2018 Winter Sampling

for Gulf of Maine Northern Shrimp

Pictures by Katherine Thompson, Maine DMR, 3-11-18, F/V Nicole Leigh

Atlantic State Marine Fisheries Commission
Northern Shrimp Technical Committee

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SUMMARY

In the absence of a commercial fishery, three trawlers participated in cooperative winter sampling programs to collect northern shrimp samples in the Gulf of Maine during January – March 2018. They caught a total of 3.1 mt; 44 samples were collected and evaluated for shrimp species; *P. borealis* size and sex-stage were determined, and the timing of egg hatch was estimated. Catches comprised mostly assumed 3- and 5-year-old females from the 2015 and 2013 year classes. The estimated time of 50% egg hatch from the Maine samples was February 21, which was the same as the previous year.

INTRODUCTION

Fisheries for northern shrimp (*Pandalus borealis*) in the Gulf of Maine (GOM) have usually been conducted in the winter when egg-bearing (ovigerous) female shrimp move inshore, and sometimes in the spring while the shrimp return offshore after egg hatch. Shrimp samples from commercial catches have been collected by Maine (ME), Massachusetts (MA), and New Hampshire (NH)) each season for over thirty years, and have informed annual stock assessment updates.

Shrimp were caught by trawlers and trappers, with ME boats accounting for about 89% of the GOM landings, and trawlers averaging about 86% of the ME landings and 100% of the MA and NH landings, in 2009–2013 (see Tables 1 and 4 in Eckert *et al.* 2017). The highest landings usually occurred in the months of January and February (Table 3 in Eckert *et al.* 2017).

The 2017–2018 winter (hereafter referred to as "2018") GOM fishery was closed by the Atlantic States Marine Fisheries Commission (ASMFC) due to low stock abundance. This was the fifth consecutive year the fishery was closed. In the absence of a fishery, the ASMFC Northern Shrimp Technical Committee (TC) recommended implementing limited cooperative winter sampling, as in the previous four years. The purpose of the project was to collect samples similar to those that might have been collected from commercial shrimp catches if there had been a fishery, in order to:

- Continue the TC's time series of samples from GOM northern shrimp fishery landings, estimating the winter size (carapace length) and sex-stage composition of the shrimp stock in traditionally fished areas.
- Estimate the timing of egg hatch. Northern shrimp in the GOM extrude eggs onto their abdomens in the late summer to early fall, and egg hatch has generally begun in February and ended in early April (Clark *et al.* 2000), but has started earlier and lasted longer in recent years (Richards 2012). It also tends to begin and end earlier in the western GOM

and later in the east (*e.g.* Whitmore *et al.* 2013, Figures 3–4), so the location of the sampling may influence the results.

At its November 29, 2017 meeting, the ASMFC Northern Shrimp Section established a 13.3 mt quota under the northern shrimp fisheries management plan (FMP) research set aside (RSA) program (ASMFC 2017) to support data collection during 2018, and directed the TC to design a sampling plan. The state of Maine declined to participate in the RSA, and instead contracted with one trawler to make three sampling trips with no landings allowed, and the RSA quota was adjusted accordingly. Massachusetts and New Hampshire were to select one trawler apiece, with each trawler shrimping for up to 10 weeks, with one trip allowed per week and an 800 pound (363 kg) landings limit per trip, for potential total landings of 16,000 lbs (7.3 mt) for the RSA.

METHODS

Sample Collection

Experienced GOM shrimp trawlers were solicited by e-mail and web announcements for the project. Only one qualified captain from each of the three states applied, and therefore were selected. The selected vessels were from Gloucester MA, Seabrook NH, and New Harbor, ME and ranged in length from 42–44 feet (12.8–13.4 m). Fishing locations were chosen by the vessel captains.

Sampling trips were made between January 11 and March 29, a span of about 12 weeks. The Massachusetts trawler made eight trips between January 11 and February 26, 2018, and then made a ninth trip on March 29 (Week 12). It made from two to four tows per trip, usually of 1.0 to 2.5 hours duration per tow, using its standard shrimp net with a compound grate (with finfish exclusion and small shrimp exclusion panels). A 2-kg sample was collected from each of two tows each trip by a state observer. The New Hampshire trawler made six trips between January 11 and February 26, and made from one to four tows per trip, usually of 1.0 to 2.5 hours duration per tow, using its standard shrimp net with a Nordmore (finfish excluder) grate. A 2-kg sample was collected from almost every tow by a state observer. The NH boat also recorded one sea surface temperature reading per tow. The MA and NH boats observed an 800-pound (363 kg) trip landing limit, and all trips were single day trips. Both boats could keep or sell their landings to offset fishing expenses. Samples were collected randomly from a tow's shrimp catch after finfish were discarded, and samples were bagged and kept on ice.

The Maine trawler made three short trips between February 13 and March 17, and three or four short tows (averaging about 25 minutes per tow) each trip, using its standard shrimp net with a Nordmore (finfish excluder) grate. The first and third trips were made from Portland, Maine and

the second was made from Boothbay Harbor. A 2-kg sample was collected from each tow by a state observer or the captain. Samples were collected randomly from a tow's shrimp catch after finfish were discarded, and later frozen. A few other shrimp samples were collected for the University of Maine (for fecundity analysis), the University of Georgia (for a black gill syndrome study), and the Maine State Aquarium (for display). No Maine shrimp were sold. The Maine boat's net was equipped with a temperature logger (DST Centi by Star-Oddi), which recorded temperature and depth once per minute throughout the project.

Other information such as date, tow duration (hours, from the time the brake was set until haul-back began), begin and end location, minimum and maximum depth (fathoms), and estimated catch weight (pounds, of all shrimp species) was recorded for each tow for all three boats. Prices paid to the MA and NH boats were recorded in dealer reports, which are confidential.

Because of the limited nature of the project, no trappers were involved this year.

Sample Work-Up

At the state labs, samples were analyzed following the usual procedures for commercial shrimp samples. Frozen Maine samples were thawed; Massachusetts and New Hampshire samples were worked up while they were still fresh. Each sample was weighed, and then separated by shrimp species. *P. borealis* specimens were counted, measured (dorsal carapace length (CL)), and sexed (male, transitional, or female), and female stage (I, II, or ovigerous) was determined. Female stage I shrimp have not yet carried eggs, and female stage II shrimp are not carrying eggs but have in the past, as determined by the presence/absence of sternal spines (McCrary 1971). All shrimp of other species, usually *Pandalus montagui*, *Dichelopandalus leptocerus*, or *Crangon septemspinosa*, were counted and measured.

Calculations

Catch rates — Pooled mean catch rates in pounds per tow-hour were calculated for each trip, state, and project total, as the total catch weight of shrimp (of all species) divided by the total number of boat-tow-hours for the trip, state, or project.

