Workshop Report

Southeast Alaska Synthesis of Marine Biology and Oceanography

Workshop Dates: March 30-31, 2005
University of Alaska Southeast
Juneau, Alaska

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Prepared by

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Additional materials available on the workshop website
http://uashome.alaska.edu/~jfgle1/SynthesisWorkshop/

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EXECUTIVE SUMMARY

A workshop was held on March 30-31, 2005 at the University of Alaska Southeast to bring together representatives from different marine science disciplines and organizations to synthesize information on the marine biology and oceanography of Southeast Alaska. Thirty-eight individuals participated, including representatives of state and national agencies, the University of Alaska Southeast and University of Alaska Fairbanks. Overviews were presented by steering committee members on physical oceanography, biological oceanography, fisheries, seabirds, nearshore ecology, and marine mammals. Each overview was followed by a general discussion of information that was not included in the overview (data gaps) and priorities for future research (data needs). The workshop was concluded with a general discussion that identified overarching research needs for the region and concluded the workshop. All participants were given an opportunity to provide editorial comments on this workshop report.

Our understanding of marine biology and oceanography in Southeast Alaska lags that of other marine regions of Alaska and abounds with research opportunities. Southeast Alaska is roughly the same size as the state of Florida and contains significant marine resources on regional, state, and national scales. It is an attractive location for research on Alaskan marine biology and oceanography, because much of the region is well-protected, and marine waters are accessible year-round. Perhaps most importantly, the ecology of Southeast Alaska is apparently decoupled from other marine areas in the Gulf of Alaska, offering an opportunity to contrast the population ecology of species with different trends in each area (e.g., salmon, sea lions, puffins). Southeast Alaska also has many unique features including tidewater and coastal glaciers, large inputs of freshwater from precipitation, and an intricate network of islands where the marine habitat is fragmented and land-marine interactions are intense. The North Pacific Current bifurcates as it approaches North America around Sitka, with one stream flowing north to form the Alaska Current, and one stream flowing south to eventually form the California Current. The relative strengths of these currents after bifurcation is at the heart of hypotheses about how decadal-scale variation in climate influences production in the Northeast Pacific—yet the process is poorly studied. Greater communication and collaborations are needed between researchers in British Columbia, Southeast Alaska and the Gulf of Alaska. Coordination could be accomplished through the creation of an interagency consortium focused on Southeast Alaska Ocean Sciences.

Several research priorities were identified at the workshop. On the practical side, we identified the need for data archiving of historical data, better coordination to share logistics, and increased effort to collect as much data as possible during shipboard operations (e.g. employ hull mounted temperature-salinity sensors, etc.). On the science side, we need to better understand trophic linkages at the ecosystem level, particularly predator-prey interactions of commercially important fish and shellfish, birds, and marine mammals. Locations that have been well studied should integrate data across disciplines to examine linkages among physical processes and higher and lower trophic levels. Early life histories and recruitment dynamics are needed to better understand critical life stages and population regulation. Trophic studies need to be conducted during all seasons because some populations may be limited by winter conditions, whereas others may be limited by different factors during another season. Primary and secondary production need to be studied in this context (e.g. phytoplankton are limited by light in the winter and can be limited by nutrients in the summer) and to understand oceanographic processes that

occur in productive versus unproductive areas. Past productivity can be extrapolated from sediments in anoxic basins and from records of growth in bivalves and fishes. Nutrient inputs, uptake, and transport must be examined to understand primary productivity. Harmful algal blooms are a persistent problem that warrants further study. A comprehensive inventory of Southeast Alaska marine resources has never been conducted and would be very valuable to examine biological and physical properties of the marine ecosystem. Comparisons between northern and southern Southeast Alaska as well as comparisons between inside waters and offshore regions of Southeast Alaska would be very interesting in light of the physical differences among these regions. Long-term time series generated by continuous sampling in discrete locations are valuable for detecting changes over time. Moorings should be established in inside waters in Southeast Alaska to continuously sample weather and oceanographic parameters. Mapping efforts should be continued and expanded, including multibeam mapping of subtidal regions and ShoreZone mapping of intertidal regions.

Future synthesis efforts will include bibliographies and review papers. Bibliographies will be made available on the Workshop website. Review papers will be prepared by steering committee members on each focus area and submitted to peer-reviewed journals. Additional information from the workshop, including PowerPoint presentations from the workshop, are available on the workshop website http://uashome.alaska.edu/~jfgle1/SynthesisWorkshop/.

WORKSHOP SYNOPSIS

Day 1 (March 30) morning

Introduction

Ginny Eckert introduced the goal and structure of the workshop. The goal was to review and synthesize what is known about marine biology and oceanography of the Southeast Alaska region and then prioritize future directions for research. The workshop was structured such that steering committee members (Eckert, Eisner, Kruse, Weingartner, Piatt, and Straley) along with additional experts provided short overviews of five focus areas (oceanography, nearshore ecology, fisheries, seabirds and marine mammals). Each overview was followed by a general discussion to address 1) additional existing data not identified by the speaker that could be included in the synthesis project and 2) priorities for research within this topic. Workshop participants were selected to represent the broad range of topics covered during the workshop, although an effort was made to keep the group small enough to facilitate cross-disciplinary interaction. The North Pacific Research Board provided funding for the workshop and for a steering committee to conduct the synthesis. Products include this workshop report and synthesis review papers to be published in peer-reviewed journals. For the purposes of this synthesis, Southeast Alaska was defined to range from Cape Fairweather to Dixon Entrance.

Oceanography Overview

Physical Oceanography – Southeast Alaska

Overview prepared and presented by Thomas Weingartner, Institute of Marine Science, University of Alaska Fairbanks.

"Southeast Alaska: Oceanographic Habitats and Bridges"

The oceanography of Southeast Alaska is intimately linked to its complex geological structure and meteorology in the Northeast Pacific Ocean. Glaciers and tectonic processes carved a complex of channels and fjords throughout the archipelago and a deep, narrow (10 – 30 km), and corrugated continental shelf. The region is bounded by steep mountains that, combined with storms associated with the Aleutian Low, influence wind and precipitation patterns. These storms result in strong winds and heavy precipitation rates year-round, which significantly affect shelf and archipelago circulation fields. The region is also forced from offshore by basin-wide circulation that flows northward as a diffuse and weak eastern boundary current (Alaska Current) along the continental slope of Southeast Alaska. The Alaska Current, which forms as the westward-flowing North Pacific Current bifurcates offshore of British Columbia, connects the Gulf of Alaska to the North Pacific Ocean and advects relatively warm water into the region. The location and strength of the Aleutian Low governs the strength of the Alaska Current and the bifurcation latitude of the North Pacific Current.

Winds and precipitation vary seasonally, resulting in seasonal changes in circulation, mixing, and stratification. Downwelling favorable winds prevail from fall through early spring; winds are stronger in northern Southeast Alaska than along the British Columbian shelf. In summer, downwelling weakens over the northern shelf while upwelling winds develop over the southern Gulf of Alaska. The shelf wind field is thus divergent year-round with potentially important consequences for the shelf and archipelago. For example, the divergence will affect cross-shelf circulation patterns, exchange between the shelf and deep basin, and, through the establishment of alongshore pressure gradients, flows in the channels of the archipelago. Within the archipelago, orography steers winds, resulting in large spatial gradients in wind velocity, circulation, and mixing.

Runoff is minimal in winter (when precipitation is stored in the mountain snowpack), increases in summer with melting, and is maximal in fall when precipitation rates are heaviest. On annual average the precipitation forces a coastal runoff of ~15,000 $m^3 s^{-1}$ (or 60% of the total coastal discharge into the Gulf of Alaska). Coastal runoff affects seasonal variations in stratification and promotes fjordal circulations in coastal embayments. In conjunction with the (mostly) downwelling favorable winds, runoff also forces a northward mean flow along the coast. This mean flow contributes to the Alaska Coastal Current and thus directly bridges the British Columbian and northern Alaskan shelves.

Tides interact with complex topography, giving rise to a plethora of small scale circulations that include tidal bores, internal hydraulic jumps, residual flows, and lee eddies. Many of these processes are likely modulated over the spring-neap cycle and by changes in wind and runoff. The tides likely affect exchange of waters between main channels and fjords and bays comprising the archipelago. These various phenomena are likely to be crucial in advecting and/or retaining plankton and fish larvae and regulating biological production within the archipelago.

In summary, tides, winds, and runoff interact with a complex bathymetry to transport mass, heat, freshwater, nutrients, and organisms northward from the southern to the northern Gulf of Alaska. These interactions also lead to large spatial and temporal gradients in biological production and create an array of diverse biological habitats. Thus, regional biology and physical oceanography will substantially modify the waters flowing northward through Southeast Alaska and likely affect production on the northern Gulf of Alaska shelf. In spite of its apparent importance to both regional oceanographic issues and to the larger Gulf of Alaska ecosystem, there have been few systematic studies in this region. Much work is needed to understand physical oceanography throughout Southeast Alaska as extrapolations based on models of dominant processes are generally inaccurate. However these models serve as a useful framework and a good starting point for future observations and studies.

