SEPTEMBER 24, 2019

LOBSTER BLOOD PROTEIN AND MOULT CYCLE ANALYSIS 2019

GULF NOVA SCOTIA FLEET PLANNING BOARD

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Project Background

The health of lobsters for shipping and holding purposes is affected by their stage in the moult cycle. Knowing and even predicting the moult cycle stage of lobsters each season is therefore desirable for harvesters, buyers, and processors to produce high quality, high price lobster for the marketplace.

The moult cycle itself can be affected by multiple parameters, such as water temperature, photoperiod, diet, health and other environmental and ecosystem factors. It takes approximately 2 months for a lobster to return to high quality conditions (full meat and hard shell) after moulting (Retzlaff et al., n.d.). Data on blood protein levels, moult stage, and shell hardness help us to understand the overall quality of lobsters for holding and shipping.

There are many factors that can affect the overall health of a lobster, including biological, environmental, and human handling factors. This must be kept in mind when determining the health of the animal and interpreting data.

This project adds to the data and analysis that has been collected in previous years (Aquatic Science and Health Services, 2015, Gulf Nova Scotia Fleet Planning Board, 2016, 2017, 2018) for the Gulf of Nova Scotia lobster fishery and builds upon the long-term data set.

Quality Assessment: The Brix Index and Moult Cycle Analysis

Brix refractometers[1] are typically used to measure the amount of sugar in a liquid sample; however, the Brix index (provided by the refractometer) is also highly correlated to lobster blood protein levels. The Brix index is now used by scientists and industry to assess lobster health and make decisions on holding, processing, and shipping lobster (Wang and McGaw, 2014; PRWeb, 2013).

A hard-shell lobster that is full of meat will generally have a high protein level (i.e. greater than 8), while a soft shell lobster that is not full of meat will have a lower blood protein level. Additionally, a healthy, strong lobster will generally have a high blood protein level and a weaker lobster will generally have a low blood protein level (Wang & McGaw, 2014). Some live lobster dealers will only hold or ship lobsters (long term) with a Brix level of 10 or higher; some may use a Brix level of 8 depending on their standards (PRWeb, 2013).

Timing of the moult is most affected by water temperature. Likewise, lobsters at deeper depths are said to moult later than lobsters at shallow depths, due likely to the cooler temperatures in deeper water. Other factors can have some affect on moult timing as well, for example, smaller lobsters (under 82.5 mm) were found to moult later and less uniformly than larger (over 82.5 mm) lobsters in LFA 33 and 34, and the sex of lobsters may also influence when they moult (Retzlaff et al., n.d.).

The stage of moult cycle is said to have the greatest effect on a lobster's blood protein level. When lobsters are preparing to moult they may lose about 30-60% of the tissue mass in their claws (Skinner, 1966 as observed in land crab), or perhaps even more (PARL, nd). This is necessary because the largest cross-sectional area of the largest part of the claw is about 10X that of the base, which it has to squeeze through during moulting (Spees et al., 2003). Shrinking of the claw, mainly through dehydration, causes the lobster's blood protein levels to increase and concentrate. After moulting, when the lobster has a very soft shell, it will take in water to expand the new shell before it hardens. The lobster will be up to

[1] we use the ATAGO Pal-1 Digital Pocket Refractometer

15-20% larger than before moulting and its weight will increase by up to 40-50% (SLGO, nd). This rehydration will cause the blood protein level to decrease sharply (blood is diluted) (Figure 1). Muscle will slowly replace the water inside the shell, filling the shell with meat and raising the blood protein level, yielding a high quality lobster about 2 months after moulting (Retzlaff et al., n.d.).

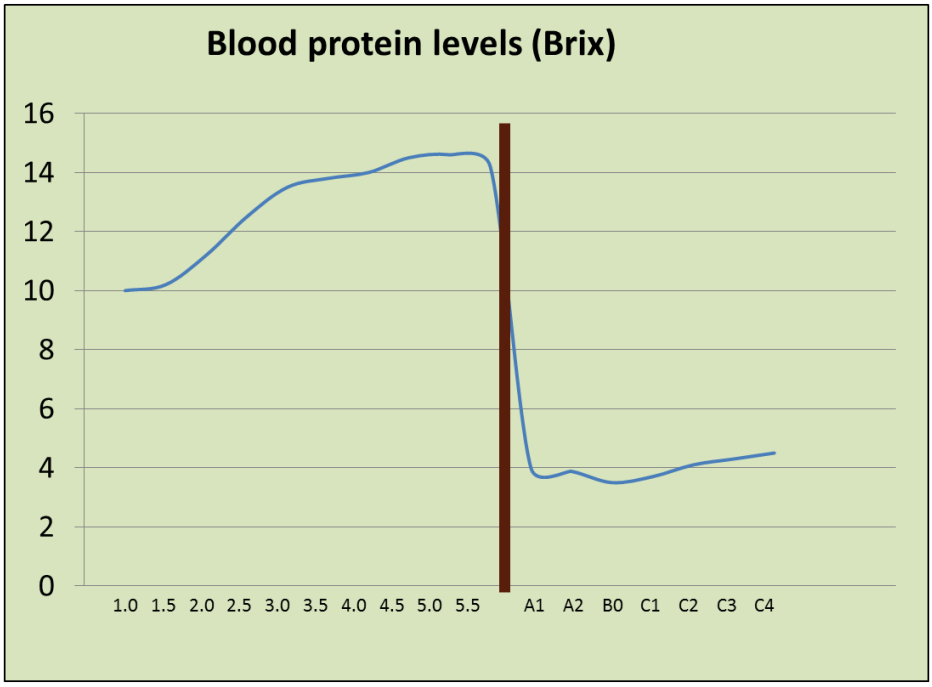

Figure 1. A normal lobster blood protein curve, over time. The sharp drop happens at the time of moulting when the lobster dilutes its blood to expand in size after moulting (Aquatic Science and Health Services, 2015).

Data Analysis and Results

Data was collected throughout the 2019 lobster season in LFAs 26A and 26B. A total of 4,312 lobsters were sampled. Information on sex, size (carapace length), blood protein levels (Brix index), shell hardness, premoult stage, presence of cement glands in pleopods of females, presence of deformed pleopods, and other notable features was collected. The data was collected from 8 sampling sites, on 56 trips (Figure 2). All sites were sampled between May 6th and July 3rd 2019, except for Cheticamp, which was sampled between May 10th and July 4th 2019.

The data is presented using weekly averages. Due to a delayed season start, there was no sampling done during 'week 1'. The following table shows the weekly dates and number of sites sampled per week (Table 1). Attempts were made to sample each site on a weekly basis, but due to weather events and technician capacity, there were some weeks where this was not possible.

Table 1. 2019 Sampling Schedule

Week	Dates
1	June 29th – May 3rd
2	May 6th – May 10th
3	May 13th – May 17th
4	May 19th – May 24th
5	May 27th – May 31st
6	June 3rd – June 7th
7	June 9th – June 14th
8	June 16th – June 21st
9	June 23rd – June 28th
10	July 1st – July 5th

Data for this project was collected by two summer university students, so some variation in the data may be due to differences in sampling techniques.

This section, Data Analysis and Results, will review findings from this year's sampling program. The following section, Interpretation, will provide some context and a comparison to previous years' findings.

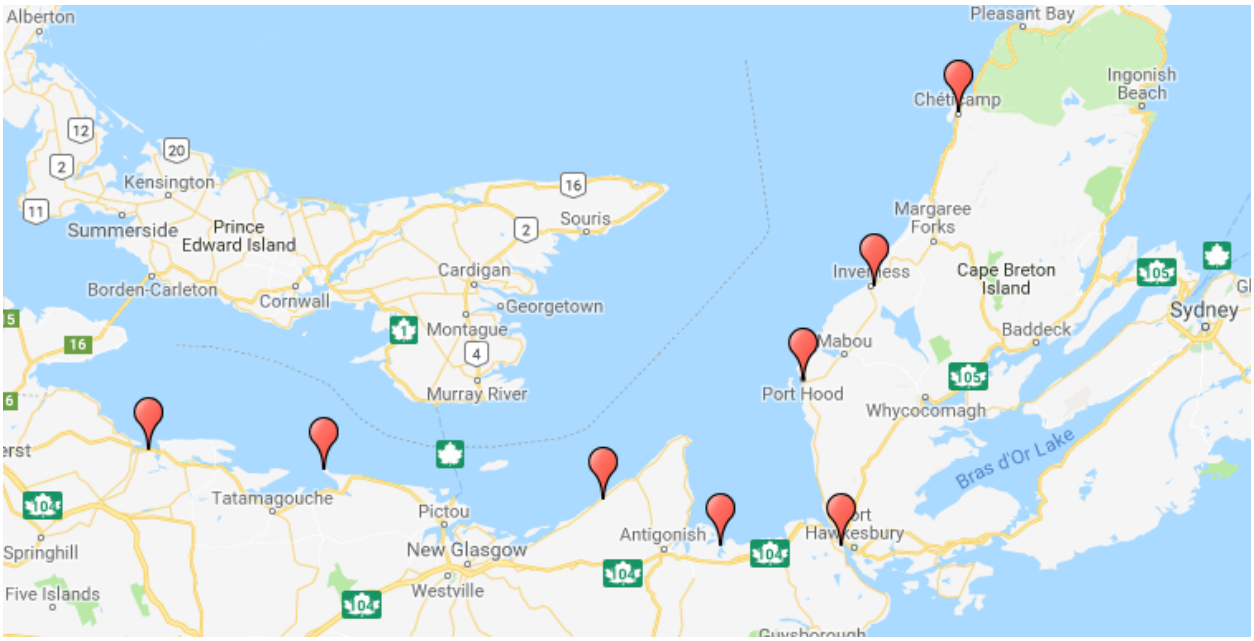

Figure 2. 2019 Sampling Locations: Pugwash, Cape John, Arisaig, Bayfield, Aulds Cove, Port Hood, Inverness, Cheticamp.