Depth — The mean depth fished for each tow was found by averaging the minimum and maximum depth for each tow; these were then averaged over all the tows for the trip to give the mean depth for the trip.

Bottom temperature — Mean bottom temperature for each Maine tow was calculated by averaging all the 1-minute temperature readings logged during towing, which were identified as those recorded after the brake was set and the depth indicated the net had reached the bottom, until the last temperature recorded at or before haul-back began, for each tow. The mean temperature for each trip was calculated by averaging the mean temperatures from that trip's tows.

Surface temperature — Mean surface temperature for each New Hampshire trip was calculated by averaging the temperatures recorded for each tow.

Size-sex-stage distributions — The number of northern shrimp of each sex, stage and size (CL in 0.5 mm categories), and shrimp of other species by size, in each sampled tow, were estimated ("raised" or "expanded") by multiplying the number in the sample by the ratio of the tow catch weight divided by the sample weight. For the Massachusetts trips and the first New Hampshire trip, where some but not all tows were sampled, the estimated numbers in sampled tows were further expanded to the trip's catch by multiplying by the ratio of the trip's total catch weight divided by the sum of the catch weights of the sampled tows, to give the estimated number for the trip's catch. Total numbers of shrimp caught for the project were estimated by summing the estimated numbers from each trip.

Count per pound — Pooled mean shrimp count per pound (all species) for each trip was calculated by dividing the estimated total number of shrimp of all species in the trip's catch by the catch weight. The pooled mean count per pound for the project was the estimated total number of shrimp of all species caught during the project divided by the sum of the trip catch weights.

Percent of catch that was *Pandalus borealis* — Similarly, the proportion of the catch, in numbers, that was *P. borealis* for each trip was calculated by dividing the estimated number of *P. borealis* in the trip's catch by the total number of shrimp of all species in the trip's catch.

Percent of egg hatch — The proportion of female *P. borealis* whose eggs had hatched off (female II) was calculated for each trip from the expanded size-sex-stage distributions for each trip described above, as the (expanded) numbers of female IIs divided by the sum of the female IIs plus ovigerous females.

Hatch Timing — A historical time series of hatch timing estimates was developed using data collected by the Maine DMR from the commercial shrimp fishery beginning in 1980 (Richards 2012). Samples were not available from Massachusetts and New Hampshire until later years, so for consistency, the time series only uses data collected from Maine ports. Probit analysis was used to estimate the timing of hatch initiation (the day of each year on which 10% of females had hatched their brood), hatch midpoint (50% hatched), and hatch completion (90% hatched). Duration of the hatch period is the number of days from initiation to completion (inclusive). Samples from both trawl and trap gear were included, except hatch metrics for the 2014 winter when there was no fishery were from limited trawl samples collected off Pemaquid Point in midcoast Maine (Hunter 2014).

For 2018, the date of 50% egg hatch was estimated using the Maine trawl percent of egg hatch, from sample sex-stage data expanded to the catch as described above, and probit analysis (Richards 2012).

RESULTS

Trips, catches, effort, and samples: The Massachusetts and New Hampshire trawlers fished from the ports of Gloucester MA (9 trips) and Seabrook NH (6 trips), respectively. The Maine trawler fished from Portland ME for the first and third of 3 trips, and from Boothbay Harbor ME (off Pemaquid Point) for the second trip. The captains described having to relocate or take steps to avoid fixed lobster gear in their traditional tows. There were 18 trips in total for the three vessels. Summaries of their results by project week are in Table 1. Total estimated catch was 6,904 pounds (3.1 mt), or 43% of the adjusted RSA (7.3 mt). Eighteen samples were collected from the MA boat, 16 from the NH boat, and 10 from the ME boat, for a total of 44 samples collected and analyzed (not including samples collected for other purposes described above). Locations fished are charted in Figures 1–2. Fishing dates are listed in Table 1. All trips were single-day trips.

Catch rates: Trip mean catch rates (all shrimp species) varied tremendously, from a low of 7 lbs/hr (3 kg/hr) (NH, January 22, Week 3) to a high of 205 lbs/hr (93 kg/hr) (MA, February 11, Week 6) (Table 1). Both the NH and MA boats had their highest catch rates on February 11, while the ME boat had its highest rate on March 17 (Week 10). The NH and MA boats were both able to catch the daily limit on February 6 and February 11. The pooled mean catch rate for all states and dates (total estimated pounds caught divided by total trawl hours) was 72 lbs/hr (33 kg/hr), and the mean catch rates by state were similar — 72 lbs/hr for MA and NH, 75 lbs/hr for ME (Table 1).

Size and sex-stage composition: Ovigerous females made up 76% of the northern shrimp catch by count, and 18% were females caught after egg hatch. Males were 4% percent of the catch, and 2% of the catch were transitionals and female I's (which have not carried eggs yet) (Figures 3–4). By state, males comprised 3.8 % of the MA catch, 2.6 % for NH, and 19.9 % for ME (data for Figure 3).

The pooled mean number of shrimp of all species per pound (Count Num/Lb, Table 1) was 40, and varied by trip from 35 (MA, February 11) to 70 (ME, March 17, when the catch comprised only 58% *P. borealis* and 42% of the smaller *Dichelopandalus leptocerus*, by count).

In general, the *P. borealis* size-frequency distributions (Figures 3–4) were bimodal, showing female modes at about 23 and 27 mm CL, likely from the 2015 and 2013 year classes respectively. In some weeks, smaller males with CL mode at about 13 mm, probably from the 2017 year class, were also caught.

The assumed 2013 year class was first observed in the 2013 fall Maine-New Hampshire inshore trawl survey, and appeared again as a weak (the 11th lowest abundance index in the 34-year time

series) and unusually fast-growing year class in the 2014 summer shrimp survey (Whitmore *et al.* 2014, Eckert *et al*. 2017). Similarly, the assumed 2015 year class first appeared in the 2015 fall Maine-New Hampshire inshore trawl survey and again as a somewhat below-average (14th lowest in the time series) abundance of age 1.5s in the 2016 summer survey (Eckert *et al*. 2017). See Figure 5 for the progress of these two year classes from season to season as detected in recent surveys and cooperative winter sampling projects. See Eckert *et al*. (2017) for survey and sampling project descriptions.

Species composition: In 8 of the 18 trips, shrimp species other than *Pandalus borealis* (mostly *Dichelopandalus leptocerus* and a few *Pandalus montagui*) made up more than 10% of the catch by count (in 3 out of 9 Massachusetts trips, 2 out of 6 New Hampshire trips, and all 3 of the Maine trips (Table 1).

