COMPARISONS OF WALLEYE POLLOCK, THERAGRA CHALCOGRAMMA, HARVEST TO STELLER SEA LION, EUMETOPIAS JUBATUS, ABUNDANCE IN THE BERING SEA AND GULF OF ALASKA

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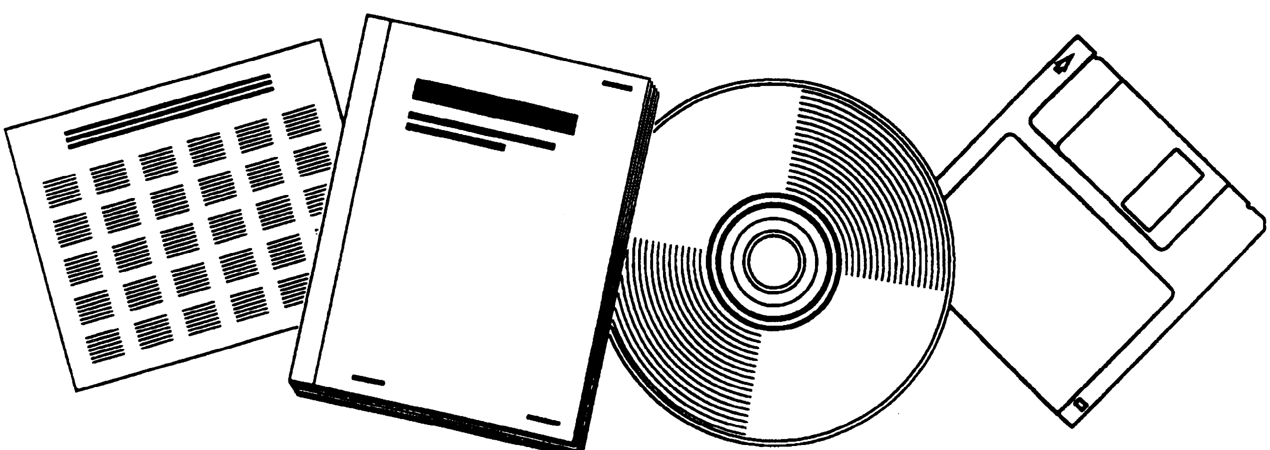

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Comparisons of Walleye Pollock, *Theragra chalcogramma*, Harvest to Steller Sea Lion, *Eumetopias jubatus*, Abundance in the Bering Sea and Gulf of Alaska

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Abstract: Steller sea lion, Eumetopias jubatus, counts made on rookeries in the Gulf of Alaska, Aleutian Islands, and the Bering Sea from 1976 to 1991 were compared to annual estimates of walleye pollock, Theragra chalcogramma, harvest to examine possible relationships between Steller sea lion abundance and commercial pollock fishing. Comparisons were made between Steller sea lion counts and pollock fishery data from the same year and from 1 to 5 years prior.

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ABSTRACT

Steller sea lion, Eumetipias jubatus, counts made on rookeries in the Gulf of Alaska, Aleutian Islands, and the Bering Sea from 1976 to 1991 were compared to annual estimates of walleye pollock, Theragra Chalcogramma, harvest to examine possible relationships between Steller sea lion abundance and commercial pollock fishing. Comparisons were made between Steller sea lion counts and pollock fishery data from the same year and from 1 to 5 years prior. Two sets of study areas were used, one encompassing 60 nmi or 120 nmi blocks around six major rookeries and another with 13 sites defined by 20 nmi radius rings around major rookeries. Lacking accurate measures of local pollock biomass, harvest data were used as approximations of annual differences in pollock abundance. Following methods used in Loughlin and Merrick (1989), correlation coefficients were calculated using a linear model and tested for significance using a 2-tailed null hypothesis (=0.05). However, since the data are probably not normally distributed, Kendall's coefficients of rank correlation were also calculated and tested for significance (=0.05).

Using the parametric approach, some significant positive -correlations were obtained comparing sea lion counts to pollock harvests 1 to 5 years prior (2 in the first set of comparisons and 8 in the second). These may indicate circumstances where pollock abundance was adequate to sustain the fishery while sea

lion abundance remained unaffected. Significant negative correlations (2 in each set of comparisons) may suggest instances where areas of low pollock biomass were effectively harvested, but the low or reduced availability of prey, or the fishing activity itself, could have affected Steller sea lion abundance 3 to 5 years later.

Only two of the significant correlations found in the parametric approach were detected using Kendall's rank correlation test. We conclude that any potential relationship between sea lion abundance and pollock harvest can not be properly determined from these data.

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INTRODUCTION

Major growth in the commercial fishery for walleye pollock, *Theragra chalcogramma*, in the Gulf of Alaska and the Bering Sea from the mid-1960s to the present (Megrey and Wespestad 1990) occurred at about the same time the Steller sea lion, *Eumetiopias jubatus*, population declined in those areas (Merrick et al. 1987). The relationship between Steller sea lion abundance and the commercial harvest of walleye pollock is unknown, but it has been repeatedly speculated that removal of sea lion prey by commercial trawl fisheries has contributed to the decline of Steller sea lion abundance (Braham et al. 1980, Lowry 1982, Merrick et al. 1987, Loughlin and Merrick 1989).

