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Historical Data Review

Synthesis and Analysis Gulf of Alaska of Small-Mesh Trawl Data
1953 to 1997
and Shelikof Strait Forage Fish Icthyoplankton Analysis
1972 to 1992

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Abstract

Large declines of apex predator populations (murres, kittiwakes, harbor seals, and Steller sea lion) have occurred in the Gulf of Alaska since the 1970s. Changes in composition and abundance of forage species may be responsible for the decline of these predator populations and their chronic low population levels. In an effort to delineate changes in forage species and a trophic regime shift, if any, over the last several decades, we have gathered together historical fishery-independent scientific survey data to address this question. This report includes three citations for recently published manuscripts resulting from project-funded studies. Nearly 10,000 individual sampling tows are in the current database of the two agencies. Recent analysis of the 1996 and 1997 trawl survey data has indicated that the fundamental trophic shift in the ecosystem is still in place. No evidence suggests that the shift is reversing itself. Recent results are discussed and future analysis strategy is discussed. There clearly is a need for moving the survey portion of this project into a long-term monitoring program to keep a time series reference intact. Additionally analysis of an icthyoplankton time series that was started during FY97 is presented and discussed.

Introduction

This project pursues analysis of small-mesh trawl sampling results from near-shore surveys in the Gulf of Alaska conducted by the National Marine Fisheries Service (NMFS) and the Alaska Department of Fish and Game (ADF&G). The data for analysis was collected starting in 1953 and continues through 1997. Only general background material concerning this part of the project will be discussed in this section. The reader is referred to the two recently published manuscripts (Anderson et al., 1997 and Bechtol, 1977) for details of the methodology and analysis used with this portion of the data.

Recently there has been information presented that the Gulf of Alaska ecosystem has undergone some abrupt and significant changes (Piatt and Anderson, 1996; Anderson et al., 1997). The extent and degree of these changes are poorly documented and is important in determining future strategies for management of the marine ecosystem. Analysis of the historic data is a first step in gaining an appreciation for the rapid and abrupt changes that have occurred in the marine species complex in the last five decades. The data from small-mesh shrimp trawl cruises provides an opportunity to review changes in the composition of forage species that occurred through time in the Gulf of Alaska.

Historically, there is evidence of major abundance changes in the fish/crustacean community in the western Gulf of Alaska. Fluctuation in Pacific cod availability on a generational scale was reported for coastal Aleutian communities by Turner (1886). Similarly, landings from the near-shore Shumagin Islands cod fishery (Cobb, 1927) showed definite periods of high and low catches with the fishery peaking in late 1870s. King crab commercial catches in the Gulf of Alaska show two major peaks of landings, one in the mid 1960s and another in 1978-1980 (Blau, 1986). All of the area was closed to fishing in response to low population levels in 1983 (Blau, 1986) and has yet to reopen. By the 1960s there was evidence of high Pandalid shrimp abundance in these same areas (Ronholt 1963). One of the highest densities of Pandalid shrimp known in the world was to spur the development of a major shrimp fishery (Anderson and Gaffney, 1977). By the late 1970s the shrimp population density had declined radically and was accompanied by a closure of the shrimp fishery and the return of cod to inshore areas (Albers and Anderson, 1985). Catches of almost all salmon stocks of Alaskan origin suddenly increased to unprecedented levels in the 1980's (Francis and Hare, 1994, Hare and Francis, 1995). These changes, witnessed over the last century, imply dynamic fluctuations in abundance of commercially fished species. Managers, fisherman, and processors should be aware of these dynamics and their impacts on the ecology and economy.

Area of Coverage

The study area includes the continental shelf (0 - 200 m.) and upper slope (201 - 400 m.) from 144° W. longitude (in the vicinity of Kayak Island) westward to 168° W. longitude (vicinity of Unalaska Island, eastern Aleutians). This area is characterized as having a relatively broad shelf, which is punctuated with numerous islands, separated by deep gullies and large inlets, sounds, and fjords. Most of the data was collected in trawlable locations associated with the numerous gullies and bays that are associated with this bathymetry. The study area covers the entire affected zone of the EVOS.

