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Recruitment of Juvenile Flatfishes in Alaska:

Habitat Preference Near Kodiak Island

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ABSTRACT

The habitat, distribution and abundance of juvenile flatfishes within the inshore waters of the Kodiak Archipelago, Alaska are examined during this ongoing interannual study. The overall objectives of this project are to (1) identify nursery grounds for juvenile flatfishes, (2) characterize those areas according to physical and biological parameters, and (3) develop indices of relative abundance for as many species as the data allow. We describe distribution for ages-0 and -1 flatfishes of each species versus location, depth, distance within (+) or outside (-) a bay, temperature, salinity, sediment type, percents gravel, sand, mud, organic content and carbonate content in the substrate, tidal stage and sunrise.

Data collected during 1991 and 1992 suggest the following conceptual models of flatfish distribution based primarily on depth and substrate. Age-0 rock sole are found predominantly in water depths less than 50 m on sand or mixed sand substrate within 10 km of bay mouths. Age-0 flathead sole are found predominantly in water depths greater than 40 m on mud or mixed mud substrate throughout bays. Age-0 Pacific halibut are found predominantly in water depths less than 40 m on mixed sand substrate near or outside mouths of bays. Age-1 yellowfin sole are found predominantly in water depths less than 40 m on mixed substrate at upper reaches of bays. Based on graphical analyses, these conceptual models appear to appropriately describe Chiniak Bay collections during August 1993 and August 1994.

EXECUTIVE SUMMARY OF RESULTS

This study was an interannual examination of the habitat parameters, distribution and abundance of juvenile flatfishes near Kodiak Island, Alaska (Figure 1), which focused on identifying flatfish nursery habitat and developing an index of juvenile recruitment. Five cruises were conducted in association with this study, including cruises in Chiniak Bay during 1993 (KI9301 and KI9302) and 1994 (KI9401 and KI9403, and a cruise in Kazakof Bay during 1994 (KI9402).

During prior funding, samples were collected in 1991 and 1992 within all major bays of Kodiak Island. The 1991 and 1992 trawl samples and physical data formed the basis of conceptual models of age-0 flatfish nursery habitat around Kodiak Island (Norcross et al. 1995A). Those models were modified slightly by the results of this study, as follows. Both age-0 and age-1 arrowtooth flounder are found in water depth >20 m on sandy mud and muddy sand near the bay mouth. Age-0 flathead sole are predominantly in water depths greater than 20 m on mud or mixed mud substrate throughout bays. Age-1 flathead sole are found in greatest abundance in depths >20 m on sandy mud and muddy sand throughout the bay. Age-0 Pacific halibut are found predominantly in water depths less than 40 m on mixed sand substrate near or outside mouths of bays. Age-1 yellowfin sole are found predominantly in water depths less than 40 m on mixed substrate at upper reaches of bays. Age-0 rock sole are found predominantly in water depths less than 50 m on sand or mixed sand substrate within 10 km of bay mouths. Age-1 rock sole are mainly in depths <40 m on sandy substrates throughout the bay.

Chiniak Bay/August 1993 (KI9301)

The cumulative CPUE of eleven species of flatfish captured at the 28 stations sampled during August 1993 within Chiniak Bay (Womens, Middle and Kalsin Bays: KI9301) was 2,798, for an average CPUE of 100±101 flatfishes/station. In order of decreasing abundance, flatfishes include flathead sole (N=1342), rock sole (N=959), yellowfin sole (N=221), Pacific halibut (N=129), arrowtooth flounder (N=69), butter sole (N=39), Alaska plaice (N=16), starry flounder (N=11), English sole (N=8), Dover sole (N=3), and sand sole (N=3). Age-0 was the numerically dominant age class collected of arrowtooth flounder, Pacific halibut, rock sole, and English sole. Age-1 fishes were caught most often of flathead sole, yellowfin sole, Alaska plaice and sand sole. Older specimens dominated catches of Dover sole, starry flounder and butter sole.

Arrowtooth flounder of ages-0 and -1 were distributed with similar patterns during KI9301. Age-0 arrowtooth flounder (N=46) were caught at 12% of stations. The mean number of age-0 fish/tow was 1.2±2.3, and the largest catch was 12 fish/tow. Age-1 arrowtooth flounder (N=18) were caught at 21% of stations. The mean number of age-1 fish/tow was 0.5±1.5, and the largest catch was eight fish/tow. Age-0 fish were caught between 20 and 80 m and age-1 fish were caught from 30 to 80 m water depth. Both ages were collected from outside to the head of the bay. Age-0 fish were caught primarily over sandy mud and gravel, while age-1 fish were nearly always caught over sandy mud.

Ages-0 and -1 flathead sole were distributed similarly during KI9301. Age-0 flathead sole (N=520) were caught at 43% of stations. The mean number of age-0 fish/tow was 13.4±38.4, and the largest catch was 166 fish/tow. Age-1 flathead sole (N=611) were caught at 61% of stations. The mean number of age-1 fish/tow was 15.8±31.4, and the largest catch was 122 fish/tow. Both ages were captured in increasing abundances from 10 to 70 m. Age-0 fish increased in abundance from outside to the head of the bay, but this pattern was not apparent for age-1 flathead sole. Age-0 flathead sole were primarily caught on sandy mud, while age-1 fish were caught on sandy mud and muddy sand. They increased in abundance with increasing percent mud in the substrate.

Age-0 Pacific halibut (N=126) were caught at 46% of stations during KI9301. The mean number of age-0 fish/tow was 5.5±10.6, and the largest catch was 60 fish/tow. During August 1993, age-0 Pacific halibut (N=126) were all caught in <30 m depth, from 3 km inside the bay to the head. They were caught mainly over sand and muddy sandy gravel, but a few fish were caught on sandy mud and muddy sand. They were slightly more abundant with increasing percent sand in the substrate.

Age-1 Pacific halibut (N=2) were caught at 11% of stations during KI9301. The mean number of age-1 fish/tow was 0.1±0.3, and the largest catch was one fish/tow.

No age-0 yellowfin sole were caught during KI9301. Age-1 yellowfin sole (N=130) were caught at 50% of stations. The mean number of age-1 fish/tow was

4.8±12.4, and the largest catch was 65 fish/tow. Age-1 yellowfin sole were caught only in depths <30 m, from 3 km inside to the head of the bay, from 9.8 to 12.0°C and 31.2 to 32.4 PSU. They were caught primarily over muddy sandy gravel and muddy sand, with lesser abundances over sand and sandy mud. Age-1 yellowfin sole increased abundance as the proportional amount of sand increased in the substrate, and decreased with increasingly muddy substrate.

Ages-0 and -1 rock sole were sometimes captured in the same strata during KI9301. Age-0 rock sole (N=687) were caught at 54% of stations. The mean number of age-0 fish/tow was 39.5±63.8, and the largest catch was 276 fish/tow. Age-1 rock sole (N=200) were caught at 64% of stations. The mean number of age-1 fish/tow was 6.6±11.3, and the largest catch was 61 fish/tow. Both age-0 (N=687) and age-1 (N=200) rock sole were caught from 0 to 70 m depth. Age-0 fish were most abundant deeper than 30 m, and age-1 fish was most abundant between 20 and 40 m. Age-0 rock sole were caught in increasing abundances from the mouth to the head of bays, while age-1 rock sole were most abundant near the mouth. Age-0 rock sole were most abundant over muddy sandy gravel, sand and muddy sand; age-1 fish were most abundant over gravel. Both age-0 and age-1 rock sole decreased slightly in abundance as the proportional amount of mud in the substrate increased.

Chiniak Bay/November 1993 (KI9302)

The cumulative CPUE of nine species of flatfish from 10 stations in Womens and Middle Bays during KI9302 was 968, for an average CPUE of 97±99 flatfishes/station. In order of decreasing abundance, these fishes include rock sole (N=352), flathead sole (N=306), yellowfin sole (N=140), arrowtooth flounder (N=130), Pacific halibut (N=18), butter sole (N=11), Alaska plaice (N=5), Dover sole (N=3), starry flounder (N=2). During November 1993 catches of age-0 flatfishes were most prevalent for arrowtooth flounder, flathead sole, Pacific halibut and rock sole. Age-1 fishes were most numerically dominant of Dover sole, yellowfin sole and Alaska plaice. Age-$\geq$2 fishes were captured most often of starry flounder and butter sole.

Ages-0 and -1 arrowtooth flounder were distributed in a similar manner during KI9302. Age-0 arrowtooth flounder (N=116) were caught at 40% of stations. The mean number of age-0 fish/tow was 11.6±23.4, and the largest catch was 67 fish/tow. Age-1 arrowtooth flounder (N=13) were caught at 20% of stations. The mean number of age-1 fish/tow was 1.3±2.8, and the largest catch was eight fish/tow. Arrowtooth flounder of both ages were only captured in water >30 m, near the mouth of Middle Bay.

Age-0 flathead sole (N=123) were caught at 70% of stations during KI9302. The mean number of age-0 fish/tow was 12.3±26.2, and the largest catch was 85 fish/tow. Age-0 flathead sole (N=123) were captured at all depths examined and at all distances from the mouth of the bay.

Age-1 flathead sole (N=119) were caught at 20% of stations during KI9302. The mean number of age-1 fish/tow was 11.9±25.6, and the largest catch was 70 fish/tow. Age-1 flathead sole were only captured in water >50 m, near the mouth of Middle Bay.

Age-0 Pacific halibut (N=15) were caught at 70% of stations during KI9302. The mean number of age-0 fish/tow was 1.5±1.8, and the largest catch was six fish/tow. Age-0 halibut were caught at all stations within bays, in depths less than 40 m.

Age-1 halibut (N=3) were caught at 10% of stations during KI9302. The mean number of age-1 fish/tow was 0.3±1.1, and the largest catch was three fish/tow. Age-1 halibut were caught at one station near the mouth of Middle Bay, in 30 - 40 m depth.

Age-0 yellowfin sole (N=9) were caught at 30% of stations during KI9302. The mean number of age-0 fish/tow was 0.9±1.7, and the largest catch was 4 fish/tow. Age-0 yellowfin sole (N=9) were caught in water <20 m deep, well within Middle Bay.

Age-1 yellowfin sole (N=80) were caught at 70% of stations during KI9302. The mean number of age-1 fish/tow was 8.0±12.0, and the largest catch was 31 fish/tow. Age-1 yellowfin sole (N=80) were caught from 10 to 60 m depth, from outside to well within the bay. The largest catches of age-1 fish were just outside the mouth of Middle Bay.

Ages-0 and-1 rock sole were distributed similarly during KI9302. Age-0 rock sole (N=255) were caught at 90% of stations during KI9302. The mean number of age-0 fish/tow was 25.5±28.1, and the largest catch was 86 fish/tow. Age-1 rock sole (N=71) were caught at 100% of stations during KI9302. The mean number of age-1 fish/tow was 7.1±5.4, and the largest catch was 21 fish/tow. Age-0 rock sole were caught at all sampled depths from outside the mouth to the head of the bay, but were most abundant in less than 40 m water depth, inside the bay. Age-1 rock sole were caught at every station during KI9302. They were most abundant in water <20 m, well within the bay.

Chiniak Bay/June 1994 (KI9401)

The cumulative flatfish CPUE from 12 stations in Womens, Middle and Kalsin Bays during KI9401 was 989, for an average CPUE of 82±56 flatfishes/station. In order of decreasing abundance, the nine species of flatfish collected during KI9401 were flathead sole (N=426), rock sole (N=354), yellowfin sole (N=135), Pacific halibut (N=55), butter sole (N=12), arrowtooth flounder (N=2), rex sole (N=2), Alaska plaice (N=1) and sand sole (N=1). During June 1994, catches of age-0 flatfishes were most prevalent only for Pacific halibut, while age-1 fishes were most numerically dominant of rex sole, flathead sole and rock sole. Age-≥2 fishes were captured most often of yellowfin sole, butter sole, Alaska plaice and sand sole. One age-0 and one age-≥2 arrowtooth flounder were caught.

Age-0 arrowtooth flounder (N=1) were caught at 8% of stations during KI9401, for a mean of 0.1±0.3 fish/tow. The age-0 fish was caught in 20 - 30 m, near the head of Kalsin Bay.

Ages-0 and -1 flathead sole were captured in the same strata during KI9401. A single age-0 was caught during KI9401 (8% of stations during KI9401, 0.1±0.3 fish/tow). This fish was caught at the head of Kalsin Bay, in <20 m depth. Age-1 flathead sole (N=265) were caught at 58% of stations during KI9401. The mean number of age-1 fish/tow was 22.1±37.7, and the largest catch was 114 fish/tow. The single age-0 flathead sole was caught at the head of Kalsin Bay, in <20 m depth. Age-1 flathead sole (N=265) were primarily caught well within Kalsin Bays, in depths 20 - 60 m.

Age-0 halibut (N=54) were caught at 75% of stations during KI9401. The mean number of age-0 fish/tow was 4.5±5.6, and the largest catch was 19 fish/tow. They were only caught in water <30 m deep and on the flood tide. No age-1 halibut were caught.

Age-0 yellowfin sole (N=60) were caught at 58% of stations during KI9401. The mean number of age-0 fish/tow was 5.0±8.8, and the largest catch was 31 fish/tow. Age-0 yellowfin sole were only captured in <30 m water depth, from 3 km within to the head of the bay. Age-1 yellowfin sole could not be separated from older fishes, and are not discussed.

Age-0 rock sole (N=57) were caught at 42% of stations during KI9401. The mean number of age-0 fish/tow was 4.8±8.4, and the largest catch was 26 fish/tow. Age-0 rock sole were all caught in less than 40 m water depth, near the head of Kalsin Bay.

Age-1 rock sole (N=172) were caught at 67% of stations during KI9401. The mean number of age-1 fish/tow was 14.4±15.5, and the largest catch was 41 fish/tow. Age-1 rock sole were caught in <30 m water depth, in large abundances from the mouth to the heads of bays.

Chiniak Bay/August 1994 (KI9403)

The cumulative CPUE of 12 flatfish species at 27 stations examined during August 1994 sampling in Middle and Kalsin Bays (KI9403) was 4486, for an average CPUE of 166±182 flatfishes/station. In decreasing order of abundance, these species include rock sole (N=2,461), flathead sole (N=901), arrowtooth flounder (N=678), Pacific halibut (N=284), yellowfin sole (N=76), butter sole (N=36), English sole (29), starry flounder (N=7), sand sole (N=5), Alaska plaice (N=4), rex sole (N=3) and Dover sole (N=2). During August 1994 age-0 was the numerically dominant age class collected of arrowtooth flounder, rex sole, Pacific halibut, rock sole, and English sole. Age-1 fishes were caught most often of flathead sole and yellowfin sole. Age-0 and age-1 were equally dominant age classes for starry flounder. Older specimens (age-

≥2) dominated the catch of Dover sole, butter sole and sand sole. Equal numbers of age-1 and age-≥2 Alaska plaice were captured.

Age-0 arrowtooth flounder (N=663) were caught at 55.6% of stations during KI9403. The mean number of age-0 fish/tow was 12.3±32.4, and the largest catch was 157 fish/tow. Arrowtooth flounder was the second most abundant age-0 fish. Age-0 arrowtooth flounder were found in all regions of the bays (-2.5 to 6.5 km from the bay mouth), from 20 to 100 m water depth and on all substrates sampled.

