34. PHYSICAL OCEANOGRAPHY AND MARINE WATER QUALITY

34.1 Introduction

Data collection for the study of physical oceanography and marine water quality were undertaken from 2004 through 2008 to provide a physical context for observed biological conditions in the Iliamna/Iniskin Estuary (IIE) and to characterize the existing water quality conditions in the estuary's marine environment. The study area for characterization of the marine nearshore habitat included all marine waters and shorelines in Iliamna and Iniskin bays (except inner Cottonwood Bay and inner Iniskin Bay) and along the bight between the bays (see Figure 1-4 in Chapter 1 for these landmarks, but note that the study area specific to this chapter is not the Cook Inlet study area depicted on that figure).

The characterization of physical oceanography and marine water quality for the Pebble Project included the following elements:

- A thorough search of literature related to the natural environment of Cook Inlet, with emphasis on the lower west side of the inlet.
- Personal experience of the investigators in the Iliamna/Iniskin Estuary and Cook Inlet dating back to the mid-1970's.
- Observations made during marine biological field work conducted from 2004 through 2008 in the Iliamna/Iniskin Estuary.

Marine water quality parameters included various chemical constituents for which laboratory analyses were done, as well as salinity, temperature, and turbidity, which were measured in the field. Field parameters were measured in conjunction with the marine habitat assessments of the Iliamna/Iniskin Estuary conducted from August 2004 through November 2008. Water samples for chemical analysis were collected in August and September 2004 and May, July, and September 2008 and were analyzed for trace elements, and inorganic and organic constituents.

34.2 Results and Discussion

34.2.1 Physical Oceanography

Iliamna and Iniskin bays were formed by glacial scouring and subsequent infilling with sediment over recent geologic time. The waters in both bays are generally well mixed by waves and tidal currents, added to, in part, by the bays' shallow bathymetry and minimal freshwater inputs during most of the year. An exception to this occurs during periods of high seasonal snowmelt runoff when a freshwater surface layer temporarily develops.

The bays are characterized by extensive mudflats in their upper reaches with deeper channels extending into the outer bay entrances adjacent to Black Reef and into Cook Inlet. Extensive reefs, shoals, offshore rocks, and islands dot the entrances to both bays and the waters in between.

Iniskin Bay has a relatively deep trough along its western shoreline (maximum depth 24 meters).This trough shallows quickly to mudflats to the west and north. The eastern side of the trough steps up more gradually to a broad shelf that extends to the eastern shore of the bay.

Iliamna Bay is smaller and generally shallower than Iniskin Bay. The upper northward-trending portion of the bay and westward-trending Cottonwood Bay are dominated by mudflats that are exposed at lower tides. Cottonwood Bay also has a number of boulders scattered across the mudflats, while central Iliamna Bay has a mud/sand bottom with a limited number of intertidal reefs and subtidal hard-bottom areas. Turtle Reef partially blocks the entrance to Iliamna Bay off South Head, and White Gull Island is located just south of the center of the entrance to the bay (Figure 1-3c in Chapter 1). The only deeper water in the bay is on either side of White Gull Island, where average depths are approximately 10 meters and the maximum depth is 12 meters.

The Iliamna/Iniskin Estuary has an extreme tidal range of approximately 7.6 meters, with a mean tidal range of about 3.75 meters. Maximum currents are estimated to be in the range of approximately 300 centimeters per second (5.8 knots), based on observed ice movement during the April 2006 marine sampling event and data from Kamishak Bay. Average ebb currents in Iniskin Bay are approximately 62 centimeters per second (1.2 knots), and average maximum flood currents are 46 centimeters per second (0.9 knots).

Field observations indicate that tidal currents generally follow the primary direction of the bays, particularly in the deeper trough sections. Small eddies have been observed in the lee of several points of land and behind islands, shoals, and other obstructions, thus providing refuge for smaller fish and areas of calmer water during peak tidal flow. A few tide rips, resulting from the often strong wave and tidal action, were observed in the bays during marine field sampling events. Tidal fluctuations and wind forcing are the primary drivers of mixing in both bays of the Iliamna/Iniskin Estuary. Sea swell, wind waves, and tidally generated waves all affect exposed shorelines from Knoll Head to North Head, as well as beaches within the bays that face the bay entrances.