Loughlin and Merrick (1989) compared sea lion counts and pollock harvest statistics in seven areas surrounding eight major rookeries to test the hypothesis that commercial catches of pollock influenced sea lion abundance. Direct comparisons of data from the same years, and lagged comparisons where pollock harvest data was paired against sea lion counts 1 - 5 years later were examined for patterns of significant negative correlations. The results were equivocal; few significant correlations were detected and they were both positive and negative.

Loughlin and Merrick (1989) noted a number of problems with their data set which may have confounded detection of significant correlations if they existed. These included the limited availability of sea lion count data, geographical differences in the utilization or recruitment of pollock stocks, positive and negative trends in pollock stock abundance during the study period, and the variable timing of pollock harvests relative to the fixed timing of sea lion counts during the breeding season, Furthermore, the application of statistical tests which include a normality assumption to these data (which are probably not normally distributed) has since been questioned, suggesting the need to also conduct tests using a more conservative non-parametric approach,

The purpose of this paper was to retest the Loughlin and Merrick (1989) hypothesis that commercial catches of pollock were correlated with sea lion abundance in light of additional sea lion count and pollock harvest data collected since 1987 using both the original and non-parametric statistical tests, Our approach also differs fundamentally from the original study in that we do not focus solely on detection of negative correlations. Instead, we discuss possible interpretations for both positive and negative relationships. We also emphasize that significant correlations, either positive or negative, do not indicate causal relationships.

METHODS

Two comparisons are included in this study, each subjected to both the parametric and non-parametric tests:

1. an update of Loughlin and Merrick's (1989) analyses, including recent sea lion count and pollock harvest data

from 1987 to 1991;

2. a comparison of sea lion counts from 13 study areas encompassing most major rookeries from the Barren Islands (Gulf of Alaska) to the western Aleutian Islands, with pollock harvests that occurred within 20 nm of those areas.

Update of Loughlin and Merrick (1989)

The first set of analyses based on the Loughlin and Merrick (1989) data set, include sea lion counts and harvest records from 1987 to 1991. The total study period extended from 1976 to 1991. Study area boundaries followed those defined in the original study (Fig. 1, Table 1), although two sites, Marmot Island and Forrester Island, were omitted. The original comparisons of sea lion pup counts with pollock harvest were not repeated.

The Marmot Island time series was used by Loughlin and Merrick (1989) to study the effects of the joint venture (JV; partnerships between domestic catcher boats and foreign processing ships) pollock fishery in Shelikof Strait. However, because the JV fishery did not occur in the area immediately surrounding Marmot Island, the hypothesis of a causal relationship between sea lion counts and pollock catches in the vicinity of Marmot Island could not be tested.

Since there has been no directed pollock fishing near Forrester Island since the early 198Os, we assumed that the relationship between sea lion counts and pollock-harvest in the eastern Gulf of Alaska had not changed since 1988 and the information in Loughlin and Merrick (1989) was still valid. The original data set was also modified to exclude Chowiet Island for 1976 because the datum reported for it was a rough ocular estimate and not a true count.

Sea lion count data were obtained from surveys conducted by the National Marine Fisheries Service (NMFS) and the Alaska Department of Fish and Game. The most recent counts were obtained from aerial surveys conducted in 1987 (NMFS, unpubl. data), 1989 (Loughlin et. al. 1990), 1990 (Merrick et. al. 1991), and 1991 (Merrick et. al. 1992) (Table 2). All counts represent the number of sea lions appearing in aerial photographs of the sites at the time of the surveys; there were no ocular estimates. All surveys except those at Walrus Island were conducted during late June and early July at the peak of breeding season Counts on Walrus Island were. generally conducted in mid-July or early August, beyond the optimal survey time frame, but they are probably still representative (Richard Merrick, NMML, pers, comm.).

Pollock catch data from 1976 to 1986 were obtained from Loughlin and Merrick (1989). To estimate study area pollock catches for 1987-91, data from three sources were used. The first source was the data collected by observers aboard foreign, JV and domestic vessels, which include amount of pollock caught and latitude and longitude of hauls sampled.

The second source of information was the Pacific Fisheries

Information Network (PacFIN[1]), from which the pollock catch in each International North Pacific Fisheries Commission (INPFC) statistical area was obtained. Study areas were located in three INPFC areas. Because of a lack of observer coverage aboard domestic vessels that delivered pollock to shore-side processing plants in 1987 to 1989, catch estimates were supplemented by data filed by shore-side processors. Study area catch estimates, C, for 1987 to 1991 were made by adjusting the observed catch in each study area by the ratio of the total to observed catches in the surrounding INPFC area:

$$C = [O_F * (T_F/I_F)] + [O_D * (T_D/I_D)] + P,$$

where O_F and O_D are the observed pollock catches in each study area by foreign/JV and domestic components, respectively; I_F and I_D are the observed pollock catches by foreign/JV and domestic components, respectively, in the three INPFC statistical areas in which the study areas were located; T_F and T_D are total pollock catches in the INPFC statistical area by each fishery component; and P is the pollock catch reported by domestic shore-side processors for appropriate ½° latitude by 1° longitude blocks for each study area. The estimated pollock catches from 1976 to 1991 in each study area are listed in Table 3.