Egg hatch: For the Massachusetts and New Hampshire boats, most of the female northern shrimp were still carrying eggs in early February (Week 6), but egg hatch was well underway by the end of the month, with NH hatch running ahead of MA (Figures 3 and 6). (Compare the MA and NH orange bars in Figure 3, especially Weeks 7–8, and the points in Figure 6a–b at days 49 and 57). The Maine boat made its first sampling trip on February 13 (Week 7), the only week that all three boats fished. The percentage of females that had hatched their eggs that week was 30% for the Maine boat, compared with 6% and 17% for the MA and NH boats respectively. This was unusual; in most other years, the MA and NH egg hatch happened earlier than ME's. The progression of egg hatch for each boat is plotted in Figures 3 and 6. Note that a second order polynomial equation fit the Massachusetts data much better than the probit curve, most likely in part because of the gap in time between the trips in weeks 8 and 12. The approximate date of 50% egg hatch was day-of-the-year (DOY) 52 (February 21) for the Maine samples (based on only 3 points), about DOY 51 (February 20) for the New Hampshire samples, and somewhere between DOY 60–70 (March 1–11) for the Massachusetts samples. Note that the MA and NH boats often fished near each other, especially in February (Figure 1).

Depths: Mean trip depths varied from 37 to 65 fa (68–118 m). The MA and ME boat followed the same trend seen in past years of the commercial fishery, fishing shallowest during the middle of their season (when the shrimp are most likely to be near shore) and deepest at the beginning and end. The NH boat fished deepest (65 fa (118 m)) during week 3, but its catch rate was its lowest then (Table 1).

Temperatures: The mean sea surface temperature for the New Hampshire boat was 4.0 °C, with a range from 3.6 on February 11 (Week 6) to 4.5 on February 26 (Week 8). The mean bottom temperatures during towing for the Maine boat varied from 6.4 °C on February 13 (Week 6, out of Portland) to 4.9 on March 11 (Week 9, out of Boothbay Harbor), with a mean of 5.5 °C (Table 1).

Prices

Due to confidentiality of the dealer data, because only two dealers bought all the MA and NH catches, we cannot report prices this year.

DISCUSSION

The 2018 cooperative winter sampling program provided winter length and sex-stage composition information and contributed to the time series of egg hatch timing estimation for the Gulf of Maine northern shrimp stock, with 44 samples analyzed from 18 trawl trips by 3 vessels. It is important to recognize that the sampling effort was limited in comparison to data collected during a typical commercial fishing season. On average, over the most recent ten years of the commercial fishery (2004–2013), about 207 trips were sampled annually through the states' shrimp port sampling programs, with a much broader spatial coverage and larger numbers of vessels.

Differences among fishing trips made on the same day within a few miles of each other in past years suggest that the results could be influenced by moving even very short distances. The presence of fixed gear influenced towing operations for all three boats.

The estimated 2018 Maine hatch midpoint of February 21 (DOY 52) was earlier than in 2014–2016, the same as 2017, and well within the ranges for the decade and the time series. The 2018 hatch midpoint was later than the warm year of 2012, for example, where the midpoint of hatch occurred on February 13 (DOY 44) (Figure 7).

Egg hatch trends observed in the 2018 winter samples were inconsistent with historical regional trends of hatch, which usually began and ended earlier in the western GOM and later in the eastern GOM. In 2018, the ME hatch midpoint was only 1 day later than NH's, and earlier than MA's (Figure 6). However, two of the three ME trips were near Portland (in western Maine), and in the past, egg hatch in Portland samples have run a few days earlier than midcoast Maine's, which are closer to the "center" of the Maine fishery (e.g. Hunter *et al*. 2017, Figure 11). On the other hand, the lack of trap samples in the 2018 data may have biased the ME egg hatch metrics in favor of later dates. Trap samples tend to exhibit more (earlier) egg hatch than trawl samples from the same date and region (e.g. Whitmore *et al.* 2015, Figure 16a vs 17a). The limited scope of the 2018 Maine sampling effort may have impacted the consistency and usefulness of the egg hatch data.

The difference in egg hatch metrics between the Massachusetts and New Hampshire boats was striking (Figure 6), given that they often fished within about three miles of each other (Figure 1). Since the Massachusetts boat was using a compound size-sorting grate and the NH boat was

using a standard finfish-exclusion Nordmore grate, it is reasonable to wonder whether female II shrimp were escaping through the small bar spaces in the compound grate after egg hatch, when they became skinnier. A reduction in female II shrimp relative to ovigerous females in the catch samples would bias the estimated MA egg hatch date toward a later date. However, this seems unlikely, given that the MA boat retained a slightly higher proportion of small shrimp than the NH boat (from data for Figure 3). Trouser trawl data from 2017 winter sampling comparing a compound and a standard grate suggested there was no significant difference in retention of female shrimp after egg hatch (ASMFC unpublished), but the grates tested were not identical to the ones used by MA and NH in 2018. It is probably unwise to try to draw too many conclusions from such a limited number of boats, trips, and samples, but further research on the selectivity of compound grates would be informative.

It is tempting to assume that the catch rates estimated here (averaging 72 lbs/hr) would be representative of a 2018 fishery had there been one. The Maine industry pooled mean catch rate for trawlers over the most recent 10 commercial fishery years was 350 lbs/hr (Eckert *et al*. 2017). But note that the purpose of this program was not to estimate catch rates. A few fishermen fishing once a week on unbroken aggregations of shrimp on their choice of day and location should do exceptionally well. On the other hand, these fishermen were asked to collect samples from areas they might normally have fished, but they were impeded by fixed gear, were lacking information from other harvesters, were lacking the opportunity to find or follow shrimp aggregations from day to day, and were told when they could begin the project and when to end. The boats fulfilled their purpose in collecting shrimp samples successfully.

ACKNOWLEDGEMENTS

We would like to thank all the fishermen who participated in cooperative winter sampling this year: Joseph Jurek, Neal Pike, and Dana Hamond, and their crews; also Mike Kersula and Katherine Thompson (Maine DMR) for catch sampling and photos, Elizabeth Morrissey (MA DMF) and Marilyn Lash (Maine DMR) for sample analysis, and Katherine Thompson at Maine DMR for providing the temperature logger.

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Table 1. Summary statistics by state and trip (top) and for the project (bottom): estimated total shrimp catch, number of tows, total towing time, mean depth, mean temperature*, pooled mean catch rate, number of samples collected for the states, type of grate used, pooled mean shrimp count per pound (all species), percent of the shrimp catch that was *Pandalus borealis* (by count), and percent of *P. borealis* females whose eggs had hatched off. "Comp" is compound grate; "Nord" is standard Nordmore grate.

* New Hampshire temperatures are at sea surface; Maine temperatures are bottom.