<u>Physical Oceanography – Gulf of Alaska</u>
"Temperature and Salinity in the Gulf of Alaska"
Overview presented by Bill Crawford, Division of Fisheries and Oceans, British Columbia.
Overview prepared by Ginny Eckert, University of Alaska Southeast.

Bill Crawford and his colleagues studied temperature and salinity anomalies in the Gulf of Alaska including Southeast Alaska using NODC-archived data and data from Station P off the coast of British Columbia from 1950 to 2004. The overall patterns are that surface waters (10 to 50 m depth) in summer were cool in the mid-1960s with a regime shift to warmer waters around 1978. El-Niño years were warm, typically followed by cool years, and temperatures in 2004 were the warmest in this time series, potentially as a result of unusual summer weather in the Gulf in spring and summer of 2004. Deeper waters (100 to 150 m depth) show similar patterns with cool and warm periods but fewer fluctuations from year to year. Salinity anomalies in surface waters (10 to 50 m depth) at Station P demonstrated fresh and salty episodes in 2000 and 2003 that were the largest and broadest in space and of opposite sign. Salinity anomalies in deeper waters (100 to 150 m depth) exceeded the range of anomalies observed at surface waters and include a large freshwater episode centered in 2002 and ranging from 2000 to 2003.

The analysis of temperature and salinity in the Gulf of Alaska also reveals eddies that persistently form in two locations: 1) the Haida eddy that is generated at the southwestern tip of the Queen Charlotte Islands and 2) the Sitka eddy west of Sitka. These eddies are generated nearshore and transport coastal water with associated higher nutrients and coast-associated species and larvae westward. Sinclair and Crawford (2005) linked cod recruitment success to sea level in Prince Rupert, presumably as an index to eddy formation which transports cod larvae offshore in poor recruitment years. Understanding forcing mechanisms, transport, and frequency of formation of these eddies is a critical research need for the Gulf of Alaska.

Sinclair, A. F., and W. R. Crawford. 2005. Incorporating an environmental stock-recruitment relationship in the assessment of Pacific cod *(Gadus macrocephalus)*. Fisheries Oceanography **14**:138-150.

Biological Oceanography

Overview prepared and presented by Lisa Eisner, NOAA Fisheries, Auke Bay Laboratory.

Southeast Alaska is a diverse and complicated system with fine and meso scale variations in timing, distribution and intensity of plankton dynamics. Limited research has been conducted in biological oceanography with long term temporal coverage only in select regions. This review provides an introduction to some of the relevant processes by focusing on areas or projects with several year of time series data on plankton and water mass characteristics in Southeast Alaska. Areas include Auke Bay, Glacier Bay, Icy Strait, the outer coast, and hatcheries near Sitka Sound, Juneau and Ketchikan. This review also lists biological oceanography data collected over broader spatial areas in Southeast Alaska (i.e. satellite surface ocean color observations and zooplankton sampling during Canadian salmon surveys).

Auke Bay is a relatively small (11 km^2) shallow (~ 50 m) bay with relatively low freshwater input located ~10 miles north of Juneau. Earlier work in Auke Bay includes sampling by the National Marine Fisheries Service (NMFS) for salinity, temperature, chlorophyll *a*, and zooplankton in the 1950s, graduate student research projects (Oregon State University, University of Alaska Juneau) on phytoplankton and nutrient cycling in the late 1960s and early 1970s, and studies on currents, water quality, and intertidal habitat during the marina expansion project in the early 1980s. Most of the peer-reviewed literature on biological oceanography is from process studies during the APPRISE (Association of Primary Production and Recruitment in Subarctic Ecosystems) project in Auke Bay in the late 1980s. The main objective of the APPRISE work was to identify relationships between environmental factors, primary and secondary production, and the recruitment success of selected larval fish and shellfish. Some of the key biological oceanography findings of APPRISE for phytoplankton and zooplankton are as follows. The spring bloom started the first or second week in April (after 5-7 days of sunny weather), lasted approximately one month and was terminated upon depletion of nutrients in photic zone (Ziemann et al. 1990). Secondary blooms throughout the spring and summer were triggered by resupply of nutrients by wind driven vertical mixing (Iverson et al. 1974, Ziemann et al. 1990). Sedimentation of the primary spring bloom peaks in May, and approximately 40% of the bloom is lost from photic zone (Laws et al. 1988). The dominant phytoplankton (diatom) genera are *Thalassiosira, Skeletonema,* and *Chaetoceros* (Waite et al. 1992). The spring zooplankton populations peak in mid May and June with abundances dominated by copepods and biomass dominated by copepods, euphausiids and decapod larvae (Coyle and Paul 1990). Copepods and euphausiids consumed no more than 30% of the spring bloom production which suggests zooplankton were not food limited (Coyle and Paul 1990). The dominant copepod genera were *Pseudocalanus, Acartia*, and *Centropages*, although the relative importance varied seasonally (Wing, pers. comm.). For king crab larvae, the length of the larval period was negatively correlated with chlorophyll *a* concentration and survival (Shirley and Shirley 1990).

Glacier Bay is a recently deglaciated fjord system (1255 km^2) in northern Southeast Alaska, located 60 miles northwest of Juneau with numerous sills and deep (over 400 m) basins, large freshwater inputs from streams and tide water glaciers and high sedimentation rates (Hooge and Hooge 2002). Glacier Bay conductivity-temperature-depth (CTD) vertical profiles with sensors for photosynthetic available radiation (PAR), chlorophyll a fluorescence, optical backscatter (OBS, turbidity) have been collected at 24 stations in the Main Basin and East and West Arms two to four times per year (often March, July, October, December) from 1993-2005 by the United States Geological Survey (USGS) for the National Park Service (Hooge and Hooge 2002, Etherington et al. 2004). The spatial variations in surface chlorophyll a concentrations provide and indication of primary production dynamics. The highest chlorophyll *a* levels occurred in the Central Bay, lower reaches of East and West Arms, and Geikie Inlet and correspond to areas of intermediate stratification, higher light levels (decreased sediment loads), and zones of potential nutrient regeneration (Etherington et al. 2004). Additional CTD stations were sampled throughout the bay in summer 1999, 2002 and 2004 (studies by John Piatt and Jim Taggart, USGS) with water samples collected for nutrients, chlorophyll *a* (total and size-fractionated), and phytoplankton species in 2002 and 2004. Initial findings show that there was surface nutrient depletion in summer 2002 (Eisner, unpublished data). Limited studies on secondary production in Glacier Bay indicate that zooplankton densities were four to five times higher in East and West Arms compared to the Central Bay and outlying Icy Strait (Robards et al. 2003).

The South East Coastal Monitoring (SECM) group at Auke Bay Laboratory (NMFS) has conducted juvenile salmon and oceanographic surveys in northern Southeast Alaska including transects in Auke Bay, Chatham Strait, Icy Strait, Cross Sound, Icy Point, Cape Edwards (Orsi et al. 2000, 2004). Surveys have been conducted from May-September for 1997 to present, although spatial coverage has varied between years. Oceanographic parameters collected include CTD vertical casts (temperature, salinity, density only), surface (2 m) chlorophyll a and nutrients**,** surface along track thermosalinograph measurements (temperature and salinity), Secchi disk (water clarity), and zooplankton (243, 333, 505 µm net tows). One preliminary finding is that daytime biomass of deep 333µm mesh samples declined seasonally along a habitat gradient, inshore to offshore (Sturdevant pers. comm. 2005). An examination of the surface nutrient concentrations indicated that dissolved inorganic nitrogen (i.e. nitrate and ammonium) declined to limiting values (< 1µM) for at least one sampling period between May and August for Auke Bay, Icy Strait and Icy Point stations in 2000-2003, but not in 1999. In general, nutrients appeared to decline earlier in the season in Auke Bay than at locations closer to the coast (Icy Strait and Icy Point) possibly due to differences in the timing of the spring bloom. Additional spatial and seasonal trends should be examined for this physical and biological oceanographic data set.

SeaWIFs ocean color images of chlorophyll a processed by The **S**ea-**A**ir-**L**and **M**odeling and **O**bserving **N**etwork (**SALMON**) Project at the University of Alaska, http://www.ims.uaf.edu/salmon/index.html) can indicate the spatial extent of surface chlorophyll *a* (indicator of phytoplankton biomass) during cloud free conditions. These images showed mesoscale features (meandering eddy like structures) in coastal waters (e.g. May 3, 2003). These images also showed that the spring bloom occurred in northern Southeast Alaska during April (between April 2 and May 3 in 2003), but generally occurred earlier (in March) off Sitka and in southern Southeast Alaska inside waters. During several days of cloud free weather in early April 2000, a bloom formed near Sitka Sound was seen to grow substantially and advect along the coast northward and offshore over the course of a few days to a week. The use of ocean color is limited since these images cannot show spatial distribution of subsurface blooms (which may occur later in the growing season) and are hindered by the cloud cover frequently coving much of Southeast Alaska.

