All these summaries are about bears and their behaviours with salmon. They are organized by what is specifically being studied in the article. Many of these articles focused on the same general area of study such as salmon abundance, sex and size, and dominant behaviours of brown bears. Some of the article as unrelated to the others so they have been put at the very bottom.

The following articles talk about the bear behaviour and how it changes with either different salmon availabilities, and/or with the sex and size of the salmon.

**Quinn, T. P., Gende, S. M., Ruggerone, G.T., & Rogers, D.E. (2003). Density-dependent predation by brown bears (*Ursus arctos*) on sockeye salmon (*Oncorhynchus nerka*). *Canadian Journal of Fisheries and Aquatic Sciences*, *60*(5), 553-562. https://doi.org/10.1139/F03-045**

**Summary**: This study wanted to focus more on the overall predatory response that bears had based on the salmon densities, and unlike previous articles, this article did not study the number of bears in the streams, as the focus was the bear's behaviour towards salmon densities. All this was studied on two temporal scales: during the spawning season at the 13 streams and during days in years at one site over 11 spawning seasons. The 13 streams were in the Wood River system in Alaska. Previous data showed that salmon death was either senescent or due to the bear, therefore surveys were conducted by the researchers during each run to figure out how the salmon died. With these surveys, an index of predation was conducted. The live count would be the highest at the start of the survey and on average only 4% of the salmon entered the streams on the last day. With the 325 surveys over 11 years, the average salmon killed per day was about 100-130. It was found that salmon was killed a lot during the beginning of the run, went down when the salmon became more available (killed number reached an asymptote) and increased again near the end of the run. The asymptotic increase was by 3000 salmon that were killed per stream every year with an increase of salmon density. Therefore, these results show that with low salmon abundance, bears fished more as they believed the food source to be limited. Finally, it was found that with the creek being wider, the chance of salmon being caught by the bears would be lower. This revealed that wider streams made it harder for the salmon to be preyed on by bears due to a greater surface area. Suggesting that bears do better in narrow streams.

**Contributions**: Much like other articles, this article studied the effect of salmon density on the bear predation behaviours by examining salmon. This article was different as it did not incorporate data about the bears but rather made predictions and found proof of the bear's behaviour through the salmon dead and alive count. The more the population of salmon, the lower the kill rate and vice versa. Some future propositions made by this article were that this data would possibly be better supported if the bears were studied more deeply, such as the time and number of bears in the area.

**Gende, S. M., Quinn, T. P., & Willson, M. F. (2001). Consumption choice by bears feeding on salmon. *Oecologia*, *127*(3), 372–382. https://doi.org/10.1007/s004420000590**

**Summary**: This study's objective was to study how bear’s salmon consumption choice changed with salmon availabilities. Previously acquired techniques were used, such as foraging theory to understand the energy allocation in salmon. The study areas were Bristol bay’s Hansen and Bear Creek, and Southeastern Alaska’s Seagull, Bear, and Himmel Creek. To observe the bears behaviours, researchers used tree stands from 1998-1999 during the salmon run from July-September. Salmon biomass was calculated by subtracting biomass not consumed by the

estimated salmon weight. The salmon was analyzed as five body parts (belly, body, hump, brain, and skin), and consuming the whole body only meant 67% biomass. This article predicted that with decreased salmon, higher biomass would be consumed per fish. With high availability, it was predicted that bears would consume parts with more biomass per ripe to maximize energy intake. Finally, it was predicted that bears would need to consume more male salmon than female salmon to achieve the same biomass, because females provided eggs. 20,230 salmon were preyed on from 1994-1999 in both study areas. Results showed that ripe fish were consumed more, although the biomass consumed for male and female salmon was similar. In high availability, bears targeted the female's eggs, and for males, the brain, body, and hump. During high availability, bears consumed less biomass, focusing on energy-rich fish. Bears consumed more biomass per fish with low availability. The brain was eaten regardless of the salmon's sex, targeted due to its high energy. It can be concluded that with high salmon abundance, bears focus on maximizing their energy-intake, consuming high energy body parts only. When the salmon abundance was low, bears focused on consuming maximum biomass, and were not picky about the sex or body part of the salmon. These techniques therefore ensure the greatest efficiency of bears when fishing.
**Contributions**: This article relates to brown bear foraging behaviour as it explores how bears choose what sex and part of salmon to consume to maximize energy. Previous research was expanded upon as it went into depth about the specific body parts of salmon (belly, body, hump, brain, and skin). One interesting behaviour was that with high availability, bears preferred female salmon as the roe was the most energy-rich. A study to further advance this understanding would be to incorporate social class and compare the fitness of dominant and subordinate bears with access to the female salmon in high availability.

