

Ecosystem Assessment

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The primary intent of this assessment is to summarize and synthesize climate, biological, and fishing effects on the shelf and slope regions of the Gulf of Alaska (GOA) from an ecosystem perspective and to provide where possible an assessment of the possible future effects of climate and fishing on ecosystem structure and function. This serves the larger goal of the Ecosystem Status Reports (ESRs) to provide ecosystem context for tactical fisheries management decisions. This assessment ties together the myriad indicator data into a narrative of the current and likely future ecosystem state, including information based on new or unexpected observations that may have implications for groundfish management. Report cards are presented at the front of this ESR to provide a succinct summary of the state of the ecosystem based on a short list of indicators.

This assessment reflects the recognition that the western and eastern GOA ecosystems have substantial differences. The GOA is characterized by topographical complexity, including: islands; deep sea mounts; continental shelf interrupted by large gullies; and varied and massive coastline features such as the Cook Inlet, Prince William Sound, Copper River, and Cross Sound, which bring both freshwater and nutrients into the GOA. The topographical complexity leads to ecological complexity, such that species richness and diversity differ from the western to eastern GOA. Thus, local effects of ecosystem drivers may swamp basin-wide signals. With this in mind, we present report cards and assessments of current ecosystem state for the western and eastern GOA ecoregions separately to highlight inherent differences.

The report card indicators were selected to best reflect the complexity of the GOA. Although there are many more people living in both large and small communities throughout the GOA relative to the Aleutian Islands or eastern Bering Sea, the complexity of the system requires a high-degree of local understanding to disentangle broad-scale patterns from local processes. We consider the GOA to be ecosystem data-moderate relative to the Aleutian Islands (data-poor) and eastern Bering Sea (data-rich). However, the division of the GOA into separate ecoregions highlights data gaps. For example, comparable forage fish indicators are not available for both regions. Also, while fresh water input is considered informative for the west, a comparable oceanographic indicator remains to be

selected for the east. The report card indicators are described at the beginning of the Indicators section of this ESR. We will continue to revise and update these indicators in future editions of this report.

Complete Recap of the 2017 Ecosystem State

Some ecosystem indicators are updated to the current year (2018), while others can only be updated to the previous year (or earlier) due to the nature of the data collected, sample processing, or modelling efforts. Therefore, some of the “new” updates in each Ecosystem Considerations Report reflect information from the previous year. This year we include a complete summary of the ecosystem status of the GOA during 2017 that includes information from both previous and current indicators. The next section (Current conditions: 2018) provides separate summaries of the 2018 ecosystem state for the western and eastern GOA based on indicators updated this year. We plan to continue developing the ecosystem assessments with this ecoregional focus in future editions.

The North Pacific atmosphere-ocean climate system was in a more moderate state during 2017 than during the previous two years. In particular, the warm sea surface temperature anomalies associated with the extreme marine heatwave of 2014–2016 moderated. A weak La Niña developed during winter 2016–2017 along with a weaker than normal Aleutian Low. The Pacific Decadal Oscillation remained in a positive state but with lower amplitude. The weather of the coastal GOA was generally warmer than normal. The freshwater runoff into the GOA was somewhat less than normal in summer 2017, with implications for the baroclinic component of the Alaska Coastal Current. The sub-arctic front was farther south than the year before, consistent with the winter surface currents shown in the Papa Trajectory Index, which has its southernmost extent since the 1930s. This patterns suggests that there was reduced transport into the Alaska Current during 2017. Eddy kinetic energy was low through most of the year, suggesting that phytoplankton and nutrients were more tightly confined to the shelf. Sea temperatures were average through the top 100m along the Seward Line in May and eastern Gulf of Alaska shelf during summer. Water temperature profiles taken during the summer bottom-trawl survey throughout the GOA showed slight overall cooling compared to the previous survey in 2015 during the heatwave, but were still among the warmer years in the survey’s record. However, the warmest water did not penetrate as deeply into the upper 100 m as in 2015. Temperature in PWS remained elevated, which is typical as PWS temperatures generally lag the Gulf of Alaska by about a year. Eastern GOA waters were 2–3°C cooler in 2017 than in the previous 3 years, although still in the range of warm. The intensity of stratification, and the shallowness of “deep” cold water offshore was notable. Average mixed layer water temperature was cooler in 2017 than in 2016, confirming that the “Warm Blob” was dissipating. Taken together, these suggest that the GOA water column was largely returning to average conditions in 2017.