Canadian cruises for juvenile salmon were conducted in Southeast Alaska four times per year from 1995 to present (Welch et al. 2003). During these cruises scientists also collected oceanographic parameters: CTD (fluorometer and transmissometer in recent years), surface nutrients, surface chlorophyll a, and zooplankton oblique or vertical tows (253 µm) for species enumeration and size fractionation. Data were collected off the coast and within inside waters depending on the season (more stations are sampled in Southeast Alaska during fall than in other seasons). These data could provide an indication of ecosystem and climate change (variations in zooplankton species, water mass properties, etc.) during the past 10 years, particularly in coastal Southeast Alaska where sampling was more frequent.

Nutrients in coastal waters in the Gulf of Alaska, including Southeast Alaska, and extending southward from British Columbia to Oregon were depleted (< 1 µM nitrate) during summer months (Whitney et al. in press). Stekoll and Else (1992a, 1992b) collected nearshore nutrient samples near Sitka for a couple of years. Because data for Southeast Alaska are limited, additional nutrient collection and data analyses for Southeast Alaska coastal and inside waters would aid in understanding productivity dynamics and allow comparisons with Northeast Pacific ecosystems.

Salmon hatcheries, including DIPAC (Douglas Island Pink and Chum), NSRAA (Northern Southeast Regional Aquaculture Association), and SSRAA (Southern Southeast Regional Aquaculture Association), measured weekly surface temperature and salinity, water clarity (Secchi disk depth), and zooplankton abundance (with limited species ID using a 243 µm net towed horizontally (SSRAA), vertically (DIPAC) or both (NSRAA)) during spring months. Sampling has been conducted by NSRAA from late March to late June since 2002 at six sites in Sitka Sound, by DIPAC from mid-April to mid-June since the early 1990s at three sites north and south of Juneau and by SSRAA from Feb to April/May since the early 1980s at four widely spaced sites in southern Southeast Alaska (Anita Bay, Neets Bay, Nakat Inlet, Kendrick Bay). A comprehensive analysis of these data has not been conducted but could provide an indication of interannual variation in oceanographic parameters, such as the timing of the spring bloom, etc.

Harmful algae species in Southeast Alaska include *Alexandrium catenella*, a dinoflagellate that produces paralytic shellfish poisoning (PSP) and *Pseudonitzschia* spp., a diatom that produces domoic acid poisoning. In Southeast Alaska, PSP occurs in shellfish in inside and coastal waters; whereas domoic acid poisoning has not been studied but is more likely to occur in coastal waters (Red Tide Newsletter, 1999, Northwest Fisheries Science Center, NOAA). Historically, several deaths in Alaska have been attributed to PSP poisoning, particularly among indigenous peoples who harvest shellfish for subsistence. The State of Alaska only monitors commercial shellfish for PSP; however, recreational and subsistence harvests and phytoplankton that cause PSP are not monitored.

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Oceanography General Discussion

Summary prepared by Ginny Eckert, University of Alaska Southeast

Overall, the oceanography of Southeast Alaska is poorly studied, and accordingly, there are many data gaps and research needs. Virtually nothing is known about water flow into, out of, and through Southeast Alaska; processes that may strongly influence the region as well as circulation in the Gulf of Alaska. Pressure gauges that have been calibrated could simply and inexpensively monitor water flow in wider channels such as the entrance of Cross Sound. An inventory of embayments within Southeast Alaska could be used to generate first-generation models of water flow. A synoptic survey of all of Southeast Alaska has never been conducted, is needed, and should include CTD & associated sensors to profile the water column. Spatial and temporal variation in productivity needs to be documented, including identification of high production areas and spatial and temporal variation in the timing of the spring phytoplankton bloom. The spatial (vertical as well as horizontal) distribution of nutrients, phytoplankton, and zooplankton are needed. Existing datasets could be used to identify temporal patterns with limited spatial resolution, and routine surveys could add sensors (PAR, fluorometer, transmissometer, etc.) to maximize information gained from ongoing CTD vertical profiles. Future sampling could obtain higher temporal resolution using moorings that continuously sample with fluorometer, radiometer and nutrient sensors at key locations. Ships of opportunity (ferries, National Oceanographic Survey ships such as the R/V Fairweather based in the region) with hull-mounted thermosalinographs or towed CTD-profiling systems could increase the oceanographic coverage in Southeast Alaska. Establishment of long-term study sites (perhaps in Glacier Bay, Berners Bay or Sitka Sound) would allow characterization of oceanographic processes and monitoring of effects of climate and other changes in Southeast Alaska.

Priority research areas

I. Water flow
   a. Coupling between shelf and inland waters – How much flow of the Alaska Coastal Current goes through the inland passage compared to along the shelf?
   b. Connections with BC? source waters?
   c. Need basic inventory of fjords and embayments – geometry, basin sizes, tides, runoff, meteorology
   d. Seasonal variability
   e. Circulation in inside waters, estuaries, fjords, bays – how much shelf edge water moves to/through inside passage?
   f. Movement of meroplankton and influences on recruitment – effect of gyres/eddies? Spatial and temporal variation in recruitment?

II. Production
   a. What are the oceanographic characteristics of hotspots for birds, marine mammals and fish? Work in other areas suggests that productivity not be a predictor of aggregations – e.g. forage fish spawning areas draw in marine mammals
   b. Seasonal and interannual variation in production
   c. Benthic-pelagic coupling
   d. Head of fjord anomalies
   e. Influence of nutrients/iron – sources of these chemicals?
   f. Influence of glaciers on production? Relation of sediments to production?

III. Mapping
   a. Benthic mapping – some already done; can differentiate hard & soft bottom.
   b. Satellite images can reveal information on sediments/productivity/SST

IV. Climate/Weather
   a. Precipitation & wind data – need better spatial coverage
   b. Glacial inputs? Freshwater, sediments
   c. Aggregate long-term data from various locations (Sitka air temperature, Little Port Walter temperature (weather station since 30s), Ketchikan tide gauge system, Maybe tide gauge at Skagway, Auke Bay data from 1960-present)

V. Data archives
   a. Archive/link to existing datasets
   b. Archive/link to existing satellite data (note bias in using data from only clear days)
   c. Need to analyze existing data(e.g. plankton data from fish hatcheries)
   d. Need to calibrate/ground-truth satellite data.

Fisheries Overview

Overview prepared and presented by Gordon Kruse, Juneau Center School of Fisheries and Ocean Science, University of Alaska Fairbanks.

<u>Fishery History</u>

For purposes of fisheries considerations, “Southeast Alaska” is taken to be those waters from Dixon Entrance to Cape Fairweather, corresponding to State of Alaska Statistical Area A.

Humans have occupied Southeast Alaska for more than 10,000 years. Middens, including remains of human use of marine resources, found in caves in Southeast Alaska have been radiocarbon dated to 5,500 years old. Pre-historical marine harvests by humans included marine mammals, red and black seaweeds, and a variety of fish and invertebrates. Ancient fishing technologies included fish clubs, salmon spears, fish basket traps, halibut hooks, eulachon dip nets, and salmon trap fences. Native halibut hooks were remarkably effective.

In Southeast Alaska, "history" began with the first European contact in 1741, when Aleksei Chirikof sailed the vessels *St. Paul* to Alexander Archipelago. The earliest commercial groundfish fisheries included Pacific cod in the 1880s and Pacific halibut and sablefish in the 1890s. Early cod fisheries were dory fisheries, but trawls were first employed in 1875. The primary product was salted cod. The Pacific halibut fishery was stemmed by demand associated with the overfishing of Atlantic halibut stocks and the completion of the transcontinental railroad in 1887. Halibut and sablefish fisheries were prosecuted by longlines in dory fisheries. The primary products were fresh and iced.

The first commercial herring fishery began in 1878 in Southeast Alaska. Most herring were rendered for oil, and the Alaska herring reduction fishery was dominated by Southeast Alaska landings through the 1920s. After harvests plummeted in the 1930s, the herring fishery shifted to Prince William Sound and Kodiak.

Commercial salmon fisheries began in the late 1880s; most salmon were caught in fixed or floating fish traps. In the early years, most of the product was salted, but canning dominated the 20^{th} Century. After salmon catches plummeted by 1921, the White Act of 1924 was adopted that required conservation measures, including closure of the salmon fishery at the midpoint of runs to allow the remaining fish up the river to spawn. Owing to poor funding and enforcement, many salmon runs are thought to have been overfished in the 1920s-1950s. The perceived need for state control of fishery management was one of the leading arguments for statehood, which was enacted in 1959.