[1]PacFIN is maintained by the Pacific States Marine Fisheries Commission, 7600 Sand Point Way, N.E., Seattle, WA 98115

Comparisons of Sea Lion Counts from 13 Study Areas to Pollock Harvest

The second set of comparisons examined pollock harvest and sea lion abundance for 13 study areas encompassing 20 nmi radii around major rookeries rather than a 60 nmi or 120 nmi blocks (Fig. 2). Smaller and more numerous study areas were created to provide finer resolution comparisons. A distance of twenty nautical miles was chosen to define the study areas because this is approximately the maximum distance travelled away from the rookery by satellite-tagged post-partum female sea lions in summer (Merrick et al., 1994). A distance of 20 nmi also corresponds to the size of the eastern Aleutian Islands and Seguam Pass trawl exclusion zones currently enacted as a sea lion conservation measure during the BSAI Region pollock roe fishery.

Sea lion counts for each area were obtained from the same survey sources used by Loughlin and Merrick (1989) (Table 4). Catches of pollock (C) within 20 nmi of the 13 study areas (Table 5) were estimated as:

$$C = [O_F * (A_{FT}/O_{FT})] + [O_D * (A_{DT}/O_{DT})],$$

where O_F and O_D are totals of observed foreign/JV and domestic pollock catches in each of the 13 study areas, respectively; A_{FT} and A_{DT} are actual totals of foreign/JV and domestic pollock catches in the GOA or BSAI Regions (as appropriate for each study area); and O_{FT} and O_{DT} are total observed foreign/JV and domestic pollock catches in the GOA or BSAI Regions (as appropriate for each study area). This was then compared to sea lion abundance for each rookery or rookery group. There were two study areas (UAA=Ugamak, Akun and Akutan and OA=Ogchul and Adugak) which straddled both North Pacific Fishery Management Council (NPMFC) districts (GOA and BSAI). In these two cases, estimates of actual catch were summed across districts.

Analytical Approach

Direct comparisons of data collected within the same year were conducted (lag year 0), along with correlations of sea lion counts with pollock harvests 1 to 5 years previous. We calculated correlation coefficients (r) using a linear model and tested for significance using a 2-tailed null hypotheses (a=0.05). Kendall's rank correlation coefficients were also calculated and tested for significance using a 2-tailed null hypothesis (a=0.05)

In the update of Loughlin and Merrick's (1989) analyses, adding three new years of sea lion counts increased the total number of observations per correlation analysis in lag years 0 and 1. However, no net increase was achieved in lag comparisons 2 - 5 where no pollock harvest data for years prior to 1977 were available to pair with the first years of sea lion data in the time series.. Consequently, as lag years increase, the number of observations per correlation run decreases (to a minimum of 4), and the relationship is more dependent on data collected since 1985, particularly 1989 to 1991.

RESULTS.

Update of Loughlin and Merrick (1989)

Four parametric comparisons provided significant correlations; 2 were positive and 2 were negative (Table 6). The significant negative correlations occurredin lag years 2 and 3 at Seguam Island. The two significant positive correlations occurred in lag years 3 and 4 at Chowiet/Chirikof Islands.

Three non-parametric comparisons provided significant negative correlations (Table 7). All were at Bogoslof Island, lag years 0, 1 and 5.

Comparisons of Sea Lion Counts from 13 Study Areas to Pollock Harvest

In the parametric tests, ten significant correlations were detected; 2 were negative and 8 were positive (Table 8). The significant negative correlations were detected at Sea Lion Rocks (lags 4 and 5). The significant positive correlations were found at Chowiet (lag 4), Chirikof (lags 0, 2, and 4), in the Atkins/Chernabura area (lag 3), the Ogchul/Adugak area (lags 3 and 5), and the Gramp/Tag/Ulak area (lag 4).

Using the non-parametric tests, 3 significant correlations were detected; 2 were negative and 1 was positive (Table 9). The negative correlations were found at Sea lion Rocks (lag 4) and Bogoslof Island (lag 0); the positive correlation at Atkins and Chernabura (lag 3).

DISCUSSION

With the exception of the significant negative correlation at Sea Lion Rocks (lag 4) and the significant positive correlation at Atkins and Chernabura (lag 39, the non-parametric test series indicates that the relationship between sea lion abundance and pollock harvest data sets detected using the parametric approach can not be confirmed using a more conservative, and perhaps more applicable test. We also emphasize, however, that even the parametric analyses resulted in far more nonsignificant correlations than significant ones and consistent patterns were elusive. The nature of the variables themselves, ranging over several orders of magnitude, and the very low sample sizes ultimately limit their utility in examining possible relationships between commercial pollock fisheries **and** the Steller sea lion decline. Furthermore, other synergistic effects such as changes in oceanographic conditions or fish community structure complicate the issue and reduce the likelihood of firm conclusions in this kind of analysis.

