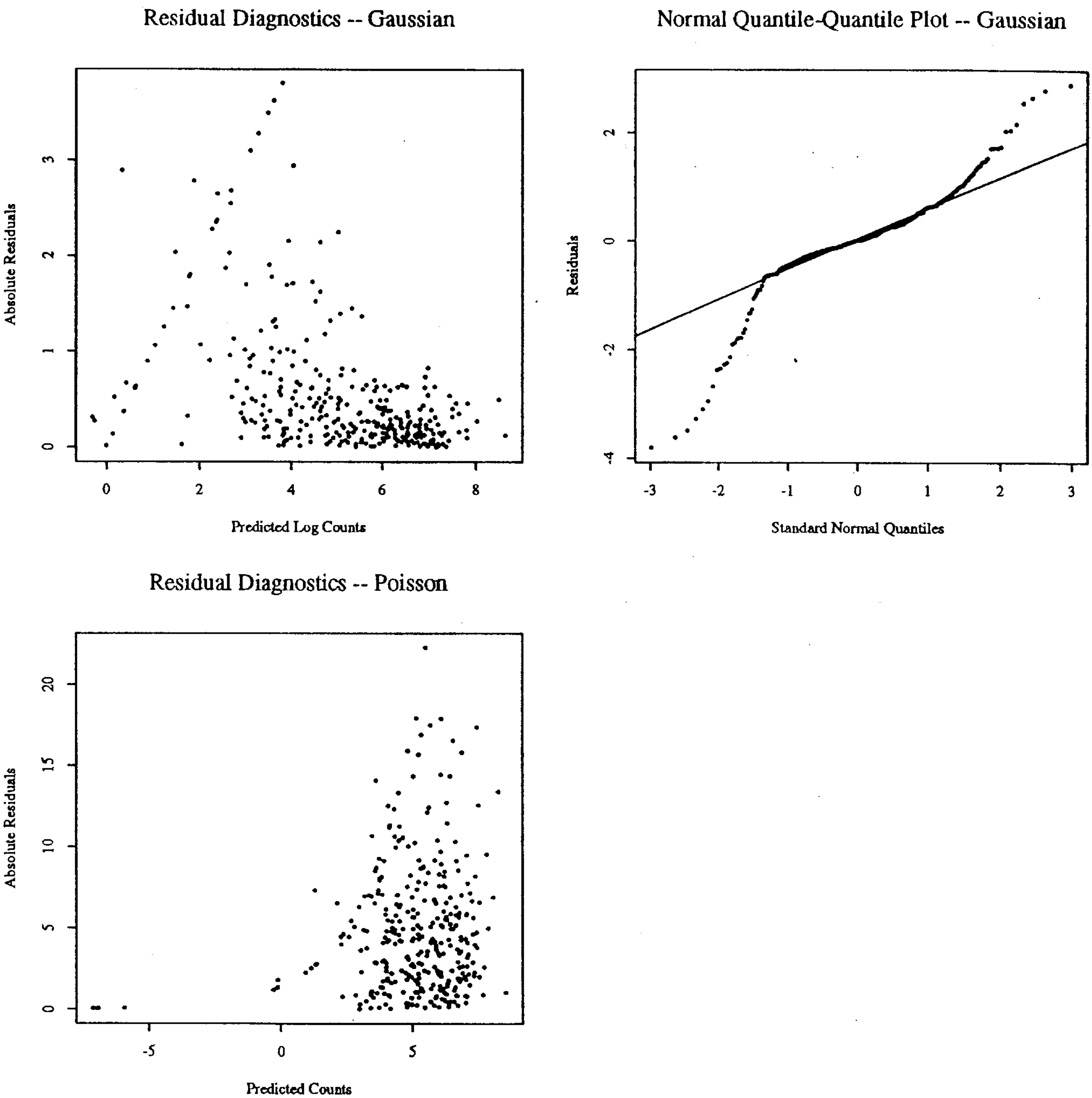


Figure 6: *Residual Diagnostics for GLM models for 1985–1992 KKT sites. The upper plots are residual diagnostics from a Gaussian model under a log transformation, the lower plot is from a Poisson (log-linear) model. The strange linear pattern in the first plot is caused by sites with zero counts. Also in the first plot the variance is seen to decrease with predicted value. For the poisson model the opposite problem is noted, the variance increases with predicted value.*

tails than that of a Gaussian distribution. Parameter estimates for the square-root model fitted to rookery and haulout count data can be found in Table 11.

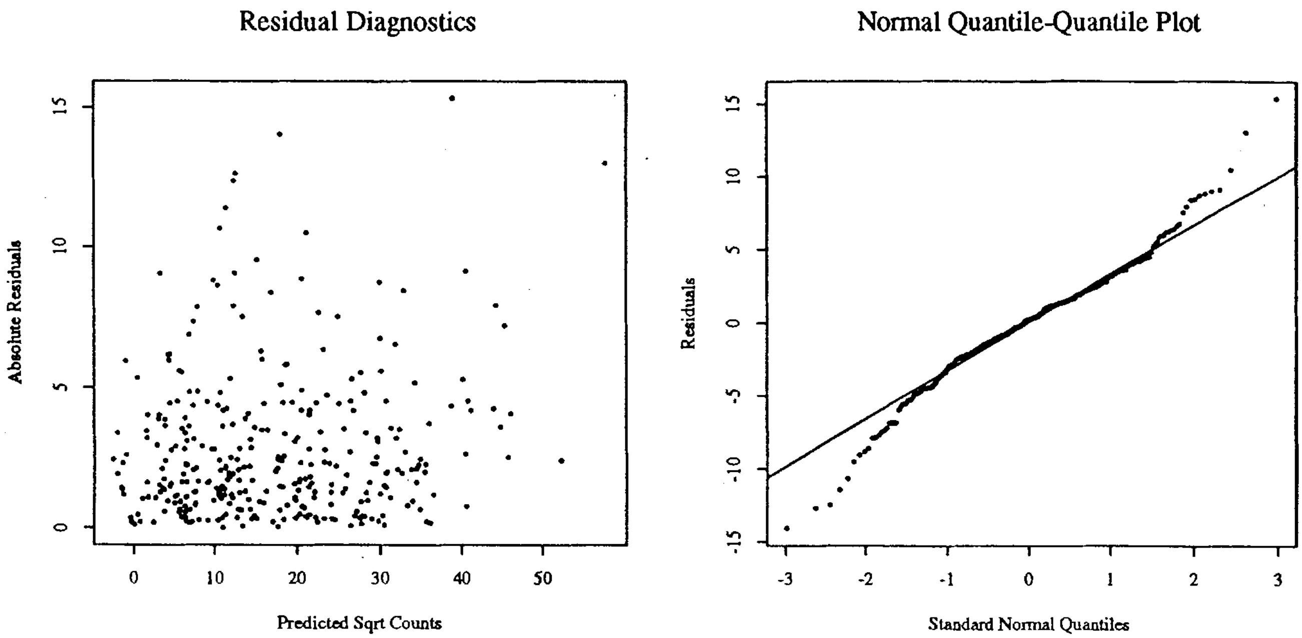


Figure 7: *Residual Diagnostics for the Gaussian linear model under a square root transformation for 1985–1992 KKT sites.*

Table 11: *GLM Gaussian parameter estimates for survey count data during 1985, 1989-1991 at Kenai-Kiska trend rookeries and haulouts. The reference year is 1985 and the reference region is C GULF. The parameter estimates are factor effects relative to the aforementioned reference levels. The fitted model is square-root(count) = Year + Site + Region*Year.*

	Value	Std. Error	t value
(Intercept)	6.8987	2.0819	3.3137
year1986	-0.7615	3.5880	-0.2122
year1989	-11.7870	1.5631	-7.5406
year1990	-11.4838	1.6046	-7.1568
year1991	-12.1509	1.6046	-7.5725
year1992	-13.5663	1.6046	-8.4546
site.num3	26.9414	2.7793	9.6937
site.num4	15.5573	2.7793	5.5976
site.num5	5.7592	2.7793	2.0722
site.num7	0.4890	2.9535	0.1656
site.num8	14.2971	2.7793	5.1442
site.num9	0.0000	2.7793	0.0000
site.num10	8.8019	2.7793	3.1670
site.num13	7.7530	2.7793	2.7896
site.num14	7.4985	2.7793	2.6980
site.num17	20.1800	2.9535	6.8326
site.num18	5.1211	2.7793	1.8426
site.num19	8.8939	2.7793	3.2001
site.num20	13.4099	2.7793	4.8250
site.num23	28.8042	2.7793	10.3640
site.num25	7.5680	2.7793	2.7230
site.num27	0.0000	2.7793	0.0000
site.num29	6.9278	2.7793	2.4927
site.num33	25.2344	2.7793	9.0795
site.num34	2.9319	2.7793	1.0549
site.num35	26.0486	2.9535	8.8196
site.num36	23.0870	2.9535	7.8169
site.num46	11.7128	2.7793	4.2144
site.num47	1.0000	2.7793	0.3598
site.num49	14.6870	2.7793	5.2845
site.num51	32.0346	2.7793	11.5263
site.num55	0.0000	2.7793	0.0000
site.num56	23.4179	2.7793	8.4259
site.num58	9.2226	2.7793	3.3183

	Value	Std. Error	t value
site.num61	5.5031	2.7793	1.9800
site.num62	37.4044	2.7793	13.4584
site.num64	13.2301	2.7793	4.7603
site.num65	22.7722	2.7793	8.1936
site.num66	19.8152	3.0796	6.4344
site.num69	12.9531	3.0796	4.2061
site.num71	28.0687	3.0796	9.1144
site.num73	6.5589	3.0796	2.1298
site.num75	17.1297	3.0269	5.6592
site.num76	18.0269	3.0269	5.9556
site.num77	25.4797	3.0796	8.2737
site.num82	15.1840	3.0796	4.9305
site.num87	3.7597	3.0796	1.2209
site.num93	28.6552	3.0796	9.3049
site.num95	7.5498	3.0796	2.4516
site.num108	3.7570	3.0796	1.2200
site.num109	27.4400	3.1485	8.7153
site.num111	9.6243	3.1485	3.0568
site.num112	5.6374	3.1485	1.7905
site.num114	20.7184	3.1485	6.5804
site.num115	29.6627	3.1485	9.4212
site.num118	2.1423	3.1485	0.6804
site.num120	33.7249	3.1485	10.7115
site.num123	10.5181	3.1485	3.3407
site.num125	10.0964	3.1485	3.2067
site.num135	5.3677	3.0366	1.7676
site.num136	16.2792	3.0366	5.3609
site.num138	19.4687	3.0366	6.4113
site.num139	37.9516	3.0366	12.4979
site.num140	34.2987	3.0366	11.2950
site.num144	25.0427	3.0366	8.2469
site.num145	11.1476	3.0366	3.6710
site.num146	50.6695	3.0366	16.6861
site.num152	23.0297	2.9466	7.8156
site.num153	12.5702	3.0366	4.1395
site.num157	45.4132	2.9466	15.4120
site.num158	15.7671	3.0366	5.1923
site.num161	25.1351	3.0366	8.2773
site.num162	11.7940	3.0366	3.8839
site.num165	8.3911	3.0366	2.7633