Fishery Governance

The federal and state governments have parallel governance for management of fishery resources off the coast of Alaska. The North Pacific Fishery Management Council is a body that recommends federal fishery regulations to the U.S. Secretary of Commerce. The National Marine Fisheries Service (NMFS) is responsible for implementing those regulations, as well as monitoring fish stocks and catches. Within NMFS, the Restricted Access Management Program is responsible for managing Alaska Region permit programs, including those that limit access to the federally-managed fisheries of the North Pacific. The NOAA Fisheries, Office of Law Enforcement, as well as the U.S. Coast Guard, have responsibilities for enforcement of federal fishery regulations. Within the state of Alaska, the Alaska Board of Fisheries establishes fishery regulations, and the Alaska Department of Fish and Game implements fishery management plans and regulations. The Commercial Fisheries Entry Commission controls the issuing of permits for those state-managed fisheries that are limited (non-open access). The Alaska Bureau of Wildlife Enforcement, within the Alaska Department of Public Safety, has responsibilities for enforcement of state fishery regulations.

Contemporary Fisheries

Most groundfish fisheries in the exclusive economic zone (EEZ, 3-200 miles offshore) are federally managed through a Gulf of Alaska fishery management plan (FMP). Exceptions include black rockfish, blue rockfish, and lingcod, which are managed by the State of Alaska throughout state and federal waters. In addition, demersal shelf rockfishes are largely managed by the state of Alaska from the coast to 140^{o} W within a framework provided within the federal FMP. Within 0-3 miles, the state also manages groundfish fisheries for Pacific cod, sablefish, and flatfish. Trawls are banned in federal groundfish fisheries in Southeast Alaska, so virtually all groundfish harvests are taken by fixed gears, such as longline and pots.

In 2004, groundfish catches from Southeast Alaska totaled 6,130 mt or 3.3% of the total groundfish catch for the entire Gulf of Alaska. Within Southeast Alaska, sablefish accounted for 82% of the groundfish landings, followed by demersal shelf rockfish (5%), shortraker/rougheye rockfish (5%), Pacific cod (2%), and thornyhead rockfish (2%).

For purposes of fishery management, Pacific halibut are not considered a "groundfish" and they are managed by the International Pacific Halibut Commission (IPHC) through treaty between Canada and the United States. In the U.S. individual fishing quotas, bycatch and subsistence harvest are regulated by federal fishery managers, whereas the state of Alaska is responsible for sport fishing regulations. Commercial halibut catches from IPHC area 2C (corresponding to Southeast Alaska) averaged 9.4 million pounds, or 18% of statewide halibut landings, during 1992-2003. All of the commercial halibut harvest is taken by longline gear.

Herring fisheries are managed by the state of Alaska. Legal gear includes purse seine, gillnet, and a small kelp pound fishery. Primary products are roe from pre-spawning herring and herring roe-on-kelp, but a small food and bait fishery exists. In 2004, 10,456 short tons of herring were harvested in Sitka Sound and 879 short tons were taken in Seymour Canal. The total (11,335 short tons) accounted for 34% of the statewide herring harvests in 2004. Traditional herring fisheries at Kah Shakes/Cat Island, Hobart/Houghton, and West Behm Canal were closed in 2004 because spawning biomass was estimated to be below threshold.

Salmon fisheries are managed by the state of Alaska under the auspices of the International Pacific Salmon Commission, formed by treaty between the U.S. and Canada. The Salmon Commission provides regulatory advice to both countries. A federal salmon FMP for the Gulf of Alaska provides a framework under which the state of Alaska is the lead authority for salmon fishery management. Primary gear types include purse seine, drift and set gillnets, and hand and power troll. All five species of Pacific salmon are taken in fisheries in Southeast Alaska. Purse seine harvests are dominated by pink salmon, followed by chum salmon. The majority of drift gillnet fisheries harvests are comprised of chum and pink salmon, but coho and sockeye salmon are significant, as well. Troll fishery catches are dominated by coho and Chinook salmon.

A diverse number of shellfish fisheries are prosecuted in Southeast Alaska. A scallop fishery is managed largely by the state under the frameworks provided by a federal fishery management plan. The state has full management authority for the other shellfish fisheries. Crab pot fisheries include red king crab, golden king crab, blue king crab, Tanner crab and Dungeness crab. A very small trawl fishery for shrimps and dredge fishery for weathervane scallops exist. The state's largest dive fisheries harvest geoduck clams, sea cucumbers and sea urchins. In 2003, 8.4 million pounds of shellfish were harvested from Southeast Alaska, including 3.34 million pounds of Dungeness crab, 1.64 million pounds of sea cucumbers, 1.06 million pounds of pot shrimp, and 0.8 million pounds of Tanner crabs.

Fishery Issues and Research Opportunities

A diversity of fishery issues exists in Southeast Alaska. For groundfish, the population structure of sablefish in inside and offshore waters remains uncertain, and increasing numbers of longline fishery interactions with whales are problematic. Fisheries for black and blue rockfish and lingcod all suffer from lack of adequate stock assessments, bycatch monitoring, estimates of discard mortality and concerns for localized depletion. The primary issues surrounding the halibut fishery involve concerns about localized depletion and allocations among commercial, sport, and charter boat operators. For herring, primary issues involve depressed prices, allocations among competing users, and concerns about the role of herring as a forage fish in the ecosystem. Salmon fisheries also suffer from depressed prices and corresponding industry restructuring, interception issues, and concerns about introductions of Atlantic salmon escaping from net pens in British Columbia. For shellfish, stock assessments and life history information are inadequate for many species, and local allocation issues exist between commercial and recreational users. Paralytic Shellfish Poisoning (PSP) is an important issue affecting fisheries for Dungeness crabs and bivalves (e.g., clams, mussels), and Bitter Crab Syndrome has depleted Tanner crab stocks in northern Lynn Canal. Data limitations and agency funding retard the development of other invertebrate fisheries (e.g. clams, mussels) and a developing mariculture industry has been limited by issues surrounding water quality, zoning, monitoring, as well as PSP.

These issues and the geography of Southeast Alaska provide a wealth of fishery research opportunities. The ability to work in relatively protected waters year-round and the location of nearby laboratories and seawater facilities make it much easier to conduct research than, for example, in eastern Bering Sea, which occurs at the same latitude as Southeast Alaska. The latitude of Southeast Alaska also provides opportunity for comparative studies of fish and shellfish, including their role as prey for marine mammal populations, to fish and shellfish assemblages in the western Gulf of Alaska and eastern Bering Sea. Fish and shellfish can be studied within the contrast of divergent trends in populations of Steller sea lions, harbor seals, and sea otters, as well as contrasts involving human interactions, such as trawl and no-trawl fishing zones. Stocks of crab, shrimp, and herring appear to be more stable in Southeast Alaska compared to the rest of the Gulf of Alaska and Bering Sea, perhaps providing opportunities to study biophysical mechanisms behind fishery stability and collapses. Institutionally, there are also excellent opportunities to build upon existing fishery programs in Southeast Alaska involving ADFG, NMFS, IPHC, USGS, and the University of Alaska Southeast and University of Alaska Fairbanks, among others.

Fisheries General Discussion

Summary prepared by Ginny Eckert, University of Alaska Southeast

For the purposes of this synthesis, we decided to focus on fisheries and not address general fish biology because of the vast amount of information available on fishes. However many aspects of fishes, including commercial and non-commercial species, are very important and poorly known in Southeast Alaska. Topics that should be addressed in another synthesis effort include but not be limited to the following.

- Trophic interactions among fishes, non-piscine predators such as marine mammals, and land-based predators and scavengers such as eagles and gulls.
- Evolutionary processes, including genetic differentiation of populations and ecotypic variation (characteristic of many salmon stocks), effects of harvest on evolution in various populations.
- Effects of hatcheries (community-wide ecological effects, effects on salmon genetics, etc.)
- Salmon stocks in SEAK that have special/unique features (See Halupka et al. reports PNW-GTR several yrs ago)
- Differences between anadromous and stream-resident populations
- Interactions among and within commercial and non-commercial species.

For many commercially harvested species in Southeast Alaska, basic life history information (e.g. timing of reproduction, fecundity, early life stages, recruitment, age of reproduction, lifespan) and basic energetic information (e.g. who eats whom and how much?) are needed. Future studies could relate oceanographic information to fisheries within Southeast Alaska to examine potential forcing mechanisms that explain temporal and spatial variability in populations and CPUE (e.g. PDO linkages, transport by eddies, etc.). An understanding of movement of individuals and stocks is important to determine effects of protected areas and apparent changes in populations/stocks at one location over time or seasons. Potential relationships between standing stock and CPUE can be evaluated to determine population sizes within this region. A comprehensive survey within Southeast Alaska is needed, as is long-term community monitoring. Studies on forage fish and other prey items and predators of commercially harvested species are needed to better understand the energetic properties of the ecosystem. Trophic linkages and energetic requirements may be very important to explaining why some populations decline, while others do not.