Age-1 arrowtooth flounder (N=3) were caught at 11.1% of stations during KI9403. The mean number of age-1 fish/tow was 0.1±0.3, and the largest catch was two fish/tow. Age-1 arrowtooth flounder were only found outside the mouth of the bays (-1.8 to -2.4 km), from 50 to 80 m water depth and on sand or muddy sand substrate.

Age-0 (N=358) and age-1 (N=385) flathead sole were found in nearly equal abundance, and the distribution parameters of age-0 and age-1 fish were nearly identical. Both ages were caught at 44.4% of stations during KI9403. The mean number of age-0 fish/tow was 10.6±41.1, and the largest catch was 271 fish/tow; the mean number of age-1 fish/tow was 9.9±24.5, and the largest catch was 135 fish/tow. Flathead were found in waters 10 - 90 m, in increasing abundance to 55 m depth and in decreasing abundance with further increasing depth. They were -2.4 to 7.7 km from the mouth of the bay, but neither age was collected at the head of either Kalsin or Middle Bay. Age-0 and age-1 flathead were found on muddy sand and sandy mud substrate, with abundances generally increasing with increasing percent mud and decreasing with percent sand.

Age-0 Pacific halibut (N=282) were caught at 51.9% of stations during KI9403. The mean number of age-0 fish/tow was 20.3±18.2, and the largest catch was 68 fish/tow. Ages-0 and -1 (N=1) Pacific halibut were found only in depths under 50 m, primarily under 30 m. While halibut were found throughout and outside the bays (age-0 from -1.6 to 8.2 km and age-1 at 2.4 km from the bay mouth), most were found at the heads of Kalsin and Middle Bays coincident with these depths. Age-0 halibut were collected over sand, muddy sand and sandy mud substrates and the age-1 fish was on sand substrate.

Age-0 was the least abundant group of yellowfin sole captured during KI9403 (N=3). Age-0 yellowfin sole were caught at 7.4% of stations. The mean number of age-0 fish/tow was 0.1±0.3, and the largest catch was two fish/tow. Age-0 yellowfin were found only outside the mouth of Kalsin Bay (-0.7 to -1.6 km). Age-0 fish were found in 20 - 50 m on sand and gravel substrates.

Age-1 yellowfin sole (N=25) were caught at 22.2% of stations during KI9403. The mean number of age-1 fish/tow was 5.0±9.9 and the largest catch was 43 fish/tow. Yellowfin sole was the third most abundant (N=25) age-1 fish. Age-1 yellowfin were found throughout and outside the bays (-0.7 to 8.2 km from the bay mouth). Age-1 fish were found in 0 - 40 m on sand and muddy sand substrates.

Ages-0 and -1 rock sole had similar distributions during KI9403. Rock sole was the most abundant (N=2,219) age-0 fish and the second most abundant (N=183) age-1 fish. Age-0 rock sole were caught at 66.7% of stations. The mean number of age-0 fish/tow was 168.0±194.5, and the largest catch was 680 fish/tow. Age-1 rock sole were caught at 51.9% of stations during KI9403. The mean number of age-1 fish/tow was 8.7±9.8, and the largest catch was 36 fish/tow. Age-0 and age-1 rock sole were found outside and throughout the bays (-2.4 to 8.2 km from the bay mouth) in depths up to 80 m, but both ages were primarily concentrated in less than 50 m water depth. Both ages were found on all substrates sampled (sand, muddy sand, sandy mud, sandy gravel, and gravel). Age-0 rock sole abundances increased with increasing percent of sand and decreasing percent of mud.

Kazakof Bay/August 1994 (KI9402)

The cumulative mean CPUE flatfish /station of flatfishes from quantitative tows at 29 stations examined during August 1994 within Kazakof Bay (KI9402) was 440, for an average CPUE of 15±18 flatfishes/station. Listed in decreasing order of abundance, these species include flathead sole (N=275), yellowfin sole (N=111), rock sole (N=47), Pacific halibut (N=4) and English sole (N=4). Catches of age-0 fish were most prevalent for Pacific halibut, rock sole and English sole. Age-1 was the numerically dominant age captured of flathead sole and yellowfin sole.

Age-0 flathead sole (N=85) were caught at 34% of stations during KI9402. The mean number of age-0 fish/tow was 3.0±6.1, and the largest catch was 27 fish/tow. Age-0 fish were captured primarily down the center of Kazakof Bay; they were not at the head of the bay. They were caught in 20 - 90 m water depth and increased in abundance with increasing depth.

Age-1 flathead sole (N=130) were caught at 48% of stations during KI9402. The mean number of age-1 fish/tow was 4.2±6.2, and the largest catch was 21 fish/tow. Distribution of age-1 fish was similar to age-0 fish. Age-1 fish were not captured at the head of the bay. Age-1 flathead sole were caught in 20 - 100 m water depth, and were most abundant from 40 to 80 m water depth.

Age-0 Pacific halibut (N=4) were caught at 3% of stations during KI9402. The mean number of age-0 fish/tow was 0.1±0.6, and the largest catch was four fish/tow. Age-0 halibut were caught at a single station near the head of Kazakof Bay, in 10 - 20 m water depth. No age-1 halibut were caught during KI9402.

Yellowfin sole were not caught as age-0 during KI9402. Age-1 yellowfin sole (N=92) were caught at 17% of stations. The mean number of age-1 fish/tow was 2.6±10.9, and the largest catch was 60 fish/tow. Age-1 yellowfin were caught in 10 - 40 m water depth, from 13 to 18 km inbay.

Age-0 rock sole (N=24) were caught at 17% of stations during KI9402. The mean number of age-0 fish/tow was 0.9±2.6, and the largest catch was 12 fish/tow. Age-0 fish were caught from 0 to 50 m water depth, and from 12 to 20 km inbay.

Age-1 rock sole (N=19) were caught at 17% of stations during KI9402. The mean number of age-1 fish/tow was 0.6±2.2, and the largest catch was 12 fish/tow. Like age-0 fish, age-1 rock sole were caught from 0 to 50 m water depth and 12 to 20 km inbay.

INTRODUCTION

Identification of Problem

Despite the strong economic importance of the commercial and sport fisheries in Alaska and possible future State and Federal gas and oil exploration in Cook Inlet and the Gulf of Alaska, knowledge of the early life history of flatfishes in Alaskan waters has been minimal prior to this study. This study was an interannual examination of the habitat parameters, distribution and abundance of juvenile flatfishes near Kodiak Island, Alaska, focused on identifying flatfish nursery habitat and developing an index of juvenile recruitment. Identification of juvenile flatfish habitat is necessary in order to protect them from habitat disruption. The index of juvenile recruitment will allow more effective and timely management by regulatory agencies and will assist with planning by members of the fishing community and oil and gas industries.

The commercial fishery for flatfish in Alaska took 267,529 mt in 1989, due to directed commercial and sport fisheries as well as to commercial bycatch. It is important to identify nursery areas in order to protect them from habitat disruption. Possible future State and Federal gas and oil exploration in Cook Inlet Sale 149 and Gulf of Alaska/Yakutat Sale 158 will benefit from this study which will identify flatfish nursery habitats which may be biologically sensitive areas. The nursery habitat is characterized by physical parameters including depth, sediment type, position in bay, temperature and salinity. The linkages between the physical and ecological processes explored here could aid in prediction of the potential effects of proposed gas and oil exploration and development in the area on the region's biological resources.

This project continued a long term study begun in 1991 to locate and characterize nursery areas for flatfishes in Alaska and to develop a juvenile recruitment index for the most abundant species. Understanding and monitoring an index of juvenile recruitment is important because it is a mechanism for testing the health of the ecosystem.

Study location

Initial selection of sampling locations and sites along the coast of Kodiak Island (Figure 1) began with the acknowledgment that the coastline of the Gulf of Alaska is more rugged and has a greater tidal range than flatfish nursery areas in many other locations around the world. Most of the Gulf coast of Alaska is completely inaccessible except by large vessel because of lack of roads and extremes of weather. Kodiak Island is representative of the coastline of the Gulf of Alaska because it provides a variety of habitat from shallow, fine-grained tidal flats to deep and rocky areas. Kodiak Island was chosen as the sample site because it has (1) a UAF/SFOS lab for staging of field work, (2) sites near town which are accessible by small boat, (3) a large trawl fleet available for charter to remote areas of the island, (4) an informed and concerned citizenry who wish to protect their resources and their fishery-based economy. Chiniak

Bay is near the town of Kodiak and is the only region of Kodiak Island which is easily accessible via road from the town of Kodiak. Chiniak Bay encompasses three inner bays which are protected to varying degrees (Figure 1: Womens, Middle and Kalsin Bays) as well as providing relatively accessible and unprotected zones outside the mouths of these bays.

Sample collection was continued during 1993 and 1994 as a result of this funding; collections were limited to Chiniak Bay during 1993, and to Chiniak Bay and Kazakof Bay (on Afognak Island) during 1994.

Previous work

Prior funding provided two years of sampling (1991 - 1992) during which all major bays of Kodiak Island were examined in order to form a broadly based characterization of flatfish nursery areas around Kodiak. We described fish distribution versus the parameters of location in the bay, depth, bottom temperature, bottom salinity and sediment type (Norcross et al. 1995A, Norcross et al. 1995B). Distributions overlapped for the most abundant juvenile flatfishes (ages-0 and 1 rock sole, yellowfin sole, flathead sole and Pacific halibut), yet patterns of peak abundance were unique to each of these species.

The following conceptual models of the physical parameters most descriptive of flatfish nursery habitat have been postulated based on 1991 - 1992 distribution of flatfishes around Kodiak Island (Norcross et al. 1995A). Age-0 rock sole are found predominantly in water depths less than 50 m on sand or mixed sand substrate within 10 km of bay mouths. Age-0 flathead sole are found predominantly in water depths greater than 40 m on mud or mixed mud substrate throughout bays. Age-0 Pacific halibut are found predominantly in water depths less than 40 m on mixed sand substrate near or outside mouths of bays. Age-1 yellowfin sole are found predominantly in water depths less than 40 m on mixed substrate at upper reaches of bays.

The current project describes and analyzes the recruitment of juvenile flatfishes to inshore waters of Kodiak Island, Alaska. Analysis of data collected in Chiniak Bay during 1992 was funded partially and during 1993 and 1994 was funded primarily by the Coastal Marine Institute. Dietary analysis of flatfishes captured during 1991 was funded partially by Coastal Marine Institute.

Overall Program Goals and Objectives

1. To identify nursery areas for juvenile flatfishes,

2. To characterize those nursery areas according to physical and biological parameters, and

3. To develop indices of relative abundances for as many juvenile flatfish species as the data allow.

Background Information

Populations of thirteen Alaskan species of flatfishes are found near Kodiak Island (Rogers et al. 1986, Norcross et al. 1993, 1995A). The prime targets for commercial fisheries are Pacific halibut (*Hippoglossus stenolepis*), flathead sole (*Hippoglossoides elassodon*), rock sole (*Pleuronectes bilineatus*), rex sole (*Errex zachirus*) and Dover sole (*Microstomus pacificus*). There are also directed fisheries for English sole (*Pleuronectes vetulus*) and starry flounder (*Platichthys stellatus*). By-catch includes yellowfin sole (*Pleuronectes asper*), Alaska plaice (*Pleuronectes quadrituberculatus*), butter sole (*Pleuronectes isolepis*) and sand sole (*Psettichthys melanostictus*) which are marketed secondarily. There is currently an attempt to develop a fishery for arrowtooth flounder (*Atheresthes stomias*) to be used in surimi. Additionally, Pacific sanddab (*Citharichthys sordidus*) has occasionally been captured near Kodiak (Norcross et al. 1993).

Relative abundance of species and community composition changes from bays across the Alaskan continental shelf, with most species of fish increasing in size with depth. This indicates shallow areas are important as nursery areas in Alaska (Rogers et al. 1986).

Preferred conditions of nursery areas for flatfishes

Little information is available on flatfish nursery habitat in Alaskan waters, although the highest mortality of fishes is during the larval and juvenile stages (Moyle and Cech 1988). However, nursery habitat has been described for flatfishes in other regions of the world. Intertidal zones, shallow coastal areas, protected bays and estuaries are often considered vital as nursery areas for flatfishes (e.g. Tyler 1971, Gibson 1973, van der Veer and Bergman 1986, Tanaka et al. 1989). Abundance and size distributions of juvenile flatfishes have been related to depth, sediment size and food availability. Flatfish nurseries are usually in shallow waters, often in less than 10 m (Edwards and Steele 1968, Allen 1988, van der Veer et al. 1991), on substrates of silt, mud, and fine to coarse sand (Poxton et al. 1982, Wyanski 1990). Shallow bays and estuaries are thought to serve as excellent nursery areas and ideal feeding habitat because of high insolation of the bottom, high water temperatures and the particular sediment types found in protected waters (Pearcy and Myers 1974), in addition to the good supply of nutrients from land drainage (Pihl and Rosenberg 1982).

Substrate type, current velocity, depth, salinity and food availability may help determine where flatfish initially settle, and may also guide the distribution of older individuals. Sediments in flatfish nursery areas are generally silt, mud or fine to coarse sand (Poxton et al. 1982, Wyanski 1990). A dominant substrate of gravel or coarser materials reduces the suitability of an area to serve as a nursery (Rogers 1985). Burying ability of juvenile flatfishes probably depends on several factors associated with sediment in addition to grain size (e.g. particle compacting, cohesion, binding by activity of benthic fauna) (Gibson and Robb 1992). Abundance of young-of-the-year flatfishes is profoundly influenced by water depth, a phenomena shown by Riley et al. (1981) for species in the English North Sea. Newly metamorphosed plaice of the genus *Pleuronectes* were found to actively select shallow depths in the North Sea (Edwards and Steele 1968).

Depth distribution changes with age, and may limit both intra- and interspecific competition among flatfishes (Poxton et al. 1983). Competitive fish species may reduce range overlap by maintaining localized feeding. A nursery may be partitioned into areas dominated by separate species or intraspecific age groups (Edwards and Steele 1968, Harris and Hartt 1977, Smith et al. 1976, Zhang 1988). The correlation between mean length of fish and depth for some species is significant (Gibson 1973). Large quantities of juvenile rock sole were taken by Harris and Hartt (1977) intertidally in the Kodiak area, with older individuals taken near the mouths of fjords. A reversal of this trend was exhibited by flathead sole in which larger fish were found toward the heads of Kodiak bays (Blackburn 1979).

Geologic description of the Kodiak Archipelago

The Kodiak Archipelago (Figure 1) is an island arc collision coast in the western Gulf of Alaska where oceanic crust is being thrust under a thicker, less dense continental plate. Uplifted subduction zone complexes have given Kodiak a rugged, mountainous relief. The topography of the Kodiak area was strongly affected by heavy glaciation during the Pleistocene. In general, the islands are erosional, with perhaps as much as 20 to 30% of the shoreline depositional, but only 2.6% of the total shoreline consists of sheltered tidal flats and marshes (Hayes and Ruby 1979). Local conditions determine the character and behavior of the sediment, but in general, mean grain size for Kodiak and Afognak Island beach samples generally ranges between very coarse sand and pebbles, with particle size decreasing seaward, producing a graded sediment distribution (Hayes and Ruby 1979).

