OA Research on Organisms Found in Alaskan Waters

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Crab

Tanner Crab: Dickinson et al. 2021

- 48 multiparous female adult southern Tanner crabs were exposed to pH 8.1 (ambient), 7.8, or 7.5 for 2 years
- Examined effects of OA on the exoskeleton (thickness, structural integrity, elemental content, phase of calcium carbonate) of mature (post-molt) female southern Tanner crabs
- Determine if the hydration state of the cuticle affects micro-mechanical responses to OA

Results

- 10 survived in pH 8.1, 6 in 7.8, and 7 in 7.5.
- Average reduction of 60% in hardness of the carapace when hydrated.
- Hardness of the claw was not affected by hydration.
- Hardness of the claw was 38% lower at pH 7.5 than pH 8.1 and 27% lower than pH 7.8.
- Claw was four times harder than carapace when dry and ten times harder when wet.
- Carapace thickness at pH 7.5 was on average 15% thinner than at pH 8.1.
- Erosion of inner carapace visible on 57% of crabs at pH 7.5, but never at pH 8.1.
- Carapace thickness at pH 7.8 was intermediate.
- Claw cuticle 31% thinner at pH 7.5 than pH 8.1.
- Greater pollex damage at pH 7.5 than pH 8.1.
- Carapace Ca content was reduced by 11% on average in pH 7.5 than pH 8.1
- Mg content increased by 17% on average in pH 7.5 than pH 8.1
- Suggested transformation of ACC to calcite in crabs at pH 7.5
- 2yr exposure at pH 7.5 caused reduction in microhardness of claw, alterations in mineral content of the carapace, thinning of the claw and carapace, internal dissolution of carapace, loss of denticles on claw, and a shift to calcite in the carapace.

Golden King Crab: Long, Swiney, and Foy 2021

- Ovigerous females collected from Aleutian Islands
- Larvae were reared in a seawater facility and 90 subsequent young-of-the-year were randomly assigned one of three acidification treatments: pH ~ 8.2 (ambient), 7.8, and 7.5 for 127 days.
- Examined how OA altered juvenile golden king crab growth, morphology, and survival

Results

- 17 crabs successfully molted in the pH 8.2, 20 in pH 7.8, and 14 in pH 7.5
- At the end of the experiment, there were 12 crabs surviving in the ambient treatment, 8 in the pH 7.8, and 8 in the pH 7.5.
- Crabs in pH 7.5 significantly smaller than pH 8.1
- Crabs in pH 8.1 grew faster than at 7.8 or 7.5
- Time to molt was greater at pH 7.5
- OA had no significant impacts to morphology
- Crabs at pH 8.1 had significantly lower mortality
- Juvenile golden king crabs exposed to pH levels below surface ambient had significantly lower growth and survival than those exposed to surface ambient water.
- GKC may be able to adapt to the environment they are reared in, so the results may favor higher pH since they were reared at ambient pH (8.1)

Snow Crab: Long et al 2018 (poster)

- Ovigerous females captured in Bering sea
- Exposed reared larvae to pH 8.1, 7.8, and 7.5 for one year
- Mated in lab, exposed to treatments for second year
- Examined how OA altered larval survival, condition, and calcification
- Determine if the response is carried over in oogenesis and embryogenesis

Results

- Low pH exposure as embryos decreased survival at year one
- Larval pH had little effect on survival at year one
- Low pH exposure as embryos did not affect survival in year two
- Larval pH did not affect survival in year two
- Embryo exposure to low pH carried over positive effects to larvae reared in low pH in both years
- Less Ca uptake in embryos at pH 7.5 in year one, but not year two

- Exposure to low pH as embryos has negative effects, but exposure during oogenesis and embryogenesis mitigates or eliminated the effects

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Tanner Crab: Swiney et al and Long et al 2016