Priority research areas

I. Life history and distribution
    a. Basic life history information needed for many commercially important species, including information on recruitment over time
    b. How early life history ties into physical oceanography/transport
        i. Movement of meroplankton and influences on recruitment – effect of gyres/eddies? Spatial and temporal variation in recruitment?
    c. Interrelate fishery data with oceanography data to examine recruitment and movement patterns.
        i. Do oceanographic changes correspond to fishery changes and vice-versa, both large-scale (e.g. PDO) and small-scale? Need long-term data sets for both oceanographic and fishery information. Encourage interdisciplinary interaction among oceanographers and fishery biologists/managers. Host meeting to bring together these two groups.
    d. Movement of individuals/stocks
        i. a good example is POST – large scale tagging study
        ii. how do movements change over time/seasons?

iii. Movements into/out of protected areas

II. Stock assessments
   a. Relationship of standing stock to CPUE – what is population size?
   b. Stock assessments done for some species and not others.
   c. Comprehensive survey needed – what is out there? Trawl survey was conducted about 20 years ago. Could this survey be done again?
   d. Analyze existing data to evaluate if populations in inside waters less variable than population in outer waters.
   e. Comparisons of BC stocks with Southeast Alaska stocks?
   f. Long-term community monitoring

III. Trophic interactions/ Ecosystem-level studies
   a. Bioenergetics – how much/what is consumed and by whom?
   b. Need data on higher order predators, which are not commercially fished – e.g. sharks, rays.
   c. Need data on forage and other non-commercial species
      i. Who are they? Where are they? When/how are they important? How do their populations fluctuate over time and space? What are their basic life history characteristics? Why/where do they aggregate?
   d. Seasonality – how do abundances/distributions/energetics, etc. change?
   e. Pelagic/benthic linkages
   f. Community structure
   g. Temporal and spatial variation in species diversity

Day 1 (March 30) afternoon

Nearshore Ecology Overview

Overview prepared and presented by Ginny Eckert, University of Alaska Southeast.

The nearshore includes intertidal and shallow subtidal benthic environments and incorporates many diverse taxa, including fish, invertebrates, and marine macrophytes (algae and eelgrass), and many different and ecologically important habitats, including, but not limited to, marshes, estuaries, fjords, kelp beds, beaches and other intertidal areas. This portion of the marine ecosystem is most heavily impacted by humans, and in Southeast Alaska, relatively little research has been conducted there. Published studies fall into four categories: 1) fishery-related, 2) ecological studies (predator-prey interactions, etc.), 3) biogeographic studies, and 4) environmental impact studies including inventories and monitoring.

Fishery-related studies include APPRISE (described in *Biological Oceanography* section above) and studies on distributions and ecology of fished species, of which salmon, Dungeness crab and king crab have been the best studied (see *Fisheries* section above). Beach seining has been conducted to study nursery areas for juvenile fish and invertebrates. Areas used for mariculture have been surveyed by the Alaska Department of Fish and Game (ADFG). A few studies have examined the ecological effects of fishing, including effects of trawling on habitat-forming species such as corals and sponges, which are very slow-growing and are severely affected by disturbance. Recently, several studies have examined movements of commercially harvested species into and out of areas in which fishing was prohibited. Lingcod showed a high degree of site fidelity and potential for increased egg production in unfished areas. Effects of subsistence harvest of nearshore fish and invertebrates are poorly known.

Ecological studies include effects of sea otter predation on community structure. In Southeast Alaska, otters are present in some locations, not in others, and are migrating into new areas at very fast rates. Because otters are major predators on urchins, clams, and crabs, nearshore community structure is drastically different when otters are present because their prey items, such as urchins, affect abundance of kelps that provide habitat and strongly structure the community. A few ecological studies have examined community structure in meiofauna (small organisms that live in sediments), however meiofauna in general are greatly understudied and include many undescribed species.

Biogeographic studies in the North Pacific often include Southeast Alaska because it is an interesting region where relict populations that survived the last ice age intermingle with populations founded by recent colonizations. High latitude populations of the intertidal copepod *Tigropius* and other species living in the high intertidal have less within-populations genetic variation than populations further south, presumably because of contractions during the last ice age and recent colonizations. However, species living lower in the intertidal or in the subtidal may have had a refuge and persisted during the last ice age, and therefore, now have greater within-population genetic variation. The origins of several taxa within Southeast Alaska have been studied and include sources from the Atlantic that migrate through the Bering Strait and from the Pacific that migrated northward after deglaciation.

Studies of human impact have largely focussed on effects of canneries, logging, mining (Boca de Quadra, Berners Bay), and other discharges. Few monitoring or inventories are conducted with the exception of the National Park Service and US Geological Survey, who have largely focussed their efforts in Glacier Bay, and surveys by US Fish and Wildlife Service that are mostly unpublished. A multi-agency group (NOAA, ADFG, Alaska Department of Natural Resources, National Park Service, and The Nature Conservancy) is now funding a series of aerial surveys called ShoreZone, which provide large-scale and detailed GIS-based maps of visually-identifiable habitats and biota. In 2004, areas in Sitka Sound, Icy Strait and Lynn Canal were surveyed. Plans for 2005 include the outer coast from Cape Spencer to the west side of Icy Bay, north Icy Strait and islands, west Lynn Canal, west Chichagof Island, west Baranof Island , Stevens Passage, and Taku Inlet. As funding permits, mapping would continue to include contiguous areas, including Mansfield Peninsula on Admiralty Island including Hawk Inlet, east Chichagof Island and east Baranof Island. Some regions of Southeast Alaska have been mapped using multibeam sonar, including parts of Glacier Bay and areas near Sitka, and in a few areas, extent of kelp has been mapped with multispectral digital mapping, including areas near Sitka and Point Baker.

Nearshore Ecology General Discussion
Summary prepared by Ginny Eckert, University of Alaska Southeast

Because the nearshore encompasses many other topic areas of this synthesis, several priority research areas overlap with previous topics, including studies of life history and distribution of both commercially and non-commercially important species, examining effects of oceanography on productivity and transport of organisms, and bioenergetic and ecosystem-level studies. An understanding of coupling of the nearshore with watersheds, pelagic zones and offshore zones is essential, as the nearshore is where these different ecosystems intersect.

The ShoreZone project (described above) is an excellent mapping project that will provide valuable data to many users. ShoreZone needs to be ground-truthed and compared with other inventories in the same region (e.g. Glacier Bay Coastwalkers). Additional needs for mapping and inventories include multibeam sonar of subtidal regions, including inventories of organisms that use these habitats, and multispectral digital mapping of kelps. The function and dynamics of habitats need to be understood to better understand their importance to commercially important species. The establishment of long-term monitoring sites as well as a systematic inventory of Southeast Alaska nearshore are needed to establish baselines within the region, because of expected changes as a result of development and other human impacts such as climate change. It is expected that localized studies of human impact will continue in areas with logging, canneries, mining or other activities, however a synthesis of previous studies may provide an intriguing look at responses of nearshore organisms to disturbance.

Food webs and tropic interactions are poorly known in the nearshore, and studies of predators and linkages to primary and secondary productivity are especially needed. Seasonal changes in community structure is not well documented, and in the nearshore may help explain distributions and ecology of commercially important species. The genetic composition and biogeography of Southeast Alaska is interesting in light of the differences in Southeast Alaska as compared to other regions of the Pacific.

Existing data needs to be archived in a centrally available location, potentially at a site hosted by the Knowledge Network for Biocomplexity (http://knb.ecoinformatics.org). Additionally, a multi-agency organization is needed to serve as a hub for all marine-related research in Southeast Alaska.

Priority research areas

- I. Life history and distribution
  - a. Recruitment of larvae – effects of oceanography on dispersal
  - b. Effects of jellyfish on larval (crab and fish) distributions/recruitment
- II. Nearshore linkages to other systems (pelagic, offshore, watersheds, terrestrial, glaciers)
- III. Habitat/ Physical processes
  - a. Habitat functions and dynamics (essential fish habitat: understand particular areas used by juvenile fish and fish prey)
  - b. Spatial/temporal variation in habitat
    - i. Community structure & habitat changes with location in a fjord
    - ii. Glacier rebound – changes in nearshore as a result?
  - c. Habitat mapping - continue ShoreZone
  - d. Groundtruth ShoreZone and compare with other inventories (e.g. Glacier Bay Coastwalkers)
  - e. Mulitspectral digital mapping of kelps

f. Habitat mapping – multibeam sonar – link to abundance and distribution of organisms
g. Systematic inventories needed as baseline & a few sites need to be established long-term to determine temporal variability.
h. Invasive species monitoring

IV. Human Impacts
a. Subsistence use of intertidal organisms, kelps, clams, chitons, etc.
b. Effects of pollutants, other discharges
c. Effects of mining – Berners Bay, Coeur

V. Trophic interactions/ecosystem-level studies
a. Effects of predators, including seastars, octopus, bears, mink, eagles, etc.
b. Effects of life histories – recruitment variability
c. Taxonomy of small stuff: e.g. Auke Bay copepods
d. Genetics and biogeography
e. Seasonal changes in species interactions, community structure, migrations
f. Food web interactions – direct and indirect interactions between different trophic levels (e.g. *Macoma*, fish, birds) – links to primary and secondary production

VI. Data archives
a. for published and unpublished work
b. need organization to serve as hub

Seabirds Overview
Overview prepared and presented by John Piatt, USGS Alaska Science Center.