Zooplankton continued to show the general pattern seen during the heatwave of abundant, but smaller, less lipid-rich taxa, with some signs of shifts to larger copepods and euphausiids. The continuous plankton recorder showed a fourth year of above average mesozooplankton abundance, but the first year since 2012 that the mean size of copepods was above average, indicating a shift in 2017 toward larger-sized species that are more lipid-rich. The biomass of copepods during May

along the Seward line was above average for the third year, but euphausiid abundance remained low. The rapid zooplankton assessment during spring and summer in the western GOA noted some hot spots of large copepods during spring, but the numbers declined over the summer. Compared with historical estimates in Shelikof Straits, large copepod abundances were similar to the long-term mean and higher than they were in 2015, the year of the last survey. Small copepods were widespread in spring and increased in abundance in summer, with both values about equal to the long term mean. The smaller life-stages of euphausiids that are sampled in the rapid zooplankton assessment appeared to be more abundant compared to historical estimates and to the low estimates in 2015. This pattern was in contrast to the preliminary euphausiid abundance estimate from the acoustic survey, which samples larger juveniles and adults, and which found less euphausiid biomass in 2017 than in 2015. Zooplankton lipid content was below average for all taxa sampled in Icy Strait.

Gelatinous zooplankton were observed in high biomass on the eastern GOA shelf and oceanic waters. Oceanic waters contained a high biomass of tunicates (doliolids and salps), while the nearshore zooplankton biomasses consisted of a high number of small (<0.25 mm) juvenile shelled pteropods, *Limacina helicina*, at a single station. High densities of zooplankton (cnidarians and pteropods) were observed near the freshwater plume emanating from Alsek River south of Yakutat. A mix of oceanic and shelf species assemblages on the shelf in 2017 indicated weak horizontal density gradients and confirmed the weak Alaska Coastal Current described by the PAPA Trajectory Index. For the third continuous warm year, the biomass of large-bodied jellyfish *Chrysaora melanaster* was down, and this species failed to dominant catches as they have in the past. Instead, jellyfish was dominated by *Ctenophora* and *Aequorea* in biomass and Ctenophores and Hydrozoans in terms of abundance. Shifts from large bodies to small bodied jellyfish may be due to shifts in water mass properties that shift distributions or a result of environmental forcing on growth and survival on the polyp stage on the benthos. The first record of pelagic tunicates *Pyrosoma atlanticum* in NOAA's acoustic, surface, and bottom trawl surveys conducted since 1982 as well as commercial fisheries were a unique tropical creature seen in the Gulf of Alaska.

Ichthyoplankton abundances for most species in the western GOA in 2017 returned to long-term averages with the notable exception of Pacific cod which remained below average. Larval arrowtooth flounder abundances were above average as was their energy density as measured in samples from the eastern GOA. Larval walleye pollock rough counts were above average and distributed widely with few zero catches. The distribution pattern contrasted notably from the extremely abundant larval pollock in 2013, which was more concentrated to the west of the Shumagin Islands and did not materialize into a large year-class. Late summer catches of pollock remained high—the second-highest in the record—and were concentrated through Shelikof Strait and east of Kodiak. Their distribution may have favored their survival over the summer as they were caught as age-1s in the winter Shelikof survey. Also, the energy density was above average for age-0 pollock in the eastern GOA in 2017, another favorable indicator for the 2017 pollock year class.

In general, forage fish abundances (age-0 pollock, age-0 Pacific cod, sablefish, juvenile salmon) and their energy density (with exception of age-0 pollock and arrowtooth) were low in surface trawl surveys of the inside waters and shelf waters of the eastern GOA during late summer. Surveys during late summer that targeted age-0 sablefish found few offshore in 2017, unlike the many found in 2016, but an exploratory extension of the survey found age-0 sablefish farther north near Kayak Island.

Overall, marine survival was low and body size was small for salmon in 2017, but there were mixed signals in terms of their energy density as juveniles. Marine survival was poor for coho

salmon (piscivores) and average for pink salmon (planktivores) that left Auke Creek and entered saltwater in 2016 and returned as adults in 2017. Auke Creek weir operators recorded low numbers of pink and coho salmon smolt outmigrants in 2016. These migrating smolts experienced warm creek temperatures and low water depths due to a lack of snowfall and snowmelt. These 2016 coho salmon out migrants had the lowest marine survival and pink salmon average marine survival for the 1980–2017 time series. Conditions for smolt outmigration improved in 2017 with cooler freshwater temperature (2°C) and deeper creek depths. Juvenile salmon sampled in inside waters en route to the GOA had small average body size but high energy density in 2017. However, offshore juvenile pink and Chinook salmon had low energy density. Marine survival was low for 2017 and 2018 outmigrants from Auke Creek in northern southeast Alaska.