State & Week	Date	Catch Pounds	Tows Count	Tow Time Hours	Depth Fathoms	*Surf or Bot Temp. °C	Rate Lbs/Hr	Samples Count	Grate	Count Num/Lb	*P.borealis* %	Egg Hatch %
Massachusetts (*Mystique Lady*) out of Gloucester												
1	11-Jan-18	70	3	3.8	48		19	2	Comp	36	99%	0%
2	18-Jan-18	310	3	6.5	45		48	2	Comp	42	89%	1%
3	22-Jan-18	446	3	7.0	47		64	2	Comp	37	94%	0%
4	28-Jan-18	674	4	7.5	43		90	2	Comp	37	93%	9%
5	06-Feb-18	800	4	8.0	39		100	2	Comp	37	94%	1%
6	11-Feb-18	820	2	4.0	39		205	2	Comp	35	97%	6%
7	18-Feb-18	468	4	7.8	39		60	2	Comp	43	87%	15%
8	26-Feb-18	420	4	8.5	38		49	2	Comp	53	63%	30%
12	29-Mar-18	195	3	5.3	57		37	2	Comp	51	91%	100%
Totals	9 trips	4,203	30	58.3			72 (avg)	18				
New Hampshire (*Sandi Lynn*) out of Seabrook												
1	11-Jan-18	22	3	2.7	41	4.4	8	1	Nord	40	89%	1%
3	22-Jan-18	15	1	2.2	65	4.1	7	1	Nord	46	97%	11%
5	06-Feb-18	800	4	7.2	38	3.7	111	4	Nord	38	93%	9%
6	11-Feb-18	820	2	4.6	39	3.6	178	2	Nord	36	96%	17%
7	18-Feb-18	410	4	7.8	37	3.7	52	4	Nord	38	96%	48%
8	26-Feb-18	330	4	8.8	37	4.5	37	4	Nord	53	68%	75%
Totals	6 trips	2,397	18	33.3			72 (avg)	16				
Maine (*Nicole Leigh*) out of Portland (weeks 6 & 10) and Boothbay Harbor (week 9)												
6	13-Feb-18	36	3	0.9	48	6.4	40	3	Nord	47	66%	30%
9	11-Mar-18	143	4	2.1	37	4.9	66	4	Nord	47	84%	75%
10	17-Mar-18	125	3	1.0	55	5.3	126	3	Nord	70	58%	99%
Totals	3 trips	304	10	4.0			75 (avg)	10				

Totals & Averages	Trips Count	Catch Pounds	Tows Count	Tow Time Hours			Rate Lbs/Hr	Samples Count		Count Num/Lb		
	18	6,904 (3.1 mt)	58	96			72 (avg)	44		40 (avg)		

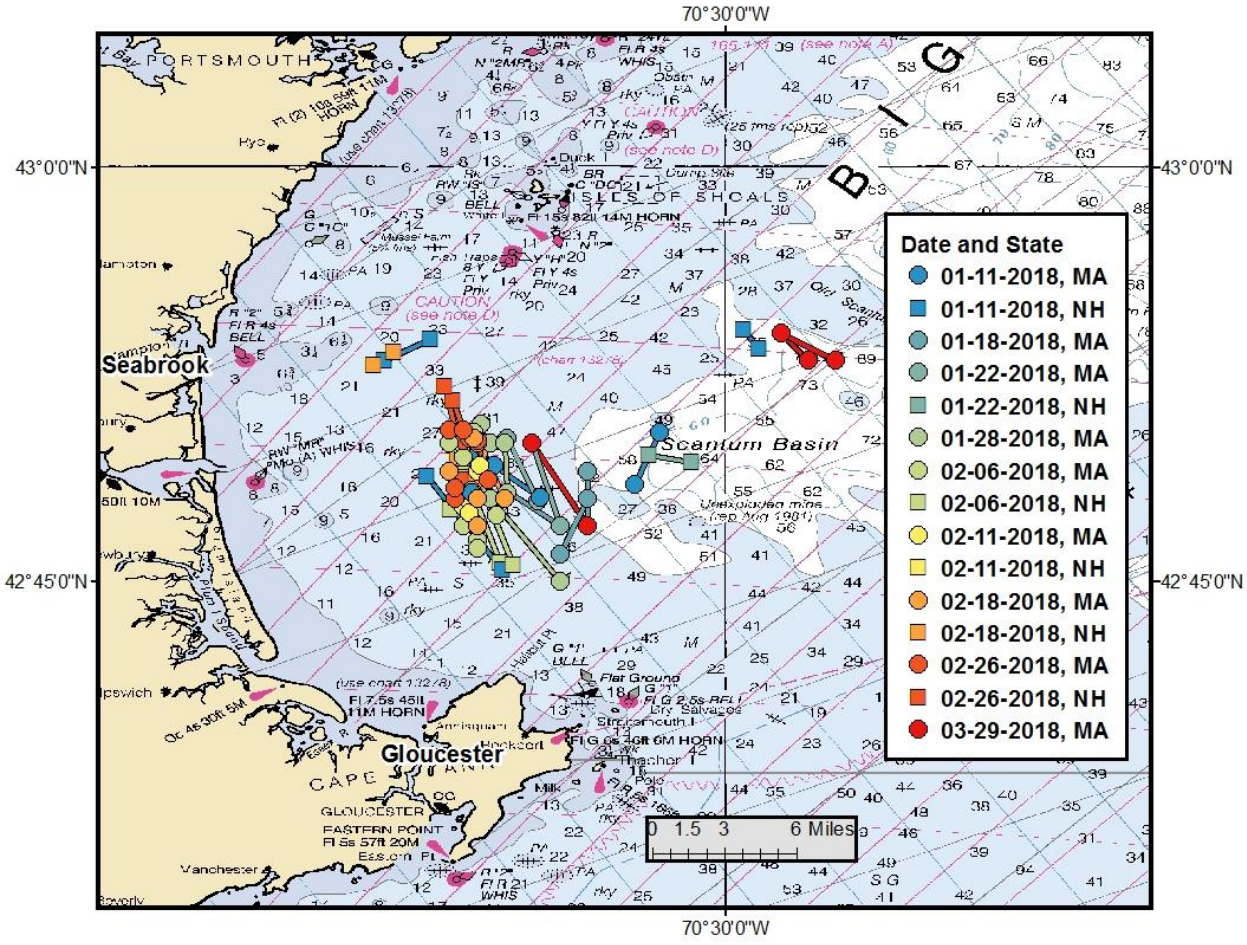


Figure 1. Begin and end locations of Massachusetts tows (MA, circles) and New Hampshire tows (NH, squares), by date.