	Value	Std. Error	t value
year1989region C ALEU	2.9745	1.9010	1.5647
year1990region C ALEU	3.3950	1.9611	1.7311
year1991region C ALEU	3.8988	1.9352	2.0146
year1992region C ALEU	4.2262	1.9352	2.1838
year1989region E ALEU	2.7509	2.3795	1.1561
year1990region E ALEU	4.5666	2.4069	1.8973
year1991region E ALEU	6.0896	2.4069	2.5301
year1992region E ALEU	9.2408	2.4069	3.8393
year1989region W GULF	5.9051	2.5951	2.2754
year1990region W GULF	5.3790	2.6203	2.0528
year1991region W GULF	6.0091	2.6203	2.2933
year1992region W GULF	6.9442	2.6203	2.6502

Since the square root transformation seems to give constant variability in this case, if we were to use this model to generate simulated site values as we did earlier in the parametric bootstrap, we should draw similar conclusions. Note, however, that the parametric bootstrap uses the replicate data, whereas the GLM technique does not.

The use of the parametric bootstrap seems to address the questions at hand by more directly summarizing the individual sources of variability first using the replicate data, and then simulating values using the primary data. However, future investigation with GLM models using square-root transformations may be warranted, for interval estimates of the time trend parameter.

E GEE Analysis

The Splus implementation used for this GEE analysis was authored by Terry Therneau of the Mayo Clinic. The Splus source code can be downloaded via anonymous ftp to statlib.cmu.edu.

Before modeling the data, minor adjustments to the data had to be performed. To simplify the analysis, all sites with zero-mean over 1989–1992 were removed as these sites provide no useful information for predicting time trend effects. Three sites had to have their 1989 data adjusted so that each year would have only one observation for each site. The sites adjusted were Sud, Ushagat, and Sugarloaf. These three sites had observations on both June 13 and 17, 1989 which are both in the June 10-30 time window. To remedy this problem, the average for those days was used. Finally, sites with only one observation in the 1989–1992 period were removed as these sites also provide no information regarding trend estimates.

A Gaussian family GEE model was fit for each strata with log(count + 1) as the response and (year - 1989) as the predictor. (One was added to the counts to eliminate problems with zero counts. This adjustment is negligible; especially in the larger strata.) The sites served as the natural clusters used to estimate the intra-site serial correlation. The strata (based on overall site means for 1989–1992) were chosen to both exploit the natural divisions in site sizes and to provide enough strata so that the log transformed model would yield reasonable residual diagnostics. No transformation and the square-root transformation were also considered, but rejected as the coefficients would not be interpretable as annual rates of change.

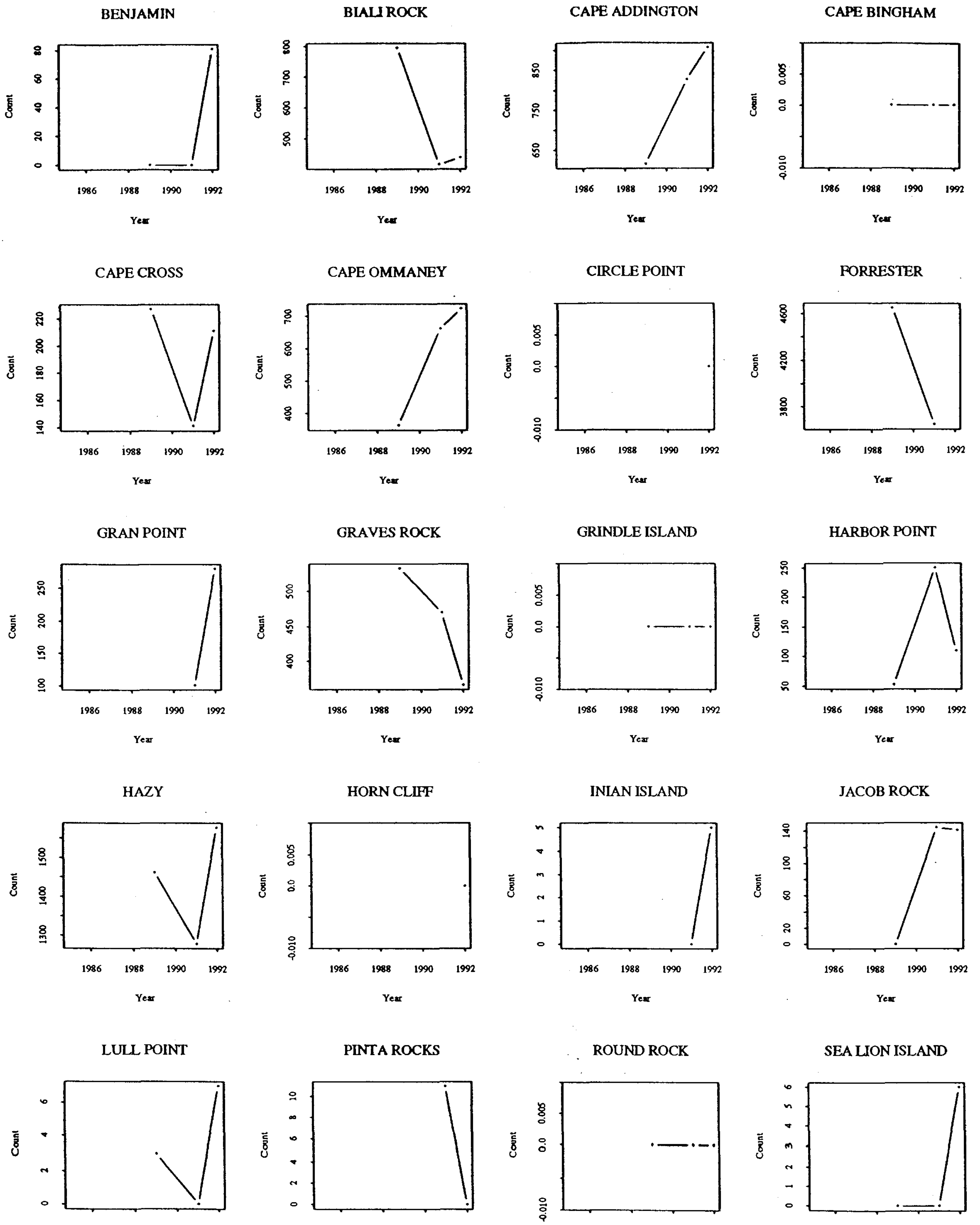
Because of missing data (some sites had observations for fewer than all four years) the GEE analysis was extremely attractive since it handles missing data well. To properly estimate the correlation structure of the time dependence, an "exchangeable" correlation structure was assumed. The exchangeable structure assumes that the correlation between deviations from the expected values for any two years is constant. The GEE analysis, however, is extremely robust to the choice of correlation structures so almost any reasonable structure could have been chosen.

For further details regarding the inner workings of GEE and its relationship to GLM see Liang and Zeger (1986).

F Site Plots

The following several pages contain plots of site counts versus year. The plots are organized by region. Recall that the Kenai-Kiska sites are those sites in the Central Gulf of Alaska (C GULF), Western Gulf (W GULF), Eastern Aleutian Islands (E ALEU), and Central Aleutian Islands (C ALEU). It is important to keep in mind that the y-axes of these plots are on varying scales. The scale for a given plot has been chosen to most clearly show trends. When comparing two or more sites be sure to take note of the scales to better understand how many animals are involved at each of the sites. For example, in the Western Gulf the negative trend at Atkins is much stronger than the positive trend at Castle Rock because of the shear number of animals involved (1500 versus 80).

SE AK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CAPE ADDINGTON
CAPE BINGHAM
CAPE CROSS
CAPE OMMANEY
CIRCLE POINT
FORRESTER
GRAN POINT
GRAVES ROCK
GRINDLE ISLAND
HARBOR POINT
HAZY
HORN CLIFF
INIAN ISLAND
JACOB ROCK
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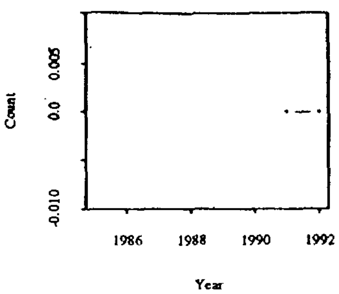
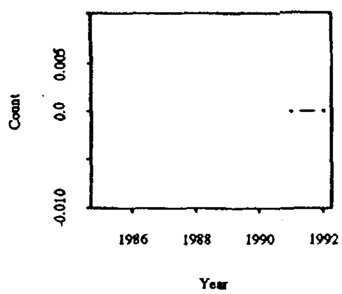
1992