Blood Protein Levels (Brix)

The protein levels were analysed over time for approximately 100 lbs, per sampling trip, in all areas. Sometimes fewer lobsters were sampled because of low catches or supply at the holding facility. Additionally, as the season progressed, fewer lobsters were required to make up the 100 lbs as lobsters became heavier (i.e. some days there were multiple lobsters in a crate that had a carapace length over 100 mm). The size and number of lobsters across each LFA may reflect differences in legal minimum carapace length.

Considering protein levels, shell hardness, and pleopod staging analysis, the lobsters in the catch did not moult during the sampling period. However, high average Brix levels (greater than 15) were recorded, particularly in Aulds Cove and River John in the last couple of weeks. The increased Brix levels may be indicative of lobsters preparing to moult. There were no extreme drops in blood protein level that are typical of a post-moult lobster. The average Brix level across all sites and weeks was 10.88. The protein levels indicate that on average, across all of our sampling locations, lobster are within the desired quality of 8-12 Brix. The following two figures (Figure 3A and 3B) show a summary of the Brix levels throughout the season for LFA 26A and 26B.

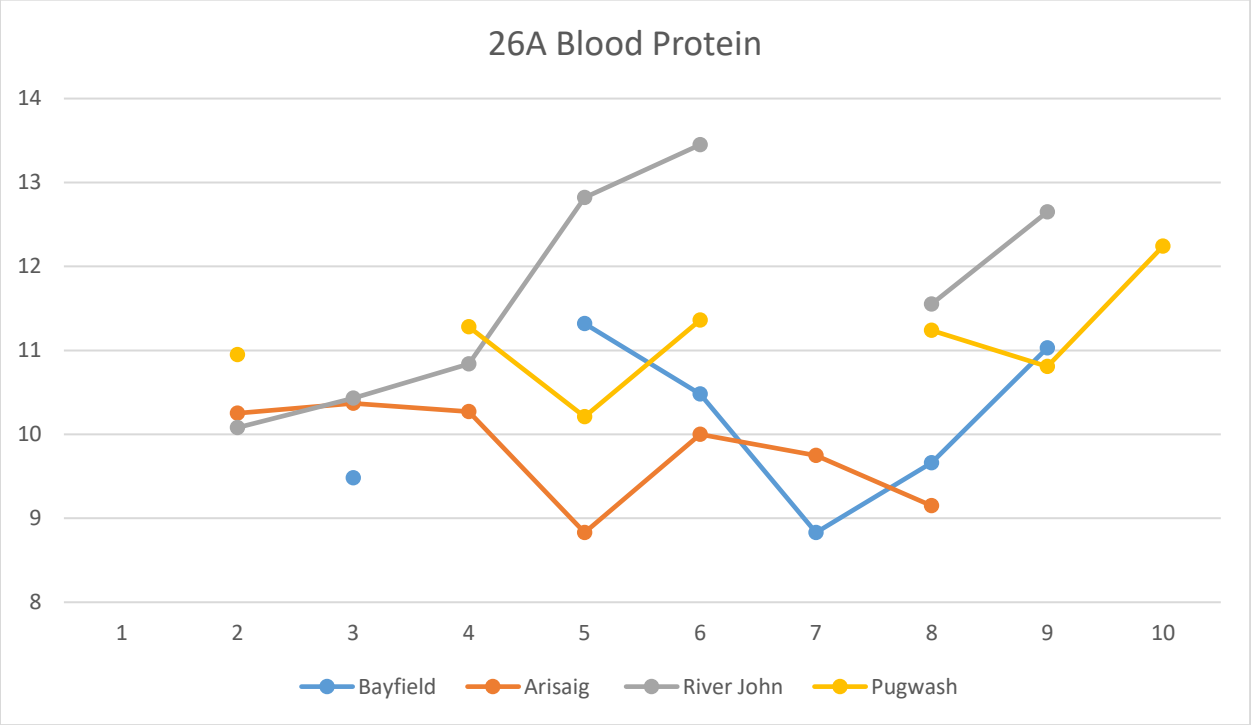

Figure 3A. Average Brix levels by week for all LFA 26A sampling locations

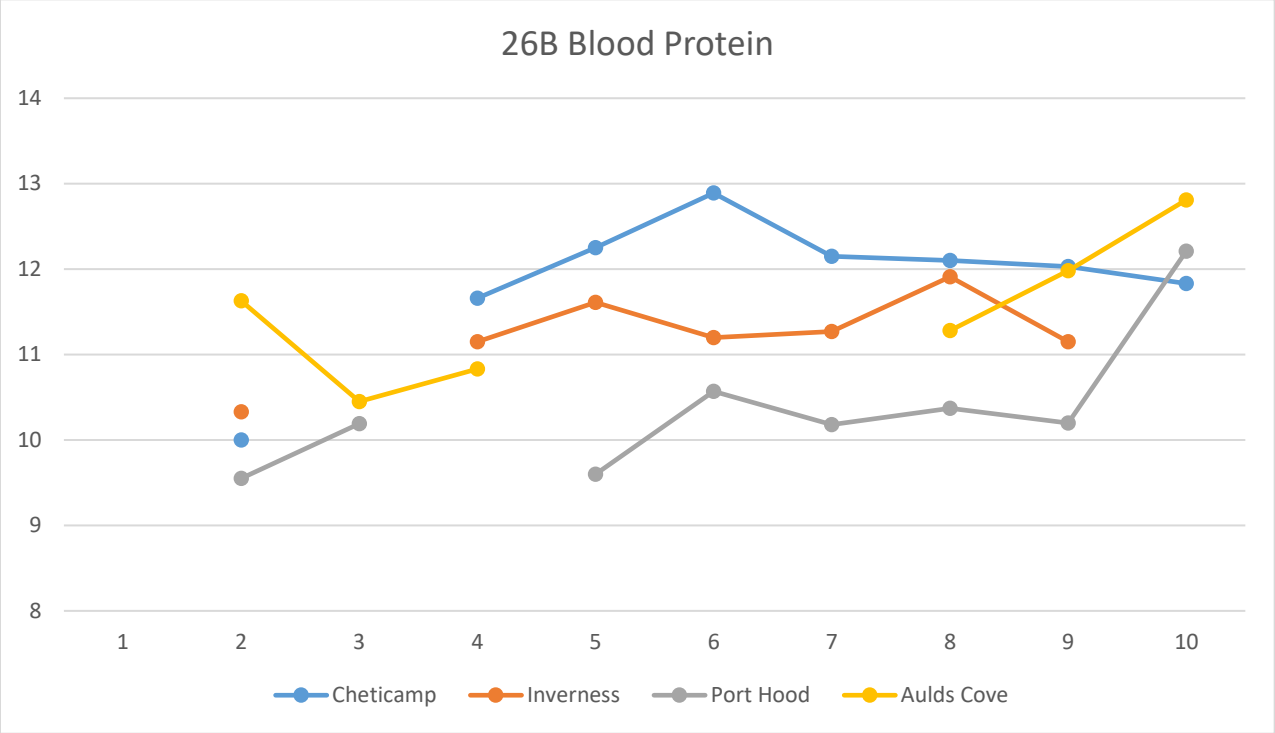

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Figure 3B. Average Brix levels by week for LFA 26B sampling locations.

Moult Stage

The lobster moult cycle has five stages, A-E, which are based on physiological and carapace changes (Waddy et al., 1995). Stage D is the premoult cycle, which lasts for about 24-75% of the entire moult cycle, and it is divided into five sub-stages in the literature. However, we group together the five sub-stages and use three sub-stages for the purpose of this project, which are described in Table 2, and pictures are provided in Appendix A. The premoult cycle was assessed through this sampling program by examining the tips of the lobster pleopods under a light microscope[2].

Table 2. The three sub-stages of Stage D, the premoult cycle.

Stage 0	Post/intermoult
Stage 0.5-2.5	Passive premoult
Stage 3 – 5.5	Active premoult – the lobster has committed to moult

Figures 4-11 below show the distribution of lobsters in each stage of the premoult cycle for each sampling location. Lobsters in active premoult were observed in very low proportions (of ~ 1-3 lobsters) as early as weeks 2 and 3 (May 6th-10th and May 13th- 17th) in River John, Port Hood and Aulds Cove.

Although they were present in earlier weeks, the proportion of lobsters in active premoult remained relatively low for all LFA 26 B sites during the time of sampling, with the exception of Aulds Cove. Cheticamp had only 2.43% active premoults in week 10. Port Hood varied by week, with 5.19% in week 9 and only 1.33% active premoults in week 10. Inverness also had low proportions throughout, except for

[2] Omano trinocular, fitted with an OptixCam camera

a jump to 8.57% active premoults in week 8, dropping to 2.56% in week 9. Aulds Cove had the highest proportion of active premoult lobsters, with 14.94% of week 10 lobsters committing to moult.