Results From 1996 and 1997 Surveys

Late summer surveys continued in the Pavlof Bay study area in 1996 and 1997. Although this area is outside the EVOS spill zone, it has been the site for the longest annual trawl survey sampling in the entire Gulf of Alaska during the last 26 years. Changes in the trophic structure were first observed in this area which led to expanded analysis of trawl survey data from other areas of the Central and Western Gulf of Alaska. This long-term study has been the impetus toward a better understanding of the degree and magnitude of the trophic shift that has occurred and continuing impacts on the marine ecosystem.

Twenty-two tows were completed each of the past two years in the Pavlof Bay study area. This same survey location has been sampled in the same manner and at the same relative time each year for the past 26 years. It is anticipated that we will again complete this survey again in late summer of 1998, thus keeping this part valuable time series continuous.

Osmerids and Pandalid shrimps continue to remain at historic low levels (Figure 1). Pandalid shrimps are at their lowest levels ever during the entire survey series. Shrimp were recorded at 7.53 and 2.53 kg/km during 1996 and 1997 respectively. Cod and pollock remained the major component of catches in each year averaging 212.89 and 379.66 kg/km in 1996 and 1997 respectively. Pleuronectid fish populations have apparently stabilized, and they averaged 144.45 and 158.21 kg/km for both 1996 and 1997. The high relative abundance of Pacific cod in survey catches (79.39 kg/km in 1996 and 126.18 kg km in 1997) may explain the lower observed shrimp and Osmerid density in 1997. The trend in higher cod abundance and a negative correlation with observed shrimp abundance seems to support the "predator forcing" hypothesis for adult populations of Pandalid shrimps.

Interesting life history table changes are also being observed for shrimp and fish species. Change in sex transformation of Pandalid shrimp in response to density dependant population levels was first reported by Charnov and Anderson, 1989. The recent survey results continue to support the hypothesis first presented in the earlier preliminary analysis. As population levels decline in Pandalid shrimp their sex tranformation from male to female is accelerated. These recent results will lead to important future work not supported by project funding that will improve our understanding of the dynamics of Pandalid shrimp in Alaskan waters.

Icthyoplankton Analysis

Our small-mesh trawls catch most of the species of direct interest to the APEX project except for one critical component, Pacific Sand Lance. We do however capture sand lance larvae in significant numbers during our icthyoplankton surveys, both by bongo and neuston sampling gear. FY97 was the first year we have attempted to quantify the changes in relative density of sand lance larvae. Some of the preliminary analysis of this new aspect of the project is discussed.

Sand lance and capelin which together make up a significant amount of the forage base in the Gulf of Alaska have a high affinity for near-shore sediments for spawning. Potential damage to these critical near-shore habitats could have occurred as a result of the EXXON Valdez oil spill, especially along the fine sediment Katmai coast and sandy beaches on the eastern coast of Kodiak Island. We propose to study the early life history and variation in production before and after the spill of sand lance larvae from NMFS collected icthyoplankton data base. Additional studies will be proposed to fund work on analyzing the capelin portion of this data.

Sand Lance are one of the main prey for marine birds, further, 0+ sand lance are a major component of nestling diet and may indicate a linkage between ocean production and nesting success of seabird colonies (Bertram and Kaiser 1993). We propose to study past abundance and test hypothesis concerning changes in abundance of the early life history of sand lance in the vicinity of Kodiak. We propose to analyze a long-term database (1972 - 1995) of an icthyoplankton collection containing sand lance for the Kodiak and Shelikof region of the Gulf of Alaska to develop hypothesis concerning observed changes in density and distribution. Preliminary analysis will focus on the critical spawning (Oct -Jan) and over wintering (Nov - March) state of sand lance and how it might relate to larval survival and year-class strength.

Methods

Larval sand lance was collected from lower Cook Inlet to Unimak Pass with two types of sampling devices. The neuston layer was sampled using a "Sameoto sampler" (Sameoto and Jaroszyinski, 1969), with an opening of .3m by .5m and a mesh of 0.505mm. The water column from near-bottom to the surface was sampled using a MARMAP bongo sampler (Posgay and Marak, 1980) with 0.6m diameter opening and either 0.333 or 0.505mm mesh nets. Depths and position were recorded for each deployment of the sampling gear. Samples of sand lance and other planktonic species were preserved using 5% formalin-seawater solution buffered with either calcium carbonate or sodium tetraborate. Specimens were separated, counted, and up to 50 individuals of sand lance were measured to the nearest 0.1mm SL (Rugen, 1990).