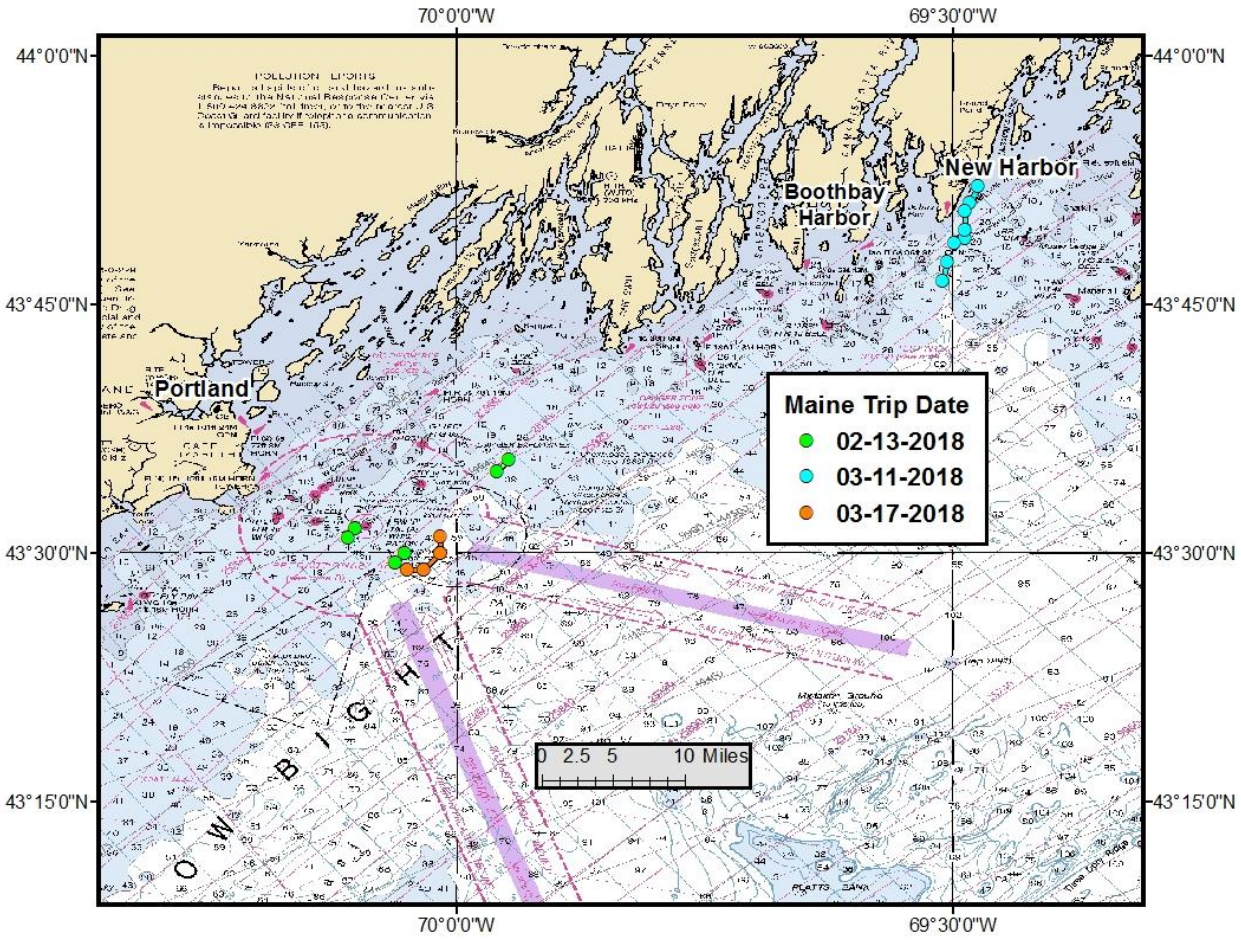


Figure 2. Begin and end locations of Maine tows, by date.

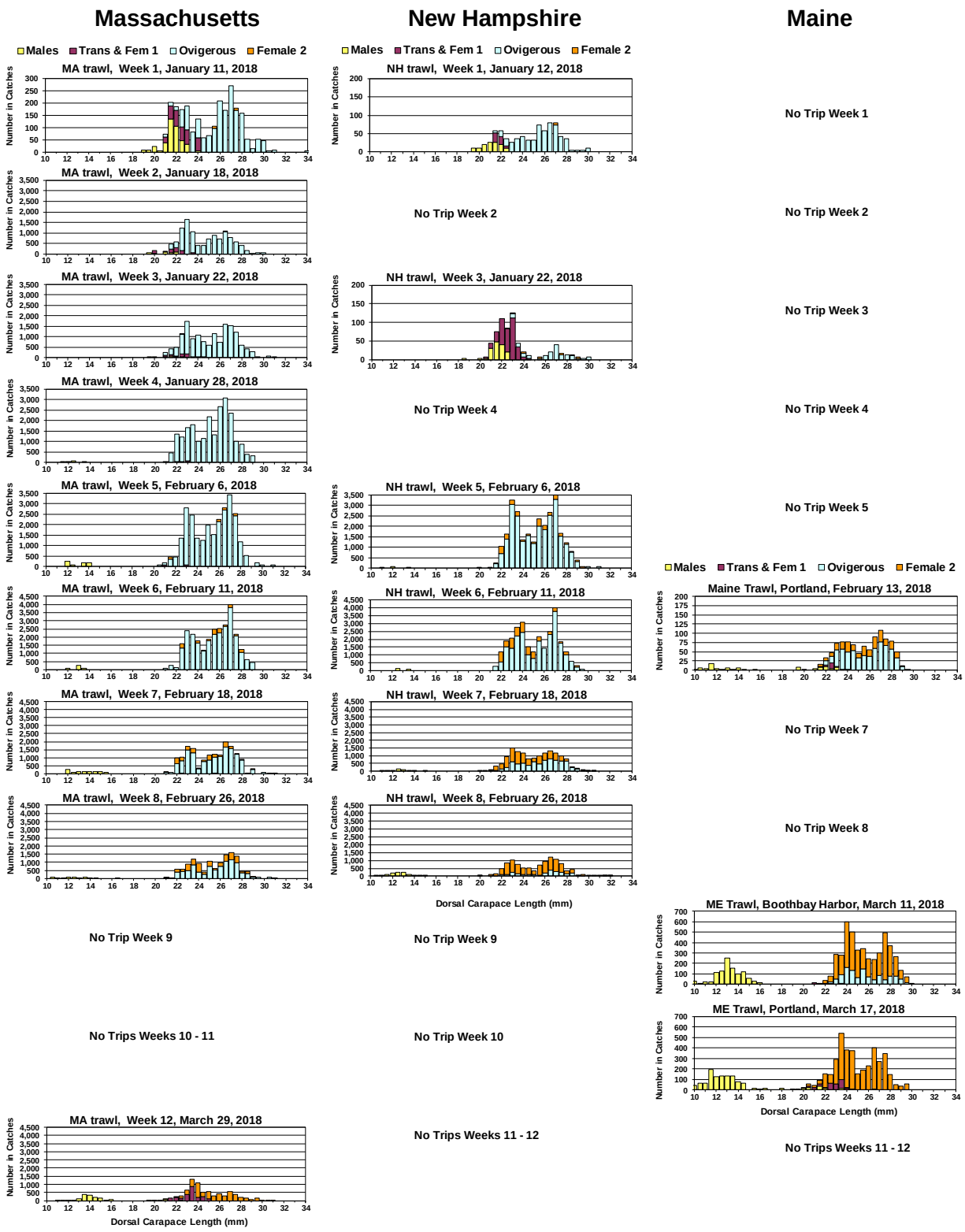


Figure 3. Northern shrimp size-sex-stage frequency distributions (in estimated total numbers of *P. borealis* in catches) by state (left to right; west to east) and week (top to bottom). Note that the vertical scales vary.