**Quinn, T. P., & Kinnison, M. T. (1999). Size-selective and sex-selective predation by brown bears on sockeye salmon. *Oecologia*, *121*(2), 273–282. https://doi.org/10.1007/s004420050929**
**Summary** This article studied the patterns of predation brown bears have on sockeye salmon originating in small creeks. The study was done in the Pedro pond-creek system (five ponds) in Pedro Bay in the Iliamna Lake of Alaska. The area and depths of the ponds were measured by the researchers and found using aerial pictures. This study went on from 1993-1998 in which the area was studied by foot for a couple of days every year, examining the salmon abundance and bear behaviours. Dead salmons were examined for sex and size. Physical counts for live salmon were made by walking around the ponds. 85 male sockeye salmon were captured from 1993-1995 and compared to the previously available data for the 525 Woody Island sockeye salmon from 1988-1995. Researchers predicted the level of predation to be the same through the years, male salmon to be targeted more, large fish to be targeted, and predation to be higher in narrow/shallow habitats. It was found that male salmon were consumed and killed more (10%) than females (4%) due to them being larger and entering the water system first. Results showed bears going for larger fish because of preference or because they were easier to see/catch. In low abundance, bears did not have a preference. Predation rates were lowest in big ponds. Salmon in the large ponds were not bigger than those in smaller ponds, and density was only a little higher in those areas. Finally, selective predation did influence sexual dimorphism in populations. With all these results it was concluded that bears chose the salmon to feed on based on the salmon's size, sex and relative abundance, and favoured feeding on the larger males. Although with low salmon abundance, bears settled with whatever they could get with no preferences.
**Contributions**: The reason I chose this article was that the results of this article contradicted with some past articles, displaying that there are discrepancies in data based on the areas being studied. Although the article also built on the limited research from other articles about small stream behaviours. One future question proposed by this article was to study more about

the links between the dynamics and the evolution of salmon and bear population, to see how it influenced the bear's fitness overtime

**Deacy, W., Leacock, W., Armstrong, J. B., & Stanford, J. A. (2016). Kodiak brown bears surf the salmon red wave: Direct evidence from GPS collared individuals. *Ecology*, *97*(5), 1091–1098. https://doi.org/10.1890/15-1060.1**

**Summary**: This article focused on brown bear behaviour based on the availability of salmon during the spawning season, focusing on bear location. Previous studies showed that brown bear's following a salmon resource wave revealed a lot of information about the bear's interaction with salmon based on its availability. It was previously known that bear's are very effective in tracing the spatiotemporal variations of the salmon's abundance across the territory. To fill knowledge gaps about how bears track salmon, this article quantified the salmon resource wave, tracked the movement of bears surfing the wave, and quantified to which degree the bears would surf the resource wave during foraging. The study location was in Alaska's southwestern Kodiak Island with the previously known average salmon escapement of over 3.2 million (2000-2009). The bodies of water for the study were identified and these 95 fishing sites included the falls, lake-tributary streams, lake-outlet rivers, and lake beaches. Researchers monitored streams using remote cameras, pictured June-September every 5 mins for 24 h/day, showing no bear activity with low/no spawning salmon. The data concluded the time at a spawning site effected the bear's opportunity to forage. The study also found how many spawning sites and days a bear forged for by using GPS collars, recording the bear's location hourly from June-November. 143,284 locations were recorded from 43 bears from 2008-2014. The major finding stated that bears visited areas with early salmon availability first (falls, streams) and areas with later salmon availability last (rivers, lake beaches). The reason for this was because there was more salmon in the falls and streams early in the run, and later in the run there was more salmon in the rivers and lake beaches. This study was significant as it concluded bears learned to follow the red wave to maximize energy intake.