In order to simplify analysis we selected a sub area which included the Shelikof Strait from just below Barren Islands to the Semidi Islands (Figure 2). We used ARC/INFO mapping software to define this area and then selected all of the samples that were taken in this area over the period 1972-92. Results are presented for this area only.

Results

Out of the sixty-six taxa identified in the neuston samples, *Ammodytes hexapterus* were the fifth most abundant in terms of number caught for all sampling made between April 1972 and May 1986 (1,546 neuston stations sampled). For the bongo samples they were the second most abundant during the same time period (2,414 bongo samples) out of 118 taxa. In the months of March through the early part of May Pacific sand lance were the single most abundant species in bongo samples. This peak abundance of sand lance larvae in the spring samples is also reflected well in the neuston samples where their peak relative abundance was found during the first half of June. Sand lance was absent from neuston samples after August and from bongo samples after June sampling periods.

Large numbers of larvae from bongo samples were spatially located close to Kodiak Island with higher concentrations located to the northeast and southwest of the island in March. This distribution pattern held steady in later time periods except for a tendency of larvae to even out their distribution in Shelikof strait. Larvae captured with neuston nets showed relatively large catches later in the year and were found close to Kodiak Island or above the slope. Lengths of larvae were larger in the neuston tows (9.6-29.7 mm SL) than in the bongo samples (5.4-18.7 mm SL).

The first occurrence of sand lance larvae was seen in the bongos as early as the sampling started (February 17 in 1979). This suggests that sand lance larvae are released into Shelikof Strait before the early part of February and probably much earlier. This early occurrence is well supported by the observations of Blackburn and Anderson, 1997 showing spawning adult fish in the Kodiak region in August through November. Spawning is not synchronous and is probably and adaptation to variable winter and early spring conditions. Variable spawning and transport of larvae and would benefit overall larval survival under changing climatic regimes..

Larvae grew rapidly during their planktonic phase. In 1981 bongo sampling was conducted continuously between March 12 and May 25. Larvae during the first part of March averaged 5.7 mm SL by the end of April they averaged 10.5 mm SL, and by the end of May larvae average 14.3 mm SL in 1981. This observation of growth of larvae fits well with Blackburn and Anderson, 1997 which found Kodiak area fish as small as 20mm SL in July.

Larvae also suffer high mortality rates during their larval phase. Again referring to 1981 where sampling was conducted continuously. Mean density of larvae steadily declined from early March through mid April. In the period from March 14-20 the mean density of larvae was 184.53 per m^2 by March 30- April 8 the density had declined to 121.01 per m^2 and finally by the period April 19-21 the average density had fallen to 89.69 per m^2 . The next sampling period's density estimates were confounded by a new size cohort of larvae entering the population, therefore compairing density estimates for these later periods is not valid when considering mortality. This study clearly indicates the value of collecting size frequency information along with density as an aide to estimating population parameters for larval fish.

Making comparisons among years to determine relative density is also complicated by advection of new larval cohorts into the sampling area. Spawning is not synchronous and therefore larvae are continuously being advected into the Shelikof Strait system from the beginning of the year until early May. Our length samples showed small post emerging larvae (4 to 5 mm SL) showing up in bongo samples as late as the middle of May. A complex model that integrates growth, and density as a function of time is needed to fully explore the variability of larval populations. However a rough estimate of relative year-class strength or density can be derived by looking at the density early occurrence of larvae in samples. We have looked at this for the time period of 1979 through 1992.

Figure 3 shows mean density of larvae per m^2 during all the years. Peak numbers of early larvae occurred in 1989 at a relatively high 153.28 per m^2; in contrast relatively low values were calculated for 1979 and 1986 where 6.82 and 7.08 per m^2. This indicates a high amount of variability in sand lance larval input into Shelikof Strait during the early part of the larval period. Low density values may relate to unfavorable egg survival conditions during the winter or extreme variability in the date of hatch and transport to the sampling area. From 1987-92 there does seem to be a trend toward increased numbers of early larvae in Shelikof Strait (Fig.3). Similarly, looking at relative density of larvae gives you a different feel for relative density (Fig. 4) . The relative high abundance in 1989 of both the late and early occurring larvae means that a significant larval population was available throughout the sampling period. This argues well for a strong year-class of sand lance being produced in the region in 1989.