SE AK

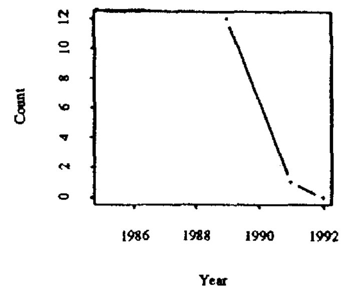
ST. LAZARIA ISLAND



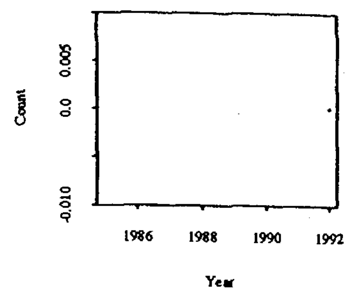
STEVENS PASSAGE



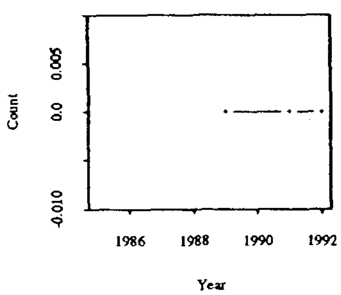
SUNSET ISLAND



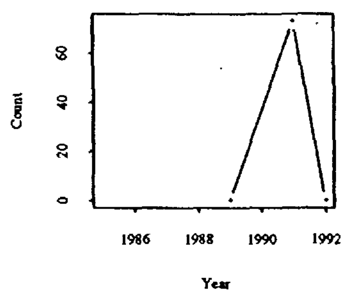
TAKU POINT



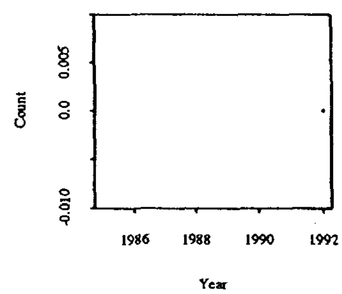
TENAKEE CANNERY PT



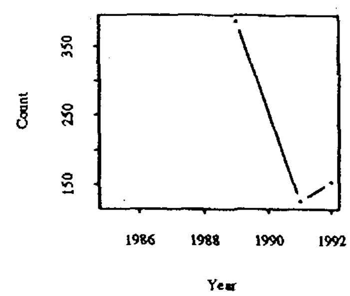
THE BROTHERS



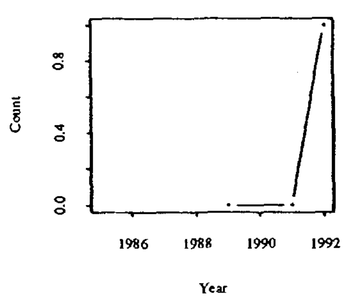
THE SISTERS



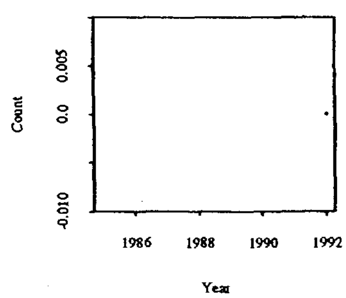
TIMBERED ISLAND



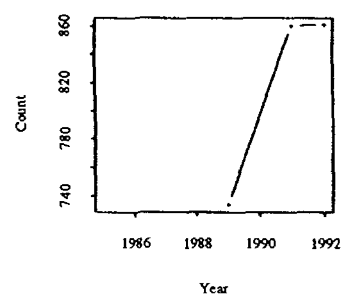
TURNABOUT ISLAND



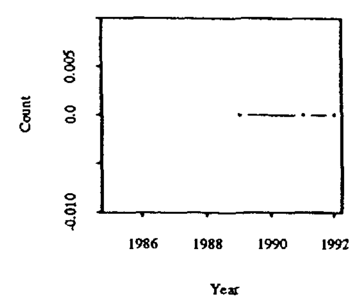
VENISA POINT



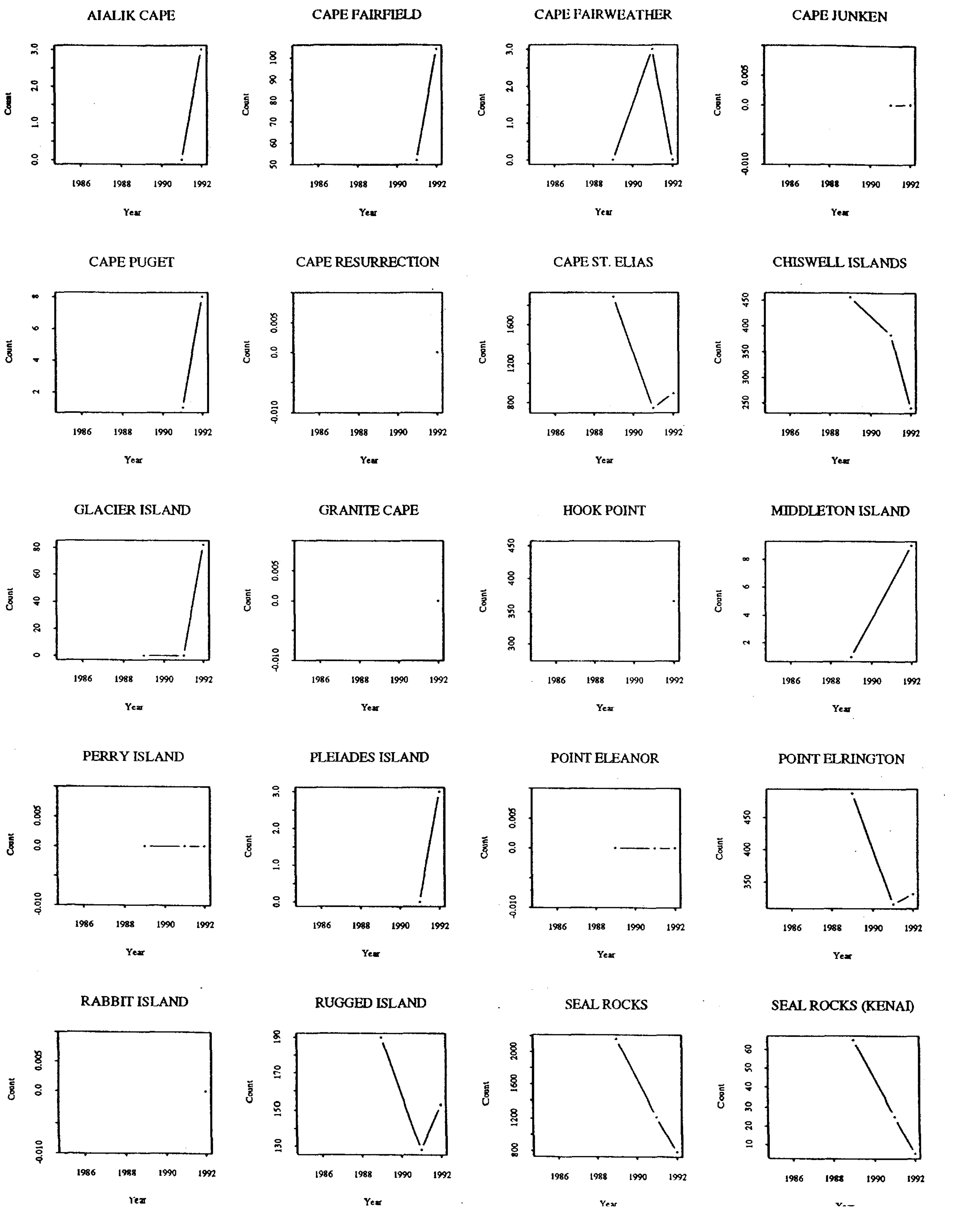
WHITE SISTERS



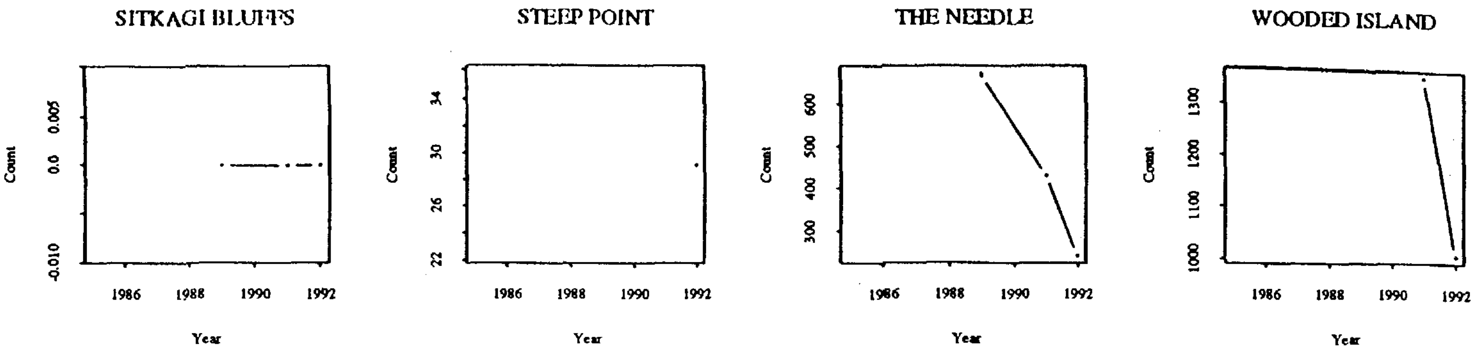
YASHA ISLAND



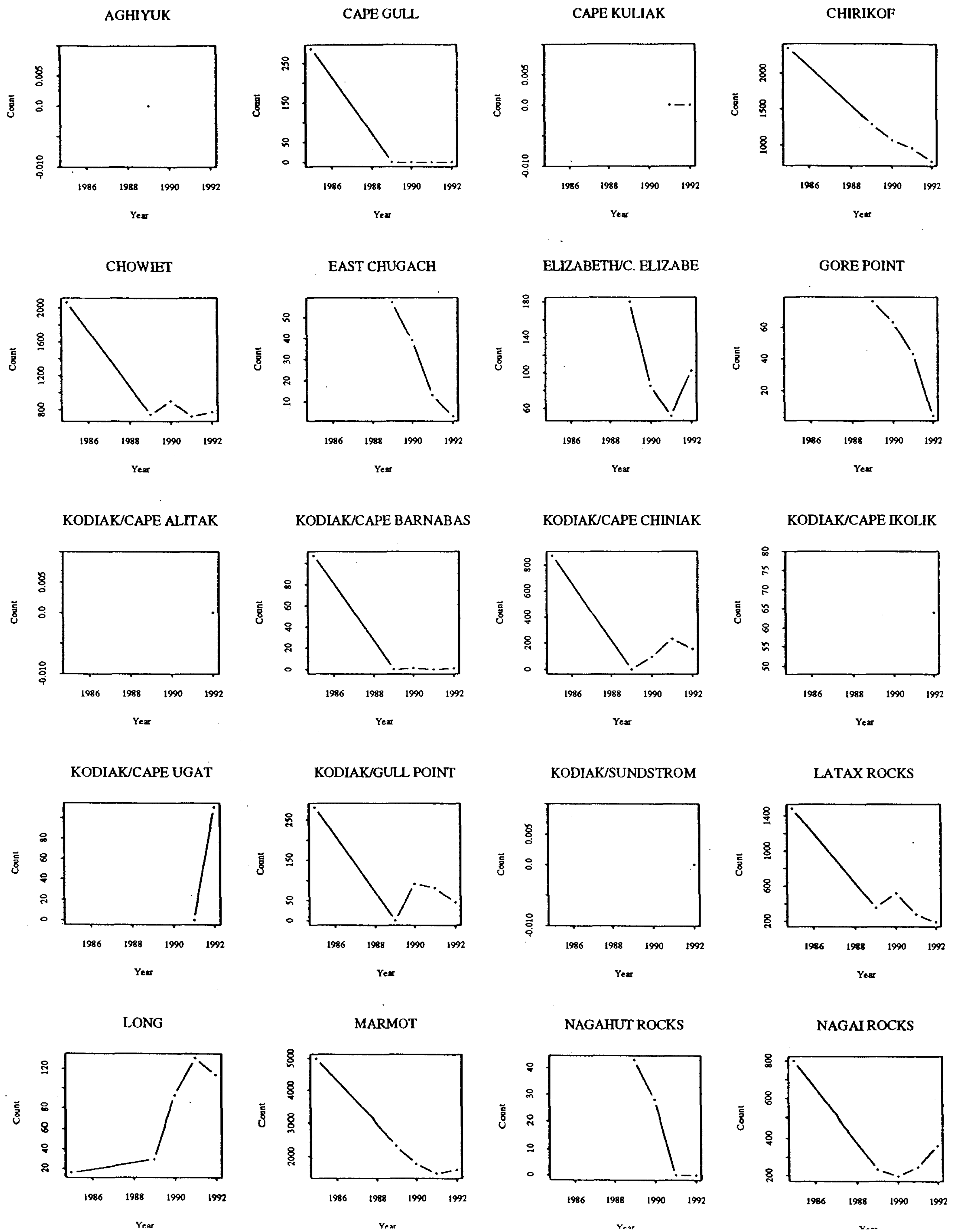
E GULF


AIALIK CAPE
CAPE FAIRFIELD
CAPE FAIRWEATHER
CAPE JUNKEN
CAPE PUGET
CAPE RESURRECTION
CAPE ST. ELIAS
CHISWELL ISLANDS
GLACIER ISLAND
GRANITE CAPE
HOOK POINT
MIDDLETON ISLAND
PERRY ISLAND
PLEIADES ISLAND
POINT ELEANOR
POINT ELRINGTON