- Ovigerous tanner crab were exposed to pH 8.0, 7.8, and 7.5 for 2 years which encompassed entire reproductive cycle (oogenesis through larval hatching)
- Examined effects of high PCO_2 on (1) embryogenesis, larval hatching success, and brooding duration and adult calcification rates; (2) starvation-survival, C and N content, and CA and Mg content of larval tanner crabs.
- (1^{st} year) ~1 yr when females brooding newly extruded eggs to larval hatching placed in treatment conditions. Oocytes developed in field under ambient conditions. Larvae were crossed (acidified embryos → non-acidified larvae). (2nd year) oocytes developed in treatment conditions, ~1 yr when females extruded a new clutch of eggs until larval hatching (acidified oocytes and embryos → non-acidified larvae). Testing for carryover-effects.

Results

- Mean embryo stage was not different among pH treatments in either year 1 or 2.
- Larvae from embryos of oocytes developed in control water were not affected by low pH during embryogenesis.
- Oocytes sensitive to low pH, hatching success decreased: ~70% fewer viable larvae in pH 7.5, but no difference between control and 7.8 pH hatching success. Reduced calcium content in females exposed to 7.5 pH.
- Embryos developed in acidified water produced larvae with morphometric differences between 7.8 and 7.5 treatments. Differences in rostrum-dorsal length likely not relevant to larval survival or performance: trivial effects.
- For Oocytes developed in acidified waters, larvae were bigger in the control and pH 7.8 treatments than the 7.5 treatment: 7.5 had 10% smaller carapace width.
- Acidified embryo larvae had higher C and N content than larvae only exposed to low pH.
- Ca and Mg reduced when exposed to acidified conditions for acidified larval embryos
- Acidified embryos produced larvae with increased starvation survival time (indicative of lower metabolic rate), decreased Ca content and mass, and changed morphology: effects mostly apparent at pH 7.5. All of these effects increased in severity when oocytes and not just embryos were exposed to acidified waters.
- Increased mortality in 1^{st} larval stage at pH 7.5 for acidified oocyte larvae.

Tanner crab: Meseck et al. 2016

- Examined if there was a difference in hemocyte immune characteristics of adult Tanner crabs after a 2 yr exposure to low pH.
- Ovigerous crabs reared in pH 8.1, 7.8, and 7.5

Results

- No significant difference in number of hemocytes suspended in hemolymph between treatments.
- There was a significant difference in percent total dead cells in circulation between treatments. Treatment 7.5 pH had the highest % dead cells followed by 7.8 pH, then ambient, 8.1 pH.
- Tanner crabs were able to regulate pH_e when exposed to low pH for 2 yrs.
- Lowest counts of semi-granular + granular cells were found in low pH treatments.
- Hemocyte variables total count, pH_i, viability and phagocytosis were linearly correlated with total number of eggs, % viable/non-viable, and Ca content in adult females.
- Phagocytosis and % dead cells negatively correlated with Ca concentration.
- Overall, low pH exposure could reduce hemocyte count and therefore hinder immune function.

Dungeness Crab: Miller et al. 2016

- Examined the effects of low pH on Dungeness crab (*Cancer magister*) eggs and newly hatched zoea to pH 8.0, 7.5, and 7.1 (PCO_2 = 466, 1781, 3920).
- Brooding female Crabs collected from Puget Sound by divers. Extruded eggs exposed for 34 days and zoea larvae exposed for 45 days.

Results

- Proportion of eggs hatched and hatching success did not differ between treatments: pH 8.0, 7.5, and 7.1.
- Hatching time probability did not differ between eggs at 8.0 pH and 7.5 pH, but did differ for eggs at pH 7.1; i.e., hatching time for longer for eggs held at pH 7.1.
- Survival was highest in the 8.0 treatment: average survival at final time point was ~60%. Average survival in the pH 7.5 and 7.1 was 13.5 and 21.1%, respectively.
- Mortality rate predicted by model indicated that zoea larvae in 7.5 and 7.1 treatments died more quickly than those in pH 8.0, but did not differ from each other.
- Overall survival and delayed development were a result from exposure to low pH.

