2018

Undergraduate Research & Creative Activity (URECA)

Project Final Report

Within one month of project completion and no later than July 15, 2018, please provide an informative but concise (1-2pp) report that addresses the questions/items below. Please submit report, along with required project photo, to both kmjensen@alaska.edu and bbuma@alaska.edu. Bonus points :>) for additional photos.

Your Name: Dawn Wehde
Your Faculty Mentor: Michael Navarro

The objective of my URECA funded project was to conduct a pilot investigation that aimed to provide a data set of the age, size, and maturity of market squid, *Doryteuthis opalescens*, collected in the Gulf of Alaska. The information I collected was used to infer the establishment of a residential or transient population of market squid in the sampled area. I hypothesized that squid collected offshore (> 100m from the shoreline) would be less sexually mature and younger than squid collected inshore which supports the establishment of a residential population. In comparison, no significant differences between size, maturity, and age between squid collected offshore and inshore supports that the squid are from a transient population.

With respect to my project objectives and activities, I have successfully completed my pilot investigation. In summary, the activities included: developing a hypothesis and method to tests it, conducting the research, interpreting the data, and summarizing and sharing the results via a written report, poster, and oral presentations. My hypothesis (mentioned above) and methods I used were devolved with guidance from my mentor Dr. Navarro. Data acquisition consisted of measuring, assessing, and removing of statoliths from donated market squid collected from the Gulf of Alaska and Sitka Sound. The two different sampling locations represented the offshore and nearshore populations. I obtained and recorded the sex, dorsal mantle length, body weight, and gonad weight, and statolith age measurements of the total 44 squid collected. I used these measurements to compare the difference in age, size, and maturity between the two groups of squid to infer whether the squid were transient or residential populations. In conclusion, the majority of my results supported that the squid were from a residential population.

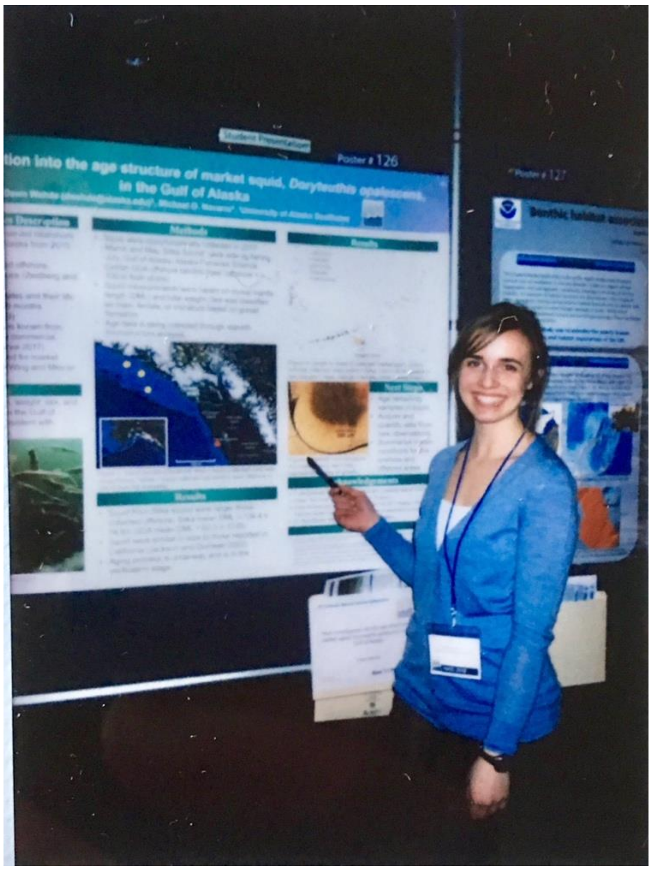
Through means of the URECA program I was able to present my research at the Alaska Marine Science Symposium (AMSS) in Anchorage, Alaska. At the conference I participated in the poster exhibition which allowed me to share my research with the public and other attendees. During the conference I was able to network with other individuals interested by the increased appearance of squid in Alaska such as commercial fisherman and representatives from the Alaska SeaLife Center. By attending this conference, I established meaningful connections with other professionals in my area of research and sharpened my public speaking form while presenting my poster.