In LFA 26A, the majority of lobsters remained in the post/intermoult stage for the duration of the season. Across all sites, we observed some small jumps in the number of active premoults on and after week 6. River John had the highest proportion of active premoults in LFA 26A, with 7.14% (5 individuals) of lobsters in the active premoult stage during week 9. In addition, River John also had a greater proportion of passive premoult lobsters relative to other 26A sites; ranging from 26-42.5%. Bayfield and Pugwash had only 5% active premoults in the final few weeks of the season. Arisaig had the lowest proportion of active premoults in LFA 26A, with 0% active premoults and 80.52% post/intermoults during week 8 (there was no sample for week 9).

The moult staging results seem to indicate that lobsters in Aulds Cove and River John are preparing to moult prior to the other sites. It is likely that Bayfield and Pugwash will be the last sites to moult.

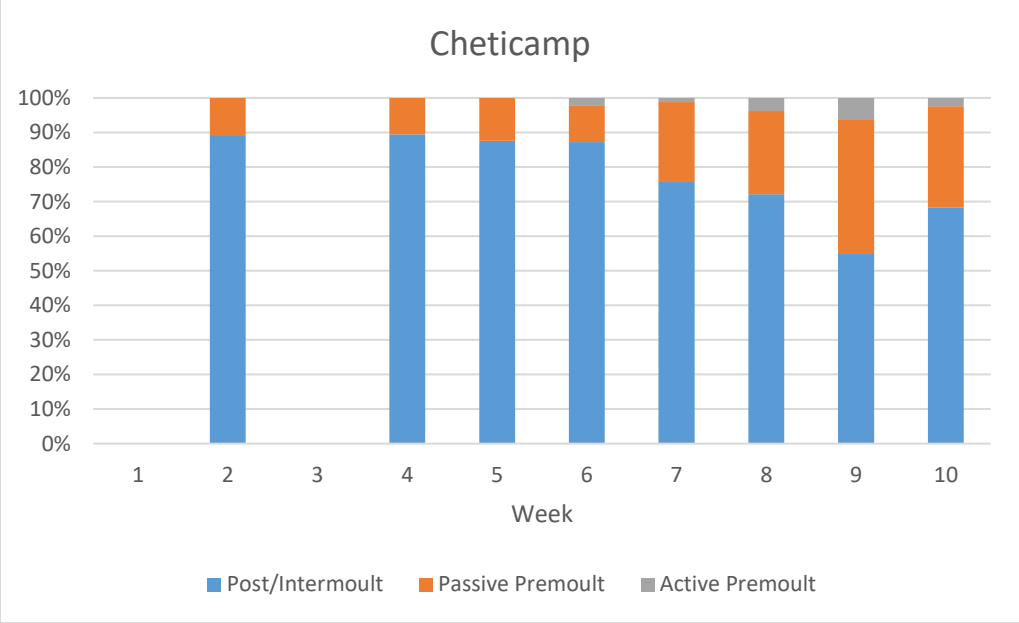

Figure 4. Moult stages by week for Cheticamp.

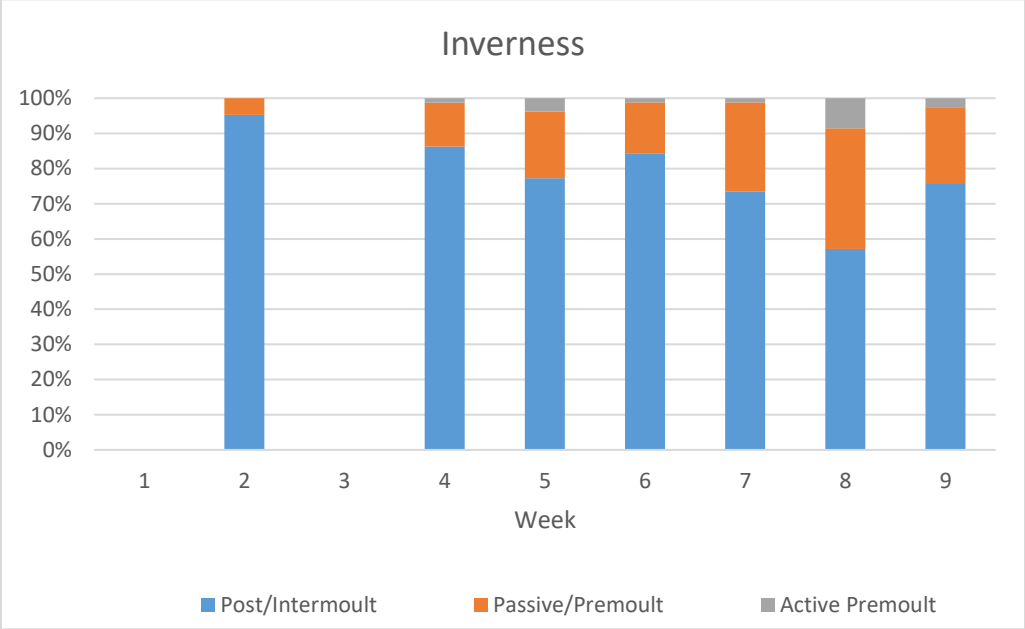

Figure 5. Moult stages by week for Inverness.

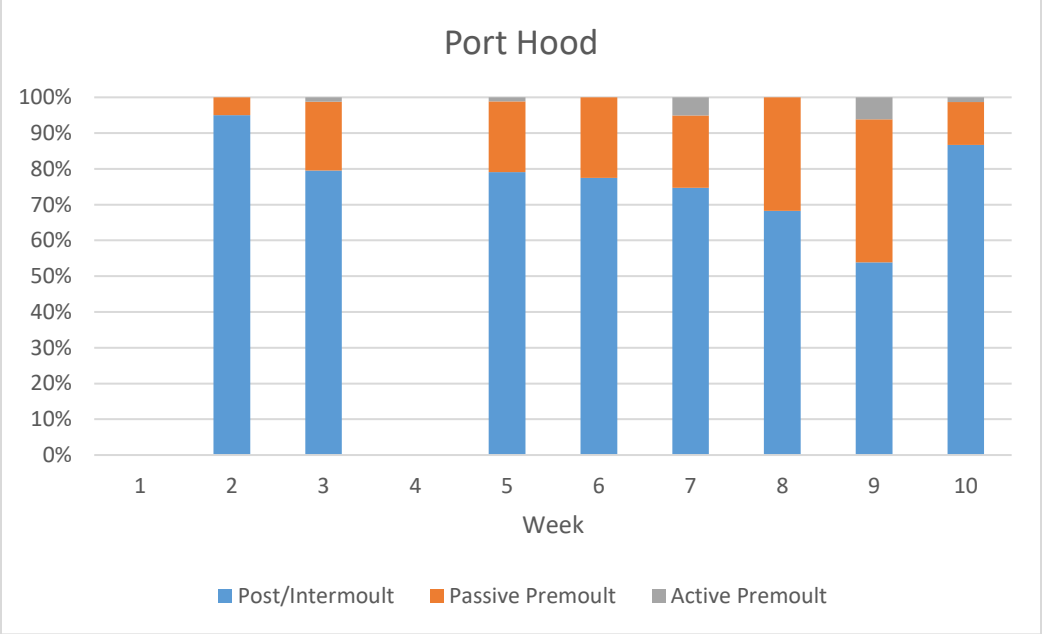

Figure 6. Moult stages by week for Port Hood.

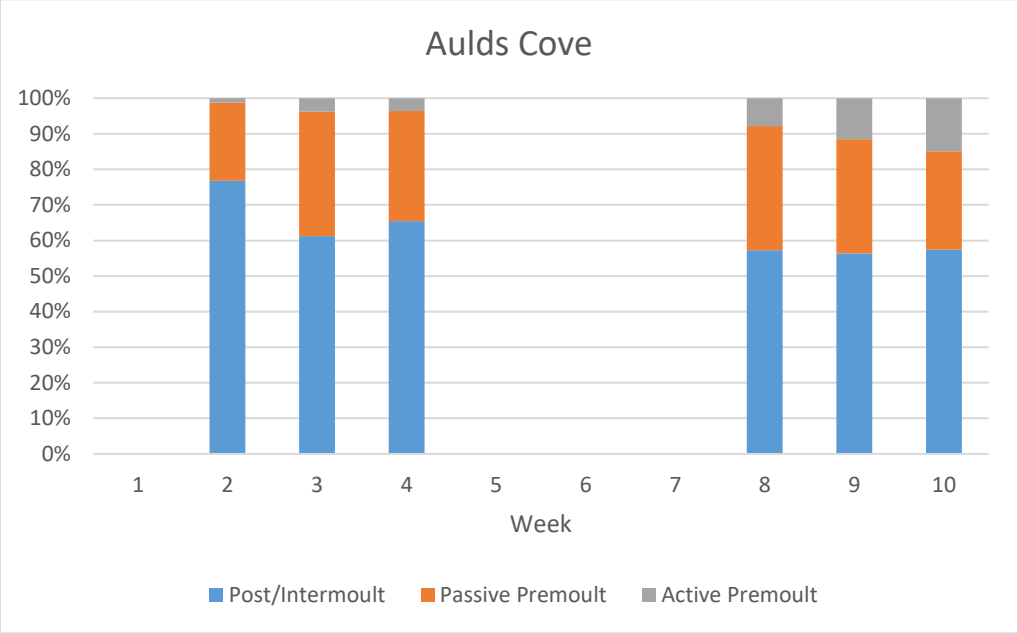

Figure 7. Moult stages by week for Aulds Cove.