RABBIT ISLAND
RUGGED ISLAND
SEAL ROCKS
SEAL ROCKS (KENAI)
Count
Year

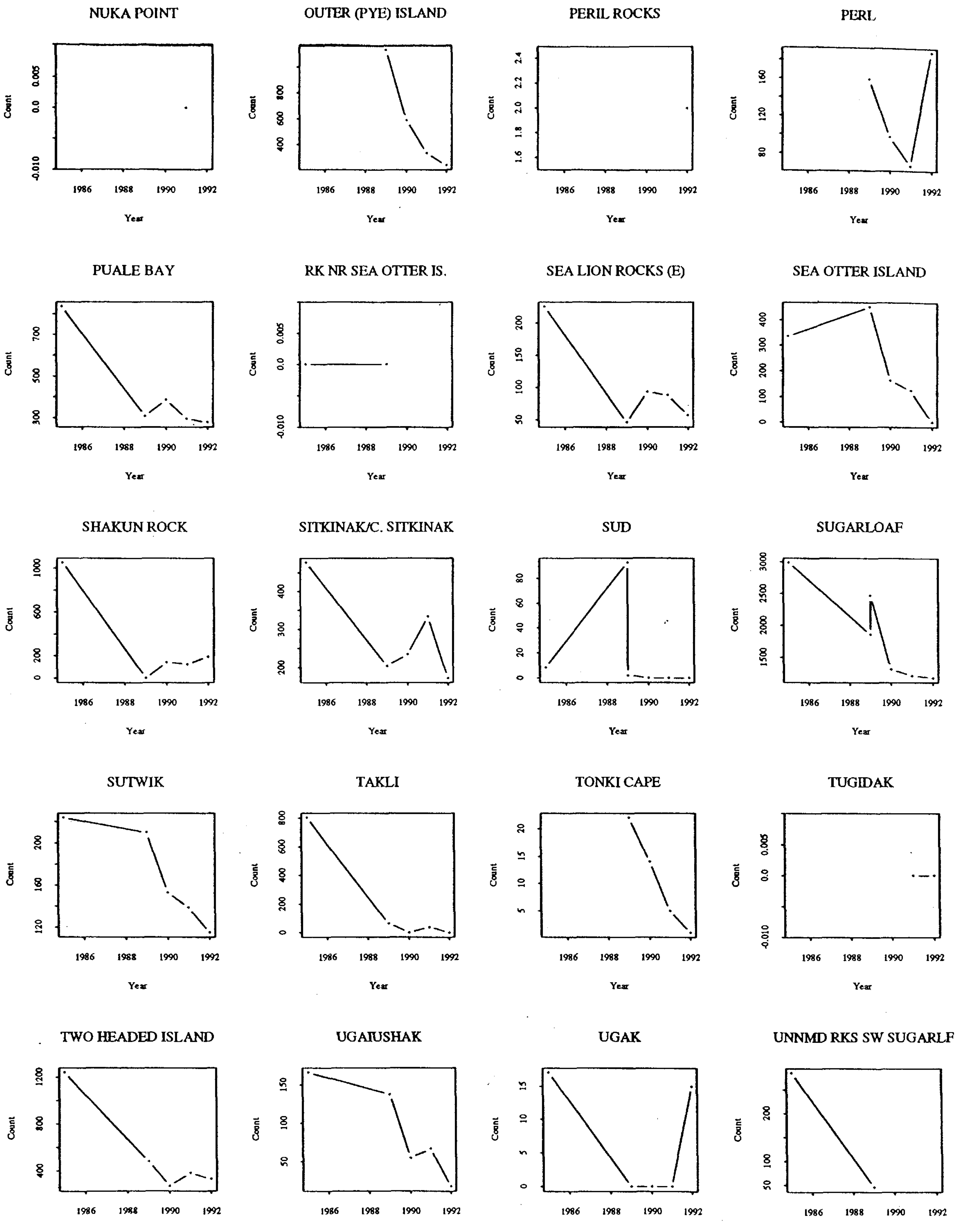
E GULF


SITKAGI BLUFFS
STEEP POINT
THE NEEDLE
WOODED ISLAND
Count
Year
1986
1988
1990
1992
-0.010
0.0
0.005
22
26
30
34
300
400
500
600
1000
1100
1200
1300

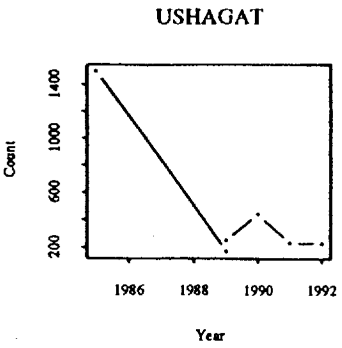
C GULF

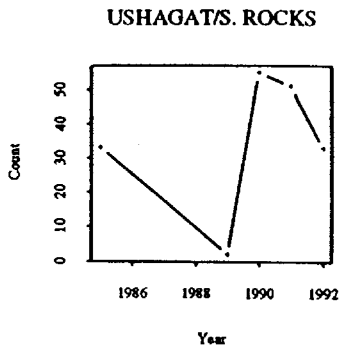

AGHIYUK
CAPE GULL
CAPE KULIAK
CHIRIKOF
CHOWIET
EAST CHUGACH
ELIZABETH/C. ELIZABE
GORE POINT
KODIAK/CAPE ALITAK
KODIAK/CAPE BARNABAS
KODIAK/CAPE CHINIAK
KODIAK/CAPE IKOLIK
KODIAK/CAPE UGAT
KODIAK/GULL POINT
KODIAK/SUNDSTROM
LATAX ROCKS
LONG
MARMOT
NAGAHUT ROCKS
NAGAI ROCKS
Count
Year
1986
1988
1990
1992

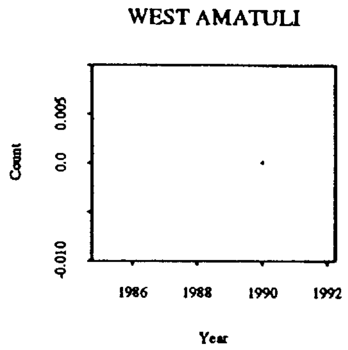
C GULF


NUKA POINT
OUTER (PYE) ISLAND
PERIL ROCKS
PERL
PUALE BAY
RK NR SEA OTTER IS.
SEA LION ROCKS (E)
SEA OTTER ISLAND
SHAKUN ROCK
SITKINAK/C. SITKINAK
SUD
SUGARLOAF
SUTWIK
TAKLI
TONKI CAPE
TUGIDAK
TWO HEADED ISLAND
UGAIUSHAK
UGAK
UNNMD RKS SW SUGARLF
Count
Year
1986
1988
1990
1992