As summarized in my Expense report, I did not end up purchasing the dissection kit, envelopes, or poster. These expenses were covered by other funding recourses through my mentor before the grant funds had been allocated. With the completion of my project I do not plan to spend the unused amount I was granted. All conference expenses that were paid by URECA were utilized completely (thank you SO much again).

The tangible results of my project include a poster in PDF form and a scientific report both included in the email along with this final report. The poster is a digital copy of the paper poster I presented at AMSS. The poster only include results up to what I had accomplished by January of 2018. The scientific report encompasses all of my final data and consists of an introduction, materials and methods, results, discussion, future research, appendix, and a literature cited sections. The information from this report will stand as initial guide and reference for future research pertaining to market squid conducted in Dr. Navarro's lab.

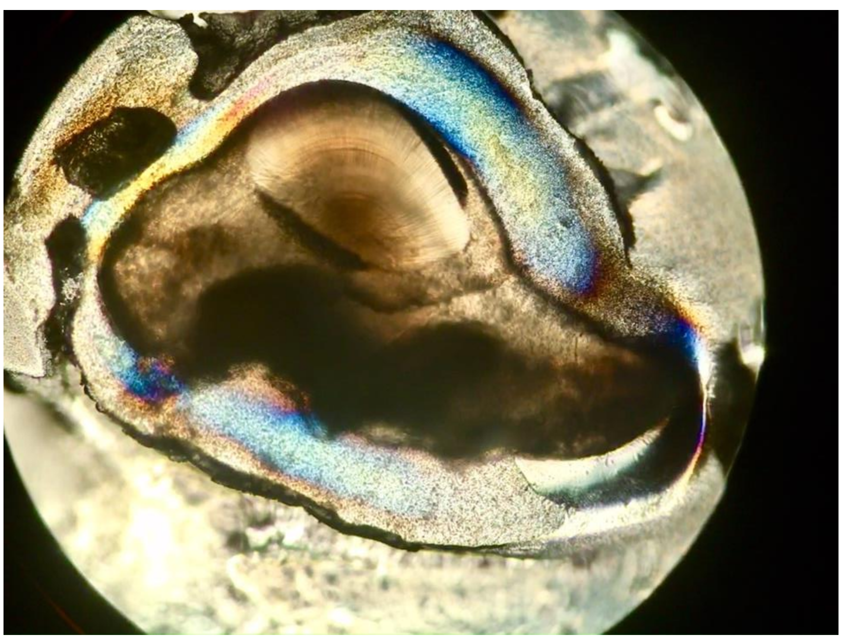
During the time working on my URECA project I grew on both a personal and professional level. I faced challenges that required me to think intuitively and independently, and at other times that required me to admit mistakes and seek guidance from my mentor. A valuable lesson I learned is when and how to ask for help. My time as an undergraduate researcher really opened my eyes to the dedicated group of professors and behind the scene office employees at UAS that are dedicated and excited to help myself and other undergraduates pursue their dreams.

One of the biggest takeaways I got from my URECA project is the how to design and conduct an inaugurl data set on a new species to a specific region. As I begin my career as a fisheries biologist in Western Alaska, one of the issues this region faces is the lack of precise information on native and new establishing marine species. The study I conducted has provided me with hands-on practice of acquiring and interpreting data collected on new marine species. The experience I gained from my project have and continue to be invaluable to my role of as a researcher.

