

Steller sea lion fishery and oceanographic analysis BiOp 2010 (February 11, 2010)

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INTRODUCTION

At the request of the Protected Resources Division of the National Marine Fisheries Service, Alaska Regional Office, AFSC undertook an analysis to understand relationships between regional changes in Steller sea lion (SSL) populations from 1991 to 2008, the spatial-temporal distribution of sea lion prey species, fisheries for these prey species, and various oceanographic measures of the North Pacific. The 1991-2008 time period was chosen because 1) the SSL was listed as threatened under the ESA in 1990, 2) the rate of population decrease changed from about 15% per year in the 1980s, to about 5% per year in the 1990s, to relatively stable in the 2000s, and 3) it is thought that this change in population trend occurred because of a drop in the rate of human-related direct mortality (e.g., legal and illegal shooting, incidental takes in fisheries; see York 1994; Holmes and York 2003; Fay and Punt 2006; Winship and Trites 2006; Holmes et al. 2007). The suite of threats facing the SSL population appears to have changed from the 1980s (direct mortality) to the 1990s and 2000s (nutritional stress) (see Trites and Donnelly 2003; Fritz and Hinckley 2005; NMFS 2008; Rosen 2009). In addition, the regional variability in SSL trends during this period (Figures 1 and 2) suggests relationships between SSLs and other processes and populations on which we routinely collect data (e.g., fish abundance, fishery catch distribution, oceanography). Consequently, we undertook an analysis to examine statistical relationships between the following data which were assembled for each of the regions depicted in Figure 1 for the 1991-2008 period:

- 1) Adult and juvenile SSL counts at all rookery and haul-out trend sites, and at rookery trend sites only;
- 2) Biomass estimates of Atka mackerel, Pollock, Pacific cod and arrowtooth flounder (four principal groundfish prey species of SSLs);
- 3) Catch estimates of Atka mackerel, Pollock, Pacific cod and arrowtooth flounder; and
- 4) Oceanographic variables.

METHODS

I. Steller sea lion population trends and analytical regions

Steller sea lion population trends are monitored by counting adults and juveniles at a series of consistently monitored haul-out and rookery sites during the summer breeding season, when the proportion of sea lions hauled out on land is the greatest during the year. During the summer, rookeries contain primarily adult mature sea lions, while haul-outs have a broader cross-section of juvenile and adult sea lions. Counts obtained from surveys of all trend sites conducted between 1991 and 2008 were used in this analysis (Table 1), and separate time series of all trend sites (Table 2) and rookery trend sites (Table 3) by SSL region (Figure 1) were created by querying the non-pup count database. Annual growth

rates (or rates of change) were calculated for three time periods (1991-2008, 1991-1998, and 2000-2008) and were derived from coefficients (m) of log-linear regressions of the natural logarithm of the non-pup counts on the survey years; $AR = e^m - 1$ (Table 4).

Eleven regions were used in this analysis (Figures 1 and 2; Table 1). Region boundaries were chosen based on similarities in population trends of sea lions at sites within each region, and bottom trawl survey strata that were used in the creation of spatially explicit groundfish biomass time series. Regions 1-5 are equivalent to the western and central Aleutian Islands SSL survey areas (NMFS 2008), the Aleutian Islands fishery management areas (541-543), and the Aleutian Islands groundfish trawl survey area. Region 6 is equivalent to the eastern Aleutian Islands SSL survey area (NMFS 2008), the eastern Bering Sea fishery management and groundfish survey areas, the SE Bering Sea portion of the Aleutian groundfish trawl survey area, and portions of the western Gulf of Alaska fishery management (610) and groundfish trawl survey areas. Regions 7-11 encompass the remainder of the Gulf of Alaska from Unimak Pass through SE Alaska (133-165°W), which includes: the western, central and eastern Gulf of Alaska, and SE Alaska SSL survey areas; the majority of the Gulf of Alaska fishery management areas (part of 610 and all the area from 620-650); and the majority of the Gulf of Alaska groundfish bottom trawl survey areas.

From west to east across the SSL range in Alaska:

- 1) Region 1 is the same as the western Aleutian Islands (NMFS 2008); SSL non-pup counts declined at ~10% per year between 1991 and 2008
- 2) Regions 2-5 are sub-sets of the central Aleutian Islands (NMFS 2008). Fritz et al. (2008) noted a west to east increase in SSL growth rates in the 1990s and 2000s in the central Aleutian Islands. It is this gradient in SSL response in this large area that we wanted to capture in our analysis and necessitated the division into 4 regions.
 - a. Region 2 encompasses the area from Kiska Island to Amchitka Pass; SSL non-pup counts declined at ~6% per year between 1991 and 2008
 - b. Region 3 is the Delarof Island group from Amchitka Pass to 177°W; SSL non-pup counts declined at ~2% per year between 1991 and 2008
 - c. Region 4 encompasses the area from Adak through Atka Islands (174-177°W); SSL non-pup counts declined between 1991 and 1994, increased from 1994 through 2004, and then declined through 2008
 - d. Region 5 encompasses the area from Amlia Island through the Islands of Four Mountains; SSL non-pup counts initially declined between 1991 and 1996, then increased slowly through 2008
- 3) Region 6 is the same as the eastern Aleutian Islands (NMFS 2008); SSL non-pup counts were stable through the 1990s, but increased at ~4% per year from 2000 through 2008
- 4) Region 7 is essentially the western Gulf of Alaska (NMFS 2008) but without Lighthouse Rocks; SSL non-pup counts were stable through the 1990s, but increased at ~5% per year from 2000 through 2008
- 5) Region 8 is essentially the western portion of the central Gulf of Alaska (NMFS 2008) with the addition of Lighthouse Rocks; SSL non-pup counts declined at ~6% per year through the 1990s and were stable from 2000 through 2008
- 6) Region 9 is essentially the eastern portion of the central Gulf of Alaska (NMFS 2008), but without the southwestern portion of the Kenai Peninsula; SSL non-pup counts declined at ~6% per year through the 1990s and were stable from 2000 through 2008
- 7) Region 10 is essentially the eastern Gulf of Alaska (NMFS 2008) with the addition of the southwestern portion of the Kenai Peninsula; SSL non-pup counts declined at ~9% per year

through the 1990s and increased in the 2000s. Counts for 2008 were estimated based on the regression of 2000-2009 data (omitting the 2008 count; DeMaster 2009) to account for seasonal movement.

- 8) Region 11 is the same as SE Alaska and is part of the eastern DPS of SSL (NMFS 2008); SSL non-pup counts were stable between 1991 and 1996, and increased through 2008. Counts for 2008 were estimated based on the regression of 1991-2009 data (omitting the 2008 count; DeMaster 2009) to account for seasonal movement.

II. Spatial distribution of pollock, Pacific cod, Atka mackerel and arrowtooth flounder catch

In the GOA and BSAI, data collected by groundfish fishery observers were used to create a spatially-explicit (based on haul retrieval location) dataset of total groundfish catch. Groundfish fishery observers collect a wide variety of information that describes the catch by fishing vessels, including position of gear deployment and retrieval, date, processor type, gear type, and detailed catch composition. These data are a sample of the entire fishery, since not all vessels carry observers on all trips, nor are all hauls sampled for catch composition. For instance, no vessels smaller than 60 feet in length overall (LOA) are required to carry an observer, and vessels between 60 and 125 LOA must only carry an observer on 30% of their trips. As a consequence, the use of observer data to estimate total catch under-represents the catch of smaller vessels that generally fish closer to shore than larger vessels. This would affect the estimated spatial distribution of the catch of species that have a coastal distribution and are fished by small vessels (e.g., Pacific cod catches in the GOA by the longline fleet) more than species that have a broader distribution and are fished by larger vessels (e.g., walleye pollock catches in the EBS by the trawl fleet). However, despite its incompleteness and potential bias, the observer data contain detailed information on catch location and composition that are available in no other catch data set for the time period of interest – 1991 through 2008.

A series of expansion factors, or ratios of total to observed catch, were computed in order to estimate the distribution of total catch from the distribution of observed catch. To compute catch expansion factors, total annual catches of each species by area, gear, and processor type were obtained from the Sustainable Fisheries Division of the Alaska Region, NMFS (the 'blend' database) or from the REFM Division of the Alaska Fisheries Science Center, NMFS (T. Hiatt) based on queries from the Catch Accounting System. For the GOA, the following categories were used to compute observed catch expansion factors:

- 1) Year: 1991-2008
- 2) Species
 - a. Pollock
 - b. Pacific cod
 - c. Arrowtooth flounder
- 3) Statistical area
 - a. 610 as defined
 - b. 620 (includes 621, Shelikof portion of 620)
 - c. 630 (includes 631, Shelikof portion of 630)
 - d. 640 (includes 649, PWS portion of 640)
 - e. 650 (includes 659, PWS portion of 650; in some years, areas 640 and 650 were pooled because of insufficient observer coverage)
- 4) Gear
 - a. Trawl (bottom and pelagic pooled; observer codes 1 and 2)
 - b. Longline (observer code 8)

- c. Pot (observer code 6)
- 5) Processor Type
 - a. Catcher Processor (observer code 1)
 - b. Shoreside delivery (observer code 3)

For the BSAI, the following categories were used to compute observed catch expansion factors:

- 1) Year: 1991-2008
- 2) Species
 - a. Pollock
 - b. Pacific cod
 - c. Atka mackerel
 - d. Arrowtooth flounder
- 3) Statistical area
 - a. EBS (eastern Bering Sea: statistical areas 500-539)
 - b. AI (Aleutian Islands: statistical areas 541-543)
- 4) Gears
 - a. Trawl (bottom and pelagic pooled; observer codes 1 and 2)
 - b. Longline (observer code 8)
 - c. Pot (observer code 6)
- 5) Processor types
 - a. Catcher Processor (observer code 1)
 - b. Shoreside delivery (observer code 3)
 - c. Mothership/Floating processor (observer codes 2 and 4).

Observed catches were obtained by querying the groundfish fishery observer databases maintained at the AFSC. Observed catch of each species in each observer record (e.g., haul) was multiplied by the appropriate year-species-area-gear-processor expansion factor to estimate total catch, which was then assigned to the observed haul location. For CDQ catches in the BSAI, observed catches were used directly since all vessels fishing CDQ are required to carry observers and 100% of the catch during CDQ operations is sampled for catch composition. Therefore, total catch for the BSAI consists of both observed-unexpanded CDQ hauls and observed-expanded open access fishery hauls. Estimated catches were assigned to SSL regions using ArcGIS (Tables 5-8).

III. Spatial and seasonal distribution of pollock, Pacific cod, Atka mackerel and arrowtooth flounder biomass

Pollock

Aleutian Islands: Bottom trawl surveys of the Aleutian Islands groundfish community were conducted in 1991, 1994, 1997, 2000, 2002, 2004, and 2006. Survey pollock biomass in SSL regions 1-5 was calculated by summing the biomass estimates from the appropriate survey strata in each region (Table 1). For the survey years, the proportion of total Aleutian survey biomass in each region was calculated. Proportions for years with no survey were linearly interpolated between the survey years prior to and following the missing year(s) for each region; distributions in 2007 and 2008 were set equal to 2006. This produced a matrix of regional-annual proportions of pollock biomass for the years 1991-2008, which was multiplied by the stock assessment time series of total Aleutian Island pollock biomass estimates (Barbeaux et al.

2008) to estimate regional-annual pollock biomass (Tables 9 and 11). Summer survey biomass distribution by SSL region was used to represent the entire year.

Gulf of Alaska: Bottom trawl surveys of the Gulf of Alaska groundfish community were conducted in 1990, 1993, 1996, 1999, 2001, 2003, 2005, and 2007. Survey pollock biomass in SSL regions 6-10 was calculated by summing the biomass estimates from the appropriate survey strata in each region (Table 1). For the survey years, the proportion of total Gulf of Alaska survey biomass in each region was calculated. Proportions for years with no survey were linearly interpolated between the survey years prior to and following the missing year(s) for each region; distribution in 2008 was set equal to 2007. This produced a matrix of regional (regions 6-10 only) *summer* proportions of pollock biomass for the years 1991-2008, which was multiplied by the stock assessment time series of total Gulf of Alaska pollock biomass estimates (Dorn et al 2008) to estimate regional-*summer* biomass for regions 6-10 (Tables 9 and 12). Biomass in region 11 (SE Alaska) from 1991-2008 was set equal to the survey biomass time series for both summer and winter.

Dorn et al. (2008) describe a method for spatially allocating ABC in the winter and spring fishing seasons based on analyses of biomass distribution from various hydroacoustic surveys of pollock pre-spawning aggregations throughout the Gulf of Alaska. We used Dorn et al's *winter* distribution in our analyses, and applied it to each year from 1991-2008:

SSL Regions	NMFS area	Proportion of Pollock Biomass by Area in Jan-Jun (QTRs 1 and 2)
6 & 7	610	0.31
8	620	0.47
9	630	0.19
10	640	0.03

A 20%:80% split was assumed between SSL regions 6 and 7 for the *winter*, respectively, based on the fact that both the Sanak and Shumagin spawning aggregations are located in region 7. *Winter* pollock biomass in area 11 (SE Alaska) was set equal to *summer* pollock biomass. In each season, total pollock biomass in the Gulf of Alaska (regions 6-10) was set to the same annual total from Dorn et al (2008).

Annual Gulf of Alaska pollock biomass distribution was estimated by averaging *winter* and *summer* proportions by region.

Eastern Bering Sea: There are two pollock stocks within the eastern Bering Sea management area – EBS shelf and Bogoslof - and each is assessed differently. The EBS shelf stock is assessed annually (e.g., Ianelli et al. 2008). The Bogoslof pollock stock has been assessed primarily in winter using a combined hydroacoustic-midwater trawl method when it is aggregated prior to spawning. Occasional surveys in summer indicated that this stock disperses throughout the off-shelf, pelagic portions of the central Bering Sea following spawning in winter, and as such, is largely located outside of the US Exclusive Economic Zone. In *summer and winter*, the entire eastern Bering Sea pollock biomass (Ianelli et al. 2008) was assigned to SSL region 6 (Figure 1). In addition, 10% of the winter Bogoslof hydroacoustic survey estimate was included to reflect an estimate of the portion remaining here in summer after spawning in late winter (Table 10). In *winter*, the entire eastern Bering Sea Pollock biomass was assigned to SSL region 6 (Figure 1). In addition, the winter Bogoslof hydroacoustic survey estimate was also included. *Annual* eastern Bering Sea pollock biomass was estimated by averaging *winter* and *summer* estimates.

Pacific cod

Aleutian Islands: Bottom trawl surveys of the Aleutian Islands groundfish community were conducted in 1991, 1994, 1997, 2000, 2002, 2004, and 2006. Survey Pacific cod biomass in SSL regions 1-5 was calculated by summing the biomass estimates from the appropriate survey strata in each region (Table 1). For the survey years, the proportion of total Aleutian survey biomass in each region was calculated. Proportions for years with no survey were linearly interpolated between the survey years prior to and following the missing year(s) for each region; distributions in 2007 and 2008 were set equal to 2006. This produced a matrix of regional-annual proportions of Pacific cod biomass for the years 1991-2008. Pacific cod biomass in the entire Bering Sea-Aleutian Islands (BSAI) region was assessed by Thompson et al. (2008b), who estimated that 16% of BSAI cod biomass resides in the Aleutian Islands management area (sea lion regions 1-5; Table 9). Annual BSAI cod biomass estimates for the years 1991-2008 were multiplied by 0.16 to estimate AI cod biomass. The annual AI cod biomass estimates were multiplied by the matrix of regional-annual biomass proportions (Table 11) to estimate regional-annual Pacific cod biomass. Summer survey biomass distribution by SSL region was used to represent the entire year.

Gulf of Alaska: Bottom trawl surveys of the Gulf of Alaska groundfish community were conducted in 1990, 1993, 1996, 1999, 2001, 2003, 2005, and 2007. Survey Pacific cod biomass in SSL regions 6-11 was calculated by summing the biomass estimates from the appropriate survey strata in each region (Table 1). For the survey years, the proportion of total Gulf of Alaska survey biomass in each region was calculated. Proportions for years with no survey were linearly interpolated between the survey years prior to and following the missing year(s) for each region. This produced a matrix of regional-annual proportions of Pacific cod biomass for the years 1991-2008, which was multiplied by the stock assessment time series of total Gulf of Alaska Pacific cod biomass estimates (Thompson et al. 2008a) to estimate regional-annual Pacific cod biomass (Tables 9 and 13). Summer survey biomass distribution by SSL region was used to represent the entire year.

Eastern Bering Sea: Pacific cod biomass in the entire Bering Sea-Aleutian Islands (BSAI) region was assessed by Thompson et al. (2008b), who estimated that 84% of BSAI cod biomass resides in the eastern Bering Sea management area. Annual BSAI Pacific cod biomass estimates for the years 1991-2008 were multiplied by 0.84 to estimate EBS cod biomass (Table 10). The entire eastern Bering Sea Pacific cod biomass (Thompson et al. 2008b) was assigned to SSL region 6.

Atka mackerel

Aleutian Islands: Bottom trawl surveys of the Aleutian Islands groundfish community were conducted in 1991, 1994, 1997, 2000, 2002, 2004, and 2006. Survey Atka mackerel biomass in SSL regions 1-6 was calculated by summing the biomass estimates from the appropriate survey strata in each region (Table 1). The stock assessment for Atka mackerel (Lowe et al. 2008) is for the entire BSAI area, but the vast majority of the biomass occurs in the Aleutian Islands region or in the southeastern Bering Sea portion of the NMFS Aleutian Island survey (north of the Aleutian chain in SSL region 6); relatively few Atka mackerel live within the eastern Bering Sea management area. For the survey years, the proportion of total Aleutian survey biomass in regions 1-6 was calculated. Atka mackerel is a patchily distributed fish that forms dense schools. Because of this distribution, Atka mackerel biomass estimates in individual survey strata often have high variance (Lowe et al. 2008), and in some years, have been unrealistically low. For instance, in 1991, survey Atka mackerel biomass estimates in SSL regions 4 and 6 were only 15 and 61 mt, respectively; by contrast, in 1991, 2,363 mt of Atka mackerel was caught by the fishery in area 6. Similar unrealistic biomass estimates occurred in region 5 in 1997, in regions 4-6 in 2000, and in regions 4 and 6 in 2006. To smooth the biomass distribution time series for Atka mackerel, the 1997

and 2000 surveys were not used in the analysis; the proportion of total Atka mackerel biomass in each region from 1995-2001 was linearly interpolated between the percentages in each region in the 1994 and 2002 surveys. In both regions 4 and 6 for 1991 and 2006, the long-term mean biomass proportions in these areas in surveys conducted between 1994 and 2004 was used. After these substitutions were made, proportions for years with no survey were linearly interpolated between the survey years prior to and following the missing year(s) for each region; distributions in 2007 and 2008 were set equal to 2006. This produced a matrix of regional-annual proportions of Atka mackerel biomass for the years 1991-2008, which was multiplied by the stock assessment time series of total BSAI Atka mackerel biomass estimates (Lowe et al. 2008) to estimate regional-annual Atka mackerel biomass (Tables 9 and 11). Summer survey biomass distribution by SSL region was used to represent the entire year.

Gulf of Alaska and Eastern Bering Sea: No attempt was made to spatially distribute Atka mackerel biomass in the Gulf of Alaska or eastern Bering Sea. Survey biomass estimates for Atka mackerel in the Gulf of Alaska are highly uncertain and from 1991-2008, have ranged from a low of 4,800 mt in 1999 to a high of 346,000 mt in 1996. Few Atka mackerel are found in the eastern Bering Sea, with survey estimates ranging from 0-664 mt from 1991-2008. Because of high survey uncertainty or low biomass, there are no quantitative stock assessments of Atka mackerel in the Gulf of Alaska or eastern Bering Sea, and hence, no reliable time series of biomass.

Arrowtooth flounder

Gulf of Alaska: Bottom trawl surveys of the Gulf of Alaska groundfish community were conducted in 1990, 1993, 1996, 1999, 2001, 2003, 2005, and 2007. Survey arrowtooth flounder biomass in SSL regions 6-11 was calculated by summing the biomass estimates from the appropriate survey strata in each region (Table 1). For the survey years, the proportion of total Gulf of Alaska survey biomass in each region was calculated. Proportions for years with no survey were linearly interpolated between the survey years prior to and following the missing year(s) for each region. This produced a matrix of regional-annual proportions of arrowtooth flounder biomass for the years 1991-2008, which was multiplied by the stock assessment time series of total Gulf of Alaska arrowtooth flounder biomass estimates (Turnock and Wilderbuer 2007) to estimate regional-annual arrowtooth flounder biomass (Tables 9 and 13). Summer survey biomass distribution by SSL region was used to represent the entire year.

Eastern Bering Sea: Arrowtooth flounder biomass in the entire Bering Sea-Aleutian Islands (BSAI) region was assessed by Wilderbuer et al. (2008), who estimated that 82% of BSAI arrowtooth flounder biomass resides in the eastern Bering Sea management area. Annual BSAI arrowtooth flounder biomass estimates for the years 1991-2008 (Table 10) were multiplied by 0.82 to estimate EBS arrowtooth flounder biomass.

IV. Oceanographic variables **Spring and Summer**

Spring was defined as May-June and summer as August-September (Ladd et al. 2005).

Sea surface temperature (SST, °C)

Sea surface temperature (SST) is an indicator of upwelling of cold, nutrient-rich waters to the surface, and/or wind-mixing of the water column. Thus cold SST is expected to be correlated with high spring and

summer productivity. Daily SST data from the Pathfinder satellite from 1991-2008 were obtained and averaged to create annual May-June and August-September composites at a resolution of 20 x 20 pixels (Version 5, Rosenstiel School of Marine and Atmospheric Science, University of Miami and NODC, <http://www.rsmas.miami.edu>). The spatial resolution was chosen to facilitate subsequent GIS analyses. Data quality (q) was at least 4 (out of a range of 2 to 6) which results in high quality composites without sacrificing data points and creating an excessive number of gaps in the coverage.

Wind mixing (m^3/s^3)

Wind mixing can be an important process for bringing deep nutrient-rich waters to the surface and facilitating spring and summer productivity. Wind-mixing (u^3) data were obtained from the National Center for Environmental Prediction (NCEP) at a 2-degree resolution and averaged to create May-June and August-September composites (Kalnay et al. 1996); NCEP Reanalysis data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, <http://www.cdc.noaa.gov/>).

Sea surface height variability (cm)

Variability in sea surface height (SSH) anomalies is an indicator of oceanographic fronts and eddies which can concentrate the food (i.e., zooplankton) of sea lion fish prey. Weekly SSH anomaly data from the AVISO satellite altimeter at 0.25-degree resolution from 1993-2008 (corrected for tidal height) were obtained and the variance in weekly anomalies was calculated over the May-June and August-September periods (Ducet et al. 2000); <http://www.aviso.oceanobs.com>). Data on the shelf (less than 200 m depth) were excluded from this analysis because the tides are not well-resolved on the shelf.

Chlorophyll (mg/m^3)

Surface chlorophyll is another indicator of ocean productivity. Satellite-derived SeaWiFS chlorophyll data (1998-2003) and Modis chlorophyll data (2004-2008) were obtained from level 1 files downloaded from the Goddard Space Center's Ocean Color website (<http://oceancolor.gsfc.nasa.gov>). May-June and August-September composites at a 20 x 20 pixel resolution were created with the SeaDAS suite of programs. Data tagged as contaminated by color due to coccolith blooms in 1998-2001 were excluded from the composites.

Winter

Surface air temperature ($^{\circ}C$)

Surface air temperature (SAT) during the winter months is an indicator of the strength of the Aleutian Low and thus the position and strength of winter storms. A strong Aleutian Low results in strong northerly winds and a decrease in SAT in the Aleutian Islands and Bering Sea. In addition, low average winter SAT is associated with higher within-season SAT variability, which has been hypothesized to directly or indirectly affect Steller sea lion survival (Rodionov et al. 2005). Daily SAT data were obtained from the National Center for Environmental Prediction (NCEP) at a 2-degree resolution and averaged to create winter, December-February, composites (Kalnay et al. 1996); NCEP Reanalysis data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, <http://www.cdc.noaa.gov/>). SAT variation was calculated from November to March data to represent within-season variability (Rodionov et al. 2005).

Sea surface height variability (cm)

Variability in sea surface height (SSH) anomalies is an indicator of oceanographic fronts and eddies which can concentrate the food (e.g., zooplankton and forage fish) of sea lion groundfish prey. Weekly SSH anomaly data from the AVISO satellite altimeter at 0.25-degree resolution from 1993-2008 (corrected for tidal height) were obtained and the variance in weekly anomalies was calculated from September-April (Ducet et al. 2000); <http://www.aviso.oceanobs.com>). The September-April period was

chosen to represent the winter, non-breeding season when adult sea lions tend to be distributed over a wide range (Gregs and Trites 2008). Data on the shelf (less than 200 m depth) were excluded from this analysis because the tides are not well-resolved on the shelf.

Definition of Steller sea lion “habitat” for oceanographic analyses

The oceanographic data were spatially aggregated into the same regions as the groundfish survey and commercial fishery data except the oceanographic regions did not extend all the way to the edge of the EEZ. Instead we identified likely ranges that sea lions would occupy in each ecosystem based on tracks of satellite-telemetered sea lions. We defined sea lion “habitat” in the Aleutian Islands as extending 50 nmi offshore to the south side of the island chain and to the EEZ boundary to the north, similar to the fishery data analyses, because the telemetry data indicated that that sea lions in the Aleutian Islands did not forage off the shelf (Fadely et al. 2005). Sea lion “habitat” in the Gulf of Alaska extended a bit further than in the Aleutians, it was defined as 50 nmi beyond the 1000 m depth contour reflecting the telemetry data that show that sea lions used the shelf and slope areas (Loughlin et al. 2003).

V. Regression-Correlation analyses

a. Harvest rate by species, year/period and Steller sea lion growth rate by region

Harvest rate was calculated as the ratio of average catch divided by average biomass for three time periods: 1991-2008, 1991-1999, and 2000-2008. For regression analysis, harvest rates (percentages removed) were transformed using the arcsine transformation (Sokal and Rohlf 1969) and were regressed against annual SSL growth rates (for the same three periods) separately for the AI-BS and GOA-BS ecosystems. Region 6 was included in both the AI-BS and GOA-BS ecosystem analyses since it occupies a ‘keystone’ or transition location geographically and in the SSL diet data between the Aleutian Islands (regions 1-5, west of Samalga Pass) and the Gulf of Alaska (regions 7-11, SE AK through Unimak Pass). Atka mackerel frequencies of occurrence in SSL diet samples are highest in the western AI, and decrease to the east through region 6, and the species is virtually absent from the diet in the GOA (regions 7-11). Just the opposite occurs for arrowtooth flounder, which appears most frequently in SSL diet samples taken in the GOA and the BS (decreasing to the west), but is virtually absent in the AI (regions 1-5). Pollock and Pacific cod are eaten by SSLs throughout all regions 1-11, but with generally higher frequencies of occurrence and less seasonal variability in the GOA than in the AI.

We analyzed the relationship of decadal harvest rates and SSL growth rates using regression analyses within the AI-BS (regions 1-6) and GOA-BS (regions 6-11) ecosystems. We also analyzed three periods: the entire 1991-2008 data set, the 1990s, and the 2000s; and used both the all trend site and rookery trend site growth rates as independent variables. Because of the few data points (6, 1 for each region per ecosystem and period), we used a liberal significance criterion ($P < 0.25$) in order to err on the side of making a Type II (mistaking a non-significant for a significant association) than a Type I error (mistaking a significant association for a non-significant relationship).

The hypotheses considered in the harvest rate and SSL growth rate regressions were:

- 1) H0: There is no association between harvest rate and SSL growth rate during the period analyzed. The slope of a graph of SSL growth rate (Y) against harvest rate (X) is 0 indicating no association between the variables.
- 2) H1: SSL growth rate is negatively associated with harvest rate. One explanation for this is that the greater the harvest rate, the less prey would be available to SSLs, which in the long-

term, would be reflected in fewer SSLs (smaller or negative growth rate). A graph of SSL growth rate against harvest rate would have a negative slope.

- 3) H2: SSL growth rate is positively associated with harvest rate. One explanation for this is that high harvest rates are associated with high fish abundance and a positive SSL population response.

b. Oceanography and Steller sea lion growth rate by region

Oceanographic data were averaged over the sea lion habitat (defined above) in each region by year. Decadal averages (1991-2008, 1991-2000 and 2000-2008) for each region were then calculated for regression analyses on annual Steller sea lion population growth rates.

The hypotheses considered in the oceanography and SSL growth rate regressions were:

- 1) H0: There is no association between oceanographic variables and SSL growth rate during the period analyzed. The slope of a graph of SSL growth rate (Y) against an oceanographic variable (X) is 0 indicating no association between the variables.
- 2) H1: SSL growth rate is positively associated with oceanographic variables indicative of spring and summer production. The slope of SSL growth rate (Y) against SST (X) is negative. The slopes of SSL growth rate (Y) against wind mixing (X) and chlorophyll (X) are positive.
- 3) H2: SSL growth rate is positively associated with sea surface height (SSH) variability, an indicator of prey aggregating processes such as fronts and eddies, in all seasons. The slope of SSL growth rate (Y) against SSH variability (X) is positive.
- 4) H3: SSL growth rate is negatively associated with oceanographic variables indicative of winter storminess. The slopes of SSL growth rate (Y) against surface air temperature, SAT (X) and SAT variability (X) are positive.

V. Other modeling analyses attempted

In addition to the regression analyses, we investigated three different modeling approaches. The first used a general linear model to fit the regional and temporal time series of SSL counts (Tables 3 and 4) as functions of regional and temporal changes in prey biomass, prey catch, prey harvest rate, and oceanographic variables. This approach was abandoned because:

- 1) It assumes a direct relationship between the SSL count and each factor at each lag value, when in reality, there is more likely a cumulative response by SSLs to multiple years of effects from one or more of the factors investigated;
- 2) The number of pair-wise comparisons between factors and SSL counts was limited because of the number of years with no SSL survey and lack of comparable catch data prior to the beginning of the SSL time series. Fishery catch data collected by observers on joint venture and foreign vessels in the late 1980s was not as complete a sample of the entire fishery (because of the growing, unobserved domestic fleet at the time) as that collected in the 1990s and 2000s; and
- 3) Perhaps most importantly, given the number of independent variables we had (4 catch, 4 biomass, 4 harvest rate, and 6 oceanographic), we could eventually fit any of the regional SSL time series but were not necessarily convinced that we had determined how these factors were related.