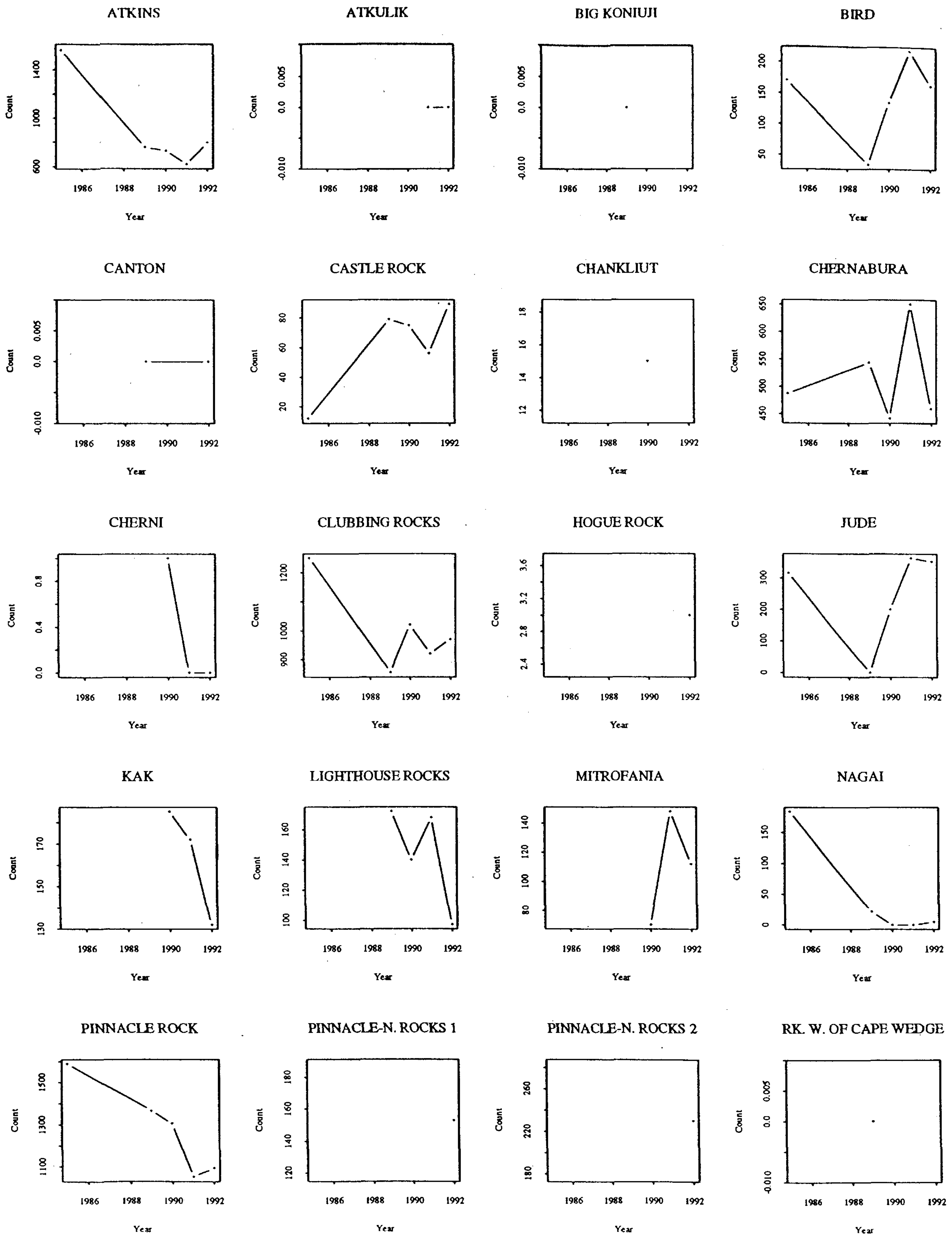
C GULF


USHAGAT
Count
200
600
1000
1400
1986
1988
1990
1992
Year

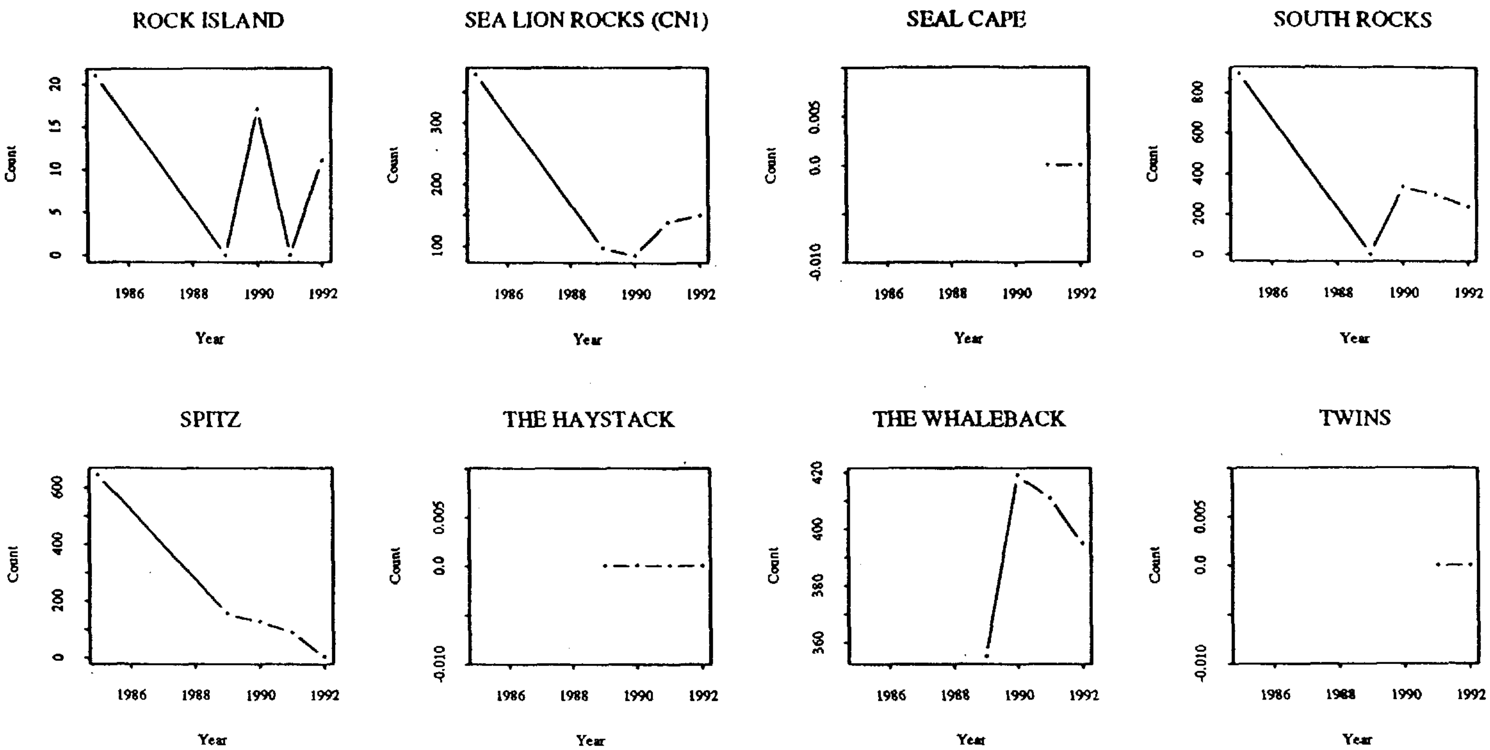

USHAGAT/S. ROCKS
Count
0
10
20
30
40
50
1986
1988
1990
1992
Year


WEST AMATULI
Count
-0.010
0.0
0.005
1986
1988
1990
1992
Year

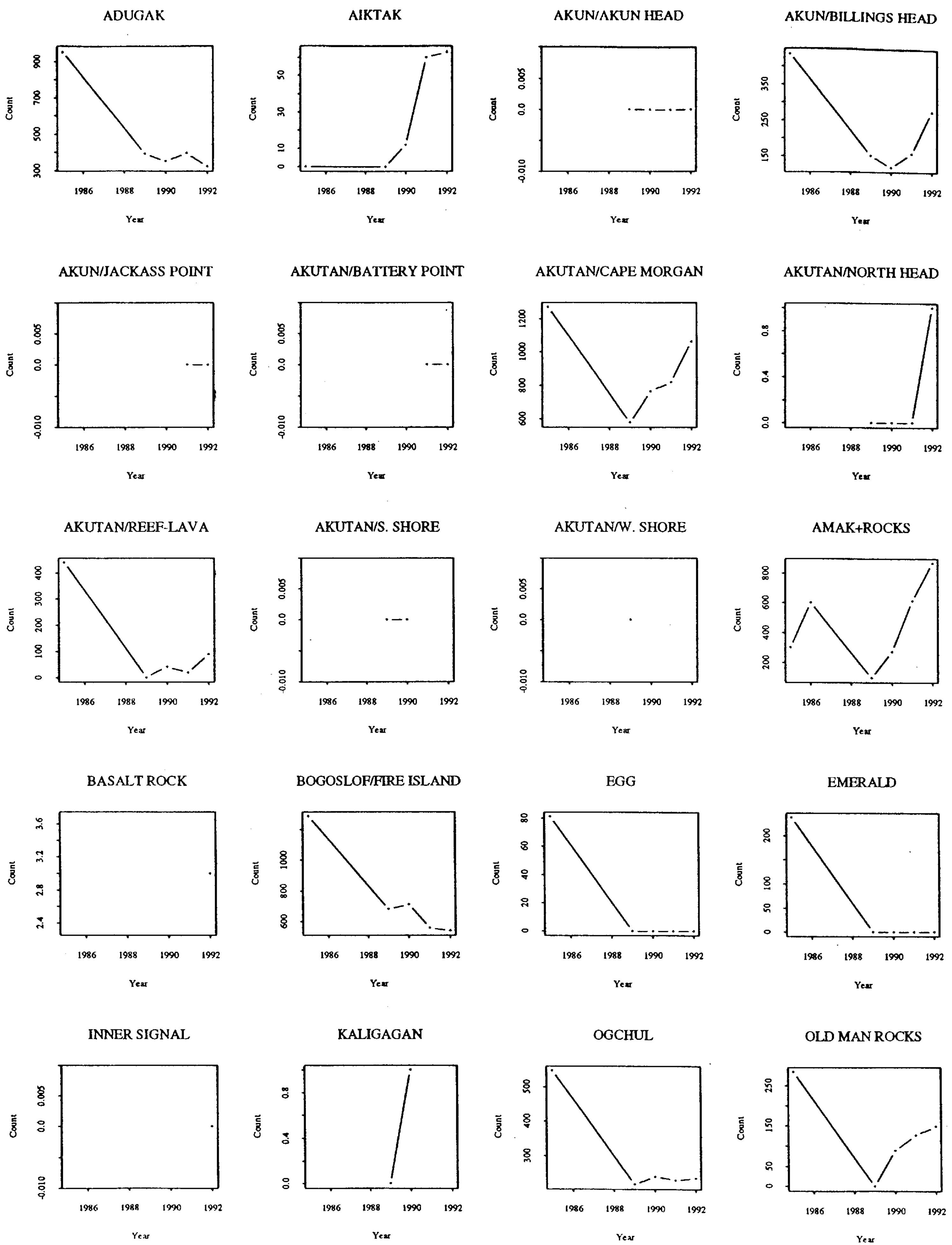
W GULF


ATKINS
ATKULIK
BIG KONIUJI
BIRD
CANTON
CASTLE ROCK
CHANKLIUT
CHERNABURA
CHERNI
CLUBBING ROCKS
HOGUE ROCK
JUDE
KAK
LIGHTHOUSE ROCKS
MITROFANIA
NAGAI
PINNACLE ROCK
PINNACLE-N. ROCKS 1
PINNACLE-N. ROCKS 2
RK. W. OF CAPE WEDGE
Count
Year
1986
1988
1990
1992