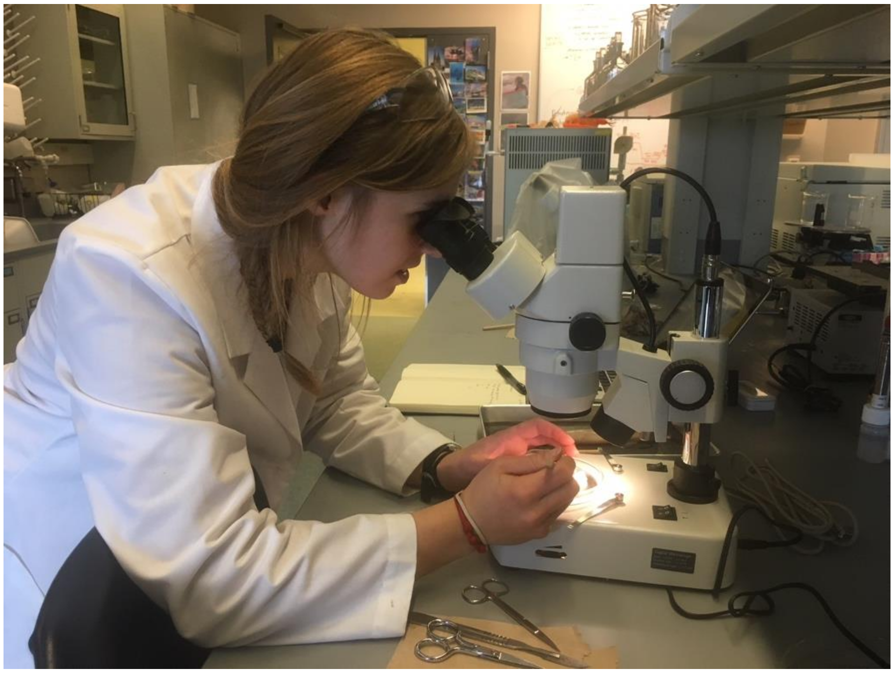


Dawn presenting her poster at the Alaska Marine Science Symposium on January 22, 2018.

Dissected squid from Sitka Sound.



Squid Statolith from market squid collected in Sitka Sound at x100 magnification.


Dawn removing the statolith from a squid in the lab.

Pilot investigation into the age structure of market squid, *Doryteuthis opalescens*, in the Gulf of Alaska

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BIO 498, Advisor: Michael Navarro

Introduction

Marine capture fisheries are a source of nutrition, income, and livelihood for people across the globe. The total global capture production in marine waters was 81.5 million tons in 2014 (FAO, 2016). This global achievement is widely accredited to the improvement and collaboration of fishery scientists and their increased knowledge and ability to monitor marine ecology. The ability to incorporate food web dynamics and species life history into management strategies has shown to be a successful way of fishing a stock at maximum sustainable yield (Hilborn, 1992). Tactics like these will play an important role in maintaining capture fisheries considering changing oceanographic conditions and species interactions due to climate change.

Alaska capture fisheries provide a pivotal example of how implementation of fishery science in conjunction with marine ecology management can be used to sustain successful fisheries. In Alaska, capture fisheries produced 96.5 million dollars in revenue for all capture species in 2016 (ASMSO, 2016). Beyond nutritional and economic importance, in Alaska, fishing and the marine environments remain significant in traditional Native Alaskan culture. Traditional Indigenousness Knowledge (TIK) is actively being integrated into management practices in Alaska. The management of forage species is a chief example of collaboration between state management and TIK. Native Alaskans have long regarded forage fish—species providing critical food source for many marine mammal, seabirds, and commercial fish species—as integral parts of the ecosystem. Today, forage fish species such as capelin, lantern fish, krill, smelt and grenadiers are managed in a manner that prevents the development of a commercially directed fishery for forage fish (NOAA, 2017).

A recent development in forage species is the increased presence of market squid, *Doryteuthis opalescens,* in Southeast Alaska. Market squid have been observed spawning in Southeast Alaska since 2015, initially by researcher Bridgette Malessa in Sitka, Alaska. The spawning behavior is believed to be heavily influenced by climate change, specifically rising sea temperatures (Ruiz-Cooley et al., 2013). It is unclear whether the squid observed are transient pods following warm fronts or are spawning in Alaska and are a residential population.

Between 2012 and 2017, the Alaska department of Fish and Game issued 31 permits for a market squid fishery, although fishermen were only able to harvest a small amount of squid. In January 2018, a proposal to create a purse seine squid fishery in Southeast was denied by the Alaska Board of Fisheries meeting in Sitka. The denial was a credited to the lack of a management plan, stock assessment, and research (ADFG, 2018). Examples of the information needed to manage a market squid fishery are available from California, for most of the known information on market squid from the West coast is based on California fishery research.

