APPENDIX L

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SYNTHESIS AND ANALYSIS OF GULF OF ALASKA SMALL-MESH TRAWL DATA: 1953 to 1995

Paul J. Anderson[1]
James E. Blackburn[2]
William R. Bechtol[3]
and
B. Alan Johnson[1]

[1] **National Marine Fisheries Service**
Alaska Fisheries Science Center
P.O. Box 1638
Kodiak, Alaska 99615

[2] **Alaska Department of Fish and Game**
211 Mission Road
Kodiak, Alaska 99615

[3] **Alaska Department of Fish and Game**
3298 Douglas Street
Homer, Alaska 99603

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 the composition and abundance of forage species may be responsible for the decline of these predator populations. In an effort to delineate changes in the trophic regime and forage species, if any, over the last several decades, we have gathered together scientific survey data covering a long time span and large area. This report includes a preliminary historical review of information and data from small–meshed trawl studies conducted in the Gulf of Alaska by the Alaska Department of Fish and Game and the National Marine Fisheries Service and its predecessor agencies from 1953 through 1995. Over 10,000 individual sampling tows are in the current database of the two agencies (ADF&G — 5,836; NMFS — 4,352). For preliminary analysis, the entire region sampled was divided into six sub–areas representing geographical, oceanographic, and biological domains. Where possible, the occurrence and relative abundance of five major species or species groups was studied to detect change in the forage ecosystem over the four decades of past sampling with small–mesh trawls and beam trawls.

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INTRODUCTION

This report provides a historical review 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 to 1995. In this report we discuss the methodology of data collection and how it changed through the years. The nature of the survey areas are discussed. A preliminary analysis is presented along with discussion of analytical procedures and assumptions.

Recently there has been information presented that the Gulf of Alaska ecosystem has undergone some abrupt and significant changes (Piatt and Anderson, 1995). The extent and degree of these changes is 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. Fluctuations 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, 1985). 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.

Evidence from long–term small–mesh trawl surveys in the Gulf of Alaska imply that a number of non–commercial species also have undergone significant change in abundance during the past 25 years. Major groups of species nearly disappeared or have become virtuallyextinct in some areas and demonstrate that huge changes have occurred in the near–bottom species complex. The abrupt decline of species that have never been commercially harvested in the Gulf of Alaska such as capelin, Pacific sandfish, and certain species of Lumpenella suggest that fishing pressure is not entirely to blame for the changes which have occurred. Based on the results obtained from the longest continually conducted trawl survey series (Piatt and Anderson, 1995) have lead to the recognition that the entire small–mesh trawl survey data collected as far back as possible be used to put a historical perspective on these changes and give direction to future research. With these ideas in mind, we have assembled and are continuing to assemble, data from small–mesh surveys in order to help understand the ecological dynamics of this abrupt change in the ecosystem.

Area of Coverage

The study area includes the continental shelf (0 – 200 m.) and upper slope (201 – 400 m.) from 144^0 W. longitude (in the vicinity of Kayak Island) westward to 168^0 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 gullys and bays that are associated with this bathymetry.

The area of coverage for the entire historical data set was divided into regions based on three guiding principles. First, areas within geographic proximity were included as groups taking into account the sampling coverage through the time series. If gaps in sampling were evident in geographic plots of the data then these were frequently used as rational for dividing the area. Second, general knowledge of the biological regimes in each area were also used as guides when defining areas for analysis. Third, oceanographic domains were used when knowledge of these domains was known. Based on the above principles the entire area covered was divided into 6 regions (Figure 1) for analysis of time series data. A description of each of the sub–areas follows.

1. Prince William Sound — Includes area west from Kayak Island to the vicinity of Cape Puget and includes all offshore sampling on the adjacent shelf area. A prominent gully intersects the shelf running from the head of Prince William Sound between Montague and Hinchinbrook Islands. A large reef area, Wessels Reef is located between Hinchinbrook and Middleton Islands. Bottom sediments in the area include soft mud, firm mud, mud with boulders, gravel and rock. Because large portions of the survey area are covered with rocky substrate, much of the area is unsuitable for sampling by trawls.

2. Kenai — Includes the region along the outer Kenai coast from the vicinity of Port Graham north and east along the coast to vicinity of Cape Puget. This area is influenced by Alaska CoastalCurrent (Reed and Shumacher, 1986). This area is also characterized by rocky areas which hinder trawl sampling in some areas.

3. Lower Cook Inlet — Includes areas north of Cape Douglas north of the a line drawn beneath the Barren Islands and intersecting with the coast near Chugach Passage. This area includes all waters of Kachemak and Kamishak Bays. This area has extremely limited flow of northern Gulf water into lower Cook Inlet (Hood and Zimmerman, 1986).

4. Kodiak — Includes all of the bays along the eastern side of the Kodiak Island group to south of the Barren Islands. This area is characterized by wind driven oceanic regime and under the direct influence of the Alaska Stream (Favorite et al., 1976).

5. Shelikof— The Shelikof region includes all waters north of Castle Cape and a line drawn to Chirikof Island and thence a line drawn to the southern tip of Tugidak Island in Trinity Island group. The region includes the bays along the western side of Kodiak Island including Alitak, Uganik, and Uyak Bays. The region also includes the bays from Chignik northeast along the Alaska Peninsula to Cape Douglas. The major oceanic feature in this area is the extreme tidal flow out of Cook Inlet and the strong winds that blow up and down the strait.

6. Shumagin — The Shumagin region encompasses the area from Unimak Island in the eastern Aleutians along the south side of theAlaska Peninsula in a northeasterly direction to Castle Cape. The area includes major embayments and straits associated with the Shumagin Island, Pavlof Island, and Sanak Island groups. The area includes Pavlof Bay the site of the longest continually conducted trawl survey in the entire Gulf of Alaska. The area also includes bays associated with Unalaska Island.

Time Series Description

The earliest sampling by small mesh gear in the Gulf of Alaska probably dates to the 1891 when the steamer RV Albatross conducted a cruise on the general biology of the Gulf of Alaska (Harriman Expedition, 1910). Small mesh studies directed at defining commercial quantities of shrimp were initiated in 1950 by the Bureau of Commercial Fisheries, the shelf region from Ketchikan to Unalaska Island was sampled in the period 1950–1957 (Ronholt, 1963). The series continues with the systematic collection of shrimp surveys that started in the GOA in 1970. In response to information needed to manage the rapidly expanding shrimp fishery both NMFS and ADF&G adopted survey methodology that was similar (Anderson and Gaffney, 1977).

Since 1971 both agencies have used the same high opening sampling gear and similar sampling methodology. Figure 2 shows the total number of tows in the data sets for each agency.

METHODS

Gear

Small–meshed sampling gears used during the studies are summarized below in Table 1. Basically, all small mesh gear was deemed to fit in this category if it was used for shrimp surveys. Also included for analysis were hauls conducted by the International Pacific Halibut Commission (IPHC) when small mesh liners were added to their standard sampling gear. Almost all of the small mesh tows of ADF&G and NMFS since 1971 have been conducted with the same sampling gear the 61' high–opening shrimp trawl. This gear as described by Wathne, 1977 is designed to sample the water column from .4 to 5 meters above the sea floor and has an opening of approximately 10 m wide.

Catch and Sample Handling

The surveys were designed to sample shrimp (biomass) abundance, however other benthic and pelagic species were quantified by weight and, in later years, by numbers as well. Seasonally, during the survey months dense aggregations of pandalid shrimp form in relatively deep water prior to mating and spawning (Anderson 1991). Earlier surveys had shown that shrimp concentrate in depths greater than 70 m (Ronholt 1963, Anderson, 1991). As a consequence, all survey tows were restricted to depths greater than 55 m in years after 1970 in order to adequately target primarily on shrimp.

Stations were sampled during daylight using a 50 to 32 mm mesh trawls. Tow duration was approximately 30 minutes; average tow length for the forty years (NMFS database) being 2.1783 km with a standard deviation of 0.463. Index of biomass estimates are conservative for the small species because small animals are not fully vulnerable to capture (Anderson, 1991)

Survey catches were sorted by species and all species were weighed separately. Occasionally catches were so large that sub–sampling of the catch was employed after the method described by Hughes, (1976). Subsamples were counted to obtain the average weight of individuals. All shrimp, juvenile fish (mostly pleuronectidae) were combined, weighed, and subsampled for species composition. The subsampled species groups were then counted and weighed using an triple–beam scale to the nearest gram. The extrapolated weights of each species were added to those of the adults of the same species.

Level of Species Sort

In the early years 1953 – 1962 only primary commercial species were enumerated, usually the top four or five species in a catch were recorded. Gradually as the surveys were designed to provide more useful information to a broader user group, catch sort and information collected was improved. Since 1970 everything in survey catches has been sorted, identified to the lowest possible taxon, weighed, and enumerated.