The second modeling approach also employed general linear modeling, but in this case, we fit SSL growth rates by area and decade (Table 5) as a function of average fish biomass, catch, harvest rate, and oceanography over these same areas and time periods. We used step-wise regression to introduce each variable independently. A decadal scale was chosen for this analysis in an attempt to address point 1 above in our first modeling exercise. Our second approach was also doomed because we had too few data points given the number of independent variables that we were investigating. For instance, for 1991-1999 in the AI-BS, we had only 6 data points representing the average SSL growth rates in each of the AI-BS regions (1-6) for the decade, but we had >6 independent variables; we could again fit any time series perfectly.

The third modeling approach we investigated was a Bayesian analysis of the relationship between the same data analyzed in the second GLM, however instead of trying to fit the series of area-decadal growth rates, we addressed the following question: What lag value (in years) is the most significant in the relationship between fishery harvest rate and SSL counts by area? We assumed a process model in which the association between harvest rate and SSL numbers was highest at some non-zero lag year reflecting both the delay between 'cause' and 'effect' as well as the cumulative nature of the factors on the response. We then used the data to estimate the parameters of the relationship between lag and fit. This approach was also limited by the same small number of pair-wise comparisons between factors and SSL counts that we encountered in our first GLM.

RESULTS

Steller sea lion growth rates

During the 1990s, population trends (annual growth rates) across the range of the western distinct population segment (DPS) in AK (regions 1-10) were negative in all regions except regions 4 and 6 at all trend sites (Tables 2-4; Figure 2). Population decline rates were greater at the eastern and western edges of the AK wDPS, with annual rates of decline between 5.1-11.4% in regions 1 and 8-10. In the AI, growth rates improved from west to east, increasing from -7%/y in regions 1 and 2 to stable in region 4. In the center of the wDPS range in AK (regions 5-7), trends were generally negative, but were smaller in magnitude than those in the eastern or western ends of the AK range. Growth rates at rookeries were similar in magnitude to those at all trend sites (with the exception that they were more negative at rookeries in regions 8-10), but they were more likely to be significantly different than 0. This is probably due to the rookery only counts tracking a segment of the population (reproductive, mature adults) that has more consistent haul-out patterns during the breeding season than the population at all trend sites, which includes juveniles and non-reproductive adults at haul-outs. In the 1990s in region 11 (SE AK), growth rates were positive at both all trend sites and rookeries, but neither was significantly different from 0 due to variability in counts.

In the 2000s, counts continued to trend negative (though not significant) in the west (regions 1-3), but were significantly positive at both all sites and rookeries in the center of the AK wDPS range (regions 6 and 7) and were largely stable (slope less than $\pm 1\%$) or not significantly different from 0 throughout the rest of AK. The lack of statistically significant growth rates in the 2000s is partially due to data limitations (only 3 data points in region 11, and only 4 data points in regions 1-3, 5, 8 and 9) but also to count variability (e.g., regions 4, 10 and 11). The 2008 survey was affected by seasonal movement of sea lions in late spring-early summer which inflated counts in region 10 (Prince William Sound area) and

reduced counts in region 11 (SE AK). To correct for this, we used estimated 2008 counts to more accurately reflect regional trends in regions 10 and 11.

Population trends within each region during the entire 1991-2008 time series predominantly reflect the 1991-1998 trends, with greater declines from east to west in the AI (from region 3 to 1), stability in the center part of the wDPS range (regions 4-7), and declines to the east (regions 8-10). Non-pup counts in the eastern DPS in SE Alaska (region 11) increased at a relatively consistent rate of 2% per year from 1991 through 2008.

Regression analyses – Fish harvest and Steller sea lion growth rates

Aleutian Islands –eastern Bering Sea

We analyzed 18 relationships between harvest rates of Atka mackerel, Pacific cod and Pollock, and SSL growth rates in regions 1-6 (Tables 14 and 15; Figures 3 and 4). The distributions of negative, positive, and no association are:

Period	Negative	Positive	No Association	Total
1991-2008	2	2	2	6
1991-1999	1	3	2	6
2000-2008	0	1	5	6
Total	3	6	9	18

Nine of the 18 regression slopes indicated associations between fish harvest and sea lion growth rates, which is double the number that would be expected by chance alone (4.5 = 25% of 18). However, 6 of the associations were positive and only 3 were negative. The majority of the associations occurred in the periods 1991-1999 and 1991-2008.

While all 6 slopes were negative between Atka mackerel harvest rates and SSL growth rates, half indicated an association (1991-2008 for both rookery and all trend sites, and 1991-1999 for all trend sites). The significance of the associations appears to be undermined by the relatively high SSL decreases and modest mackerel harvest rates in region 1, since all positive and small negative SSL rates are associated with relatively low mackerel harvest rates.

For Pacific cod, 4 of 6 slopes were positive, and 1 indicated a positive association between cod harvest and SSL growth rates at all sites in the 1990s. For all Pacific cod regressions, the association is strongly influenced by the pairing of positive SSL growth rates and high cod harvest rates in region 4, since all other points are clustered near the origin.

For Pollock harvest rates, five of the six slopes indicated a positive association with SSL growth rates. In the Pollock regressions, the time periods were slightly different than the others to account for the virtual closure of the Pollock fishery in the Aleutians beginning in 1999. Harvest rate averages for the periods 1991-1998 and 1999-2008 were used instead of 1991-1999 and 2000-2008. Associations in the 2000s are strongly influenced by region 6 (Bering Sea) since Pollock harvest rates were very low in regions 1-5 during this period. All four of the 1991-2008 and 1991-1998 associations were positive, due primarily to the pairing of relatively low Pollock harvest rates with large negative SSL growth rates in regions 1 and 2. Computation of average harvest rates by region and period smoothed the highly pulsed nature of the Pollock fishery in the AI that is evident by scanning the catch in Table 8. For instance, Pollock catch in region 1 was 17,669 t in 1998, but the catch in all other years was 550 t or less. The average Pollock harvest rate in region 1 from 1991-1998 was 3.1%, but the harvest rate in 1998 was estimated at 59%. Similar, relatively high annual harvest rates were also estimated for region 3 from

1995-97, and for region 4 in 1995 and 1997, yet 1991-1998 average harvest rates for each region were only 20% and 19%, respectively, which are approximately the rates expected based on the harvest policy used at the time. If there is an association between SSL regional growth rates and these short-term, localized AI Pollock fisheries, it has not been captured in our analysis.

Gulf of Alaska – eastern Bering Sea

We analyzed 30 relationships between harvest rates of Pacific cod, Pollock (Jan-Jun, Jul-Dec, and annual) and arrowtooth flounder, and SSL growth rates in regions 6-11 (Tables 14 and 15; Figures 5 and 6). The distributions of negative, positive and no associations are:

Period	Negative	Positive	No Association	Total
1991-2008	0	0	10	10
1991-1999	6	0	4	10
2000-2008	0	0	10	10
Total	6	0	24	30

Six of the 30 regression slopes indicated an association between fish harvest and sea lion growth rates, which is about 1-2 less than expected by chance alone ($7.5 = 25\%$ of 30). All six indicated a negative association. Eighty percent of the 1991-1999 regression slopes were negative, with 6 indicating an association, about 3-4 more than expected by chance alone ($2.5 = 25\%$ of 10). Seventy percent of the 2000-2008 regression slopes were positive but none indicated an association. When all the data were considered (1991-2008), all 10 regressions had negative slopes (reflecting the relatively consistent negative associations between harvest rates and SSL growth rates of the 1990s), but none indicated an association (reflecting the inclusion of the positive slope of the 2000s data).

For Pollock, 3 of the 4 1991-1999 regressions between Jan-Jun (Qtrs 1 and 2) and annual Pollock harvest rates and both SSL growth rates indicated a negative association. Pollock harvest rates during Jul-Dec (Qtrs 3 and 4) were generally lower than those in Jan-Jun or during the year as a whole, and none indicated an association with SSL growth rate.

For Pacific cod, the 1991-1999 regressions between harvest rate and both SSL growth rates indicated a negative association, while all of the other regressions showed no association. The distribution of points in the 2000s is somewhat dome-shaped, with the highest SSL growth rates paired with modest cod harvest rates, and lower SSL growth rates paired with both high and low harvest rates.

For arrowtooth flounder harvest and sea lion growth rates, no associations were indicated, reflecting both the low range and magnitude of harvest rates for this species in the Gulf of Alaska.

Regression analyses – oceanographic data

We analyzed the association of decadal oceanographic parameters and SSL growth rates using regression analyses within the AI-BS (regions 1-6) and GOA (regions 7-11) ecosystems. Our definition of the GOA does not include region 6, as the fishery harvest rate analysis does because the oceanographic processes in the eastern Aleutians (region 6) are likely very different than the GOA (regions 7-11). We also analyzed data from the AI only (excluding the Bering Sea regions), because the oceanographic processes operating in the Aleutian Islands are expected to be different from those operating in the Bering Sea. The three decadal periods were: the entire 1991-2008 data set, the 1990s, and the 2000s;

and used both the all trend site and rookery trend site growth rates as independent variables. Because of the few data points, we used a liberal significance criterion ($P < 0.25$) in order to err on the side of making a Type II (mistaking a non-significant for a significant association) than a Type I error (mistaking a significant for a non-significant association).

Aleutian Islands

Of the 11 oceanographic variables examined for statistical relationships with Steller sea lion population growth rate on all rookery and haul-out trend sites in the Aleutian Islands (Table 16 and Figs. 7, 8, 9), seven showed a significant association. Those variables were spring SST, spring wind mixing, spring chlorophyll, summer chlorophyll, winter surface air temperature, winter surface air temperature variability (2000-2008 only) and sea surface height variability (Table 17 and Figs. 10, 11). The same variables (Table 18 and Figs. 12, 13, 14) were significantly related to Steller sea lion population growth rate on rookery sites alone, with the addition of summer wind mixing (1991-2000) and spring sea surface height variability (Table 17 and Figs. 15, 16).

Aleutian Islands – Bering Sea

Of the 11 oceanographic variables examined for statistical relationships with Steller sea lion population growth rate on all rookery and haul-out trend sites in the Aleutian Islands – Bering Sea (Table 16 and Figs. 17, 18, 19), four showed a significant association. Those variables were spring wind mixing, spring chlorophyll, summer chlorophyll and winter surface air temperature variability, 2000-2008 only (Table 17 and Fig. 20). The same variables (Table 18 and Figs. 21, 22, 23) were significantly related to Steller sea lion population growth rate on rookery sites alone (Table 19 and Fig. 24).

Gulf of Alaska

Of the 11 oceanographic variables examined for statistical relationships with Steller sea lion population growth rate on all rookery and haul-out trend sites in the Gulf of Alaska (Table 16 and Figs. 25, 26, 27), three showed a significant association. Those variables were spring sea surface height variability, summer sea surface height variability and winter surface air temperature (1991-2000 and 2000-2008 only) (Table 17, Fig. 28). The same variables were analyzed with respect to Steller sea lion population growth rate on rookery sites alone (Table 18 and Figs. 29, 30, 31) and one statistical association was found, with winter surface air temperature, 2000-2008 only (Table 19).

DISCUSSION

Fishery harvest rates

This analysis was designed to uncover associations between the distribution of fisheries and SSL population growth rates between 1991 and 2008, a period in which considerable spatial and temporal variability in both has been observed. This analysis did not determine ‘cause and effect’, but merely associations between the paired data sets (e.g., are ‘high’ harvest rates for species X associated with ‘low’ SSL growth rates, or vice versa). The null hypothesis (H_0) is that there is no association between harvest rate of species X and SSL growth rate, while H_1 was that SSL growth rate is negatively associated with harvest rate, such that the greater the harvest rate, the less prey would be available to SSLs, which in the long-term, would be reflected in fewer SSLs (smaller or negative growth rate). If the slope is 0 (H_0) or positive (H_2), then there is either no detectable association between SSL growth rate and

harvest rate, or potentially an association of high harvest rate (and potentially high fish abundance) with high SSL growth rate.

There were negative associations between some harvest rates and SSL growth rates that were consistent with H1. These occurred for species that were the most prevalent in the diet of SSLs within the ecosystems tested. For instance, three of the 6 associations between Atka mackerel harvest rates and SSL growth rates in the AI were consistent with H1. Atka mackerel is the most prevalent species found in the diet of SSLs in the AI region (Sinclair and Zeppelin 2002). Similarly, there were negative associations between Pollock (winter and annual) and Pacific cod harvest rates, and SSL growth rates in the GOA in the 1990s. Both Pollock and Pacific cod are commonly found in the GOA SSL diet (Sinclair and Zeppelin 2002; MacKenzie and Wynne 2008; Trites et al. 2007).

There were no negative associations between Pollock and Pacific cod harvest rates and SSL growth rates in the AI. Both Pollock and Pacific cod are prevalent in the SSL diet in the GOA, but in the AI, are eaten seasonally (winter) and their consumption in the AI appears to be 'patchier' than in the GOA (Logerwell Barbeaux Fritz NPRB). This temporal/spatial patchiness in both consumption by SSLs and in fish distribution may not be captured well in our analysis because of scale mismatches. In addition, there has essentially been no Pollock fishery in the AI since 1999. There were also no negative associations between summer Pollock or arrowtooth flounder harvest rates and SSL growth rates and GOA SSL growth rates. This may be the result of the relatively low harvest rates for both species estimated in our analyses. Sampson (1995) also found a negative association between winter Pollock catch and SSL growth rate around rookeries, and no association with summer pollock catch; our results support both of Sampson's earlier findings.

We found associations between some harvest rates and SSL growth rates that were consistent with H1 for one time period, but not for others. This is most clearly shown in the GOA, where there were several negative associations in the 1990s (Pacific cod, Pollock winter, and Pollock annual) that did not continue into the 2000s. There are several possible explanations for this temporal change in the relationships:

- 1) The 1990s negative associations were spurious; while this is possible, our results indicate a relatively strong association and were similar to those of Sampson (1995)
- 2) Density-dependence: Any effect of regional differences in harvest rate were expressed in the 1990s, and by the 2000s, the SSL population had declined enough in those regions that the harvest rate-SSL growth rate relationship had changed
- 3) Management changes enacted in the 2000s removed the effect of fishing that was expressed in the 1990s and that was independent of harvest rate.

Our analyses do not enable us to determine the relative plausibility of explanations 2 and 3.

There are several issues with the data that we analyzed that could obscure the true relationships between local fishery intensity and SSL population response. The first has to do with temporal scale. We calculated average growth rates and harvest rates for decadal periods. This would hide any effect of short-term intense regional fisheries, of which the AI Pollock fishery in the 1990s is an example. However, there were problems associated with comparing annual SSL counts and annual harvest rates that we thought were worse (as described above), and there were too few SSL surveys to estimate shorter-term growth rates. Hence, we settled on decadal scales knowing that we were smoothing over long periods in the calculation of average harvest rates.

Another issue that could reduce statistical significance of relationships was observation and process errors within the data sets. Regarding the SSL data, movement of sea lions between regions could

obscure the true relationships between the variables tested, but less when using the rookery SSL counts than the all trend site counts. However, the movement issue is likely involved in the highly variable counts in regions 10 and 11, particularly in 2008. Information collected in 2009 on seasonal movement between regions 10 and 11 strongly support this; SSL counts in these regions in 2008 were corrected for this movement. For region 11, the non-pup trends in the all site and rookery counts have more variability and suggest a less robust population growth than the pup counts analyzed by Pitcher et al (2007). This could be a result of variability in survey timing in SE AK that is reflected in variability in adult and juvenile abundance on SE AK rookeries and haulouts. Regarding the fish data, the 1 or 2 year gaps between bottom trawl surveys in the AI and GOA required smoothing between years to estimate annual biomass and harvest rate within each region. This process may have produced inaccurate biomass estimates and harvest rates in those years without surveys, but there is no ancillary information available to determine the magnitude or frequency of this issue and its effect on the analysis.

We did not consider the effect of other factors on regional SSL growth rates, such as predation, subsistence take, incidental catch in fisheries, contaminants, disease, and others listed in NMFS (2008). Regarding the influence of direct mortality factors (e.g., predation, subsistence takes, incidental catch in fisheries), population modeling (Fay and Punt 2006; Holmes et al. 2007) and preliminary estimates of survival from resights of permanently marked animals (Pendleton et al. 2006; NMFS and ADFG, unpublished) indicates that survival rates of western SSL s were greater in the 1990s and 2000s than in the 1980s. Consequently, the available information does not suggest that direct threats contributed significantly to the regional patterns in SSL growth rates observed here, but this cannot be entirely ruled out particularly for regions 1 and 2 where SSLs may range into waters where there is less information regarding threats of this nature.

Hennen (2006) analyzed the relationship between SSL counts at individual rookeries and various fishery metrics using data collected between the late 1970s and 2001. He found "...a positive correlation... between several metrics of historical fishing activity and the SSL population decline [from the 1970s through 1990]. The relationship is less consistent after 1991,...". Our analysis, while similar to Hennen's, differs from his in several key ways:

- 1) We analyzed data only from 1991-2008, since SSLs were listed under ESA and after some conservation measures had been implemented. This avoided using SSL data from the 1980s when factors affecting SSL populations were different from those after the listing (e.g., higher levels of direct mortality resulting in lower juvenile survival and steeper rates of population decline; Holmes et al. 2007; NMFS 2008; Rosen 2009)
- 2) We used pooled regional SSL counts rather than individual SSL rookery counts, which gave us 11 areas rather than 32 individual rookeries. In our analysis, counts at haul-outs and rookeries were pooled based on proximity and similarity in trend
- 3) We used individual fish species harvest rates (catch divided by an estimate of available biomass) rather than catch or fishery catch-per-unit-effort.

Hennen found no consistent relationship between the fishery metrics in the 1990s and SSL trends at rookeries. By contrast, we found associations consistent with H1 for the 1990s between winter Pollock and Pacific cod harvest rates in the GOA and Atka mackerel in the AI, and regional SSL population trends. This difference is likely due to differences in the data employed in each analysis, which in our case used estimates of individual fish biomass and catch rather than pooled fishery-derived metrics (e.g., catch-per-unit-effort). In all cases, associations that were consistent with our first hypothesis in the 1990s were not consistent in the 2000s (as discussed above).

Oceanography

Steller sea lion annual population growth rates in the Aleutian Islands were significantly related to variables indicative of spring and summer ocean production (SST, wind mixing and chlorophyll). Sea lion population growth rates were higher in areas of high spring and summer chlorophyll, consistent with oceanographic H1. Interestingly, the association of sea lion population growth to spring SST and wind mixing was the opposite of what was originally expected. The expectation (H1) was that high wind mixing and the resulting low SST would be indicative of high spring ocean production that would favor sea lion population growth. However, we found that relatively warm SST and low wind mixing were associated with high population growth rate. We suggest that different from other coastal ecosystems, tidal forces in the Aleutian Island passes are strong enough to substantially mix the water column such that additional mixing due to winds in the spring results in chlorophyll cells being transported down to depths below the light compensation level (Stabeno et al. 2005). A moderate amount of stratification of the water column is required to retain chlorophyll near the surface where light levels are sufficient for photosynthesis to compensate for respiration such that chlorophyll production can occur (Ladd et al. 2005). Supporting this idea, we found a positive correlation between spring chlorophyll and SST ($r=0.97$). During summer a different mechanism may be operating. We found a positive association between sea lion growth rates on rookeries only and summer wind mixing during one decade (1991-2000). This result is not conclusive but suggests that during summer the role of wind mixing may change, becoming an important mechanism for renewing nutrient supplies in the upper water column depleted during a spring bloom (Ladd, pers. com.). We also found a positive association between spring sea surface height variability and sea lion growth rates on rookeries only, consistent with oceanographic H2. Because this association was not observed with sea lion growth rates on all sites, we consider it inconclusive, but suggestive of the importance of fronts, eddies and other mechanisms that may aggregate ocean production.

This appears to be one of the only studies of the relationship between sea lion population growth and ocean temperature and chlorophyll. The only other analysis focused on the importance of spatial and temporal variability in SST and chlorophyll (Lander et al. 2009). The results of that study showed that low temporal variability and high spatial variability were associated with relatively high sea lion population growth rates. An alternative explanation of the relationship between sea lion population growth and ocean temperature is that SST is an indicator of which currents are affecting a region. An ecological classification of sea lion rookeries identified five distinct classes of rookeries characterized by variables including SST, which the authors interpreted to be related to the different currents affecting the specific areas (Call and Loughlin 2005). The Alaska Coastal Current (ACC) is characterized by relatively warm water, whereas the Alaska Stream (AS) and Aleutian North Slope Current (ANSC) are cooler. The ACC extends from the Gulf of Alaska into the eastern Aleutian Islands, to Samalga Pass. The Alaska Stream influences the Aleutian Islands oceanography west of Samalga Pass (Ladd et al. 2005). Our SST data are consistent with this pattern, SST declines from region 6 in the eastern Aleutian Islands west to region 1 in the far western Aleutian Islands (Fig. 31). The ACC has been shown to support a zooplankton community made of primarily coastal species, whereas the AS contains oceanic zooplankton species (Coyle 2005). How this difference would influence the productivity and availability of Steller sea lion fish prey species is not known.

Steller sea lion population growth rate in the Aleutian Islands was positively related to winter surface air temperature (SAT), consistent with oceanographic H3. Low SAT has also been associated with a stronger Aleutian Low and stormier weather (Rodionov et al. 2005) which, in addition to cold air temperatures could directly impact sea lions through physiological stress. SAT could also be an indicator of oceanographic processes influenced by the Aleutian Low that indirectly impact ocean productivity and thus sea lion foraging opportunities, but this mechanism has yet to be identified (Rodionov et al. 2005).

There was also a positive association between winter SAT variability and sea lion population growth rate in one decade, 2000-2008. However this association was driven by one point, high SAT variability in region 6 (eastern Aleutians and SSLCA) and although statistically significant, should be interpreted with caution. A third winter oceanographic variable, sea surface height variability, was positively related to sea lion growth rates, consistent with oceanographic H2. High sea surface height variability is indicative of aggregating processes such as fronts and eddies which may result in local concentrations of sea lion prey. Fadely et al. (2003) analyzed tracks of satellite-tagged sea lions and suggested that some animals occupied and tracked oceanographic eddies north of the Aleutian Island chain.

The differences in bottom topography and oceanographic structure of the Aleutian Islands and Bering Sea were expected to obscure any statistical associations between sea lion population growth and oceanographic variables when the oceanographic data from the regions were combined. However, the analysis did show that spring wind mixing and spring and summer chlorophyll were related to sea lion population growth. Similar to the results for the Aleutian Islands alone, sea lion population growth rates were higher in regions of high spring and summer chlorophyll and lower in regions of high wind mixing. Similar to the explanation above for the unexpected negative association between sea lion population growth rate and wind mixing, it's possible the high spring wind mixing in the Bering Sea actually results in low productivity because some degree of stratification is necessary to keep chlorophyll near the surface where light levels are sufficiently high for production to compensate for respiration. There was also a statistically significant association between sea lion population growth and winter surface air temperature (SAT) variability in one decade (2000-2008), but the association was driven by a single point of very high SAT variability in area 6, which included the entire Bering Sea for this analysis. The remaining points showed no relationship between SAT variability and sea lion population growth.

Fewer oceanographic variables examined showed a statistically significant association to Steller sea lion population growth rates in the Gulf of Alaska (GOA) than in the Aleutian Islands and Bering Sea, and the patterns are difficult to interpret. There was a negative association between spring sea surface height variability and population growth rate at all trend sites. However, the expectation (H2) was that there would be a positive association because SSH variability is an indicator of oceanographic fronts and eddies that can aggregate ocean production. There is no ready explanation for a negative association between these two variables. There was a positive association between sea lion population growth at all trend sites and summer sea surface height variability, consistent with the H2 that fronts and eddies may be important foraging areas for sea lions. There were significant associations between sea lion population growth and winter surface air temperature (SAT) in the 1990s and 2000s, although the slopes were opposite of each other – positive in the 1990s and negative in the 2000s. The expectation (H3) was that SAT, would be positively correlated with sea lion population growth rate, cold temperatures being an indicator of winter storminess. None of the oceanographic variables tested showed a significant association with sea lion population growth rates on rookeries only. The lack of consistent oceanographic correlates for sea lion population growth in the GOA could be because the variables chosen, while indicative of important oceanographic processes in the Aleutian Islands and Bering Sea, were not good indicators of the processes important in the Gulf of Alaska (GOA). The GOA shelf is dominated by the Alaska Coastal Current which is forced by along-shore winds and freshwater run-off (Stabeno et al. 2004). Unfortunately, time series of those data are only available at the scale of virtually the entire Gulf, so analyses at the relatively small scale of our Steller sea lion regions were not possible. It is also possible that we found no statistically significant associations between oceanographic variables and sea lion population growth rate because oceanographic processes were not the primary determinant of sea lion survival or production in the GOA. The Lander et al. (2009) analyses showed that the patterns of relationships between SST and chlorophyll spatial variability and sea lion population

growth rates across the Aleutians were not observed in the central GOA. Similarly, while Call and Loughlin (2005) found that sea lion rookeries in the Aleutian Islands separated cleanly into ecological regions based on oceanographic properties, the rookeries in the GOA did not.

Not only do our results suggest that oceanographic processes could be more important to sea lion population growth rates in the Aleutians Islands than in the GOA, our results also indicate that the western Aleutians may be a particularly unproductive and harsh environment for sea lions. There are longitudinal trends in all the significant spring, summer and winter oceanographic variables. The western Aleutians are characterized by higher wind mixing, lower spring SST, lower spring and summer chlorophyll and lower winter surface air temperature (Fig. 32).

CONCLUSIONS

Harvest rate

- 1) We found no association between harvest rates for SSL prey species and SSL population growth rates within ecosystems where the prey species has a relatively low frequency of occurrence in annual SSL diets or where harvest rates for the prey species were relatively low in each of the SSL regions (arrowtooth flounder in the GOA-BS (all 6), and Jun-Dec Pollock in the GOA-BS (5 of 6)).
- 2) We found negative associations consistent with H1 between harvest rates for SSL prey species and SSL population growth rates:
 - a. within ecosystems where the prey species has a relatively high frequency of occurrence in annual SSL diets and where there was contrast between SSL regions in fishery harvest rates for the prey species (3 of 6 associations for Atka mackerel in the AI-BS, 5 of 12 for Jan-Jun and annual Pollock in the GOA-BS, and 2 of 6 associations for Pacific cod in the GOA-BS), and
 - b. predominately in the 1990s.
- 3) We found positive associations consistent with H2 between harvest rates for SSL prey species and SSL population growth rates within ecosystems where the prey species has a relatively low frequency of occurrence in annual SSL diets, where SSL consumption of the prey species may be seasonal, or where harvest rates for the prey species were low in most of the SSL regions (5 of 6 associations for Pollock in the AI-BS, and 1 of 6 associations for Pacific cod in the AI-BS).

Oceanography

We found significant associations consistent with oceanographic H1 between variables indicative of spring and summer ocean production (SST, wind mixing and chlorophyll) and SSL population growth rates in the Aleutian Islands and Bering Sea.

We found significant associations consistent with oceanographic H2 between a variable indicative of oceanographic prey aggregating mechanisms, such as fronts and eddies (sea surface height variability) and SSL population growth rates in the winter in the Aleutian Islands.

We found significant associations consistent with oceanographic H3 between a variable indicative of winter storminess (surface air temperature) and SSL population growth rates in the Aleutian Islands. High surface air temperature, or reduced storminess, was associated with high population growth rates.

Few oceanographic variables examined showed statistically significant associations to SSL population growth rates in the Gulf of Alaska (GOA), and the patterns were difficult to interpret.

Our results suggest that oceanographic processes are more important to SSL population growth rates in the Aleutians Islands than in the GOA, and that the western Aleutians may be an unproductive and harsh environment for sea lions. This apparent sensitivity of SSL populations to oceanographic processes coupled with the negative effects of harvest rate may contribute to the continuing negative rates of SSL population growth in the Aleutian Islands, particularly in the western islands.

RECOMMENDATIONS FOR FUTURE WORK

- 1) Consider different spatial units for the GOA analysis and for region 6
 - a. Conduct the GOA analysis with regions 6-11 and alternatively with only regions 7-11. Region 6 (essentially the eastern Bering Sea) is a different ecosystem than the remaining GOA regions and should be considered separately.
 - b. Use 2 different sizes of region 6 in the GOA and AI analyses. The first would be as used in this analysis, which is the entire eastern Bering Sea fishery management area plus the area south of the Aleutian Island chain in the GOA between 165-170°W. The second would only use the Sea Lion Conservation Area (SCA) north of the Aleutian Island chain plus the same area to the south. This would require a model of seasonal Pollock movement into and out of the SCA in the eastern Bering Sea.
- 2) Consider different temporal periods for the GOA and AI analyses, and look at statistical methods for determining the periods in each region.
- 3) Consider alternative methods (besides linear interpolation) to estimate the distribution of fish biomass in years when no survey was conducted.
- 4) Consider different statistical models that incorporate lagged sea lion response to oceanographic and fish/fishery variables that use the data themselves rather than a parameter (in this case, rate of change) calculated from them.

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Table 1. Zones for analysis of Steller sea lion, groundfish fishery and groundfish survey data. Fish: AM=Atka mackerel, P=Pollock, PC=Pacific cod, AF=Arrowtooth flounder. AI=Aleutian Islands, GOA=Gulf of Alaska, EBS=Eastern Bering Sea. EEZ=Exclusive Economic Zone. EIMWT=Echo-integration Midwater Trawl.