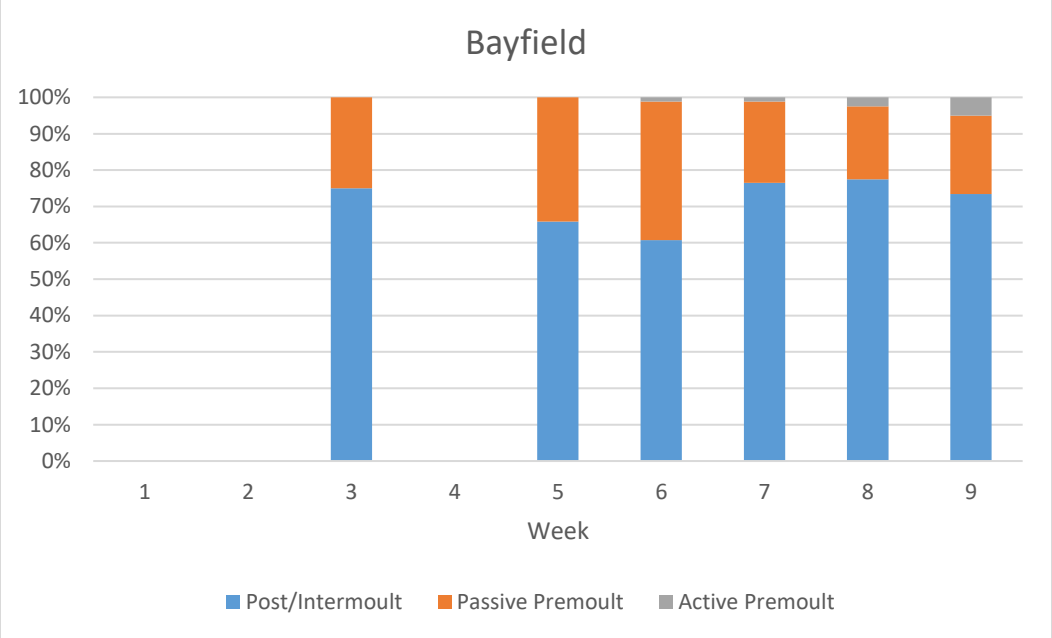

Figure 8. Moult stages by week for Bayfield.

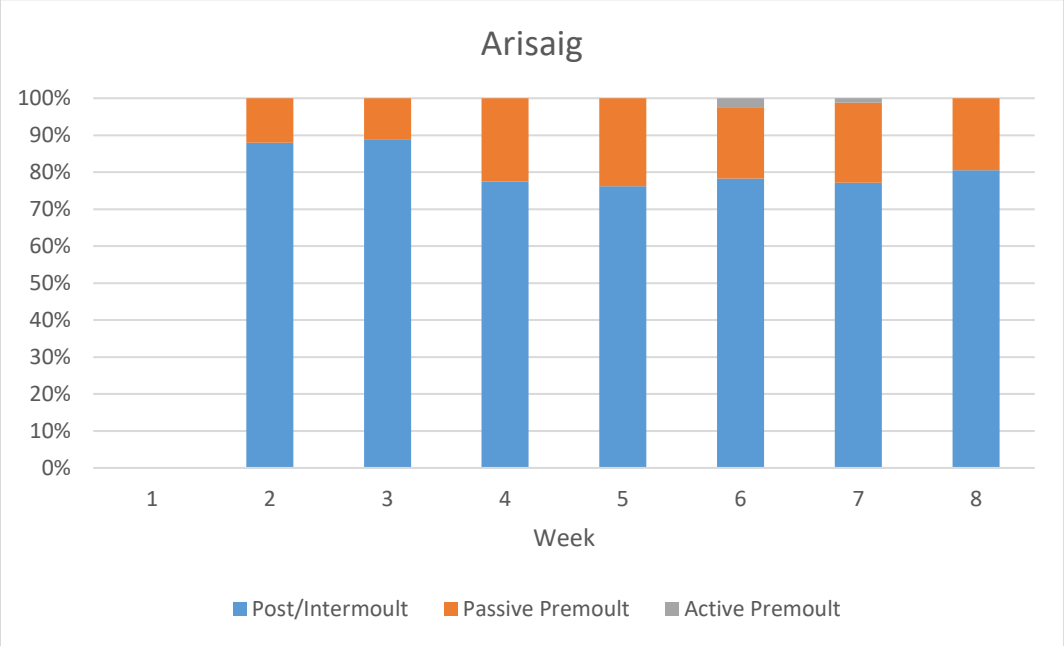

Figure 9. Moult stages by week for Arisaig.

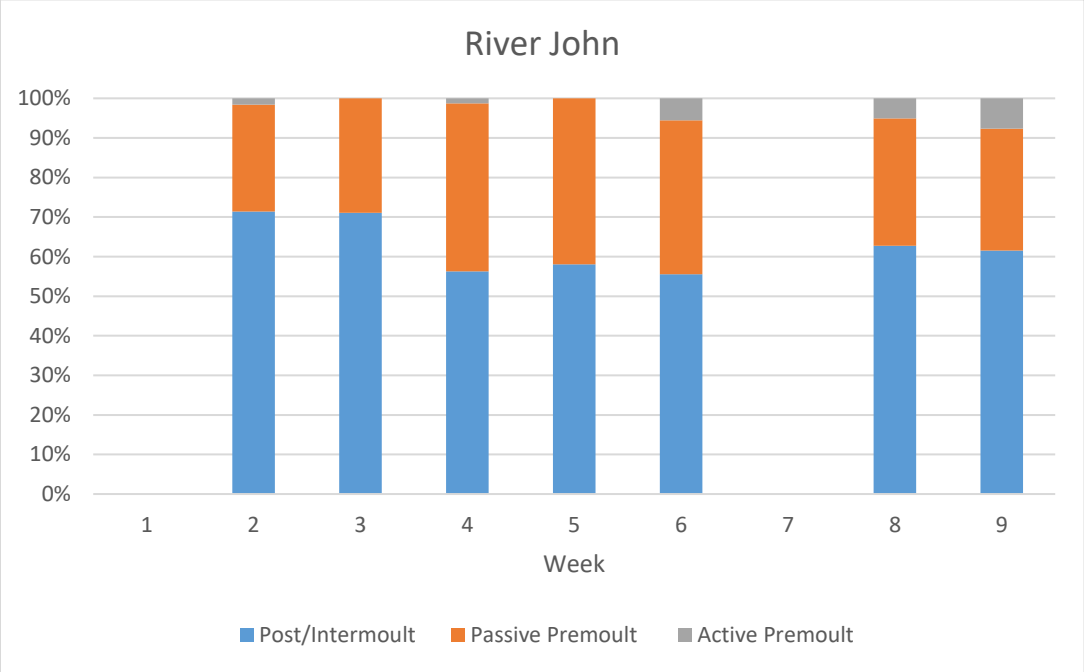

Figure 10. Moult stages by week for River John.

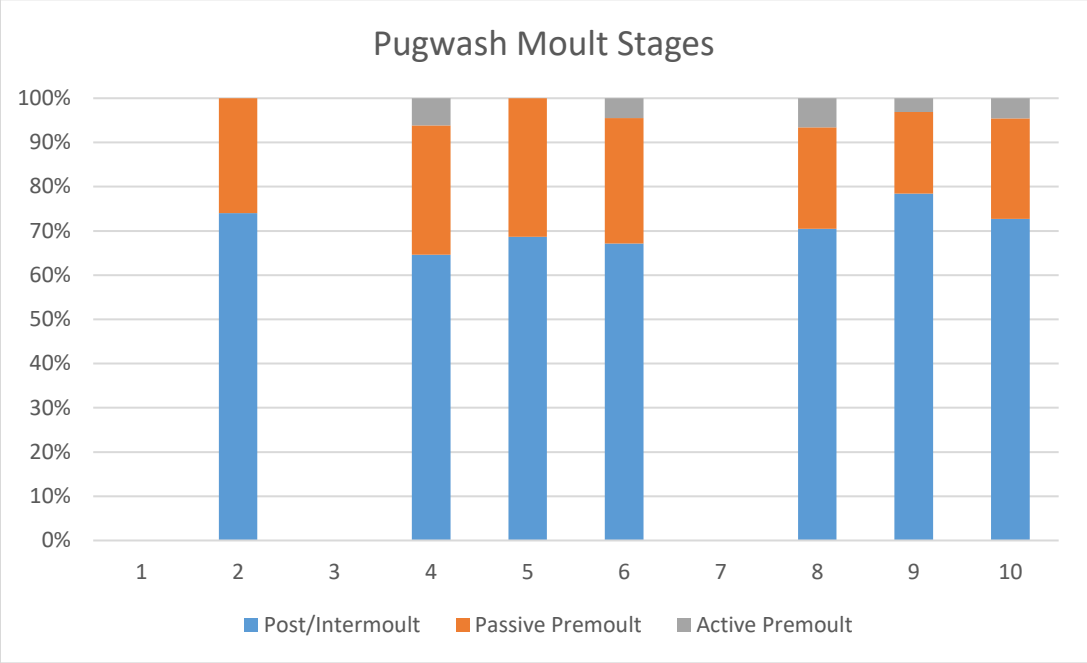

Figure 11. Moult stages by week for Pugwash.

Shell Hardness

Data on shell hardness was collected through gently squeezing the carapace of the lobster and subjectively determining if the lobster had a soft, medium, or hard shell (Table 3).

The majority of lobsters sampled, 97.36%, were hard shelled (4210 lobsters). A small portion, 2.32% (100 lobsters), were medium shelled. 71% of all medium shelled lobsters were found in Arisaig and Bayfield. Only 2 soft shelled lobsters were observed throughout the entire season; 1 during week 3 in Arisaig and 1 during week 5 in Bayfield.