Red King Crab: Long et al 2013a

- Examined the effects of OA on growth, condition, calcification, and survival of juvenile of Red king crab (*Paralithodes cantschaticus*) and Tanner crab (*Chionoecetes bairdi*)
- Crabs provided by Alutiiq pride hatchery, ovigerous crabs from Bristol Bay.
- Crabs reared at hatchery to first crab stage then transported to Kodiak lab.
- Tanner crab caught in local Kodiak waters.
- Crabs reared for 200 days in pH: 8.04, 7.80, 7.50; PCO_2: 437, 791, 1637 uatm
- Temperature started at 9.3°C in June, to 11.9°C in Sept. and fell to 4.4°C in Dec.
- Temperature effects were constrained by fitting data to "time" as degree days

Results

- Mortality rates increased nonlinearly with decreasing pH for both species.
- Red king crab had a higher mortality rate than tanner crab at high low pH.
- Red king crab reared at pH 7.8 was larger than control 8.1 at molt stages 1 and 2, but was significantly smaller at molt stages 3, 4 and 5. These were determined by negative correlations with morphometrics Carapace width and length, orbital spine width, and 1st spine length
- Tanner crabs exposed to pH 7.8 and 7.5 were smaller than the controls at molt stages 1 and 2.
- Red king crabs grew faster in control pH, and were predicted to be 11% longer with a 61% greater mass than the treatment 7.8 crabs by the end of the experiment.
- Tanner crabs grew faster in control and pH 7.8 than the 7.5 crabs.
- Longer intermolt periods and smaller growth increments occurred for crabs in the 7.5 treatment.
- Control treatment crabs had 5% larger carapace width and 16% larger wet mass than crabs in 7.8 treatment.
- Low pH did not affect red king crab did Ca content, but did decrease condition index (dry mass (g) / carapace length or width)
- Tanner crabs had decreased Ca content but unchanged condition index

Red King Crab: Long et al 2013b

- Examined effects of OA on Red king crab embryos and larvae (*Paralithodes cantschaticus*)
- Brooding females held in acidified and control seawater (pH 7.7 and 8.0) during last 2 mo. of embryogenesis.

- Carry-over effects were also examined by swapping larvae to reverse control and treatment seawater.

Results

- Eggs and eyes smaller and yolks larger in control pH than in acidified treatment (i.e., acidified embryos were bigger but had smaller yolks)
- All four control females and only one acidified female successfully molted and survived 2 wks post-molt—small *n* but acidification may interfere with molting
- Mg and Ca were higher in control than in acidified females.
- Hatch duration was longer for acidified females (46 days) compared to control females (34 days).
- Acidified embryos had significantly different Mg/Ca ratio.
- Acidified larvae had significantly greater Ca content, Mg/Ca ratio.
- Acidified embryos and larvae had an overall decreased survival and fitness
- Larvae hatched from embryos in acidified water were larger than larvae hatched from control pH—may be a result of acidified larvae holding more water.
- Acidified larvae had lower survival

Shrimp

Northern Shrimp: Bechmann et al 2011

- Seawater (pH 8.1) pumped from 75 m depth in fjord close to lab, filtered down to 30 um, fed to header tanks. Adult female shrimp from a local stock in Norway. Newly hatched larvae < 24hrs old used for experiments. Experiment run for 5 wks. Larvae fed once a day.
- pH monitored with a glass electrode autonomously and CO2 regulated by pH monitoring computer (i.e., gas streamed to maintain set pH) pH varied ~7.6 and 7.55

Results

- Shrimp larvae survival was similar when reared at pH 8.1 and 7.6 for 5 wks. Low pH survival (mean accumulated %) was significantly different on day 35 only. Overall, no significant effect on survival.
- Low pH larvae had significantly delayed development from zoea stage I to II, II to III, and from III to IV.