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Data Structure
Two general data tables are used in the small–mesh sampling database. The haul table structure is given in table 2. Generally the haul table contains details on the location, time, depth, temperature, and gear type employed for a given sampling. The catch table structure is given in table 3. The catch record contains a species code usually identified to the lowest taxon possible, the total weight of the species caught and the number of individuals of the subject species.

Data Limitations
Fishes and invertebrates observed during these small–mesh surveys and the relative importance of species and species groups within the areas surveyed is largely a function of the sampling gear deployed. Trawls, as most sampling apparatus, employed to sample marine biota, are selective. Sizes and even species of fish captured are influenced by the mesh size used, particularly that in the end of the net or cod end. Species within the size range which theoretically would be retained if engulfed by the trawl, may differ substantially in their ability to escape through the mouth of the trawl or avoid capture altogether. The selective features of trawls thus alter the observed species composition and size frequencies which occur in the swept sampling area. The degree to which the "apparent" distribution and abundance differ from the actual is unknown. Therefore it is important to note thatsubsequent discussion in this report will deal with distribution and relative abundance obtained with the small mesh sampling gears used during the time period. The estimates presented and trends observed are representative only for those species, and sizes of species which are vulnerable to the trawl (Alverson et al., 1964).

Some of the earlier collected data does not have good position information represented in the on–line data sets, however original working charts and copies of them are available. If further funding is available these on–line data will be upgraded for future use by other investigators and will also increase the accuracy of historic catch–per–unit of effort values for important species in the time line analysis.

RESULTS

Species Occurrence and Composition
In general, preliminary results from the analysis of the entire trawl survey data set showed a change, beginning in the late 1970's, from catches being dominated by shrimps to a swift and abrupt change to higher fish proportions in catches. Coincident with changes observed in the composition of survey catches dramatic declines in the commercial fisheries for shrimp and later crab also indicated drastically smaller landings and closures of these fisheries. Just as quickly, fisheries for pollock and cod were beginning to increase in importance and catch levels. These changes witnessed during the past two decades show no sign of reverting tothe crustacean dominated fishery regime.

In all, over 411 species and specie groups were identified in survey samples from 1953 to 1994 in small–mesh trawl survey sampling. Ranking these species by total catch weight in the data base gives the relation of species occurrence in the data set (Table 4). Not surprisingly, several shrimp species are well represented in the top rankings. In addition to several shrimp species many other important forage species are represented in the top 20 entries on the rank order list. Among those that are of principle interest in this study are; capelin, sandfish, pollock, eulachon, cod, and possibly jellyfish (Scyphoza).

The focus of this study is directed towards the relative abundance and distribution of the five species mentioned above and a group of flatfish species. Many of the principle study species are true forage species such as capelin, sandfish, and eulachon. Many others serve a dual role acting as forage when juveniles and then becoming predators as they grow. Examples of this later group are cod, pollock, and flatfish. One of the declining species that has been studied is the longsnout prickleback which may be an important forage species only during its juvenile phase. Other species, including jellyfish, are probably indicators of productivity changes in the environment and their distribution and relative abundance will be studied as well.

Changes in Forage Species Abundance and Distribution

Capelin
Capelin are primarily planktivores with a relatively short life span. Their abundance is highly variable from year to year and is linked to zooplankton availability and to the feeding influence of their competitors or predators (Gerasimova, 1994). Capelin play a key role in the trophic interaction of species, transferring energy from primary production to higher level predators, including cod, marine mammals, and birds.

Data from shrimp cruises in the Gulf of Alaska starting in 1953 and continuing to the present showed no capelin present in catches prior to 1963. A possible reason for this observation may be explained by survey techniques which ignored "non–commercial" species in the early years when the emphasis was entirely directed toward commercial species. A review of what written material that still remains from these tows revealed that species were simply identified as "smelt" in the early data sets. We believe that many of these records most undoubtedly refer to capelin and eulachon since both of these species have high occurrences in the entire data set. Unfortunately we have no way of telling for sure, except that they are in the family Osmeridae. With the advent of MARMAP program in the early 1970's a more through approach to analyzing catch components in surveys was adopted. In the analysis of the data the year 1970 is useful as a baseline for comparison purposes due to this weakness in the data. Occurrences of capelin between 1963 and 1970 will be used in analyzing distributional patterns only.

Capelin showed two peaks in abundance since 1970 in the GOA Figure 3 (top). The first peak in abundance occurred in 1974 at little over 4 kg/km in survey catches. The second peak in relative abundance was in 1980 at 7.22 kg/km. In 1980 and 1981 the catch rates dropped to around 1 kg/km and has remained below a tenth of a kg/km since 1985. ADF&G data also clearly shows the peak value of 1980, mostly represented in the Kodiak region Figure 3 (bottom). The peaks in relative abundance observed in the mid 1970's and at the late 1970's and 1980 probably reflect strong cohorts or year classes of capelin during those times. Unfortunately data prior to 1970 frequently lacked specificity as discussed above so accurate trends in the data prior to 1970 cannot be assessed.

Mapping of relative densities of capelin showed defined areas of relative high abundance. The Shelikof region showed relative high catches in Kujulik, Alitak, and Olga Bays. Most catches of capelin were closely associated with bays with the exception of high catches offshore of Cape Ikolik at the southwest end of Kodiak Island Figure 4. Isolated offshore areas east of Kodiak Island showed some high catches, most of the high catches were associated with Ugak and Kazakof Bays (Figure 5; bottom). Only isolated catches of less than 50 kilograms were evident in the database from Prince William Sound, Kenai Coast, and Lower Cook Inlet regions (Figure 5 top). More detailed analysis of these areas of historical high relative abundance will be analyzed in the future.

Eulachon
Eulachon showed a peak in abundance in 1981 with an abrupt decline thereafter. Another subsequent peak in abundance at over 1 kg/km occurred in 1986. Since 1987 eulachon has

remained at a low level of relative abundance in the data (Figure 6 top). Eulachon are known to be relatively abundant in areas adjacent to spawning rivers. Subsequent analysis will rely on mapping to better define areas of relative high abundance and abundance trends in those areas.

Longsnout Prickleback and Pacific Sandfish
Longsnout prickleback and the Pacific sandfish were two non–commercial species that showed decreased abundance in the 1980's. Longsnout prickleback abundance was variable showing a peak abundance in 1973 and a subsequent decline and increasing to a lesser peak in 1979 (Figure 6 middle). The abundance of longsnout pricklebacks has remained relatively low since 1984. Pacific sandfish peaked in abundance in 1980 and subsequently declined to relative low abundance since 1982 (Figure 6 bottom).

Juvenile and Adult Gadoids
Walleye pollock are pelagic throughout their life. Young–of–the–year occur in the upper 100 m and older juveniles are found down to 400 m. Adult fish are usually found in the upper 300 m in the water column. Pollock undergo diel vertical migration in thewater column, coming off bottom during darker periods of the day and settling down to near bottom depths during the brighter periods. Seasonal movements of fish also occur with movement offshore during the winter and returning inshore during the spring were they remain through the late summer and fall. Pollock are known for forming large pelagic spawning schools in the late winter and spring period. One of the most important areas for this mass spawning is the Shelikof Strait. Walleye pollock feed mostly on free–swimming pelagic animals. Juveniles and small adults feed on euphasids, copepods, amphipods, and isopods. Larger fish feed primarily on euphasids and pollock. Pollock are preyed on by pinnipeds, cetaceans, diving birds, and larger fishes.

Pacific cod are considered a demersal species along the continental shelf of the GOA from inshore to the upper slope. During the winter and spring cod concentrate in the gullys and canyons that cut across the shelf. Most spawning occurs in late winter to early spring at depths of 150 –200m. In summer they move to shallower depths of usually less than 100m. Pacific cod are a fast–growing and short–lived species attaining a maximum age of 10 to 13 years. Juveniles feed on benthic amphipods and worms, adult fish feed on crabs, shrimp, benthic and pelagic fishes. Pacific cod are preyed on by Pacific halibut and some cetaceans.

Pollock and Pacific cod abundance was highly variable but showed a trend to general overall higher relative abundance through the time series (Figure 7 top and middle). An unusually strong peak in cod abundance occurred in 1979. Recent data suggest an overall lower level of abundance averaging around 21 to 45 kg/km since1991, these values are much higher than those prior to 1975. Pollock exhibit several peaks in abundance 1973, 1977, 1979, 1983, 1989, and relatively high sustained abundance since 1991. The peak abundance in 1991 is the highest recorded in the data series at nearly 300 kg/km.