Some of the oldest historical observations of marine birds in Alaska were made in Southeast Alaska by early naturalists, and a wealth of anecdotal information has been collected in recent decades as well. Species composition and relative abundance of seabirds are described for most areas of Southeast Alaska. A few systematic avifaunal surveys in Southeast Alaska show that the seabird community is similar to that found in sheltered waters of Prince William Sound (PWS) to the north, but it is also distinctive from PWS because it includes species found in abundance only in Southeast Alaska. The southern third of Southeast Alaska shares greater biogeographic affinity with British Columbia (BC) than with areas to the north. However, the root causes of biogeographic patterns of abundance are not known in Southeast Alaska because intensive scientific investigations of seabird ecology, such as those funded in the Gulf of Alaska and Bering Sea during the 1970s (e.g., OCSEAP), 1980s (e.g., PROBES) and 1990s (e.g., EVOSTC), have no equivalent in Southeast Alaska.

Sources of information on seabirds in Southeast Alaska derive from two basic sources: studies of birds at their colonies and surveys of birds made from vessels at sea. Major colonies of seabirds were visited and censused by US Fish and Wildlife Service (USFWS) biologists, mostly during the 1970s, as part of a larger program to census seabird colonies throughout the state of Alaska (Sowls et al. 1980). Colonies were visited and censused from boat- and land-based observation sites, and the most common colonial species were counted or estimated by sampling of breeding habitat. Leach’s and Fork-tailed storm-petrels account for about 70% of the 1.6 million seabirds estimated to occur at known colonies in Alaska. Because storm-petrels are small and nest underground in small burrows on offshore islands, these estimates are likely minimal. Storm-petrels forage on zooplankton in offshore waters, and are generally not a conspicuous member of the Southeast Alaska bird community. Members of the alcid family comprise 29% of all colonial seabirds, i.e., most of the remaining species, and are much more familiar to visitors of the inside waters of Southeast Alaska. Of this family, the most abundant colonial species include Rhinoceros Auklets, Ancient Murrelets and Cassin's Auklets—all nocturnal, burrowing species found in greatest abundance in southern Southeast Alaska and British Columbia (see more below). Most large colonies are found along the outer coast, including those of Common Murres and Tufted Puffins. Smaller colonies of Glaucous-winged Gulls, Pigeon Guillemots and Arctic Terns are scattered widely among islands within the archipelago. Survey effort in Southeast Alaska is incomplete, and while the largest colonies have been documented, it is likely that many small colonies have not been surveyed. Intensive shoreline surveys for ground-nesting species in Glacier Bay revealed that nests of Mew and Glaucous-winged gulls, Arctic Terns, and Pigeon Guillemots are more common, albeit dispersed, than ever suspected previously (Arimitsu et al. 2004). This may be true throughout Southeast Alaska.

Relative to other areas of Alaska, little is known about population trends or breeding biology of seabirds in Southeast Alaska. Most attention has been focused on seabirds breeding on rookeries monitored by the USFWS at St. Lazaria Island, and to a much lesser extent, Forrester Island. Census data have been collected for less than 10 years for several species such as Rhinoceros Auklet, Fork-tailed Storm Petrel and Common Murre. Ancillary data are collected on diets and breeding success as well. Limited collection of adult and chick meal data suggest that breeding birds rely on a few important forage species, such as euphausiids, squid, myctophids (by offshore species such as storm-petrels), juvenile pollock, capelin, sand lance and herring (Sanger 1987, FWS unpubl.).

Considerable data have been collected on the distribution and abundance of seabirds at sea in Southeast Alaska. Offshore in the Gulf of Alaska, seabirds were surveyed on ships of opportunity during OCSEAP (1975-1982). Systematic surveys were conducted in Sitka Sound by USFWS in 2000 and included measures of seabird abundance in relation to water properties and acoustic biomass of prey (Piatt et al. 2000). These surveys revealed marked habitat partitioning in which offshore slope and oceanic water was occupied by pelagic species such as Black-footed Albatross and Fork-tailed Storm-petrel, shelf waters were used by Common Murres and Rhinoceros Auklets, and more sheltered inside waters were used by Marbled Murrelets and Pigeon Guillemots. To some degree, this segregation is related to the types of prey consumed by each species (see above), but this is poorly known for most seabirds in Southeast Alaska.

There are few data on pelagic ecology of seabirds within the inside waters of Southeast Alaska. Only Glacier Bay has been studied in detail, with concurrent studies of oceanography, primary production, zooplankton, forage fish and marine predators, including seabirds (Robards et al. 2003). There is a strong environmental gradient in Glacier Bay from North to South, ranging from glacial-river fed, stratified, highly productive waters at the head of the bay to tidally-mixed, more oceanic waters at the mouth of the bay. Most fish biomass is found within 0.5 km of shore in shallow (<80m) waters, and most (>75%) fish-eating birds are found nearshore as well. The system is also structured from North to South, with higher production of zooplankton and forage fish in the upper arms, and a corresponding higher abundance of fish-eating seabirds. The upper bay is heavily glaciated, and contains a high concentration of pagophilic species as well, such as

Kittlitz's Murrelet and Black-legged Kittiwake (and also harbor seals, which pup on the ice and feed locally). The role of glaciers in the enhancement of marine productivity is poorly understood, and few studies have been conducted to identify the linkages between glaciers and coastal marine ecosystems.

There have been two extensive avifaunal surveys of Southeast Alaska. During summer, 1994, about 600 coastal and offshore transects were surveyed from small boats at randomly selected sites throughout the entire Southeast Alaska region (Agler et al. 1995). During a five year period (1997-2001), a low-altitude aerial survey of the entire shoreline of Southeast Alaska was conducted and all marine birds and mammals were censused (J. Hodges, unpubl. data). These surveys, while imperfect (boats surveys less than 0.1% of total area, aerial surveys on coast only, cannot identify all species), offer a snapshot of avian biogeography not available from any other source and provide a census of all marine birds including non-colonial species excluded from colony surveys previously described. Indeed, of the 1.9 million birds estimated to occur at sea (excluding offshore Gulf waters), a large proportion were non-colonial breeders (35% Marbled Murrelets, 32% seaducks) or did not breed locally (8% shearwaters, fulmars).

Several different patterns of distribution are evident from aerial and boat-based survey datasets. Estimated to number more than half a million birds, the Marbled Murrelet is the single most abundant species in Southeast Alaska and is widely distributed throughout. Marbled Murrelets nest in high-volume old-growth coniferous trees, and their distribution is strongly influenced by the availability of nesting habitat. Thus, while they are widely distributed, numbers are about half in southern Southeast Alaska than in northern Southeast Alaska, reflecting in part the extensive logging of high-volume old-growth forest that has taken place in the southern half of Southeast Alaska. Some species are found mostly in the northern half of Southeast Alaska (Bonaparte's Gull), some mostly in the southern half (Rhinoceros Auklets), some are found almost exclusively in inside waters (scoters), and some mostly along the outer coast (cormorants).

For most cases, we can only speculate on the cause of observed geographic patterns of distribution. Many are likely to be related to geographic variability in food resources or nesting habitat. We know that both Marbled and Kittlitz's Murrelets, for example, feed on small forage fish such as sand lance and herring, which are widely available in Southeast Alaska; as are Marbled Murrelets. However, Kittlitz's Murrelets have a restricted distribution during summer, where they nest on post-glacial till at high altitudes and feed in coastal marine waters influenced by glacial river outflows. Rhinoceros Auklets and Cassin's Auklets are concentrated in southern Southeast Alaska, mostly along outer coasts south of Sitka. In British Columbia, where both these species are abundant, they tend to feed in shelf and shelf break waters and may require upwelling processes to bring their preferred prey to the surface. The North Pacific Current bifurcates during summer near the break point in distribution of auklets (at Sitka), and only the southward flowing current induces upwelling. Thus, the northward distribution of Rhinoceros and Cassin's Auklets may be ultimately constrained by large-scale current patterns offshore.

In summary, much remains to be learned about seabirds of Southeast Alaska and their role in the marine ecosystem. Compared to other areas of Alaska, where long-term studies of seabirds provide unique insights into marine ecosystem dynamics and often serve as barometers of ecosystem change, little is known about seabirds in Southeast Alaska. It appears that at least a few species have declined rapidly over some or all of their ranges in recent years (e.g., Kittlitz's Murrelet, Marbled Murrelet, Pelagic Cormorant, Surf Scoter, Tufted Puffin, etc.). Because Southeast Alaska has a different oceanographic setting from the rest of the Gulf of Alaska or Bering Sea, it may be useful to compare and contrast the ecology of seabirds residing in Southeast Alaska with those found elsewhere. This may help us better understand community changes occurring in different areas in response to natural climate cycles, global warming and potential anthropogenic impacts from fisheries, pollution and vessel traffic.

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Seabirds General Discussion

Summary prepared by Ginny Eckert, University of Alaska Southeast

For the purposes of this synthesis, we decided to focus on seabirds because there was a fair amount of information available on this taxanomic group of higher marine vertebrates. Other marine and coastal birds, including waterfowl and shorebirds, deserve study as well but were outside the scope of this effort.