The western coastline of the Kodiak archipelago is backed by steep slopes of glacial till, leading to a coarse-grained beach supplied by glacial deposits. A predominance of sandy beaches is found on the western coast of Kodiak and within the Trinity Islands due to an abundance of unconsolidated glacial material with a high percentage of sand. The northwest side is a dramatic example of glaciation, having steep slopes butted up against straight shorelines with narrow gravel beaches. The northwest shore is indented by long narrow fjords. Thick deposits of glacial till blanket the southwest corner of Kodiak Island. Shorelines in this area are generally long and continuous, with glacial till contributing sand, gravel and boulders to the beach and coastal sediments. Southwest Kodiak and the nearby Trinity Islands have fine to coarse grained sediments (Hayes and Ruby 1979).

Bedrock outcrops back the beaches on the east of Kodiak and Afognak Islands, producing beach sediments which are very coarse grained and homogeneous (Hayes and Ruby 1979). Along southeast Kodiak, short, wide estuaries tend to run northeast-southwest, a direction parallel to the major thrust faults of the island. Afognak Island and northeast Kodiak have small pocket beaches eroded by wave action, similar to the southeast of Kodiak. Northeastern Kodiak bays have fine to coarse grained sand, with muddy areas in deeper portions of bays. We have observed the sediment of southeast Kodiak around Sitkinak Strait and Alitak Bay to be of shell hash and medium to fine-grained sand.

Rivers draining into the fjords dump large amounts of glacial till, creating deltas of sand and fine gravel. The beaches in Kodiak fjords are variable, but tend to be coarse due to local bedrock sediment sources. Where rivers empty onto the open coast, sand and gravel beaches occur downdrift (Hayes and Ruby 1979).

METHODS

Description of sample locations

Description of Chiniak Bay

Cruises during 1993 (KI9301 and KI9302), and two of three cruises during 1994 (KI9401 and KI9403) consisted of land-based collections conducted within Chiniak Bay, near the town of Kodiak, Alaska (Figure 1). Kalsin, Middle and Womens Bays were chosen for intensive sampling because they were near town, facilitating land-based operations, and thus could be sampled on repeated days at a low cost. The NMFS laboratory on the Kodiak Coast Guard Support Center was the base for sampling operations, and the Fishery Industrial Technology Center (FITC/SFOS/UAF) provided vehicles, space for office and laboratory work as well as storage space for gear and frozen samples.

Womens, Middle and Kalsin Bays are offshoots of Chiniak Bay (57°40'N, 152°30'W) approximately 10 nmi from the town of Kodiak. Tidal range in this area is approximately 2.5 m. Because these bays were sampled with a small vessel, extremely shallow collections could be made.

Womens Bay is about 7 km long, with an area of approximately 12 km^2. Womens Bay is more shallow and protected than either Kalsin or Middle Bays. Womens Bay is less than 10 m in depth at the mouth, but there is a deep hole midbay (z=33 m). At the head of Womens Bay, a tidal marsh extends for nearly 1 km inland. Most of inner Womens Bay is less than 10 m deep.

Middle Bay is about 8 km long with an area of approximately 21 km^2. It is intermediate with regard to depth and protected shoreline than Womens or Kalsin

Bays, and has a depth of 50 m at the mouth. Middle Bay is surrounded by cliffs and at the head of the bay there are marshes behind a sandy beach. The shallow areas extend farther from the shoreline of Middle Bay than do the shallow areas of Kalsin Bay. Inner Middle Bay, approximately 2 km wide, is less than 10 m deep, much shallower than Kalsin Bay.

Kalsin Bay covers an area of approximately 34 km^2, and is 8 km from mouth to head. It is a deep bay with waters in excess of 100 m at the mouth. Nearshore waters drop off rapidly, with waters of < 10 m depth comprising a narrow zone of < 0.5 km around most of the edges of the bay to 1 km at the head. Kalsin Bay is surrounded by cliffs except at the head where a marsh extends behind a sandy beach.

Description of Kazakof Bay

Cruise KI9402 during 1994 consisted of land-based collections conducted within Kazakof Bay, Afognak Island (Figure 1). Ben A. Thomas Logging Camp was the base for sampling operations and personnel.

Kazakof Bay is a long, narrow bay, covering an area of approximately 60 km^2. It opens to the south along the southern coast of Afognak Island. Kazakof Bay is 20 km long, and the mouth of the bay is approximately 5 km wide. The bottom contour is steep in nearshore areas along the east and west sides of the bay. Near the head of the bay, stations could be occupied in depths less than 30 m.

Sample collections

General collection procedure, all cruises

Four of the cruises were a joint effort between the Institute of Marine Science, University of Alaska Fairbanks (IMS/UAF) and the National Marine Fisheries Service, Kodiak Laboratory (NMFS/Kodiak). Collection gear and sampling vessel used in Chiniak Bay during KI9301, KI9302, KI9401 and KI9403 were identical, but were not the same as had been used during previous years (Cruises KI9101, KI9102, KI9201 and KI9202). The vessel used during cruises KI9301, KI9302, KI9401 and KI9403 was the *R/V Pumkin*, a 25 ft Boston Whaler owned and operated by NMFS/Kodiak. Identical gear was deployed from a 25 ft aluminum skiff in Kazakof Bay during KI9402. The slightly different sampling procedure used during KI9402 is explained in a following section; methods used in Chiniak Bay are described in this section. Gear is listed and described in Appendix 1.

Station numbers were assigned in consecutive order (hereafter referred to as consecutive station number or CS#) for each cruise. Consecutive station numbers were assigned for all sites at which gear was deployed. Usually, a CTD, sediment grab and trawl were deployed at each station. Trawl tow numbers were assigned consecutively at each station whether or not the tow was judged quantitative. During

KI9301 and KI9403, selected stations were examined by NMFS divers using SCUBA gear.

In addition to the consecutive station numbers which were reassigned on each cruise, many sites which were sampled annually have been identified by a permanent station code. The permanent station code reflected the bay, depth range and sediment type at which the sample was taken (Table 1). The "depth" portion of the permanent station codes was assigned based on the depth at low tide; due to the broad tidal range near Kodiak, the towing depth may appear to be inconsistent with the depth of the station code. Stations within the same bay, depth and sediment type had the same permanent station code regardless of location within a bay, and were considered as replicate stations. Within a specific bay and depth range, various sediment types were found. Sites within one bay of the same depth range, but with different sediment types were distinguished by a single digit added to the depth increment (i.e. KB20, KB21 and KB22). All sampling sites in the same depth increment and sediment type had the same digit for the specific sediment type (i.e. KB31 and MB31 had the same depth and sediment type; KB50 and MB52 had the same depth, but different sediment types). With this naming system, sites for comparison among and within bays were readily apparent.

Substrate was collected for grain size analysis using a 0.06 m^3 Ponar grab. Single substrate samples were taken at nearly every station. Except for dive transect stations where multiples grabs were taken, we rarely collected replicate substrate samples. Sediment was retained frozen and shipped to Fairbanks for laboratory grain size analysis. During 1991, 1992 and 1993 (KI9101, KI9102, KI9103, KI9201, KI9202 and KI9301) sediment was subsampled and preserved in 10% formalin for benthos taxonomy, but following cruise KI9301, we determined not to collect further benthos or analyze benthos collected during 1992 or 1993. KI9201, KI9202 and KI9301 benthos samples were discarded and no further benthos samples were retained during this project, due to time and fiscal limitations.

Vertical profiles of salinity and temperature were recorded with a portable SeaBird Seacat Profiler 19 (CTD). This instrument is a self-contained unit which does not have a real-time readout, and the data were dumped periodically to a portable computer. Replicate CTD casts were collected only in rare instances. The CTD was allowed to equilibrate for two min. at 1 m depth and was then deployed by hand until the 10 lb. weight fastened below the sensors touched bottom. The CTD recorded measurements of temperature, depth and salinity at half second intervals. The array of temperature and salinity profiles collected during each cruise indicates general patterns of water movement.

Fishes were sampled using a plumb staff beam trawl with a double tickler chain adapted from a design by Gunderson and Ellis (1986). The very small mesh (7 mm square) and codend liner (4 mm) retains flatfishes as small as 12 mm (Norcross et al. 1993). With a few exceptions, all collections in 1993 and 1994 were made with a 3.05

m (10 ft) beam rather than the 3.66 m (12 ft) beam which had been used during 1991 (KI9101, KI9102 & KI9103) and 1992 (KI9201 & KI9202). As in previous years of sampling, the trawl design was modified via the addition of floats to the ends of the beam and 150 mm lengths of chain knotted to the footrope at 150 mm intervals. In 1993 and 1994, endeavors were made to sample as slowly as possible in order to tow at a speed comparable to previous years' collections. The tow speed was approximately 0.5 kt for KI9101 and KI9201, 1.0 - 2.0 kt for KI9102 and KI9202, KI9301, KI9302, KI9401, KI9402 and KI9403.

Precise measurements of distance towed were unavailable for many tows, and therefore the number of fishes captured during each tow was standardized to a 10 min. tow duration. The standardized catch-per-unit-effort (CPUE) accounts for the value of N being other than a whole number. Figures report the N of fishes as the nearest whole number (or 1). In exceptional cases the number of fish plotted on a figure may not appear to equal the N stated in the title. To avoid confusion, many of these instances are noted on the plot (i.e. *rounded value). The effective width of the tow was expected to be 0.74 * beam length (Gunderson and Ellis 1986), and was estimated as 2.257 m for the 3.05 m beam and 2.707 for the 3.66 m beam, resulting in an approximate average tow area of 1000 m^2, assuming that the net was towed over a distance of 450 m. Future analyses will be based on distance CPUE standardized to a 1000 m^2 tow area, rather than on tow duration.

While the original hypothesis was that juvenile flatfishes should be found in shallow water on relatively smooth bottoms, a variety of depths and substrates were sampled. Collections generally were stratified in 5 m depth increments from 0 to 10 m and in 10 m increments for deeper sites. Trawling was primarily done during the rising tide and in daylight. The start time of each tow or dive was quantified by minutes after high tide and minutes after sunrise (e.g. -100 signifies 100 minutes before high tide, 10 signifies 10 minutes after high tide. The same pattern holds for minutes before and after sunrise).

One half to 5/8 in. nylon double braided line was put out to achieve a 8:1 line:depth ratio at stations less than 10 m, 5:1 ratio for depths 10 - 50 m and 3:1 ratio at depths greater than 50 m. Aboard the *R/V Pumkin*, (KI9301, KI9401 and KI9403) line was put out by hand through the crab block. The crab block was equipped with hydraulic power, was used off the starboard to deploy the grab and CTD, and was pivoted inboard to deploy, tow and retrieve the tow line off the stern. The trawl was deployed and retrieved off the starboard. A bolt held the crab block in place during starboard operations, and a line from the bow was clipped to the block during trawl operations to secure the block perpendicular to vessel motion. The tow line was attached at the port cleat during tows. Tow speed was approximately 1.0 - 2.0 kt with an estimated 380 - 700 m covered by each tow. Tow duration was usually 10 min. When the bottom was excessively muddy, we reduced tow time to 5 min. to facilitate sorting and because we expected towing with a clogged net to reduce fishing efficiency.

Flatfishes and roundfishes sampled with the trawl were identified and total length (mm) was measured in the field. These data were later entered into a database using either a Limnoterra digital fish measuring board (KI9301) or manual data entry (all other cruises). Large numbers (>100) of a single species were sometimes collected during one tow; occasionally we measured a subsample of the youngest year-class, all older fishes were measured. During KI9301 and all 1994 cruises, a subsample of large (>200 mm) flatfishes was examined in the field for stomach contents, sex and maturity stage. Stomachs, sex and maturity were not examined for any fishes during KI9302. Small specimens of all flatfishes except flathead sole, yellowfin sole and rock sole were retained frozen for possible gut content analysis. Flathead sole, yellowfin sole and rock sole were not retained, because a large amount of feeding data had been collected for these species in 1991 (KI9101 & KI9102). No weight data were collected on fishes during 1993 or 1994.

Trawl/dive transects were established at two stations in 1993 and two stations in 1994. Similar to tows at all other stations, trawl/dive comparisons were conducted primarily on a flood tide and always during day light. The beam trawl was towed parallel to, and approximately 100 ft on either side of, diver transect lines. Trawling was conducted concurrent with the dives. A transect line of 1/2 or 5/8 in. nylon line was weighted at each end by a 15 or 20 pound anchor and deployed at each station. A large buoy was fastened to each anchor with sufficient 3/16 in. polypropylene line for the buoy to float freely and mark the diver transect. Two transect lines were generally laid end to end. NMFS divers worked in teams of two persons; while the first diver sampled one transect, the other diver dove on the adjacent transect. After waiting a minimum of 15 minutes, a diver surveyed the transect which had just been sampled by the other diver. During both 1993 and 1994 NMFS divers observed a 2 or 3 ft (0.61 or 0.91 m) swath (dependent upon visibility) along a 600 ft (182.9 m) transect line and reported on numbers of flatfishes and roundfishes seen concentrating their observations on flatfishes. An exception to this was KI9403 CS#6 (tows 2, 3, 5 and 7 and dives 2, 3, 5 and 8) which used a 778 ft (255.2 m) transect line.

Divers differentiated between small, medium and large flatfishes at all stations. Small flatfish were defined as 0 - 99 mm, medium as 100 - 179 mm, and large as 180 mm and larger. Flatfish data are quantitative, but divers were able to identify only the larger flatfish to species with certainty. Divers were able to observe flatfishes as small as 10 mm total length.

Collections within Chiniak Bay/August 1993 (KI9301)

Trawling and diving surveys were conducted within Chiniak Bay during 12 - 24 August 1993 (Table 3, Figure 2). The fisheries field crew for cruise KI9301 consisted of Brenda Norcross and Brenda Holladay of IMS/UAF, both of whom had been involved in field collections of juvenile flatfishes in 1990 - 1992. The crab field crew included Eric Munk, Susan Payne, Pete Cummiskey and Bob Otto, all of NMFS/Kodiak. Braxton Dew (NMFS/Kodiak) and Eric Munk performed SCUBA dives concurrently with KI9301 trawling operations. Eric Munk usually operated the *R/V Pumkin*, but during simultaneous trawling/diving operations, Pete Cummiskey was vessel operator.

Cruise KI9301 (9 sampling days: 12 - 24 August) added to our annual August index of juvenile flatfish distribution and abundance in Womens, Middle and Kalsin Bays. Target species included flatfishes, tanner crabs and miscellaneous roundfishes and crabs. Collections occurred at new sites as well as established station sites which had been occupied during previous years. Five stations were occupied within Womens Bay during KI9301. Womens Bay was previously sampled during 1992 (KI9201), but not 1991. Ten stations were occupied in Middle Bay during KI9301. Middle Bay was examined intensively during 1991 (KI9101, KI9102 and KI9103) and 1992 (KI9201). Fifteen stations were occupied in Kalsin Bay during KI9301. Kalsin Bay was sampled intensively during 1991 (KI9101, KI9102 and KI9103) and 1992 (KI9201).

Tows during KI9301 used a 3.05 m or 3.66 m beam. At the first 26 consecutive stations, fishes and crabs were collected with a 3.05 m beam rather than the 3.66 m beam which had been used during 1991 (KI9101, KI9102 & KI9103) and 1992 (KI9201 & KI9202). At CS#27-30, tows were conducted with both the 3.05 m and 3.66 m beams in order to compare ease of deployment and catch collected using the two beams. The shorter beam was easier to manipulate both on deck and during deployment/retrieval and has since been used in 1993 and 1994 trawling operations.