Northern Shrimp: Dupont et al 2014

- Adult Female shrimp (*Pandalus borealis*) were collected from central Gullmarsfjorden. Exposed to experimental conditions for 3wks: control pH of 8.0 and treatment of 7.5.
- Living shrimp counted every 4th day and dead individuals removed. Fed mixed diet: herring and mussels.

Results

- Mortality rate was significantly different between control and treatment seawater pH, 2.05 % d^{-1} and 1.27 % d^{-1}, respectively. These results differ from those of Hammer and Pedersen 2013 who found adult shrimp tolerance at extreme acidosis (deltapH1.2). The difference between the studies was temperature: Dupont was 11°C and Hammer and Pendersen 7°C. 11°C is upper thermal tolerance.
- Significant difference in sensory quality (appearance and taste) between exposed high and low pH adult female shrimp. Low pH exposed shrimp.

Spot Shrimp: No published data, however keep an eye on Dr. Sherry Tamone and her team (UAS), currently working with Alaska Sea Grant on a project regarding this.

Pteropods

Pteropods: Mekkes et al. 2021

- Shell diameter, height and thickness were measured based on 3D models acquired by micro-CT scanning of 80 individuals; shells were also examined with a scanning electron microscope to assess if thinner shells were a result of dissolution.
- DNA analysis was used to ensure specimens were from single population.

Results

- Average shell thickness declined significantly where upwelling brings colder water with lower pH to the surface
- Intense upwelling in coastal areas characterized by CO_2-rich waters with low pH was associated with a substantial decline in shell thickness
- Shell thickness was not correlated with the level of dissolution; the decline in shell thickness was probably not the result of enhanced dissolution, but rather the consequence of reduced calcification in response to environmental conditions associated with the upwelling gradients.

Pteropods: Bednaršek et al. 2021

- Global literature review, meta-analysis, and consensus of pteropod experts on OA stress

Results

- Aragonite saturation state as measure of OA stress
- Severe shell dissolution, egg developmental impairment, larval growth, and survival affected by OA and have highest correlation with Aragonite saturation
- Larvae and juveniles more affected by aragonite saturation state than adults
- Shell dissolution occurs at aragonite saturation state of 1.50 for 5 days
- Embryonic exposure to OA slowed development rate

Pteropods: Comeau et al. 2009

- Analysis of Pteropod shell growth and Calcification were measured under pCO_2 levels of 350 and 760 µatm (expected for year 2100).
- Pteropods were collected in Kongsfjorden, Svalbard.

Results

- Calcification was estimated using a fluorochrome (calcein) and the radioisotope ^{45}Ca.
- Calcification exhibited a 28% decrease under future acidification conditions when compared to ambient conditions.
- Shell growth was also reduced under acidified conditions.

Bivalves

Geoduck Clam: Spencer et al. 2018

- Geoduck were placed in protected tubes in 2 different habitats (eelgrass and unvegetated) in 4 different bays for 30 days

Results

- pH ranged from 6.71 to 8.34 across sampling region
- No phenotypic differences between pH differences
- No differences in protein abundance, growth, or survival found
- Geoduck may tolerate a wide range of pH in the context of the environment they are reared in

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Razor Clam Washburn et al. (unpublished)

- Strip spawned razor clams treated for 28 days at pH 8.0, 7.7, and variable (fluctuated between pH 8.0 and 7.7 every 12 hours)
- Examine impacts of ambient, variable, and elevated pCO_2 on larval razor clams
- Sampling occurred at Embryonic, trochophore, D-veliger, Pedi-veliger, and pre-settlement individual stages

Results

- Razor clams are concretion users
- Potential for altered mineral transition of ACC to vaterite under OA conditions
- OA may speed up development

Pinto Abolone: Friedman et al 2012 (Poster only)

- Reduced survival of day 6 veliger pinto abalone exposed to PCO2 of 750 uatm compared to 400 uatm after 48 and 72 hr exposures.