Much is known about birds during breeding and while they are in colonies, but less is known about their at-sea or non-breeding distributions, behavior and ecology. Productivity and oceanography can have a strong influence on the foraging success of seabirds, but little is known about the linkages between physical properties of the water, lower- and mid-trophic level organisims and the marine birds that depend on them. The effect of the North Pacific Current bifurcation on the biogeography of seabirds in southeast Alaska needs particular attention. The oceanography of foraging 'hotspots' in southeast Alaska and the processes that influence their productivity also need study. The effect of birds as predators in the nearshore needs to be studied, both for benthic and pelagic feeding species. For example, sea ducks reach extremely high densities in nearshore areas of Southeast Alaska during winter, and likely have a large effect on benthic community composition and the abundance of their prey. Human impacts of seabirds that deserve study include effects of habitat degradation (e.g., from mining effluents), habitat loss (e.g., impacts of logging of old-growth on Marbled Murrelets), pollutants (including organochlorines and petroleum products) on reproductive success, effects of vessel disturbance on birds at sea, effects of fisheries on either the prey populations used by seabirds or on the bycatch of adult members of the population, and effects of climate changes (e.g., loss of glaciers and glacially influenced habitat for Kittlitz's Murrelet).

Priority research areas

- I. Life history and distribution
  - a. Link abundance and distribution to oceanography
    - i. Use satellite imagery, concurrent oceanographic studies
    - ii. Influence of glaciers on local productivity
    - iii. Effects of N. Pacific Current bifurcation off Sitka
  - b. Seasonal distributions – particularly in winter
  - c. Migrating seaducks – where do they stage in Southeast Alaska?
  - d. Banding, tagging colony returns and adult survival rates
  - e. Marbled murrelet population trends – most abundant species and indicator for region (time series); redo complete surveys of SE, continue local surveys
  - f. Major declines in Kittlitz's Murrelets – associated with glacial recession?
- II. Trophic interactions/ Ecosystem-level studies
  - a. Bioenergetics – how much/what is consumed and by whom?
  - b. Energy flow/consumption/productivity
  - c. Locations and mechanisms of foraging 'hotspots'
  - d. Seasonal changes in diets?
  - e. Monitoring of parasite loads (trematodes)
  - f. Effects of birds on pelagic/benthos as predators: role of sea ducks in nearshore communities (lack of mobility of prey and high abundance of sea ducks in winter)
- III. Human impacts
  - a. DDT/organic contaminant monitoring, effects of mining effluent, oil spills
  - b. Effects of logging on Marbled Murrelet nesting, populations
  - c. Vessel disturbance/human interactions on Kittlitz's Murrelets
  - d. Mortality from fisheries (including longlines and night lights)
    - i. Logbook data of bird observations and bycatch

Day 2 (March 31) morning

Marine Mammals Overview

Overview prepared and presented by Jan Straley, University of Alaska Southeast.

In Southeast Alaska, two living marine mammal groups are represented. These are (1) the carnivores which include the seals, sea lions and sea otters and (2) the cetaceans which include the whales, dolphins and porpoises.

Carnivores have blubber and/or fur and can live on land and in the water. Harbor seals, Steller sea lions, and sea otters are commonly seen carnivores in the waters extending from Cape Fairweather to the north, Dixon Entrance to the south and out to the edge of the oceanic shelf approximately 12-25 miles offshore. Cetaceans have blubber and live exclusively in water. They are divided into two suborders; baleen and toothed whales. The common baleen whales are minke, humpback and gray whales. Historically, northern right whales and fin whales were present but commercially harvested to depletion. The common toothed whale is the killer whale. Also present and included in the toothed whale family are Dall's and harbor porpoises. Additionally, sperm whales are seen along the shelf edge and Pacific white-sided dolphins are seen offshore and occasionally in the inside waters of the archipelago. Humpback, minke, fin, northern right and sperm whales are listed as endangered and Steller sea lions as threatened under the Endangered Species Act (ESA). Sea otters, harbor seals and Steller sea lions are harvested by Alaska natives for subsistence use.

Harbor seals are found throughout Southeast Alaska. Their population is estimated to be about 21,000 seals from National Marine Fisheries (NMFS), National Park Service (NPS) and Alaska Department of Fish and Game (ADFG) aerial survey and trend site data. The population is increasing in all areas except Glacier Bay which has declined over 70% in the past 12 years. Due to genetic differentiation found in many areas in Alaska, NMFS and Alaska native groups are currently reassessing stock boundaries for harbor seals which may result in multiple stocks for Southeast Alaska.

Steller sea lions number about 15,000 and are distributed throughout Southeast Alaska with trends increasing at all sites. Historically, three rookeries were identified and in recent years two additional rookeries have been documented. Numerous studies by NMFS, ADFG and the North Pacific Universities Marine Mammal Research Consortium (NPUMMRC) have investigated diet, population dynamics and biomass of forage species available to Steller sea lions in Southeast Alaska.

Sea otters were extirpated in the 1800s and reintroduced to 7-10 locations along the outer coast of Southeast Alaska during the 1960s. The United States Geological Survey (USGS) and US Fish Wildlife Service (USFWS) have surveyed the distribution of sea otters throughout Southeast Alaska and found their range extends along most of the entire outer coast and they have moved to inside waters in Glacier Bay, lower Chatham Strait and parts of Clarence and Icy straits. Glacier Bay has had dramatic increases in sea otters since 1992 when there were none present to a count of 2,000 in 2004. In the rest of Southeast Alaska, however, there has been about a 6% decline in numbers during their range expansion. However, because of the increase in Glacier Bay, overall numbers are stable with about 11,000 sea otters currently in Southeast Alaska.

Of the large baleen whales, only the humpback has been studied to any degree by numerous independent research groups since the late 1960s. Primary study areas have been in northern Southeast Alaska (Frederick Sound, Sitka Sound, Chatham Strait, Icy Strait and Glacier Bay). In 2000, a collaborative effort by J. Straley and NPS estimated about 1000 whales use these areas on an annual basis. Other studies by NPS, NMFS and the University of Hawaii (UH) investigated distribution, acoustics and forage species in the early 1980s. When these studies ended, NPS continued to monitor humpback whales in Glacier Bay and parts of Icy Strait.

Today the NPS research program involves studies of vessel-whale interactions, acoustics and prey species. No information exists on the distribution or numbers of minke or gray whales in Southeast Alaska, although minke whales are seen in low numbers on a regular basis in some areas and gray whales migrate seasonally twice a year along the coast and some remain as summer residents, presumably forgoing their northbound migration to the Bering Sea feeding grounds. There is some evidence that fin whales may be recovering because they are seen along the shelf edge, off Prince of Wales Island, and one was seen in Sitka Sound in 2004.

Of the toothed whales, only the killer whale has been studied to any extent in Southeast Alaska. Three ecotypes have been seen in these waters: residents which eat fish; transients which prey upon marine mammal and offshores which are infrequently seen and their diet is unknown. Both the resident and transient groups number in the low hundreds, and offshores, which may range from the Bering Sea to California, possibly number in the thousands. Sperm whales are found along the shelf edge, however, little is known about the stock structure or population numbers in the North Pacific. These whales are eating sablefish and halibut off commercial demersal longline gear. Studies are ongoing investigating this behavior and the levels of depredation occurring in these fisheries (NMFS Auke Bay Lab, University of Alaska Southeast and Scripps Institute of Oceanography). Harbor porpoise are found in quiet bays and sounds of Southeast Alaska and NMFS surveys estimate numbers of harbor porpoise to be about 11,000 for this area. No specific estimate exists for either Dall's porpoise or Pacific white-sided dolphins in Southeast Alaska because they are considered as one stock in Alaska or the North Pacific and estimated as such.

There are some seasonal hotspots, for cetaceans in particular. Humpback whales congregate at the prominent points, pinnacles and areas where water flow is constricted (Pt. Adolphus, Pt. Baker, Frederick Sound, southern Chatham Strait, possibly the Fairweather Grounds) during the summer months. Gray whales are seen feeding in the same areas each spring and summer along the outer coast. Harbor porpoise are often seen in large numbers in Icy Strait and Clarence Strait. During winter, hot spots occur where herring gather to spend the winter and humpback whales, harbor seals and Steller sea lions are often found in large feeding concentrations in these areas.

Needs for increasing our knowledge of marine mammals in Southeast Alaska can divided into those based on 1) a lack of knowledge and 2) the intersection of increasing or recovering marine mammal populations and increasing human actions such as increased vessel traffic in areas of frequent use by feeding marine mammals or habitat degradation due to coastal development or resource extraction. A third need would be to investigate reasons behind declines in populations, such as harbor seals in Glacier Bay, or major ecosystem changes, such as the reintroduction of sea otters and their range expansion to areas that have not had sea otters present for over 100 years or more (or ever such as in Glacier Bay).