Sediment was collected at each station during KI9301, and CTD profiles were recorded at all stations during KI9301 except CS#27-30. Due to operator or equipment error, no CTD data are available to relate with tows from the final four stations during KI9301. Twenty-eight stations were sampled successfully by beam trawl, including CS#2-9 and CS#11-30. Successful replicate tows were collected only at CS#27-30.

Consecutive stations 27-30 during KI9301 were examined repeatedly by trawl and SCUBA divers in order to create a baseline for quantifying trawl catches versus diver observations. At each station, four dives and three (CS#27) or four (CS#28-30) quantitative tows were conducted. Dive transects were always 600 ft long, and the trawl was towed for ten minutes.

Collections within Chiniak Bay/November 1993 (KI9302)

Cruise KI9302 (Table 4, Figure 3) was conducted by Eric Munk, Susan Payne and Brad Stevens (NMFS/Kodiak); IMS/SFOS/UAF was not represented. Tanner and other crabs were the target species. In addition to the target species, flatfishes were collected for this project. Five sampling days (8, 9 and 17 - 19 November) provided a seasonal component to both the flatfish length analyses and to indices of flatfish distribution and abundance. The only gear deployed successfully was the 3.05 m beam trawl. A 1.8 m beam trawl with a net of like mesh but shorter headrope and footrope than the 3.05 m beam trawl was deployed unsuccessfully at CS#1 and CS#2 Tow#1, after which that gear type was abandoned. The CTD was deployed, but due to equipment malfunction, no data were retrieved. The sediment grab was not deployed. Three stations were sampled in Womens Bay, and nine stations were sampled in Middle Bay during KI9302. Kalsin Bay was not occupied during this cruise.

Collections within Chiniak Bay/June 1994 (KI9401)

Eric Munk and Susan Payne of NMFS/Kodiak and Brenda Holladay of IMS/UAF collected data within Chiniak Bay during 20 - 21 June 1994 (Table 5, Figure 4). Eric Munk operated the vessel. The 3.05 m beam trawl was deployed. The CTD was not deployed due to equipment malfunction, and the sediment grab was not deployed. During KI9401, one station in Womens Bay, four stations in Middle Bay and seven stations in Kalsin Bay were occupied.

Collections within Chiniak Bay/August 1994 (KI9403)

Similar to KI9301, trawling and diving surveys were conducted during KI9403, and target species included flatfishes, tanner crabs and miscellaneous roundfishes and crabs (Table 6, Figure 5). The fisheries field crew for cruise KI9301 consisted of Brenda Norcross, Brenda Holladay, Franz Müter and Sherri Dressel of IMS/UAF. Eric Munk collected crab data. Braxton Dew (NMFS/Kodiak) and Pete Cummiskey performed SCUBA dives concurrently with KI9403 trawling operations. Eric Munk operated the *R/V Pumkin* during all consecutive station tows, as well as during simultaneous trawling/diving operations.

Data were collected at each station by one or more of the following: beam trawl, sediment grab, CTD and SCUBA divers. Womens Bay was not sampled during KI9403. Of the 12 stations sampled in Middle Bay, all except CS#23 and 29 were sampled in previous years. CS#23 consisted of four non-quantitative tows at the head of Middle Bay with no sediment or CTD data collected and is not included in KI9403 figures. Of the 18 stations sampled in Kalsin Bay, eight were new stations (CS#13-18 and 24) and 10 had been previously sampled. In KI9403, several of the new Kalsin stations sampled were deeper and further outside the mouth of the bay than in previous years (CS#13-15, 17 and 18). Consecutive stations 22 and 28 in Kalsin Bay consisted of only non-quantitative tows, and therefore are absent from fish abundance plots. Sediment and CTD data were collected at CS#28 but not at CS#22. Sediment samples were retained from all stations except CS#22 and 23, for grain size analysis. Replicate sediment samples were taken only at CS#13 and 14, since tows were made on different days, and at dive transects CS#6 and 12.

Fifty-nine successful CTD casts were recorded, including CTD casts at all stations except CS#22 and 23, where all tows were non-quantitative. Replicate CTD casts were made at consecutive station numbers 10, 13, 14, 25 and 26 where tows were made on different days (CS#13, 14, 25 and 26), when a significant amount of time passed between tows (CS#26 tow 2 and tow 3) or when location varied slightly (CS#13 tow 2). Multiple CTD casts were also made at the dive transects, CS#6 and 12.

Fishes were sampled at thirty stations with a 3.05 m beam trawl, resulting in a total of 56 quantitative tows at 27 stations (CS#1-21, CS#24-27 and CS#29-30). Replicate tows were made at CS#6, 12, 13, 25 and 26.

In addition to the trawls completed in KI9403, and as was done in 1993, two stations (CS#6 and 12) were sampled with repetitive tows and SCUBA dives in order to compare the efficiency of beam trawl versus SCUBA divers in identifying and quantifying flatfishes on different bottom types. In order to make statistical comparisons between beam trawl catches and diver observations, we maximized the number of replicated diver observations and beam trawl catches at these two stations. Data collected at the trawl/dive stations sampled during both 1993 and 1994 will be used to determine whether SCUBA divers may be used interchangeably with beam trawl tows in areas and on substrates where trawling is ineffective or impossible.

During KI9403, CS#6 and CS#12 were each sampled with 14 quantitative tows and 12 or 16 dives, respectively, over a period of two days. Transect lines were laid end to end in the same manner as in 1993. Unlike KI9301, when the trawl was towed for 10 min. during trawl/dive comparisons, the duration of tows during KI9403 was determined by distance, using the transect lines and buoys for measurement. Unlike 1993, when the dive transects were always 600 ft, the two transects at one of the dive stations were different lengths on the first day of sampling. On the first day (9 August) at dive transect station CS#6, the east transect line measured 778 ft (tows 1, 4, 6, 8 and dives 2, 3, 5, 8). On the second day of sampling transect CS#6 (tows 9-14 and dives 9-12), two 600 ft lines were laid. The 600 ft lines were used for all tows and dives at dive transect CS#12.

All collected fishes were measured, with the following exceptions: age-0 rock sole were subsampled at CS#18, and age-0 northern sculpin (*Icelinus borealis*) were subsampled at CS#30, since more than 300 individuals of that year class were captured.

Collections within Kazakof Bay/August 1994 (KI9402)

Franz Müter, Brenda Holladay and Sherri Dressel (IMS/UAF) collected samples during 2 - 7 August 1994 in Kazakof Bay, Afognak Island using a Boston Whaler (Table 7, Figure 6). Brenda Norcross assisted with collections during 2 August. Franz Müter operated the vessel. Sampling procedure was slightly different from cruises aboard the *R/V Pumkin*. The crab block was fixed in place on the starboard, and the trawl was towed from and was tied off at the stern.

Samples were collected from 31 stations. Substrate was collected from all stations, with replicate grabs at CS#4 and 6. Substrate was observed but not retained at CS#20, where no tow was taken. Sediment grain size has not yet been examined for KI9402, and will be completed in 1995 - 96. CTD data are available for all stations except CS#20. A single CTD profile is representative of both CS#26 and CS#27 because these stations were close together and were occupied within a short time span. Replicate CTD casts were collected at CS#1, 4, 6 and 13.

Tows were of variable duration (3.3 - 10 min.), and were collected on both flood and ebb tides. Tows were attempted at all stations except CS#20, but were often either questionably quantitative or not quantitative. Tows where the catch did not overflow the codend and the net appeared to have fished correctly were quantitative. Non-quantitative tows were where the gear did not fish correctly or where a portion of the catch was lost while retrieving the net. Questionable tows were where the catch overflowed the codend or where the codend was completely filled with mud or kelp.

Sample Processing

Processing of physical data

Temperature, salinity and depth data were downloaded to computer disk and processed with SeaBird CTD software. For all stations, data collected during the 2 min. temperature equilibration of the CTD were omitted to avoid erratic temperature and salinity spikes. Raw data from the down cast of the CTD were averaged on 0.1 m intervals for stations <10 m depth, and on 0.5 m intervals for deeper stations, and profiles of temperature and salinity were plotted. The distribution of mean bottom temperatures and bottom salinities were charted for each station.

The distance (km) from the station to the nearest position at the mouth of a bay was calculated after drawing lines across the mouths of Womens, Middle, Kalsin and Kazakof Bays. The shortest distance from the station to this line was measured. Stations inside the mouth were designated as positive distances, and stations outside of bays were assigned negative distances.

Processing of sediment data

The proportional weights of the gravel, sand and mud fractions were obtained for all substrate samples collected using a wet and dry sieving technique (Appendix 2). The Wentworth grade scale (Sheppard 1973) defined grain sizes of boulder, cobble, gravel (pebble + granule), sand and mud (silt + clay). Sediment samples were sieved to determine relative percent at each Phi level of gravel and sand. The mud fraction was not partitioned into Phi levels. Phi level classifications were calculated for the gravel and sand fractions, but are not reported here. Results of grain size analyses were categorized after Folk (1980) (Table 2). We employed Folk's classifications with the following exceptions. Folk's classifications of (g)sM and (g)mS (meaning less than 5% gravel) were incorporated within the categories of sM and mS for our analysis.

Additionally, substrates larger than Folk had analyzed (i.e. containing cobble or boulder) were classified visually according to the Wentworth scale (Sheppard 1973).

Percent volatile matter and carbonate present in the sediment were obtained by a generally accepted method (Appendix 2) when sufficient sediment remained after grain size had been examined. Percent volatile matter provides an indirect estimate of organic content which may be available as food for benthic feeding fishes, and percent carbonate is an estimate of shell content within the substrate.

Processing of fish data

Ages of flatfishes were estimated from total length using 1) total length/frequency plots of fishes produced for each cruise, 2) total length/frequency plots of fishes collected previously in Kodiak during August (Norcross et al. 1993, 1995A), 3) analysis of regional differences in total lengths of fishes caught during August 1991 (Norcross et al. 1995B) and 4) additional literature references (e.g. Hart 1980). Length/frequency plots and tabulated flatfish lengths include lengths and counts of measured fish only. The counts therefore are not equal to catch-per-unit-effort (CPUE) values or the total number of fish captured. Ages could be assigned as 0, 1 and gt 2 using this method. Without otolith aging, more precise estimates of ages are not possible.

Abundance of fish was standardized to a 10 min. towing time for all cruises. Tow CPUE values were used for comparisons of fishing efficiency between 3.05 m and 3.66 m beams and to estimate intrastation variability. All plots, charts and text reflect the average CPUE of all quantitative and questionably quantitative tows at a station, unless otherwise stated. Except for cases which are mentioned below, the number of fish (N) plotted is a cumulative value calculated from average station CPUE. Because of standardizing fish abundances to a 10 min. tow and averaging tow abundances within a single consecutive station, the actual value of N was not always a whole number. N is reported as the nearest whole number in all figures. Because of this, there are exceptional cases where the number of data points plotted may not appear to equal the N stated in the title. To avoid confusion, many of these instances are noted on plots by an asterisk after the N stated in the title. The N of fish used in CPUE plots of temperature and salinity includes only those fish captured at stations with temperature and salinity data, and is not always equal to the cumulative CPUE of fishes caught at quantitative stations. Similarly, the N of fishes used in CPUE plots of tidal stage and light stage is the cumulative CPUE of fishes captured at each tow.

The greater quantity and variety of collections during KI9301 and KI9403 allowed analysis of fish distribution versus more parameters than for KI9302, KI9401, and KI9402. Analyses of KI9302 and KI9401 are limited to examination of length/frequency plots and scatterplots of CPUE versus average tow depth. Analysis of KI9402 includes length/frequency plots, scatterplots of CPUE versus average tow depth, distance from the mouth of the bay, bottom temperature and bottom salinity. Figures reporting data from KI9301 and KI9403 include the plots analogous to those prepared for KI9402 and additionally include histograms of fish CPUE by sediment type, and scatterplots of CPUE versus percent gravel, percent sand and percent mud. These plots report the log transformed value of CPUE (+1) for each station or tow, rather than depicting the average CPUE within a physical parameter range, as had been presented during previous years of this study. As is standard in fishery analysis, a logarithmic scale of fish abundances was used on all scatterplots to minimize the overemphasis of unusually large or small abundance values. On this a logarithmic scale, faint patterns of increasing or decreasing fish abundance may nevertheless indicate strong trends in relation to the particular parameter measured.

Data on flatfish distribution and abundance are presented for age-0, age-1 and age-$\geq$2 fish. Age-$\geq$2 fish are not discussed in the text, since the category arbitrarily groups a wide assortment of ages. Text summarizes the presented tables, charts and graphs. Trends mentioned are limited to conceptual descriptions, as no statistical analyses have been performed.

Fish data are reported in alphabetical order by genus and species in accordance with the order used by the American Fisheries Society (1991).

Data analyses

R-Base (Microrim 1990) was used as a data base manager, but most data summaries, plots and tables were produced using EXCEL (Microsoft Corporation 1993). CTD profiles were plotted using SYSTAT (Wilkinson 1990) or EXCEL.

RESULTS and DISCUSSION

Aging of flatfishes

Length analyses of flatfishes during August and November 1993 (KI9301 & KI9302)

Ages of flatfishes captured in August and November 1993 were estimated using total lengths (Table 8, Figure 7). Due to past collections during August near Kodiak, estimates of length-at-age were consistently reliable for age-0, age-1 and age- ≥2 fish.

For several species, an estimate of growth was possible for the three month time span between collections. Flatfishes of different species grew at different rates, as evidenced by the shift of the 5 mm mode and a comparison of mean length at age. The 5 mm mode of age-0 arrow tooth flounder increased by 45 mm from 45 - 49 mm to 90 - 94 mm, and the mean length at age of age-0 arrowtooth flounder shifted 44 mm during this period, from 56±12 mm to 100±11 mm. Age-1 arrowtooth flounder did not have a distinct mode, but the mean length at age increased by 35 mm during August to November, from 163±25 mm to 198±22 mm. The mode of age-0 flathead sole shifted 10 mm from August (30 - 34 mm) to November (40 - 45 mm), and the average length at age increased by 14 mm from August (32±4 mm) to November (46±9 mm). The mode of age-1 flathead sole increased 5 mm (from 90 - 54 mm to 95 - 99 mm), but its mean length at age was also 14 mm larger in November (112±23 mm) than in August (98±15 mm). No mode shift could be followed for Pacific halibut, but the mean length at age increased by 38 mm for age-0 fish (from 71±11 mm to 109±16 mm) and 30 mm for age-1 fish (from 174±10 mm to 204±5 mm). The 5 mm mode of age-1 yellowfin sole increased by 20 mm from August (65 - 69 mm) to November (85 - 89 mm), and the mean length at age also increased by 20 mm (from 72±9 mm to 92±9 mm). The mode of age-0 rock sole increased by 20 mm, from 35 - 39 mm in August to 55 - 59 mm in November, and the average length at age of age-0 rock sole increased by 17 mm (from 41±7 mm to 58±16 mm). The mean length at age of age-1 rock sole increased by 31 mm (from 109±22 mm to 140±20 mm). The mean length of age-1 Alaska plaice increased by 54 mm from August (163±22 mm) to November (217±32 mm).