Flatfish Complex
The flatfish complex comprised of five pleuronectid species, arrowtooth flounder, flathead sole, yellowfin sole, rock sole, and Pacific halibut are all considered demersal species with varying depth ranges, but all are commonly found in the entire study area. Arrowtooth flounder and Pacific halibut are usually found over a broader depth range 100 – 500m than the other species. All spawn on or near the bottom with arrowtooth and Pacific halibut spawning during the winter and the other species spawning during the spring. The small–mouthed soles (rock and yellowfin) feed primarily on detrital–consuming invertebrates, polychaete worms, clams, amphipods, shrimp, snails, and brittlestars. Flathead sole are primarily benthic feeders but also feed on small nektonic animals such as shrimp, herring, and smelt. Arrowtooth feed primarily on nektonic prey. Halibut feed primarily on fishes, crabs, and other invertebrates.

A group of five pleuronectid species, arrowtooth flounder, flathead sole, yellowfin sole, rock sole, and Pacific halibut showed an almost continual increase in the data series from 1970(Figure 7 bottom). These trends are different than any of the other species groups studied. Questions yet to be answered revolve around the possibility of inshore migration of species and possible displacement or competition with other species groups.

Shrimp
Recent declines in shrimp abundance throughout the Gulf of Alaska have mirrored the decline of other species as well (Piatt and Anderson, 1995). Caredian shrimp of four major families; Pandalidae, Crangonidae, Hippolytidae, and Phasapheidiae occupy an important niche in the pelagic realm in Alaskan waters. There is a long history of commercial harvesting of several species in the Pandalidae family in the Bering Sea and Gulf of Alaska, no known harvests of members of the other families has occurred. Most of the available biological information in Alaskan waters relates to the commercially important shrimps in the family Pandalidae. With out exception Pandalid shrimps have declined in the entire central and western GOA. One species, the humpy shrimp, which was second in relative abundance to the northern pink shrimp has become nearly extinct since the late 1970's.

Commercially important pandalid shrimp first hatch as larvae in the spring (April) through early June. Shrimp larvae remain in near–surface waters until undergoing metamorphosis to the juvenile phase and settle into a semi–benthic existence. Pandalid shrimp are protandric hermaphrodites maturing first as males and thenundergoing a transformation to female depending on growth rate of the individual (Charnov and Anderson, 1989). Massive swarms of shrimp take part in diel migration up into near surface water at night to feed. During daylight shrimp are mostly near bottom. Females which bear eggs on attachments to the pleopods after spawning do not actively migrate up in the water column until after eggs hatch.

Shrimp are a major food item for important commercial fish species, birds and marine mammals. Albers and Anderson (1985) found that pandalid shrimp were a dominant food item by frequency of occurrence (63%) in Pacific cod diet in Pavlof Bay. Jewett (1978) and Hunter (1979) found significant amounts of shrimp in cod taken from offshore areas but not as high as that found in inshore populations. Shrimp are also important in the diet of almost all fishes where they co–occur with shrimp. Shrimp larvae and juveniles are preyed on by pink, sockeye and coho salmon, sand lance, walleye pollock, longfin smelt, surf smelt, juvenile great sculpin, starry flounder, and rock sole taken from near–shore samples (Blackburn et al., 1983). MacDonald and Peterson (1976) report shrimp in the diet of Beluga whales, Steller's sea lion, and harbor seal. Hatch et al. (1978) reported glacous–winged gulls, kittiwakes, and tufted puffins preyed on shrimp. Shrimp therefore are a major forage species that is an important source of food when available.

CONCLUSIONS ON SPECIES' CHANGES IN RELATIVE ABUNDANCE

During the late 1970's to early 1980's an abrupt reorganization of species groups occurred in the demersal ecosystem in the Gulf of Alaska. A crustacean dominated species complex abruptly declined while round and flatfishes uniformly have increased over a short span of time in the late 1970's and early 1980's (Piatt and Anderson, 1995). Commercially fished crustaceans both of shrimps and crabs have declined to very low levels and the fisheries have remained closed for many years (Blau, 1986; Anderson, 1991). Pollock and Pacific cod abundance is variable probably due to influxes of strong year–classes but in a general up trend. Strong year–classes of cod moved into inshore areas in the late 1970's where they had been absent before. This influx of predators is responsible for the initial decline of many species (Albers and Anderson, 1985). Five species of pleuronectids have been in a general up trend from beginning of the 1970's, increasing to the highest recorded level in 1994. In turn many non–commercial species such as capelin, eulachon, longsnout prickleback, and Pacific sandfish declined and have remained in relative low abundance similar to that experienced by the crustacean populations. These general trends may obscure the effects of distributional patterns that may have also changed during the time period. Future studies will concentrate on changes by mapping distribution patterns and define trends in isolated areas were persistent populations of forage species occur.

Seasonal Component
A review of the data reveals that the most consistent time series are usually those taken from the late–summer and fall periods. An example is the data from Kachemak Bay which showed much more variability in the spring or early summer than the fall or late–summer period (Fig 8). This is probably not a function of this one single location. It was found that late–summer/fall sampling period was beneficial for the sampling of in–shore bays in the western GOA (Anderson, 1991). The reason for this is not enterly clear however the fall period is the time of year when spawning aggregations of shrimp form prior to matting and spawning, it is also the period of maximum bottom temperature for these areas. It could be that a stable temperature regime as found during this time period also leads to stability in the fish populations as well. Future analysis will focus on this apparent relationship.

FUTURE DIRECTION OF RESEARCH AND ANALYSIS

1. Monitor critical forage species

Capelin
Monitor known spawning beaches for eggs and larvae. Much easier than sampling for the adults (Mangel and Smith, 1990). An indication of shoal spawning of capelin in the GOA is illuded to in this study, this deserves further investigation.
Predator stomach sampling, including birds, mammal and fishes. Continuation of hydroacoustic and trawl surveys in areas ofdemonstrated high historical abundance.

Eulachon
Monitor spawning rivers for abundance, probably concentrate on larval out–migration indexing.

Sandlance
Monitor spawning beaches after late–summer inshore migration.
Predator sampling conducted on selected species, index on frequency of occurrence. Trawl surveys inadequate but hydroaccoustic surveys may prove viable for estimating abundance of inshore migrating schools in late summer. Surface tow nets are also a possible sampling tool for inshore migrating schools and offshore migrating larval fish.

Shrimp
Monitor selected bays where shrimp densities were high during the crustacean regime era. Pay particular attention to recovery of near–extinct shrimp species.

2. Compile complete integrated database which combines all elements of each data set to provide a database for more complete analysis.

3. Creating a geographic information system (GIS) on forage species for the GOA that can be used by other researchers and serve as a repository for future data collection.

4. Spatial analysis of historic data to analyze for changes in distribution patterns over time and employing spatial analysis models in order to understand the dynamics of the changes that have occurred (once GIS database has been developed).