Too few significant correlations were detected using the non-parametric tests to exclude explanation by random chance alone. However, since the few significant results were both positive and negative, a limited interpretation of the direction of significance is useful, particularly if better, more complete data sets can be compared using these approaches in the future.

Interpretation of Positive Correlations

Loughlin and Merrick (1989) did not offer a biological rationale for the occurrence of significant positive correlations since they were focusing on pollock harvest as a possible negative impact on sea lion abundance. They did suggest that inconsistencies in the sign of correlations across lag years at a given site may have been an artifact of the study time frame. The largest sea lion declines occurred prior to 1976; when those data were paired with pollock harvest, which also diminished through the mid-1970's, positive correlations resulted.

We suggest that significant positive correlations may indicate circumstances where pollock harvest paralleled pollock abundance and that the available pollock biomass satisfied both harvest and sea lion needs. However, we can not explain significant positive correlations in direct comparisons (lag 0) lacking evidence to suggest that adult and juvenile sea lion survival is directly effected by pollock abundance in the same year or that pollock harvest directly benefits sea lions in any way.

The results of modelling (e.g., York 1994; Pascual and Adkison, 1994) and field studies (e.g., Castellini et al. 1993; Richard Merrick, NMML, unpubl. data) suggest that an increase in mortality of weaned pups and juveniles is the most likely proximate cause of sea lion declines. This implies that a correlations between harvest data and sea lion data (positive or negative) are more likely to surface in lagged comparisons, particularly at 3-5 years.

Interpretation of Negative Correlations

Loughlin and Merrick (1989) viewed the effect of pollock harvest as the removal of prey otherwise available for sea lions, but noted-that they would have preferred to compare sea lion abundance to a measure of pollock biomass remaining after harvest. Such a measure still does not exist. However, we suggest that significant negative correlations using the harvest statistic are informative in that they may indicate circumstances where pollock biomass was adequate to meet the needs of the fishery, but not sea lions. Alternatively, other factors such as vessel disturbance or coincidental environmental processes could have impacted sea lion abundance independent of pollock biomass. Even so, we can not rule out the possibility that developments in fishing technology (e.g. hydroacoustics, and net design and construction) and increases in numbers of vessels may have enabled fishermen to sustain catches even as the target stock declined in the local area fished (Laevastu and Favorite 1988; Angelsen and Olsen 1986). Where pollock biomass may have been low to begin with and/or where harvests were exceptionally efficient, the result could have been localized depletions that ultimately impacted sea lion survival. These circumstances would explain significant negative correlations in lagged comparisons.

Negative correlations in direct comparisons can not be explained in the same way. If a large, direct reduction of sea lions occurred prior to the counts (e.g., high incidental takes early in the year), lag 0 could be explained, but such is not the case, Incidental takes did occur in the study period, but they were not high enough nor consistent from year to year to appear as a factor in sea lion counts (Perez and Loughlin 1991). Therefore, we can not determine a biological explanation for them.

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CITATIONS

Angelsen, K. K., and S. Olsen. 1986. Impacts of fish density and effort level on efficiency of fishing gear, p. 437-445. In M. Alton (compiler), A workshop on comparative biology, assessment, and management of gadoids from the North Pacific and Atlantic Oceans, 24-28 June 1985, Alaska Fisheries Science Center, NMFS, 7600 Sand Point Way, N.E., Seattle, WA 98115.

Braham, H. W., R. D. Everitt, and D. J. Rugh. 1980, Northern sea lion population decline in the eastern Aleutian Islands. J. Wild. Manage. 44:25-33.

Castellini, M. A., R. W. Davis, and T. R. Loughlin. 1993. The health status of Steller sea lion pups in the Gulf of Alaska: Blood chemistry and body condition. Mar. Mammal Sci. 9:202-208.

Laevastu, T., and F. Favorite. 1988. Fishing and Stock Fluctuations. Fishing News Books, Ltd., Farnham, Surrey, England. 239 p.

Loughlin, T. R., A. S. Perlov, and V. A. Vladimirov. 1990. Survey of northern sea lions (*Eumetopias jubatus*) in the Gulf of Alaska and Aleutian Islands during June 1989. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-176, 26 p.

Loughlin, T. R., and R. L. Merrick. 1989. Comparison of commercial harvest of walleye pollock and northern sea lion abundance in the Bering Sea and Gulf of Alaska, p. 679-699. In L. Lowery (ed.), Proc. Int. Symp. Mgmt. Walleye Pollock, Alaska Sea Grant Rept. No. 89-1, Univ. Alaska, Anchorage AK.

Lowry, L. F. 1982 . Documentation and assessment of marine mammal-fishery interactions in the Bering Sea, p. 300-311. In Kenneth Sobol (ea.), Transactions of the Forty-seventh North American Wildlife and Natural Resources Conference, Wildlife Management Institute, Washington, D.C.