Zone	Steller Sea Lion Non-Pup Counts at Trend Sites			Summer Bottom Trawl Survey Strata				EIMWT Survey			Fishery Spatial Range	
	Rookeries	All Trend Sites	Fish	Season	Area	0-100m	101-200m	200+m	Survey Years	Season		Area
1	BULDIR AGATTU (2) ATTU/CAPE WRANGELL	BULDIR							1991			
		SHEMYA							1994			
		ALAID							1997			
		AGATTU/CAPE SABAK	AM						213			
		AGATTU/GILLON POINT	P	Annual	AI	211	212		214			
		ATTU/MASSACRE BAY	PC			221	222		223			
		ATTU/CHIRIKOF POINT							224			
2	AMCHITKA/COLUMN ROCK AYUGADAK KISKA/LIEF COVE KISKA/CAPE ST STEPHEN	ATTU/CHICHAGOF POINT							2002			
		ATTU/KRESTA POINT							2004			
		ATTU/CAPE WRANGELL							2006			
		SEMISOPOCHNOI/POCHNOI										
		SEMISOPOCHNOI/PETREL										
		AMCHITKA/EAST CAPE								1991		
		AMCHITKA/COLUMN ROCK								1994		
		AYUGADAK	AM							313		
		RAT	P	Annual	AI	311	312		314			
		SEA LION ROCK (KISKA)	PC			411	412		413			
3	GRAMP ROCK TAG ULAK/HASGOX POINT KANAGA/SHIP ROCK	TANADAK (KISKA)				58% of 321	71% of 322		2000			
		KISKA/SOBAKA-VEGA							65% of 323			
		KISKA/CAPE ST STEPHEN							60% of 324			
		KISKA/LIEF COVE							2004			
		KISKA/PILLAR ROCK							2006			
		KANAGA/N CAPE										
		KANAGA/SHIP ROCK								1991		
		TANAGA/CAPE SASMIK								1994		
4	KASATOCHI/NORTH POINT ADAK	TANAGA/BUMPY POINT										
		GRAMP ROCK	AM						423			
		UGIDAK	P	Annual	AI	421	422		424			
		TAG	PC			42% of 321	29% of 322		35% of 323			
		ULAK/HASGOX POINT							2000			
		KANAGA/SHIP ROCK							2002			
		KAVALGA							40% of 324			
		ULAK/HASGOX POINT							2004			
		AMATIGNAK/KNOB POINT								2006		
		UNALGA+DINKUM ROCKS										
5	ATKA/NORTH CAPE ATKA/CAPE KOROVIN SALT OGLODAK IKIGINAK KASATOCHI/NORTH POINT FENIMORE ANAGAKSIK GREAT SITKIN LITTLE TANAGA STRAIT KAGALASKA ADAK (2)	AMATIGNAK/NITROF POINT										
		ATKA/NORTH CAPE										
		ATKA/CAPE KOROVIN										
		SALT										
		OGLODAK								1991		
		IKIGINAK	AM							1994		
		KASATOCHI/NORTH POINT	P	Annual	AI	511	512		514			
		FENIMORE	PC			611	612		613			
		ANAGAKSIK								2000		
		GREAT SITKIN								2002		
6	ADAK (2)	LITTLE TANAGA STRAIT							2004			
		KAGALASKA							2006			

Table 1 (continued)

Zone	Steller Sea Lion Non-Pup Counts at Trend Sites			Summer Bottom Trawl Survey Strata			EIMWT Survey			Fishery Spatial Range				
	Rookeries	All Trend Sites	Fish	Season	Area	0-100m	101-200m	200+m	Survey Years		Season	Area	Other	
5	YUNASKA SEGUAM/SADDLERIDGE	HERBERT							1991					
		CARLISLE							1994					
		YUNASKA							1997					
		CHAGULAK							2000					
		AMUKTA+ROCKS	AM						523					
		SEGUAM/TURF POINT	P	Annual	AI	521	522		524					
		SEGUAM/SADDLERIDGE	PC				621	622		623				
		AGLIGADAK								624				
		TANADAK (AMLIA)								2004				
		AMLIA/EAST CAPE								2006				
SAGIGIK														
AMLIA/SVIECH. HARBOR														
6	UGAMAK (2) AKUN/BILLINGS HEAD AKUTAN/CAPE MORGAN BOGOSLOF/FIRE ISLAND ADUGAK OGCHUL SEA LION ROCK (AMAK)	AMAK+ROCKS	AM	Annual					1991					
		SEA LION ROCK (AMAK)							1994					
		UGAMAK/ROUND	P	Summer	AI	711	712		793	1997				
		UGAMAK COMPLEX				721	722		794	2000				
		AIKTAK								2002				
		UNIMAK/CAPE SARICHEF	AF,PC	Annual						2004				
		TIGALDA/ROCKS NE								2006				
		TIGALDA/SOUTH SIDE												
		TANGINAK								1990				
		ROOTOK	P	Summer						1993				
		AKUN/BILLINGS HEAD							50% of 210	1996				
		AKUTAN/CAPE MORGAN			GOA	10	111		50% of 310	1999		GOA EEZ 165-170°W		
		EGG							50% of 410	2001				
		OUTER SIGNAL							50% of 510	2003				
		OLD MAN ROCKS	AF,PC	Annual						2005				
		UNALASKA/CAPE SEDANKA								2007				
		AKUTAN/REEF-LAVA												
		UNALASKA/BISHOP POINT												
UNALASKA/MAKUSHIN BAY														
UNALASKA/SPRAY CAPE														
UNALASKA/CAPE IZIGAN														
POLIVNOI ROCK														
BOGOSLOF/FIRE ISLAND														
THE PILLARS														
OGCHUL														
UMNAK/CAPE ASLIK														
VSEVIDOF														
ADUGAK														
KAGAMIL														
CHUGINADAK														
ULIAGA														
EBS														
1991-2007 annual														
Summer														
EBS														
EBS EEZ 158-180°W N of 55°N & 164-170°W S of 55°N														
Winter														
EBS Bogodof														

Table 1 (continued)

Zone	Steller Sea Lion Non-Pup Counts at Trend Sites			Summer Bottom Trawl Survey Strata				EIMWT Survey		Fishery Spatial Range					
	Rookeries	All Trend Sites	Fish	Season	Area	0-100m	101-200m	200+m	Survey Years		Other				
7	ATKINS CHERNABURA PINNACLE ROCK CLUBBING ROCKS JUDE	ATKINS	P PC AF	Annual Summer	GOA	11		50% of 210	1990 1993 1996		GOA EEZ: 159- 165°W				
		CASTLE ROCK				12	110	50% of 310	1999						
		CHERNABURA				13	112	50% of 410	2001						
		KUPREANOF POINT						50% of 510	2003						
		THE HAYSTACKS							2005						
		THE WHALEBACK							2007						
		NAGAI/MOUNTAIN POINT													
		SEA LION ROCKS (SHUMAGINS)													
		UNGA/ACHEREDIN POINT													
		JUDE													
		PINNACLE ROCK													
		CHERNI				P	Winter	GOA							Dorn et al. 2008
		CLUBBING ROCKS													
SOUTH ROCKS															
BIRD ROCK															
8	LIGHTHOUSE ROCKS CHIRIKOF CHOWIET	TAKLI	P PC AF	Annual Summer	GOA			220	1990 1993 1996		GOA EEZ: 154- 159°W (Area 620)				
		PUALE BAY				20	120	221	1999						
		CHIRIKOF				21	121	320	2001						
		NAGAI ROCKS				22	122	420	2003						
		CHOWIET						520	2005						
		UGAIUSHAK							2007						
		SUTWIK													
		LIGHTHOUSE ROCKS													
		KAK													
		MITROFANIA SPITZ				P	Winter	GOA							Dorn et al. 2008
9	MARMOT SUGARLOAF USHAGAT	MARMOT	P PC AF	Annual Summer	GOA				1990 1993 1996		GOA EEZ 152- 154°W & 147- 152°W S of 59°N				
		SEA LION ROCKS (MARMOT)				30	130	231	1999						
		AFOGNAK/TONKI CAPE				31	131	232	2001						
		SUGARLOAF				32	132	330	2003						
		KODIAK/CAPE CHINIYAK				35	134	430	2005						
		LONG ISLAND						530	2007						
		SEA OTTER													
		UGAK													
		USHAGAT													
		USHAGAT/ROCKS SOUTH													
		LATAK ROCKS													
		KODIAK/GULL POINT													
		KODIAK/CAPE BARNABAS													
		KODIAK/STEEP CAPE				P	Winter	GOA							Dorn et al. 2008
		TWOHEADED													
SHAKUN ROCKS															
SHIKINAK/CAPE SITKINAK															
KODIAK/CAPE UGAT															

Table 1 (continued)

Zone	Steller Sea Lion Non-Pup Counts at Trend Sites			Summer Bottom Trawl Survey Strata				EIMWT Survey		Fishery Spatial Range	
	Rookeries	All Trend Sites	Fish	Season	Area	200+m	Survey Years	Season	Area		Other
10	SEAL ROCKS WOODED (FISH) OUTER (PYE) CHISWELL ISLANDS	CAPE ST. ELIAS					1990				
		CAPE HINCHINBROOK				230	1993				
		SEAL ROCKS					240	1996			
		GLACIER	P	Annual	GOA	33	133	241	1999		
		WOODED (FISH)	PC	Summer		40	140	340	2001		
		THE NEEDLE	AF			41	141	341	2003		
		POINT ELRINGTON						440	2005		
		CAPE PUGET						540	2007		
		CAPE FAIRFIELD									
		RUGGED									
		AIALIK CAPE									
		CHISWELL ISLANDS									GOA EEZ 140-147°W & 147-152°W N of 59°N
		SEAL ROCKS (KENAI)									
		OUTER (PYE)									
		GORE POINT	P	Winter	GOA						Dorn et al. 2008
		EAST CHUGACH									
		PERL									
NAGAHUT ROCKS											
ELIZABETH/CAPE ELIZABETH											
11	FORRESTER COMPLEX HAZY WHITE SISTERS GRAVES ROCK	BIALI ROCK					1990				
		CAPE CROSS					250	1993			
		CORONATION	P	Annual	GOA	50	142	251	1996		
		FORRESTER COMPLEX	PC	Summer			143	350	1999		
		GRAVES ROCK	AF				150	351	2001		
		HARBOR POINT					151	450	2003		
		HAZY						550	2005		
		JACOB ROCK							2007		
		THE BROTHERS	P	Winter	GOA						Dorn et al. 2008
		WHITE SISTERS									

Table 2. Number of adult and juvenile Steller sea lion (non-pups) counted at ALL rookery and haulout trend sites by region, 1991-2008. Years and regions with blanks indicate that no survey was conducted that year or not all trend sites were surveyed. Counts in 2004-2008 were adjusted -3.64% to reflect higher counts obtained on vertically-oriented, higher resolution photographs taken in 2004-08 than on oblique 35 mm slides taken in 1991-2002. 2008 data estimated for regions 10 and 11 (DeMaster 2009).

Year	Steller Sea Lion Region										
	1	2	3	4	5	6	7	8	9	10	11
1991	4,920	2,294	2,771	1,666	1,999	5,514	4,777	3,021	4,757	5,482	8,034
1992	4,530		2,674	1,350		5,890	4,770	2,656	4,429	4,637	8,014
1993											
1994	3,368	1,688	2,290	1,314	1,717	5,756	5,217	2,301	4,092	4,225	9,001
1995											
1996	3,407	1,583	2,251	1,339	1,363	6,077	4,781	2,088	3,280	3,095	8,230
1997											
1998	2,865	1,383		1,651	1,551	5,902	4,726	2,101	2,900	2,605	8,693
1999											
2000	1,650	1,132	2,100	1,839	1,435	5,127	3,730	1,507	2,916	2,500	9,855
2001											
2002	1,199	985	1,915	1,943	1,546	5,456	4,275	1,764	2,671	3,117	9,949
2003											
2004	1,286	1,009	1,946	2,194	1,627	6,218	4,934	1,767	2,271	3,304	
2005											
2006						6,203					
2007				1,615			5,363			3,252	
2008	895	772	1,896	1,351	1,645	6,519	5,274	1,492	2,814	3,675	11,163
No. of Sites	10	12	12	12	12	31	16	11	18	19	10

Table 3. Number of adult and juvenile Steller sea lion (non-pups) counted at ROOKERY trend sites by region, 1991-2008. Years and regions with blanks indicate that no survey was conducted that year or not all trend sites were surveyed. Counts in 2004-2008 were adjusted -3.64% to reflect higher counts obtained on vertically-oriented, higher resolution photographs taken in 2004-08 than on oblique 35 mm slides taken in 1991-2002. 2008 data estimated for regions 10 and 11 (DeMaster 2009).

Year	Steller Sea Lion Region										
	1	2	3	4	5	6	7	8	9	10	11
1991	4,069	1,443	2,351	1,313	1,082	3,516	3,597	1,830	2,907	3,442	6,911
1992	3,945	1,112	2,213	991	1,090	3,713	3,665	1,637	3,007	2,408	6,310
1993											
1994	3,040	1,064	1,887	1,053	1,119	3,513	3,565	1,136	2,268	1,870	7,226
1995											
1996	2,801	1,017	1,892	948	893	3,538	3,384	1,066	1,953	1,479	6,679
1997											
1998	2,437	799	1,802	1,033	796	2,785	3,398	912	1,569	1,417	7,053
1999											
2000	1,437	662	1,700	1,264	811	2,731	3,004	844	1,476	1,461	7,454
2001											
2002	1,007	553	1,602	1,350	942	3,272	3,294	986	1,701	1,487	7,906
2003											
2004	1,150	595	1,620	1,614	1,140	3,725	3,734	920	1,420	1,598	
2005											
2006						4,116			1,503	1,985	
2007				1,341	912	4,434	4,218	990	1,240	1,374	
2008	808	592	1,644	1,128	1,076	4,552	4,191	985	1,530	1,753	9,119
No. of Rookeries	3	4	4	2	2	8	5	3	3	4	4

Table 4. Annual rates of change in Steller sea lion non-pup counts at: A) all rookery and haulout trend sites, and B) rookery trend sites. P = probability that growth rate is significantly different from 0. - = not significantly different from 0 (P>0.05); * = P< 0.05, ** = P<0.01, ***=P<0.001.

A. Annual growth rates at all rookery and haulout trend sites (Table 1)

Region	1991-2008	P		1991-1998	P		2000-2008	P	
1	-0.102	0.000	***	-0.072	0.012	*	-0.066	0.070	-
2	-0.061	0.000	***	-0.068	0.021	*	-0.044	0.047	*
3	-0.022	0.001	***	-0.044	0.050	*	-0.010	0.243	-
4	0.011	0.303	-	0.003	0.923	-	-0.035	0.212	-
5	-0.007	0.422	-	-0.043	0.180	-	0.016	0.114	-
6	0.009	0.152	-	0.012	0.159	-	0.037	0.003	**
7	0.003	0.627	-	-0.002	0.848	-	0.045	0.011	*
8	-0.038	0.001	***	-0.051	0.021	*	-0.006	0.792	-
9	-0.038	0.002	**	-0.070	0.001	**	-0.004	0.865	-
10	-0.021	0.128	-	-0.099	0.001	**	0.038	0.058	-
11	0.020	0.001	***	0.010	0.033	*	0.016	0.111	-

B. Annual growth rates at rookery trend sites (Table 2)

Region	1991-2008	P		1991-1998	P		2000-2008	P	
1	-0.099	0.000	***	-0.073	0.003	**	-0.060	0.123	-
2	-0.054	0.000	***	-0.066	0.024	*	-0.008	0.624	-
3	-0.021	0.001	**	-0.037	0.024	*	-0.002	0.675	-
4	0.013	0.166	-	-0.025	0.307	-	-0.010	0.667	-
5	-0.003	0.710	-	-0.046	0.042	*	0.023	0.333	-
6	0.013	0.138	-	-0.030	0.131	-	0.065	0.000	***
7	0.008	0.191	-	-0.011	0.039	*	0.045	0.002	**
8	-0.030	0.018	*	-0.095	0.007	**	0.015	0.163	-
9	-0.042	0.000	***	-0.090	0.002	**	-0.013	0.449	-
10	-0.025	0.072	-	-0.114	0.016	*	0.018	0.335	-
11	0.018	0.002	**	0.006	0.572	-	0.025	0.029	*

Table 5. A. Catch (t) of Atka mackerel in the Aleutian Islands (regions 1-5) and the eastern Bering Sea (region 6), 1991-2008. B. Catch (t) of arrowtooth flounder in the Gulf of Alaska (regions 6-11) and the eastern Bering Sea (region 6), 1991-2008.

Year	A. Atka mackerel AI-BS only						B. Arrowtooth flounder GOA-BS only					
	Steller Sea Lion Region						Steller Sea Lion Region					
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
1991	14	502	7,212	0	16,411	2,363	18,861	2,294	2,117	11,417	396	80
1992	453	8,112	5,914	12	30,612	2,413	11,229	1,553	3,524	14,876	1,225	495
1993	2,322	23,468	1,595	12	37,537	111	8,143	1,532	3,185	13,101	750	383
1994	12,306	31,060	6,438	146	14,507	135	12,933	1,152	8,418	12,341	816	204
1995	20,621	40,298	7,269	384	12,642	334	8,425	1,204	4,773	11,065	1,028	161
1996	41,861	21,465	11,218	525	28,078	758	13,416	1,795	9,224	10,239	865	204
1997	30,408	12,092	5,910	364	16,884	169	9,680	2,109	4,448	7,987	526	829
1998	24,634	13,453	5,937	41	12,131	894	15,897	2,083	3,280	6,175	487	68
1999	16,388	14,269	8,040	554	14,677	2,308	11,330	2,917	4,360	7,192	752	113
2000	11,406	17,903	3,284	37	13,773	182	15,556	2,641	4,591	12,762	621	91
2001	19,516	27,385	6,516	238	6,890	205	14,937	3,948	3,873	9,521	345	105
2002	17,751	20,369	2,048	16	4,147	313	13,986	2,377	5,083	9,785	159	41
2003	19,077	26,086	1,189	411	6,149	5,454	14,196	6,497	8,747	13,355	144	21
2004	18,375	27,899	2,405	285	3,559	6,518	17,584	2,573	2,266	10,054	137	24
2005	19,130	31,648	4,244	32	3,421	3,501	13,525	2,299	5,645	11,486	82	19
2006	14,962	36,602	2,668	58	4,280	3,114	11,936	1,765	8,397	17,087	85	43
2007	9,401	21,461	4,381	26	20,298	3,007	11,248	2,723	5,295	16,764	149	29
2008	16,054	18,373	4,560	53	18,650	391	19,389	2,919	4,279	22,017	130	58

Table 6. Catch (t) of Pacific cod by Steller sea lion region in the Aleutian Islands (regions 1-5), eastern Bering Sea (region 6), and in the Gulf of Alaska (regions 6-11), 1991-2008.

<u>Year</u>	Steller Sea Lion Region										
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
1991	4,195	230	739	1,381	3,251	211,714	30,146	16,871	24,458	1,063	171
1992	13,630	9,169	1,022	5,956	13,124	167,019	35,168	15,076	21,154	5,345	4
1993	6,155	7,018	479	7,481	13,019	134,378	17,109	9,096	22,809	5,708	392
1994	2,660	5,393	1,892	5,109	6,333	173,760	13,049	9,182	15,750	5,828	104
1995	1,616	3,693	1,607	5,167	4,451	230,021	19,954	12,021	27,837	6,466	148
1996	4,197	2,547	1,490	9,968	12,305	208,597	18,179	19,692	19,413	9,112	296
1997	1,100	2,986	1,753	10,864	8,358	232,268	21,717	10,613	29,899	4,206	122
1998	4,209	7,290	1,713	12,273	9,416	161,088	18,649	10,772	29,904	1,248	200
1999	2,232	3,811	1,876	11,905	7,341	149,576	19,884	11,965	30,377	2,399	414
2000	7,775	6,924	2,253	10,034	11,335	152,927	17,811	5,702	25,856	362	109
2001	13,436	4,868	1,899	8,215	5,662	142,016	13,012	4,428	21,895	1,021	77
2002	3,152	7,838	1,583	9,594	15,435	158,509	16,508	6,524	15,487	3,220	12
2003	3,323	4,645	1,175	14,437	8,871	179,748	20,274	6,983	22,761	968	95
2004	3,228	5,008	1,569	12,556	6,491	184,016	20,261	7,346	27,111	164	142
2005	4,225	2,779	1,104	6,795	7,475	186,843	18,070	1,630	24,380	85	40
2006	4,774	1,647	967	6,042	10,369	175,300	15,842	3,935	19,968	402	54
2007	5,446	2,247	1,610	10,501	13,317	141,879	21,860	4,063	21,968	433	33
2008	9,136	2,885	1,441	6,910	11,821	141,040	18,662	11,481	24,225	2,109	52

Table 7. Catch (t) of pollock by Steller sea lion region in the Aleutian Islands (regions 1-5), eastern Bering Sea (region 6), and in the Gulf of Alaska (regions 6-11), 1991-2008.

<u>Year</u>	Steller Sea Lion Region										
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
1991	13	163	442	170	79,716	1,543,557	26,985	7,705	46,287	5,704	4
1992	8	82	139	8,158	42,875	1,399,239	11,758	17,237	53,850	254	18
1993	110	243	2,345	13,933	40,061	1,327,960	20,935	23,788	63,221	689	0
1994	121	391	39	5,301	52,526	1,333,406	13,845	22,237	60,933	6,880	12
1995	97	2,643	37,404	18,915	5,865	1,268,184	26,771	13,080	23,255	5,857	0
1996	271	324	21,481	2,476	4,504	1,195,075	22,237	12,297	11,803	2,961	3
1997	772	423	17,451	7,186	104	1,127,084	22,964	32,812	20,405	10,451	94
1998	17,669	160	3,698	1,727	568	1,102,225	28,243	48,891	33,348	13,672	0
1999	112	259	371	202	66	994,545	18,370	38,312	28,876	5,418	0
2000	151	374	447	193	75	1,133,686	20,996	11,722	35,074	4,048	7
2001	117	253	161	133	151	1,389,961	27,726	15,404	22,258	3,943	0
2002	182	156	31	78	160	1,481,865	16,944	18,337	12,951	3,180	0
2003	355	437	191	398	269	1,492,736	14,528	19,455	11,229	3,484	0
2004	273	286	139	150	301	1,483,188	20,860	19,646	19,296	1,353	0
2005	550	166	113	212	580	1,486,965	26,945	27,370	19,147	3,391	0
2006	216	198	76	122	1,115	1,494,548	16,577	25,831	17,110	4,237	0
2007	122	209	235	919	1,038	1,352,127	16,708	17,381	16,184	596	1
2008	113	124	168	470	404	992,601	13,986	19,103	14,436	1,166	1

Table 8. Catch (t) of Pollock I in the Gulf of Alaska (regions 6-11) and the eastern Bering Sea (region 6), 1991-2008 in A. January-June and B. July-December.

Year	A. January-June						B. July-December					
	Steller Sea Lion Region						Steller Sea Lion Region					
	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
1991	867,578	8,310	5,731	15,679	5,686	4	675,979	18,674	1,974	30,608	18	0
1992	770,249	11,746	9,978	29,745	184	4	628,990	11	7,258	24,105	71	14
1993	565,279	15,556	15,829	25,762	556	0	762,681	5,378	7,959	37,459	132	0
1994	583,892	5,019	7,179	30,376	6,870		749,514	8,825	15,058	30,558	9	12
1995	589,679	15,543	8,445	6,857	5,778	0	678,505	11,228	4,635	16,398	79	0
1996	543,948	9,529	5,072	7,793	2,900	0	651,128	12,708	7,225	4,010	61	3
1997	529,102	7,530	18,067	9,173	10,428	92	597,982	15,435	14,746	11,231	23	2
1998	524,283	19,108	22,097	19,631	13,660	0	577,942	9,135	26,795	13,717	12	0
1999	417,214	13,338	20,970	18,862	5,403	0	577,330	5,032	17,342	10,014	15	0
2000	454,093	6,439	11,695	22,989	4,038	7	679,594	14,557	27	12,085	10	0
2001	583,952	9,935	13,616	11,629	113	0	806,009	17,790	1,788	10,629	3,830	0
2002	663,957	4,174	12,103	2,484	3,178	0	817,909	12,770	6,235	10,467	3	0
2003	703,719	6,743	14,673	3,204	3,481	0	789,017	7,784	4,782	8,025	4	0
2004	716,390	7,110	17,356	8,911	1,344	0	766,797	13,750	2,290	10,385	9	0
2005	735,361	6,050	26,855	10,334	3,388	0	751,604	20,895	515	8,813	3	0
2006	707,056	8,813	24,249	5,071	4,224	0	787,492	7,765	1,582	12,038	13	0
2007	660,160	5,321	15,799	8,145	593	1	691,967	11,388	1,582	8,039	3	0
2008	486,076	5,110	16,032	6,877	1,158	0	506,525	8,876	3,071	7,558	8	1

Table 9. Biomass estimates (t) for Atka mackerel, Pacific cod, Pollock, and arrowtooth flounder in the Aleutian Islands (Steller sea lion regions 1-5) and Gulf of Alaska (Steller sea lion regions 6-11) used in the analysis (based on stock assessments completed in 2008). Region 11 (SE Alaska) is assessed separately from the age-structured model for Gulf of Alaska Pollock which covers regions 6-10.

Regions	Aleutian Islands			Gulf of Alaska			Arrowtooth flounder 6-11
	Atka mackerel 1-6	Pacific cod 1-5	Pollock 1-5	Pollock 6-10	11	Pacific cod 6-11	
Year							
1990				1,277,240	33,805	401,025	1,550,490
1991	665,820	250,091	790,030	1,388,000	29,399	374,683	1,588,780
1992	714,020	232,125	608,130	1,696,050	26,964	356,112	1,611,650
1993	686,190	233,578	502,380	1,535,150	16,298	340,730	1,633,480
1994	649,200	244,538	411,400	1,284,490	56,246	346,463	1,636,730
1995	629,100	254,366	330,790	1,077,890	82,955	358,082	1,614,180
1996	572,320	251,120	258,350	890,664	98,091	351,127	1,592,570
1997	472,400	242,435	225,910	902,004	81,907	347,741	1,575,660
1998	463,690	231,869	199,720	820,016	58,781	335,431	1,586,500
1999	433,990	243,602	175,420	658,920	34,565	321,952	1,628,570
2000	442,280	255,325	180,200	576,655	52,674	295,611	1,712,390
2001	533,050	262,648	188,830	541,654	70,553	282,343	1,835,900
2002	662,330	272,424	212,870	668,375	63,021	285,445	2,022,940
2003	742,090	273,149	227,740	803,818	46,883	284,783	2,153,650
2004	737,500	260,886	234,090	706,218	45,584	281,936	2,202,930
2005	686,040	238,570	239,180	589,406	41,711	272,978	2,245,770
2006	615,660	212,968	242,290	503,048	45,586	280,114	2,258,230
2007	583,090	186,430	254,550	481,137	53,152	311,870	2,256,030
2008	545,210	172,152	272,370	537,018	59,326	405,367	2,244,870

Table 10. Biomass estimates (t) for Pollock, Pacific cod, and arrowtooth flounder in **the eastern Bering Sea** (Steller sea lion region 6) used in the analysis (based on stock assessments completed in 2008). Pollock biomass in the summer in the Bogoslof portion of Region 6 was assumed to be 10% of that surveyed in winter of the same year.

Season	Pollock				Pacific cod	Arrowtooth flounder
	Winter		Summer		Annual	Annual
Regions	6 Shelf	6 Bogoslof	6 Shelf	6 Bogoslof	6	6
Year						
1991	5,590,000	1,283,017	5,590,000	128,302	1,312,979	473,272
1992	8,966,000	888,148	8,966,000	88,815	1,218,655	495,717
1993	11,175,000	630,538	11,175,000	63,054	1,226,282	522,137
1994	10,782,000	490,078	10,782,000	49,008	1,283,822	543,783
1995	12,704,000	1,019,630	12,704,000	101,963	1,335,424	556,005
1996	10,829,000	582,176	10,829,000	58,218	1,318,380	571,284
1997	9,403,000	341,634	9,403,000	34,163	1,272,785	581,458
1998	9,467,000	432,431	9,467,000	43,243	1,217,311	599,254
1999	10,379,000	392,537	10,379,000	39,254	1,278,908	617,849
2000	9,503,000	269,816	9,503,000	26,982	1,340,455	644,148
2001	9,175,000	207,547	9,175,000	20,755	1,378,902	674,583
2002	9,554,000	226,000	9,554,000	22,600	1,430,226	706,950
2003	11,182,000	198,000	11,182,000	19,800	1,434,031	746,230
2004	10,274,000	225,500	10,274,000	22,550	1,369,654	785,223
2005	8,423,000	253,000	8,423,000	25,300	1,252,490	819,512
2006	6,340,000	240,059	6,340,000	24,006	1,118,082	854,164
2007	5,015,000	291,580	5,015,000	29,158	978,760	880,671
2008	4,222,000	291,580	4,222,000	29,158	903,798	899,333

Table 11. Distribution (%) of Atka mackerel, Pacific cod and Pollock biomass in the Aleutian Islands by Steller sea lion region. Total biomass listed in Table 10. Years with Aleutian Islands bottom trawl survey are listed in bold type.