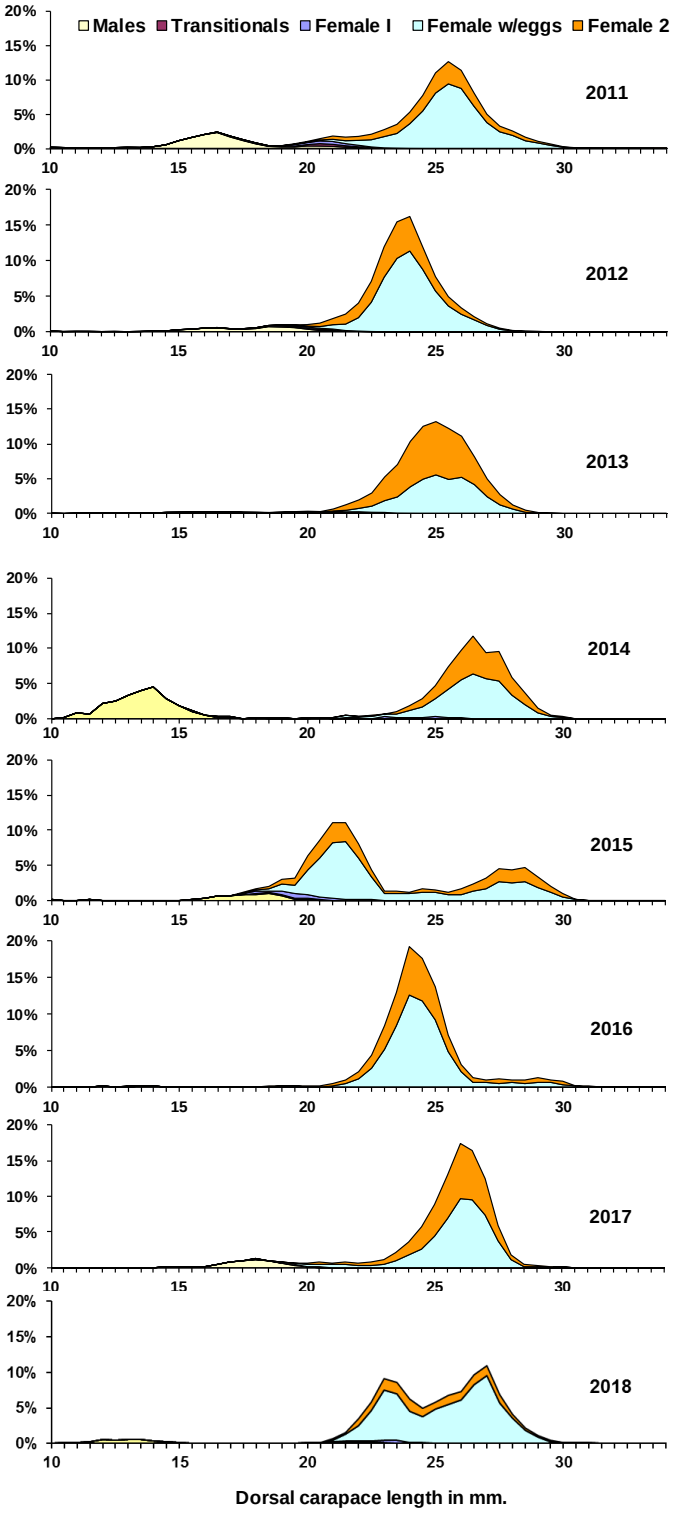


Figure 4. Northern shrimp relative size-sex-stage frequencies from winter sampling with data from 2011–2013 GOM fishery samples expanded to landings, and 2014–2018 GOM RSA and Maine samples expanded to catches.