Discussion

Pacific sand lance are one of the most, important larval fish components of the icthyoplankton around Kodiak Island during the spring period. The only larval fish component that outnumbers sand lance in bongo samples was the walleye pollock, *Theragra chalcogramma*. The analysis of total numbers of larvae captured showed that pollock larvae were nearly 20 times more abundant (233,762) overall than sand lance (13,739). The next most abundant species was *Bathymaster* sp. only accounted for 80 total individuals caught in the 1972-1986 bongo samples.(Rugen, 1990)

Walleye pollock, *Theragra chalcogramma*, are also a locally prominent component of the icthyoplankton during the same period as sand lance larvae and may compete with them for food. Distribution of pollock larvae is concentrated in lower Shelikof strait during the March which is quite different then that of sand lance during the same time period. Also there is indication that as the larvae age and attain a larger size, sand lance are more commonly found in the neuston layer than pollock (Bodeur and Rugen, 1995) which suggests a different vertical distribution in the water column. Therefore it seems likely that sand lance may only be a competitor with pollock during the early spring at only a few localized areas mainly in lower Shelikof strait.

Future Direction of Analysis

1. Determine relative year-class strength of sand lance larvae in study area. Do this by examining larval size data and adjusting for differences in hatch dates and growth between years. A model is needed to integrate density, time, and growth while adjusting for variable advection of larvae into the system throughout the sampling period.

2. Compare density estimates from neuston samples with those of the same year set for bongo sampling to investigate the feasibility of determining a relative survival index among year-classes.

3. Examin the competion hypothesis by compairing relative density of pollock and sand lance larvae and see if there is a negative or positive correlation between abundance levels. This data is not available in the data set we are analizing.