**Contributions:** This article was chosen by me as it demonstrates the foraging behaviours that the brown bears act upon based on the movement of salmon, by following them. The method of study used in this article used GPS trackers that located the bear's movements over the spawning season. This method was stated to be an effective method as it allows for active tracing of the bears. One proposition for future studies suggested by the article was to conduct a study with adult male bears as well as it would result in a more accurate studying of this topic.

These three articles relate the behaviours brown bears have while feeding, and relate it to some aspect of social class or brown bear dominance.

**Gende, S. M., & Quinn, T. P. (2004). The relative importance of prey density and social dominance in determining energy intake by bears feeding on Pacific salmon. *Canadian Journal of Zoology*, *82*(1), 75–85. https://doi.org/10.1139/z03-226**

**Summary**: The foraging behaviours of brown bears on pink salmon and adult chum based on salmon's density were studied. This was then related to the bear's behaviour in a social setting. The study areas were three streams in the Northeast Chichagof Islands near Juneau Alaska. As per previous knowledge, two streams had chum and pink salmon, whereas the other only had pink salmon. Scientists who wrote this paper observed bears from stands in coniferous trees above the streams. Examination started as salmon entered the streams in 1999 and 2000 and continued until the last salmon run, relating to the bear's activity in the area. Studies happened during the day for 7-12h by alternating observers. These observers used binoculars and recorded audios to identify bears, analyze bout times (anything other than fishing i.e., searching) and how bears caught salmon. Researchers predicted that salmon and energy

intake would be higher with more salmon density, and higher for dominant bears. They predicted bout time would be longer with more salmon density as the likelihood of catching fish would increase. Finally, they predicted dominant bears to spend more time foraging bouts and subordinate bears would not, therefore visiting the streams more. It was found that more salmon were killed with higher densities although the energy intake was not related to salmon density. Dominant bears (large females) had access to more salmon with high densities although the time spent foraging bout was not related to salmon density. Therefore, the reason that dominant bears had the highest energy intake was just that they spent the most time at the streams, and subordinate bears had lower energy intake due to them having less access to the streams. Finally, it was found that the highest possible energy intake bears could get is through salmon (not vegetation) to maximize fitness.
**Contributions**: This article differs from the others as it studies the effect of chum (*Oncorhynchus keta*) and pink salmon (*Oncorhynchus gorbuscha*) and their relative density on bears. Researchers studied if the salmon density influenced the bear's energy intake and its effect on social class, building on past research. This article was different as the method of study was done physically by researchers, not through set-up cameras. One future proposition made by the researchers was the area of study lacked bear interactions, therefore the accuracy for the social status results would be better if the study area had high bear interactions.