Cement Glands

The reproductive rate of a species is a key indicator of population health and growth. By understanding reproductive trends, we can better identify the impact of external factors such as changing water temperature or other environmental conditions. Female lobsters 'typical' reproductive cycle length can vary greatly in nature, which complicates the interpretation of this data. During the typical cycle, moulting and mating will occur during the same summer, with the eggs extruded and held on the abdomen under the pleopods for the next nine to eleven months (Comeau & Savoie, 2004). However, studies have shown that up to 20% of mature females (having spawned in previous years) and 20% of first time spawning females can moult and spawn in the same year in the Gulf of St. Lawrence (Comeau & Savoie, 2004). The 2004 study indicates that factors such as lobster size, bottom temperature and lobster density may play a role in successive annual spawning (Comeau & Savoie, 2004).

In this study, we use the presence of cement glands as an indicator that the lobster has reached sexual maturity and will be producing eggs within the next 1-2 seasons. Around half of reproductive lobsters will carry eggs in a given year, so by observing the presence of cement glands we are able to capture a more representative estimate of the proportion of sexually mature females (Aiken & Waddy, 1982).

Sites in LFA 26B had a higher proportion of cement gland bearing females than sites in LFA 26A. Notably, in the first week of sampling (week 2), 70% of females in Cheticamp and 79% of females in Aulds Cove already had cement glands. Inverness had a slightly lower proportion, at 51% of females with cement glands. Port Hood had 0% cement glands during the first week of sampling, however only 20 lobsters were sampled on this day as it was used as a training day for our lobster technicians. For this reason, it is not a representative sample and is not included in the average for 26B in Table 3.

In 26A, the average cement gland presence across all four sites was 35.06% in week 2. River John and Arisaig had the lowest proportions of cement glands in the first few weeks, at 27% and 20% respectively in week 2. A rapid increase occurred between weeks 4 and 5, bringing the average up to 77.78% in week 4. The trends were less consistent amongst 26A sites, with some sites fluctuating up and down throughout the season. Fluctuations in cement gland levels are likely a result of shifts in the number of egg bearing females, which is not captured in this analysis.

In the final few weeks of the season, the average proportion of cement glands across all sites ranged from 87.78%-95.04%, indicating that a significant majority of females have reached sexual maturity and will soon be ready to carry eggs. It is important to note that the cement gland indicator is meant to capture the proportion of non-egg bearing females; these statistics do not reflect the proportion of females who are bearing eggs, nor do they account for differences in the sex-ratio across all sites.

Table 3: Summary statistics of cement gland presence for 26B and 26A

	26B	**26A**
First sample	69.67%	35.05%
Last sample	94.80%	84.51%
Average Increase	43.13%	49.52%

Descriptive Statistics

Detailed statistics on sex ratios, size, shell hardness, brix level, cement glands and moult stages are presented in Tables 4A and 4B below.

Table 4A: Descriptive statistics for LFA 26 B (Cape Breton) sampling locations, 2019.

Port	Week	N	Sex			CL (mm)		Protein level (Brix)		Shell hardness		
			male	female	F/N	mean	std. dev.	mean	std. dev.	soft	medium	hard
Cheticamp	1	N/A										
	2	82	60	22	0.27	87.03	3.38	10.00	1.32	0	1	81
	3	N/A										
	4	86	31	55	0.64	87.78	4.45	11.66	1.58	0	1	85
	5	89	31	58	0.65	86.90	3.79	12.25	1.81	0	0	89
	6	86	26	60	0.70	87.86	4.40	12.89	1.96	0	0	86
	7	83	39	44	0.53	88.02	5.19	12.15	2.05	0	0	83
	8	79	30	49	0.62	89.07	8.53	12.10	1.87	0	0	79
	9	78	46	32	0.41	89.60	6.43	12.03	2.21	0	0	78
	10	41	22	19	0.46	89.78	8.28	11.83	1.77	0	0	41
Inverness	1	N/A										
	2	85	26	59	0.69	86.47	4.16	10.33	1.70	0	0	85
	3	N/A										
	4	81	40	41	0.51	87.60	4.27	11.15	1.85	0	2	79
	5	80	45	35	0.44	87.75	5.23	11.61	1.95	0	0	80
	6	83	30	53	0.64	87.31	4.54	11.20	1.76	0	0	83
	7	83	34	49	0.59	88.66	3.79	11.27	1.94	0	0	83
	8	70	36	34	0.49	91.41	7.91	11.91	1.92	0	0	70
	9	78	33	45	0.58	89.26	6.38	11.15	2.04	0	0	78
Port Hood	1	N/A										
	2	21	18	3	0.14	88.09	4.46	9.55	1.51	0	0	21
	3	83	63	20	0.24	86.61	3.52	10.19	1.64	0	0	83
	4	N/A										
	5	87	56	31	0.36	86.96	3.31	9.60	1.76	0	2	85
	6	81	48	33	0.41	87.94	5.01	10.57	1.74	0	1	80
	7	81	52	29	0.36	88.97	5.62	10.18	1.97	0	1	80
	7b	82	49	33	0.40	88.26	6.45	10.37	2.19	0	1	81
	9A	65	37	28	0.43	89.34	7.39	10.20	1.90	0	0	65
	10	75	23	52	0.69	88.04	6.76	12.21	1.57	0	0	75
Aulds Cove	1	N/A										
	2	82	68	14	0.17	88.77	6.35	11.63	2.05	0	0	82
	3	80	67	13	0.16	89.44	7.07	10.45	2.26	0	1	79
	4	85	65	20	0.24	88.76	5.36	10.83	2.57	0	1	84
	5	N/A										
	6	N/A										
	7	N/A										
	8	90	45	45	0.50	87.05	4.49	11.28	1.90	0	1	89
	9	78	50	28	0.36	90.88	8.96	11.98	2.29	0	1	77
	10	87	57	30	0.34	88.41	4.82	12.81	2.36	0	0	87

Table 4B: Descriptive statistics for LFA 26 A (Mainland) sampling locations, 2019.

Port	Week	N	Sex			CL (mm)		Protein level (Brix)		Shell hardness		
			male	female	F/N	mean	std. dev.	mean	std. dev.	soft	medium	hard
Bayfield	1	N/A										
	2	N/A										
	3	84	69	15	0.18	85.08	4.57	9.48	3.31	0	10	74
	4	N/A										
	5	85	67	18	0.21	84.78	4.97	11.32	3.11	1	5	79
	6	84	70	14	0.17	84.52	9.20	10.48	3.24	0	2	82
	7	85	63	22	0.26	84.85	9.44	8.83	2.45	0	6	79
	8	80	47	33	0.41	87.34	5.75	9.66	2.88	0	3	77
	9	79	60	19	0.24	87.34	8.20	11.03	2.37	0	4	75
Arisaig	1	N/A										
	2	83	61	22	0.27	85.84	5.55	10.25	2.20	0	6	77
	3	89	62	27	0.30	85.15	5.31	10.37	2.75	1	5	83
	4	89	47	42	0.47	84.83	3.91	10.27	2.11	0	8	81
	5	84	55	29	0.35	86.12	6.23	8.83	2.88	0	5	79
	6	84	69	15	0.18	85.64	6.01	10.00	3.13	0	11	73
	7	83	43	40	0.48	87.57	7.28	9.75	2.72	0	0	83
	8	77	40	37	0.48	89.44	9.34	9.15	1.76	0	4	73
	9	N/A										
River John	1	N/A										
	2	63	58	5	0.08	94.79	6.02	10.08	2.99	0	5	58
	3	76	66	10	0.13	87.97	5.68	10.43	3.56	0	1	75
	4	80	71	9	0.11	88.05	7.53	10.84	3.13	0	3	77
	5	81	70	11	0.14	89.11	7.77	12.82	3.49	0	1	80
	6	90	75	15	0.17	90.40	8.71	13.45	3.21	0	0	90
	7	N/A										
	8	59	46	13	0.22	90.05	5.29	11.55	2.66	0	1	58
	9	70	67	3	0.04	91.88	7.46	12.65	2.53	0	0	70
Pugwash	1	N/A										
	2	77	58	19	0.25	90.079	8.1	10.95	3.01	0	3	74
	3	N/A										
	4	65	47	18	0.28	90.91	11.08	11.28	3.30	0	0	65
	5	67	56	11	0.16	91.58	11.56	10.21	2.84	0	2	65
	6	67	51	16	0.24	91.64	8.85	11.36	2.88	0	0	67
	7	N/A										
	8	61	46	15	0.25	95.11	12.13	11.24	2.66	0	0	61
	9	65	50	15	0.23	93.35	12.89	10.81	2.39	0	0	65
	10	44	19	25	0.57	94.48	12.09	12.24	1.83	0	2	42

Lobster Diseases and External Growth on Pleopods

Lobster diseases have been studied in freshly captured lobsters off PEI (Lavalee et al., 2001), and in lobsters that have been held in holding facilities (Cawthorn et al., 2001, Greenwood et al., 2005). In freshly caught lobsters, the presence of agents that cause bumper car disease and gaffkemia were found to be very low, with no bumper car disease agents found in the spring and only 0.72% in the fall; the presence of gaffkemia agents was only 6.9% in the spring and 5.8% in the fall. Lobsters with bumper car disease and gaffkemia experience reduced interest in food and compromised metabolism, respectively, so estimates of disease in wild populations is likely underestimated as they do not trap easily (Lavalee et al., 2001). Cawthorn et al (1996) suggested that the causative parasite has been observed in at least 17.8% of wild caught lobsters in the south shore of PEI, but the point that the infection becomes "bumper car disease", and lethal to lobsters is unknown. Bumper car disease is seen primarily at cold temperatures (0-5^{o}C) and in lobster impoundments, where there are high stocking densities and disease can spread easily (Lavalee et al., 2001, Cawthorn et al., 1996, Greenwood et al., 2005). Another disease that affects wild populations of lobster is shell disease, but this has only been reported anecdotally in Prince Edward Island (Lavalee et al., 2001).