Baltic Clam: Jansson et al 2016

- Experiment performed in on *Macoma balthica* Mesocosms (Baltic clam) deployed in Gulf of Finland: Target PCO_2 values 320 (control), 600, 1300, and 1650 uatm. Actual treatment PCO_2 values 469, 857, 1072, and 1347 uatm.
- Sediment traps used to quantify settling larvae
- Temp varied from 8 to 16 °C during the experiment, ~ 45 days, average salinity was 5.7 and TA was 1550 mmol kg^{-1}

Results

- Time to settlement increased with higher PCO_2. That is, at low PCO_2 time to settlement was shorter.
- Larvae settled at a larger size in high PCO_2
- Survival not found to be affect by increased PCO_2

Common Cockle: Klok et al 2013

- Mesocosms with sandy sediment and water from the North Sea were used to perform CO_2 experiments on the common cockle (*Cerastoderma edule*).

- Cockles collected from the tidal flats of the Dutch Wadden Sea.
- pH conditions: 8.3 ± 0.1, 6.95 ± 0.2, 6.7 ± 0.2, and temp averaged 16.9 ± 2.7°C

Results

- decreased pH negatively affected shell length, shell weight, and flesh dry weight for juvenile cockles (~1.8 cm shell length)

Baltic Clam: Van Colen et al 2012

- Examined the effects of OA on *Macoma balthica* from fertilization through metamorphosis.
- 600 adults collected from Westerchelde estuary Netherlands, and 22.3% were induced to spawn.
- Fertilized eggs were exposed to pH conditions 8.1, 7.8 and 7.5

Results

- Only 76% of eggs fertilized at pH 7.5, which was 9 and 8% lower than compared to those fertilized at pH 8.1 and 7.8, respectively.
- Significantly fewer embryos produced normal D-shape at low pH treatments than at control
- Hatching success was 48 and 29 % lower at pH 7.5 compared to pH 8.1 and 7.8.
- Length of larvae shell was reduced and increased mortality in low pH
- No significant difference in % of larvae that metamorphosed at day 19 among treatments.
- Larvae under acidified conditions did metamorphose at smaller sizes.

Fish

Walleye Pollock: Hurst et al. 2021

- Walleye Pollock eggs and larvae were reared at ambient and elevated CO_2 levels (pH 7.6).
- 15 fish were used for size measurements, 50 fish were preserved for histological analysis, and 50 fish were used for lipid class and fatty acid analysis.
- Examine the effects of OA on larval development, swimming behavior, and lipid composition of Walleye Pollock from fertilization to 4 weeks post-hatch at ambient and elevated CO_2 levels.

Results

- Size metrics of walleye pollock were generally insensitive to CO_2 treatment.
- 4-week post-hatch larvae had significantly reduced rates of swim bladder inflation.
- No differences in overall lipid levels between CO_2 treatments
- Ratio of energy storage lipids (triacylglycerols) to structural membrane lipids (sterols) was lower among larvae reared at high CO_2 levels.
- Higher survival to 4 weeks post-hatch among fish reared at high CO_2 levels
- Observations of reduced swim bladder inflation rates and changes in lipid cycling suggest the presence of sub-lethal effects of acidification that may carry over and manifest in later life stages.

Pacific Cod: Hurst et al. 2019

- Multi-faceted analysis of the sensitivity of Pacific cod larvae to elevated CO_2
- Fish behavior in a horizontal light gradient was used to evaluate the sensitivity of behavioral phototaxis in 4–5 week old cod larvae
- Growth of larval Pacific cod was examined under two different feeding treatments for the first 5 weeks of life

Results

- Elevated CO_2 levels strengthened behavioral phototaxis in larval Pacific cod.
- High CO_2 reduced growth and energy storage during the first 2 weeks of life, but this effect was reversed by 5 weeks of age.
- Effects of CO_2 on fatty acid composition of the larvae differed between the two diets, an effect possibly related more to dietary equilibrium and differential lipid class storage than a fundamental effect of CO_2 on fatty acid metabolism.
- These experiments point to a stage-specific sensitivity of Pacific cod to the effects of OA.