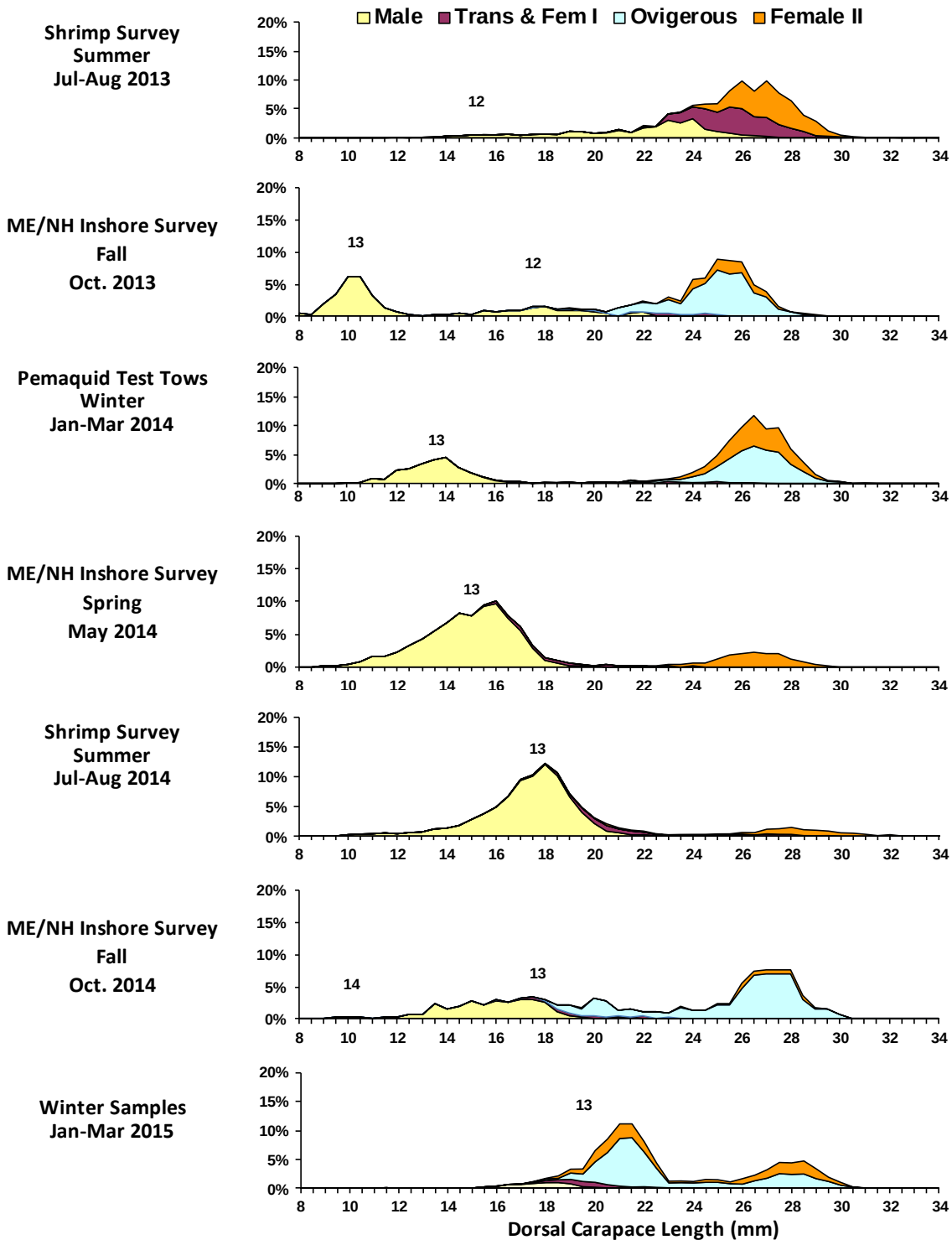


Figure 5: Northern shrimp relative size-sex-stage frequencies from 2013–2018 GOM surveys and winter sampling programs. Two-digit years denote the mode of assumed 2012–2017 year classes. All fall survey data are preliminary.

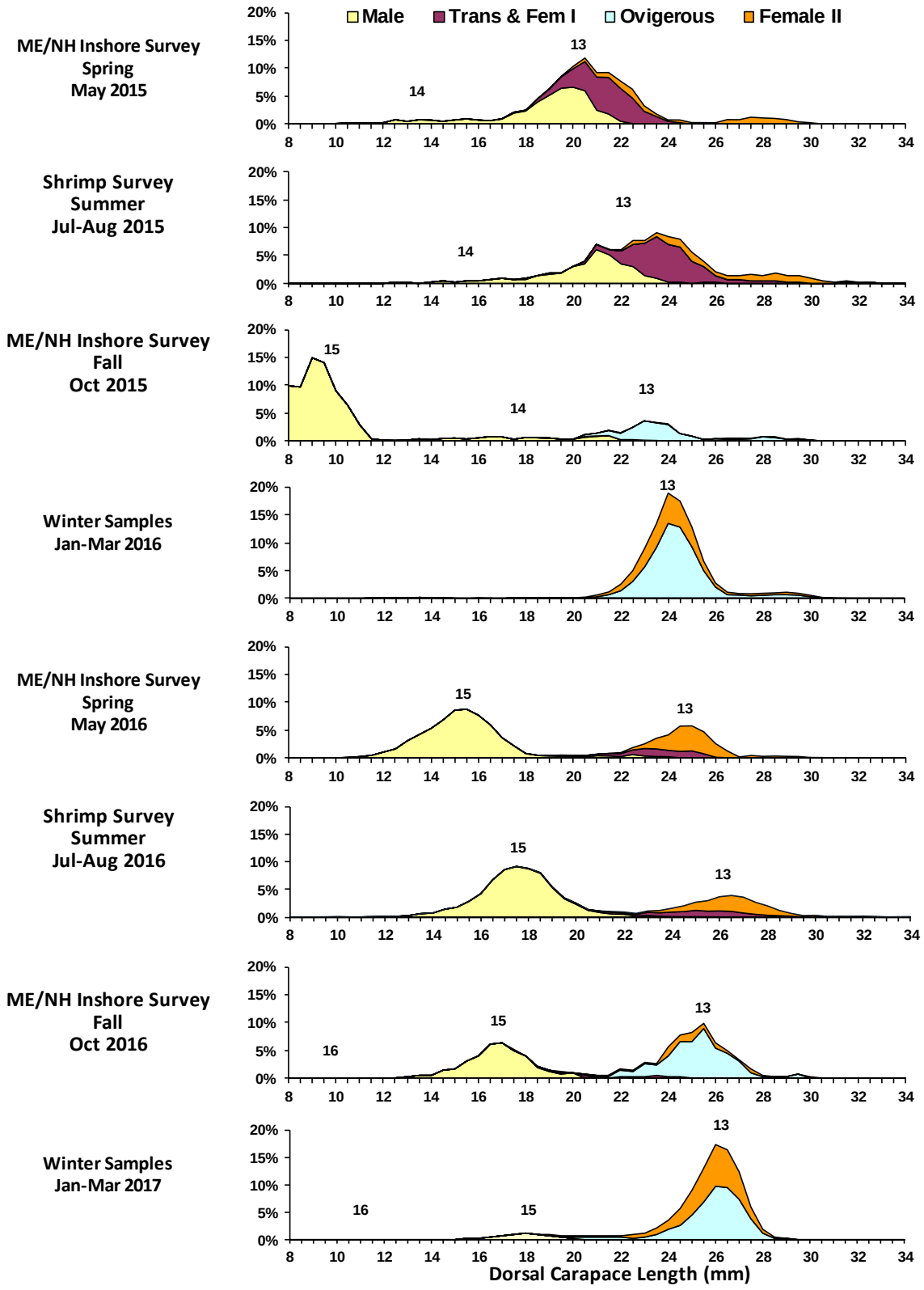


Figure 5: Continued. Northern shrimp relative size-sex-stage frequencies from 2013–2018.