Data on the presence of ciliates (small parasites) has been recorded for the past couple of years under this sampling regime. Ciliates have only been recorded in low numbers. However, sampling discrepancies and current desk-top research suggests that some of the "ciliates" recorded in the past may not have actually been ciliates, but may have been recorded as such. The "parasite eggs" that were recorded in 2016 were found to be organisms growing externally on pleopods, and not actually an internal parasite (Figure 12). Therefore, through this sampling regime, and using the resources that we have, we are only able to record the presence of organisms growing externally on the pleopods, likely algae or colonial animals (Figure 13).

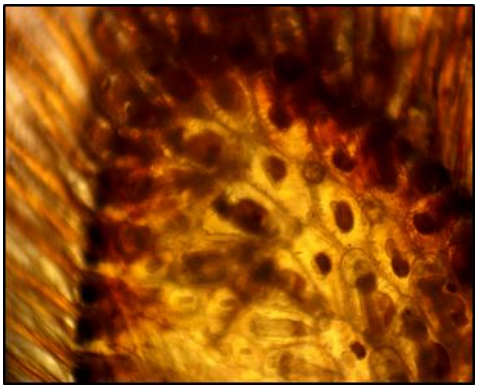

Figure 12. This is what was being recorded as "parasite eggs" in 2016, but were found to likely be algal or other growth (i.e. colonial animals) on the pleopods.

Figure 13. Growth on the pleopods in 2017.

Deformed Pleopods

The number of deformed pleopods was very low, accounting for less than 2% of all lobsters sampled in 2019. Arisaig had several deformed pleopods early in the season. Port Hood had 1 deformed pleopod.

Temperature Data

Temperature loggers (Vemco Minilog 2) were placed at 12 locations throughout the Gulf of Nova Scotia to cover the distribution of blood protein sample sites, with the exception of Inverness (loggers were placed nearby at Margaree and Port Hood).

Interpretation 2015-2019

The GNSFPB has been collecting data for this lobster quality monitoring project since 2015. The project has grown from 4 to 8 sites, and collects data annually on blood protein levels, shell hardness, size, moult stages and other notable quality features. Having an archive of annual data such as this allows us to identify trends and offer a snapshot of lobster quality in LFA 26A and 26B. The following table shows the sampling history from 2015-2019 (Table 5).

Table 5: Historical blood protein sampling summary, from 2015-2019.

Year	Sites Sampled	Number of trips	# Lobsters sampled	Dates
2015	Port Hood, Bayfield, Arisaig, River John	29	3103	May 13 – July 2
2016	Cheticamp, Inverness, Bayfield, Arisaig, River John, Wallace	51	4532	May 1 – June 30 *May 6 – July 6
2017	Cheticamp, Inverness, Port Hood, Aulds Cove, Bayfield, Arisaig, River John, Wallace	70	5835	May 1 – June 30 *May 16 – July 8
2018	Cheticamp, Inverness, Port Hood, Aulds Cove, Bayfield, Arisaig, River John, Wallace	58	4354	May 1 – June 30 *May 15 – July 5
2019	Cheticamp, Inverness, Port Hood, Aulds Cove, Bayfield, Arisaig, River John, Wallace	56	4312	May 6 – July 2 *May 9 – July 4

** Cheticamp samples are subject to 26B North season dates*

Based on the data collected in 2019, it was not evident that lobsters in LFA 26A and 26B moulted during the sampling season. There were only 2 soft shell lobsters recorded throughout the season, and there were no extreme drops in the blood protein levels that is typical of a post-moult lobster. These results are positive, and consistent with the four years' previous data collected by the GNSFPB and other studies done in the area (Aquatic Science and Health Services 2015, www.lobstermoult.ca).

In 26A we have had five years of consistent sampling in Bayfield, Arisaig and River John (Figure 14A). In the subzone 26A3, we have sampling from two sites within close proximity; Wallace from 2016-2017 and Pugwash from 2018-2019. Although sampling was completed at 2 different sites within the 26A3 subzone, we can see in Figure 14 that the blood protein trend in Wallace and Pugwash appears to follow the same trend as the other 3 sites. From 2015-2017, we saw a gradual increase in blood protein levels across all LFA 26A sites. The data then shows a slight annual decline in both 2018 and 2019; -0.68 brix and -0.99 brix respectively. The average brix level for all LFA 26A sites in 2019 is 10.62. Despite the declines since 2017, the average protein levels in 26A lobsters are well within the healthy range of 8-12.

In 26B we have four years of data for Cheticamp, Inverness and Port Hood, and three years for Aulds Cove (Figure 14B). Cheticamp and Inverness were sampled from 2016-2019, while Port Hood was sampled in 2015-2019, except for 2016. Aulds Cove was sampled from 2017-2019. Despite some inconsistency in sampling years, we can see that the trend in 26B is moving in the opposite direction to 26A sites. From 2016-2018, the average 26B brix level declined by -0.20 brix and -1.04 brix respectively. Following this decline, every 26B site has increased in 2019 by an average of 0.65 brix. Port Hood increased only slightly by 0.02, to an average brix level of 10. Aulds Cove increased by 0.08 to 11.50. Cheticamp and Inverness both saw larger increases of 0.97 and 1.53 respectively. Overall, the average brix level for 26B in 2019 is 11.15 which is also within the healthy range of 8-12.

At the site level we did not observe any dramatic spikes or dips in the blood protein level, which would indicate that the lobsters in the sample were preparing for or recovering from a moult. In the final few weeks of sampling, higher than average blood protein levels (>15) were observed in both Aulds Cove and River John. This increase in protein levels may be explained by the typical spike in protein levels just prior to moulting. This result is consistent with the findings of the 2017, 2018 and 2019 pleopod moult staging; which indicates Aulds Cove and River John have the highest number of active premoults in the final 2-3 weeks of sampling. Together, this data suggests that Aulds Cove and River John may be the first to moult, shortly after the lobster season closes in LFA 26A and LFA 26B.

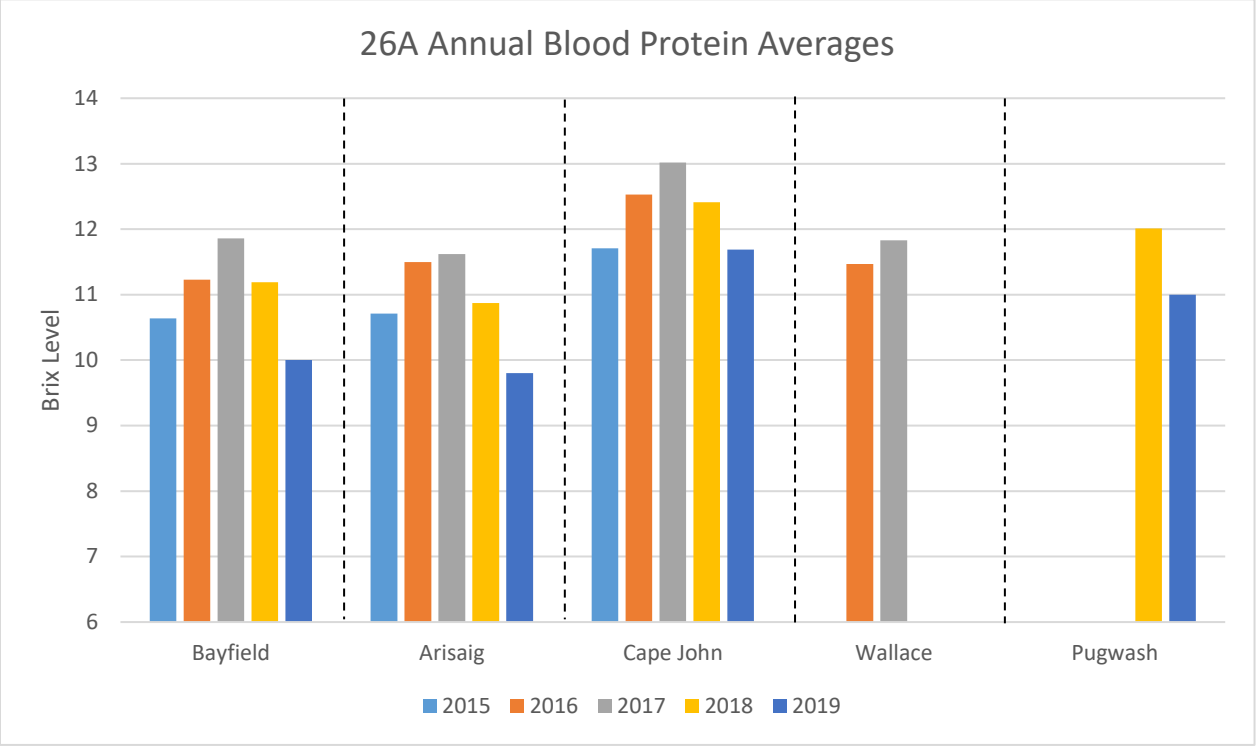

Figure 14A. Average annual brix levels for all weeks, for all 26A sampling sites, from 2015 to 2019.