Year	Atka mackerel						Pacific cod					Pollock				
	Region						Region					Region				
	1	2	3	4	5	6	1	2	3	4	5	1	2	3	4	5
1991	39.7	25.5	8.6	3.7	8.9	13.6	41.3	16.6	6.5	6.0	29.5	19.4	24.7	11.6	7.3	37.0
1992	41.9	20.3	6.6	6.2	12.6	12.4	32.6	15.1	11.6	6.6	34.1	18.8	23.2	12.6	8.6	36.8
1993	44.1	15.1	4.6	8.7	16.3	11.2	24.0	13.5	16.6	7.1	38.8	18.1	21.7	13.6	9.9	36.7
1994	46.3	9.9	2.7	11.2	20.0	10.0	15.3	12.0	21.7	7.6	43.4	17.5	20.2	14.5	11.2	36.5
1995	44.4	11.2	4.6	10.0	20.2	9.6	16.7	15.8	20.6	7.9	39.0	18.2	23.7	12.5	9.6	36.0
1996	42.4	12.6	6.6	8.7	20.4	9.3	18.1	19.6	19.4	8.2	34.7	18.8	27.3	10.5	8.0	35.4
1997	40.5	13.9	8.5	7.5	20.6	8.9	19.5	23.4	18.3	8.5	30.3	19.5	30.8	8.6	6.3	34.9
1998	38.6	15.2	10.5	6.2	20.9	8.6	24.4	20.9	16.5	8.9	29.4	15.0	30.4	9.4	13.0	32.2
1999	36.6	16.6	12.5	5.0	21.1	8.3	29.3	18.3	14.7	9.3	28.4	10.6	30.1	10.2	19.6	29.5
2000	34.7	17.9	14.4	3.8	21.3	7.9	34.1	15.8	12.9	9.7	27.4	6.2	29.7	11.0	26.3	26.8
2001	32.7	19.2	16.4	2.5	21.5	7.6	33.3	17.9	13.0	8.8	26.9	6.6	36.0	15.3	13.7	28.4
2002	30.8	20.6	18.4	1.3	21.8	7.2	32.4	20.1	13.1	7.9	26.5	7.1	42.2	19.5	1.2	30.0
2003	31.7	14.5	16.6	1.6	20.5	15.2	22.1	16.3	12.9	7.8	40.9	6.1	24.9	10.4	1.0	57.6
2004	32.5	8.5	14.7	1.9	19.2	23.1	11.7	12.5	12.7	7.7	55.3	5.1	7.7	1.3	0.7	85.3
2005	22.0	12.6	14.8	2.8	29.5	18.3	17.5	12.5	13.1	6.0	51.0	6.0	11.2	3.0	0.7	79.2
2006	11.4	16.7	14.9	3.7	39.8	13.6	23.2	12.5	13.4	4.3	46.6	6.9	14.7	4.8	0.7	73.0
2007	11.4	16.7	14.9	3.7	39.8	13.6	23.2	12.5	13.4	4.3	46.6	6.9	14.7	4.8	0.7	73.0
2008	11.4	16.7	14.9	3.7	39.8	13.6	23.2	12.5	13.4	4.3	46.6	6.9	14.7	4.8	0.7	73.0

Table 12. Distribution (%) of Pollock biomass in the Gulf of Alaska by Steller sea lion region. Total biomass listed in Table 10. Years with Gulf of Alaska bottom trawl survey are listed in bold type. January-June distribution is based on method outlined in Dorn et al (2008). The percentages for regions 6-10 add up to 100% each year and season; region 11 is expressed as a percentage of total biomass in regions 6-10.

Year	Pollock – January-June						Pollock – July-December						Pollock - Annual					
	Region						Region						Region					
	6	7	8	9	10	11	6	7	8	9	10	11	6	7	8	9	10	11
1990	6.1	24.6	46.9	19.4	2.9	2.6	0.6	19.3	22.3	41.2	16.6	2.6	3.4	21.9	34.6	30.3	9.8	2.6
1991	6.1	24.6	46.9	19.4	2.9	2.1	7.1	21.8	22.9	34.9	13.3	2.1	6.6	23.2	34.9	27.2	8.1	2.1
1992	6.1	24.6	46.9	19.4	2.9	1.6	13.6	24.2	23.5	28.7	10.0	1.6	9.9	24.4	35.2	24.1	6.4	1.6
1993	6.1	24.6	46.9	19.4	2.9	1.1	20.1	26.7	24.1	22.4	6.7	1.1	13.1	25.6	35.5	20.9	4.8	1.1
1994	6.1	24.6	46.9	19.4	2.9	4.4	17.3	22.1	29.8	25.0	5.8	4.4	11.7	23.3	38.4	22.2	4.3	4.4
1995	6.1	24.6	46.9	19.4	2.9	7.7	14.4	17.6	35.5	27.6	4.9	7.7	10.3	21.1	41.2	23.5	3.9	7.7
1996	6.1	24.6	46.9	19.4	2.9	11.0	11.6	13.0	41.2	30.2	4.0	11.0	8.9	18.8	44.0	24.8	3.5	11.0
1997	6.1	24.6	46.9	19.4	2.9	9.1	9.3	31.0	30.3	25.5	3.9	9.1	7.7	27.8	38.6	22.5	3.4	9.1
1998	6.1	24.6	46.9	19.4	2.9	7.2	7.0	49.1	19.4	20.7	3.8	7.2	6.6	36.8	33.2	20.1	3.4	7.2
1999	6.1	24.6	46.9	19.4	2.9	5.2	4.7	67.1	8.5	16.0	3.7	5.2	5.4	45.8	27.7	17.7	3.3	5.2
2000	6.1	24.6	46.9	19.4	2.9	9.1	2.9	53.6	12.1	27.4	4.0	9.1	4.5	39.1	29.5	23.4	3.5	9.1
2001	6.1	24.6	46.9	19.4	2.9	13.0	1.1	40.1	15.7	38.8	4.3	13.0	3.6	32.3	31.3	29.1	3.6	13.0
2002	6.1	24.6	46.9	19.4	2.9	9.4	2.8	44.4	16.8	30.7	5.3	9.4	4.5	34.5	31.9	25.0	4.1	9.4
2003	6.1	24.6	46.9	19.4	2.9	5.8	4.6	48.8	17.9	22.5	6.2	5.8	5.4	36.7	32.4	21.0	4.6	5.8
2004	6.1	24.6	46.9	19.4	2.9	6.5	7.9	38.4	17.5	27.0	9.3	6.5	7.0	31.5	32.2	23.2	6.1	6.5
2005	6.1	24.6	46.9	19.4	2.9	7.1	11.2	28.0	17.1	31.4	12.3	7.1	8.7	26.3	32.0	25.4	7.6	7.1
2006	6.1	24.6	46.9	19.4	2.9	9.1	13.0	23.7	24.4	26.1	12.7	9.1	9.6	24.1	35.7	22.8	7.8	9.1
2007	6.1	24.6	46.9	19.4	2.9	11.0	14.9	19.4	31.8	20.9	13.1	11.0	10.5	22.0	39.4	20.1	8.0	11.0
2008	6.1	24.6	46.9	19.4	2.9	11.0	14.9	19.4	31.8	20.9	13.1	11.0	10.5	22.0	39.4	20.1	8.0	11.0

Table 13. Distribution (%) of Pacific cod and Arrowtooth flounder biomass in the Gulf of Alaska by Steller sea lion region. Total biomass listed in Table 10. Years with Gulf of Alaska bottom trawl survey are listed in bold type.

Year	Pacific cod						Arrowtooth flounder					
	Region						Region					
	6	7	8	9	10	11	6	7	8	9	10	11
1990	9.4	21.2	39.6	20.2	6.3	3.3	4.4	7.3	43.7	27.5	12.3	4.8
1991	9.7	20.4	34.3	26.8	5.7	2.9	4.2	8.1	39.3	29.3	13.9	5.2
1992	10.1	19.6	29.1	33.4	5.1	2.6	4.1	8.9	35.0	31.0	15.4	5.6
1993	10.5	18.8	23.9	40.0	4.6	2.2	4.0	9.7	30.6	32.8	16.9	6.0
1994	9.7	21.5	24.2	38.1	4.4	2.1	4.1	9.2	30.4	32.8	16.6	6.9
1995	9.0	24.1	24.5	36.2	4.2	2.0	4.1	8.7	30.3	32.8	16.4	7.8
1996	8.2	26.8	24.9	34.3	4.0	1.9	4.1	8.3	30.1	32.7	16.1	8.7
1997	8.5	27.0	26.6	31.4	3.7	2.9	3.9	8.2	27.8	34.7	14.3	11.2
1998	8.8	27.2	28.3	28.4	3.4	3.9	3.6	8.1	25.4	36.7	12.4	13.8
1999	9.1	27.4	30.0	25.4	3.2	4.9	3.4	8.0	23.0	38.7	10.6	16.3
2000	16.9	26.0	27.9	21.6	2.7	4.9	3.6	8.0	31.4	34.1	8.3	14.5
2001	24.7	24.5	25.9	17.8	2.2	4.9	3.9	8.0	39.8	29.5	6.0	12.8
2002	15.2	22.1	25.9	29.6	2.8	4.4	3.3	8.7	28.8	41.9	7.5	9.8
2003	5.6	19.8	25.8	41.4	3.4	3.9	2.7	9.4	17.8	54.2	9.0	6.8
2004	7.0	27.5	25.9	32.6	3.1	4.0	2.2	9.5	23.5	45.7	12.6	6.5
2005	8.3	35.2	25.9	23.9	2.7	4.0	1.7	9.6	29.3	37.2	16.1	6.2
2006	7.9	38.3	19.5	27.8	2.9	3.6	2.1	10.3	29.8	37.2	13.8	6.7
2007	7.5	41.5	13.2	31.6	3.1	3.2	2.6	11.0	30.3	37.2	11.6	7.3
2008	7.5	41.5	13.2	31.6	3.1	3.2	2.6	11.0	30.3	37.2	11.6	7.3

Table 14. Summary of linear regression analyses of Steller sea lion ALL rookery and haul-out trend site non-pup growth rates on transformed fishery harvest rates by area. Ecosystem: AI-BS = Aleutian Islands and Bering Sea, areas 1-6; GOA-BS = Gulf of Alaska and Bering Sea, areas 6-11. Period refers to period used for fishery harvest rate determination. - = non-significant association $P > 0.25$; ** = $P < 0.1$; * = $P < 0.25$.

<u>Ecosystem</u>	<u>Species</u>	<u>Period</u>	<u>Year</u>		<u>Slope</u>	<u>P</u>	
			<u>Begin</u>	<u>End</u>			
AI-BS	Atka mackerel	Annual	1991	2008	-0.179	0.214	*
		Annual	1991	1999	-0.154	0.085	**
		Annual	2000	2008	-0.113	0.355	-
	Pacific cod	Annual	1991	2008	0.102	0.367	-
		Annual	1991	1999	0.129	0.174	*
		Annual	2000	2008	-0.034	0.711	-
	Pollock	Annual	1991	2008	0.266	0.050	**
		Annual	1991	1998	0.128	0.200	*
		Annual	1998	2008	0.166	0.258	-
GOA-BS	Pacific cod	Annual	1991	2008	-0.048	0.521	-
		Annual	1991	1999	-0.168	0.154	*
		Annual	2000	2008	0.087	0.382	-
	Pollock	Annual	1991	2008	-0.060	0.467	-
		Annual	1991	1999	-0.177	0.205	*
		Annual	2000	2008	0.102	0.326	-
	Pollock	Winter	1991	2008	-0.063	0.465	-
		Winter	1991	1999	-0.222	0.069	**
		Winter	2000	2008	0.168	0.150	*
	Pollock	Summer	1991	2008	-0.045	0.672	-
		Summer	1991	1999	-0.018	0.924	-
		Summer	2000	2008	0.101	0.463	-
	Arrowtooth flounder	Annual	1991	2008	-0.085	0.740	-
		Annual	1991	1999	-0.034	0.946	-
		Annual	2000	2008	0.065	0.835	-

Table 15. Summary of linear regression analyses of Steller sea lion rookery non-pup growth rates on transformed fishery harvest rates by area. Ecosystem: AI-BS = Aleutian Islands and Bering Sea, areas 1-6; GOA-BS = Gulf of Alaska and Bering Sea, areas 6-11. Period refers to period used for fishery harvest rate determination. - = non-significant association $P > 0.25$; ** = $P < 0.1$; * = $P < 0.25$.

<u>Ecosystem</u>	<u>Species</u>	<u>Period</u>	<u>Year</u>		<u>Slope</u>	<u>P</u>	
			<u>Begin</u>	<u>End</u>			
AI-BS	Atka mackerel	Annual	1991	2008	-0.172	0.235	*
		Annual	1991	1999	-0.058	0.306	-
		Annual	2000	2008	-0.089	0.510	-
	Pacific cod	Annual	1991	2008	0.103	0.363	-
		Annual	1991	1999	0.057	0.314	-
		Annual	2000	2008	-0.013	0.897	-
	Pollock	Annual	1991	2008	0.258	0.062	**
		Annual	1991	1998	0.099	0.037	**
		Annual	1998	2008	0.205	0.174	*
GOA-BS	Pacific cod	Annual	1991	2008	-0.051	0.512	-
		Annual	1991	1999	-0.155	0.210	*
		Annual	2000	2008	0.066	0.518	-
	Pollock	Annual	1991	2008	-0.056	0.526	-
		Annual	1991	1999	-0.207	0.127	*
		Annual	2000	2008	0.129	0.193	*
	Pollock	Winter	1991	2008	-0.079	0.374	-
		Winter	1991	1999	-0.213	0.099	**
		Winter	2000	2008	0.120	0.346	-
	Pollock	Summer	1991	2008	-0.017	0.884	-
		Summer	1991	1999	-0.098	0.606	-
		Summer	2000	2008	0.166	0.193	*
	Arrowtooth flounder	Annual	1991	2008	-0.016	0.954	-
		Annual	1991	1999	-0.213	0.671	-
		Annual	2000	2008	0.258	0.383	-

Table 16. Summary of linear regression analyses of Steller sea lion ALL rookery and haul-out trend sites on oceanographic variables. Ecosystem: AI=Aleutian Islands (areas 1-6), AI-BS=Aleutian Islands-Bering Sea (areas 1-6, SSLCA, NWBS, NEBS), GOA=Gulf of Alaska (areas 6-11). Period refers to period used for oceanographic variables.

Ecosystem	Oceanographic variable (units)	Period	Begin	End	R ²	Slope	P
AI	SST (°C)	April-May	1991	2008	0.74	0.08	0.03
			1991	2000	0.45	0.06	0.15
			2000	2008	0.68	0.05	0.04
	Wind mixing (m ³ /s ³)	April-May	1991	2008	0.66	-14.9	0.05
			1991	2000	0.41	-7.88	0.17
			2000	2008	0.44	-14.21	0.15
	Sea surface height variability (cm)	April-May	2000	2008	0.20	0.003	0.37
	Chlorophyll (mg/m ³)	April-May	2000	2008	0.81	0.06	0.01
	SST (°C)	August-September	1991	2008	0.003	0.006	0.92
			1991	2000	0.02	0.02	0.79
			2000	2008	0.10	0.03	0.55
	Wind mixing (m ³ /s ³)	August-September	1991	2008	0.26	7.91	0.30
			1991	2000	0.28	7.2	0.28
			2000	2008	0.02	2.01	0.78
	Sea surface height variability (cm)	August-September	2000	2008	0.24	0.01	0.32
	Chlorophyll (mg/m ³)	August-September	2000	2008	0.58	0.13	0.08
	Surface air temperature (°C)	December-February	1991	2008	0.64	0.05	0.06
			1991	2000	0.37	0.04	0.20
			2000	2008	0.47	0.03	0.13
	Surface air temperature variability	November-March	1991	2008	0.11	0.009	0.52
			1991	2000	0.09	0.007	0.57
2000			2008	0.36	0.02	0.21	
AI-BS	Sea surface height variability (cm)	September-April	2000	2008	0.51	0.001	0.11
	SST (°C)	April-May	1991	2008	0.03	0.01	0.72
			1991	2000	0.02	0.01	0.78
			2000	2008	0.0008	-0.002	0.96
	Wind mixing (m ³ /s ³)	April-May	1991	2008	0.44	-7.21	0.15
			1991	2000	0.30	-4.24	0.26
			2000	2008	0.63	-11.25	0.06
	Sea surface height variability (cm)	April-May	2000	2008	0.02	0.001	0.82
	Chlorophyll (mg/m ³)	April-May	2000	2008	0.75	0.05	0.03
	SST (°C)	August-September	1991	2008	0.003	0.006	0.92
			1991	2000	0.02	0.02	0.79
			2000	2008	0.10	0.03	0.55
	Wind mixing (m ³ /s ³)	August-September	1991	2008	0.07	3.25	0.61
			1991	2000	0.04	1.95	0.69
			2000	2008	0.002	0.64	0.93
	Sea surface height variability (cm)	August-September	2000	2008	0.16	0.01	0.44
	Chlorophyll (mg/m ³)	August-September	2000	2008	0.58	0.13	0.08
	Surface air temperature (°C)	December-February	1991	2008	0.03	-0.003	0.74
			1991	2000	0.04	-0.003	0.72
			2000	2008	0.20	-0.007	0.37
	Surface air temperature variability	November-March	1991	2008	0.16	0.001	0.43
1991			2000	0.13	0.001	0.49	
2000			2008	0.45	0.002	0.14	
Sea surface height variability (cm)	August-September	2000	2008	0.24	0.005	0.32	

Ecosystem	Oceanographic variable (units)	Period	Begin	End	R ²	Slope	P
GOA	SST (°C)	April-May	1991	2008	0.06	0.004	0.69
			1991	2000	0.02	0.005	0.82
			2000	2008	0.02	-0.004	0.81
	Wind mixing (m ³ /s ³)	April-May	1991	2008	0.06	-0.82	0.70
			1991	2000	0.007	0.49	0.89
			2000	2008	0.05	-1.29	0.71
	Sea surface height variability (cm)	April-May	2000	2008	0.81	-0.003	0.04
	Chlorophyll (mg/m ³)	April-May	2000	2008	0.0001	-0.002	0.98
	SST (°C)	August-September	1991	2008	0.14	0.007	0.54
			1991	2000	0.04	0.008	0.73
			2000	2008	0.02	-0.004	0.84
	Wind mixing (m ³ /s ³)	August-September	1991	2008	0.10	-0.70	0.60
			1991	2000	0.01	-0.37	0.87
			2000	2008	<0.001	0.03	0.99
	Sea surface height variability (cm)	August-September	2000	2008	0.51	0.007	0.18
	Chlorophyll (mg/m ³)	August-September	2000	2008	0.37	-0.07	0.28
	Surface air temperature (°C)	December-February	1991	2008	0.02	0.001	0.82
			1991	2000	0.44	0.01	0.22
			2000	2008	0.50	-0.009	0.18
	Surface air temperature variability	November-March	1991	2008	0.12	-0.002	0.56
1991			2000	0.13	-0.003	0.55	
2000			2008	<0.001	0.001	0.99	
Sea surface height variability (cm)	September-April	2000	2008	0.08	0.006	0.64	

Table 17. Summary of linear regression analyses of Steller sea lion ALL rookery and haul-out trend sites on selected oceanographic variables. Ecosystem: AI=Aleutian Islands (areas 1-6), AI-BS=Aleutian Islands-Bering Sea (areas 1-6, SSLCA, NWBS, NEBS), GOA (ares 7-11). Period refers to period used for oceanographic variables.

Ecosystem	Oceanographic variable (units)	Period	Begin	End	R ²	Slope	P
AI	SST (°C)	April-May	1991	2008	0.74	0.08	0.03
			1991	2000	0.45	0.06	0.15
			2000	2008	0.68	0.05	0.04
	Wind mixing (m ³ /s ³)	April-May	1991	2008	0.66	-14.9	0.05
			1991	2000	0.41	-7.88	0.17
			2000	2008	0.44	-14.21	0.15
			2000	2008	0.81	0.06	0.01
			2000	2008	0.58	0.13	0.08
			2000	2008	0.64	0.05	0.06
	Surface air temperature (°C)	December-February	1991	2008	0.64	0.05	0.06
			1991	2000	0.37	0.04	0.20
			2000	2008	0.47	0.03	0.13
	Surface air temperature variability	November-March	2000	2008	0.36	0.02	0.21
Sea surface height variability (cm)	September-April	2000	2008	0.51	0.001	0.11	
AI-BS	Wind mixing (m ³ /s ³)	April-May	1991	2008	0.44	-7.21	0.15
			1991	2000	0.30	-4.24	0.26
			2000	2008	0.63	-11.25	0.06
	Chlorophyll (mg/m ³)	April-May	2000	2008	0.75	0.05	0.03
	Chlorophyll (mg/m ³)	August-September	2000	2008	0.58	0.13	0.08
	Surface air temperature variability	November-March	2000	2008	0.45	0.002	0.14
	Sea surface height variability (cm)	April-May	2000	2008	0.81	-0.003	0.04
GOA	Sea surface height variability (cm)	August-September	2000	2008	0.51	0.007	0.18
			2000	2008	0.51	0.007	0.18
	Surface air temperature (°C)	December-February	1991	2000	0.44	0.01	0.22
			2000	2008	0.50	-0.009	0.18

Table 18. Summary of linear regression analyses of Steller sea lion Rookery trend sites on oceanographic variables. Ecosystem: AI=Aleutian Islands (areas 1-6), AI-BS=Aleutian Islands-Bering Sea (areas 1-6, SSLCA, NWBS, NEBS), GOA=Gulf of Alaska (areas 6-11). Period refers to period used for oceanographic variables.

Ecosystem	Oceanographic variable	Period	Begin	End	R ²	Slope	P
AI	SST (°C)	April-May	1991	2008	0.73	0.08	0.03
			1991	2000	0.38	0.04	0.19
			2000	2008	0.52	0.05	0.10
	Wind mixing (m ³ /s ³)	April-May	1991	2008	0.068	-14.92	0.05
			1991	2000	0.25	-4.91	0.31
			2000	2008	0.40	-14.45	0.18
	Sea surface height variability (cm)	April-May	2000	2008	0.39	0.005	0.19
	Chlorophyll (mg/m ³)	April-May	2000	2008	0.82	0.07	0.01
	SST (°C)	August-September	1991	2008	0.003	0.006	0.91
			1991	2000	0.003	-0.005	0.92
			2000	2008	0.10	0.03	0.53
	Wind mixing (m ³ /s ³)	August-September	1991	2008	0.25	7.75	0.31
			1991	2000	0.47	7.44	0.13
			2000	2008	<0.001	-0.26	0.97
	Sea surface height variability (cm)	August-September	2000	2008	0.06	0.007	0.63
	Chlorophyll (mg/m ³)	August-September	2000	2008	0.67	0.15	0.04
	Surface air temperature (°C)	December-February	1991	2008	0.65	0.05	0.05
			1991	2000	0.45	0.03	0.14
			2000	2008	0.48	0.04	0.13
	Surface air temperature variability	November-March	1991	2008	0.12	0.009	0.51
			1991	2000	0.02	0.002	0.82
2000			2008	0.45	0.02	0.14	
Sea surface height variability (cm)	September-April	2000	2008	0.32	0.004	0.24	
AI-BS	SST (°C)	April-May	1991	2008	0.03	0.01	0.74
			1991	2000	0.09	0.02	0.56
			2000	2008	0.04	-0.01	0.71
	Wind mixing (m ³ /s ³)	April-May	1991	2008	0.44	-7.25	0.15
			1991	2000	0.15	-2.39	0.45
			2000	2008	0.66	-12.33	0.04
	Sea surface height variability (cm)	April-May	2000	2008	0.09	0.003	0.56
	Chlorophyll (mg/m ³)	April-May	2000	2008	0.79	0.05	0.02
	SST (°C)	August-September	1991	2008	0.003	0.006	0.91
			1991	2000	0.003	-0.005	0.92
			2000	2008	0.11	0.03	0.53
	Wind mixing (m ³ /s ³)	August-September	1991	2008	0.06	3.11	0.63
			1991	2000	0.16	2.95	0.44
			2000	2008	0.01	-1.55	0.83
	Sea surface height variability (cm)	August-September	2000	2008	0.02	0.004	0.79
	Chlorophyll (mg/m ³)	August-September	2000	2008	0.66	0.15	0.04
	Surface air temperature (°C)	December-February	1991	2008	0.03	-0.003	0.73
			1991	2000	0.000	-0.000	0.99
			2000	2008	0.29	-0.009	0.28
	Surface air temperature variability	November-March	1991	2008	0.17	0.001	0.42
			1991	2000	0.03	0.0004	0.74
2000			2008	0.56	0.003	0.09	
Sea surface height variability (cm)	August-September	2000	2008	0.09	0.003	0.56	

Ecosystem	Oceanographic variable	Period	Begin	End	R ²	Slope	P
GOA	SST (°C)	April-May	1991	2008	<0.001	<0.001	0.98
			1991	2000	0.03	0.006	0.79
			2000	2008	0.33	-0.01	0.31
	Wind mixing (m ³ /s ³)	April-May	1991	2008	0.003	-0.17	0.94
			1991	2000	<0.001	-0.04	0.99
			2000	2008	0.01	0.41	0.88
	Sea surface height variability (cm)	April-May	2000	2008	0.40	-0.002	0.25
	Chlorophyll (mg/m ³)	April-May	2000	2008	0.11	0.04	0.57
	SST (°C)	August-September	1991	2008	0.02	0.003	0.80
			1991	2000	0.05	0.009	0.71
			2000	2008	0.24	-0.01	0.40
	Wind mixing (m ³ /s ³)	August-September	1991	2008	0.01	-0.23	0.87
			1991	2000	0.04	-0.75	0.76
			2000	2008	0.15	1.03	0.52
	Sea surface height variability (cm)	August-September	2000	2008	0.20	0.003	0.44
	Chlorophyll (mg/m ³)	August-September	2000	2008	0.32	-0.05	0.32
	Surface air temperature (°C)	December-February	1991	2008	0.02	0.001	0.82
			1991	2000	0.25	0.009	0.39
			2000	2008	0.43	0.004	0.23
	Surface air temperature variability	November-March	1991	2008	0.02	>-0.001	0.82
			1991	2000	0.13	-0.004	0.55
2000			2008	0.19	0.003	0.47	
Sea surface height variability (cm)	September-April	2000	2008	0.16	<0.001	0.50	

Table 19. Summary of linear regression analyses of Steller sea lion Rookery trend sites on selected oceanographic variables. Ecosystem: AI=Aleutian Islands (areas 1-6), AI-BS=Aleutian Islands-Bering Sea (areas 1-6, SSLCA, NWBS, NEBS), GOA=Gulf of Alaska (areas 7-11). Period refers to period used for oceanographic variables.

Ecosystem	Oceanographic variable	Period	Begin	End	R ²	Slope	P
AI	SST (°C)	April-May	1991	2008	0.73	0.08	0.03
			1991	2000	0.38	0.04	0.19
			2000	2008	0.52	0.05	0.10
	Wind mixing (m ³ /s ³)	April-May	1991	2008	0.068	-14.92	0.05
			1991	2000	0.25	-4.91	0.31
			2000	2008	0.40	-14.45	0.18
	Sea surface height variability (cm)	April-May	2000	2008	0.39	0.005	0.19
	Chlorophyll (mg/m ³)	April-May	2000	2008	0.82	0.07	0.01
	Wind mixing (m ³ /s ³)	August-September	1991	2000	0.47	7.44	0.13
	Chlorophyll (mg/m ³)	August-September	2000	2008	0.67	0.15	0.04
	Surface air temperature (°C)	December-February	1991	2008	0.65	0.05	0.05
			1991	2000	0.45	0.03	0.14
			2000	2008	0.48	0.04	0.13
Surface air temperature variability	November-March	2000	2008	0.45	0.02	0.14	
Sea surface height variability (cm)	September-April	2000	2008	0.32	0.004	0.24	
AI-BS	Wind mixing (m ³ /s ³)	April-May	1991	2008	0.44	-7.25	0.15
			1991	2000	0.15	-2.39	0.45
			2000	2008	0.66	-12.33	0.04
	Chlorophyll (mg/m ³)	April-May	2000	2008	0.79	0.05	0.02
	Chlorophyll (mg/m ³)	August-September	2000	2008	0.66	0.15	0.04
Surface air temperature variability	November-March	2000	2008	0.56	0.003	0.09	
GOA	Surface air temperature (°C)	December-February	2000	2008	0.43	0.004	0.23

Figure 1. Zones used used in the analysis of Steller sea lion, fish, fishery and oceanographic data. See Table 1 for details.

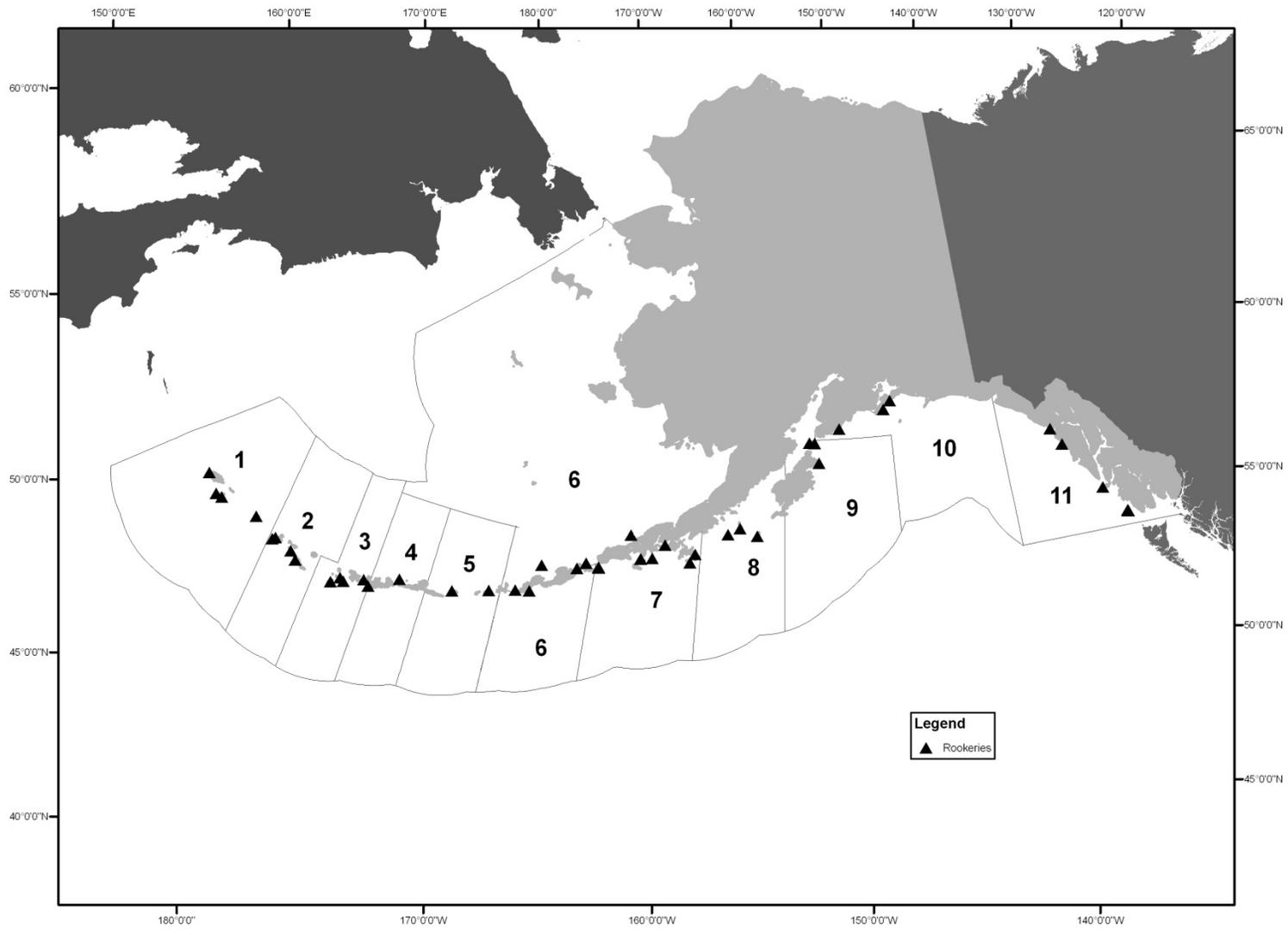


Figure 2. Annual growth rate in non-pups at ALL rookery and haulout trend sites, and at ROOKERY trend sites by region and time period (1991-2008, 1991-2000 and 2000-2008). Solid bars indicate growth rate is significantly different from 0 ($P < 0.05$) while open bars indicate growth rate is not significantly different from 0 ($P > 0.05$).