Figures

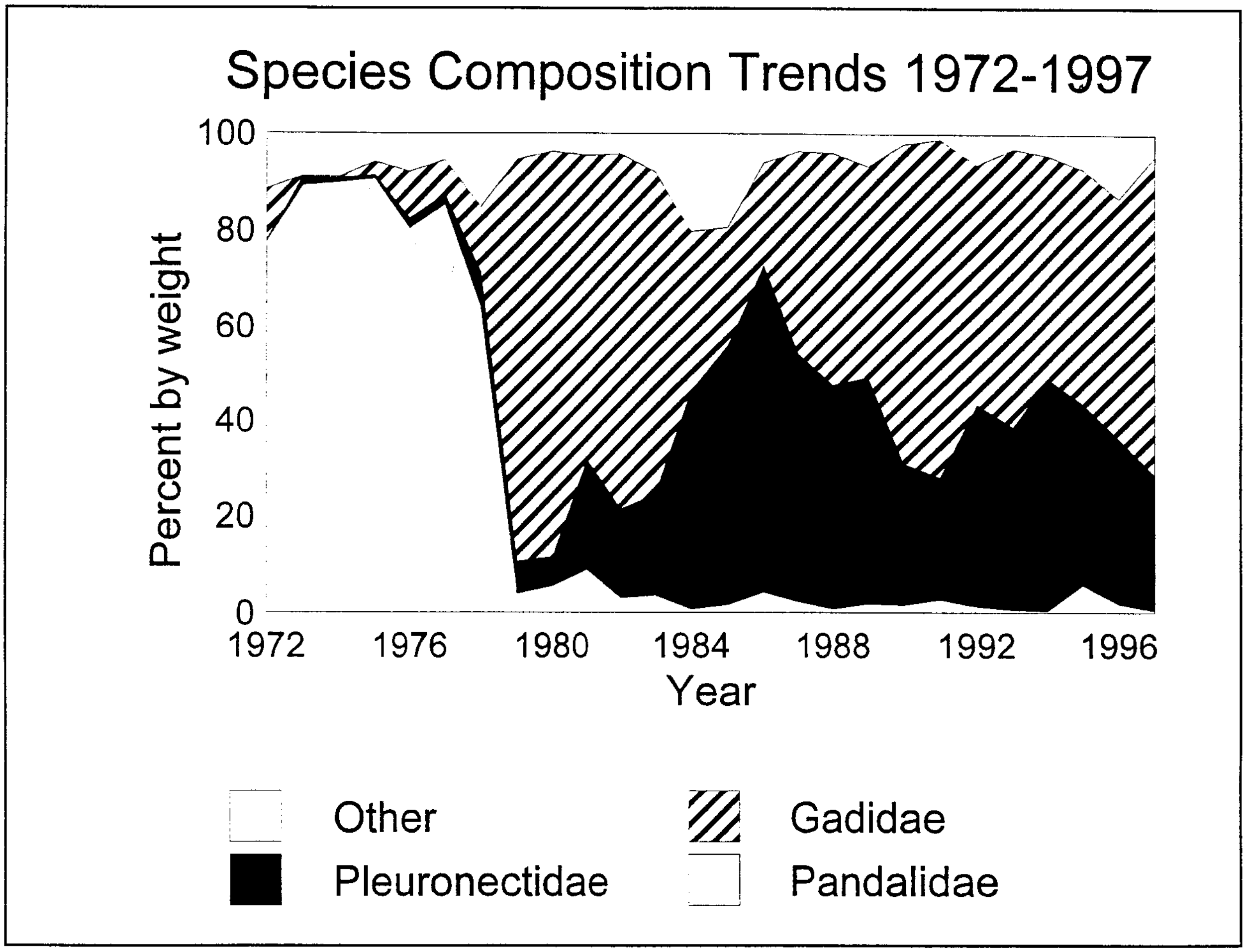

Figure 1. Percent species composition from annual small-mesh survey sampling from 1972 to 1997 in Pavlof Bay only by NMFS. All tows late summer or early fall.