Length analyses of flatfishes during June and August 1994 (KI9401, KI9403 & KI9402)

Ages of flatfishes captured during June (KI9401) and August (KI9403) 1994 within Chiniak Bay, and flatfishes caught during August 1994 (KI9402) within Kazakof Bay were estimated using total length frequency plots (Table 9, Figures 8-10). Growth was estimated as the difference between length modes during June and August collections within Chiniak Bay. Age-1 flathead sole grew 30 mm during this time, from 75 - 79 mm to 105 - 109 mm. Age-0 halibut increased by 20 mm, from 35 - 39 mm to

55 - 59 mm. Age-0 yellowfin increased by 20 - 25 mm and passed a “birthday” between June and August. Age-0 yellowfin sole in June were 55 - 64 mm and the same group were age-1 during August (80 - 84 mm). Age-0 rock sole grew 25 mm, from 15 - 19 mm to 40 - 44 mm.

Flatfishes caught during August were consistently larger at age within Chiniak Bay (KI9403) than in Kazakof Bay (KI9402). Age-0 flathead sole were 35 - 39 mm in Chiniak Bay and 5 mm smaller in Kazakof Bay (30 - 34 mm). Age-1 flathead sole were 105 - 109 mm in Chiniak Bay and 15 mm smaller in Kazakof Bay (90 - 94 mm). Age-1 yellowfin sole were 20 mm larger in Chiniak Bay (80 - 84 mm) than in Kazakof Bay (60 - 64 mm). Both ages-0 and -1 rock sole were 5 mm larger in Chiniak Bay than in Kazakof Bay. Age-0 rock sole were 40 - 44 mm in Chiniak Bay and 35 - 39 mm in Kazakof Bay. Age-1 rock sole were 115 - 119 mm in Chiniak Bay and 110 - 113 mm in Kazakof Bay.

Chiniak Bay/August 1993 (KI9301)

Physical data within Chiniak Bay/August 1993 (KI9301)

Temperature within Chiniak Bay/August 1993 (KI9301)

The general pattern for all bays was for warmer bottom water at shallow depths and cooler water at deeper stations (Table 3, Figures 11-12). Deep central areas within bays and deep regions outside bays had colder water than was found in shallow areas.

During KI9301, all stations within Womens Bay (CS#1-5) had a thermocline in the upper 5 meters and warm bottom water (11.5 - 15.1 °C). The warmest bottom water (15.1°C) examined during KI9301 was at the head of Womens Bay in water <5 m deep.

Stations near the head of Middle Bay (CS#16-18) were usually isothermal. However, CS#27, also at the head of Middle Bay, had a 0.5°C thermocline between 3 and 5 m water depth. Within outer Middle Bay (CS#11-15), temperatures either decreased gradually with increasing depth (CS#11-15) or thermoclines were present in the top 10 m and again in the bottom 20 m (CS#12-14). The outermost station examined in Middle Bay (CS#15) had four distinct thermoclines: at 0 - 2 m, 5 - 10 m, 30 - 40 m, and 60 - 75 m. Bottom temperatures in Middle Bay ranged from 8.3 to 10.8°C The coldest bottom water examined during KI9301 (8.3°C) was outside the mouth of Middle Bay.

Stations near the head of Kalsin Bay (CS#19-23) were fairly isothermal. Stations further out the bay on the northern side (CS#24-26) and midbay (CS#6) had a thermocline in the upper 5 m. Consecutive station #6 had a second thermocline at 10 - 15 m. Temperature profiles of the outermost stations in Kalsin Bay (CS#7-10) all gradually decreased from the surface to depth. Bottom temperatures in Kalsin Bay ranged from 8.9 to 10.7°C.

Salinity within Chiniak Bay/August 1993 (KI9301)

When present, the halocline was usually in the upper 5 m (Figure 13). In general, surface salinity values were lower inside bays than outside. Conditions were usually isohaline in the mid to outer bay. Bottom salinity of stations sampled during KI9301 was within a narrow range (Table 3, Figure 14). Bottom salinity ranged from 29.2 to 32.4 PSU in Womens Bay, 31.1 to 31.8 PSU in Middle Bay, and 31.1 to 32.1 in Kalsin Bay.

Substrate within Chiniak Bay/August 1993 (KI9301)

Sites examined during KI9301 included the primary sediment types of gravel, sand and mud (Table 10, Figures 15-20). All three primary sediments were collected in Middle and Kalsin Bays, but gravel was not collected in Womens Bay. The predominant sediment type within Chiniak Bay was muddy sand, with pure sand at the head of both Middle and Kalsin Bays. Stations with >20% gravel were only within Middle Bay.

Fishes within Chiniak Bay/August 1993 (KI9301)

A total of 6646 fishes were entered in the database for use in CPUE (Table 11) distribution and length analyses. A subsample of the captured fishes (87%, N=5809) fishes was measured, of which 3461 were flatfishes. The cumulative CPUE of flatfishes from 28 stations sampled during KI9301 was 2,798, for an average CPUE of 100±101 flatfishes/station during KI9301.

Eleven species of flatfish were collected during KI9301. Listed in decreasing order of abundance, the species composition (cumulative station CPUE of all ages) was flathead sole (N=1342), rock sole (N=958), yellowfin sole (N=221), Pacific halibut (N=129), arrowtooth flounder (N=69), butter sole (N=39), Alaska plaice (N=16), starry flounder (N=11), English sole (N=8), Dover sole (N=3), and sand sole (N=3).

Flatfishes were caught at all but two trawl stations during KI9301. Rock sole were caught at 78% of stations sampled, flathead sole were caught at 52% of stations and halibut were caught at 48% of stations. Both arrowtooth flounder and yellowfin sole were taken at 30% of stations, butter sole were taken at 27% of stations and other flatfishes were collected at 11% of stations.

During August 1993 age-0 was the numerically dominant age class collected of arrowtooth flounder, Pacific halibut, rock sole, and English sole (Table 12). Age-1 fishes were caught most often of flathead sole, yellowfin sole, Alaska plaice and sand sole. Older specimens dominated the catch of Dover sole, starry flounder and butter sole.

Multiple tows were collected at four stations using a 3.66 m beam and a 3.05 m beam. Catch-per-unit-effort of flatfishes using a 3.66 m beam was very similar to CPUE using a 3.05 m beam (Table 13).

Distribution of flatfishes by age within Chiniak Bay/August 1993 (KI9301)

Arrowtooth flounder (Figures 21-33)

Age-0 arrowtooth flounder (N=46) were caught at 12% of stations during KI9301. The mean number of age-0 fish/tow was 1.2±2.3, and the largest catch was 12 fish/tow. Age-0 arrowtooth flounder were caught between 20 and 80 m, with peak abundance between 20 and 30 m water depth. Age-0 fish were collected from outside to the head of the bay, and were caught primarily over sandy mud and gravel, although a few fish were captured over muddy sand. Age-0 fish were only in the cooler temperatures sampled (8.2 - 10.2°C), and were caught in highest abundances at the warmest of these temperatures (10.2°C). Age-0 arrowtooth flounder were caught in 31.5 to 32.1 PSU water. All were caught during flood or high slack tide.

Age-1 arrowtooth flounder (N=18) were caught at 21% of stations during KI9301. The mean number of age-1 fish/tow was 0.5±1.5, and the largest catch was eight fish/tow. Age-1 arrowtooth flounder were caught from 30 to 80 m water depth, from well outside (-5 km) to the head of the bay. The peak abundance of age-1 arrowtooth flounder was at 10.2°C. Age-1 arrowtooth flounder were caught in 31.5 to 32.0 PSU water. Age-1 fish were nearly always caught over sandy mud, with a few captured on muddy sand. Abundance decreased with decreasing percent sand, and increased with increasing per cent mud. All were caught during flood or high slack tide.

Age-$\geq$2 arrowtooth flounder were captured during KI9301 (N=5).

Flathead sole (Figures 21 & 34-45)

Age-0 flathead sole (N=520) were caught at 43% of stations during KI9301. The mean number of age-0 fish/tow was 13.4 ± 38.4, and the largest catch was 166 fish/tow. Age-0 flathead sole were captured in increasing abundances from 10 to 70 m. They also increased in abundance from outside to the head of the bay, although one large catch 2 km outside the bay did not fit this pattern. Age-0 flathead sole were captured between 8.2 and 11.5°C, and increased in abundance with increasing temperatures. They were captured in 31.2 - 32.1 PSU. Age-0 flathead sole were primarily caught on sandy mud, and they increased in abundance with increasing percent mud in the substrate. Nearly all age-0 flathead sole were caught on a flood or high slack tide.

Age-1 flathead sole (N=611) were caught at 61% of stations during KI9301. The mean number of age-1 fish/tow was 15.8 ± 31.4, and the largest catch was 122 fish/tow. Age-1 flathead sole were caught between 5 and 80 m depth, and increased in abundance with increasing depth. They were caught in high abundances from outside the mouths to the heads of bays. Age-1 flathead were caught between 8.2 and 11.8°C, but were most abundant in temperatures below 10.4°C. Age-1 flathead sole were caught in 31.2 - 32.0 PSU, and were abundant from 31.5 to 32.0 PSU. Age-1 flathead sole were nearly all captured on sandy mud and muddy sand. Age-1 flathead sole were mainly captured on a flood or high slack tide.

Age-$\geq$2 flathead sole were captured during KI9301 (N=211).

Pacific halibut (Figures 21 & 46-57)

Age-0 Pacific halibut (N=126) were caught at 46% of stations during KI9301. The mean number of age-0 fish/tow was 5.5 ± 10.6, and the largest catch was 60 fish/tow. Age-0 Pacific halibut were all caught in <30 m depth, from 3 km inside the bay to the head. Age-0 Pacific halibut were taken where bottom temperature was between 10.0 and 12.0°C, and decreased in abundance with increasing temperature. Age-0 halibut were caught mainly over sand and muddy sandy gravel, but a few fish were caught on sandy mud and muddy sand. They were slightly more abundant with increasing percent sand in the substrate. Nearly all age-0 halibut were caught on a flood tide.

Age-1 Pacific halibut (N=2) were caught at 11% of stations during KI9301. The mean number of age-1 fish/tow was 0.1 ± 0.3, and the largest catch was one fish/tow. Age-1 fish were collected from 5 to 30 m, 2 - 4 km within the bay, at 9.7 - 10.5°C and at 31.4 - 31.7 PSU. One fish was captured over each of three substrates: gravelly mud, muddy sand, and pure sand. Age-1 fish were only caught at high slack tide.

Age-$\geq$2 halibut were rarely captured during KI9301 (N=1).

Dover sole (Figures 21 & 58-69)

During August 1993, Dover sole were only caught as age-$\geq$2 (N=3).

Starry flounder (Figures 21 & 70-81)

Age-0 starry flounder (N=1) were caught at 4% of stations during KI9301. The mean number of age-0 fish/tow was 0.0±0.2, and the largest catch was one fish/tow. The single age-0 starry flounder was caught at the head of Middle Bay in 5 - 10 m water depth over sand. Temperature and salinity data are missing from that station.

Age-1 starry flounder were not captured during KI9301.

Age-≥2 starry flounder were occasionally captured during KI9301 (N=10).

Yellowfin sole (Figures 21 & 82-93)

No age-0 yellowfin sole were captured during KI9301.

Age-1 yellowfin sole (N=130) were caught at 50% of stations during KI9301. The mean number of age-1 fish/tow was 4.8±12.4, and the largest catch was 65 fish/tow. Age-1 yellowfin sole were caught only in depths <30 m, from 3 km inside to the head of the bay, from 9.8 to 12.0°C and 31.2 to 32.4 PSU. They were caught primarily over muddy sandy gravel and muddy sand, with lesser abundances over sand and sandy mud. Age-1 yellowfin sole increased abundance as the proportional amount of sand increased in the substrate, and decreased with increasingly muddy substrate.

Age-≥2 yellowfin sole were caught during KI9301 (N=91).

Rock sole (Figures 21 & 94-105)

Age-0 rock sole (N=687) were caught at 54% of stations during KI9301. The mean number of age-0 fish/tow was 39.5±63.8, and the largest catch was 276 fish/tow. Age-0 rock sole were caught from 0 to 70 m depth, and were most abundant below 30 m. They were caught in increasing abundances from the mouth to the head of bays. Age-0 rock sole were captured from 9.6 to 10.8°C and from 31.1 to 31.7 PSU, with high abundances throughout these ranges. Rock sole were most abundant over muddy sandy gravel, sand and muddy sand, and a few fish were caught over sandy mud and gravel. Age-0 rock sole decreased slightly in abundance as the proportional amount of mud in the substrate increased.

Age-1 rock sole (N=200) were caught at 64% of stations during KI9301. The mean number of age-1 fish/tow was 6.6±11.3, and the largest catch was 61 fish/tow. Like age-0 fish, age-1 rock sole were caught from 0 to 70 m, but this age was most abundant from 20 to 40 m depth. Age-1 rock sole were caught from 2 km outside to the heads of bays, and their highest abundances were near the mouth. Age-1 rock sole were caught within a broader range of temperature and salinity than were age-0 fish. Age-1 fish were caught in 8.2 - 12.0°C and 31.1 - 32.4 PSU, with peaks in abundance near the midranges of these values. Age-1 rock sole were most abundant over gravel, but were captured over other substrates in lesser abundances: muddy sandy gravel, muddy sand, sand, gravelly mud and sandy mud. Like age-0 rock sole, abundance of age-1 rock sole decreased slightly with increasingly muddy substrate.

Age-$\geq$2 rock sole were caught during KI9301 (N=72).

Butter sole (Figures 21 & 106-117)

During KI9301, only age-$\geq$2 butter sole were captured (N=39).

Alaska plaice (Figures 21 & 118-129)

Age-0 Alaska plaice (N=1) were caught at 4% of stations during KI9301. The mean number of age-0 fish/tow was 0.0±0.2, and the largest catch was one fish/tow. This fish was caught in <10 m water depth, near the head of Kalsin Bay, in warm (10.7°C) fresh (31.2 PSU) water, over muddy sand. It was caught at high slack tide.

Age-1 plaice (N=15) were caught at 11% of stations during KI9301. The mean number of age-1 fish/tow was 0.8±2.2, and the largest catch was 11 fish/tow. Age-1 Alaska plaice were caught in depths £10 m, near the heads of bays. These shallow depths corresponded to warm (10.8 - 10.9°C), fresh (31.1 - 31.2 PSU) waters. All age-1 plaice were caught over sand, at high slack tide.

Age-≥2 Alaska plaice were not caught during KI9301.

English sole (Figures 21 & 130-141)

Age-0 English sole (N=8) were caught at 14% of stations during KI9301. The mean number of age-0 fish/tow was 0.2±0.7, and the largest catch was three fish/tow. Age-0 English sole were in depths <20 m, well within the bay, in temperatures 10.1 - 10.7°C and 31.1 - 31.6 PSU. All fish were on sand or muddy sand.

No age-1 or age-≥2 English sole were caught during KI9301.

Sand sole (Figures 21 & 142-153)

Age-0 sand sole were not caught during KI9301.

Age-1 sand sole (N=2) were caught at 4% of stations during KI9301. The mean number of age-1 fish/tow was 0.1±0.3, and the largest catch was two fish/tow. Age-1 sand sole were caught only at the most shallow depths examined (<5 m), in warm (10.7°C) fresh (31.1 PSU) water. They were caught over muddy sand at high slack tide.

A single age-≥2 sand sole was captured during KI9301.