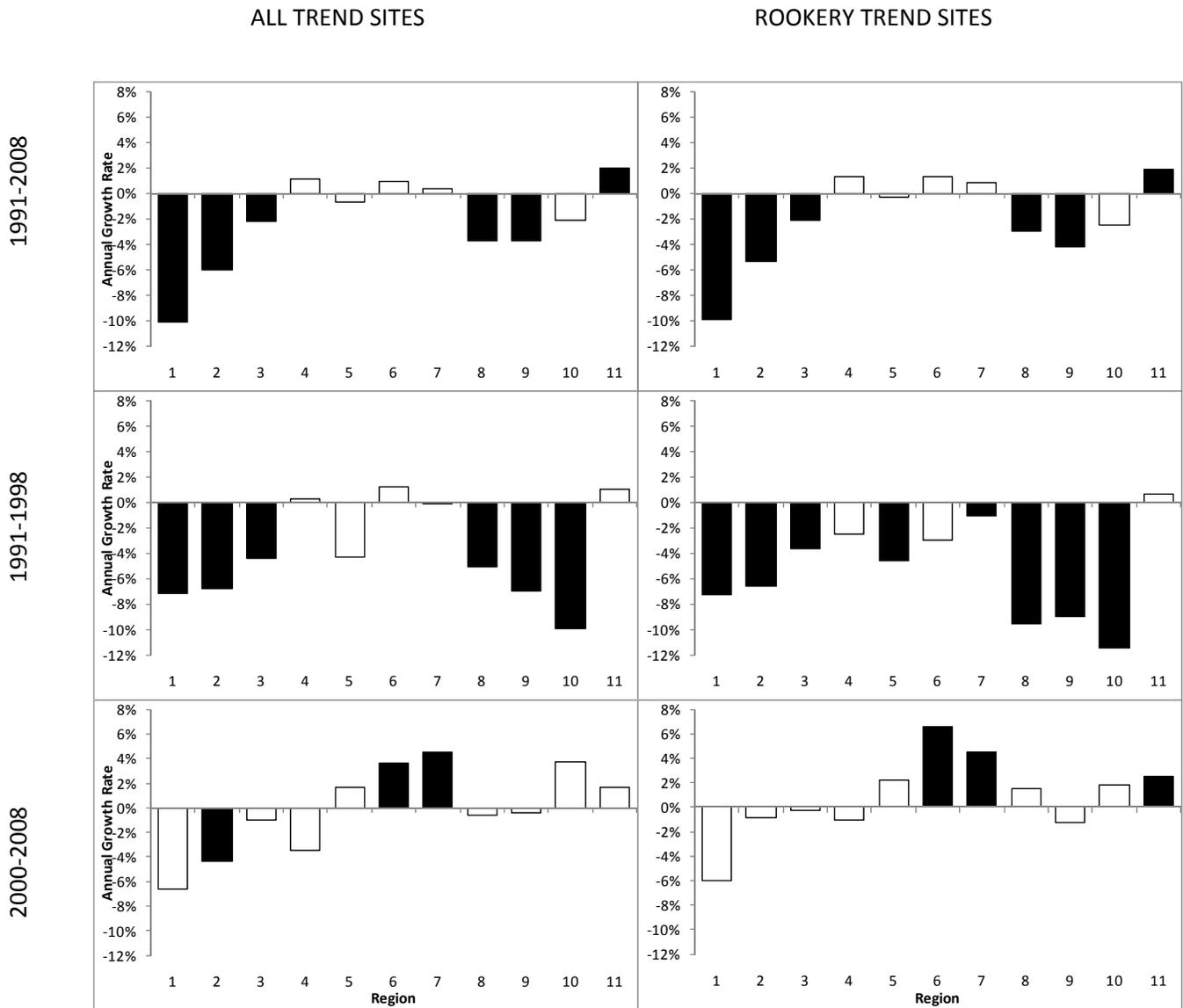


Figure 3. Steller sea lion growth rate (non-pups at ALL trend sites) by region (1-6) in the AI-BS plotted against annual harvest rates of Atka mackerel, Pacific cod and Pollock for the years 1991-2008, 1991-1999 and 2000-2008. Line is regression of SSL growth rate on arcsin-transformed harvest rates. See Table 8 for significance of regression coefficients (slopes).

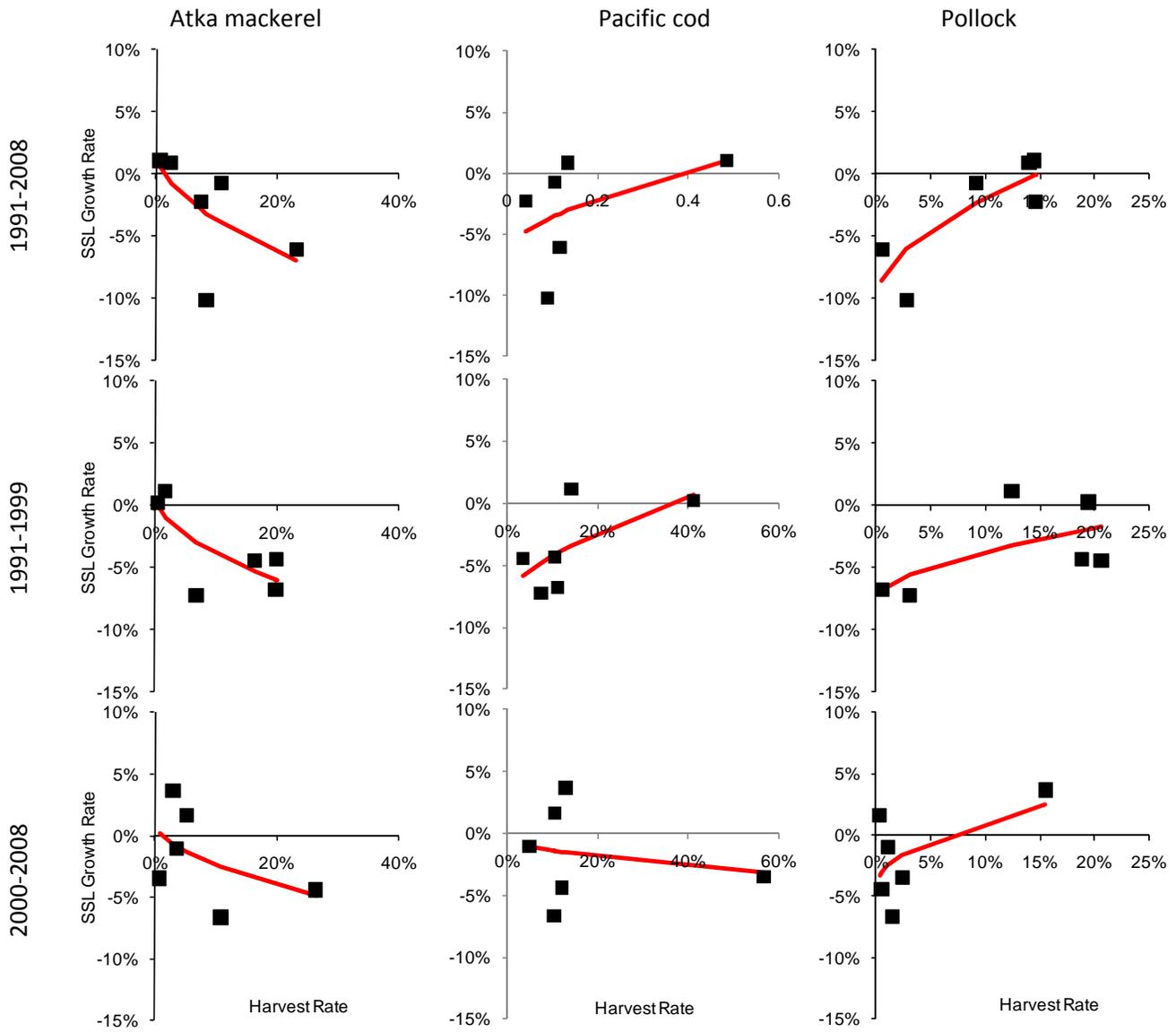


Figure 4. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (1-6) in the AI-BS plotted against annual harvest rates of Atka mackerel, Pacific cod and Pollock for the years 1991-2008, 1991-1999 and 2000-2008. Line is regression of SSL growth rate on arcsin-transformed harvest rates. See Table 9 for significance of regression coefficients (slopes).

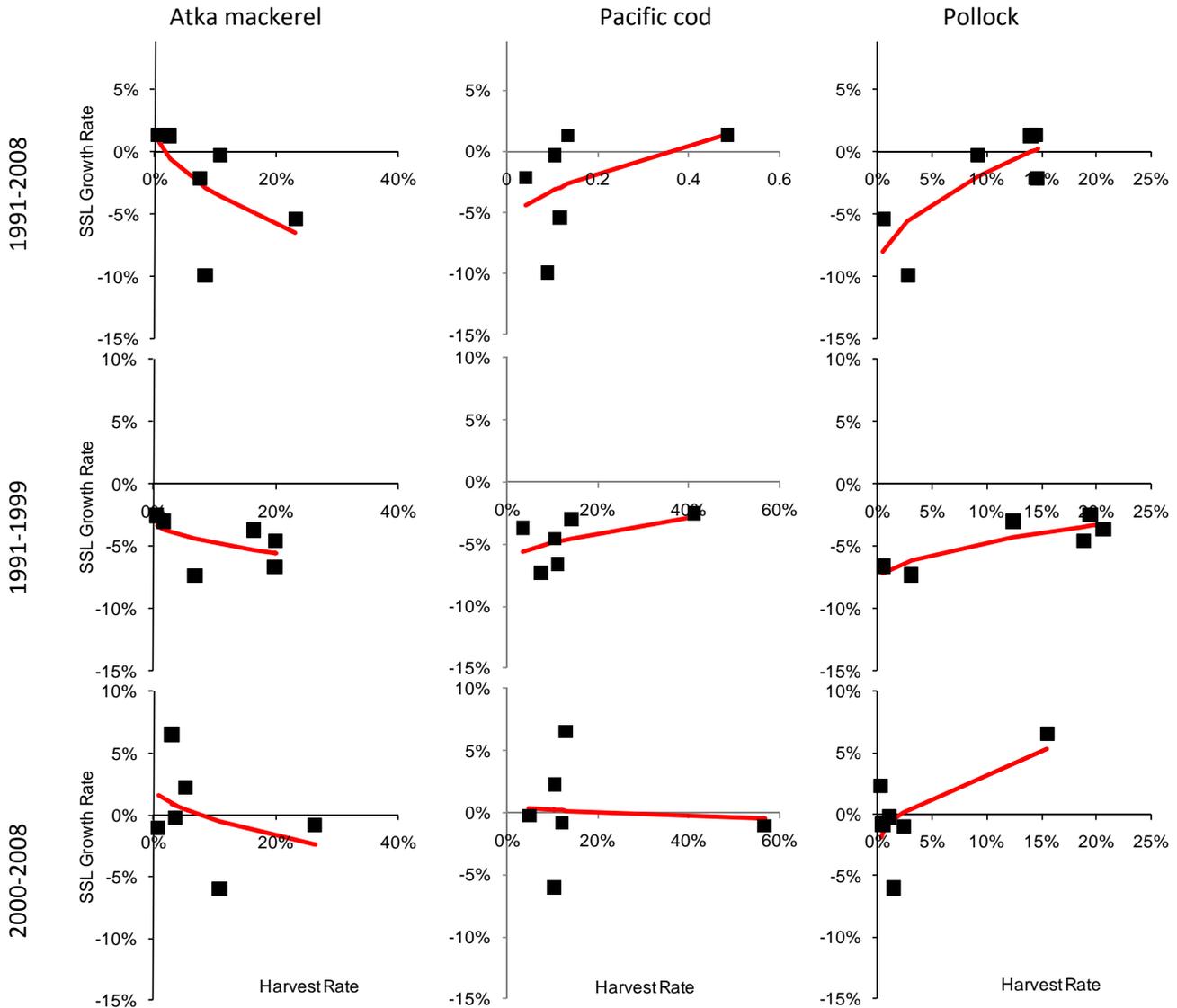


Figure 5. Steller sea lion growth rate (non-pups at ALL trend sites) by region (6-11) in the GOA-BS plotted against annual harvest rates of Pacific cod, Pollock (summer: quarters 3 and 4; winter: quarters 1 and 2; annual), and arrowtooth flounder for the years 1991-2008, 1991-1999 and 2000-2008. Line is regression of SSL growth rate on arcsin-transformed harvest rates. See Table 8 for significance of regression coefficients (slopes).

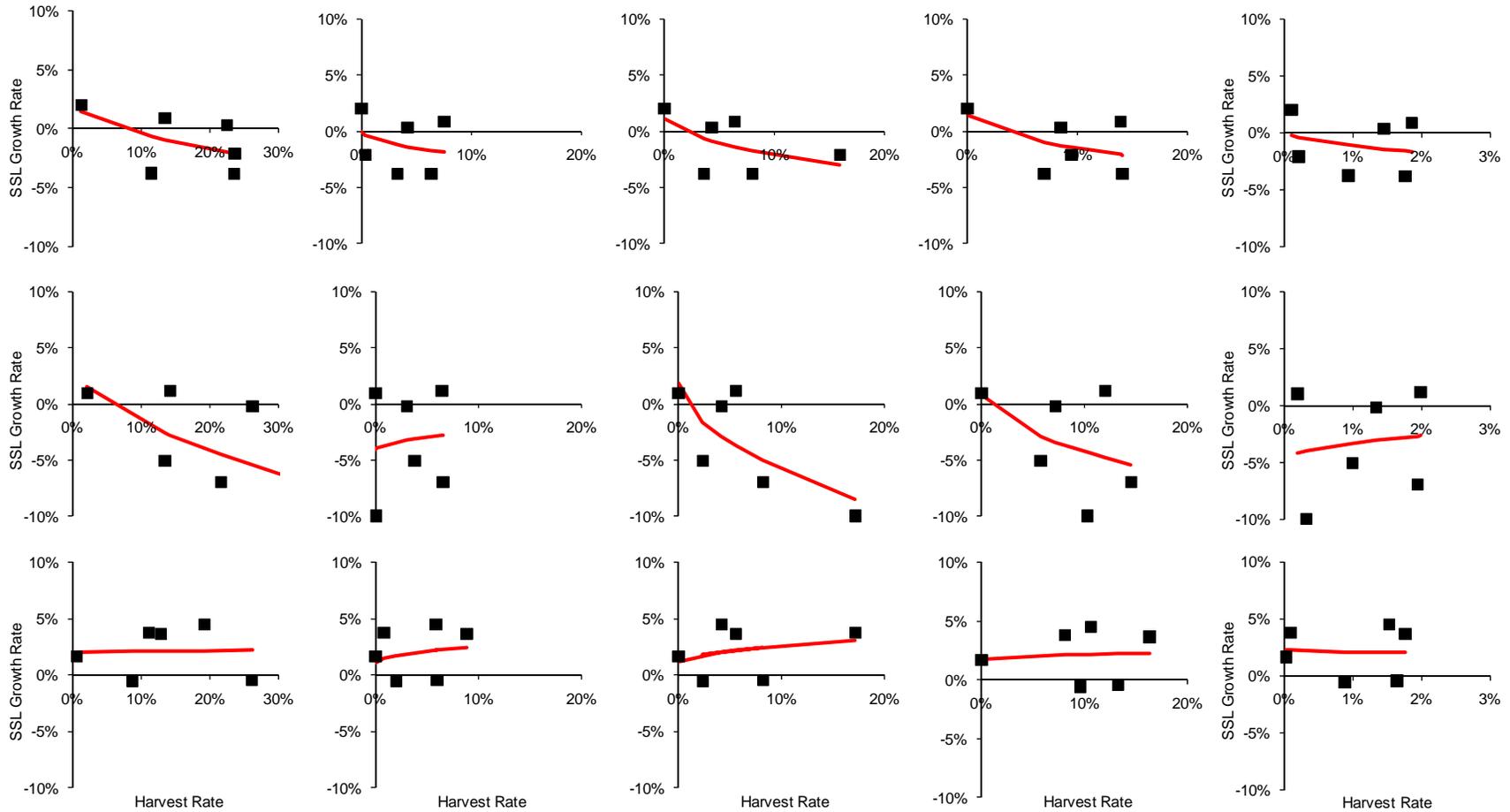
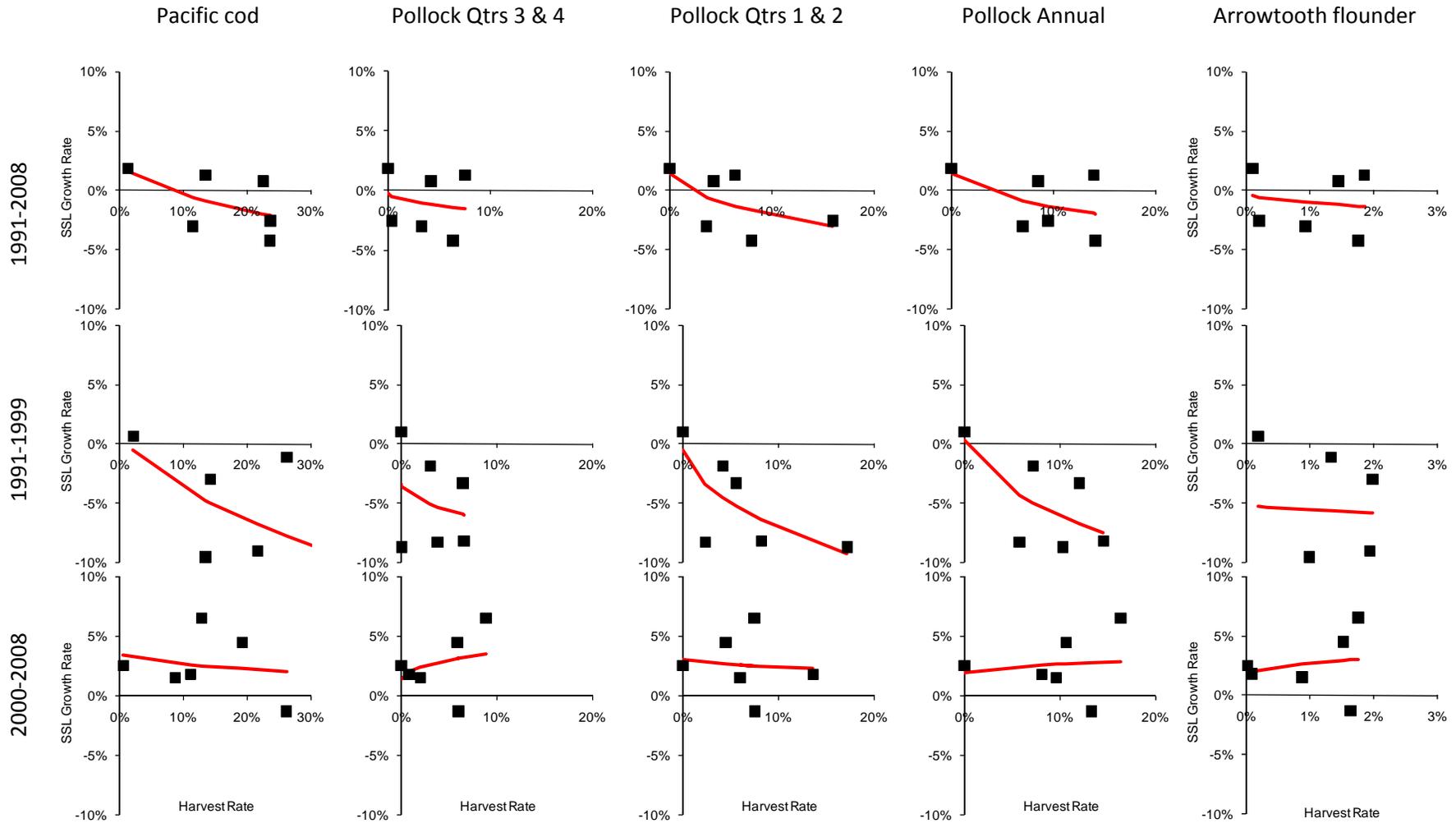


Figure 6. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (6-11) in the GOA-BS plotted against annual harvest rates of Pacific cod, Pollock (summer: quarters 3 and 4; winter: quarters 1 and 2; annual), and arrowtooth flounder for the years 1991-2008, 1991-1999 and 2000-2008. Line is regression of SSL growth rate on arcsin-transformed harvest rates. See Table 9 for significance of regression coefficients (slopes).



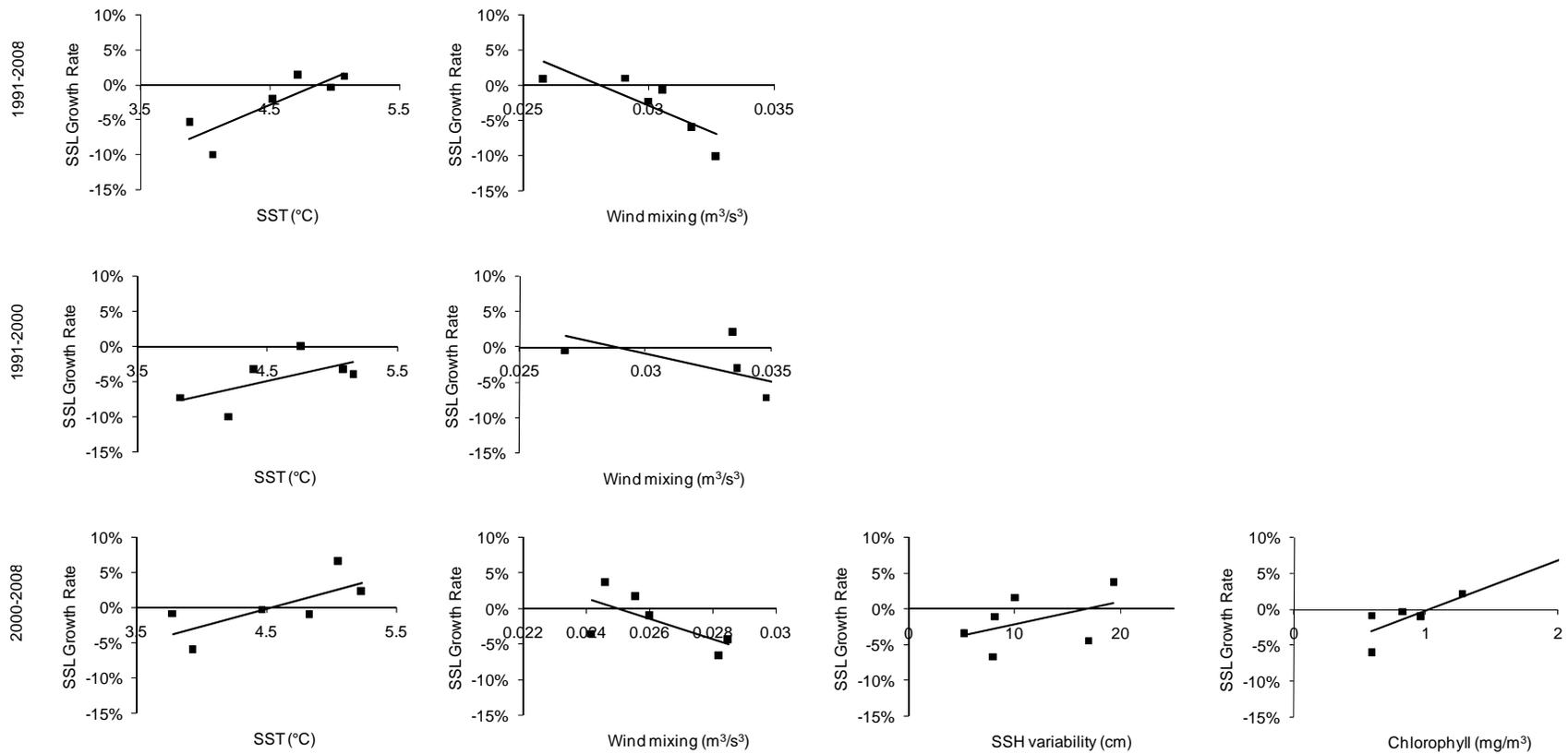


Figure 7. Steller sea lion growth rate (non-pups at ALL trend sites) by region (1-6, excluding Bering Sea) in the AI plotted against spring oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 16 for significance of regression coefficients (slopes).

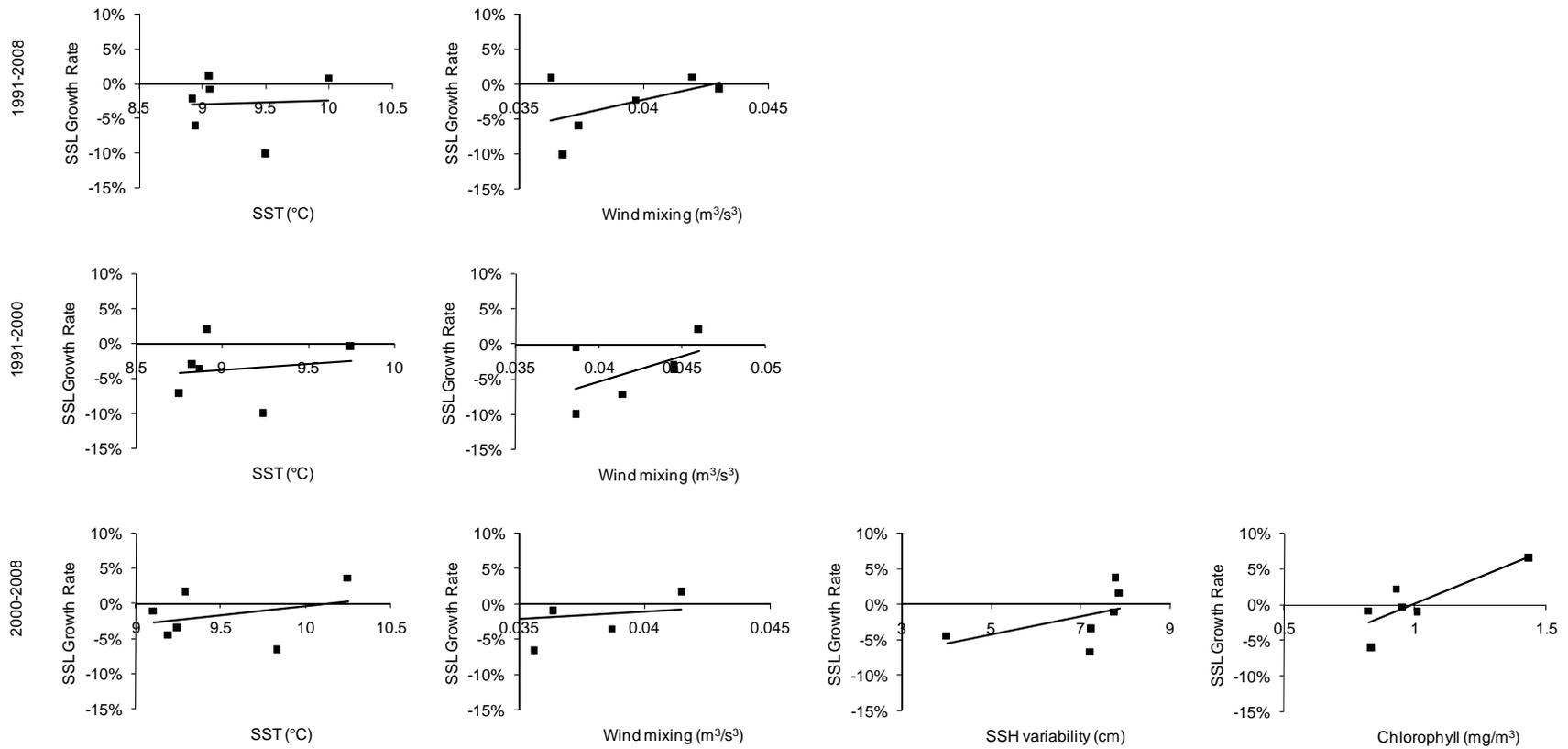


Figure 8. Steller sea lion growth rate (non-pups at ALL trend sites) by region (1-6, excluding Bering Sea) in the AI plotted against summer oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 16 for significance of regression coefficients (slopes).