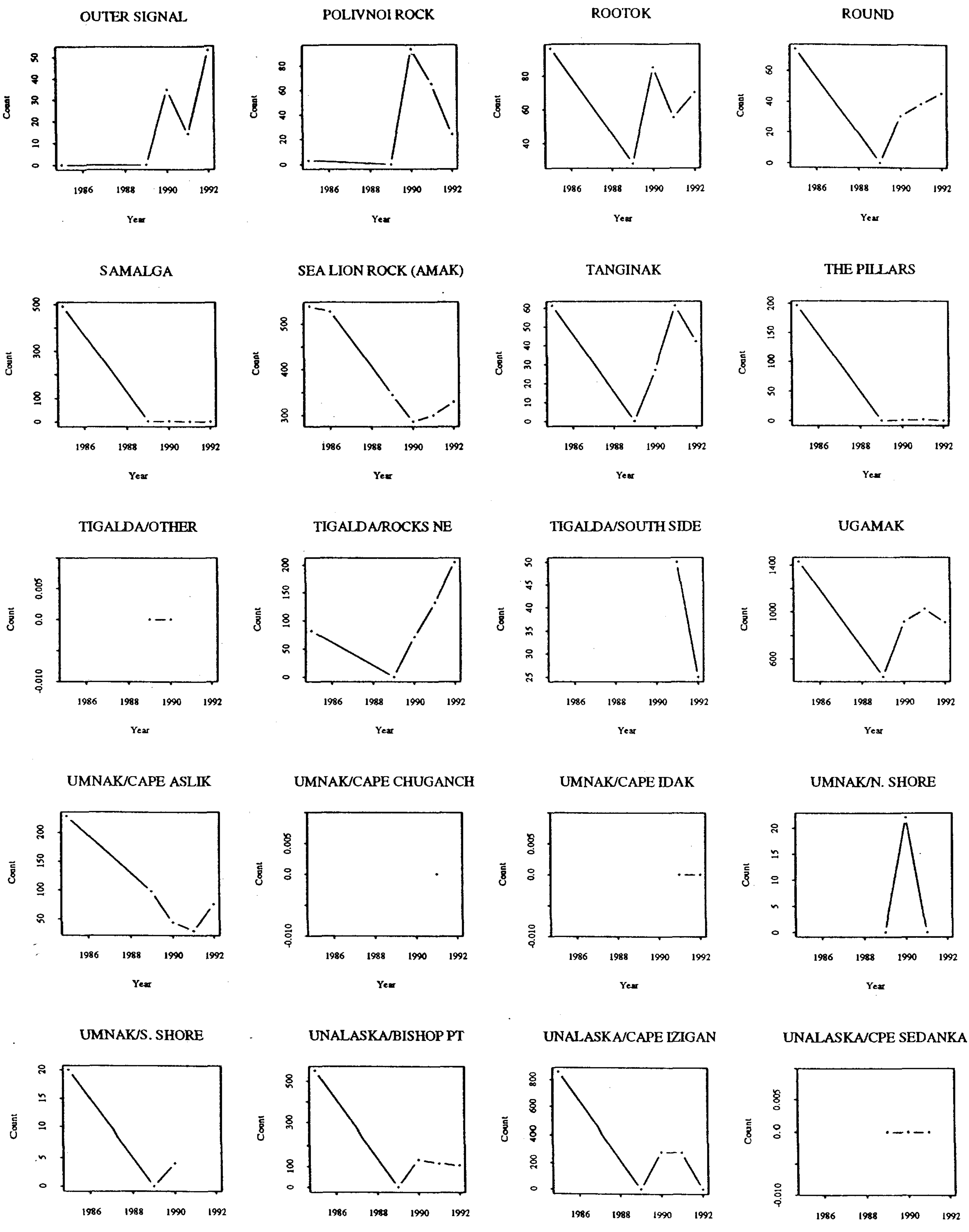
W GULF


ROCK ISLAND
SEA LION ROCKS (CN1)
SEAL CAPE
SOUTH ROCKS
SPITZ
THE HAYSTACK
THE WHALEBACK
TWINS
Count
Year
1986
1988
1990
1992
0
5
10
15
20
100
200
300
-0.010
0.0
0.005
200
400
600
800
360
380
400
420

E ALEU

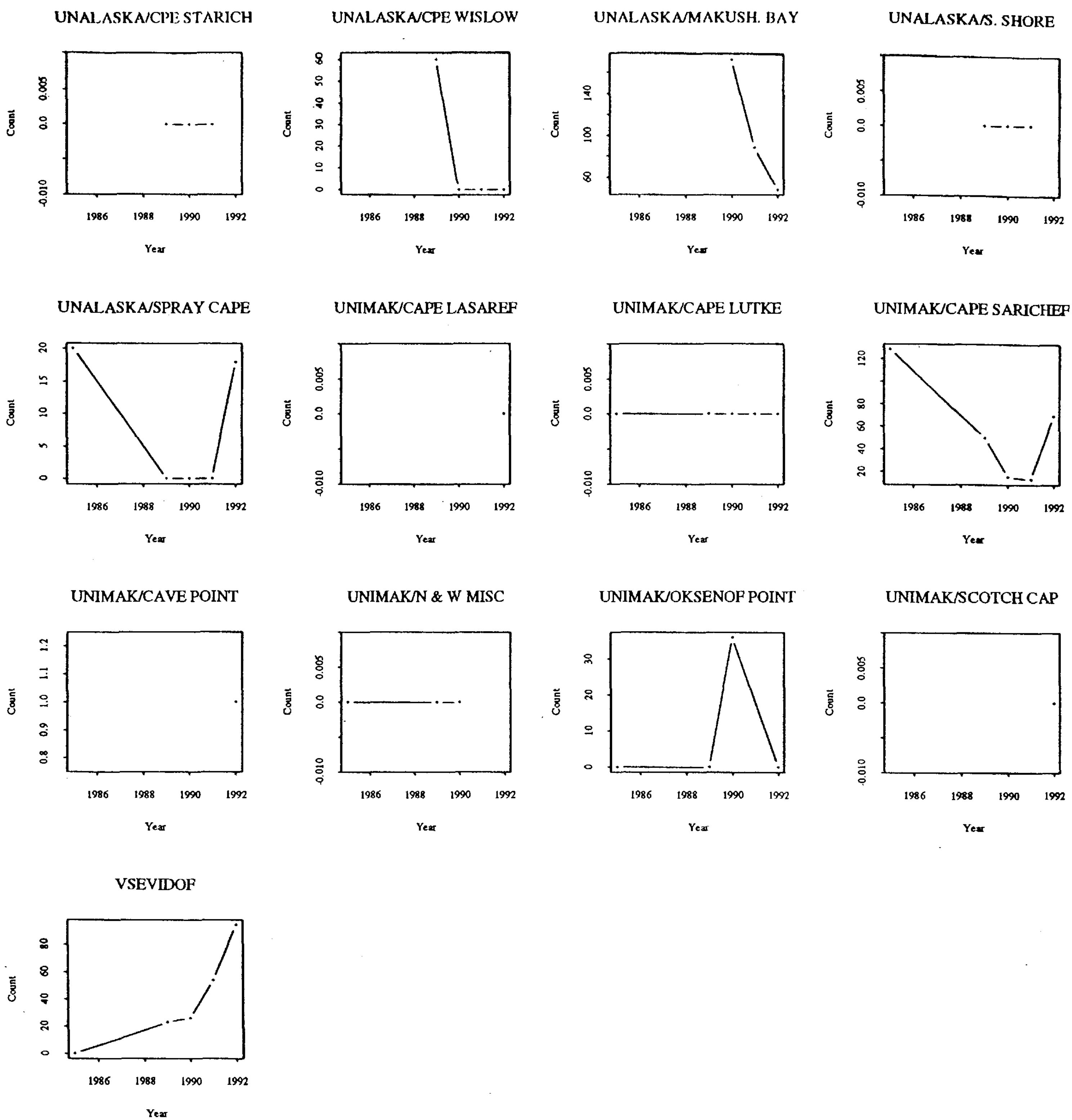

ADUGAK
AIKTAK
AKUN/AKUN HEAD
AKUN/BILLINGS HEAD
AKUN/JACKASS POINT
AKUTAN/BATTERY POINT
AKUTAN/CAPE MORGAN
AKUTAN/NORTH HEAD
AKUTAN/REEF-LAVA
AKUTAN/S. SHORE
AKUTAN/W. SHORE
AMAK+ROCKS
BASALT ROCK
BOGOSLOF/FIRE ISLAND
EGG
EMERALD
INNER SIGNAL
KALIGAGAN
OGCHUL
OLD MAN ROCKS
Count
Year
1986
1988
1990
1992