Chiniak Bay/November 1993 (KI9302)

Fish data within Chiniak Bay/November 1993 (KI9302)

No data on roundfishes were retained, and few data were retained for non-quantitative tows during November 1993 within Chiniak Bay (KI9302). Flatfishes were captured and measured (N=935) from each of the 10 stations with quantitative tows.

The cumulative flatfish CPUE from 10 stations during KI9302 was 968, for an average CPUE of 97±99 flatfishes/station. Nine species of flatfish were collected during KI9302 and are listed in decreasing order of CPUE abundance (cumulative CPUE of all ages): rock sole (N=352), flathead sole (N=306), yellowfin sole (N=140), arrowtooth flounder (N=130), Pacific halibut (N=18), butter sole (N=11), Alaska plaice (N=5), Dover sole (N=3), starry flounder (N=2). During November 1993 (Table 14) catches of age-0 flatfishes were most prevalent for arrowtooth flounder, flathead sole, Pacific halibut and rock sole. Age-1 fishes were most numerically dominant of Dover sole, yellowfin sole and Alaska plaice. Age-≥2 fishes were captured most often of starry flounder and butter sole.

Distribution of flatfishes by age within Chiniak Bay/November 1993 (KI9302)

Arrowtooth flounder (Figures 154-158)

Age-0 arrowtooth flounder (N=116) were caught at 40% of stations during KI9302. The mean number of age-0 fish/tow was 11.6±23.4, and the largest catch was 67 fish/tow. Age-0 arrowtooth flounder were captured in water >30 m, near the mouth of Middle Bay.

Age-1 arrowtooth flounder (N=13) were caught at 20% of stations during KI9302. The mean number of age-1 fish/tow was 1.3±2.8, and the largest catch was eight fish/tow. Like age-0 fish, age-1 arrowtooth flounder were captured in water >30 m, near the mouth of Middle Bay.

Age-≥2 arrowtooth flounder were caught during KI9302 (N=1).

Flathead sole (Figures 159-163)

Age-0 flathead sole (N=123) were caught at 70% of stations during KI9302. The mean number of age-0 fish/tow was 12.3±26.2, and the largest catch was 85 fish/tow. The largest catches of flathead sole were at the mouth of Middle Bay, but age-0 flathead sole were captured at all depths examined and at all distances from the mouth of the bay.

Age-1 flathead sole (N=119) were caught at 20% of stations during KI9302. The mean number of age-1 fish/tow was 11.9±25.6, and the largest catch was 70 fish/tow. Age-1 flathead sole were only captured in water >50 m, near the mouth of Middle Bay.

Age-≥2 flathead sole were captured during KI9302 (N=64).

Pacific halibut (Figures 164-168)

Age-0 Pacific halibut (N=15) were caught at 70% of stations during KI9302. The mean number of age-0 fish/tow was 1.5±1.8, and the largest catch was six fish/tow. Age-0 halibut were caught at all stations within bays, in depths less than 40 m.

Age-1 halibut (N=3) were caught at 10% of stations during KI9302. The mean number of age-1 fish/tow was 0. 3±1.1, and the largest catch was three fish/tow. Age-1 halibut were caught at a single station near the mouth of Middle Bay, in 30 - 40 m depth.

Age-≥2 halibut were not captured during KI9302.

Dover sole (Figures 169-173)

Age-0 Dover sole were not captured during KI9302.

Age-1 Dover sole (N=2) were caught at 20% of stations during KI9302. The mean number of age-1 fish/tow was 0.2±0.4, and the largest catch was one fish/tow. Dover sole were only caught near the mouth of Middle Bay. Age-1 Dover sole was caught at two stations just outside the mouth of Middle Bay, in water >40 m.

Age-≥2 Dover sole were captured during KI9302 (N=1).

Starry flounder (Figures 174-178)

Age-0 starry flounder were not captured during KI9302.

Age-1 starry flounder were not captured during quantitative tows, but a single age-1 fish was caught during a non-quantitative tow near shore in Womens Bay.

Age-≥2 starry flounder were caught during KI9302 (N=2).

Yellowfin sole (Figures 179-183)

Age-0 yellowfin sole (N=9) were caught at 30% of stations during KI9302. The mean number of age-0 fish/tow was 0.9±1.7, and the largest catch was 4 fish/tow. Age-0 yellowfin sole were caught in water <20 m deep, well within Middle Bay. They were caught only on the flood tide.

Age-1 yellowfin sole (N=80) were caught at 70% of stations during KI9302. The mean number of age-1 fish/tow was 8.0±12.0, and the largest catch was 31 fish/tow. Age-1 yellowfin sole were caught from 10 to 60 m depth, from outside to well within the bay. The largest catches were just outside the mouth of Middle Bay.

Age-≥2 yellowfin sole were captured during KI9302 (N=51).

Rock sole (Figures 184-188)

Age-0 rock sole (N=255) were caught at 90% of stations during KI9302. The mean number of age-0 fish/tow was 25.5±28.1, and the largest catch was 86 fish/tow. Age-0 rock sole were caught at all sampled depths, from outside to the head of the bay, but were most abundant in less than 40 m depth and inside the bay.

Age-1 rock sole (N=71) were caught at 100% of stations during KI9302. The mean number of age-1 fish/tow was 7.1±5.4, and the largest catch was 21 fish/tow. Age-1 rock sole were caught at every station during KI9302. They were most abundant in water <20 m, well within the bay.

Age-≥2 rock sole were caught during KI9302 (N=26).

Butter sole (Figures 189-193)

Age-0 butter sole were not captured during KI9302.

Age-1 butter sole (N=1) were caught at 10% of stations during KI9302. The mean number of age-1 fish/tow was 0.1±0.3, and the largest catch was one fish/tow.

Age-≥2 butter sole were captured during KI9302 (N=10).

Alaska plaice (Figures 194-198)

Age-0 Alaska plaice were not caught during KI9302.

Age-1 plaice (N=5) were caught at 20% of stations during KI9302. The mean number of age-1 fish/tow was 0.5±1.1, and the largest catch was three fish/tow. Age-1 Alaska plaice were caught only in water <20 m depth, at stations near the head of Middle Bay, in abundances of 2 - 3 fish/station.

No age-≥2 plaice were caught during KI9302.

Chiniak Bay/June 1994 (KI9401)

Fish data within Chiniak Bay/June 1994 (KI9401)

A single quantitative tow at each of 12 stations was collected during June 1994 within Chiniak Bay (KI9401). Flatfishes were captured at each station (Table 15), and all flatfishes were measured.

The cumulative flatfish CPUE from 12 stations during KI9401 was 989, for an average CPUE of 82±56 flat fishes/station. The nine species of flatfish collected during KI9401 are listed in decreasing order of CPUE abundance (cumulative CPUE of all ages): flathead sole (N=426), rock sole (N =354), yellowfin sole (N=135), Pacific halibut (N=55), butter sole (N=12), arrowtooth flounder (N=2), rex sole (N=2), Alaska plaice (N=1) and sand sole (N=1). During June 1994 (Table 16), catches of age-0 flatfishes were most prevalent only for Pacific halibut, while age-1 fishes were most numerically dominant of rex sole, flathead sole and rock sole. Age-≥1 was numerically dominant of yellowfin sole. Age-≥2 fishes were captured most often of butter sole, Alaska plaice and sand sole. One age-0 and one age- ≥2 arrowtooth flounder were caught.

Distribution of flatfishes by age within Chiniak Bay/June 1994 (KI9401)

Arrowtooth flounder (Figures 199-203)

Age-0 arrowtooth flounder (N=1) were caught at 8% of stations during KI9401, for a mean of 0.1±0.3 fish/tow. The age-0 fish was caught in 20 - 30 m, near the head of Kalsin Bay.

No age-1 arrowtooth flounder were caught during KI9401.

A single age-≥2 arrowtooth flounder was caught during KI9401.

Rex sole (Figures 204-208)

Age-0 rex sole were not caught during KI9401.

Age-1 rex sole (N=2) were caught at 8% of stations during KI9401. The mean number of age-1 fish/tow was 0.2±0.6, and the largest catch was two fish/tow. Both age-1 rex sole were caught at a single station well within Kalsin Bay, in 50 - 60 m depth.

No age-≥2 rex sole were caught during KI9401.

Flathead sole (Figures 209-213)

A single age-0 was caught during KI9401 (8% of stations during KI9401, 0.1±0.3 fish/tow). This fish was caught at the head of Kalsin Bay, in <20 m depth.

Age-1 flathead sole (N=265) were caught at 58% of stations during KI9401. The mean number of age-1 fish/tow was 22.1±37.7, and the largest catch was 114 fish/tow. Age-1 flathead sole were caught in Womens and Kalsin Bays, in depths 10 - 60 m. The highest abundances were well within Kalsin Bay in depths ^{3}20 m, during high slack or ebb tide.

Age-$\geq$2 flathead sole were caught during KI9401 (N=160).

Pacific halibut (Figures 214-218)

Age-0 halibut (N=54) were c aught at 75% of stations during KI9401. The mean number of age-0 fish/tow was 4.5±5.6, and the largest catch was 19 fish/tow. Age-0 halibut were caught in small numbers throughout Middle Bay, but were most abundant at the head of Kalsin Bay. They were only caught in water <30 m deep and on th e flood tide.

Age-1 Pacific halibut were not caught during KI9401.

A single age-≥2 halibut was caught during KI9401.

Yellowfin sole (Figures 219-223)

Age-0 yellowfin sole were not caught during KI9401.

Age-0 yellowfin sole (N=60) were caug ht at 58% of stations during KI9401. The mean number of age-0 fish/tow was 5.0±8.8, and the largest catch was 31 fish/tow . Age-0 yellowfin sole were only captured in <30 m water depth, from 3 km within to the head of the bay, on a flood or high slack tide.

Age-≥1 yellowfin sole were caught during KI9401 (N=75), but as age-1 fis h could not be separated from older fish by length frequency analysis, they are no t discussed here..

Rock sole (Figures 224-228)

Age-0 rock sole (N=57) were caught at 42% of stations during KI9401. Th e mean number of age-0 fish/tow was 4.8±8.4, and the largest catch was 26 fish/tow . Age-0 fish were only caught in less than 40 m water depth, near the head of Kalsi n Bay. All were caught on a flood or high slack tide.

Age-1 rock sole (N=172) were caught at 67% of stations during KI9401. Th e mean number of age-1 fish/tow was 14.4±15.5, and the largest catch was 41 fish/tow. Age-1 rock sole were caught in <30 m water depth, in large abundances from th e mouth to the heads of bays. All age-1 fish were caught on the flood or high slack tide.

Age-≥2 rock sole were caught during KI9401 (N=125).

Butter sole (Figures 229-233)

Age-0 butter sole were not caught during KI9401.

A single age-1 butter sole was caught (8% of stations during KI9401, 0.1±0. 3 fish/tow). This fish was caught in 20 - 30 m water depth, near the mouth of Middle Bay, just before high tide.

Age-≥2 butter sole were caught during KI9401 (N=11).

Alaska plaice (Figures 234-238)

No age-1 or age-1 Alaska plaice were caught during KI9401.

A single age-≥2 Alaska plaice was captured.

Sand sole (Figures 239-243)

No age-0 or age-1 fish were caught during KI9401.

A single age-$\geq$2 sand sole was captured in Middle Bay, at the same station as the age-$\geq$2 plaice was caught.

Chiniak Bay/August 1994 (KI9403)

Physical data within Chiniak Bay/August 1994 (KI9403)

Temperature within Chiniak Bay/August 1994 (KI9403)

Bottom temperatures in Middle Bay ranged from 7.6 to 13.5°C (Table 6), the wide range of bottom temperatures indicative of a relatively shallow bay. Bottom temperatures decreased with increasing depth (Figures 244-245). Surface water temperatures in Middle Bay ranged from approximately 10.5 to 15°C, also decreasing with increasing depth.

In Kalsin Bay, bottom temperatures ranged from 7.6 to 9.2°C. The fairly uniform distribution of bottom temperatures in Kalsin Bay is indicative of a relatively deep bay. Kalsin Bay surface temperatures ranged from approximately 8.5 to 14°C. Unlike surface temperatures in Middle Bay, surface temperatures in Kalsin Bay did not decrease with increasing water depth. The coldest temperatures were found at the head of the bay, indicative of cold freshwater input. Temperatures in both Middle and Kalsin Bays were likely influenced not only by depth and location, but by tidal cycle and solar heating.

Salinity within Chiniak Bay/August 1994 (KI9403)

Middle Bay bottom salinities ranged from 29.8 to 32.1 PSU (Table 6, Figure 246-247) and surface salinities ranged from approximately 25 to 32 PSU. Both bottom and surface salinities in Middle Bay increased from the head to the mouth of the bay, corresponding with increasing depth. The wide range of surface salinities, in particular, display the effects of fresh water input at the head of the bay.

Kalsin Bay bottom salinities ranged from 31.7 to 31.9 PSU and surface salinities ranged from approximately 30.5 to 31.7 PSU. The range of both bottom and surface salinities in Kalsin Bay were small and the distribution was fairly uniform. Like temperature, salinities in both Middle and Kalsin Bays were likely influenced not only by depth and location, but by tidal cycle and solar heating.

Substrate within Chiniak Bay/August 1994 (KI9403)

Combinations of sand, muddy sand and sandy mud were found throughout Middle Bay (Table 17, Figures 248-254). Substrate at the head of Kalsin Bay was pure sand, shifting to muddy sand and then sandy mud with increasing depth down the central region of the bay toward the mouth. Outside the mouths of Kalsin and Middle Bays, sand, muddy sand, sandy gravel and pure gravel were found. Areas with gravel in sediment were examined only at and outside the mouths of the bays.

Fish data within Chiniak Bay/August 1994 (KI9403)

A total of 10,659 fishes was captured during sampling in Chiniak Bay, August 1994 (Table 18). A subsample of 94% (10,034) of these fishes was measured. The cumulative CPUE of 12 flatfish species at 27 quantitative stations examined during August 1994 sampling in Chiniak Bay (KI9403) was 4,486, for an average CPUE of 166±182 flatfishes/station. This was the highest average CPUE of flatfishes/station for all 1993 and 1994 cruises. In addition, 208 flatfishes which were captured during non-quantitative tows were included in the database for use in length analyses only.

Twelve species of flatfish were collected in KI9403. The species composition, listed in decreasing order of CPUE abundance over all stations was rock sole (2,461), flathead sole (901), arrowtooth flounder (678), Pacific halibut (284), yellowfin sole (76), butter sole (36), English sole (29), starry flounder (7), sand sole (5), Alaska plaice (4), rex sole (3), and Dover sole (2).

During KI9403, age-0 was the numerically dominant age class collected of arrowtooth flounder, rex sole, Pacific halibut, rock sole, and English sole (Table 19). Age-1 fishes were caught most often of flathead sole and yellowfin sole. Age-0 and age-1 were equally dominant age classes for starry flounder. Older specimens (age-≥2) dominated the catch of Dover sole, butter sole and sand sole. Equal numbers of age-1 and age-≥2 Alaska plaice were captured.

Habitats of juvenile (age-0 and age-1) flatfishes were analyzed to characterize nursery grounds for flatfish of each species as described in the sections below.