The natural life history of market squid is described as short and dependent on environmental conditions and food availability (Jackson and Domeier, 2003). The life span of male and female market squid is up to 260 and 230 days respectively, and are terminal spawners (CDFG, 2005). Market squid hatch inshore, frequently in locations where the sea floor is mud or sand, and remain there until they are passed offshore by ocean currents (Fields, 1965). Squid remain and feed near the edge of the seafloor shelf until maturation at which time they return to inshore waters to spawn (Arkhipkin et al., 2004). The duration and latitudinal range where they remain offshore is believed to be temporally and food availability driven. A study by Jackson and Domeier (2003) shows that days spent inshore and offshore were influenced by the cold and warm conditions between El Nino and La Nina events off the coast of California. Because market squid are opportunistic feeders, another spatial driver is the abundance of krill. A new study suggests strong correlation between krill and market squid densities (Ralston et al., 2018). The effect of these factors on the spatial distribution of market squid sparked the question of whether the increased presence of market squid in Alaska is due to transient population following warming oceanographic conditions and subsequently prey species, or if they are an established residential population. This question demands the need for information on the natural life history of squid collected on Alaska.

Indirect reconstruction of squid life history and population ecology can be obtained through interpretation of their statoliths, dorsal mantle length, and gonadal somatic index. The statoliths are paired calcareous microstructures utilized by the squid for balance and direction, and they produce daily growth increments (Arkhipkin and Perez, 1998). The method of counting the daily age rings in the statolith have been verified as means of aging the squid and estimating hatch time (Arkhipkin and Perez, 1998). Dorsal mantle length has been used as a proxy for studying the relationship of size of squid between sex, region, and other different physical parameters (Jackson and Domeier, 2003). The gonadal somatic index, calculated as the weight of the reproductive organs divided by the total weight of the squid, has been used as a parameter to estimate maturity of the squid (Tafur, 2001). Invaluable information on squid ecology has been derived from the comparison of geographical location, age, and sexual maturity with the measurements discussed above.

This pilot investigation aims to provide an inaugural data set of the age, size, and maturity of squid collected in Alaska. This information will be used to infer the establishment of a residential verses transient population. It is hypothesized that squid collected offshore (> 100m from the shoreline) will be less sexually mature and younger than squid collected inshore which supports a residential population. In comparison, no significant differences between size, maturity, and age between squid collected offshore and inshore supports that the squid are from a transient population.

Materials and Methods

Squid were opportunistically collected in 2017; four on March 15 and seven on May 7 from Sitka Sound via dock side jig fishing (GPS: 57.043099, -135.230255 and 57.055525, -135.352510 respectively). Additionally, four squid were collected from two locations in the Gulf of Alaska on July 5 and twenty-nine on July 9 via the 2017 Alaska Fisheries Science Center Ecosystem Monitoring and Assessment GOA benthic trawl survey (GPS: 59.6502,-140.5019 and 59.4989,-139.9164 and 59.1592,-139.5174 respectively).