Coho Salmon: Williams et al. 2019

- Coho salmon were offspring of spawned adults in the Washington Department of Fish and Wildlife's Issaquah Creek Hatchery
- Exposures to CO_2 levels of ambient (700uatm), medium (1600uatm), and high (2700uatm) for 14 days
- Examined salmon behaviors at different CO_2 levels

Results

- Salmon in ambient state avoided alarm odor and explored the maze.
- Salmon in medium and high levels did not avoid alarm odor and had reduced exploration of the maze.
- Increased CO_2 levels decreased gene expression of genes linked to neurotransmitter function.
- Increased CO_2 led to increased gene expression of melatonin.
- Elevated CO2 levels disrupted neural signaling pathways for olfactory bulb.

Northern Rock Sole: Hurst et al 2015

- Examined the direct effects of acidification on Northern Rock Sole eggs and larvae.
- Eggs and larvae exposed to pCO_2 range of 300- 1500 uatm.

Results

- Only minor effects of elevated CO_2 level on sizes of northern rock sole larvae.
- No significant effect of CO_2 on egg survival or size at hatch.
- Lower condition factor observed at high CO_2 level after 28 days post hatch.
- Little effect of elevated CO_2 on larval growth rates.

Pink Salmon: Munday 2015 (review of Ou et al 2015)

- Embryos and juvenile pink salmon were reared in tanks for 10-weeks: ambient (450 uatm), high CO_2 (1,000 and 2,000 uatm), and an oscillating 450 – 2,000 uatm)

Results

- Percentage of yolk converted to tissue was lower in high CO_2 during freshwater stage. Fish were therefore lighter and smaller.
- High CO_2 exposed fish were bolder and spent more time in water that were subject to alarm cues
- Freshwater juvenile fish reared in high CO_2 were less likely to engage in predator avoidance
- Effects of high CO_2 on growth in seawater were more pronounced, that is growth was negative and fish lost weight. Fish in ambient conditions grew substantially.
- Exposure to high CO_2 in freshwater and seawater, effects were compounded. Lost weight at double the rate of fish only exposed to high CO_2 in seawater.

- Maximum capacity for O_2 uptake was 30% lower for fish exposed to high CO_2 in seawater.

Walleye Pollock: Hurst et al 2013

- Examined the direct effects of acidification on Walleye Pollock eggs and larvae.
- Eggs obtained over 3 spawning seasons by captive broodstock at Newport OR.
- Experiment PCO_2 ranged from ~300 – 1850 uatm
- Larvae age was approximately 7 days post-hatch.

Results

- No significant effect of CO_2 on hatching success
- Significant effect of CO_2 on mean time-to-hatch: low CO_2 having the shortest mean time-to-hatch. At highest CO_2 only a < 1 day increase.
- CO_2 effect on mean time-to-hatch was smaller in magnitude than the variance within an egg batch
- No clear effect of CO_2 on larval survival
- Likely more susceptible to indirect effects
- Higher CO_2 did not result in smaller size at hatching

Walleye Pollock: Hurst et al 2012

- 1st experiment: yearling (age-1) Walleye Pollock reared for 6 wks to evaluate short-term responses in growth, condition, and otolith accretion/composition.
- 2nd experiment: sub-yearling (age-0) walleye Pollock were reared under elevated CO2 for 28 wks to examine prolonged exposure to elevated CO_2. Exposed to 2 week warm 8°C and 3 week cold 2°C rotating intervals.
- Age-0 (10 – 20 mm length) pollock captured in Puget Sound waters, and held for 24 hrs before being shipped to Alaska Fisheries center in Newport OR. Reared in 8 to 9°C for 18 mo before use in experiment.
- Sub-yearling experiment: fish caught in similar manner but only reared for 6 weeks before exposure to treatments.

Results

- No significant difference in survival, growth rate (length and mass) across CO_2 treatments for yearlings reared at ~8°C: PCO_2 400 – 1800 uatm
- There was a difference in otolith accretion across CO_2 treatments.