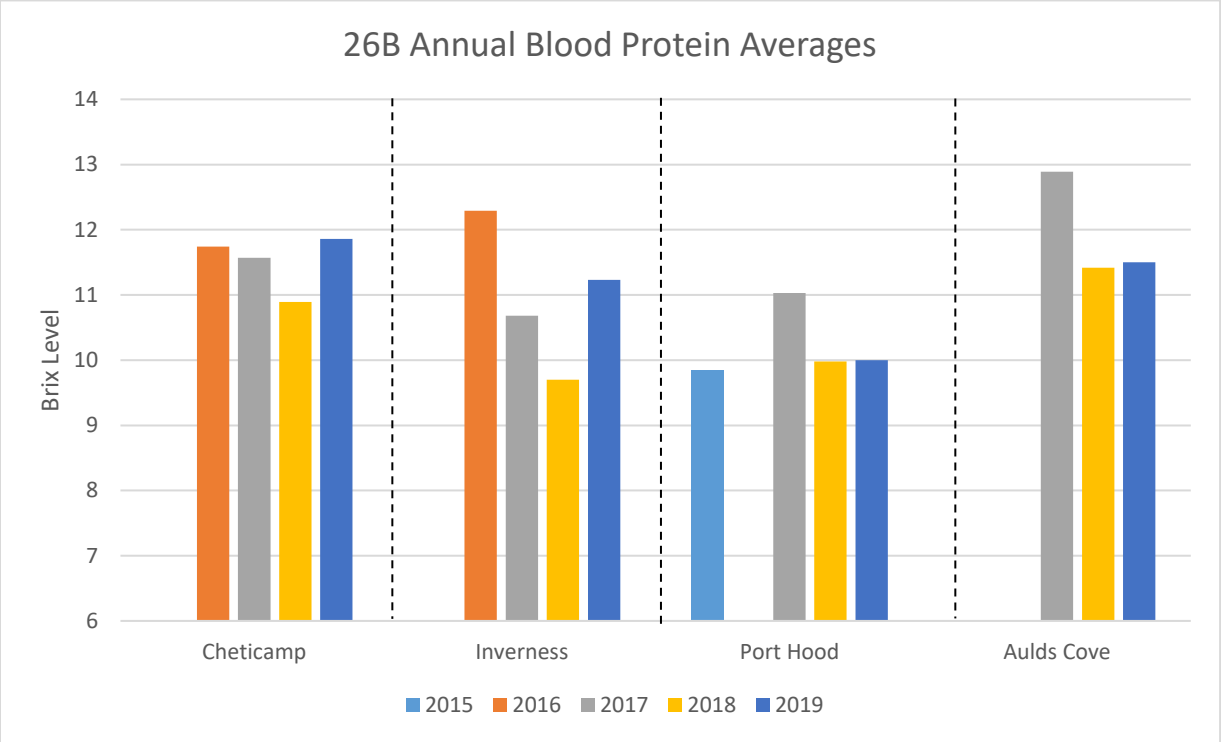

Figure 14B. Average annual brix levels for all weeks, for all 26B sampling sites, from 2015 to 2019.

The 2019 results on shell hardness for all sites in LFA 26A and 26B are relatively consistent with 2015-2017 data, which further highlights the differences observed in the 2018 sampling season. The following table is a summary of the proportion of soft, medium and hard shells across all locations for the five years of sampling (Table 6). We acknowledge that sampling for shell hardness is semi-subjective, so findings can vary slightly due to individuals sampling techniques.

Table 6: Proportion of soft, medium and hard shells across all sites from 2015-2018.

	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)
Soft	0	0	0.037	0.045	0.05
Medium	4	0.44	3	16.33	2.32
Hard	96	99.56	96.96	83.58	97.63

Only 2 soft shelled lobsters were observed throughout the entire season, 1 in Arisaig and 1 in Bayfield. In addition, 71% (71/100) of the medium shelled lobsters sampled were found in Arisaig and Bayfield. Similarly, in 2018 the majority of the medium shelled lobsters were observed on the mainland, however there was a more even distribution among all 4 sites.

From 2015-2017 and 2019, we generally see that around 96% or more of lobsters were hard shelled. This highlights the discrepancy in the high number of medium hardness shells observed in 2018. Considering together the medium hardness shells, slightly lowered brix and some anecdotal evidence of soft-shelled and not full (of meat) lobsters, we can suggest that the lobsters sampled in 2018 may not have fully recovered from their previous moults. This may be due to the generally colder and stormy weather that was experienced in 2018; temperatures were 5-10°C cooler in some sites on some days. We will compare our 2019 results to the temperature data in the fall of 2019 to further our understanding of the impacts of temperature on shell hardness and overall quality.

Cement glands were present in large numbers at the beginning of the season in LFA 26B. Sites in 26B had, on average, 69.67% of females presenting with cement glands in the first week of sampling. In 26A sites, cement glands were present in around 35% of females in the first week of sampling. These results are consistent with previous years, where sites in LFA 26B presented high proportions early in the season, increasing gradually each week, while sites in LFA 26A start the season with low proportions of cement glands, but undergo a jump between weeks 4 and 6. Overall, the majority of female lobsters in the catch appear to have reached their sexual maturity, indicating that the population is in a reproductively healthy state.

Presence of external ciliate growth on pleopods was particularly high on our 26A mainland sites. On average, mainland sites saw 6%-18% of lobsters with external ciliates. These proportions were steady throughout the season, with the highest amounts found in River John. The external ciliates do not appear to impact lobster quality (Brix level, shell hardness) or general survivability.

Temperature loggers were provided by DFO for this project. A new piece of equipment was purchased in 2017 which allows the GNSFPB to retrieve the data from temperature loggers upon their retrieval in the fall. Temperature is a major factor influencing the moult cycle and protein levels, and is a critical piece of information. The temperature data will be analyzed separately in November of 2019, with a report to follow.

This year's sampling marks the fifth consecutive year of data collection for this area by the Gulf Nova Scotia Fleet Planning Board. Each study represents a "snapshot" of that year, and results may vary from year-to-year. In this case, long-term data collection is crucial to building an understanding of the evolution of the moult cycle and lobster quality in the Gulf of Nova Scotia. Blood protein analysis has been done in 26 B North for many years, and they are now gaining a better understanding of the population dynamics in that area. In addition, this information proves useful for promoting the quality of Gulf Nova Scotia lobsters.

Acknowledgements

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Glossary

Blood: Lobster blood is the fluid that circulates throughout the body of the lobster, carrying gases (i.e. oxygen), nutrients, cellular waste, hormones, defence molecules, and hemocytes. The primary protein in the blood is the copper-rich hemocyanin (60-90% of total blood protein). Lobster blood volume is highest immediately after molt (about 55% of total weight), and decreases to about 30% by stage C of the molt cycle (Factor, 1995). Synonyms for lobster blood include: hemolymph, serum.

Cement glands: glands in the pleopods of mature female lobsters which are believe to secrete a sticky substance that “glues” the eggs to the lobsters’ abdomen once they are extruded.

Ciliates: parasite found in lobsters that can result in death of the lobster. An outbreak of ciliates was observed in at a holding facility in Nova Scotia, and it is commonly referred to as “bumper car disease”.

Deformed pleopod: deformation of the pleopod, not apparently due to an injury or mishandling.

LFA 26 A: Mainland sites in the Gulf of Nova Scotia, including Pugwash, Cape John, Arisaig, and Bayfield.

LFA 26 B: North and South sub-management areas; Port Hood, Inverness, Cheticamp and Aulds Cove.

Moult: the process of lobster growth whereby a lobster sheds its shell.

Photoperiod: day length

Pleopod: the pleopod is an appendage attached to the abdomen of a lobster. They are used for swimming and females use them to attach eggs to their abdomen. Synonyms: swimmerets.

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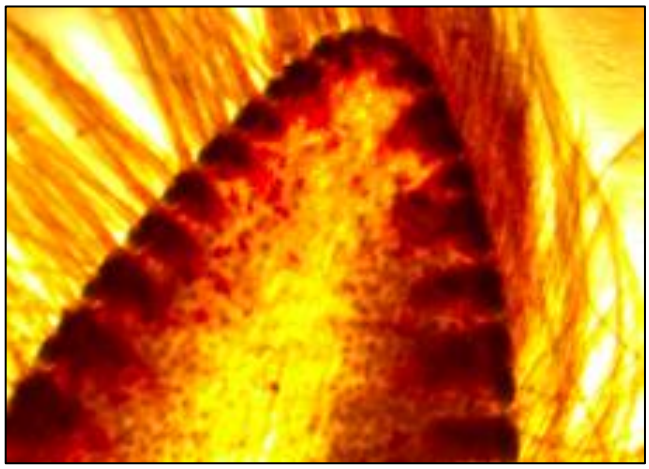
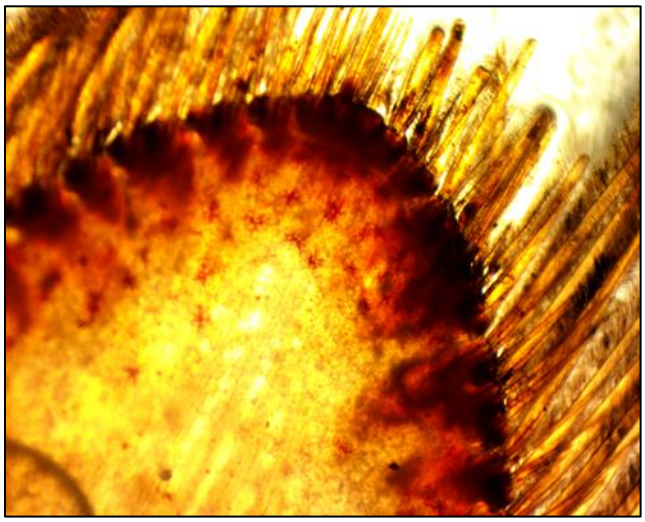
Appendix A