Megrey, B. A., and V. G. Wespestad. 1990. Alaskan groundfish resources: 10 years of management under the Magnuson Fishery Conservation and Management Act. North Amer. Jour. Fish. Manage. 10:125-143.

Merrick, R. L., T. R. Loughlin, and D. G. Calkins. 1987. Decline in abundance of the northern sea lion, Eumetopias jubatus, in Alaska, 1956-86. Fish. Bull., U.S. 85:351-365.

Merrick, R. L., L. M. Ferm, R. D. Everitt, R. R. Ream, and L. A. Lessard. 1991. Aerial and ship-based surveys of northern sea lions (Eumetopias jubatus) in the Gulf of Alaska and Aleutian Islands during June and July 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-196, 34 p.

Merrick, R. L., D. G. Calkins, and D. C. McAllister. 1992. Aerial and ship-based surveys of Steller sea lions (Eumetopias jubatus) in Southeast Alaska, the Gulf of Alaska, and Aleutian Islands during June and July 1991. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-1, 41 p.

Merrick, R. L., T. R. Loughlin, G. A. Antonelis, and R. Hill. 1994. Use of satellite-linked telemetry to study Steller sea lion and northern fur seal foraging. Polar Research 13:105-114, Pascual, M. A., and M. D. Adkison. 1994. The decline of northern sea lion populations: Demography, harvest, or environment. Ecological Applications 4:393-403.

Perez, M. A., and T. R. Loughlin. 1991. Incidental catch of marine **mammals** by foreign and joint venture trawl vessels in the U.S. EEZ of the North Pacific, 1973-88. U.S. Dep. Commer., NOAA Tech Report NMFS-104, 57 p.

York, A. E. 1994. Population dynamics of northern sea lions, 1975-1985. Mar. Mammal Sci. 10:31-37.

Table 1. Definition of 5 study areas used to estimate catches of pollock modeled after areas in Loughlin and Merrick 1989.

Study Area	Longitude from	to	Latitude from	to	INPFC Area
Seguam I.	171°W	173°W	52°00'N	53°00'N	54
Bogoslof I.	167°	169°	53°30'	54°30'	51
Walrus I.	168°	170°	56°00'	57°00'	51
Ugamak I.	165°	167°	54°00'	55°00'	51
Chirikof I.	154°	158°	55°00'	57°00'	62

Table 2. Sea lion counts from 1976 to 1991 for 5 study areas modeled after areas in Loughlin and Merrick 1989.

Year	Seguam Island	Bogoslof Island	Walrus Island	Ugamak Island	Chirikof/Chowiet Islands
1976		3,308			
1977		2,238	1,093	5,409	
1978					8,118
1979	7,349	1,468	1,996	1,321	9,640
1980					
1981			880		
1982	3,700		800		
1983			500		
1984		1,379		1,252	
1985	3,600	1,287		1,429	4,405
1986					
1987			114		
1988					
1989	709	682		450	2,015
1990	1,014	713		915	1,958
1991	845	558	50	1,025	1,662

Table 3. Estimated catches of walleye pollock (in metric tons) in each study areas listed in Table 1.

Year	Seguam Island	Bogoslof Island	Walrus Island	Ugamak Island	Chirikof Island
1976	82	241	28,507	191,618	5,895
1977	1,718	133	19,654	107,159	8,238
1978	1,257	159	22,224	95,891	12,769
1979	1,634	250	15,904	97,927	21,050
1980	15,853	262	30,549	114,181	20,809
1981	11,183	1,499	20,660	149,717	14,922
1982	18,613	710	14,440	142,980	2,886
1983	5,067	1,223	36,549	150,119	27,553
1984	25,322	834	24,360	133,358	37,641
1985	12,962	288	23,835	166,241	5,752
1986	17,639	19,863	124,114	71,297	0
1987	22,297	175,391	219,379	143,344	46
1988	20,403	114,903	29,962	397,006	2,105
1989	14,554	9,178	102,580	345,986	21,583
1990	47,590	75,710	119,443	197,800	1,082
1991	1,495	68,341	49,192	226,074	1,586

Table 4. Sea lion counts from 1977 to 1991 for the following 15 study areas surrounding rookeries from the Barren Islands to the western Aleutian Islands: SM=Sugarloaf and Marmot; CHT=Chowiet; CHF=ChirFkof; AC=Atkins and Chernabura; PC=Pinnacle and Clubbing Rocks; SLR=Sea Lion Rocks (near Amak Island); UAA=Ugamak, Akun and Akutan; BO=Bogoslof; OA=Ogchul and Adugak; Y=Yunaska; SA=Seguam and Agligadak; K=Kasatochi; GTU=Gramp Rock, Tag and Ulak (Delarof Islands).