5. Prepare bibliography of forage species.

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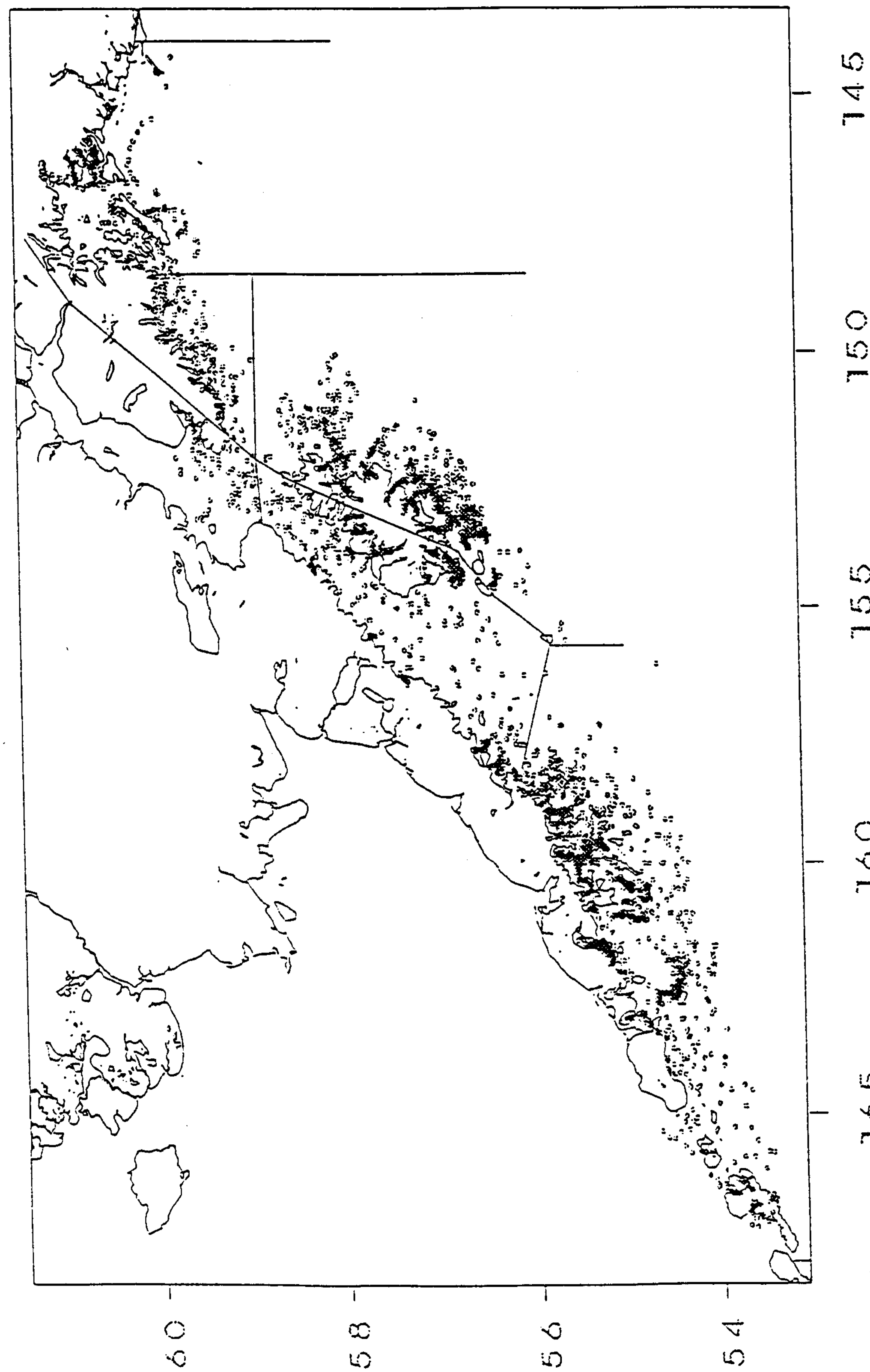
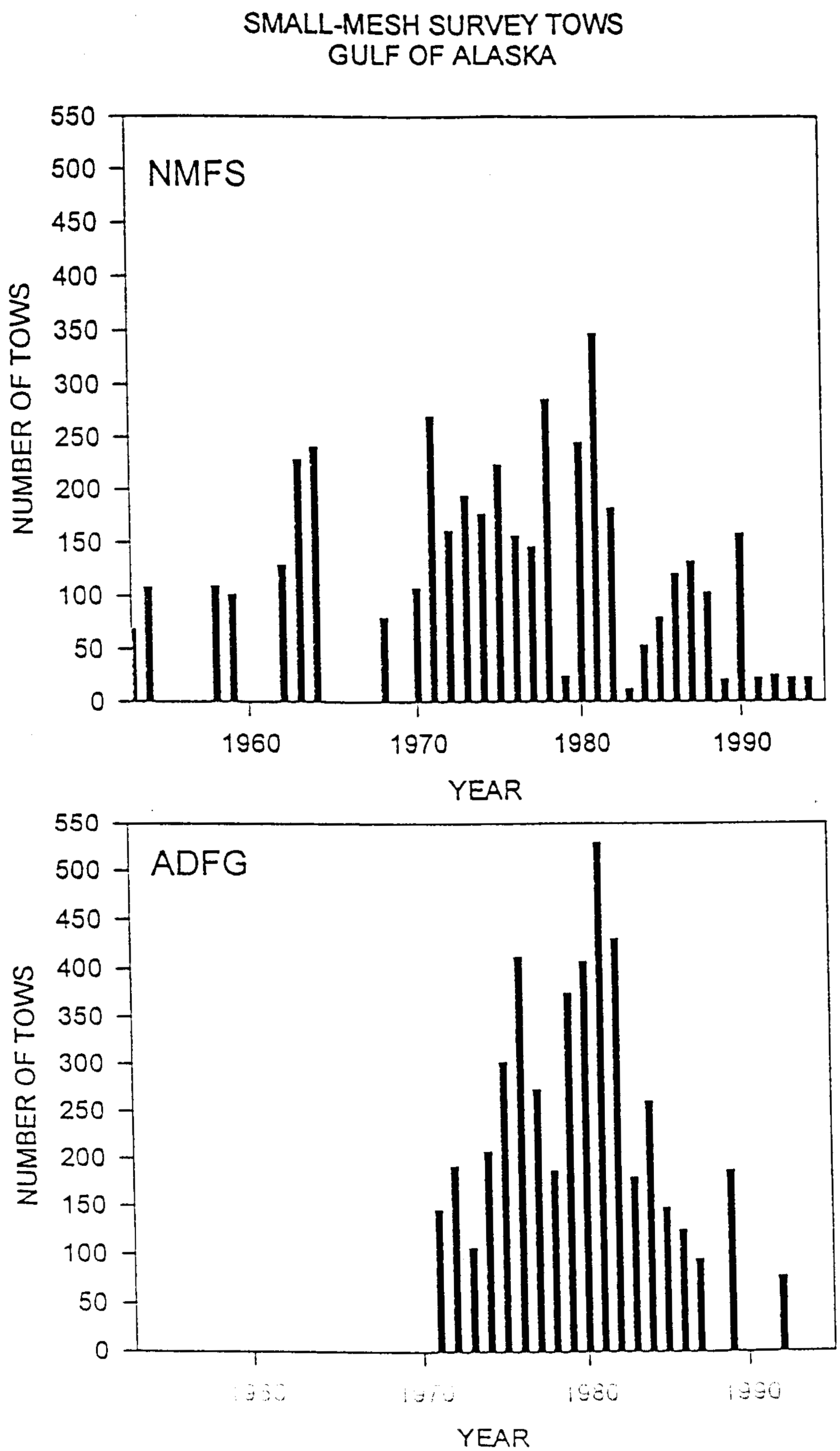
Appendix L-12

Figure 1. Distribution of small–mesh survey sampling 1953 to 1994 in the Gulf of Alaska with sub–area delineation.



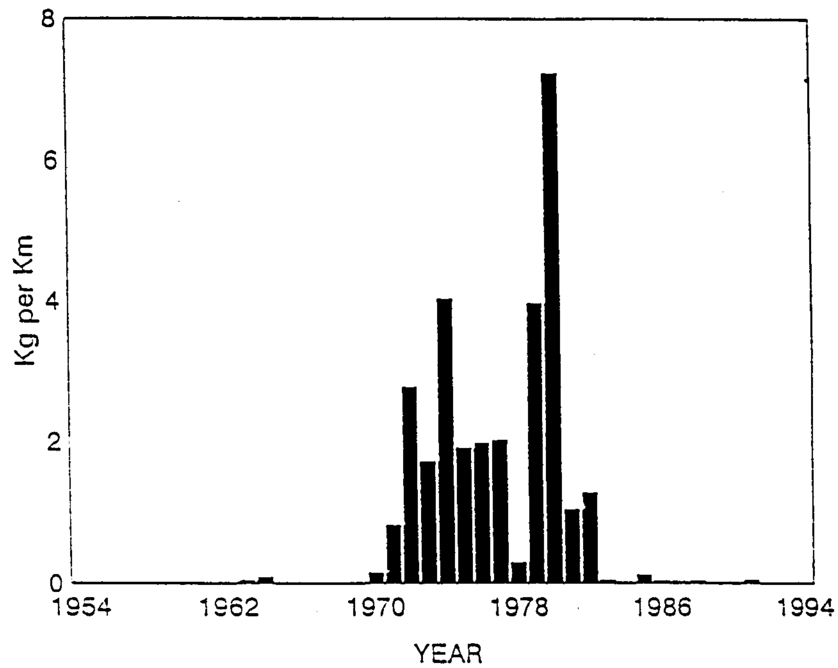
Appendix L-13

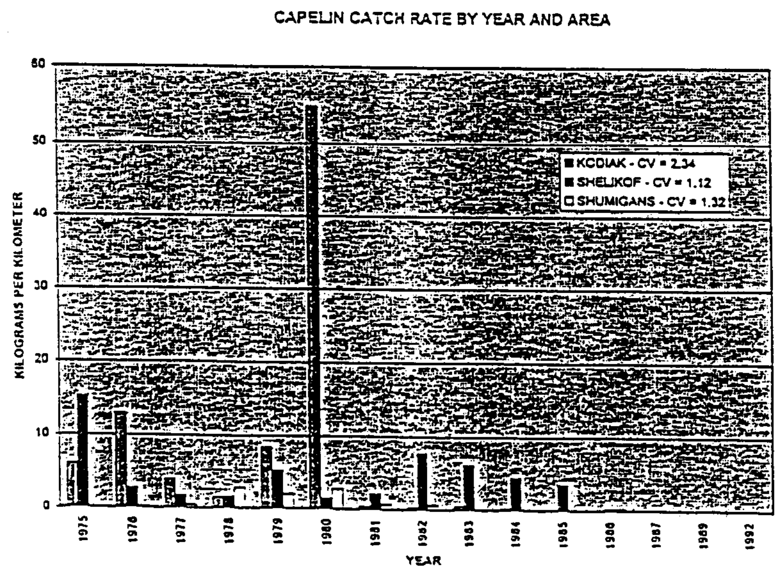
Figure 2. Number of small–mesh survey tows by year currently in ADF&G and NMFS databases.