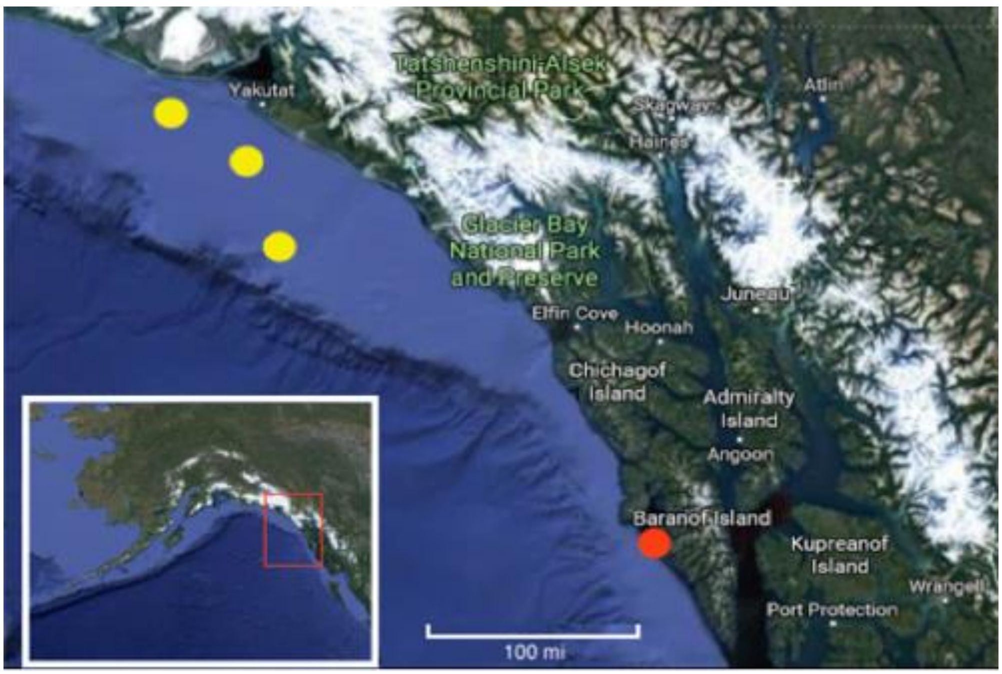

Figure 1. Squid collection sites. The yellow circles indicate the locations where squid were collected offshore in the Gulf of Alaska and the red circle indicates the location of squid collected inshore from Sitka Sound.

On January 13 and 14 of 2018 the squid were thawed in a Ziploc bag and their morphological parameters were measured. Once removed from the Ziploc bag, the squid was gently patted of with a paper towel for five seconds then placed on a scale. The total weight (TW) was measured to the nearest tenth of a gram. Squid length was taken using the dorsal mantle lengths (DML). The mantle of the squid was then opened, the sex identified, and the gonads removed. The weight of gonads (GW) was measured to the nearest tenth of a gram. The gonadosomatic index (GSI) was calculated with methods adopted from Tafur (2001). The GSI ratio of gonad weight over total weight was used as an estimate for maturity of the squid.

The statolith was used for age measurements. Statolith removal technique was adopted from Jellison (2009). A slit under the siphons of the squid was cut to expose the statoliths, opaque structures within the statocyst. Statoliths were removed using dissecting tweezers. Both the left and right statoliths were dried and stored together at room temperature in miniature manila envelopes. Statoliths were mounted onto a microscope slide by first placing a single drop of super glue on the slide followed by using a dissection prong to carefully push the statolith into the drop anterior side up and flat. After statoliths dried they were ground by hand on a 30µm paper, and then polished by hand on a 3µm polishing paper. Grinding was accomplished by executing ten preliminary circular motions on both polishing papers. Then the statoliths were examined and ground until the increment plane was reached. Increment counts were taken using a Leica compound microscope (Figure. 2). Four photos were taken with the Lecia microscope camera in conjunction with LAS EZ photo software: the center, middle, and edge of statolith all in focus and a final photo of the entire statolith. The middle photo was omitted for smaller statolith. Statolith counts were take using the software ImageJ using the counter option. Two technicians aged each statolith independent of each other. For the final photo, the first reader would remove the counted marks from the statolith and leave only the first and last ring count on the photo. If the ages by each counter-varied by 10% or less then the age was determined as the average of both counts (Jellison, 2009). Microsoft Excel 2016 Analysis Toolpack was used for analysis of results; a t-Test for two sample assuming equal variances was used to compare the means of the two sample locations.

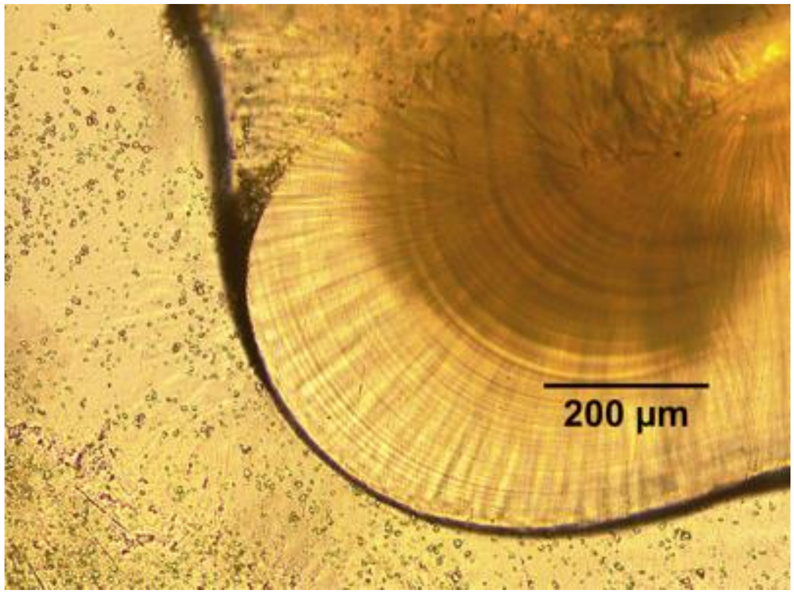

Figure 2. Image shows the daily increments on a statolith using a compound microscope.