Year	SM	CHT	CHF	AC	PC	SLR	UAA	BO	OA	Y	SA	K	GTU
1977						2,130	9,239	2,238	2,972				
1978	13,316	4,419	3,699	6,701	6,355								
1979	10,755	4,441	5,199	6,504	3,893			1,468					
1980													
1981													
1982													
1983													
1984								1,379					
1985	7,974	2,059	2,346	2,049	2,839	538	3,207	1,287	1,502	1,071	3,456	1,170	4,963
1986													
1987													
1988													
1989	4,192	737	1,278	1,299	2,222	344	1,178	682	609	466	734	659	2,460
1990	3,085	897	946	1,170	2,326	286	1,828	713	590	391	1,108	641	2,514
1991	2,675	716	770	1,266	1,969	300	2,037	558	624	398	915	466	2,259

Table 5. Estimated catches of walleye pollock (metric tons) within 20 nmi of each of the following study areas or rookery groups: SM=Sugarloaf and Marmot; CHT=Chowiet; CHF=Chirikof; AC=Atkins and Chernabura; PC=Pinnacle and Clubbing Rocks; SLR=Sea Lion Rocks (near Amak Island); UAA=Ugamak, Akun and Akutan; BO=Bogoslof; OA=Ogchul and Adugak; Y=Yunaska; SA=Seguam and Agligadak; K=Kasatochi; GTU=Gramp Rock, Tag and Ulak (Delarof Islands).

Year	SM	CHT	CHF	AC	PC	SLR	UAA	BO	OA	Y	SA	K	GTU
1977	0	0	1,527	71	0	0	1,933	0	799	0	0	0	0
1978	0	0	1,012	453	0	0	3,254	0	30	514	17	0	1
1979	77	0	2,095	1,201	0	0	4,603	0	1,048	1	6	0	16
1980	0	7	89	401	1,276	0	3,932	0	4,033	60	3	0	0
1981	0	176	1,466	1,901	0	225	23,041	0	163	887	3	0	87
1982	0	0	61	2,493	1,987	0	25,595	0	1,444	554	733	0	0
1983	111	0	529	287	286	43	31,129	62	559	669	3,263	0	0
1984	60	335	1,013	472	34	3,067	23,625	22	219	1,619	6,888	0	0
1985	82	32	541	1,177	7	3,054	28,641	0	29	575	5,856	0	0
1986	0	0	0	82	14	4,186	22,436	7,842	0	827	15,422	0	0
1987	4	0	0	0	0	4,155	17,813	81,074	163	0	28,289	4	4
1988	126	0	17	47	1,022	7,525	10,092	48,905	31	8,221	13,342	0	18
1989	8,135	0	0	0	0	2,025	101,266	1,036	937	2	10,015	72	37
1990	6,556	146	436	228	299	7,127	103,198	20,215	21,603	9,608	25,495	151	8,690
1991	1,197	3	66	1,190	278	1,265	103,527	23,085	47,973	20	1,260	9	268

Table 6. Correlation coefficients (r) for Steller sea lion counts and 0 to 5 year lags of pollock harvest for 5 study areas modeled after Loughlin and Merrick 1989. Significant correlations (a=0.05) are marked with an asterisk. Ch/Ch stands for Chowiet and Chirikof Islands.

	Lag Year					
	0	1	2	3	4	5
Ugamak	-.540	-.273	-.241	+.238	-.181	-.379
Seguam	-.413	-.655	-.850*	-.824*	-.787	-.676
Bog	-.584	-.645	-.626	-.731	-.584	-.554
Walrus	-.552	-.691	-.494	-.043	-.663	-.541
Ch/Ch	+.525	+.073	-.074	+.918*	+.945*	+.274

Table 7. Kendall's coefficients of rank correlation (t) between Steller sea 'lion counts and 0 to 5 year lags of pollock harvests for 5 study areas modeled after Loughlin and Merrick 1989. Significant correlations (a=0.05) are marked with an asterisk. Ch/Ch stands for Chowiet and Chirikof islands.

	Lag Year					
	0	1	2	3	4	5
Ugamak	-.619	-.619	-.333	+.200	000	-.200
Seguam	-.067	-.600	-.600	-.467	-.600	-.800
Bog	-.714*	-.714*	-.733	-.600	-.600	-1.00
Walrus	-.619	-.238	-.600	-.200	-.663	000
Ch/Ch	+.467	+.333	-.067	+.400	+.667	+.667

Table 8. Correlation coefficients (r) between Steller sea lion counts at 15 rookery sites and 0-5 year lags of pollock harvest within 20 nmi of each site. Significant correlations (cx=0.05) are marked with an asterisk.