Appendix L-14

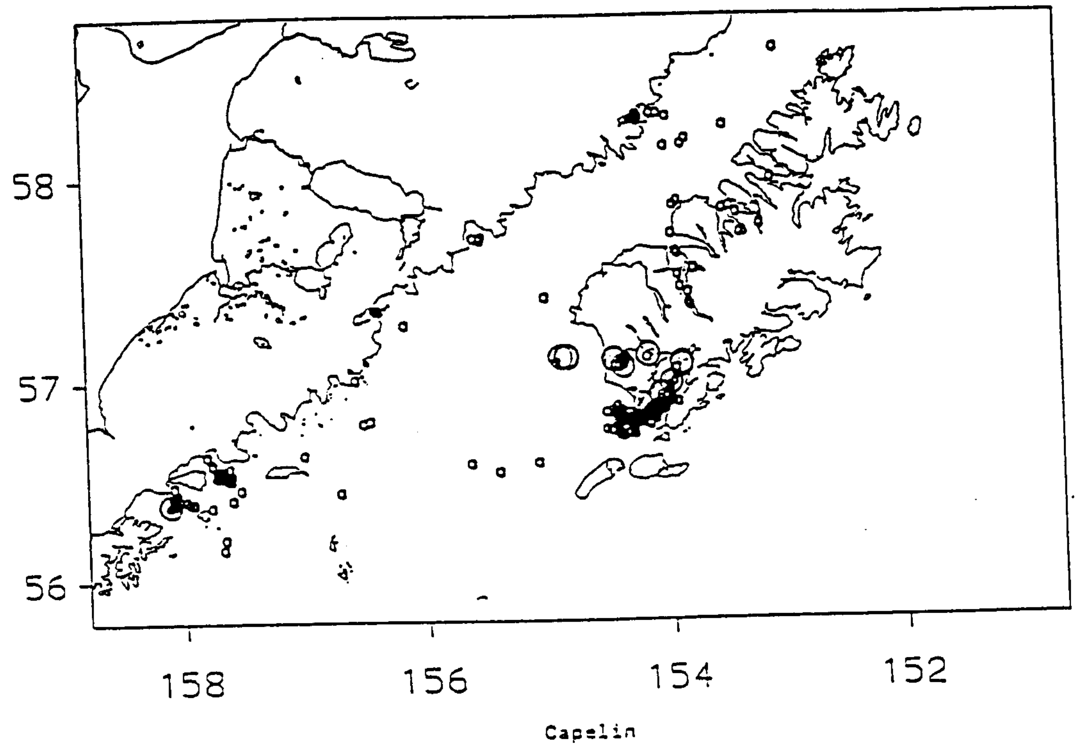
Figure 3. Capelin relative abundance in Gulf of Alaska small-mesh trawl samples expressed as kilograms caught per kilometer towed (NMFS database top). Capelin relative abundance for three regions (ADFG database bottom).

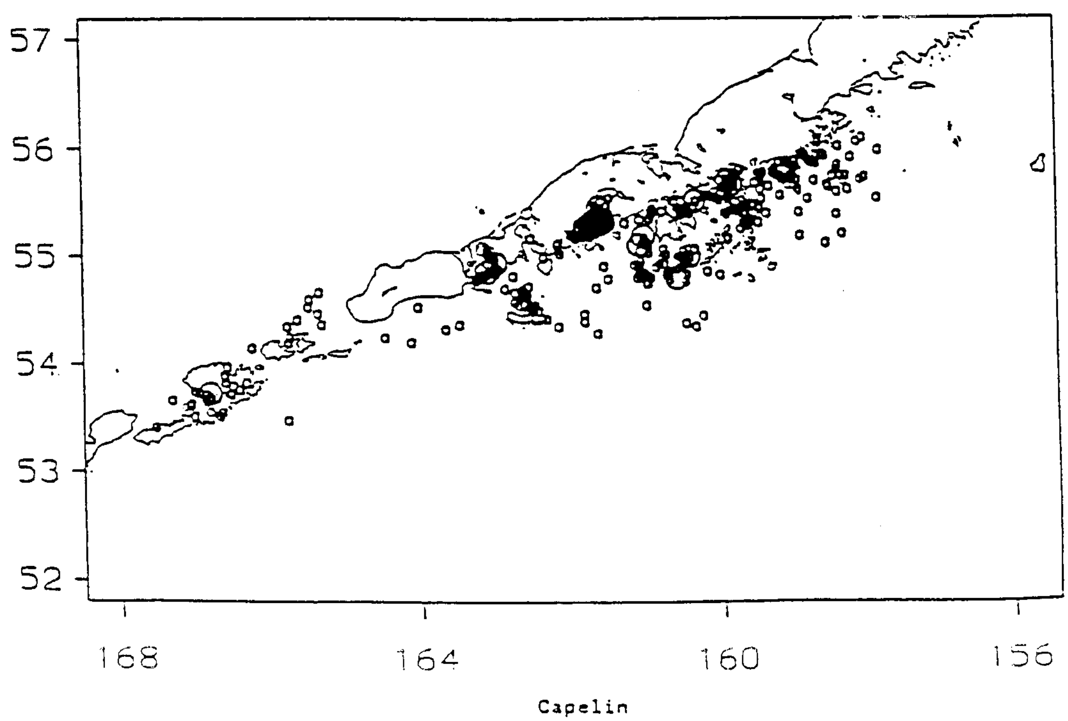




Appendix L-15

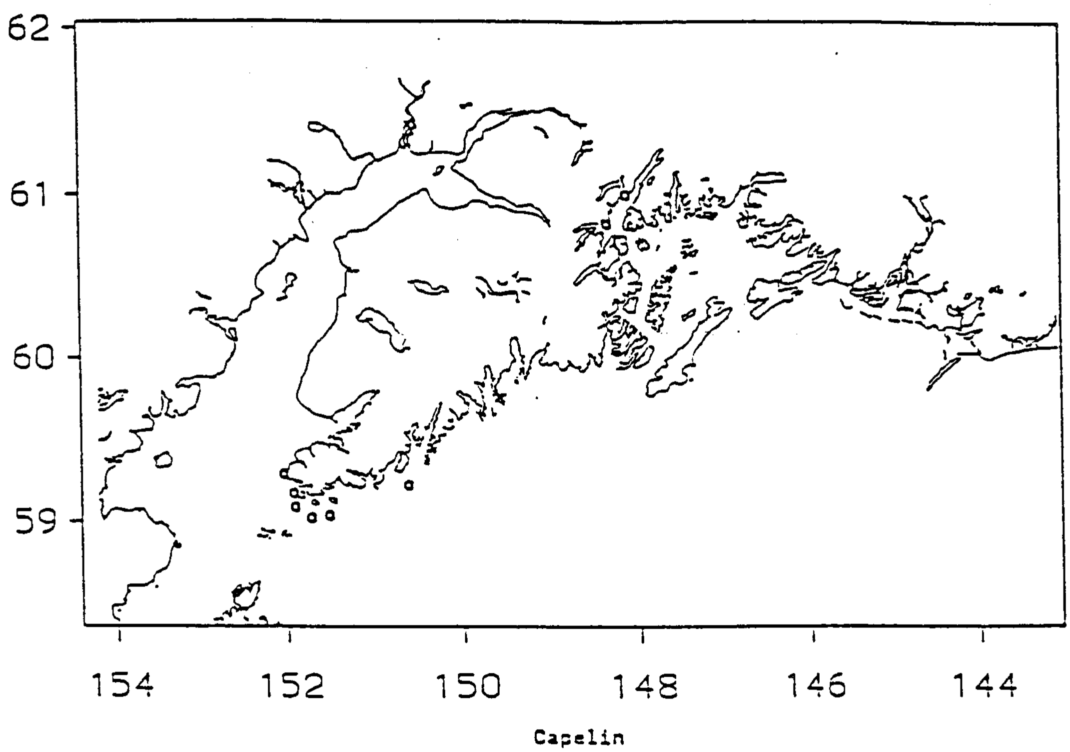
Figure 4. Maps of relative catch density of capelin in the Shelikof and Shumagin areas. Large circles represent catches greater than 50 kilograms; small circles less than 49 kilograms.