During the 2017 bottom trawl survey, all groundfish species but Pacific cod had below average body condition, suggesting that overall, the Pacific cod that survived the heatwave were able to forage sufficiently in 2017 to effectively improve their body condition. An analysis of their condition by size class that is in the 2018 Pacific cod assessment shows that the overall pattern of good body condition was seen in the larger cod, but that the smaller cod remained thin, further supporting the hypothesis that adult cod can quickly take advantage of improved foraging conditions as predicted by their short-lived/high growth potential life history strategy. Fish condition for arrowtooth flounder and northern rockfish were the lowest on record, indicating that foraging conditions for most species remained poor following the heatwave. Pacific cod diets, particularly in the larger sizes, contained large proportions of pollock and *C. bairdi* crab, which had been noticeably absent in 2015. The depth distribution of rockfish caught during the bottom trawl survey remained unchanged relative to previous years. Their mean distribution relative to temperature was lower, reflecting the temperature difference in the water column.

Seabirds and marine mammals continued to do poorly overall in 2017 with some exceptions. Several fish-eating seabirds had unusually low reproductive success in 2017. In general, murrens appear to have been negatively affected during the heatwave of the past few years, with widespread reproductive failures, die-offs, and low attendance at breeding colonies. Other species did not show broad-scale failures during this period; planktivorous seabirds were generally successful, perhaps reflecting the abundant, although small, copepods. Despite overall low reproductive success of murrens in 2017, some improvement in murre attendance and fledging success indicated some improvement in foraging conditions. In Glacier Bay, biologists only documented two mother-calf humpback whale pairs, which was the second year in a row of anomalously low birth rates. In addition, one of the whale mothers in 2017 appeared to be abnormally thin, and the other lost her calf by mid-July. Counts of humpback whales throughout northern southeast Alaska were low. Counts of steller sea lions indicated that there was a significant decline in pup counts in the eastern and central GOA relative to 2015 (Sweeny and Fritz pers. comm). These were the first region-wide declines in western Steller sea lion pup counts that the NOAA Marine Mammal Lab has observed east of Samalga Pass since the overall stock decline ceased in the early 2000s. Pup counts had consistently increased at all rookeries in these 2 regions through 2013, and through 2015 at 8 of the 10. Whatever caused the substantial drop in pup counts observed in 2017 appears to have had the greatest impact in the Prince William Sound area, where herring abundance has remained low for over 20 years, and less impact to the west and east.

Current Environmental State—Western Gulf of Alaska

The North Pacific atmosphere-ocean system in 2017–2018 was similar to that from the year before, as seen in the continuation of largely average conditions in the western Gulf of Alaska following the end of the 2014–2016 marine heatwave. The Pacific Decadal Oscillation index shifted to a neutral state, reflecting a broad scale pattern of warmer than average temperature across the North Pacific. Across the western GOA, sea surface temperatures were largely average with some warming during the spring. At a local scale, sea temperatures within the top 100m along the Seward Line showed average to slightly cooler than average temperatures during May. Surface currents during winter were not strongly directional, indicating weak flow into the Alaska current. Eddy kinetic energy continued to be low, indicating less cross-shelf exchange of nutrients. By late summer, temperatures crossed a threshold to be considered a heatwave. The intensity so far is not as great as that in 2014–2016 and the duration is unknown, yet sustained warm temperatures can be expected to be unfavorable for lower trophic organisms such as zooplankton and age-0 fish heading into winter. Climate models are forecasting a weak-moderate El Niño as well as anomalously warm sea surface temperatures throughout the winter in the GOA, which would mean a return to warm conditions for the GOA ecosystem.

The limited indicators of zooplankton abundance available for 2018 show mixed signals. The biomass of copepods and euphausiids during May along the Seward line was above average. This was the fourth year of abundant copepods, but the first for euphausiids since 2014, indicating an increase in higher quality zooplankton prey for predators. The only other indicator of zooplankton availability to predators in the western GOA in 2018 is reproductive success of planktivorous seabirds. Parakeet auklets had poor reproductive success in the Semidi Islands south of the Alaska Peninsula. This is notable because they maintained average-to-high reproductive success through the heatwave years and last had poor reproductive success in 2011. In the Barren Islands at the mouth of the Cook Inlet, fork-tailed storm petrels had average reproductive success, suggesting zooplankton availability was moderate in that region.

In contrast, piscivorous seabirds had above average reproductive success at the Semidi Islands, indicating that there were sufficient forage fish prey (including possibly age-0 gadids) to raise chicks. Kittiwakes and rhinoceros auklet chick diets at Middleton Island showed notable increases in sand lance, an important forage fish, but few capelin, which disappeared from chick diets during the heatwave. However, based on reproductive success, prey appeared to be limiting for the surface-foraging kittiwakes but sufficient for average production for diving rhinoceros auklets. Kittiwakes also had below average reproductive success at the Barren Islands. Taken together, these observations suggest that forage fish were abundant and available around the Semidi Islands, but less so, at least to surface foragers, to the northeast.