Rookery or Rookery Group	Lag Year 0	1	2	3	4	5
Sugarloaf and Marmot	-.658	-.723	-.494	-.518	-.109	-.434
Chowiet	-.388	-.218	-----	-----	+.967*	-.411
Chirikof	+.956*	+.762	+.997*	+.891	+.982*	-.263
Atkins and Chernabura	+.216	+.255	+.100	+.994*	+.854	-.298
Pinnacle and Clubbing	-.524	-.435	-.205	+.589	-.130	+.912
Sea Lion Rocks	-.571	-.296	-.744	-.869	-.996*	-.951*
Ugamak, Akun and Akutan	-.865	-.065	+.141	+.293	-.415	-.862
Bogoslof	-.620	-.513	-.399	-.576	-.552	-.518
Ogchul and Adugak	-.511	-.320	+.249	+.992*	+.594	+.998*
Yunaska	-.335	-.410	-.314	-.348	+.528	-.655
Seguam and Agligadak	-.229	-.594	-.723	-.748	-.627	-.742
Kasatochi	-.344	-.719	-.608	-.204	-.589	-----
Gramp Rock, Tag and Ulak	-.296	-.414	-.689	-.501	+.992*	-----

Table 9. Kendall's coefficients of rank correlation (ɪ) between Steller sea lion counts at 15 rookery sites and 0 to 5 year lags of pollock harvest within 20 nmi of each site. Significant correlations (a=0.05) are marked with an asterisk.

Rookery or Rookery Group	Lag Year 0	1	2	3	4	5
Sugarloaf and Marmot	-.600	-.828	-.800	-.913	-.183	-.183
Chowiet	-.298	-.258	-----	-----	+.548	0
Chirikof	+.733	+.467	+.738	+.183	+.913	-.333
Atkins and Chernabura	+.200	+.333	+.316	+1.00*	+.667	-.333
Pinnacle and Clubbing	-.447	-.596	-.120	0	+.183	+.333
Sea Lion Rocks	-.400	+.333	-.667	-.333	-1.00*	-.333
Ugamak, Akun and Akutan	-.400	+.333	+.333	0	-.333	-.667
Bogoslof	-.720*	-.733	-.690	-.527	-.598	-.837
Ogchul and Adugak	-.400	0	+.667	+.333	+.913	+.333
Yunaska	-.333	0	-.333	0	+.333	0
Seguam and Agligadak	0	-.667	-.667	-.333	-.333	-.667
Kasatochi	-.333	-.913	-.548	-.236	-.707	-----
Gramp Rock, Tag and Ulak	-.333	-.667	-.667	-.548	+.183	-----