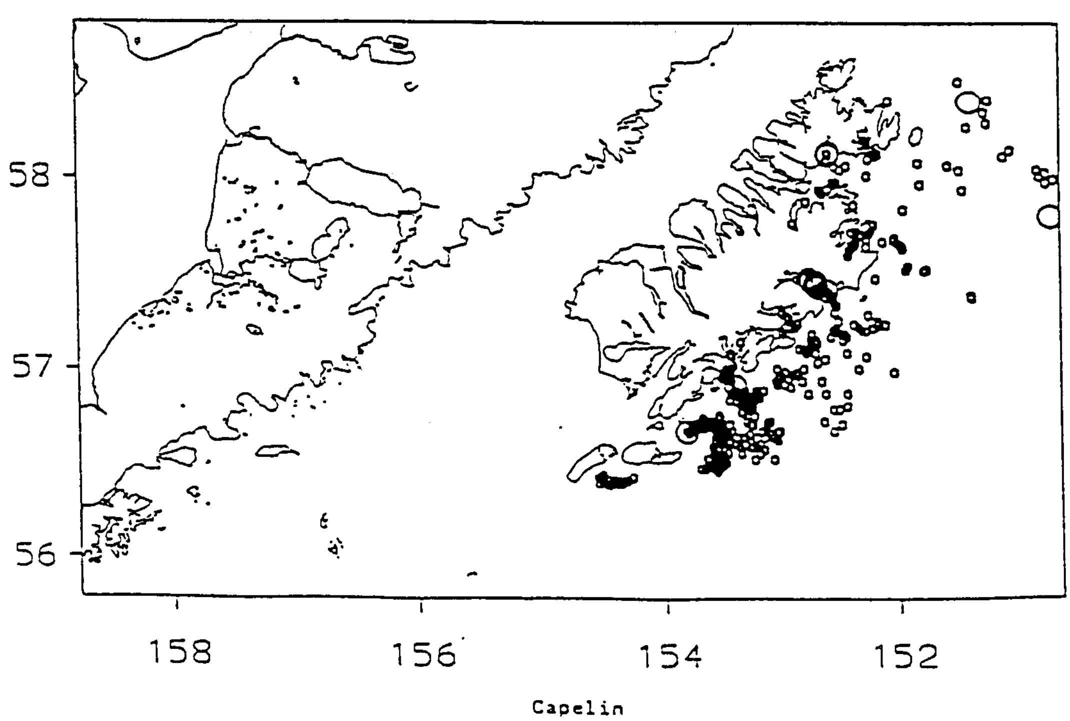




Appendix L-16

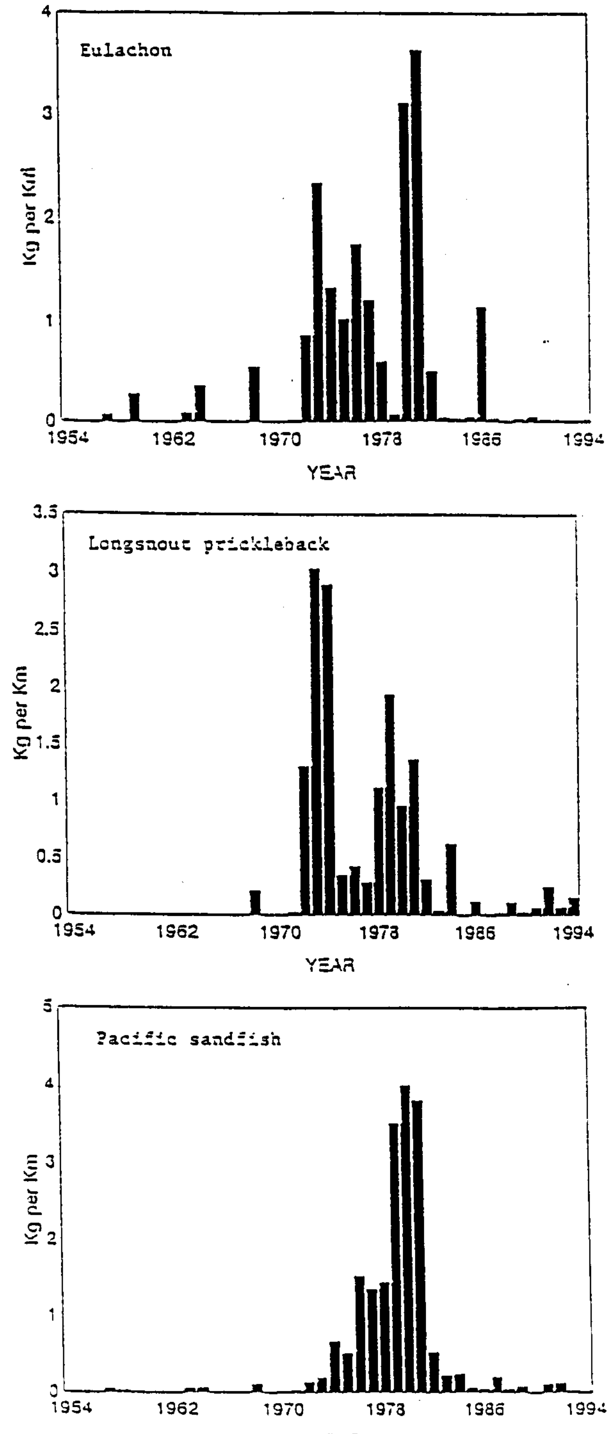
Figure 5. Maps of relative catch density of capelin in the Lower Cook, Kenai, and Prince William Sound (top) and Kodiak areas (bottom). Large circles represent catches greater than 50 kilograms; small circles less than 49 kilograms.





Appendix L-17

Figure 6.Relative abundance of eulachon (top), longsnout prickleback (middle), and Pacific sandfish (bottom).



Appendix L-18

Figure 7. Relative abundance of Pacific cod (top), walleye pollock (middle), and a group of faltfish (bottom).