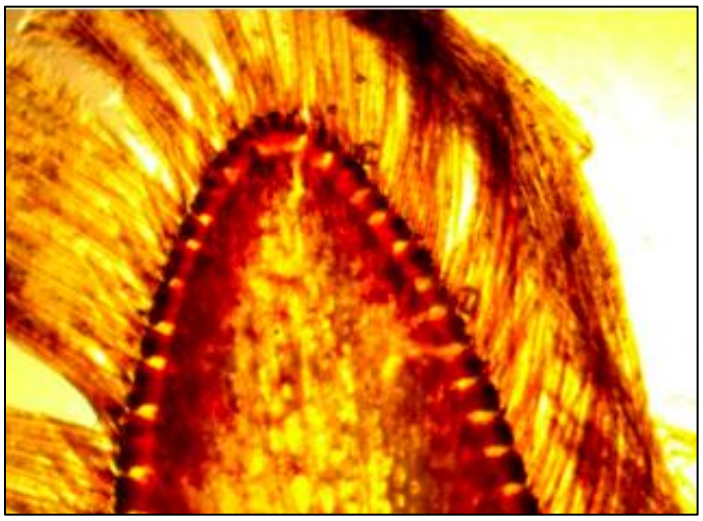
Pictures of various stages in the premoult cycle. Photographed using an Omano trinocular microscppe, fitted with an OptixCam camera, 2017 & 2018 sampling.



Stage 0, no line is visible.

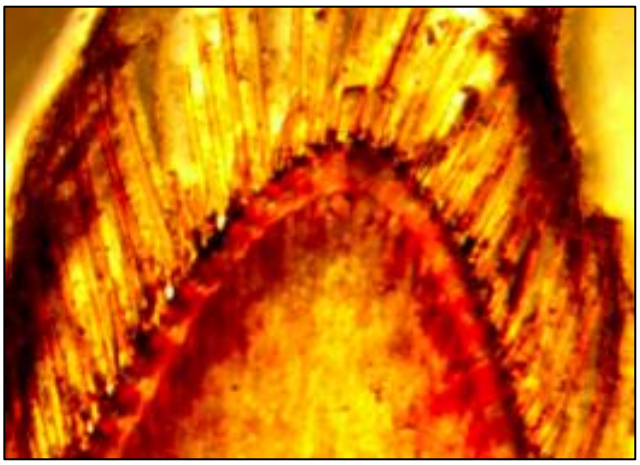


Stage 1-1.5. The line is becoming visible at the tip of the pleopod.

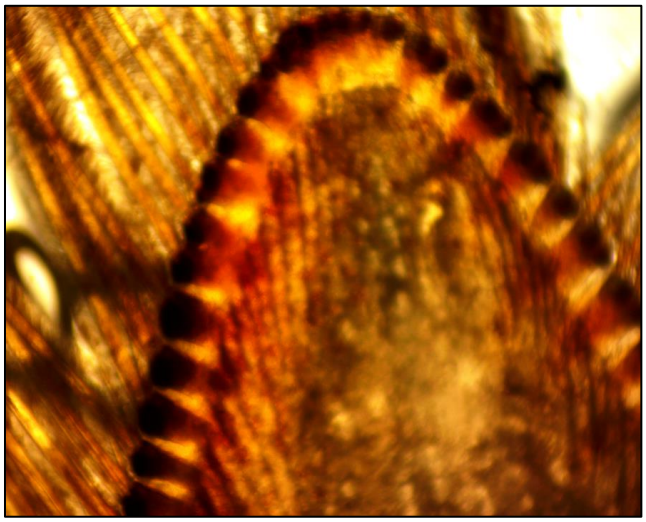


Stage 2-2.5. The line is becoming even more clear, and is pulling down and away from the tip of the pleopod, forming a “double-bordered” area at the tip.

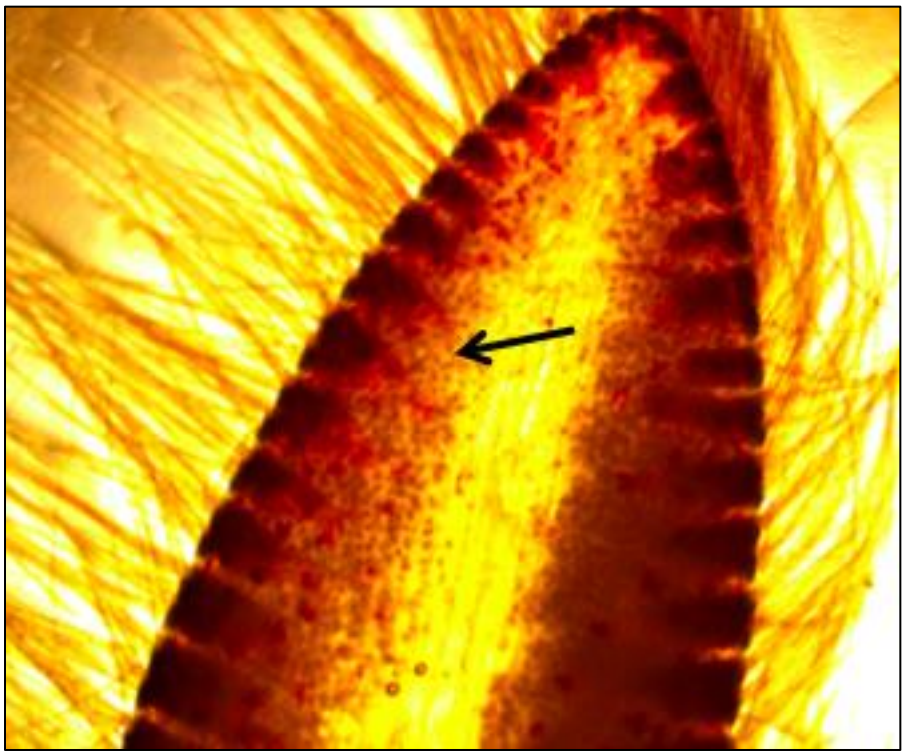
Stage 3-3.5. The line is very clear now, has pulled away from the outside of the pleopod and is beginning to look “wavy”. New setae are also becoming visible.



Stage 4-4.5. The wavy line is clearly visible here, as well as the developing shafts of new setae, but the proximal ends are not yet blunt.

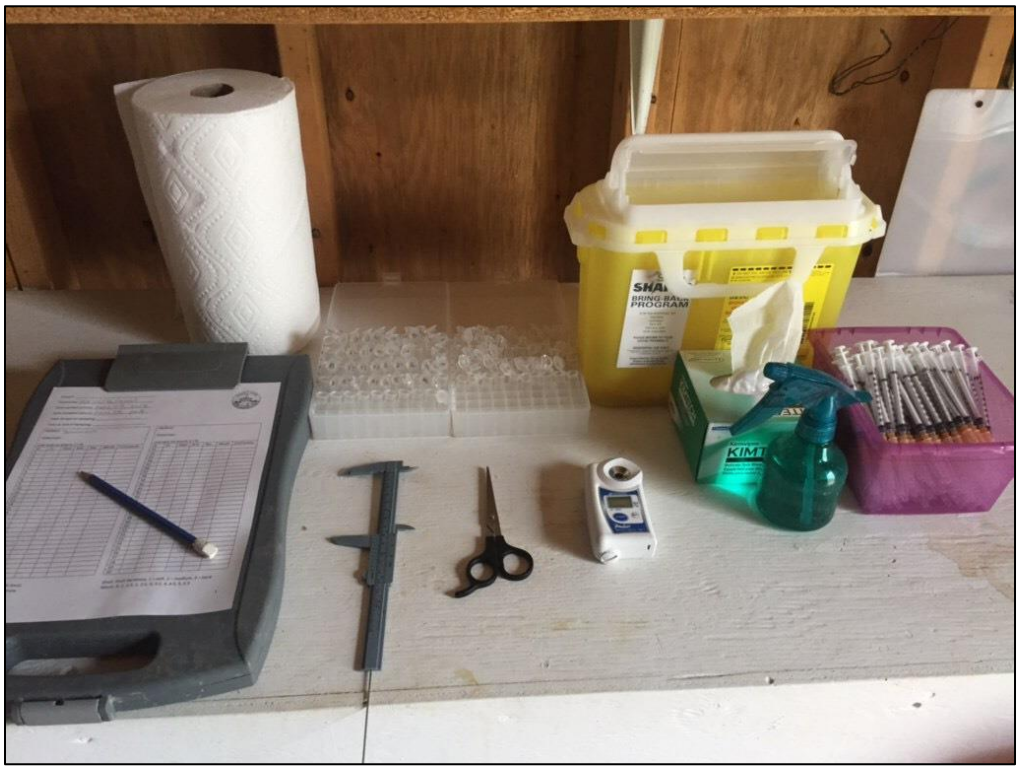


Stage 5. Shafts of new setae are very clear and their proximal ends are becoming blunt.



Cement glands in a female lobster's pleopod (the small grey dots, indicated by arrow).

Appendix B



A typical sampling set up including: data sheets, carapace measuring tool, Brix Refractometer, syringe and needle (and disposal), vials for transporting pleopod sample.