Distribution of flatfishes by age within Chiniak Bay/August 1994 (KI9403)

Arrowtooth flounder (Figures 254-266)

Age-0 arrowtooth flounder (N=663) were caught at 55.6% of stations during KI9403. The mean number of age-0 fish/tow was 12.3±32.4, and the largest catch was 157 fish/tow. Age-0 arrowtooth flounder were found in water from 20 to 100 m deep, at 7.6 - 9.7°C and 31.7 - 32.1 PSU. They were on all substrates sampled (sand, muddy sand, sandy mud, sandy gravel and gravel) and in all regions (-2.5 to 6.5 km from the mouth of the bay) except the shallow heads of bays. Seventy-five percent of age-0 arrowtooth were in Middle Bay and 25% were in Kalsin Bay. Age-0 arrowtooth slightly decreased in abundance relative to minutes after sunrise.

Age-1 arrowtooth flounder (N=3) were caught at 11.1% of stations during KI9403. The mean number of age-1 fish/tow was 0.1±0.3, and the largest catch was two fish/tow. While age-1 arrowtooth flounder were not nearly as abundant as age-0, their nursery characteristics were similar to that of age-0 arrowtooth: 50 - 80 m, 7.6 - 8.4°C, 31.9 - 32.0 PSU, on sand or muddy sand substrate. Unlike age-0 arrowtooth, age-1 fish were found only outside the mouth of the bay (-1.8 to -2.4 from the bay mouth). Age-1 arrowtooth were found only within the range of 160 - 280 minutes after sunrise and, like age-0, over 75% were found in Middle Bay and less than 25% in Kalsin Bay.

Age-≥2 arrowtooth flounder were captured during KI9403 (N=12).

Rex sole (Figures 254, 267-278)

Two age-0 rex sole were caught during a single tow at KI9403 CS#11 Tow#1 (corresponding to 3.7% of stations). The mean number of age-0 fish/tow was 0.0±0.3. Age-0 rex sole were found 6.1 km within Kalsin Bay, between 30 and 40 m depth, at 8.3°C, 31.8 PSU, on muddy sand substrate.

A single age-1 rex sole was caught at KI9403 CS#20 (corresponding to 3.7% of stations). The mean number of age-1 fish/tow was 0.0±0.1. The age-1 rex sole was found -1.8 km from the mouth of Middle Bay, between 60 and 70 m, at 7.6°C, 32.0 PSU, on muddy sand substrate.

Age-$\geq$2 rex sole were not caught during KI9403.

Flathead sole (Figures 254, 279-290)

Age-0 flathead sole (N=358) were caught at 44.4% of stations during KI9403. The mean number of age-0 fish/tow was 10.6±41.1, and the largest catch was 271 fish/tow. Age-0 flathead sole were found in waters 10 - 90 m, in increasing abundance to 55 m depth and in decreasing abundance with further increasing depth. Age-0 fish were found at 7.6 - 9.7°C and 31.8 - 32.1 PSU and from -2.4 to 6.5 km from the bay mouth. Age-0 flathead sole were not found at the head of either Kalsin or Middle Bay. Eighty-four percent of age-0 flathead sole were caught in Kalsin Bay. They were associated only with mixed substrates, and were primarily over muddy sand and sandy mud substrates. Fish abundances increased with increasing percent mud and decreasing percent sand, except for five fish which were caught at a sandy gravel station in Middle Bay. Age-0 flathead were found in decreasing abundance with increasing time after sunrise. Although fewer samples were collected after high tide than before, it appears that age-0 flathead were found in sharply increasing numbers up to 212 minutes before high tide and in decreasing numbers through slack high tide and after.

Age-1 flathead sole (N=385) were caught at 44.4% of stations during KI9403. The mean number of age-1 fish/tow was 9.9±24.5, and the largest catch was 135 fish/tow. Age-1 flathead sole were found in greater abundance than age-0 flathead. The distribution parameters of ages-0 and -1 fish were nearly identical. Similar to age-0 fish, age-1 flathead were distributed throughout bays (-2.4 to 7.7 km from the mouth of the bay) and were primarily (>80%) captured in Kalsin Bay. Age-1 flathead sole were found in 10 - 90 m water (highest abundance between 20 and 60 m), 7.6 - 9.7°C, 31.8 - 32.1 PSU. Abundances of age-1 flathead sole paralleled the patterns discussed for age-0 flathead sole in substrate usage and catch relative to sunrise and tidal stage.

Age-≥2 flathead sole were captured during KI9403 (N=158).

Pacific halibut (Figures 254, 291-302)

Age-0 Pacific halibut (N=282) were caught at 51.9% of stations during KI9403. The mean number of age-0 fish/tow was 20.3±18.2, and the largest catch was 68 fish/tow. Age-0 Pacific halibut were found within Middle and Kalsin Bays and outside the mouth of Kalsin Bay. Age-0 halibut were only in depths under 50 m and were primarily <30 m. While age-0 Pacific halibut were found throughout and outside the bay (-1.6 to 8.2 km from the bay mouth), most were at the heads of Kalsin and Middle Bays. Age-0 halibut were at 8.2 - 13.5°C, 29.8 - 32.0 PSU, and were captured over sand, muddy sand and sandy mud substrates. Age-0 halibut abundance increased with increasing percent sand and decreasing percent mud. Age-0 halibut were caught 261 minutes after sunrise and later.

The cumulative CPUE of age-1 Pacific halibut caught during KI9403 was one fish, corresponding to 3.7% of stations and 0.1±0.4 fish/tow. Fish were captured at two stations, and the largest catch was actu ally three fish/tow at CS#12, but due to the high number of replicates at this station and an absence of age-1 halibut during other tows at CS#12, the averaged abundance for the station was negligible (N=0.18 fish). Th e presence of age-1 Pacific halibut at CS#12 is noted at the head of Kalsin Bay (Figure 291b). The other age-1 halibut was found at CS#5 in Middle Bay, 2.4 to 7.7 km fro m the bay mouth, in 20 - 30 m, 8.2°C, 32.0 PSU, and on sand substrate.

One age-≥2 Pacific halibut was captured during KI9403.

Dover sole (Figures 254, 303-314)

No age-0 or age-1 Dover sole were caught during KI9403.

Age-≥2 Dover sole were captured during KI9403 (N=2).

Starry flounder (Figures 254, 315-326)

During KI9403 we captured three age-0 and three age-1 starry flounder, all in a single tow (CS#3 Tow#1) at the head of Middle Bay (corresponding to 3.7% of stations). The mean number caught of each age was 0.1±0.4 fish/tow. Starry flounder were captured in shallow (0 - 5 m), nearshore waters, 7.5 km from the bay mouth, at 13.5°C, 29.8 PSU, and on muddy sand sediment.

A single age-≥2 starry flounder was captured during KI9403.

Yellowfin sole (Figures 254, 327-338)

Age-0 (N=3) was the least abundant group of yellowfin sole captured during KI9403. Age-0 yellowfin sole were caught at 7.4% of stations. The mean number of age-0 fish/tow was 0.1± 0.3, and the largest catch was two fish/tow. All age-0 yellowfin were captured outside the mouth of Kalsin Bay (-0.7 to -1.6 km). The small number and size of age-0 yellowfin sole taken indicated that recruitment was just starting. Age-0 yellowfin sole were found in 20 - 50 m, 8.4 - 8.9°C, and 31.8 PSU. Age-0 yellowfin sole were captured on sand and gravel substrates.

Age-1 yellowfin sole (N=25) were caught at 22.2% of stations during KI9403. The mean number of age-1 fish/tow was 5.0±9.9 and the largest catch was 43 fish/tow. Due to the large number of replicate tows at the station where this large catch was collected, the calculated CPUE of the fish for the station was only 16. Age-1 yellowfin sole were found throughout and outside the bay (-0.7 to 8.2 km from the bay mouth), most were found closer to the head of the bay than age-0 yellowfin sole. All age-1 yellowfin sole were collected at depths less than 40 m and in waters 8.2 - 8.9°C and 31.7 - 32.0 PSU. Age-1 fish were found only on sand and muddy sand substrate and were only caught 330 minutes after sunrise and later. Of the 25 age-1 yellowfin sole caught, 87% were from Kalsin Bay.

Age-≥2 yellowfin sole were caught during KI9403 (N=48).

Rock sole (Figures 254, 339-350)

Rock sole was the most abundant species of flatfish captured during KI9403 (N of all ages=2,461) and was also the most abundant age-0 fish caught (N=2,219). Age-0 rock sole were caught at 66.7% of stations. The mean number of age-0 fish/tow was 168.0±194.5, and the largest catch was 680 fish/tow. Eighty-one percent of age-0 rock sole were in Kalsin Bay and 21% were caught in Middle Bay. Age-0 rock sole were found throughout and outside the bay (-2.4 to 8.2 km from the bay mouth) in depths up to 80 m, but were primarily concentrated in water <50 m. Age-0 rock sole were collected in 7.6 - 9.9°C, 31.6 - 32.1 PSU, and on all substrates sampled (sand, muddy sand, sandy mud, sandy gravel, and gravel). Age-0 rock sole abundances increased with increasing percent of sand and decreasing percent of mud.

Age-1 rock sole (N=183) were caught at 51.9% of stations during KI9403. The mean number of age-1 fish/tow was 8.7±9.8, and the largest catch was 36 fish/tow. The abundance of age-1 rock sole was spread fairly evenly throughout and outside Middle and Kalsin Bays (-1.8 to 8.1 km from the bay mouth). The abundance of age-1 rock sole was split fairly evenly between the two bays, 41% in Middle Bay and 59% in Kalsin Bay. Age-1 rock sole were found only in depths < 60 m, with highest abundances between 20 and 50 m and decreasing abundance at shallower and greater depths. Age-1 rock sole were collected in 8.2 - 13.5°C waters and across the full range of sampled salinities (29.8 - 32.1 PSU). Like age-0 fish, age-1 rock sole were on all substrates sampled (sand, muddy sand, sandy mud, sandy gravel and gravel).

Age-≥2 rock sole were caught during KI9403 (N=59).

Butter sole (Figures 254, 351-362)

Age-0 butter sole (N=3) were caught at 14.8% of stations during KI9403. The mean number of age-0 fish/tow was 0.2±0.7, and the largest catch was four fish/tow. The age-0 butter sole were caught outside the mouth of Middle Bay (-0.8 to -2.4 km from the bay mouth). The presence of age-0 butter sole at two stations at the head of Kalsin Bay are noted (Figure 351a), but due to the high number of replicate tows at these stations, the calculated CPUE of fish was negligible (N=0.32 and N=0.14 fish at CS#6 and 12, respectively). Age-0 butter sole were found in 5 - 80 m water depth, 7.6 - 9.1°C, and 31.7 - 32.1 PSU. They were found on sand, muddy sand, and sandy gravel substrate.

No age-1 butter sole were caught during KI9403.

Age-$\geq$2 butter sole were captured during KI9403 (N=33).

Alaska plaice (Figures 254, 363-374)

No age-0 Alaska plaice were caught during KI9403.

Two age-1 plaice were captured at a single station during KI9403 (CS#3), corresponding to 3.7% of stations and an average of 0.0±0.3 fish/tow. The plaice were at the head of Middle Bay, 7.5 km from the bay mouth. The fish were captured in 0 - 5 m water, at 13.5°C, 29.8 PSU, and on muddy sand sediment. This station had the lowest salinity and highest temperature of all the sites sampled during KI9403.

Two age-$\geq$2 Alaska plaice were caught during KI9403.

English sole (Figures 254, 375-386)

Age-0 English sole (N=29) were caught at 22.2% of stations during KI9403. The mean number of age-0 fish/tow was 1.3±3.2, and the largest catch was 21 fish/tow. English sole were found only near the heads of Middle and Kalsin Bays (7.5 - 8.2 km from the bay mouth). Eighty-one percent of these fish were caught in a single station (CS#3) in Middle Bay, the station with the lowest salinity and highest temperature of all the sites examined during KI9403. Age-0 English sole were found in <30 m water depth (primarily in 0 - 5 m), 8.2 - 13.5°C (primarily 13.5°C) and 29.8 - 31.9 PSU (primarily 29.8 PSU). English sole were captured over sand and muddy sand substrates.

Age-1 and age-$\geq$2 English sole were not captured during KI9403.

Sand sole (Figures 254, 387-398)

No age-0 sand sole were caught during KI9403.

A single age-1 sand sole was found at the head of Kalsin Bay (CS#8), 8.2 km from the bay mouth, corresponding to 3.7% of the stations sampled during KI9403. The mean number of age-1 fish/tow was 0.0±0.1. The sand sole was caught in 0 - 5 m water, at 8.2°C, 31.9 PSU, and on sand substrate.

Age-$\geq$2 sand sole were captured during KI9403 (N=4).

Kazakof Bay/August 1994 (KI9402)

Physical data within Kazakof Bay/August 1994 (KI9402)

Temperature within Kazakof Bay/August 1994 (KI9402)

Temperatures recorded from most stations within Kazakof Bay decreased gradually from the surface to about 15 m below the surface (Figure 399). Profiles usually encompassed a temperature shift of several degrees within this depth range, and below 15 m depth, conditions were fairly isothermal.

Bottom temperatures in Kazakof Bay ranged from 4.4 to 14.2°C (Table 7, Figure 400). The warmest bottom temperatures (9.4 - 14.2°C) were in shallow (<10 m), nearshore water. Bottom temperatures decreased with increasing depth, and the coldest waters (4.4 - 5.0°C) were in water deeper than 70 m.

Salinity within Kazakof Bay/August 1994 (KI9402)

Conditions within Kazakof Bay were usually isohaline, except for the surface 10 m (Figure 401). At CS#9 & 18 a sharp variation in salinity occurred near the bottom. This feature was not echoed within the temperature profiles, but since these stations were in close proximity (0.5 km apart) it is likely the salinity variation is not due to gear error.

Bottom salinities within Kazakof Bay ranged from 28.8 to 34.0 PSU (Table 7, Figure 402).

KI9402 Substrate within Kazakof Bay/August 1994 (KI9402)

Substrate at most stations appeared to be predominantly mud, but as sediment grain size has not yet been analyzed for this cruise, flatfish distribution was not described relative to substrate type.

Fish data within Kazakof Bay/August 1994 (KI9402)

A total of 645 fishes were entered in the database from KI9402 for use in CPUE (Table 20), distribution and length analyses. All captured fishes were measured, of which 217 (34%) were flatfishes. The cumulative mean CPUE flatfish/station of flatfishes from quantitative tows at 29 stations was 440, for an average CPUE of 15 flatfishes/station during KI9402.

Five species of flatfish were collected during KI9402. Listed in decreasing order of abundance (cumulative CPUE of all ages), these species were flathead sole (N=275), yellowfin sole (N=111), rock sole (N=47), Pacific halibut (N=4) and English sole (N=4).

Flatfishes were caught at all but 17% (N=5) trawl stations during KI9402. Flathead sole were caught at 62% of stations, halibut were caught at 3% of stations, yellowfin sole were caught at 21% of s tations, rock sole were caught at 28% of stations sampled, and English sole were caught at 3% of stations.

During August 1994 within Kazakof Bay (Table 21), age-0 was the numerically dominant age class colle cted of halibut, rock sole and English sole. Age-1 fishes were caught most often of flathead sole and yellowfin sole.

Distribution of flatfishes by age within Kazakof Bay/August 1994 (KI9402)

Flathead sole (Figures 403-409)

Age-0 flathead sole (N=85) were caught at 34% of stations during KI9402. The mean number of age-0 fish/tow was 3.0±6.1, and the largest catch was 27 fish/tow. Age-0 fish were captured primarily down the center of Kazakof Bay. They were caught in 20 - 90 m water depth and increased in abundance with increasing depth. Age-0 flathead sole were not caught at the head of Kazakof Bay, but were caught well within the bay, at sites 12 - 16 km from the mouth. They were captured only in cool temperatures (4.7 - 7.7°C), and in salinities from 28.8 to 32.0 PSU.