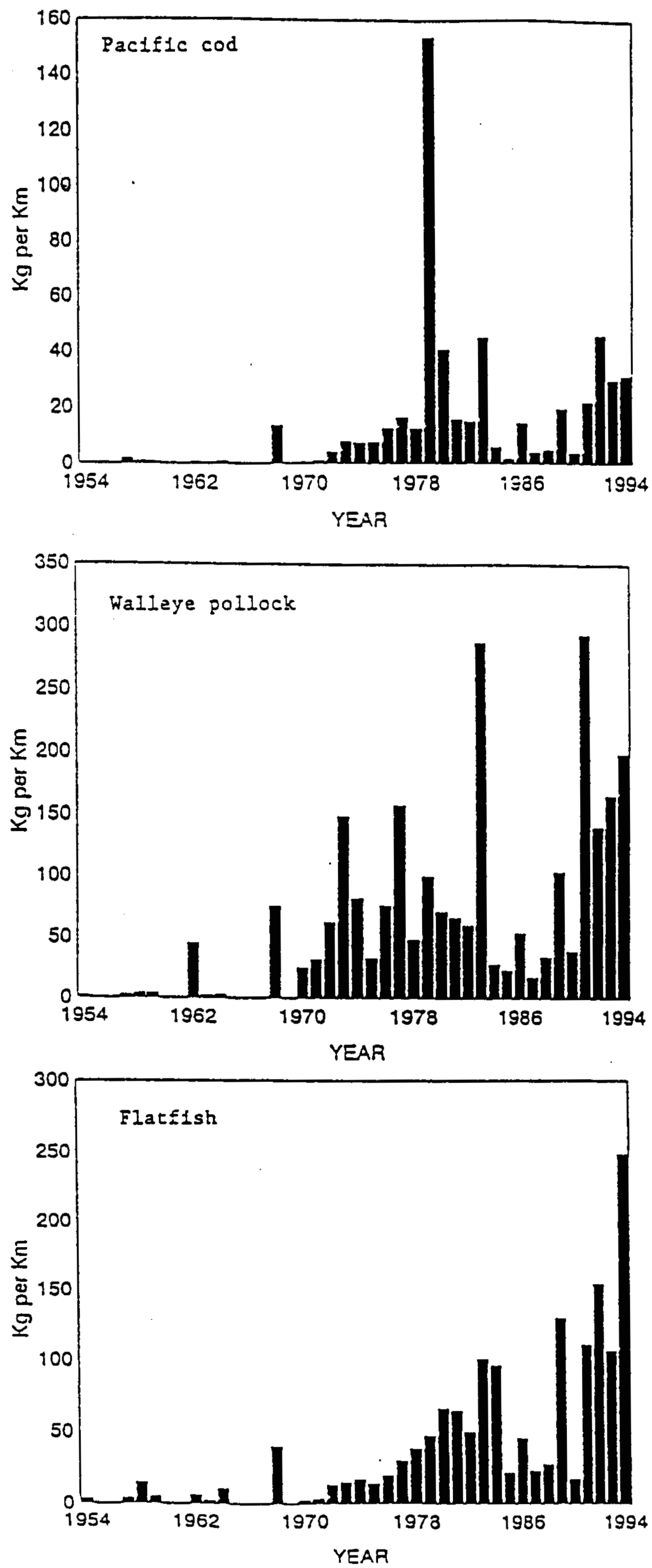
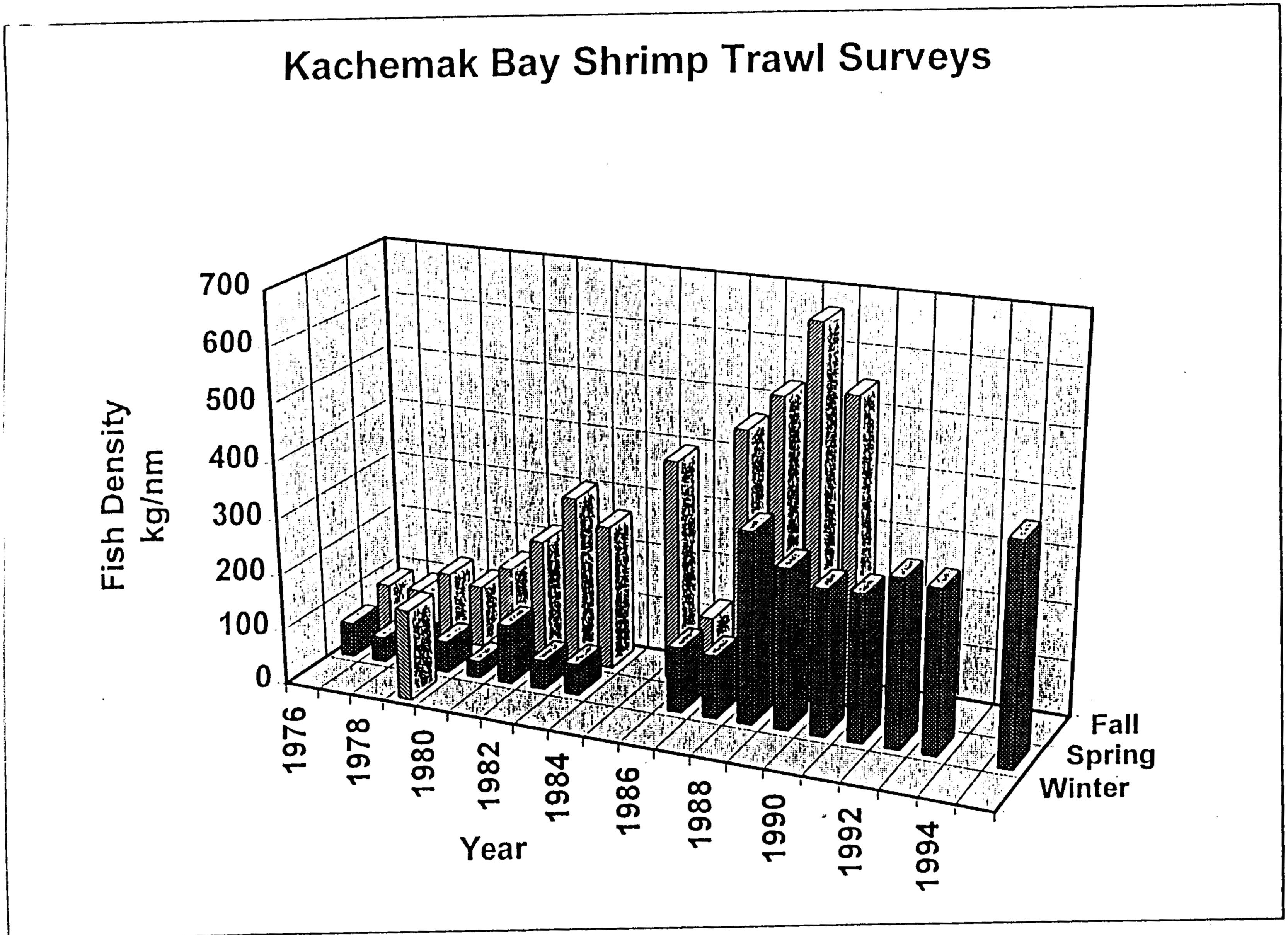


Figure 8. Fish catch (kg/km) in Cook Inlet trawl shrimp surveys from 1976 to 1995.



Fish catch (kg/nm) in Cook Inlet trawl shrimp surveys from 1976 to 1995.

Appendix L-20

Table 1. Cruises by vessel that includes most small-mesh survey sampling as of 11/13/95 in NMFS database.

VESSEL	CRUISE	STARTDATE	ENDDATE	SURVEY TYPE	GEAR CODES
1	8104	08/31/81	09/14/81	SHRMP PAV	508
1	8404	08/29/84	08/30/84	SHRMP PAV	508
1	8405	09/04/84	09/12/84	Y OF YR	508, 507, 509
2	5301	03/10/53	04/07/53	SHRMP YAKUT	610
2	5401	02/26/54	04/06/54	SHRMP PR.WM	610
2	5402	07/13/54	09/08/54	SHRMP PR.WM	610
2	5801	07/22/58	08/26/58	SHRMP KODK	506
2	5902	10/14/59	11/11/59	SHRMP KENAI	506
2	7205	05/10/72	05/31/72	SHRMP KODK	516
2	8203	08/14/82	08/21/82	SHRMP KOD-PAV	508
2	8605	08/28/86	09/01/86	SHRMP PAV	508
2	8606	09/03/86	10/08/86	Y OF YR	508, 507, 305
3	8001	06/16/80	08/06/80	IPHC	751
3	8101	06/11/81	07/30/81	IPHC	751
4	7103	06/09/71	07/20/71	SHRMP KODK	514
4	7302	05/23/73	06/14/73	SHRMP KODK	508
9	6306	07/13/63	08/01/63	ROCK	761
14	7102	04/17/71	05/24/71	SHRMP KODK	516
14	7203	08/25/72	09/28/72	SHRMP SHUM	508
14	7305	08/29/73	10/23/73	SHRMP SHUM	508
14	7401	04/15/74	05/22/74	SHRMP KODK	508
14	7403	09/01/74	10/27/74	SHRMP SHUM	508
14	7501	04/01/75	05/22/75	SHRMP KODK	508
14	7503	09/07/75	10/31/75	SHRMP SHUM	508
14	7603	09/08/76	10/28/76	SHRMP SHUM	508
14	7704	08/21/77	09/23/77	SHRMP SHUM	508
14	7803	08/25/78	10/16/78	SHRMP SHUM/AL	508
14	7903	09/01/79	09/07/79	SHRMP PAV/AL	508
14	8003	08/12/80	09/16/80	SHRMP PAV/AL	508
15	7003	08/30/70	10/10/70	SHRMP KODK	510
21	9009	09/07/90	09/22/90	Y OF YR	507, 302
24	8201	06/11/82	07/17/82	IPHC	751
27	7801	06/18/78	07/06/78	SHRIMP/PLK	508
33	6202	08/21/62	10/02/62	SHRMP PR.WM	506, 512
33	6302	07/12/63	09/10/63	SHRMP PR.WM	506
34	6802	07/03/68	09/26/68	SHRMP KODK	506, 510, 605
37	8102	08/30/81	09/23/81	ADFG SHRMP	508
37	8302	08/11/83	08/12/83	SHRMP PAV	508
37	8502	08/12/85	08/15/85	SHRMP PAV	508
37	8503	08/21/85	09/09/85	Y OF YR	508
37	8702	08/05/87	08/08/87	SHRMP PAV	508
37	8703	08/13/87	09/19/87	Y OF YR	508
37	8802	08/10/88	08/15/88	SHRMP PAV	508
37	8803	08/18/88	09/10/88	Y OF YR	508
37	8902	08/18/89	08/21/89	SHRMP PAV	508
37	9002	08/09/90	08/16/90	SHRMP PAV/KOD	508
37	9102	08/19/91	08/21/91	SHRMP PAV	508

Table 1 Cont.