Results

A total of 44 individuals were sampled from the Gulf of Alaska and Sitka Sound between March and July of 2018. The GOA group had 2 identified females and 5 identified males out of 33 individuals and the Sitka Sound group had 3 females and 8 identified males out of 11 individuals. The remaining individuals were juvenile and sex was not determined. The average DML for GOA was 60.0mm +/- 10.61mm and Sitka was 134.4mm +/- 14.83mm. The average weight for GOA was 6.2g +/- 2.92g and Sitka was 44.2g +/- 13.22g. The average gonad weight for GOA females was 1.8g +/- 1.00g and Sitka females was 4.9g +/- 0.62g; the average gonad weight for GOA males was 1.0g +/- 0.23g and Sitka males was 2.3g +/- 0.61g. The DML and the average weight were both found to be significantly different. (Figure 3, t-test $p = <0.01$ and <0.01 respectively). The average male gonad weight and female weight between both locations were found to be (Figure 4, t-test $p = <0.01$ and 0.01 respectively). Seventeen GOA squid had ages that agreed within 10% variation of the two counts. The average age of the seventeen squid was 122.7 days +/- 58.21 days.

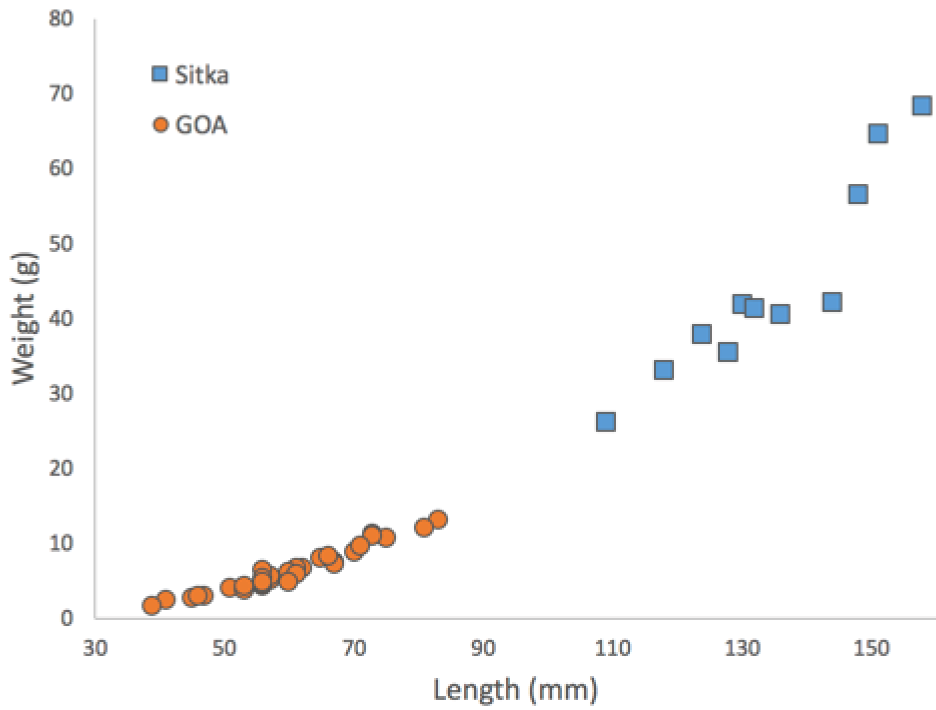

Figure 3. The ratio of weight to length of squid collected in the Gulf of Alaska (orange) and Sitka Sound (blue).