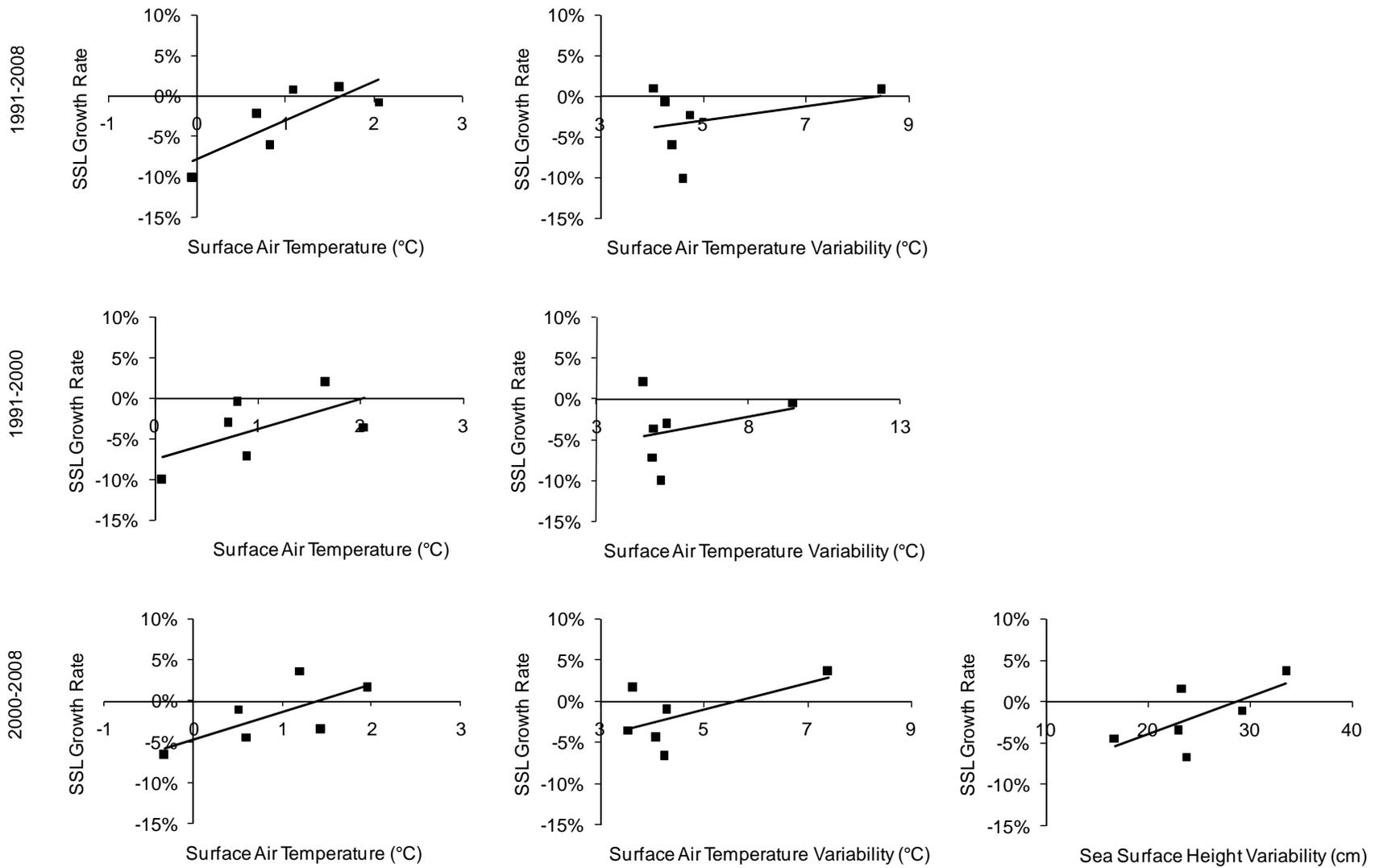


Figure 9. Steller sea lion growth rate (non-pups at ALL trend sites) by region (1-6, excluding Bering Sea) in the AI plotted against winter oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 16 for significance of regression coefficients (slopes).

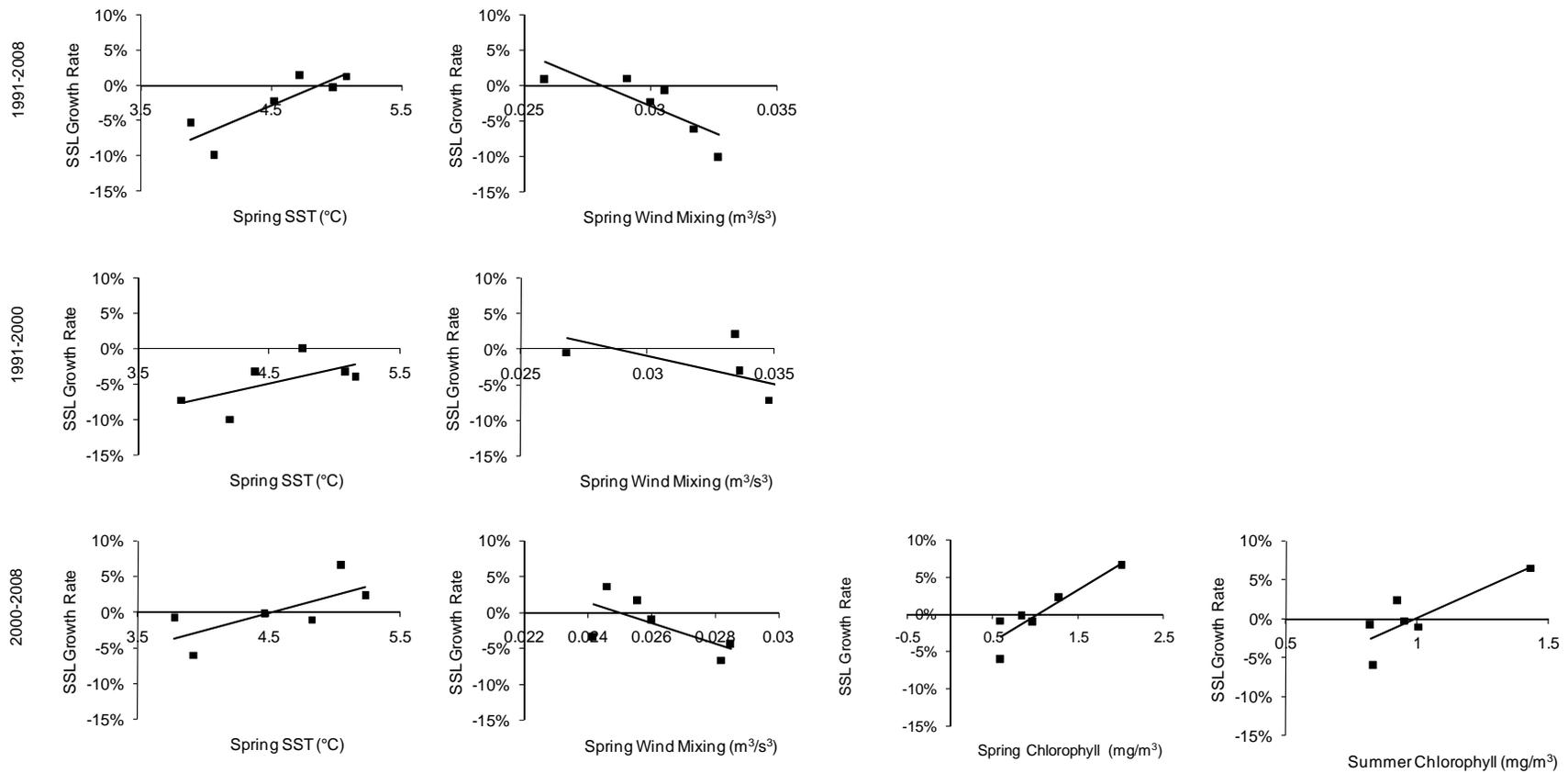


Figure 10. Steller sea lion growth rate (non-pups at ALL trend sites) by region (1-6, excluding Bering Sea) in the AI plotted against selected spring and summer oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 17 for significance of regression coefficients (slopes).

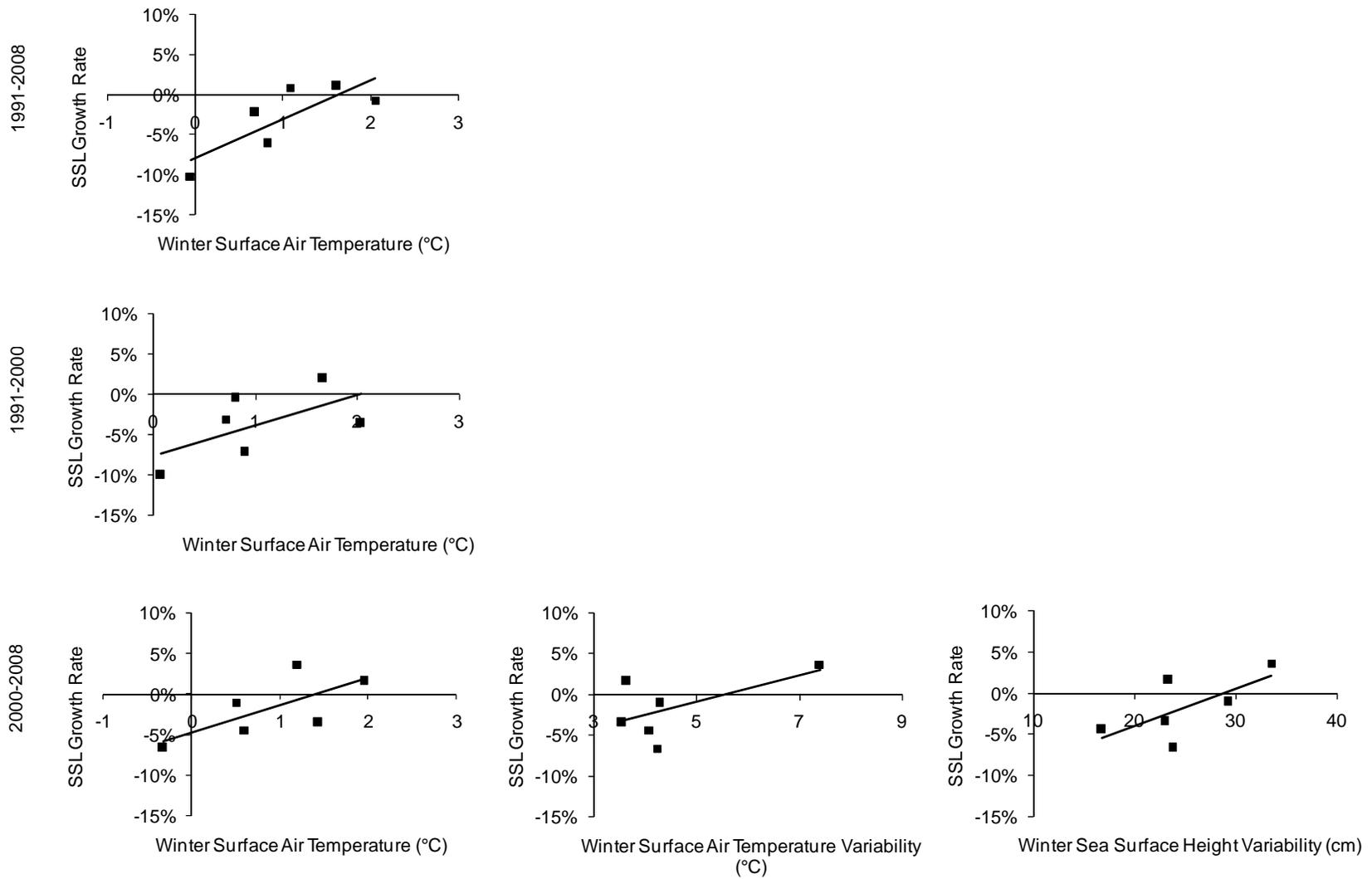


Figure 11. Steller sea lion growth rate (non-pups at ALL trend sites) by region (1-6, excluding Bering Sea) in the AI plotted against selected winter oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 17 for significance of regression coefficients (slopes).

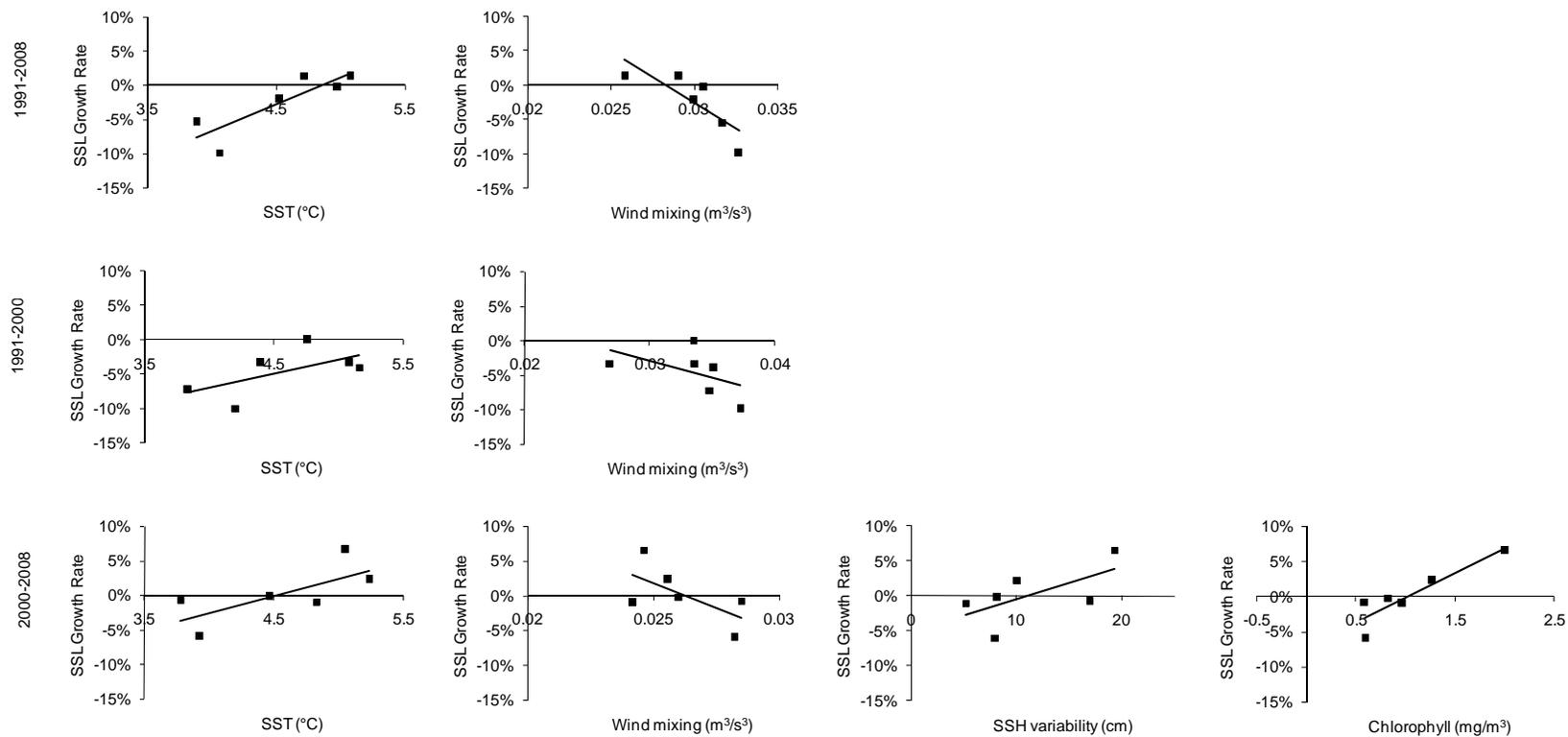


Figure 12. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (1-6, excluding Bering Sea) in the AI plotted against spring oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 18 for significance of regression coefficients (slopes).

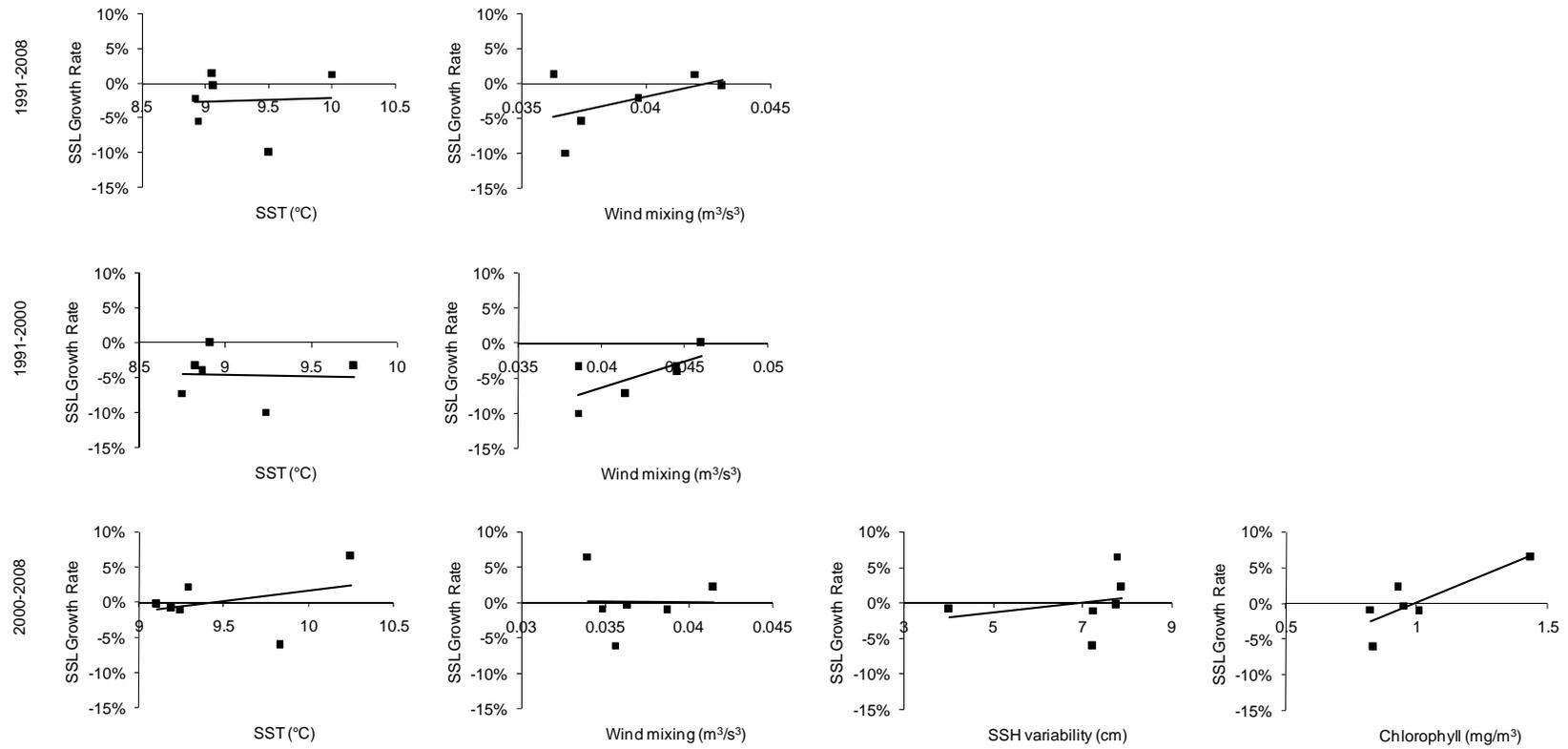


Figure 13. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (1-6, excluding Bering Sea) in the AI plotted against summer oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 18 for significance of regression coefficients (slopes).

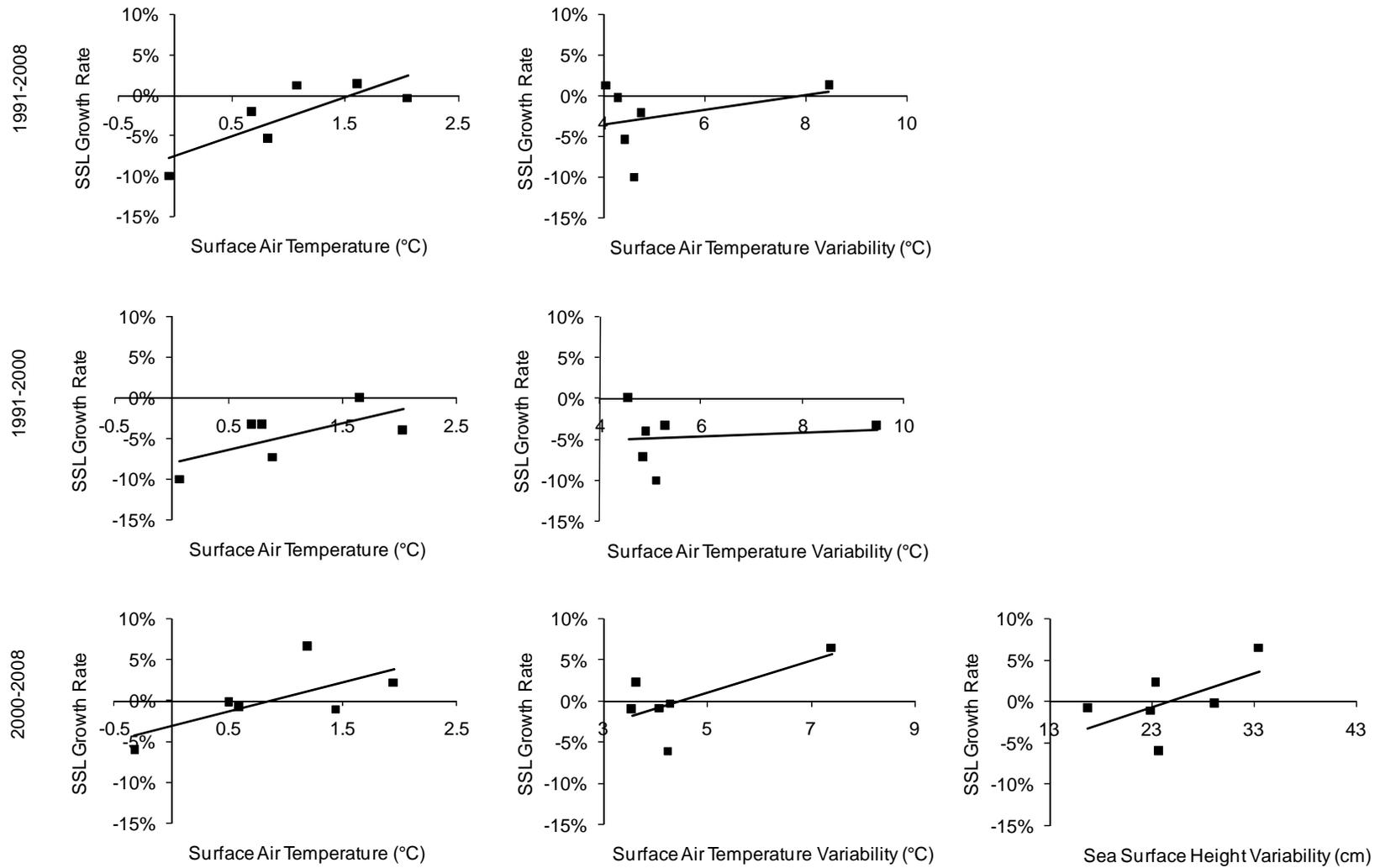


Figure 14. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (1-6, excluding Bering Sea) in the AI plotted against winter oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 18 for significance of regression coefficients (slopes).

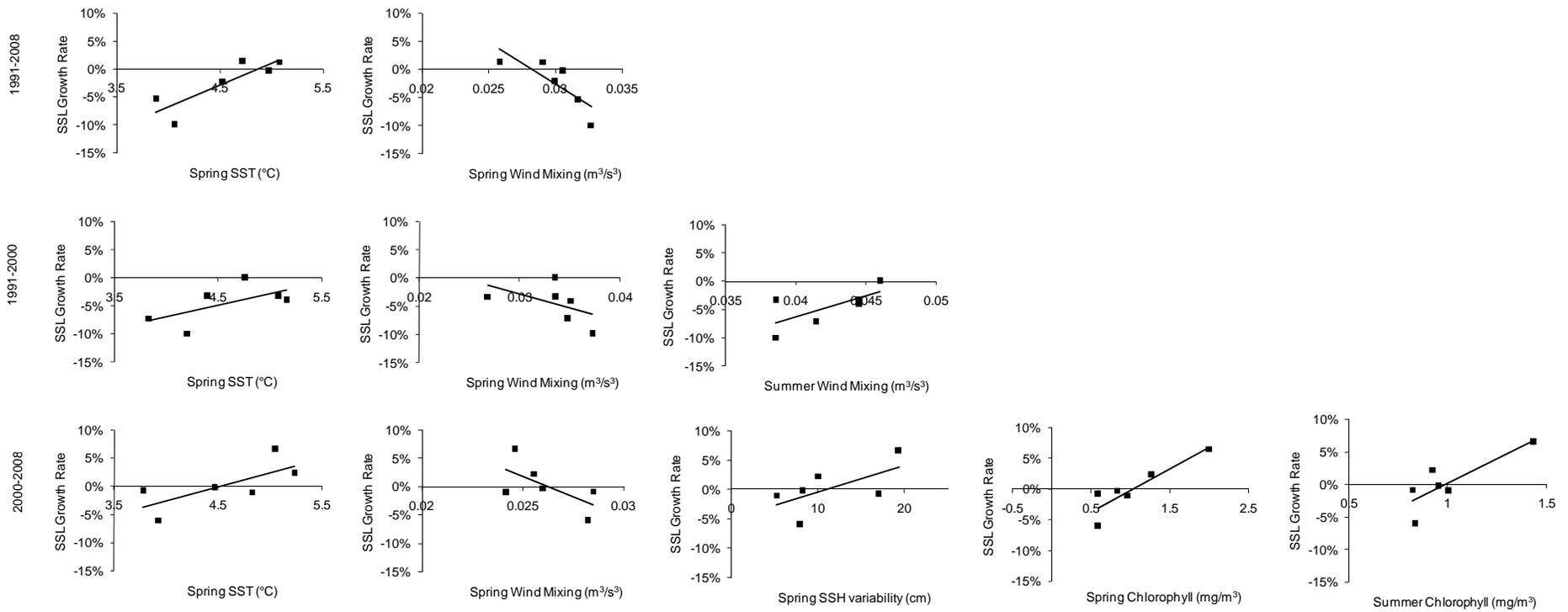


Figure 15. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (1-6, excluding Bering Sea) in the AI plotted against selected spring and summer oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 19 for significance of regression coefficients (slopes).

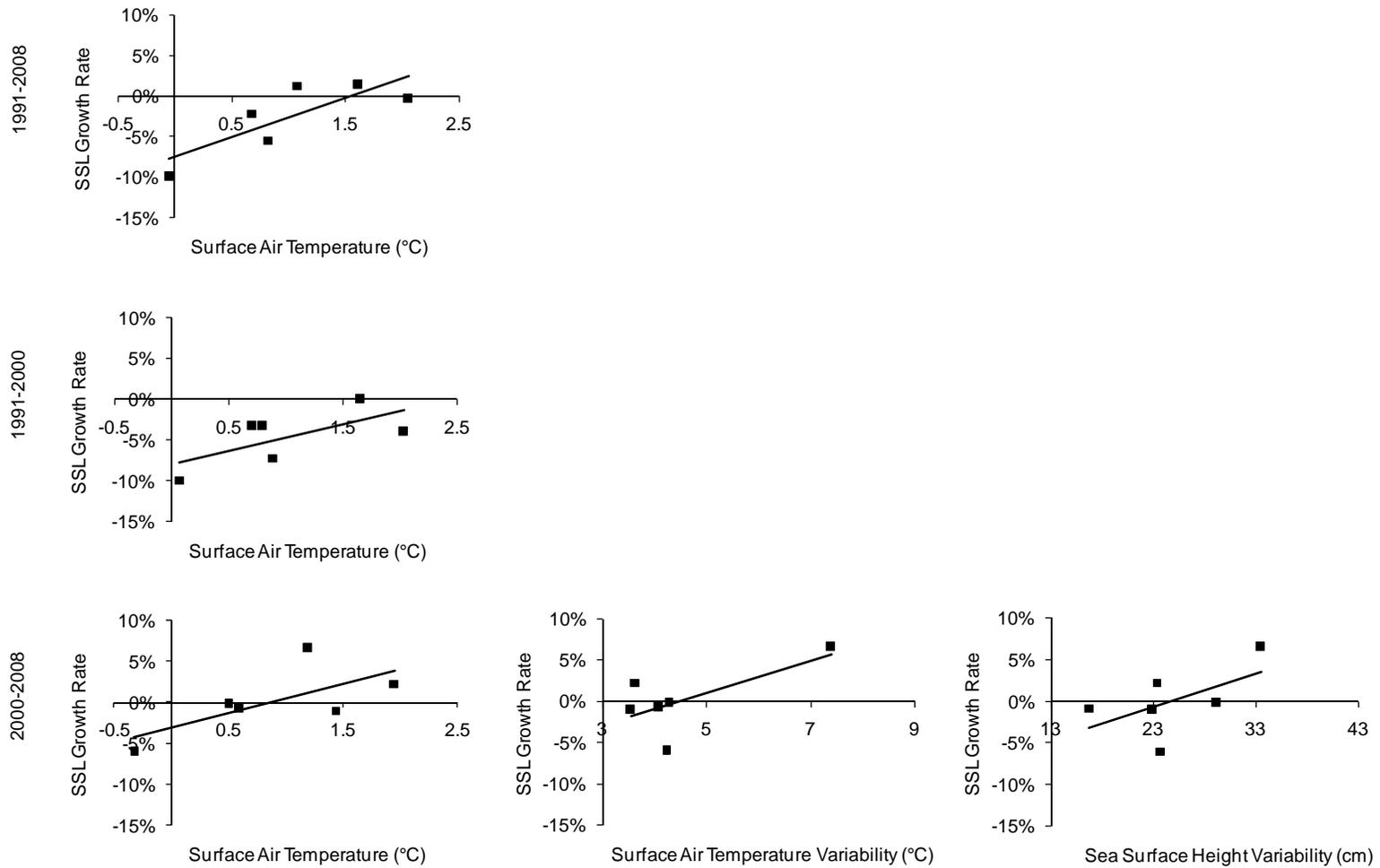


Figure 16. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (1-6, excluding Bering Sea) in the AI plotted against selected winter oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 19 for significance of regression coefficients (slopes).