**Gill, I. D., & Helfield, J. M. (2012). Alternative foraging strategies among bears fishing for salmon: A test of the dominance hypothesis. *Canadian Journal of Zoology*, *90*(6), 766–775. https://doi.org/10.1139/z2012-045**
**Summary**: The researchers in this article tested the dominance theory and how social class plays a role in foraging for salmon. The dominance hypothesis is that social dominance will influence how much fish an individual has access to, more effect than the relative abundance of salmon. Dominance theory says that the behaviours of the bears have a great effect on foraging efficiency. The dominant behaviours were split into four categories: theft, displacement, popular location use and productive location use. The predictions made stated that these behaviours would increase individual fishing efficiency and nondominant behaviours (deferral and fish loss) would not. The subjects of this study were brown bears and chum salmon at the McNeil River in Alaska that has a mean of 19,793 spawners. The 74 bears were observed overall in an alternating manner (five every day) during the day from June 30th to August 1st, 2010, for 200h total (done by observers). The area was split into sections and salmon caught was counted by the hour, found to be 8696 salmon. The foraging efficiency was expressed as the relative foraging performance (RFP), and the dominance score was also calculated. For a focal of 26 bears, the average catch rate was 3.05 fish/h. The dominance behaviours in fact did not correlate much with the individual's RFP score, although a high RFP was correlated with how often the bear was at the fall. There was limited support for this hypothesis as the non-dominant individual had alternative strategies to catch salmon, resulting in similar catch rates. If the dominant bears had high efficiency due to being superior, the nondominant worked their way around to maximize efficiency. A possible reason for this is that the nondominant bears of the falls have adapted and familiarized themselves with the falls to feed efficiently.
**Contributions**: I chose this article as it studied the effect of dominant bear behaviours and compared that to the non-dominant bear behaviours to figure out if the dominant bears had more salmon catching efficiency. It was found that the two are not related and non-dominant bears had alternative strategies to maximize their efficiency. This article continues past research, going into depth about the social behaviours of brown bears with relation to salmon and proposes many future questions such as if the bears were not familiar with the area of study, then would the social dominance play a role in catch rates?

**Klinka, D. R., & Reimchen, T. E. (2002). Nocturnal and diurnal foraging behaviour of brown bears (*Ursus arctos*) on a salmon stream in coastal British Columbia. *Canadian Journal of Zoology*, *80*(8), 1317–1322. https://doi.org/10.1139/z02-123**

**Summary:** As there was limited information about the foraging behaviours of brown bears on salmon during the night, this article chose to study that behaviour. As seen in black bears, diurnal and nocturnal foraging is very effective, and researchers wanted to test this in brown bears. Therefore, it was predicted that the brown bears would be able to display this behaviour very well in salmon streams and forage well at night. The area of the study was along the Glendale River in B.C., and the study went on for 10 days In September 1999. 11 bears were observed and the salmon escapement from late August to late October was 550,000 pink salmon. Observations were made from towers 10 and 50m from the weir, and the total time of observations was 76.5h. The three-light regimes studied were darkness, civil twilight, and daylight, thus for the night observations, a handheld night-vision monocular was used, and daylight observations were done manually. Standing was the most common fishing technique in the night, and the least during the day. The running technique was more common during the day but showed no differences in efficiency from day and night. Standing was the most common at night to prevent movement-induced waves, preventing salmon from knowing a bear is there. The highest capture efficiency was found during darkness (36%) due to less evasive behaviours, and lowest during daylight (20%). Adult brown bears dominated this nighttime behaviour more than females that had cubs (to prevent infanticide), and subadults who preferred to fish during daylight/twilight. This study therefore proved that brown bears opted to using alternative sensory modes to optimize fishing in the dark. With these acquired techniques, and with limited competition at night, male brown bears were able to achieve higher efficiency's when fishing at night than day.

**Contributions**: This article studied the topic of nocturnal foraging behaviours of brown bears and found that brown bears did relatively well when foraging at night. This article built on past studies such as those that proved this behaviour for black bears, and this article also deemed some past studies wrong. This article proved that brown bears were able to forage during the night (efficiently) and this was not just an effect of restrictions of suboptimal foraging periods. One future study can be to study the efficiency of nocturnal foraging with relation to the abundance of salmon to further understand this behaviour.

These two articles are not related enough to any of the categories above, therefore placed at the very bottom. They talk about bears fishing for small stream salmon and the keystone relationship that bears have with salmon respectively.