E ALEU

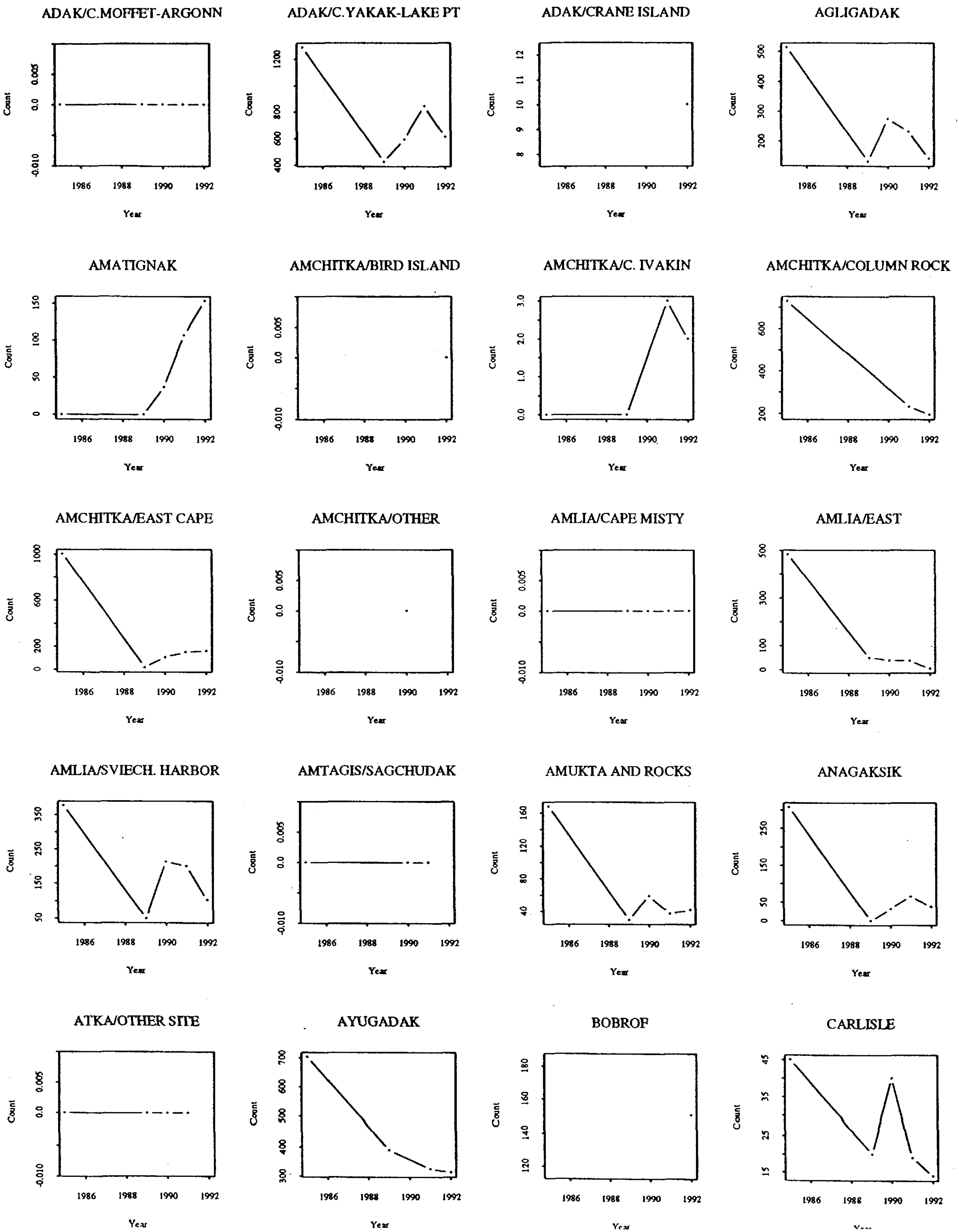


OUTER SIGNAL
POLIVNOI ROCK
ROOTOK
ROUND
SAMALGA
SEA LION ROCK (AMAK)
TANGINAK
THE PILLARS
TIGALDA/OTHER
TIGALDA/ROCKS NE
TIGALDA/SOUTH SIDE
UGAMAK
UMNAK/CAPE ASLIK
UMNAK/CAPE CHUGANCH
UMNAK/CAPE IDAK
UMNAK/N. SHORE
UMNAK/S. SHORE
UNALASKA/BISHOP PT
UNALASKA/CAPE IZIGAN
UNALASKA/CPE SEDANKA
Count
Year
1986
1988
1990
1992

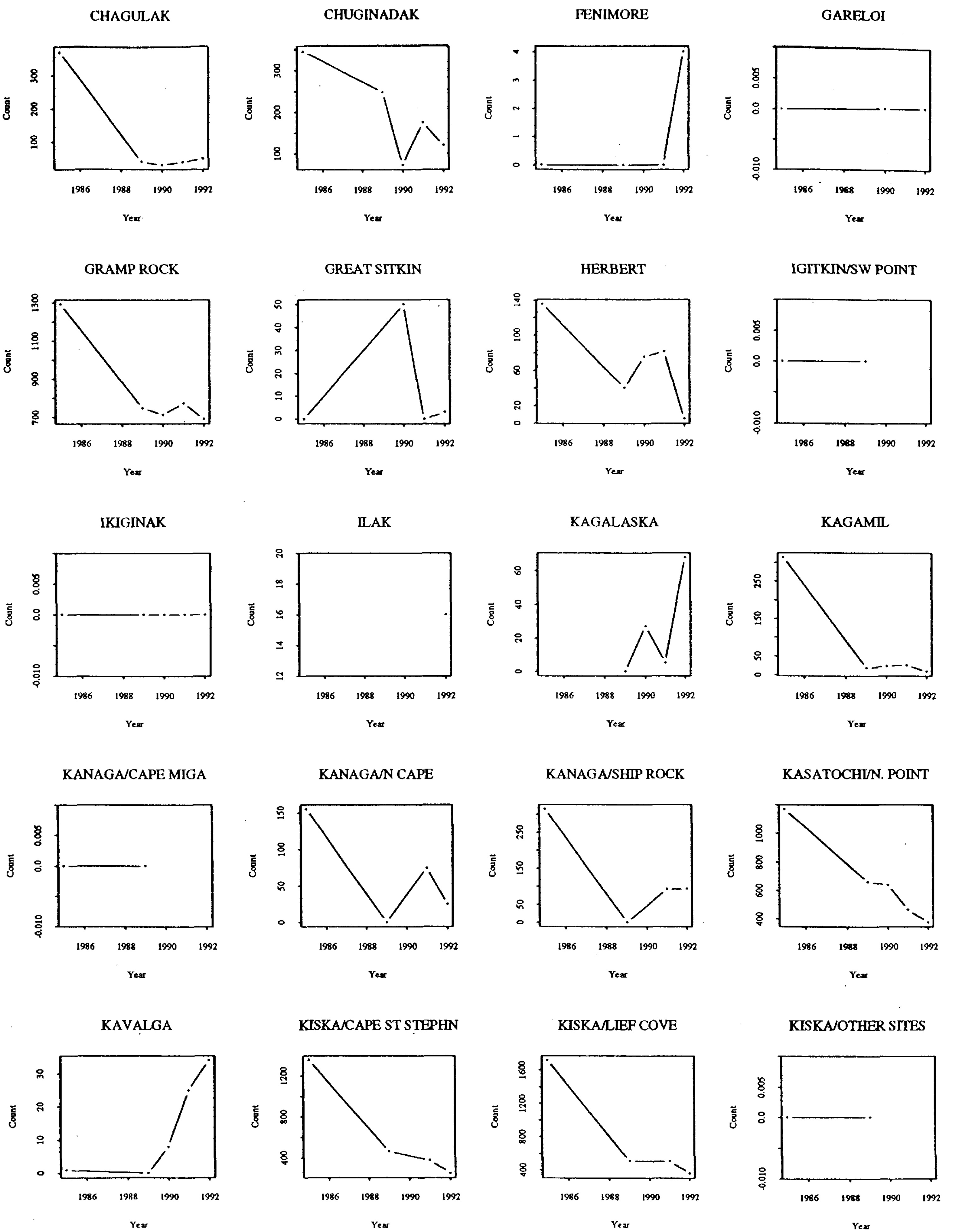
E ALEU


UNALASKA/CPE STARICH
UNALASKA/CPE WISLOW
UNALASKA/MAKUSH. BAY
UNALASKA/S. SHORE
UNALASKA/SPRAY CAPE
UNIMAK/CAPE LASAREF
UNIMAK/CAPE LUTKE
UNIMAK/CAPE SARICHEF
UNIMAK/CAVE POINT
UNIMAK/N & W MISC
UNIMAK/OKSENOF POINT
UNIMAK/SCOTCH CAP
VSEVIDOF
Count
Year
1986
1988
1990
1992

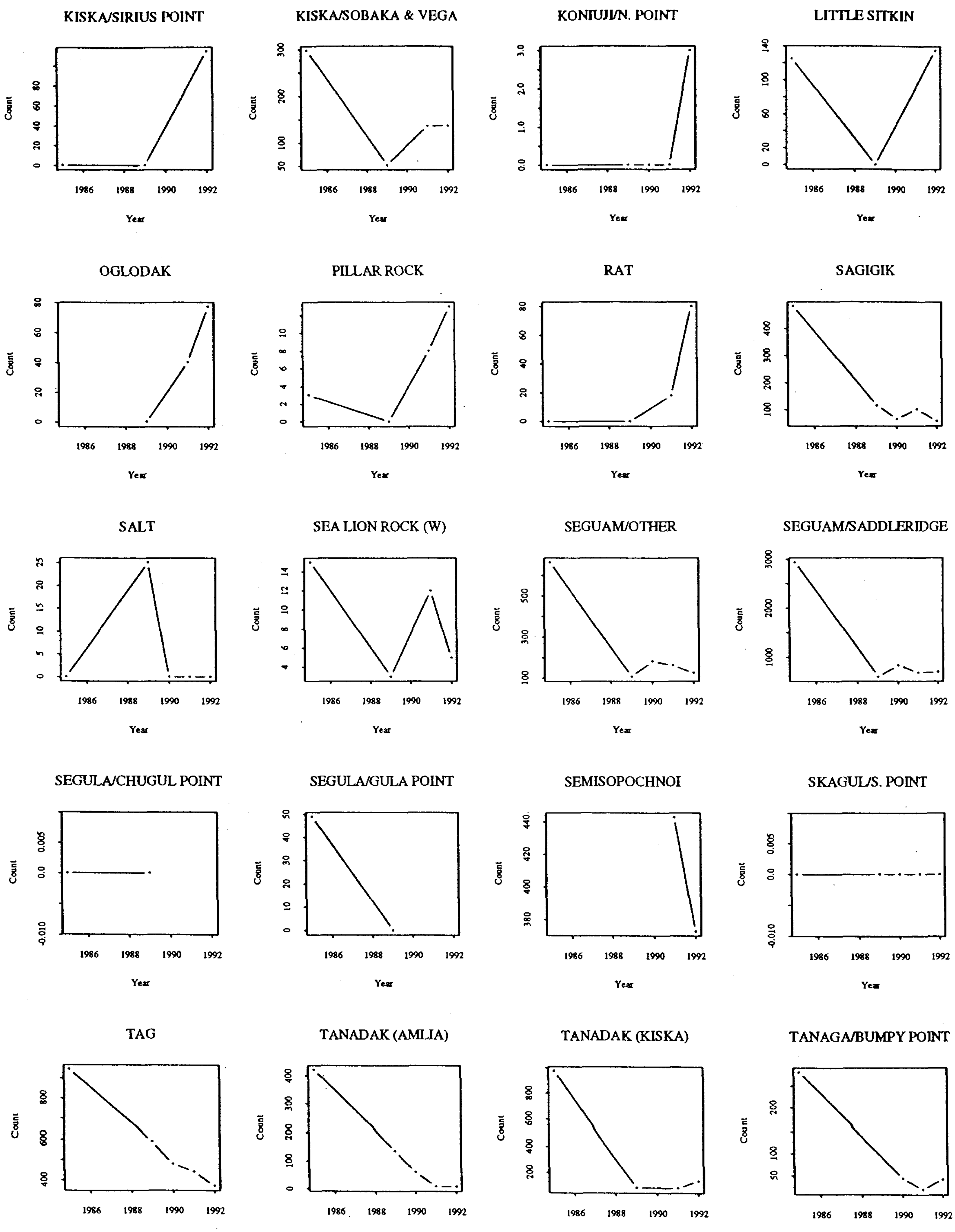
C ALEU


ADAK/C.MOFFET-ARGONN
ADAK/C.YAKAK-LAKE PT
ADAK/CRANE ISLAND
AGLIGADAK
AMATIGNAK
AMCHITKA/BIRD ISLAND
AMCHITKA/C. IVAKIN
AMCHITKA/COLUMN ROCK
AMCHITKA/EAST CAPE
AMCHITKA/OTHER
AMLIA/CAPE MISTY
AMLIA/EAST
AMLIA/SVIECH. HARBOR
AMTAGIS/SAGCHUDAK
AMUKTA AND ROCKS
ANAGAKSIK
ATKA/OTHER SITE
AYUGADAK
BOBROF
CARLISLE
Count
Year
1986
1988
1990
1992