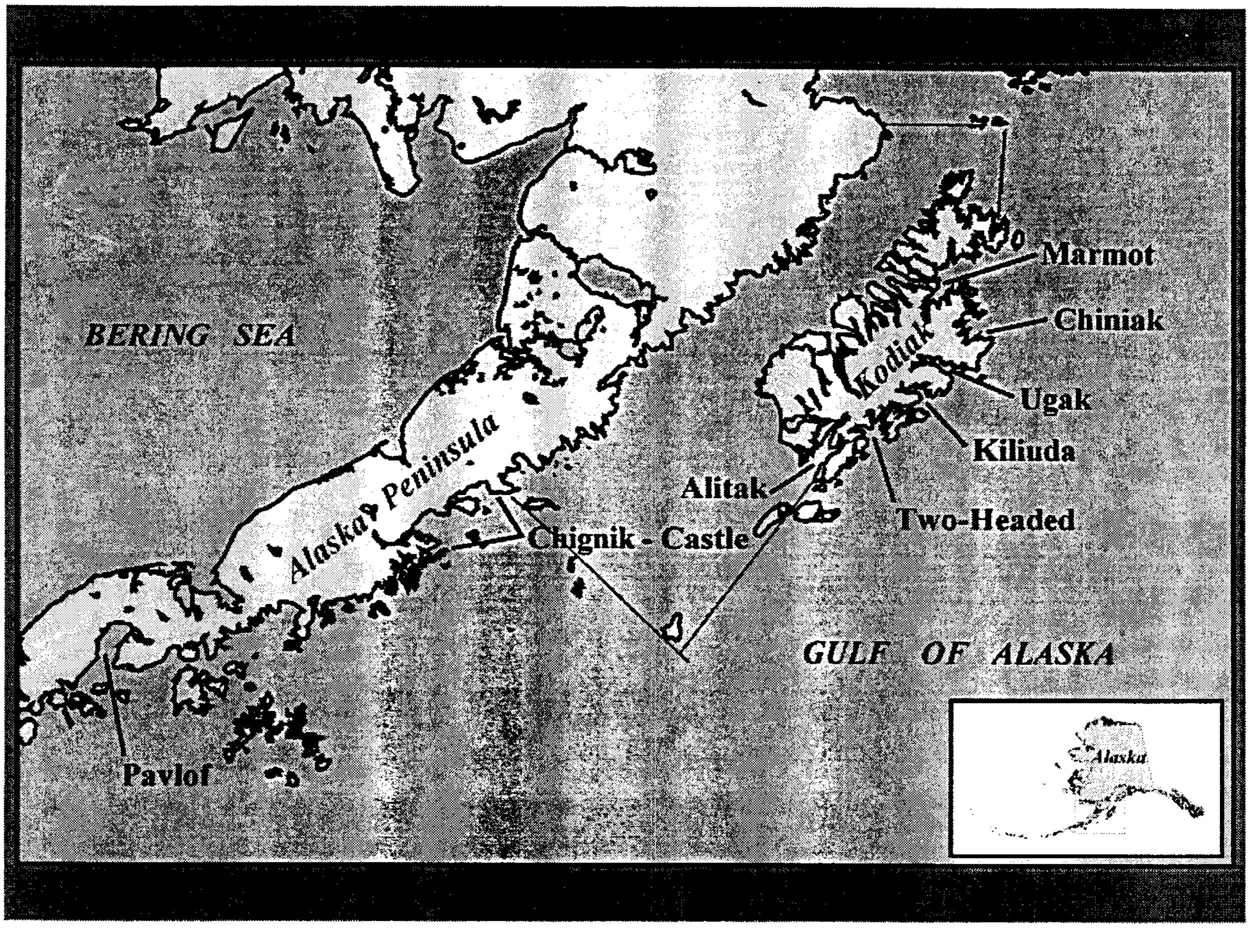

Figure 2. Pacific sand lance larvae study area in the Kodiak - Shelikof Strait region 1971 - 1992. Other project study areas are shown in relation to the area selected for icthyoplankton analysis.