The extent of ice coverage varies yearly, but ice is consistently present from January through March in the Iliamna/Iniskin Estuary and can extend from December into April in the coldest years. Relatively continuous floating masses of ice have been observed in the outer portions of the bay, at times cutting off access to certain portions of the bays, but constantly moving with tidal and wind fluctuations.

34.2.2 Marine Water Quality

Water quality in the Iliamna/Iniskin Estuary during the period from 2004 through 2008 appeared to be dominated by tidal exchange with Cook Inlet and Kamishak Bay, with smaller, localized effects from freshwater inputs and local wind waves. Observed gradients in salinity between the

inner (lower salinity) and outer (higher salinity) portions of Iliamna Bay are consistent with this conclusion. Average salinity was observed to decrease from the outer stations of Iliamna Bay to the inner stations. This is likely a result of freshwater inputs at the head of Iliamna Bay. Salinity decreases from spring to late summer and increases again in the fall, thus providing an additional indicator of the influence of regional water on the bays. A certain amount of stratification was observed during both the spring snowmelt season and during the warmer summer months, particularly during calmer weather and in more sheltered portions of the bays. Snowmelt or significant rain events create a freshwater surface lens in areas adjacent to freshwater inputs; these lenses were never observed to be greater than a few centimeters deep and are expected to rapidly diminish as a result of tidal and wind-driven mixing.

Water temperatures are driven by insolation and seasonal variations; ice is present through the winter months, a warming trend occurs during the spring and summer, and temperatures decline again in the fall. Temperatures also vary with water depth, thus reinforcing the idea of insolation as a factor in temperature trends. The lowest water temperatures were recorded during March sampling events, while the highest water temperatures were generally recorded during August sampling events. There was an indication of higher temperatures in inner Iliamna Bay than in the outer bay, with exceptions that could be attributed to local physical characteristics, such as colder freshwater inputs reducing temperature locally. This temperature differential between the inner and outer bay supports the expectation that solar radiation in summer (when the majority of temperature readings were collected) has a greater influence on shallow inner-bay waters than on deeper outer-bay waters. The findings suggest that the primary factors influencing water temperature are tidal exchange with Cook Inlet and nearshore solar heating.

Analysis of available data indicates that turbidity is generally moderate and does not exhibit any obvious trends that indicate point-source inputs. Turbidity in Iliamna Bay is greatest in the late summer and early fall and, in the Iniskin Bay, is at a maximum in early spring and in late fall. Overall, though, on a monthly basis, average turbidity among all sites remained relatively constant over the study period, generally ranging between 3.1 and 13.0 nephelometric turbidity units.

Analyses of hydrocarbon concentrations in marine water from the Iliamna/Iniskin Estuary in 2004 and of metal and trace element concentrations in 2008 showed little to no connection to anthropogenic effects. Concentrations of all inorganic constituents were less than water quality maximum criteria recommended by the Environmental Protection Agency and others for marine habitat, many by orders of magnitude. Organic constituents were similarly at low levels and appeared to be derived from biologic, petrogenic, and anthropogenic sources. Data analyses show the marine waters of the Iliamna/Iniskin Estuary to be high-quality habitat for marine biota. The data provide some support for a relationship between increased concentrations of inorganic constituents and total suspended solids, but demonstrate no strong patterns with respect to depth in the water column, to geography, or to tidal elevation.

Wind and waves churn the Iliamna-Iniskin Estuary in March 2008.

Pancake ice covers the entrance of Iniskin Bay, March 2008.

The quiescent waters of summer in the Iliamna/Iniskin Estuary, June 2008.

Collecting a discrete water sample for physio-chemical analysis, July 2008.