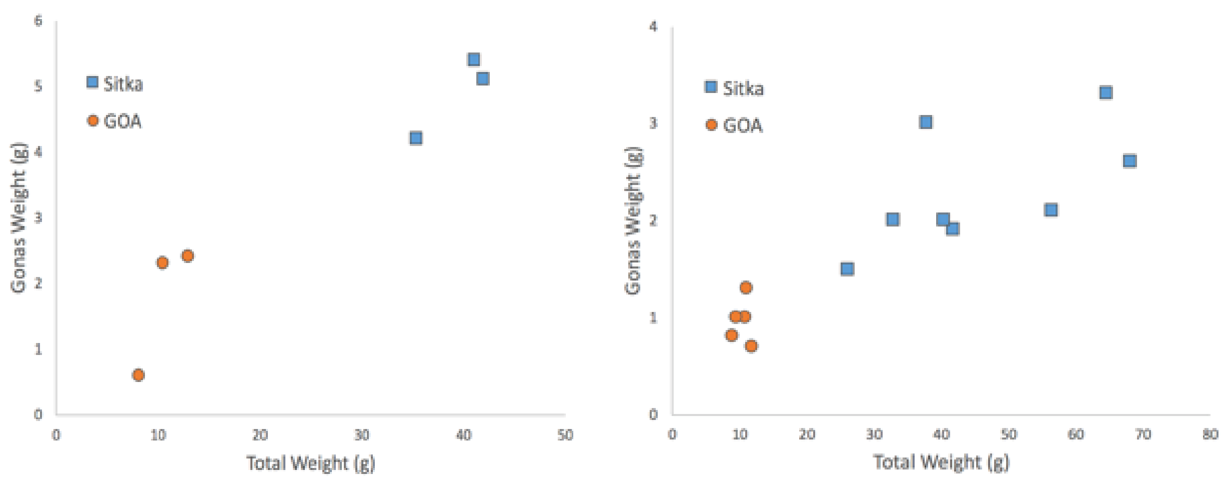

Figure 4. Comparison of maturity of squid based on the ratio of gonad weight over total weight between males (right) and females (left) from the Gulf of Alaska (orange) and Sitka Sound (blue).

Discussion

The average dorsal mantle length, total weight, and gonad weight of squid collected from inshore (<100m from the shoreline) Sitka Sound were all significantly greater than those of squid collected offshore (>100m from the shoreline) in the Gulf of Alaska. This suggests that the GOA squid were less sexually mature and smaller than the squid collected in Sitka Sounds. This data supports the establishment of a residential population and opposes the idea that the squid migrated from southern water because the significant differences between the two groups suggests that the squid are likely to have hatched in Alaskan waters. The results that the less mature squid were collected offshore and more mature squid found inshore is consistent with ontogenetic migration of squid (Arkhipkin et al., 2004) and supports the hypothesis that the market squid are transitioning to a residential population.

17 of the GOA samples that had age counts agree within 10% of the two bind counts. None of the Sitka Sound sample ages were able to be determined. The average age of 122.7 days is just below the age at which males and female squid mature, 129 and 137 days respectively (Jackson and Domeier, 2003). The majority of the GOA squid were identified as juvenile due to the lack of developed gonads. As more samples are collected, different aging methods can provide means for more definitive conclusions to be drawn.

It has been observed that range expansion of species can have potential negative consequences for the population dynamics of native species, trophic structure, and biodiversity in marine ecosystems (Ruiz-Cooley et al., 2013). The introduction of a new forage species means there will be direct competition with other native forage species that are crucial lower trophic organisms for important commercial species the five species of Pacific salmon (NOAA, 2018). Cephalopods are predicted to adapt quickly to changing environmental conditions because of their short-life spans and rapid growth (Doublday et al., 2016). What this means in Alaska is that market squid may be better equipped to outcompete native forage species. This possibility heads the importance expanding knowledge of fisheries science regarding market squid.