Indications of groundfish biomass trends in 2018, an “off-year” for the GOA-wide bottom trawl surveys, are based on ADF&G surveys off Kodiak Island over Barnabus Gully and in two inshore bays. Catch rates were below the long-term mean for arrowtooth flounder, Pacific halibut, Pacific cod, skates, and flathead sole. Catch rates were above the long-term mean for pollock offshore, but below at the inshore bays. While there has been a generally decreasing trend in total catch rates for 10–15 years, there was a slight increase in 2018. In this offshore region, the increase from the previous year was primarily due to increases in the pollock and arrowtooth catch relative to last year.

Upper trophic marine birds and mammals appear to continue to show signs of negative impacts from the marine heatwave. Numbers of murre showing up to breed in the Semedis were low—although those that were there did well reproductively—possibly reflecting a population impact of the immense die-off seen during the heatwave. Similarly, encounter rates of humpback whales in PWS fall surveys were very low in 2018, similar to what was observed in 2017. The highest encounter rates were noted just before and at the beginning of the heatwave. The murre die-off (2015–2016), large whale Unusual Mortality Event (2015–2016), and decline in sea lion counts during and immediately after the heatwave signaled the extreme impact of the heatwave and lagged responses to adverse conditions that would be expected in long-lived, k-selected species such as these.

Current Environmental State—Eastern Gulf of Alaska

The eastern Gulf of Alaska atmosphere and ocean temperatures in coastal regions continued to return to average conditions in 2018 following the marine heatwave of 2014–2016. Winter and spring sea temperatures were normal followed by slightly above average temperatures during summer in the eastern GOA. Satellite derived monthly temperatures on the eastern Gulf of Alaska shelf indicate a cooling off in southeast Alaska waters during the winter (Dec–April) and summer (March–Sept) of 2018. During May within the archipelago of northern southeast Alaska, the top 10-m integrated temperatures were average for the 22-year time series. However, freshwater temperatures during the summer were warmest on record in Auke Creek since 1980. In general, the return to normal temperatures throughout the summer was followed by a reappearance of warm waters in the eastern Gulf of Alaska during fall of 2018. Predictions for 2019 indicate a return of warm waters in the eastern Gulf of Alaska.

Zooplankton sampled in archipelago waters of northern southeast Alaska showed an increase in total densities consisting primarily of small copepods and a higher lipid content of most zooplankton taxa. Although zooplankton densities were above average in Icy Strait, the community consisted primarily of small calanoid copepods. Densities of larger zooplankton, which are prey items for small fish, were below average for large calanoid copepods, euphausiids, hyperiid amphipods, and gastropods. The lipid contents increased to above average in 2018 for small calanoid copepods, *Calanus marshallae* and *Pseudocalanus* spp., young euphausiids (furcillia and juveniles), *Limacina helicina* (gastropod), and *Themisto pacifica* (hyperiid amphipod), but decreased for the large calanoid copepods.

Humpback whale presence in southeast Alaska waters continued to remain low. In Glacier Bay, the number of calves and juvenile return rates of humpback whales have declined substantially starting in 2015. In Glacier Bay, crude birth rates, number of calves per adult whale sighted, remained anomalously low from 2016–2018. During the SPLISH surveys of northern southeast Alaska, crude birth rates of humpback whales continue to drop. Only two calves were seen in southeast Alaska waters during the summer of 2018, one of these is believed to have died, and no calves were seen during the SPLISH survey window (June–August). Some whales have poor body condition but to a lesser extent than was observed in 2016 and 2017. These changes in calving and juvenile return rates may be related to recent changes in whale prey availability and/or quality, which may in turn be negatively affecting maternal body condition and therefore reproductive success and/or overall

juvenile survival.

Salmon captured during the summer surface trawl surveys in Icy Strait were in low numbers and had small body sizes, with the exception of an increase in juvenile Chinook salmon (2nd highest) and sockeye salmon abundance (but still low) since 1997 for the 22-year time series. Juvenile salmon lengths and weights were below average in 2018 indicating poor feeding conditions or a delayed migration.

Salmon monitoring at Auke Creek weir in northern southeast Alaska since 1980 showed low adult returns and poor freshwater and marine survival of salmon. Age-0 coho salmon that outmigrated as smolts in 2018 had record low marine survival when they returned later in 2018. Age-1 coho salmon that migrated from freshwater to saltwater in 2017 and returned as adult in 2018 to Auke Creek had the second lowest marine survival for the weir since 1980. The 2018 outmigrating smolts experienced warm creek temperatures and low water depths. Lack of snowfall and snowmelt contributed to warmer creek temperatures in 2017 and 2018. Pink salmon had low marine survival and a record low numbers of adult pink salmon returns in 2018 since 1980. These trends indicate poor conditions for salmon survival in the Gulf of Alaska during 2017 and 2018.