- No significant effect of prolonged exposure to elevated CO_2 on growth and survival of sub yearlings: PCO_2 warm 600 – 2900 uatm, cold 225 – 1550 uatm
- Sub-yearlings did not maintain growth rates by increasing consumption (i.e., no effect of increased CO_2 on consumption rates)
- There was a small positive trend of higher growth rates with higher CO_2 in sub-yearlings 7.2 % (highest treatments) 2.3 % (lowest treatments).

Urchins

Red Sea Urchins: Reuter et al. 2011

- Examined effects of low pH on Red Sea Urchin (*Strongylocentrotus franciscanus*) sperm function and fertilization
- Organisms collected in Barkley Sound off coast of Vancouver Island.
- Collected adult sperm and eggs placed in treatments of pH 8.04, 7.81, and 7.55

Results

- Time of polyspermy blocking was reduced at lowest pH compared to control and mid pH.
- Decreased fertilization efficiency at low pHs compared to control.
- Reduced fertilization success at low pH.

Fish that have not been studied for potential OA sensitivity

Capelin (*Mallotus villosus*)

- Distribution — Entire Alaska coastline/ Gulf of Alaska and the Bering Sea. Adult distribution is associated with the polar ice front.
- Forage fish for Herring and Cod.

Crescent Gunnel (*Pholis laeta*)

- Distribution — Abundant throughout Alaska's coast waters east of the Aleutians.
- Forage fish for Predators include Great Blue Heron (Ardea herodias), Pigeon Guillemot (*Cepphus columba*), river otter (*Lontra canadensis*), mink (*Mustela vison*), and subtidal fishes.

Pacific Halibut (*Hippoglossus stenolepis*)

- Distribution — Near the continental shelf through much of the northern Pacific Ocean, from California northward to the Chukchi Sea.

- Sport and commercial fishery

Arctic Lamprey (*Lampetra camtschatica*)
- Distribution — lampreys are found from the Kenai Peninsula north along Bering Sea drainages and east along the Arctic coast to the Anderson River
- Subsistence and sport fishery

Pacific Lamprey (*Lampetra tridentata*)
- Distribution — Pacific lampreys are found from Nome, Saint Mathew Island, the Wood River, Unalaska Island, Bristol Bay, Cook Inlet
- Subsistence and sport fishery

Lingcod (*Ophiodon elongatus*)
- Distribution — Alaska Peninsula/Aleutian Islands south to Baja California and are common throughout Southeast Alaska, the outer Kenai Peninsula, Kodiak, and Prince William Sound.
- Subsistence, commercial, and sport fishery

Black Rockfish (*Sebastes melonops*)
- Distribution — range from Amchitka Island in the Aleutian Islands and stretch down southeast Alaska coast.
- Commercial and sport fishery

Yelloweye Rockfish (*Sebastes ruberrimus*)
- Distribution — range from Amchitka Island in the Aleutian Islands and stretch down southeast Alaska coast.
- Commercial, subsistence, and sport fishery

Sablefish (Black Cod) (*Anoplopoma fimbria*)
- Distribution — eastern north Pacific coast from Baja Mexico to Alaska, along the Aleutian Island chain, and the continental slope in the Bering Sea.
- Commercial and sport fishery

Chinook Salmon (*Oncorhynchus tshawytscha*)
- Distribution — Chinook salmon range from the Monterey Bay area of California to the Chukchi Sea area of Alaska. In Alaska, they are abundant from the southeastern panhandle to the Yukon River.
- Commercial, sport, personal use, and subsistence fishery

Chum Salmon (*Oncorhynchus keta*)

- Distribution — While at sea, most of Alaska's chum salmon remain in the eastern Chukchi and Bering seas and the Gulf of Alaska.
- Commercial, sport, and subsistence fishery

Coho Salmon (*Oncorhynchus kisutch*)

- Distribution — coastal waters of Alaska from Southeast to Point Hope on the Chukchi Sea.
- Commercial, sport, and subsistence fishery

Sockeye Salmon (*Oncorhynchus nerka*)

- Distribution — range from the Klamath River in Oregon to Point Hope in northwestern Alaska. Largest populations flow into Bristol Bay.
- Commercial, sport, personal use, and subsistence fishery

Pacific Sand Lance (*Ammodytes hexapterus*)

- Distribution — abundant throughout Alaskan coastal waters.
- Important forage fish for halibut, rockfish, and salmon as well as seabirds such as the Rhinoceros Auklet Double-crested Cormorant and Redthroated Loon and marine mammals including the Steller sea lion fur seal and humpback whale.