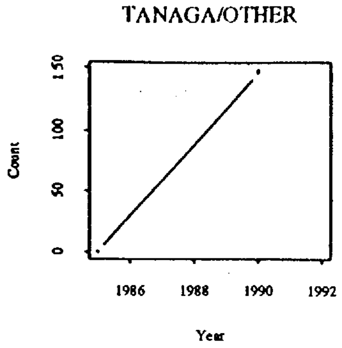
C ALEU

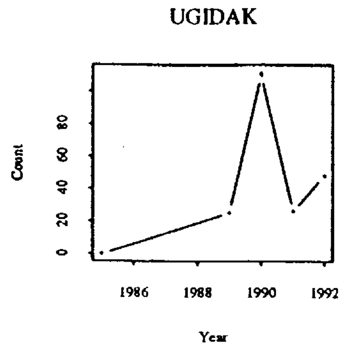

CHAGULAK
CHUGINADAK
FENIMORE
GARELOI
GRAMP ROCK
GREAT SITKIN
HERBERT
IGITKIN/SW POINT
IKIGINAK
ILAK
KAGALASKA
KAGAMIL
KANAGA/CAPE MIGA
KANAGA/N CAPE
KANAGA/SHIP ROCK
KASATOCHI/N. POINT
KAVALGA
KISKA/CAPE ST STEPHN
KISKA/LIEF COVE
KISKA/OTHER SITES
Count
Year
1986
1988
1990
1992

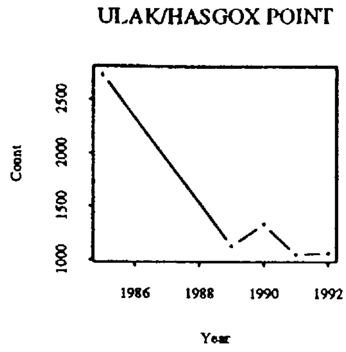
C ALEU

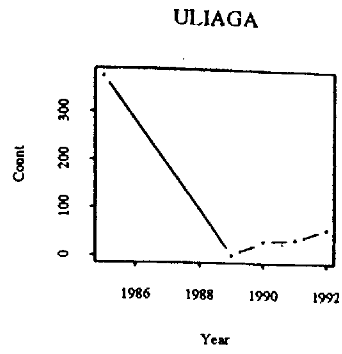

KISKA/SIRIUS POINT
Count
0 20 40 60 80
1986 1988 1990 1992
Year
KISKA/SOBAKA & VEGA
Count
50 100 200 300
1986 1988 1990 1992
Year
KONIUJI/N. POINT
Count
0.0 1.0 2.0 3.0
1986 1988 1990 1992
Year
LITTLE SITKIN
Count
0 20 60 100 140
1986 1988 1990 1992
Year
OGLODAK
Count
0 20 40 60 80
1986 1988 1990 1992
Year
PILLAR ROCK
Count
0 2 4 6 8 10
1986 1988 1990 1992
Year
RAT
Count
0 20 40 60 80
1986 1988 1990 1992
Year
SAGIGIK
Count
100 200 300 400
1986 1988 1990 1992
Year
SALT
Count
0 5 10 15 20 25
1986 1988 1990 1992
Year
SEA LION ROCK (W)
Count
4 6 8 10 12 14
1986 1988 1990 1992
Year
SEGUAM/OTHER
Count
100 300 500
1986 1988 1990 1992
Year
SEGUAM/SADDLERIDGE
Count
1000 2000 3000
1986 1988 1990 1992
Year
SEGULA/CHUGUL POINT
Count
-0.010 0.0 0.005
1986 1988 1990 1992
Year
SEGULA/GULA POINT
Count
0 10 20 30 40 50
1986 1988 1990 1992
Year
SEMISOPOCHNOI
Count
380 400 420 440
1986 1988 1990 1992
Year
SKAGUL/S. POINT
Count
-0.010 0.0 0.005
1986 1988 1990 1992
Year
TAG
Count
400 600 800
1986 1988 1990 1992
TANADAK (AMLIA)
Count
0 100 200 300 400
1986 1988 1990 1992
TANADAK (KISKA)
Count
200 400 600 800
1986 1988 1990 1992
TANAGA/BUMPY POINT
Count
50 100 200
1986 1988 1990 1992

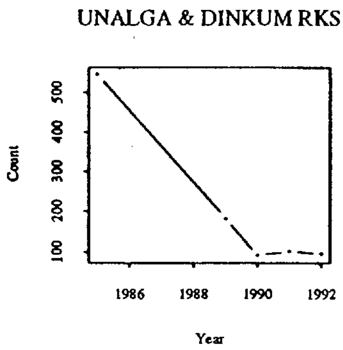
C ALEU

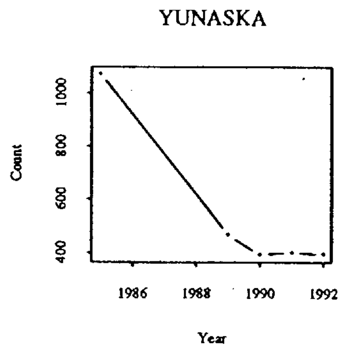

TANAGA/OTHER
Count
0
50
100
150
1986
1988
1990
1992
Year


UGIDAK
Count
0
20
40
60
80
1986
1988
1990
1992
Year

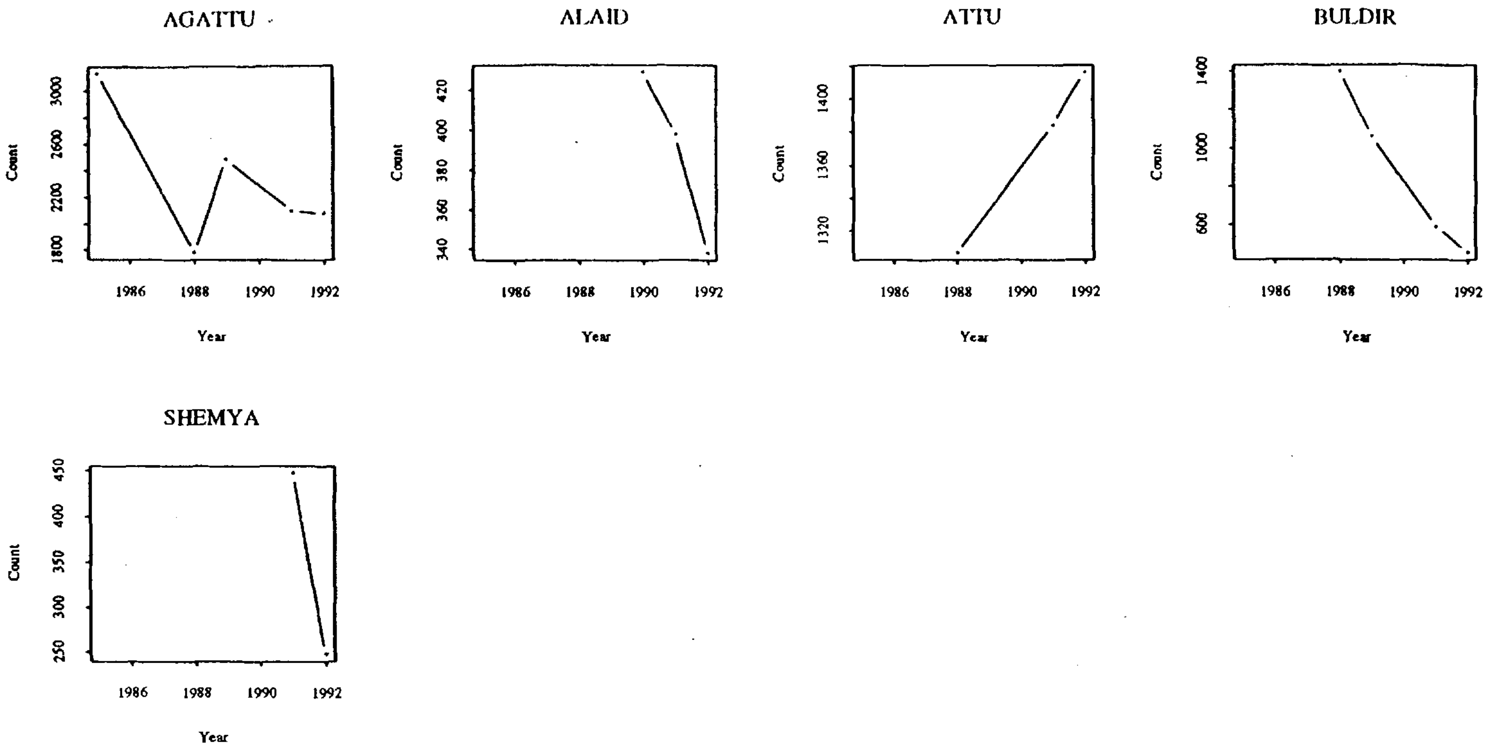

ULAK/HASGOX POINT
Count
1000
1500
2000
2500
1986
1988
1990
1992
Year


ULIAGA
Count
0
100
200
300
1986
1988
1990
1992
Year


UNALGA & DINKUM RKS
Count
100
200
300
400
500
1986
1988
1990
1992
Year


YUNASKA
Count
400
600
800
1000
1986
1988
1990
1992
Year

W ALEU


AGATTU
ALAID
ATTU
BULDIR
SHEMYA
Count
Year
1986
1988
1990
1992
1800
2200
2600
3000
340
360
380
400
420
1320
1360
1400
600
1000
1400
250
300
350
400
450

BERING