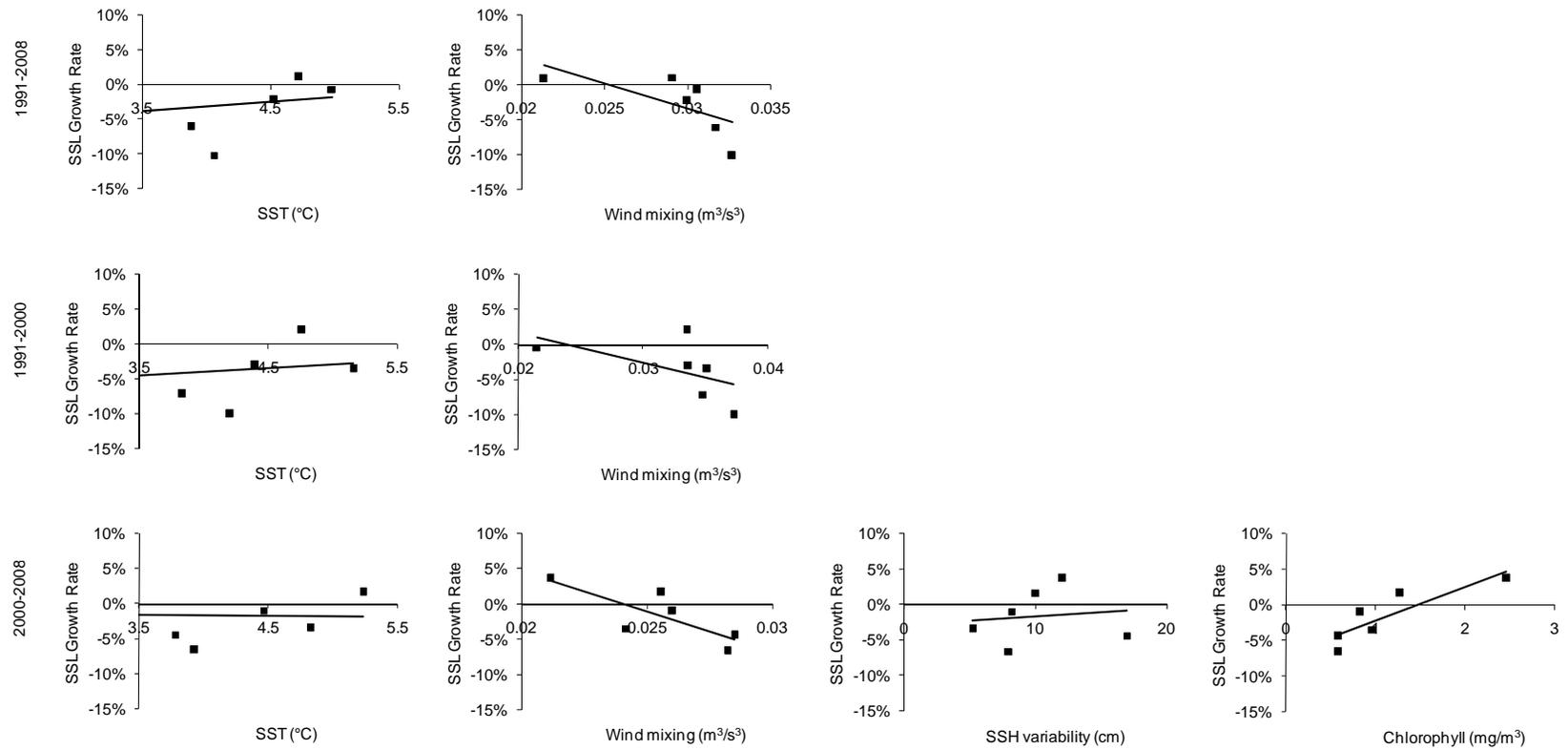


Figure 17. Steller sea lion growth rate (non-pups at ALL trend sites) by region (1-6, including Bering Sea) in the AI-BS plotted against spring oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 16 for significance of regression coefficients (slopes).

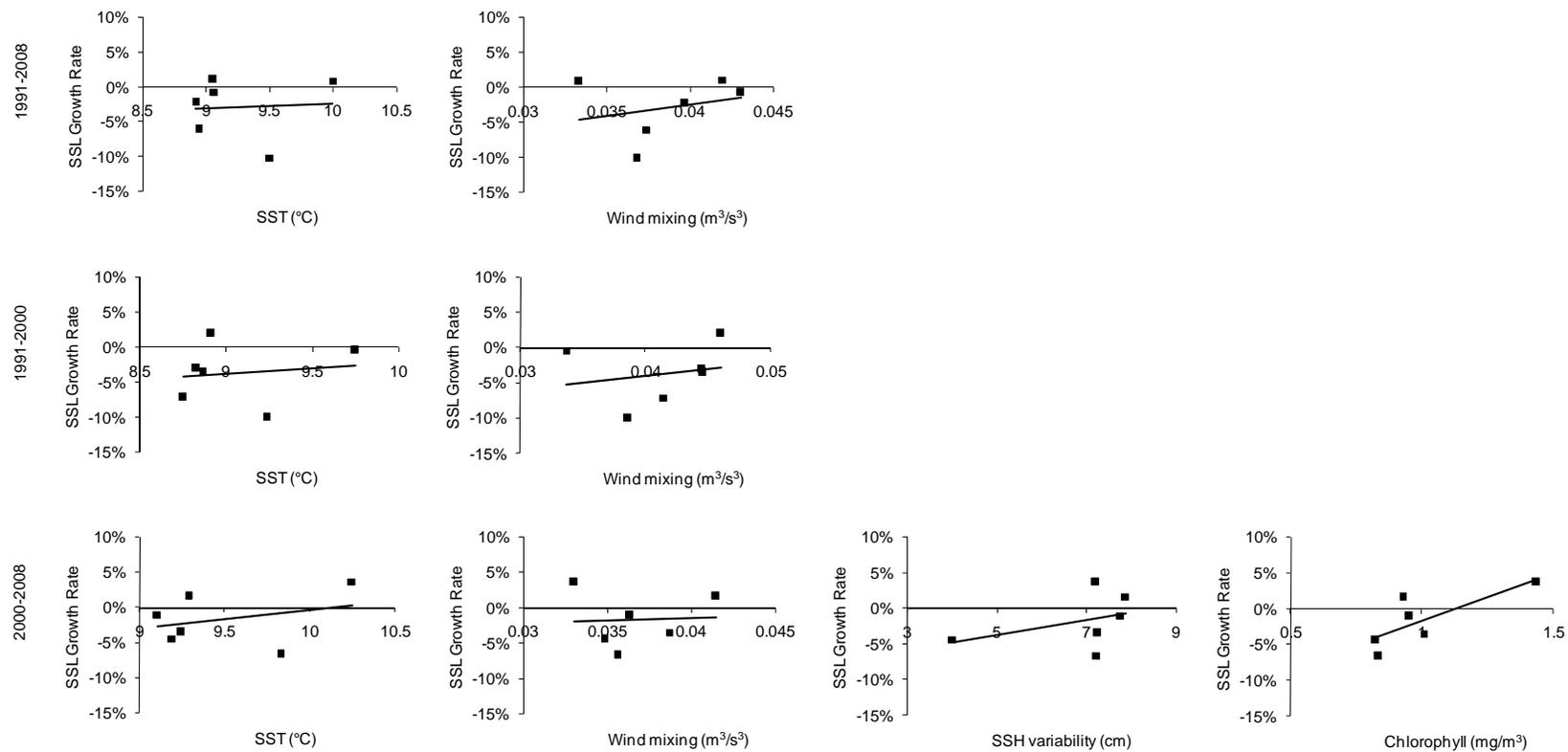


Figure 18. Steller sea lion growth rate (non-pups at ALL trend sites) by region (1-6, including Bering Sea) in the AI-BS plotted against summer oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 16 for significance of regression coefficients (slopes).

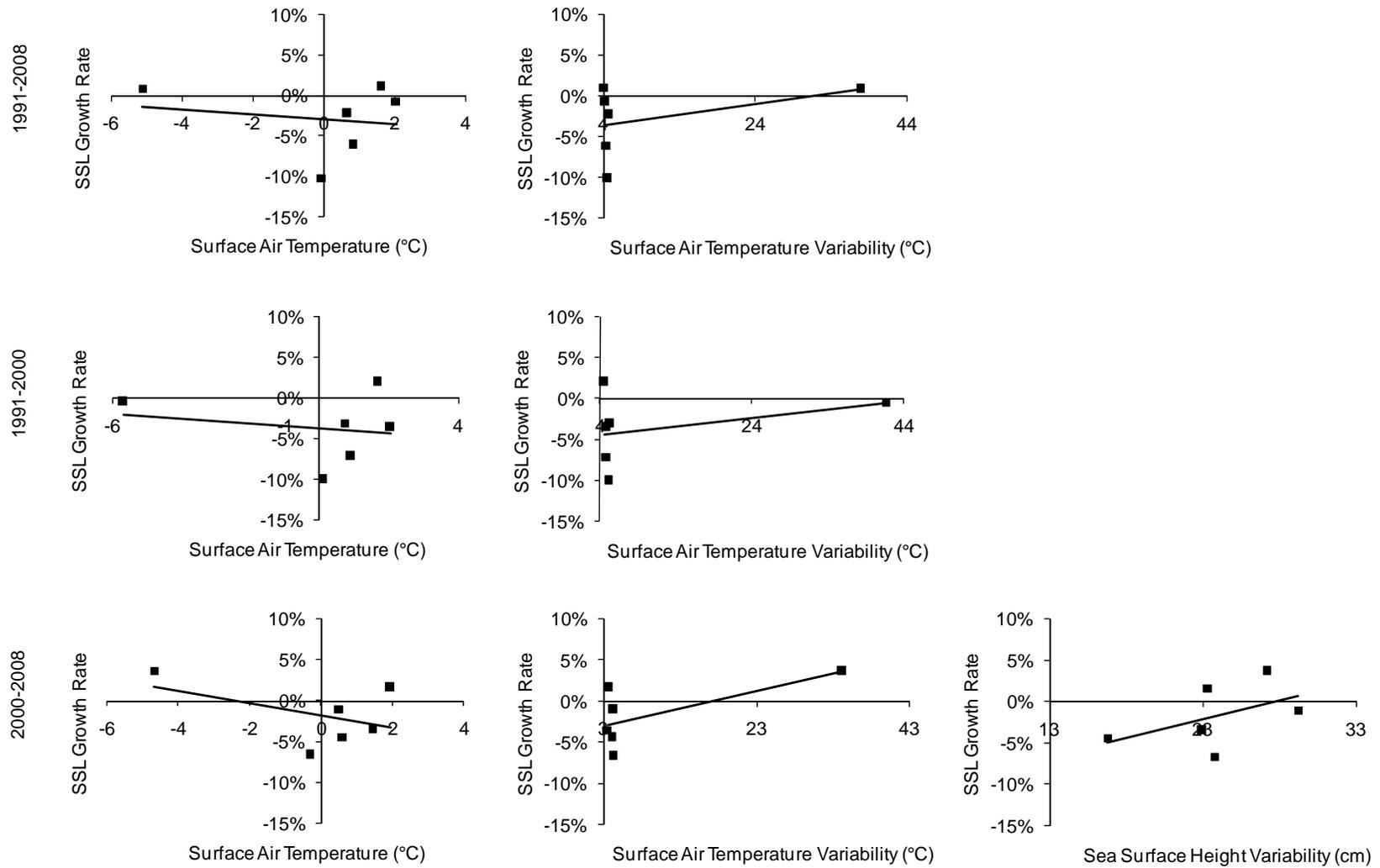


Figure 19. Steller sea lion growth rate (non-pups at ALL trend sites) by region (1-6, including Bering Sea) in the AI-BS plotted against winter oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 16 for significance of regression coefficients (slopes).

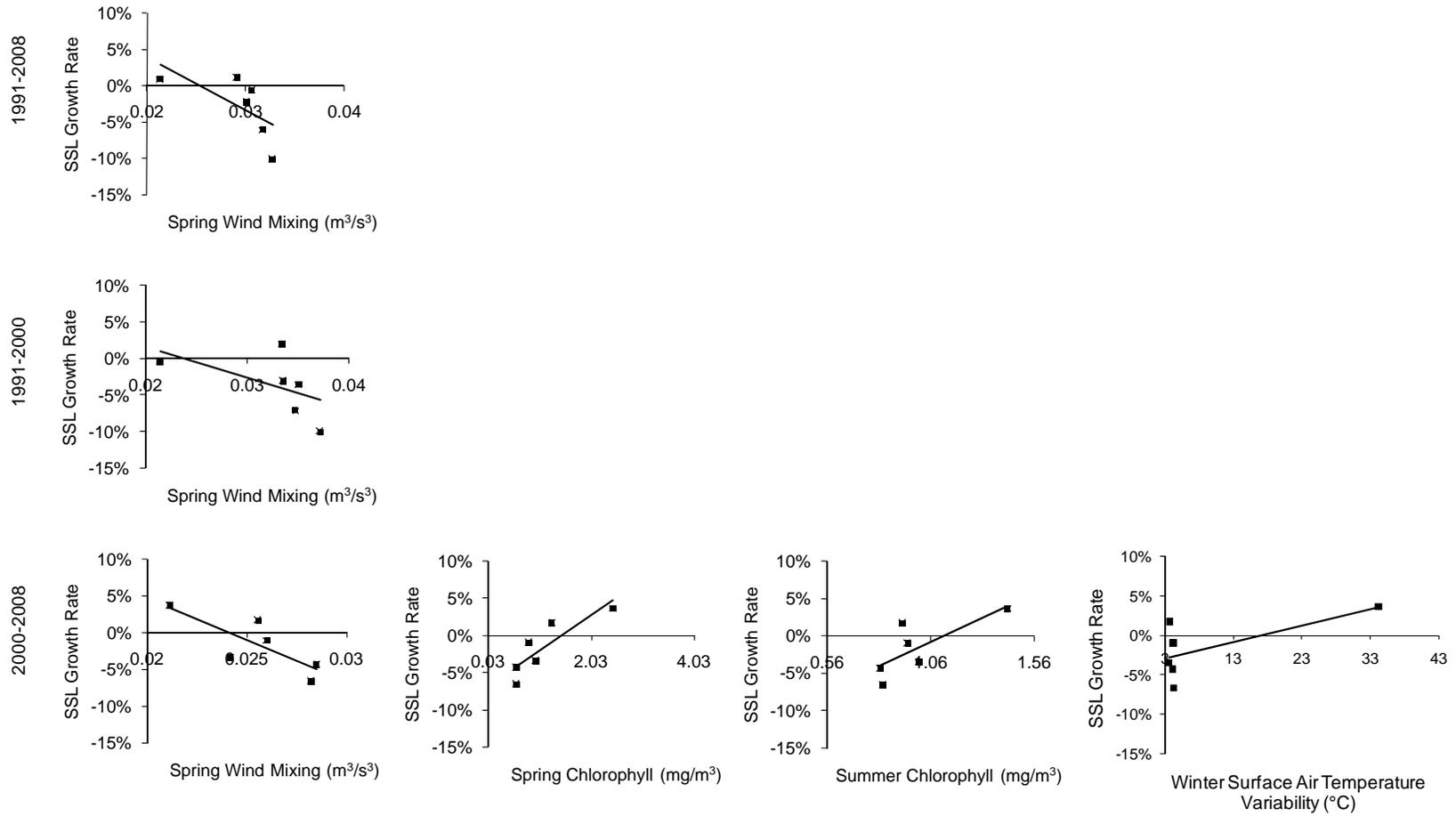


Figure 20. Steller sea lion growth rate (non-pups at ALL trend sites) by region (1-6, including Bering Sea) in the AI-BS plotted against selected (statistically significant) oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 17 for significance of regression coefficients (slopes).

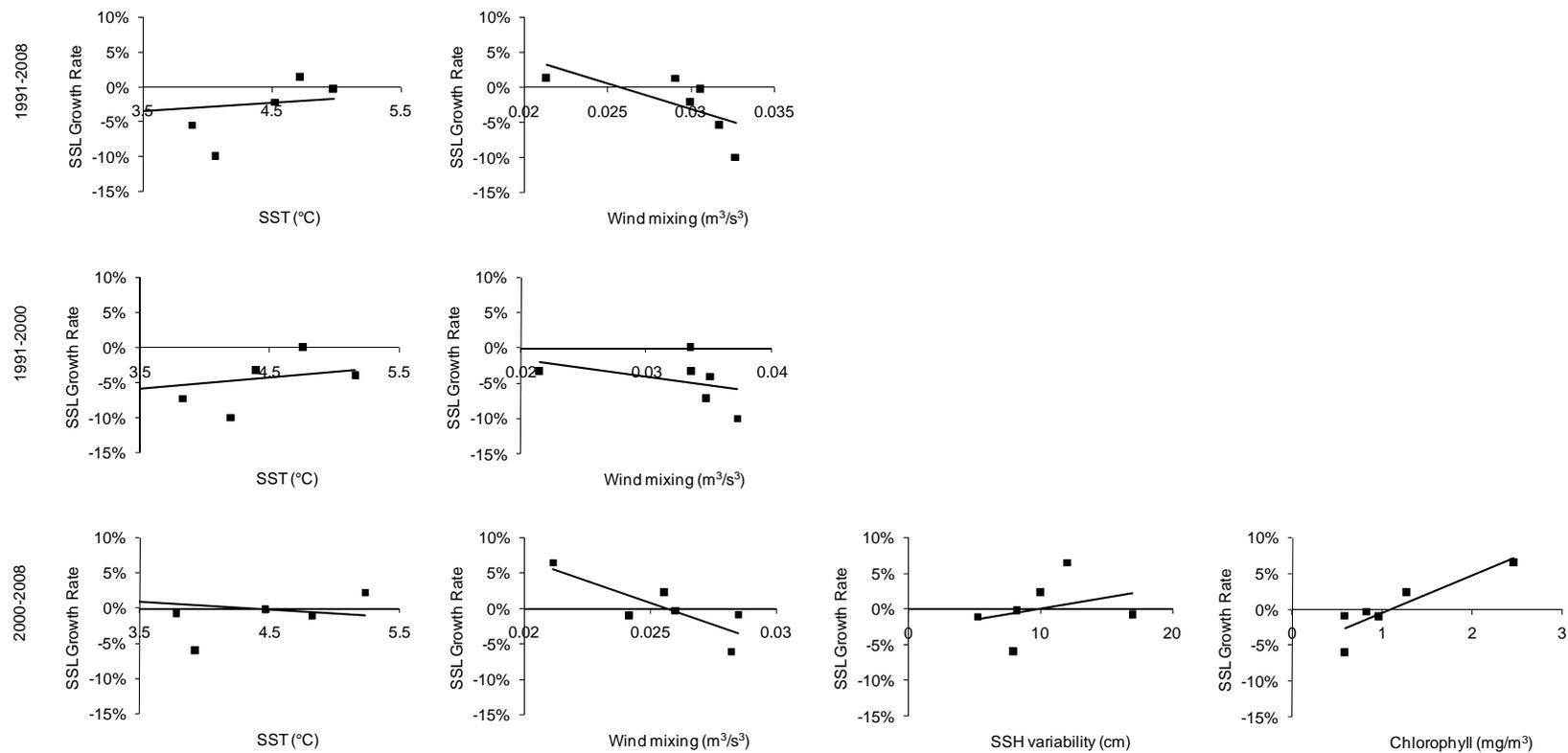


Figure 21. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (1-6, including Bering Sea) in the AI-BS plotted against spring oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 18 for significance of regression coefficients (slopes).

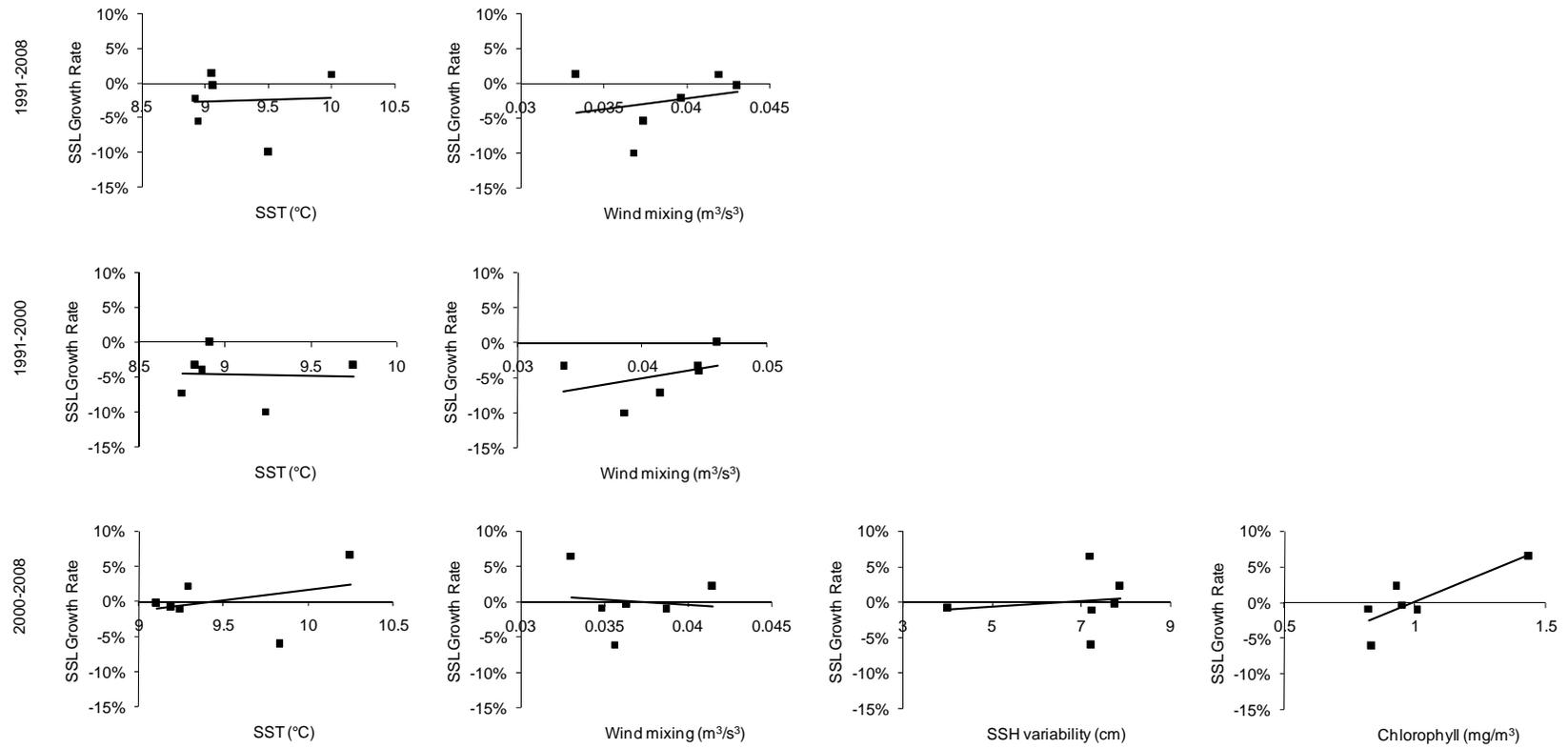


Figure 22. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (1-6, including Bering Sea) in the AI-BS plotted against summer oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 18 for significance of regression coefficients (slopes).

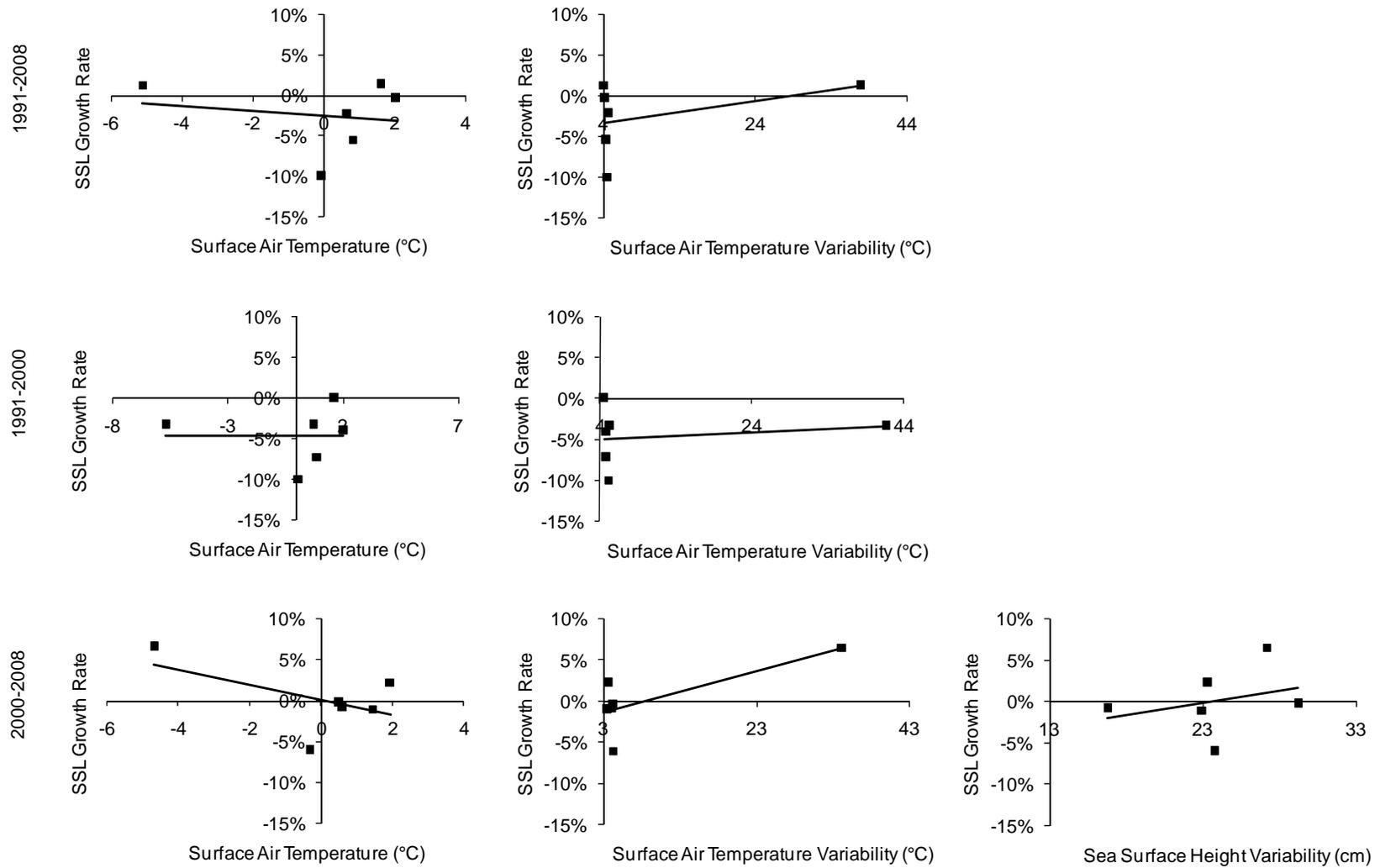


Figure 23. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (1-6, including Bering Sea) in the AI-BS plotted against winter oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 18 for significance of regression coefficients (slopes).

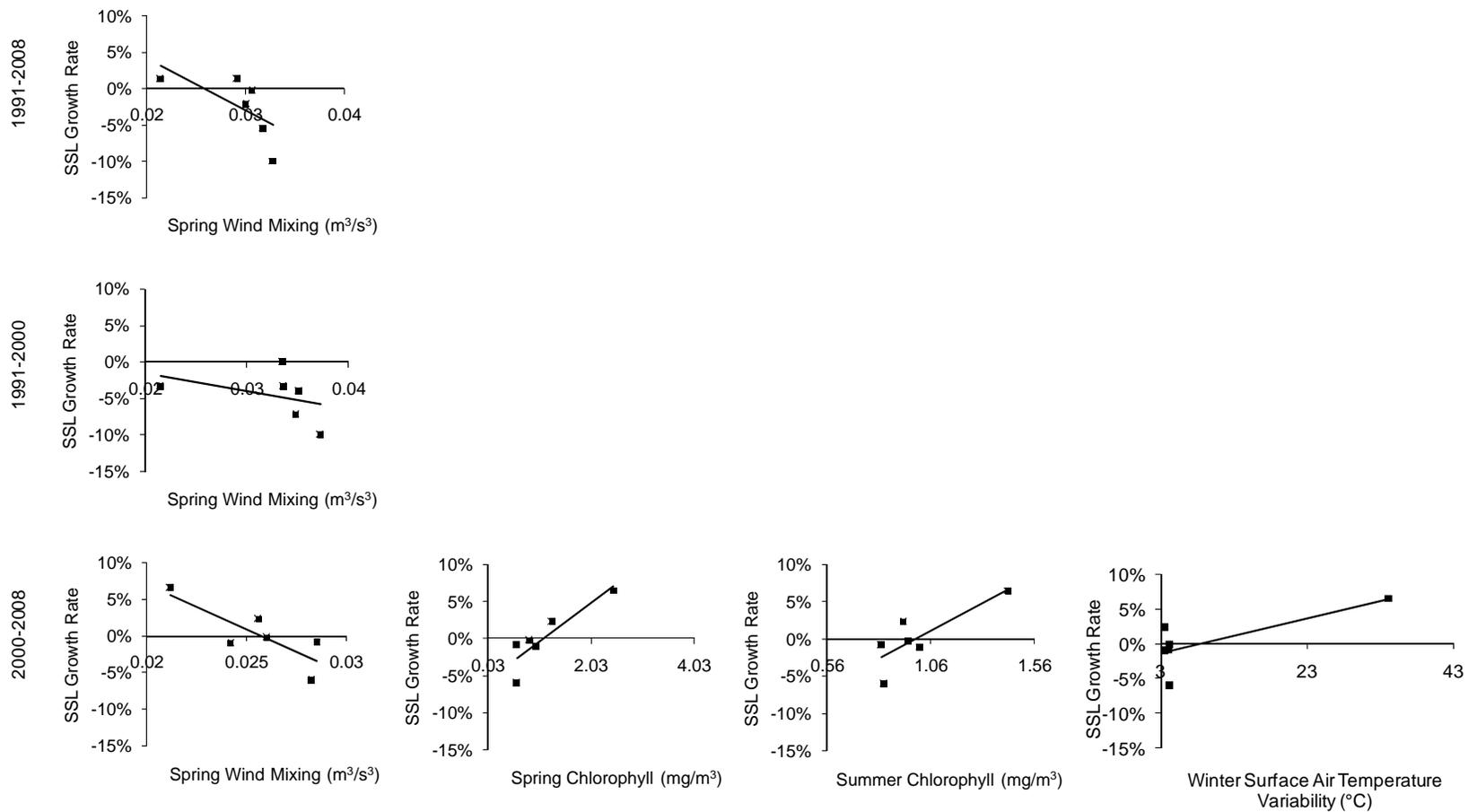


Figure 24. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (1-6, including Bering Sea) in the AI-BS plotted against selected (statistically significant) oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 19 for significance of regression coefficients (slopes).