Age-1 flathead sole (N=130) were caught at 48% of stations during KI9402. The mean number of age-1 fish/tow was 4.2±6.2, and the largest catch was 21 fish/tow. Distribution of age-1 fish was similar to age-0 fish. Age-1 flathead sole were caught in 20 - 100 m water depth, and were most abundant from 40 to 80 m water depth. Age-1 flathead sole were not caught at the head of the bay. They were collected in waters of 4.6 - 7.9°C and 28.8 - 32.1 PSU.

Age-≥2 flathead sole were caught during KI9402 (N=60).

Pacific halibut (Figures 410-416)

Age-0 halibut (N=4) were caught at 3% of stations during KI9402. The mean number of age-0 fish/tow was 0.1±0.6, and the largest catch was four fish/tow. Age-0 halibut were caught at a single station near the head of Kazakof Bay, in 10 - 20 m water depth, 8.5°C, and 32.8 PSU.

No age-1 or age-≥2 Pacific halibut were caught during KI9402.

Yellowfin sole (Figures 417-423)

Age-0 yellowfin sole were not captured during KI9402.

Age-1 yellowfin sole (N=92) were caught at 17% of stations during KI9402. The mean number of age-1 fish/tow was 2.6±10.9, and the largest catch was 60 fish/tow. Age-1 yellowfin were caught in 10 - 40 m water depth, from 13 to 18 km inbay, in 7.5 - 8.2°C and 31.3 - 32.0 PSU water.

Age-≥2 yellowfin sole were caught during KI9402 (N=19).

Rock sole (Figures 424-430)

Age-0 rock sole (N=24) were caught at 17% of stations during KI9402. The mean number of age-0 fish/tow was 0.9±2.6, and the largest catch was 12 fish/tow. Age-0 fish were caught from 0 to 50 m water depth, 12 to 20 km inbay. They were caught within a wide range of temperatures (6.8 - 14.2°C). Age-0 rock sole were caught in 30.5 - 32.0 PSU water salinity.

Age-1 rock sole (N=19) were caught at 17% of stations during KI9402. The mean number of age-1 fish/tow was 0.6±2.2, and the largest catch was 12 fish/tow.

Like age-0 fish, age-1 rock sole were caught from 0 to 50 m water depth and 12 to 20 km inbay. Temperature ranges where age-1 rock sole were captured were slightl y narrower (7.3 - 14.2) than for age-0 fish. Salinity of capture was 30.5 - 34.0 PSU.

Age-≥2 rock sole were caught during KI9402 (N=5).

English sole (Figures 431-437)

Age-0 English sole (N=4) were caught at 3% of stations during KI9402. The mean number of age-0 fish/tow was 0.3±1.0, and the largest catch was four fish/tow. English sole were captured at a single station, in 0 - 5 m water depth, at the head of Kazakof Bay in water of 14.2°C and 30.5 PSU.

Neither age-1 nor age-≥2 English sole were caught during KI9402.

CONCLUSIONS

During prior funding, samples were collected in 1991 and 1992 within all major bays around Kodiak Island. The 1991 and 1992 trawl samples and physical data formed the basis of the following conceptual models of flatfish nursery habitat around Kodiak Island (Norcross et al. 1995A, 1995B). Age-0 rock sole are found predominantly in water depths less than 50 m on sand or mixed sand substrate within 10 km of bay mouths. Age-0 flathead sole are found predominantly in water depths greater than 40 m on mud or mixed mud substrate throughout bays. Age-0 Pacific halibut are found predominantly in water depths less than 40 m on mixed sand substrate near or outside mouths of bays. Age-1 yellowfin sole are found predominantly in water depths less than 40 m on mixed substrate at upper reaches of bays.

During 1991 and 1992, only age-0 rock sole, flathead sole, Pacific halibut and age-1 yellowfin sole were captured in large enough numbers to form models. The conceptual models of flatfish distribution (Norcross et al. 1995A, 1995B) based on 1991 - 1992 data were verified during collections within Chiniak Bay during 1993 and 1994. As in 1991 - 1992, station locations were selected based on depth and sediment strata, and data were analyzed using the physical parameters of location in the bay, depth, bottom temperature, bottom salinity and sediment type. Data from KI9403 suggests that flathead sole are predominantly found in >20 m water depth, a modification from the >40 m mentioned in the models.

In 1993 and 1994, age-1 of flathead sole and rock sole and ages-0 and 1 of arrowtooth flounder were captured in sufficiently large abundances for us to develop conceptual models of distribution for additional age-groups and species. Age-1 flathead sole were found in greatest abundance in depths >20 m on sandy mud and muddy sand throughout the bay. Age-1 rock sole were mainly in depths <40m on sandy substrates throughout the bay. Both age-0 and age-1 arrowtooth flounder were found in water depth >20m on sandy mud and muddy sand near the bay mouth.

We found that our conceptual models of distribution did not fit well in all seasons sampled. However, since sampling was most extensive in August, we did not have sufficient data to develop models for other seasons. This is a prime objective of a separately funded CMI project which is currently underway.

The four years of data now available on physical parameters and flatfish abundances within Chiniak Bay have enabled us to narrow the scope of future collections. In Chiniak Bay, we will sample only at "permanent" stations which have been determined based on 1991 - 1994 data. Using these "permanent" stations, we will develop indices of interannual abundance changes. In comparisons of fish abundance and distribution from 1991 through 1994, differences among species and among stations can be identified in addition to interannual variability. In particular, the distribution of rock sole and flathead sole appear to be strongly related to depth and substrate type. In the future we will examine depth and substrate patterns in more detail and will investigate other parameters which may affect the distribution of the abundant flatfishes. From this, we will discern the key habitat characteristics for each species, enabling us to monitor their abundances over time.

ADDITIONAL PRODUCTS PRODUCED

Funding from Coastal Marine Institute assisted with analysis of 1991 flatfish stomach contents and with comparisons of juvenile flatfish distribution from 1991 and 1992. Thus far, three manuscripts based on these data have been accepted for publication and another has been submitted. All are available upon request. The distribution and abundance of flatfishes captured during August 1991 was evaluated by linear discriminant function analysis in the manuscript "Nursery area characteristics of Pleuronectids in coastal Alaska, USA" (Norcross et al. 1995A), which has been accepted for publication in the Netherlands Journal of Sea Research. Multivariate analysis of distribution and abundance of flat fishes captured during 1991 and 1992 was summarized in the manuscript, "Habitat models for juvenile Pleuronectids around Kodiak Island, Alaska, USA" (Norcross et al. 1995B). Feeding diversity of juvenile flatfishes was described in "Diet diversity as a mechanism for partitioning nursery grounds of Pleuronectids" (Holladay and Norcross 1995). These last two manuscripts were presented orally at the International Symposium on North Pacific Flatfish, held 26 - 28 October 1994 in Anchorage, Alaska, and will be published in the unrefereed proceedings of that symposium. The habitat model manuscript was submitted to Fishery Bulletin (US) and has since been revised based on reviewers' comments. The information on diet diversity is the topic of Brenda Holladay's M.S. thesis. Additional sampling and analysis to develop indices of interannual flatfish abundance is Sherri Dressel's M.S. thesis.

Related projects assisted through this funding

Live juvenile flatfishes were captured during 1992 - 1994 field work for a separate lab study (Moles et al. 1994, Moles and Norcross in press) to assess sediment preferences of various juvenile flatfish species. The lab study addresses the response of flatfishes to various concentrations of petroleum hydrocarbons in sediment, submits fishes to physiological tests which assess the effect of non-avoidance of oiled sediment on the survivability of the fish, and also provides a monitor for rates of growth, feeding, and respiration during long term (chronic) exposure to low levels of oiled sediments. This research is Adam Moles' Ph.D. thesis.

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LITERATURE CITED

Allen, L.G. 1988. Recruitment, distribution and feeding habits of young-of-the-year California halibut (*Paralichthys californicus*) in the vicinity of Alamitos Bay-Long Beach Harbor, California, 1983-1985. Bull. So. Calif. Acad. Sci. 87(1):19-30.

American Fisheries Society. 1991. Common and scientific names of fishes from the United States and Canada, 5th Ed. AFS Special Publication 20, Bethesda, Maryland. 183 p.

Blackburn, J.E. 1979. Demersal fish and shellfish assessment in selected estuary systems of Kodiak Island. IN: Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators, 6:727-851.

Edwards, R. and J.H. Steele. 1968. The ecology of 0-group plaice and common dabs at Loch Ewe. J. Exp. Mar. Biol. Ecol. 2:215-21
38.

Folk, R.L. 1980. Petrology of sedimentary rocks. Hemphill Publishing Co., Austin, TX. 182 p.

Gibson, R.N. 1973. The intertidal movements and distribution of young fish on a sand beach with special reference to the plaice (*Pleuronectes platessa* L.). J. Exp. Mar. Biol. 12:79-103.

Gibson, R.N. and L. Robb. 1992. The relationship between body size, sediment grain size and the burying ability of juvenile plaice, *Pleuronectes platessa*. J. Fish. Biol. 40:771-778.

Gunderson, D.R. and I. E. Ellis. 1986. Development of a plumb staff beam trawl for sampling demersal fauna. Fish. Res. 4:35-41.

Harris, C.K. and A.C. Hartt. 1977. Assessment of pelagic and nearshore fish in three bays on the east and south coasts of Kodiak Island, Alaska: Final report. IN: Environmental Assessment of the Alaskan Continental Shelf, Quarterly Reports of Principal Investigators. 1:483-688.

Hart, J.J. 1980. (ed.) Pacific fishes of Canada. Fish. Res. Bd. Can., Ottawa, Canada. 740 p.

Hayes, M. O. and C. H. Ruby. 1979. Oil spill vulnerability, coastal morphology and sedimentation of the Kodiak archipelago. IN: Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators. Volume 2. Physical Science Studies: 1-155.

Holladay, B.A. and B.L. Norcross. 1995. Diet diversity as a mechanism for partitioning nursery grounds of Pleuronectids. IN: Proceedings of the International Symposium on North Pacific Flatfish. Alaska Sea Grant College Program Report No. 95-04, University of Alaska Fairbanks. 643 p.

Microrim, Inc. 1990. R-Base User's Manual, 3rd ed. 605 p.

LITERATURE CITED (continued)

Microsoft Corporation. 1993. Microsoft Excel User's Guide. 786 p.

Moles, A., S. Rice and B.L. Norcross. 1994. Non-avoidance of hydrocarbon laden sediments by juvenile flatfishes. Neth. J. Sea Res. 32:361-367.

Moles, A. and B.L. Norcross. In press. Sediment preference in juvenile Pacific flatfishes. Neth. J. Sea Res.

Moyle, P.B. and J.J. Cech, Jr., eds. 1988. Reproduction. IN: Fishes: An introduction to Ichthyology, 2nd ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey. 559 p.

Norcross, B.L., B.A. Holladay, and M. Frandsen. 1993. Recruitment of juvenile flatfish in Alaska, Phase 1. Final Contract Report, NOAA # NA 16FD0216-01. 504 p.

Norcross, B.L., B.A. Holladay, and F.J. Müter. (1995A). Nursery area characteristics of pleuronectids in coastal Alaska, USA. Neth. J. Sea Res. 33.

Norcross, B.L., F.J. Müter, and B.A. Holladay. (1995B). Habitat models for juvenile pleuronectids in coastal Alaska, USA. IN: Proceedings of the International Symposium on North Pacific Flatfish. Alaska Sea Grant College Program Report No. 95-04, University of Alaska Fairbanks. 643 p.

Norcross, B.L., F.J. Müter, and B.A. Holladay. In review. Habitat models for juvenile Pleuronectids around Kodiak Island, Alaska, USA. Fish. Bull. (US).

Pearcy, W.G., and S.S. Myers. 1974. Larval fishes of Yaquina Bay, Oregon: A nursery ground for marine fishes? Fish. Bull. 72(1):201:213.

Pihl, L., and R. Rosenberg. 1982. Production, abundance, and biomass of mobile epibenthic marine fauna in shallow waters, western Sweden. J. Exp. Mar. Biol. Ecol. 57:273-301.

Poxton, M.G., A. Eleftheriou, and A.D. McIntyre. 1982. The population dynamics of 0-group flatfish on nursery grounds in the Clyde Sea area. Est. Coast. Shelf Sci. 14:265-282.

Poxton, M.G., A. Eleftheriou and A.D. McIntyre. 1983. The food and growth of 0-group flatfish on nursery grounds in the Clyde Sea Area. Est. Coast. Shelf Sci. 17:319-337.

Riley, J.D., D.J. Symonds and L. Woolner. 1981. On the factors influencing the distribution of 0-group demersal fish in coastal waters. Rapp. P.-v. Reun. Cons. int. Explor. Mer. 178:223-228.

Rogers, C. 1985. Population dynamics of juvenile flatfish in the Grays Harbor estuary and adjacent nearshore areas. Abstract. Wash. Sea Grant Report WSG-TH-85-2.

LITERATURE CITED (continued)

Rogers, C.W., D.R. Gunderson, and D. A. Armstrong. 1988. Utilization of a Washington estuary by juvenile English sole, *Parophrys vetulus.* Fish. Bull. (USA), 86:823-831.

Sheppard, F.M. 1973. Submarine Geology. 3rd ed. Harper and Row Publishers, New York, New York. 517 p.

Smith, R. L., A. C. Paulson and J. R. Rose . 1976. Food and feeding relationships in the benthic and demersal fishes of the Gulf of Alaska and Bering Sea, IN: Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators. 7:471-508. RU 0284.

Tanaka, M., T. Goto, M. Tomiyama, and H. Sudo. 1989. Immigration, settlement and mortality of flounder (*Paralichthys olivaceus*) larvae and juveniles in a nursery ground, Shijiki Bay, Japan. Neth. J. Sea Res. 24(1):57-67.

Tyler, A.V. 1971. Surges of winter flounder, *Pseudopleuronectes americanus*, into the intertidal zone. J. Fish. Res. Bd. Canada. 28:1727-1732.

van der Veer, H.W. and M.J.N. Bergman. 1986. Development of tidally related behaviour of a newly settled 0-group plaice (*Pleuronectes platessa*) population in the western Wadden Sea. Mar. Ecol. Prog. Ser. 31:121-129.

van der Veer, H.W., M.J.N. Bergman, R. Dapper, and J.I. Witte. 1991. Population dynamics of an intertidal 0-group flounder *Platichthys flesus* population in the western Dutch Wadden Sea. Mar. Ecol. Prog. Ser. 73:141-148.

Wilkinson, L. 1990. Sygraph: The System for Graphics. SYSTAT, Inc., Evanston, IL. 677 p.

Wyanski, D.M. 1990. Patterns of habitat utilization in 0-age summer flounder (*Paralichthys dentatus*). M.S. Thesis, College of William and Mary, Gloucester Point, VA. 54 p.

Zhang, C.I. 1988. Food habits and ecological interactions of Alaska plaice, *Pleuronectes quadrituberculatus*, with other flatfish species in the eastern Bering Sea. Bull. Korean Fish. Soc. 21(3):150-160.