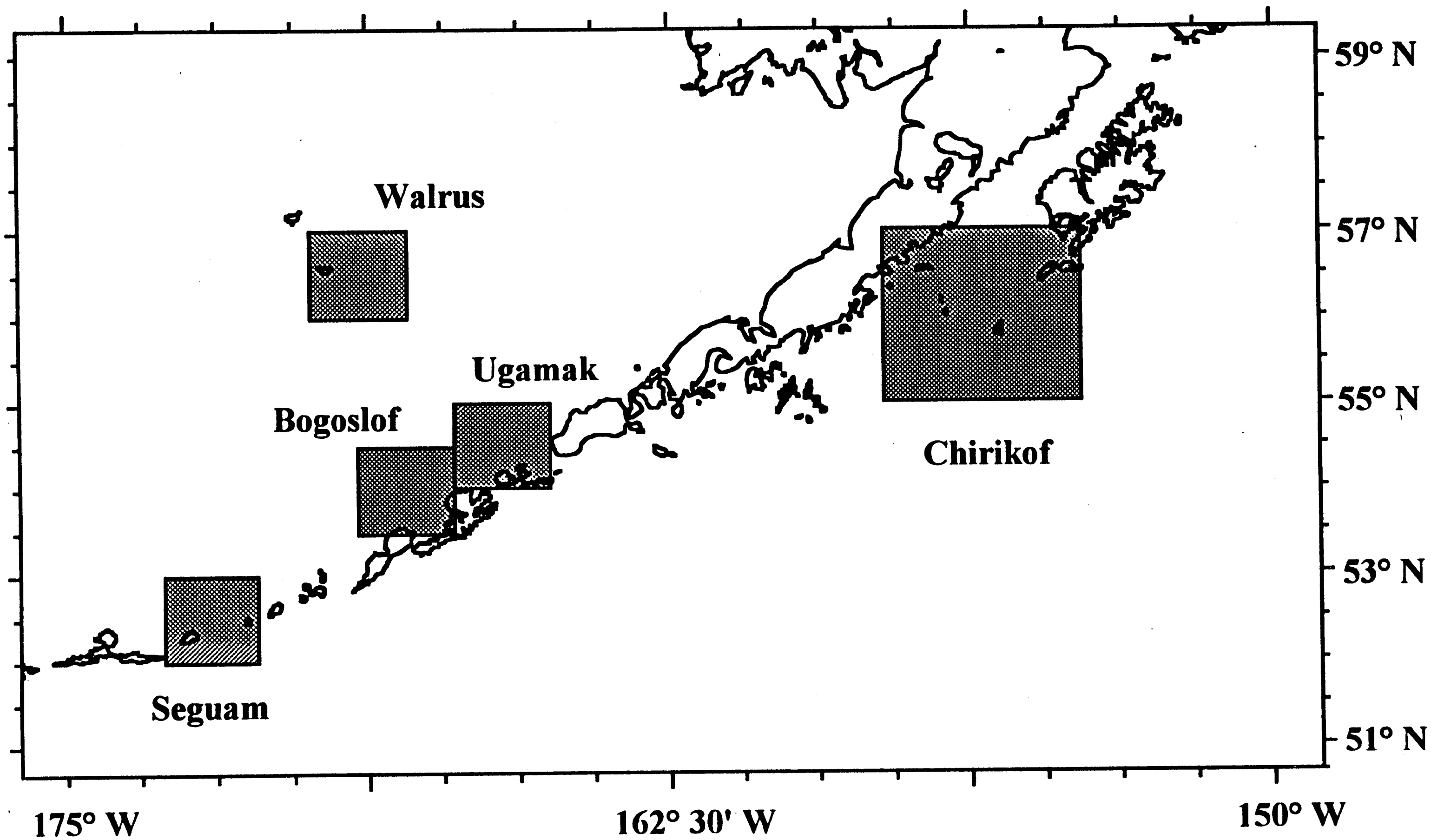

Figure 1. Study areas as defined by Loughlin and Merrick (1989).

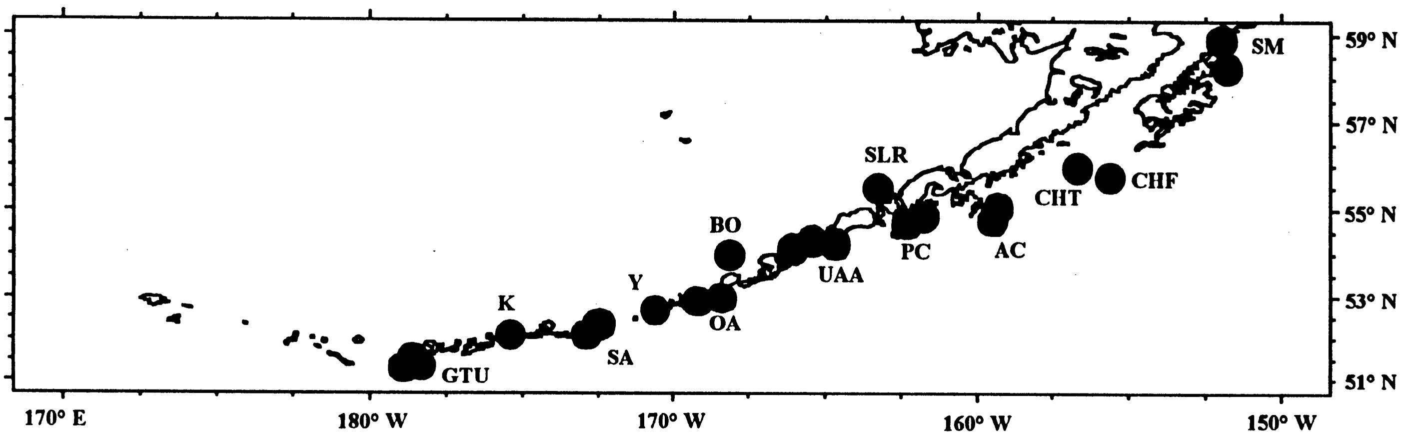

Figure 2. Study areas as defined in this study.

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Walleye pollock Theragra chalcogramma Pallas occupies a central place in ecosystems of the North Pacific and is an important target species of fisheries. The species is characterized by daily vertical, spawning, feeding, and wintering migrations and spawning occurring under the sea ice. Since population structure estimation by the tagging with recapture is inefficient in walleye pollock, the pollock resources are difficult to estimate by conventional methods, requiring population genetic studies with molecular markers.Â Walleye pollock distribution in the western Bering Sea in the periods of foraging and wintering. In: Ekologiya, zapasy i promysel mintaya (Walleye Pollock: Ecology, Stock, and Commercial Fishing). Vladivostok: TINRO, pp. 57â€“62.Google Scholar. Steller sea lion, Eumetopias jubatus, counts made on rookeries in the Gulf of Alaska, Aleutian Islands, and the Bering Sea from 1976 to 1991 were compared to annual estimates of walleye pollock, Theragra chalcogrmma, harvest to examine possible relationships between Steller sea lion abundance and commercial pollock fishing. Comparisons were made between Steller sea lion counts and pollock fishery data from the same year and from 1 to 5 years prior. Two sets of study areas were used, one encompassing 60 nmi or 120 nmi blocks around six major rookeries and another with 13 sites defined by 20 nmi Expected declines in recruitment of walleye pollock (Theragra chalcogramma) in the eastern Bering Sea under future climate change. A multispecies virtual population analysis of the eastern Bering Sea A multispecies virtual population analysis of the eastern Bering Sea.Â A separable catch-age stock assessment model that accommodates predation mortality is applied to the Gulf of Alaska walleye pollock (Theragra chalcogramma) assessment. Three predators are incorporated in the model: arrowtooth flounder (Atheresthes stomias), Pacific halibut (Hippoglossus stenolepis), and Steller sea lion (Eumetopias jubatus). The effect of these predators is examined by defining the predation mortality as a type of fishery.