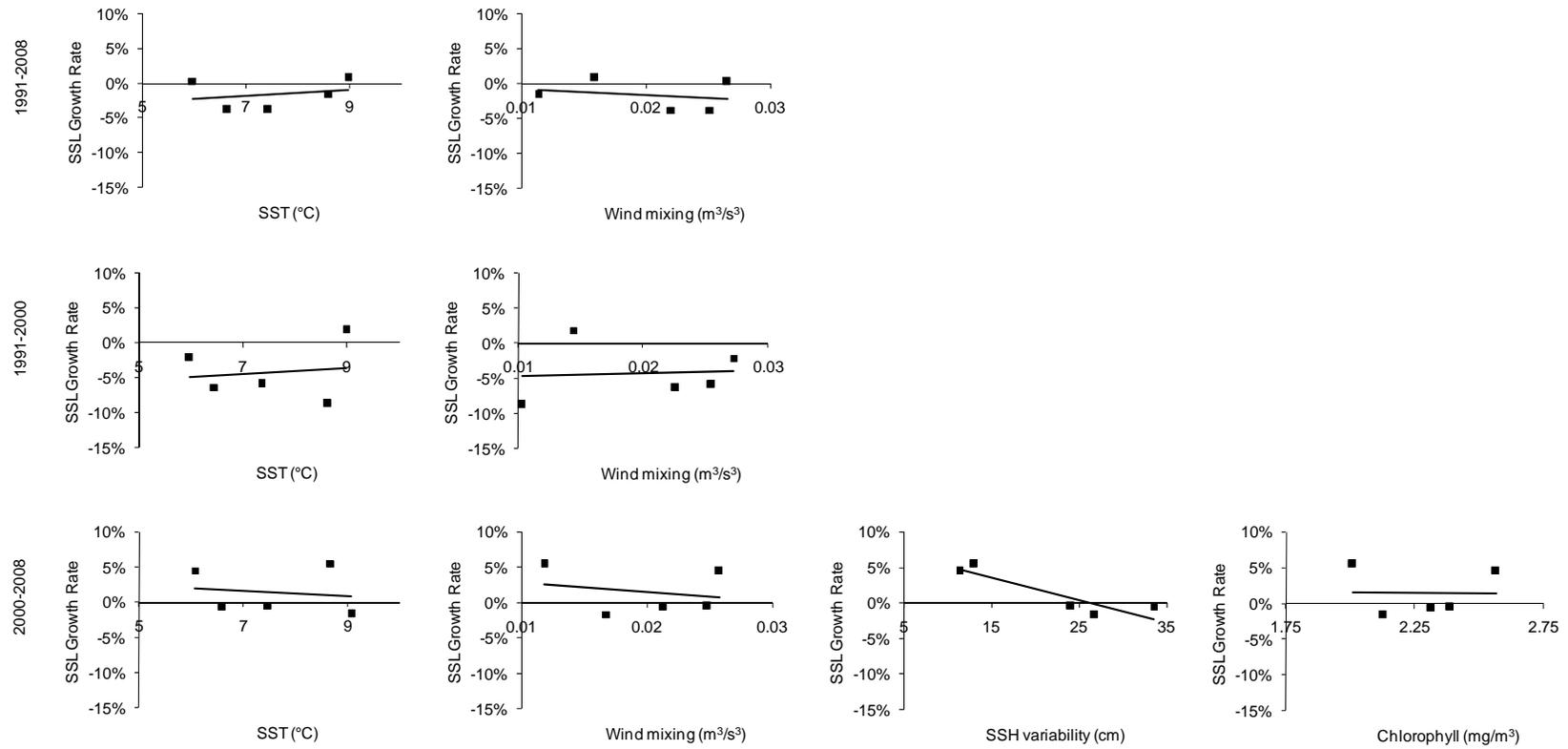


Figure 25. Steller sea lion growth rate (non-pups at ALL trend sites) by region (7-11) in the GOA plotted against spring oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 16 for significance of regression coefficients (slopes).

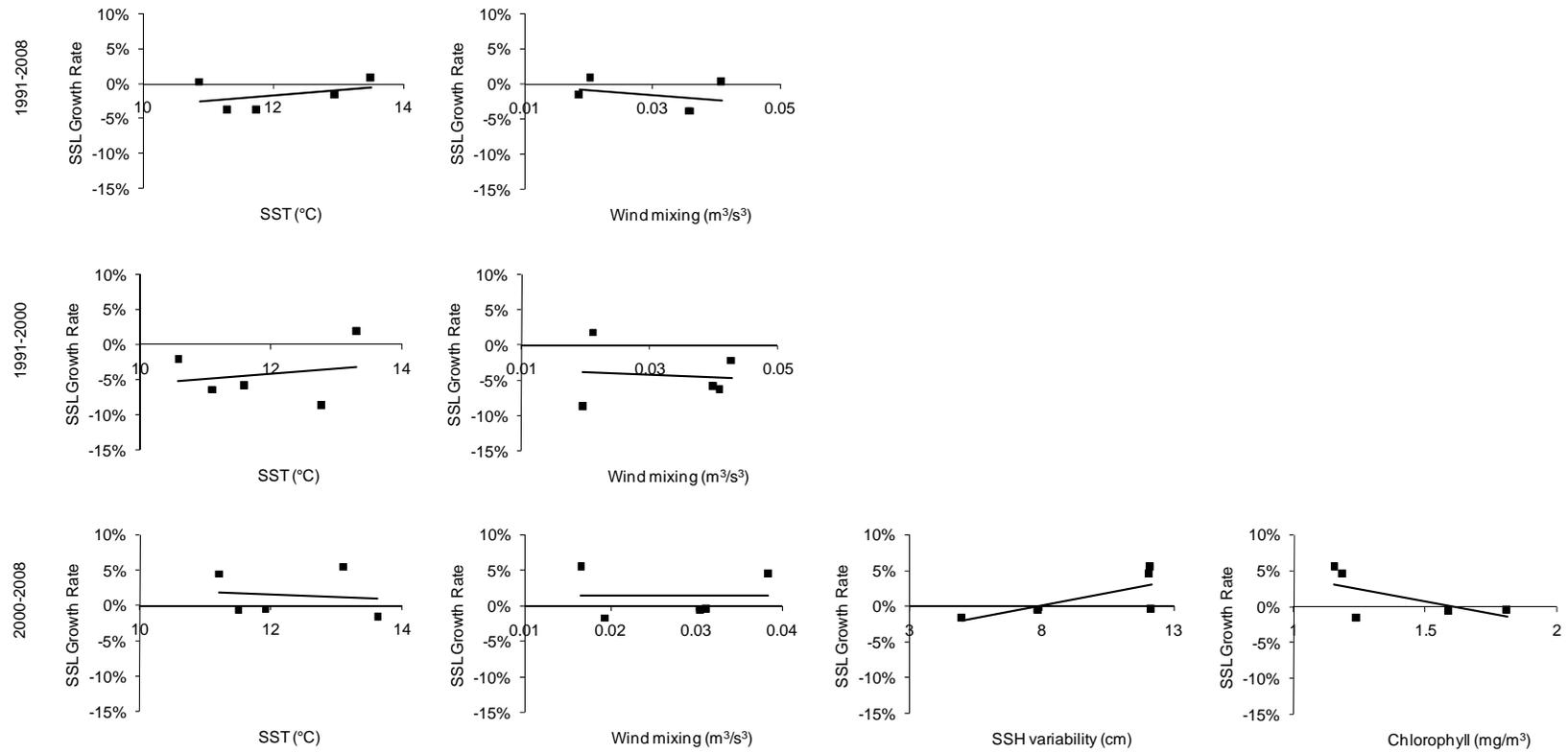


Figure 26. Steller sea lion growth rate (non-pups at ALL trend sites) by region (7-11) in the GOA plotted against summer oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 16 for significance of regression coefficients (slopes).

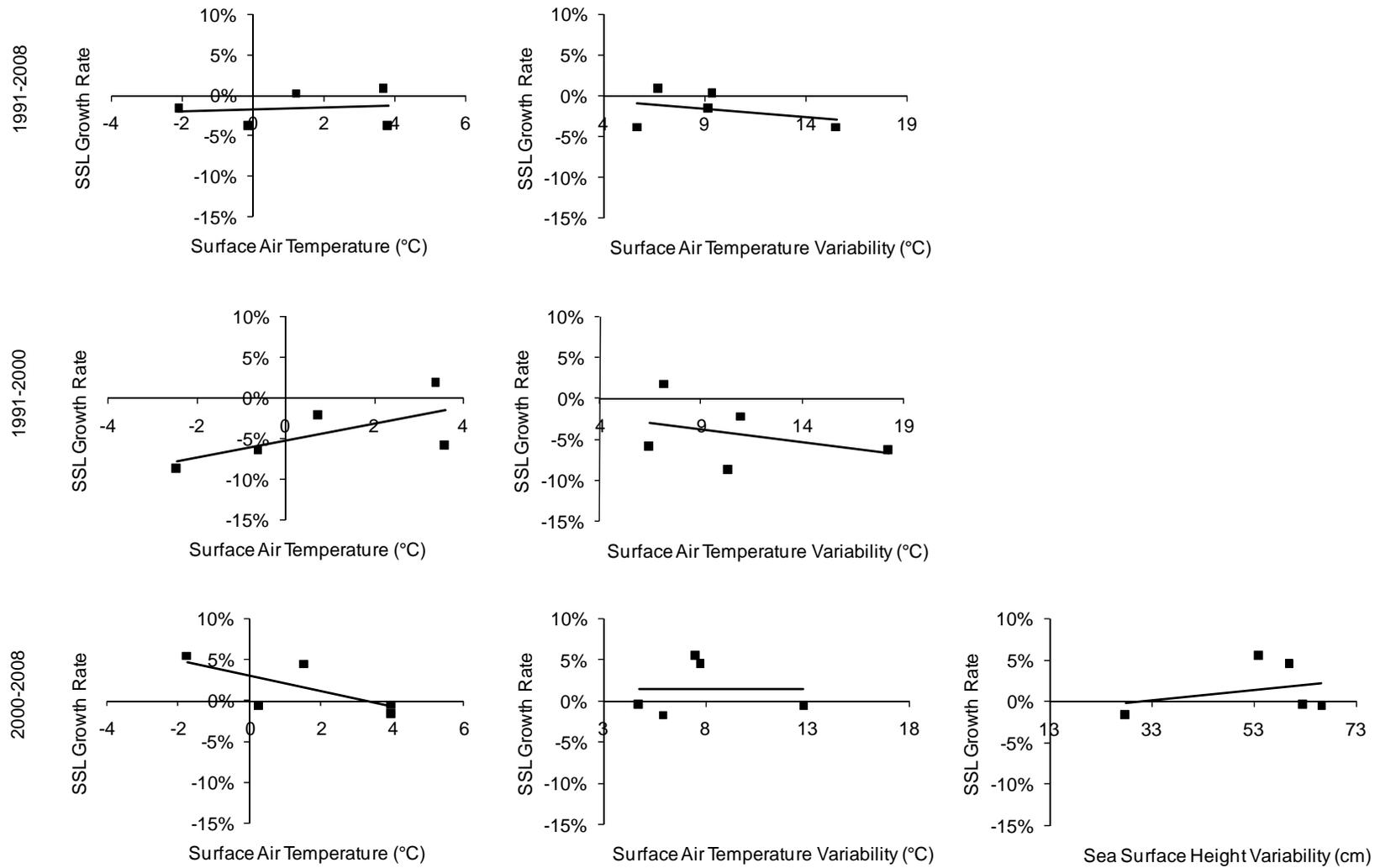


Figure 27. Steller sea lion growth rate (non-pups at ALL trend sites) by region (7-11) in the GOA plotted against winter oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 16 for significance of regression coefficients (slopes).

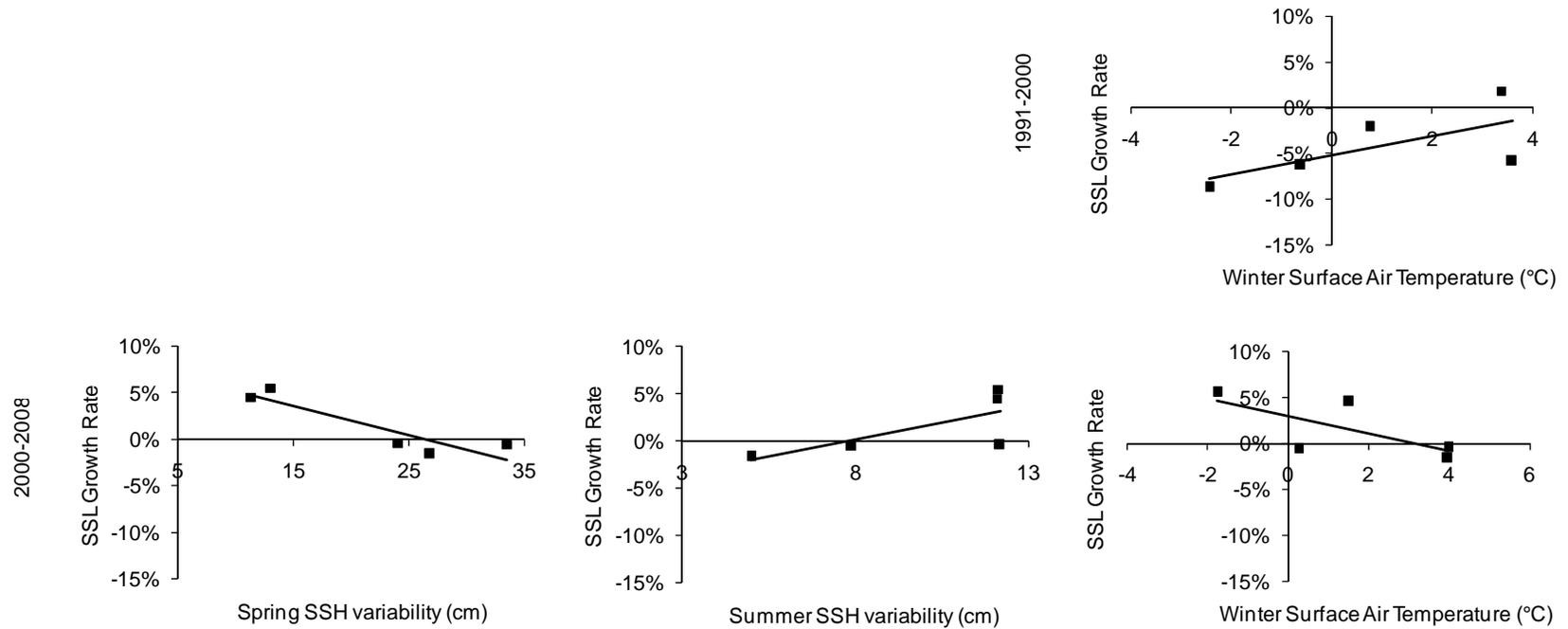


Figure 28. Steller sea lion growth rate (non-pups at ALL trend sites) by region (7-11) in the GOA plotted against selected (statistically significant) oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 17 for significance of regression coefficients (slopes).

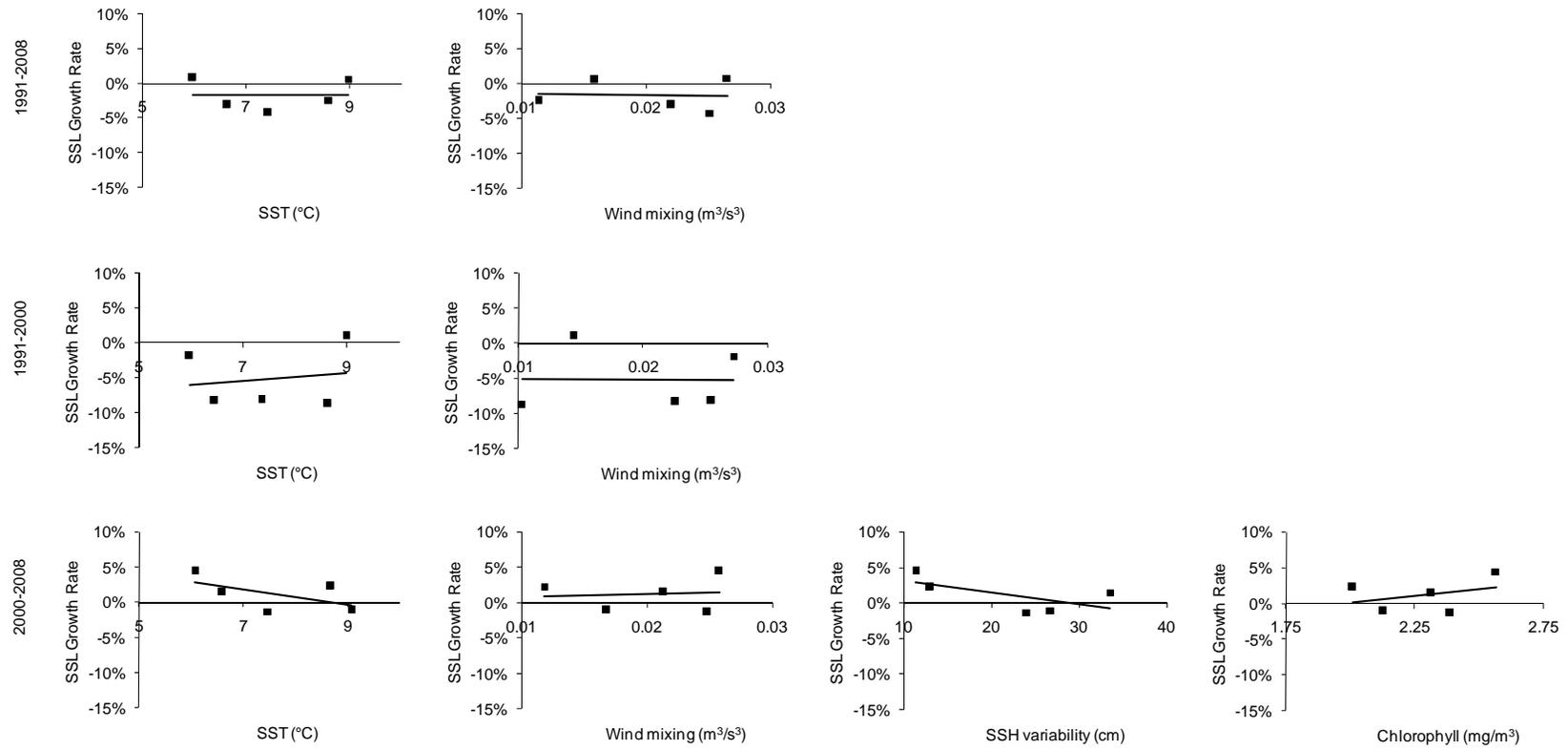


Figure 29. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (7-11) in the GOA plotted against spring oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 18 for significance of regression coefficients (slopes).

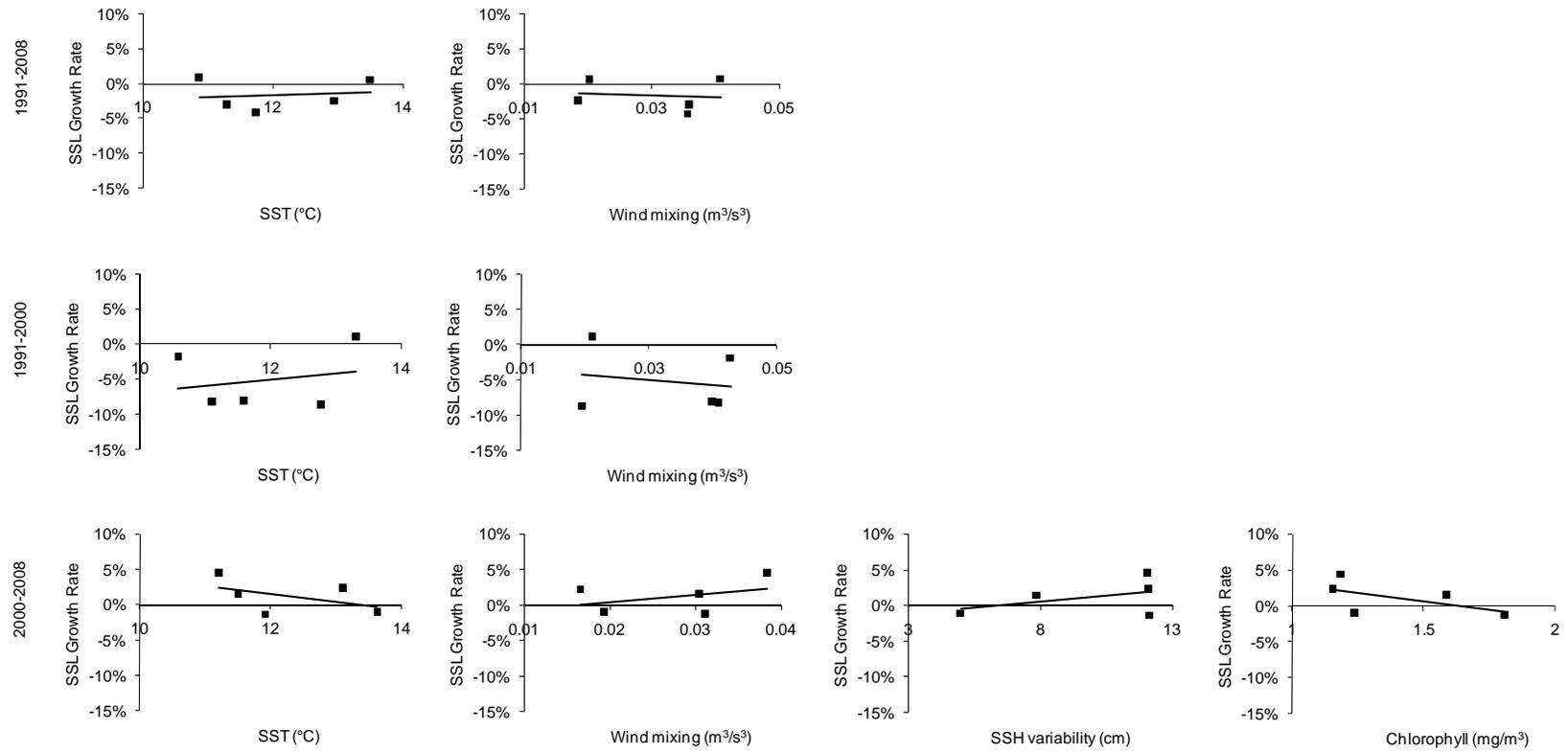


Figure 30. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (7-11) in the GOA plotted against summer oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 18 for significance of regression coefficients (slopes).

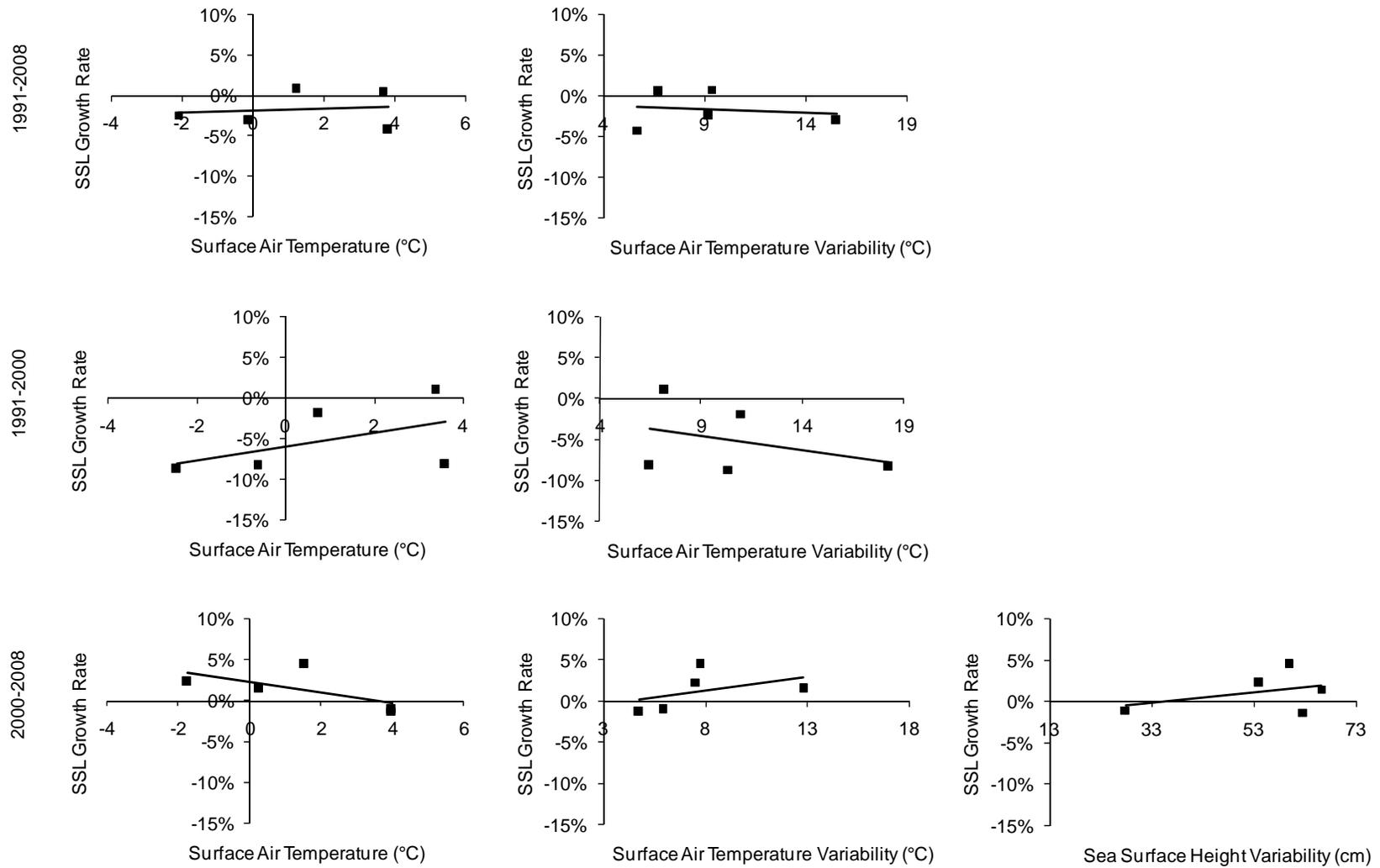


Figure 31. Steller sea lion growth rate (non-pups at ROOKERY trend sites) by region (7-11) in the GOA plotted against winter oceanographic variables for the years 1991-2008, 1991-2000 and 2000-2008. Line is regression of SSL growth rate on oceanographic variable. See Table 18 for significance of regression coefficients (slopes).

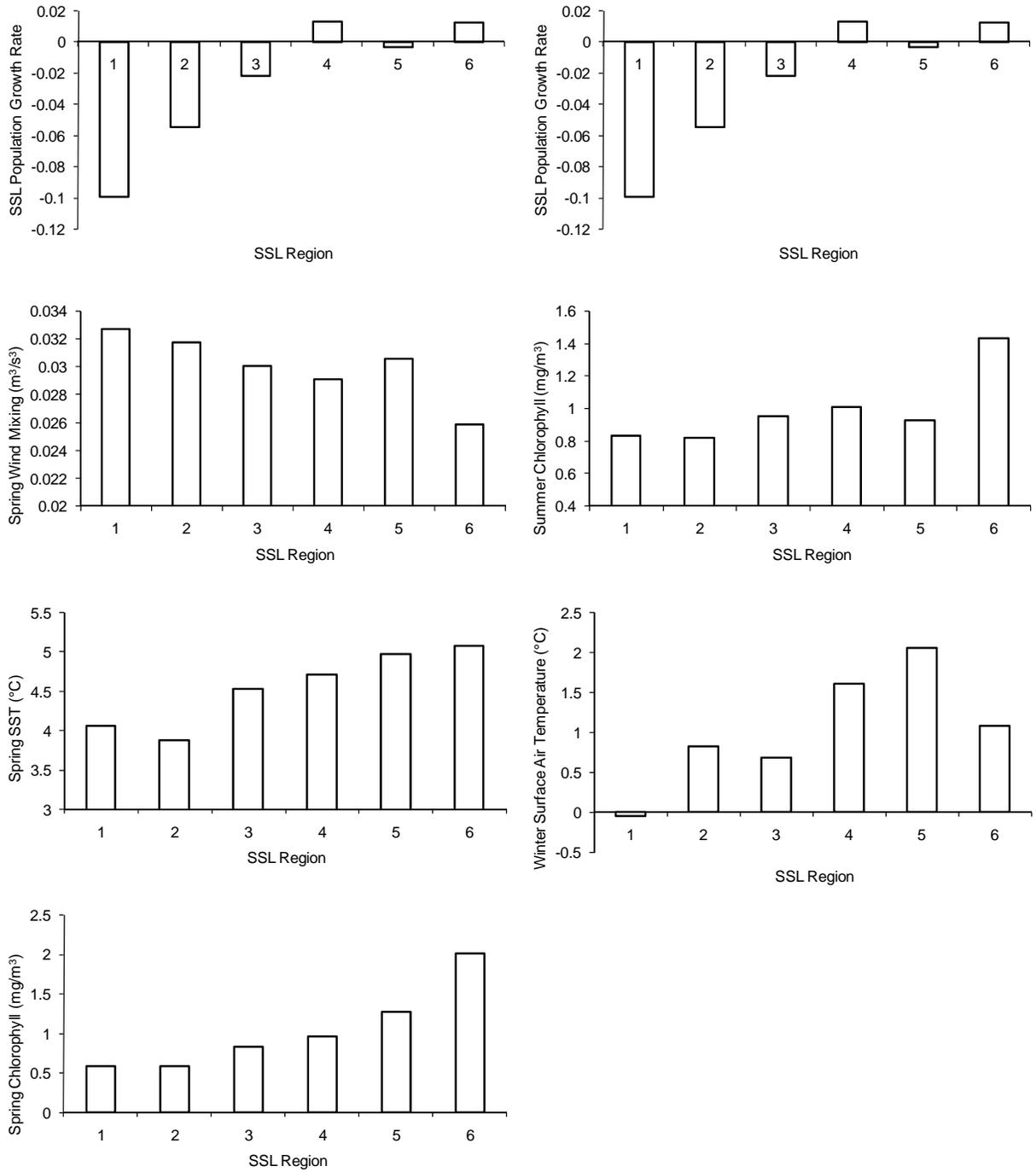


Figure 32. Selected (statistically significant) oceanographic variables for each Steller sea lion (SSL) region in the Aleutian Islands from western (region 1) to eastern (region 6, excluding Bering Sea) compared to SSL annual population growth rate (top of each column of graphs). Data are from 1991-2008, with the exception of chlorophyll which are from 2000-2008 (data from 1991 are not available).