Marine Mammals General Discussion
Summary prepared by Ginny Eckert, University of Alaska Southeast

General research needs for marine mammals are focused around three issues: 1) forage, 2) populations and stocks, and 3) human impacts. Information on energetic requirements and available prey for marine mammals are needed to inform ecosystem-level management and ecosystem models. Parameters specific to Southeast Alaska are needed because of variation in energy content among and within forage species. Information is needed on patchiness of prey and oceanographic conditions that might be associated with prey aggregations and seasonal and ontogenetic changes in diets. Populations and stocks are relatively well demarcated for some species (e.g. harbor seals) however greater spatial and temporal resolution is needed for many species to better identify populations and stocks (e.g. harbor porpoise). Phenotypic and genotypic variation in stocks needs to be characterized and explored. Distributions during winter are greatly needed. Effects of human harvests and vessels (including effects of fishing) are the two primary focal areas for human impacts.

Priority research areas

I. Forage/trophic interactions
   a. Energetic needs – how much food? – parameters for Ecopath (Note - energy content of same spp and size of krill vary greatly) Variation of energy content among/within spp.
   b. What/where feeding? Also - Need info on density of prey patches – this drives a lot of their pop dynamics.
   c. Changes in diet seasonally - winter? Juvenile diets?
   d. What oceanographic forces aggregate forage?
   e. Need to know a lot more about Euphausiids and forage fishes in SE AK. A lot of taxa depend on them

II. Populations & stocks
   a. Spatial and temporal coverage - need finer resolution
   b. Distributions during winter? (most studies during breeding season)
   c. Effects of predation
   d. Comparisons of stocks – different physical characteristics between stocks, why? Understand differences (body size)
   e. Fitness consequences – repro rates of diff habitats

III. Human impacts
   a. Effects of harvest, bottlenecks
   b. Vessel interactions
      i. Need information on vessel/whale interaction. Speed and size of boat vs size/age of whale vs density. Need info on noise, air quality, contaminants
      ii. Info on entanglement rates, defining what is a serious injury

IV. Specific species
   a. Sea otters
      i. As sea otters move to inside waters – what are the effects? Otter effects on communities with pop increase and colonization. Take a focus on South SE AK because they've moved over to S. Prince of Whales shore (W. side Clarence Strait). Have not moved yet to E. side. This will greatly impact sea urchin fishery. Impact to fisheries – Dungeness crabs, urchins, abalone, cucumbers, Tanner crabs, king crabs (feed on juvenile king crab in shallow waters)
   b. Harbor seals

i. Comparative studies of seal populations – Sitka, Ketchikan vs. Glacier Bay
ii. Gaps in genetic analysis – harbor seals
iii. Glacier dynamics – ice production/changes and how impacts harbor seals.

WORKSHOP FINDINGS AND RECOMMENDATIONS

Opportunities for expanding our knowledge about the marine biology and oceanography of Southeast Alaska are great. Southeast Alaska is roughly the same size as the state of Florida and contributes significantly to Alaskan fisheries, particularly for salmon, halibut, herring, Dungeness crabs, sea cucumbers, and other shellfish and contains feeding and breeding grounds for many species of marine mammals and birds. Southeast Alaska is an attractive location for research on Alaskan marine biology and oceanography, because much of the region is well-protected, and marine waters are accessible year-round. Many processes or questions that would be difficult to address in other regions of Alaska could be more easily researched in Southeast Alaska. In fact, Southeast Alaska could serve as a model for Alaska as a whole. Many processes, such as circulation patterns and their linkages to population dynamics, might be best addressed there.

Broad research priorities that were agreed upon at the workshop include the following.

- Southeast Alaska bridges the Gulf of Alaska with regions further south through the Alaska Current which bifurcates in British Columbia and transports relatively warm water into the North Pacific. Oceanography and marine biology along the British Columbia coast probably most resemble that in Southeast Alaska, and *collaborations with Canadian colleagues should be explored and expanded*.
- Hydrography in Southeast Alaska is poorly known and likely drives circulation in the Gulf of Alaska. For this reason, the circulation in the Gulf of Alaska will not be understood until more is known about Southeast Alaska, particularly water flow into and out of the region. *Greater collaborations and partnerships should be formed between researchers in Southeast Alaska and the Gulf of Alaska. Researchers exploring differences in salmon populations between the lower 48 and Alaska should include information from Southeast Alaska.*
- Southeast Alaska has many unique features including its many tidewater and coastal glaciers, large input of freshwater from precipitation, and an intricate network of islands where the marine habitat is fragmented. The geological and glacial history of the region must be well-recognized. *Interactions between marine, terrestrial and glacial environments and organisms need to be better studied.*
- The marine research community in Southeast Alaska consists of many different agencies and organizations who partner and collaborate, however greater coordination is needed. *An interagency consortium consisting of agencies and organizations should be developed and focused on Southeast Alaska. Alternatively, a new organization could be created and serve as a Southeast Alaska Ocean Science Institute (SEA-OSI).*
- Partnerships among existing organizations should be enhanced; one mechanism for doing so includes sharing logistics for marine shipboard operations and maximizing existing ship time to collect as much data as possible at stations and while underway. *Hull-*

mounted thermosalinographs or towed CTD-profiling systems should be routinely employed on all research vessels operating in the area, and resultant data should be uploaded to NODC databases to ensure usability by a broad audience. Vessels with home ports in Southeast Alaska should establish routine transects that they survey on their way into and out of port (e.g. new NOAA vessel R/V Fairweather*).*

- *Data from past studies from Southeast Alaska should be archived in a central and easily-accessed location.* For example, existing CTD data should be uploaded to NODC databases. Ecological data can be uploaded to ecological databases such as the KNB. *Previous sites should be resampled to evaluate changes over time with coincident measures of physical processes. Long-term monitoring should be initiated or continued in several key locations throughout the region.*

Specific research priorities for each topic area are included in General Discussion sections above. Priorities that are broad in nature and recurrent include the following.

- Trophic linkages, particularly predators and forage for fish and shellfish, birds, and marine mammals, need to be studied and should be studied at the ecosystem level.
- Trophic studies need to be conducted during all seasons because some populations may be limited by winter conditions, whereas others may be limited by conditions during another season.
- Early life histories and recruitment dynamics are needed to better understand critical life stages and population regulation.
- Areas that have been well studied (e.g. Glacier Bay) should integrate data across disciplines to examine linkages among physical processes and higher and lower trophic levels.
- Primary and secondary production need to be studied to understand oceanographic processes that occur in productive versus unproductive areas. Past productivity can be extrapolated from sediments in anoxic basins and from records of growth in bivalves and fishes. Nutrient inputs, uptake, and transport must be examined to understand primary productivity.
- Harmful algal blooms are persistent; however their spatial and temporal extent is unknown and needs to be studied.
- A comprehensive inventory of Southeast Alaska marine resources has never been conducted and would be very valuable to examine biological and physical properties of the marine ecosystem.
- Comparisons between northern and southern Southeast Alaska as well as comparisons between inside waters and offshore regions of Southeast Alaska would be very interesting in light of the physical differences among these regions.
- Long-term time series are very valuable in detecting changes over time, as is continuous sampling in discrete locations.
- Moorings should be established in inside waters in Southeast Alaska to continuously sample weather and oceanographic parameters.
- Additional sensors, such as chlorophyll a fluorometers, beam transmissometers, and PAR sensors should be added to physical oceanographic sampling (CTD profilers) to understand vertical variations in phytoplankton dynamics.

- Scientists should study vertical and horizontal variation in zooplankton and fisheries abundances using multi nets and/or acoustics, to determine “hot spots” in both vertical and horizontal spatial domains.
- Mapping efforts should be continued and expanded, including multibeam mapping of subtidal regions and ShoreZone mapping of intertidal regions.

Appendix 1. Workshop Agenda

Southeast Alaska Synthesis of Marine Biology and Oceanography
March 30-31, 2005
University of Alaska Southeast, Juneau

WORKSHOP AGENDA

March 30	**Egan 221-222 Glacier View Room**	
8:00-8:30	Bagels and Coffee	Glacier View Room
8:30	Introduction and Overview	Ginny Eckert
8:40	Oceanography Overview	Lisa Eisner & Tom Weingartner
9:10	Oceanography Discussion	
10:30	Break	
10:45	Fisheries Overview	Gordon Kruse
11:05	Fisheries Discussion	
12:30	Catered Lunch	Lake Room – Mourant Building
1:45	Nearshore Ecology Overview	Ginny Eckert
2:05	Nearshore Ecology Discussion	
3:30	Break	
3:45	Seabirds Overview	John Piatt
4:05	Seabirds Discussion	
5:30	Adjourn	
6:30	Dinner	Hanger Ballroom (downtown)
March 31	**Egan Library 105** (basement of the library – to the left of the books)	
8:00-8:30	Bagels and Coffee	outside library entrance
8:30	Marine Mammals Overview	Jan Straley
8:50	Marine Mammals Discussion	
10:15	Break	
10:30	General Discussion of Priorities for Southeast Alaska	
12:30	Adjourn	

Appendix 2. List of Attendees

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