The future of Alaskan capture fisheries in light of climate change is uncertain. Rising sea temperatures, variable prey abundance, expanding species ranges and consequently the introduction of new species will all have an effect of the prosperity of commercial species. While market squid may indirectly put pressure on commercial species (Ruiz-Cooley et al., 2013), they may have the means to be an economic alterative. The establishment of a residential population would increase the prospects of a commercial fishery and reduce the problem of insufficient densities of squid collected during previous fishing attempts (ADFG, 2018). A commercial market squid fishery could provide economic relief in the case that climate change reduces the production of current commercial fisheries in Alaska. More research is needed in the life history of market squid in Alaska to better understand the effect their presence will have on fisheries and marine ecology of the state. The information from this research has paved the way for future research to aid in the development of management plans potential in Alaskan commercial squid fisheries and how to adapt present management of native commercial species in light of increased market squid interactions.

Further Research

Because temperature is a driver in the market squid ecology, monitoring oceanographic condition across the state and taking physical measurements at collection sites could add valuable insight to any patterns associated with the persistence of market squid in Alaska. $\delta^{15}N$ values in gladii and muscle tissue of jumbo squid have been used to determine their origin through habitat analysis; tissue sampling of market squid could help dissolve the mystery of their transient or residential origin. Considering the location of this study, I believe that this research would benefit from any consultations with Native Alaskan elders and leaders who could provide their insight on the presence of squid in the region.

Regarding aging, for future studies I suggest that different statolith mounting techniques be explored and practiced on store-bought squid. Instead of the anterior side up perhaps have the posterior side up. This may keep the plane straighter and more lines visible at the same time. A second thought was polishing on larger statolith be done gently because many of the Sitka squid had cracks making it difficult to read. Finally, some of the Sitka squid age rings appeared on the statolith but were too close together to be distinguished under the magnification available. Jellison (2009) showed that difficult aging areas on a statolith can be estimated using a logarithmic equation and I recommend applying this technique to the Sitka Sound statoliths. Although aging was not conclusive in this study, with the collection of additional samples and further practice more definitive results are obtainable.

Appendix

ID	Weight (g)	Length (mm)	Sex	Gonad wt (g)	Age (days) <10%
SIT170315_001	41.8	130	M	1.9	-
SIT170315_002	37.7	124	M	3.0	-
SIT170315_003	40.3	136	M	2.0	-
SIT170315_004	64.5	151	M	3.3	-
SIT170507_001	56.4	148	M	2.1	-
SIT170507_002	35.4	128	F	4.2	-
SIT170507_003	41.9	144	F	5.1	-
SIT170507_004	32.9	118	M	2.0	-
SIT170507_005	26.0	109	M	1.5	-
SIT170507_006	41.1	132	F	5.4	-
SIT170507_007	68.1	158	M	2.6	-
GOA170705_1	11.0	73	M	1.3	115

GOA170705_2	13.0	83	F	2.4	
GOA170705_3	7.4	67	J	-	-
GOA170705_4	8.0	65	J	-	-
GOA179709_1	5.0	57	J	-	-
GOA179709_2	2.9	47	J	-	126.5
GOA179709_3	5.4	57	J	-	135
GOA179709_4	6.2	56	J	-	129.5
GOA179709_5	3.8	51	J	-	142
GOA179709_6	7.2	67	J	-	139.5
GOA179709_7	5.0	56	J	-	-
GOA179709_8	4.3	56	J	-	111.5
GOA179709_9	5.2	56	J	-	-
GOA179709_10	5.2	60	J	-	123.5
GOA179709_11	3.7	53	J	-	-
GOA179709_12	6.5	62	J	-	103.5
GOA179709_13	10.5	75	F	2.3	117
GOA179709_14	6.5	61	J	-	115
GOA179709_15	2.7	45	J	-	139
GOA179709_16	6.0	60	J	-	-
GOA179709_17	8.8	70	M	0.8	127
GOA179709_18	2.4	41	J	-	121.5
GOA179709_19	4.5	56	J	-	141
GOA179709_20	10.9	73	M	1.0	-
GOA179709_21	11.8	81	M	0.7	92
GOA179709_22	8.1	66	F	0.6	107
GOA179709_23	5.8	61	J	-	-
GOA179709_24	4.6	56	J	-	-
GOA179709_25	9.5	71	M	1.0	
GOA179709_26	4.6	60	J	-	-
GOA179709_27	2.8	46	J	-	-
GOA179709_28	4.1	53	J	-	-
GOA179709_29	1.6	39	J	-	-

Acknowledgments

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