Salmon Shark (*Lamna ditropis*)

- Distribution — range across the North Pacific from the Bering Sea and Gulf of Alaska to Baja California.
- Sport Fishery

Longfin Smelt (*Spirinchus thaleichthys*)

- Distribution — abundant in several drainages from Southeast Alaska, north to Prince William Sound and Cook Inlet and westward to Shelikof Strait in the Gulf of Alaska.
- Personal use and subsistence fishery

Rainbow Smelt (*Osmerus mordax*)

- Distribution — In Alaska, rainbow smelt inhabit waters along the entire coast but are less common in the Gulf of Alaska as other species of smelt. Rainbow smelt occur in Bristol Bay and north to Saint Lawrence Island
- Personal use and subsistence fishery

Ninespine Stickleback (*Pungitius pungitius*)

- Distribution — Found from the Kenai Peninsula side of Cook Inlet, into the Mat-Su valley, west and north along the coast to the Bering and Beaufort Seas, and are reported on St. Lawrence Island, Kodiak Island and the Aleutian Chain
- Important forage fish for piscivorous birds

Dolly Varden (*Salvelinus malma*)

- Distribution — occurs throughout the coastal areas of the state from Southeast Alaska across the Gulf of Alaska and the Bering Sea into the Beaufort Sea to the Mackenzie River in northern Canada.
- Sport and subsistence fishery

Broad Whitefish (*Coregonus nasus*)

- Distribution — freshwater drainages of the Bering Sea (including the Yukon and Kuskokwim rivers) and drainages of the Chukchi Sea and the Arctic Ocean.
- Subsistence fish

Shellfish that have not been studied for potential OA sensitivity

Littleneck Clam (*Protothaca stamineais*)

- Distribution — throughout the Aleutian Islands, south to Cape San Lucas, and Baja California. Along entire southeast coast of Alaska
- Subsistence fishery

Butter Clam (*Saximdomus giganteus*)

- Distribution — Aleutians to Northern California along the coast.
- Subsistence and recreation

Razor Clam (*Siliqua patula*)

- Distribution — southern Cook Inlet westward to the Bering Sea and across Aleutian Islands
- Commercial and recreation

Weathervane Scallop (*Patinopecten caurinus*)

- Distribution — California to the Bering Sea and as far west as the Aleutian Islands.
- Subsistence, commercial, and personal use

Red Sea Cucumber (*Parastichopus californicus*)

- Distribution — Southeast Alaska and has been observed at least as far west and north as the Alaska Peninsula, Aleutian Islands, and Bering Sea.
- Commercial and subsistence fishery

Coonstripe Shrimp (*Pandalus hypsinotis*)

- Distribution — coastal Pacific rim waters from the Bering Sea to the Strait of Juan de Fuca. Southeast Alaska most coonstripe shrimp are harvested seaward of glacial estuaries including Bradfield Canal, Port Snettisham, upper Lynn Canal, Lituya Bay, and Yakutat Bay. In Southcentral Alaska they are known to occur in Lower Cook Inlet, particularly in the Kachemak Bay area and in Prince William Sound. In Southwest Alaska they also are found in Kodiak waters
- Recreation and commercial fishery

Sidestriped Shrimp (*Pandalopsis dispar*)

- Distribution — Bering Sea to northern Oregon along the southeast coast of Alaska and out across the Aleutians.
- Commercial, subsistence, sport, and personal use