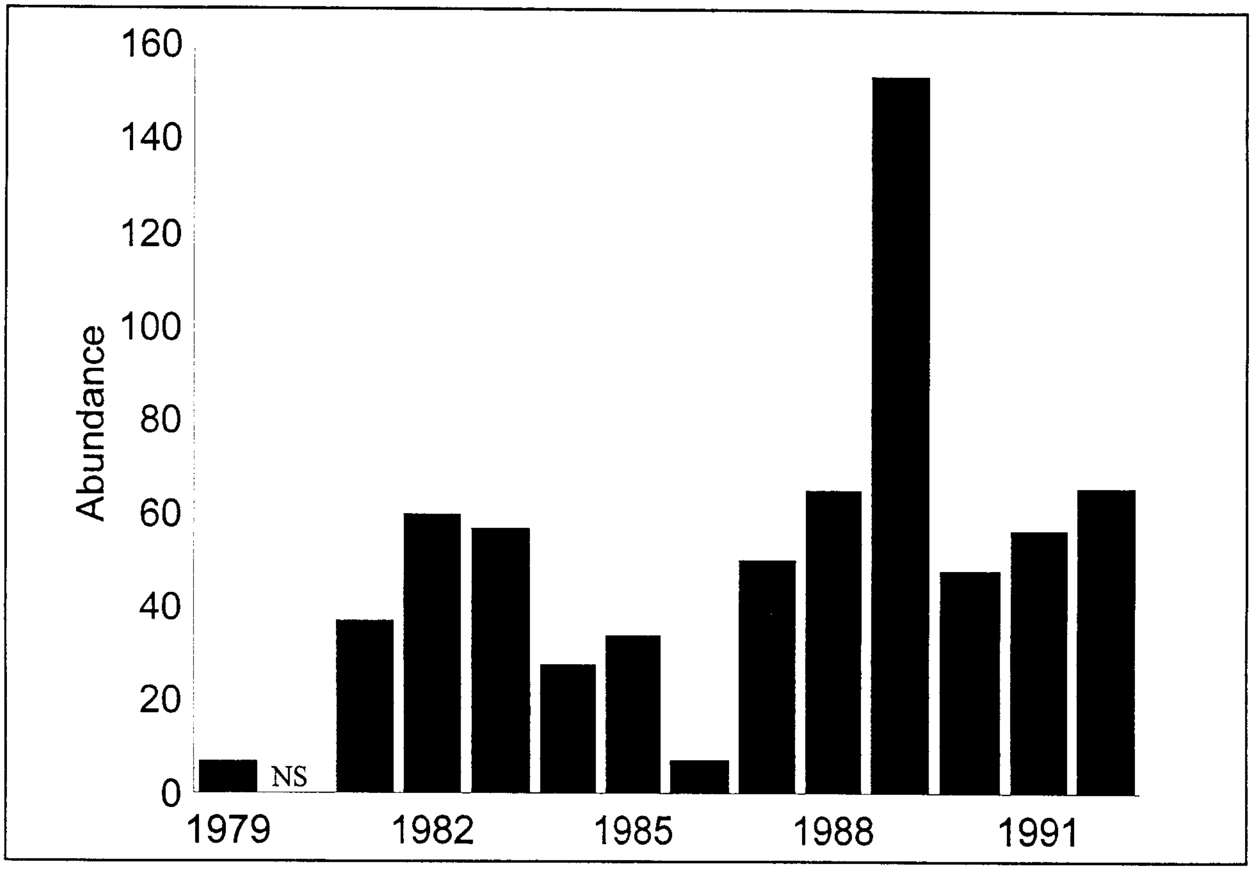

Figure 3. Relative density of early occurring sand lance larvae in the Shelikof Strait study area. No sample in 1980; density in numbers per meter squared.

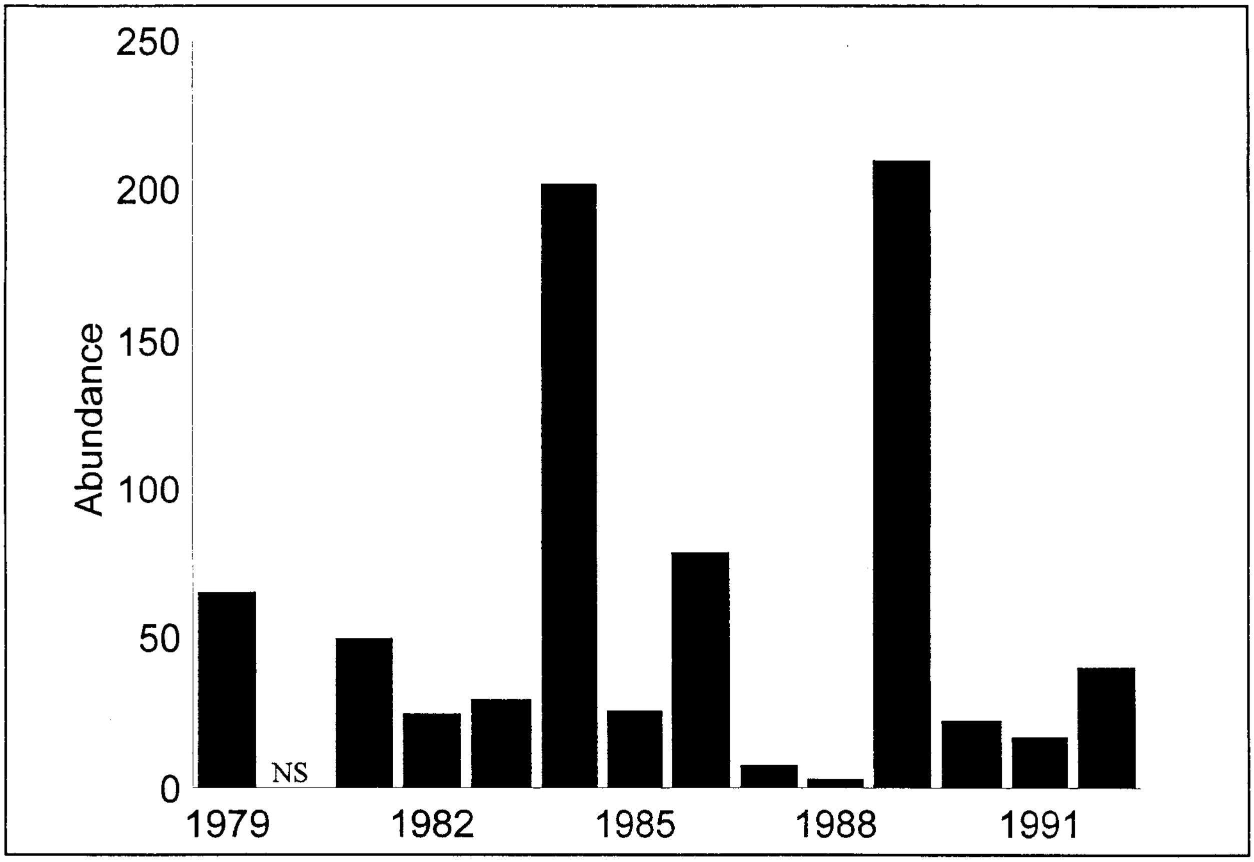

Figure 4. Late occurring sand lance larvae in Shelikof Strait bongo samples 1979-92. Density in numbers per meter squared.

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