VESSEL	CRUISE	STARTDATE	ENDDATE	SURVEY TYPE	GEAR CODES
38	6402	08/13/64	09/04/64	SHRMP KODK	506
38	6402	06/16/64	09/15/64	SHRMP KODK	506, 512
41	8001	09/09/80	09/23/80	ADFG SHRMP	508
41	8101	09/03/81	10/03/81	ADFG SHRMP	508
42	8001	08/23/80	09/16/80	ADFG SHRMP	508
43	8001	08/23/80	09/05/80	ADFG SHRMP	508
43	8201	08/24/82	09/23/82	ADFG SHRMP	508
87	9202	08/09/92	08/13/92	SHRMP PAV	508
88	9302	08/04/93	08/06/93	SHRMP PAV	508
89	9402	08/04/94	08/06/94	SHRMP PAV	508
88	9502	08/05/95	08/09/95	SHRMP PAV	508
620	5702	09/06/57	09/30/57	SHRMP SHUM	506
620	7801	06/23/78	08/17/78	IPHC	751

GEAR CODES:

305 --Marinovitch mid-water; 32 mm mesh.
506 --Gulf Shrimp Trawl; 38 mm mesh.
507 --High-opening Shrimp Trawl; 32 mm mesh.
508 --High-opening Shrimp Trawl; 32 mm mesh.
509 --High-opening Shrimp Trawl; 32 mm mesh.
510 --Kodiak Shrimp Trawl; 32 mm mesh with 19 mm mesh liner
512 --Gulf Semi-balloon Shrimp Trawl; 38 - 41 mm mesh.
514 --Kodiak Shrimp Trawl; 32 mm mesh with 19 mm mesh liner.
516 --Nordby Shrimp Trawl; 32 mm mesh.
610 --Beam Trawl; 32 mm mesh.
751 --INPHC Samll-mesh Trawl; 32 mm mesh.
761 --Semi-balloon Shrimp Trawl; 38 mm mesh with 13 mm mesh liner.

Appendix L-22

Table 2. Structure for haul table in NMFS and ADF&G small-mesh database.

NMFS Field	Field Name	Type	Width	Decimals	Definition
1	CRUVESHAL	Numeric	12		Identification
2	THEREGION	Character	3		Region Code
3	VESSEL	Numeric	4		Vessel Code
4	CRUISE	Numeric	4		Cruise Number
5	HAUL	Numeric	4		Haul Number
6	HAULTYPE	Numeric	4		Haul Type Code
7	PERFORMANC	Character	2		Performance Code
8	STARTDATE	Date	8		Date of Haul
9	STARTHOUR	Numeric	4		Time of Haul
10	DURATION	Numeric	7	3	Duration Time
11	DISTANCE	Numeric	8	4	Distance Kilometers
12	NETWIDTH	Numeric	7	3	Net Width Meters
13	NETMEASURD	Character	2		Measurement Code
14	NETHEIGHT	Numeric	7	3	Net Height Meters
15	STRATUM	Numeric	4		Stratum Code
16	STARTLAT	Numeric	10	6	Starting Latitude
17	ENDLAT	Numeric	10	6	Ending Latitude
18	STARTLON	Numeric	11	6	Starting Longitude
19	ENDLON	Numeric	11	6	Ending Longitude
20	STATIONID	Character	10		Identification
21	GEARDEPTH	Numeric	6		Gear Depth Meters
22	BOTTOMDEPT	Numeric	6		Bottom Depth Meters
23	BOTTOMTYPE	Character	3		Bottom Type Code
24	SURFTEMP	Numeric	5	1	Surface ^{0}C
25	GEARTEMP	Numeric	5	1	Gear ^{0}C
26	WIRELENGTH	Numeric	7		Trawl Warp Meters
27	GEAR	Character	4		Gear Code
28	ACCESSORIE	Character	3		Gear Accessory Code
29	SUBSAMPLE	Character	2		Subsample Code

ADFG No.	Column Name	Attributes	Definition
1	Cruise	INTEGER, Index:MULTI-COLUMN	Cruise Number
2	Haul	INTEGER, Index:MULTI-COLUMN	Haul Number
3	Region	INTEGER	Region Code
4	Area	INTEGER	Area Code
5	Stratum	INTEGER	Stratum Code
6	Station	TEXT 4	Station Code
7	Vessel	TEXT 2	Vessel Code
8	Dateup	DATE	Date
9	LatDeg	INTEGER	Start Latitude
10	LatMin	REAL	"
11	LongDeg	INTEGER	Start Longitude
12	LongMin	REAL	"

No.	Column Name	Attributes	Definition
13	TowHeading	INTEGER	Heading Degrees

Table 2. Structure for haul table in NMFS and ADF&G small-mesh database. CONT.

ADFG Cont.

No.	Column Name	Attributes	Definition
14	StartHaul	TIME	Start Time
15	EndHaul	TIME	End Time
16	Minutes	INTEGER	Duration Time
17	Distance	REAL	Distance Naut. Mi.
18	Loranx	INTEGER	Loran Position
19	Lorany	INTEGER	"
20	DepthMax	INTEGER	Maximum Depth Fm
21	DepthMin	INTEGER	Minimum Depth Fm
22	Weather	TEXT 3	Weather Code
23	Scope	INTEGER	Trawl Warp Fathoms
24	Perform	INTEGER	Performance Code
25	DepthAvg	INTEGER	Average Depth Fthms
26	Temperature	REAL	Gear Temperature ?C
27	Latitude	REAL	End Latitude
28	Longitude	REAL	End Longitude
29	The Area	TEXT 4	Area Code

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Table 3. Structure of catch table in NMFS and ADF&G small-mesh database.

NMFS Field	Field Name	Type	Width	Decimals	Definition
1	CRUVESHAL	Numeric	12		Numeric ID
2	THEREGION	Character	3		Region Seperator
3	VESSEL	Numeric	4		Vessel Code
4	CRUISE	Numeric	4		Cruise Number
5	HAUL	Numeric	4		Haul Number
6	SPECIES	Numeric	10		Species Code
7	WEIGHT	Numeric	12	4	Weight Kg
8	NUMBERS	Numeric	7		Number Caught
9	SUBSAMPLE	Numeric	2		Sub-sample Code

ADFG No.	Column Name	Attributes	Definition
1	Cruise	INTEGER	Cruise Number
2	haul	INTEGER	Haul Number
3	region	INTEGER	Region Code (Different than NMFS)
4	area	INTEGER	Area Designator
5	spcode	INTEGER	Species Code (Same as NMFS)
6	catchlbs	INTEGER	Weight Pounds
7	lbseach	INTEGER	Number Caught

Appendix L-25

Table 4. Rank order by weight of species and species groups caught in NMFS small-mesh surveys 1953 to 1994 in the Gulf of Alaska (Partial listing).

Species Name	Total Weight
Pandalus borealis	579290.6243
Theragra chalcogramma	461348.0636
Hippoglossoides elassodon	127052.4604
Gadus macrocephalus	93530.7165
Scyphozoa (class)	89143.0956
Pandalus goniurus	84706.3639
Atheresthes stomias	54169.9554
Pandalopsis dispar	52019.9269
Pleuronectes asper (prev. Limanda aspera)	45522.9413
Chionoecetes bairdi	20388.2346
Pandalus hypsinotus	19428.4267
Paralithodes camtschatica	18234.4558
Hippoglossus stenolepis	14911.9423
Hemilepidotus jordani	12287.4737
Pleuronectes bilineatus (prev. Lepidopsetta bilineata)	11816.2032
Mallotus villosus	11301.6434
Myoxocephalus sp.	9363.9947
Thaleichthys pacificus	8785.2017
Lycodes brevipes	8717.7221
Trichodon trichodon	7750.9781
Anoplopoma fimbria	7735.5310
Clupea pallasi (=Clupea harengus pallasi)	6205.9402
Lumpenella longirostris	5376.1010
Starfish unident.	5028.5994
Microgadus proximus	4954.5920
Myoxocephalus polyacanthocephalus	4816.4318
Ophiuroid unident.	4451.8761
Cottidae	3805.1354
Chionoecetes tanneri	3242.5600
Crangonidae (family)	3241.7790
Platichthys stellatus	3027.6931
Zoarcidae	2905.3840
Sebastes alutus	2875.0132
Chionoecetes sp.	2813.5810
Shrimp unident.	2352.5960
Dasycottus setiger	2166.7533
Cancer magister	2137.0568
Rajidae unident.	1967.5116
Psettichthys melanostictus	1944.2313
Asterias amurensis	1851.8155
Myoxocephalus jaok	1807.6141
Isopsetta isolepis (=Pleuronectes isolepis)	1737.5801
Pleuronectes quadrituberculatus	1597.1843
Porifera	1588.5310
Argis dentata	1456.5558

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Lumpenus sagitta	1430.0163
Pandalus jordani	1396.2030