**Wirsing, A. J., Quinn, T. P., Cunningham, C. J., Adams, J. R., Craig, A. D., & Waits, L. P. (2018). Alaskan brown bears (*Ursus arctos*) aggregate and display fidelity to foraging neighbourhoods while preying on Pacific salmon along small streams. *Ecology and Evolution*, *8*(17), 9048–9061. https://doi.org/10.1002/ece3.4431**

**Summary**: This article studied the relationship between brown bears (*Ursus arctos*) and Pacific salmon (*Oncorhynchus spp.*) in two small stream neighbourhoods, rather than the commonly studied large streams. The major objective was to understand the movement patterns between the neighbouring streams and other brown bear foraging behaviours from 2012-2015 in relation to salmon availability. There were six streams (two neighbourhoods) studied that flowed into Lake Aleknagik in Alaska. Instead of using videos/pictures to observe the bears, the researchers in this study used the technique of bear hair sampling wires. These wires were stretched across the six streams so that the bear hair samples would be caught while they were

fishing. These samples were studied in the lab, allowing for more precision in bear detection. Over the four summers, 2,026 bear hair samples were collected, and 524 samples were successfully amplified, yielding a total of 121 bears detected in the two neighborhoods. The first prediction stated that many individual bears would stay and fish in one stream neighbourhood during the spawning season (the one they are familiar with), having limited movement between neighbourhoods**.** Results confirmed these predictions as bears only moved between streams of the same neighborhood over the years. Another prediction was that the bear detection rates will be different from one stream to another, and highest in streams with more salmon. There was no consistent difference in the detection rates that supported this prediction. The last prediction stated that females would be more present in streams than males as females tend to be less sensitive to human (researcher) presence. The qualitative data showed that over the years, 14/18 comparisons supported this prediction. Despite this evidence, there was a 95% confidence interval for the males and females that had overlap, indicating the different data was not significant, rejecting this prediction.
**Contributions**: I chose this article as it demonstrates the relationship between brown bears and the effect of salmon abundance on the patterns that the bears follow to fish. This was the first article that studied the foraging behaviours of brown bears in small streams. One contradicting finding was that all previous articles underestimated was the abundance of bears in small streams. The more precise data was a result of the hair sampling method. Future questions to explore were exploration and studying of other small streams in the North Pacific Rim that have not been studied before, using the same method.

**Helfield, J. M., & Naiman, R. J. (2006). Keystone interactions: Salmon and bear in riparian forests of Alaska. *Ecosystems*, *9*(2), 167–180. https://doi.org/10.1007/s10021-004-0063-5**
**Summary**: This review studied the nitrogen influx in the riparian forest's Lynx Creek with relation to the keystone relationship of brown bears and salmon, with meta-analysis. The main objective of this review was to study the different spatiotemporal aspects that influenced nitrogen in the environment with relation to salmon and brown bears. Furthermore, the study wanted to prove the importance of salmon and brown bear relationships in the long run on the productivity and the species composition in the riparian forest. The review talked about brown bears' use of their foraging techniques to feed on salmon during spawn or through scavenging post-spawn carcasses. The annual escapement of sockeye salmon in Lynx Creek had a mean of 3084 in the spawning seasons of July-August. The average salmon had about 82g of N inside its tissue. The area also could hold about 2.8 bears in 100km2. The calculations in the study calculated the N (nitrogen) influx in a 200m wide corridor of the riparian forest from both sides of the Lynx Creek. To understand the relationship better, the total annual N influx was calculated under 1,296 scenarios with the combinations of min, max and mean contributions from the sources of N. It was stated that the influx of N in the forest of the study was increased the most with the active presence of salmon and bears both. It was shown that brown bears were responsible for 84% of marine-derived nitrogen and this resulted from the abundance of both bears and salmon. The bear activity with relation to the abundance of N was found through the various interactions that the bear had with salmon. Therefore, the study finally states that the interaction between salmon and brown bears is the most important and effective relationship when it comes to marine-derived nitrogen.
**Contributions**: I chose this article as it talks about the relationship between brown bears and salmon, and this relates to my topic about brown bear behaviour with relation to feeding on salmon. This article specifically talks about nitrogen around the area of study and how the keystone relationship impacts it. This review supports past articles it was reviewing and adds new insight with the added research and calculations done. New questions that the articles

proposed were to study the relationship and its impact on N levels in other areas, or even study other natural elements with the same relation.