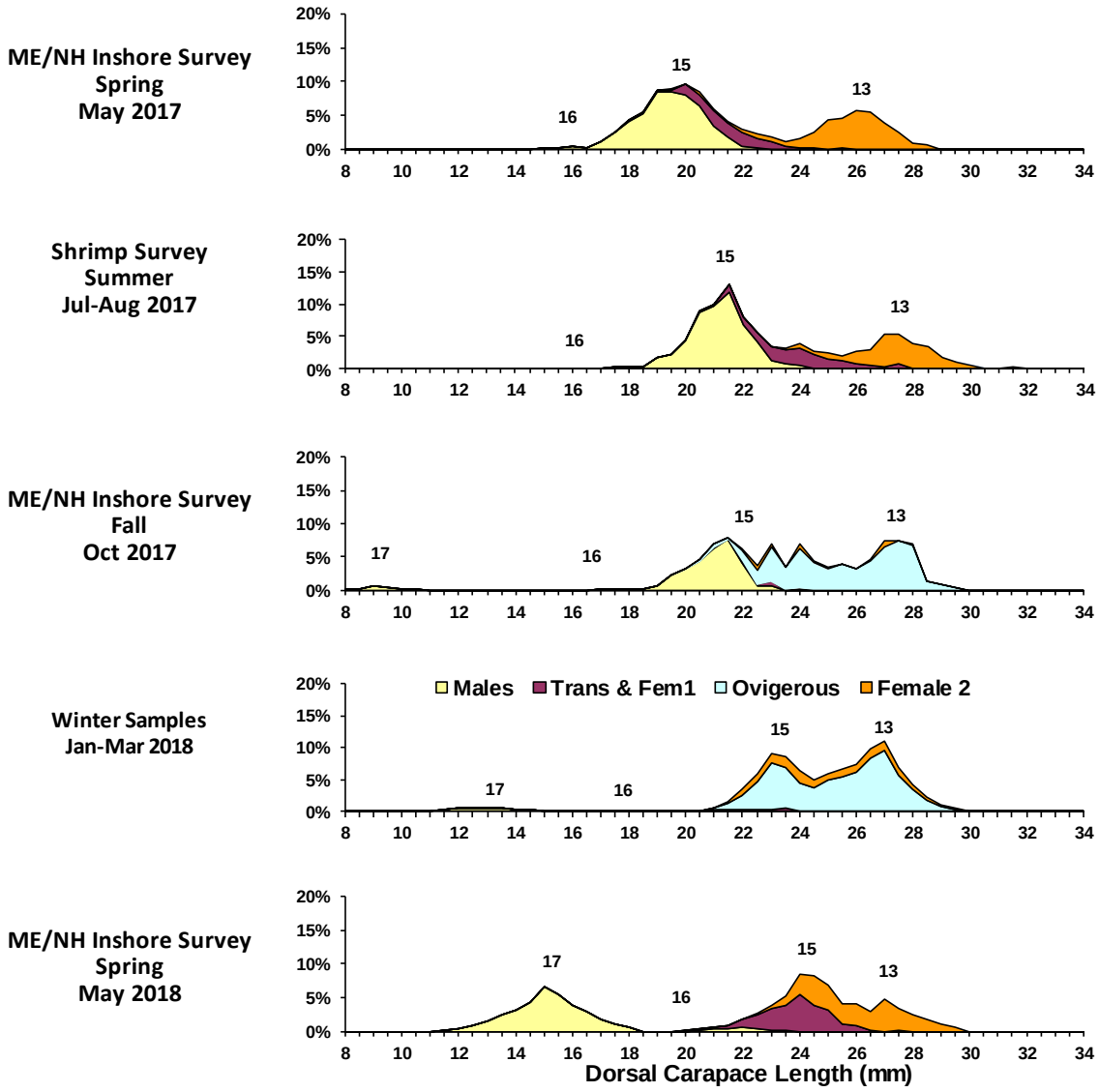
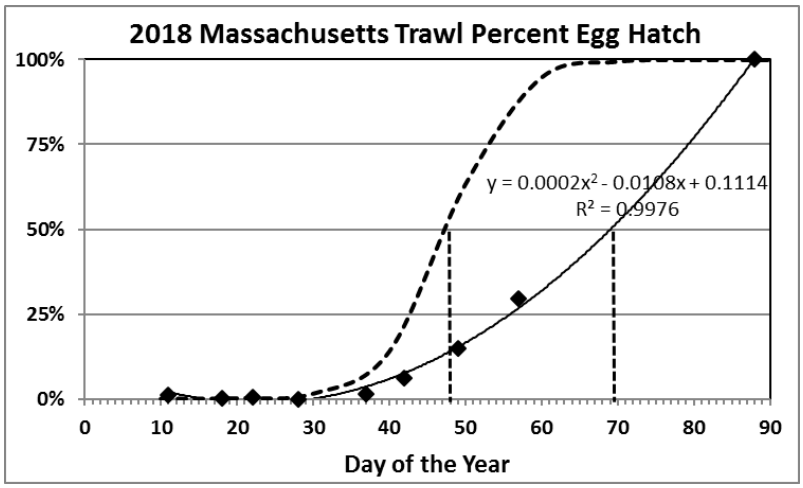
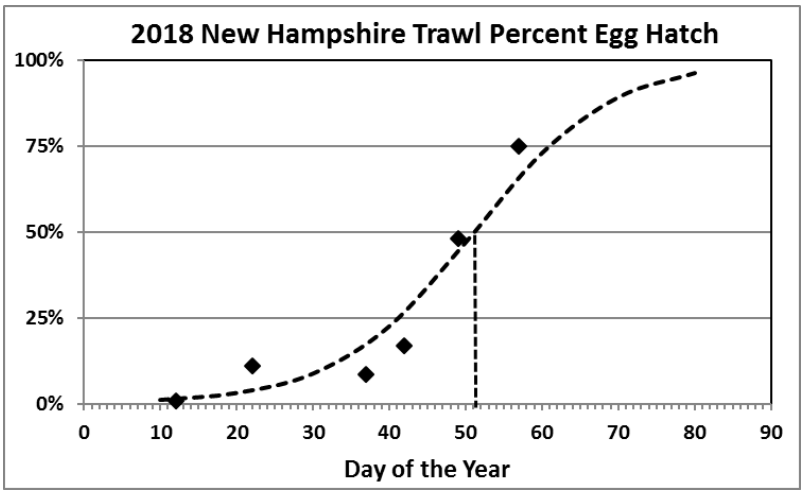


Figure 5: Continued. Northern shrimp relative size-sex-stage frequencies from 2013–2018. Spring 2018 data are preliminary.





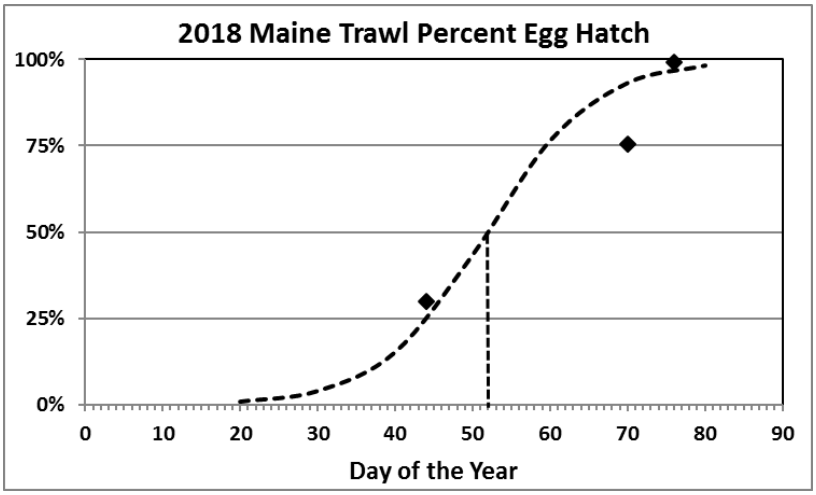


Figure 6. Mean percentage of egg hatch by day of the year (2018) for female northern shrimp, by state. Curved dotted lines are from probit analysis. Solid curved line for Massachusetts is a second order polynomial. Vertical dotted line indicates approximate day of 50% hatch (with two options for Massachusetts).

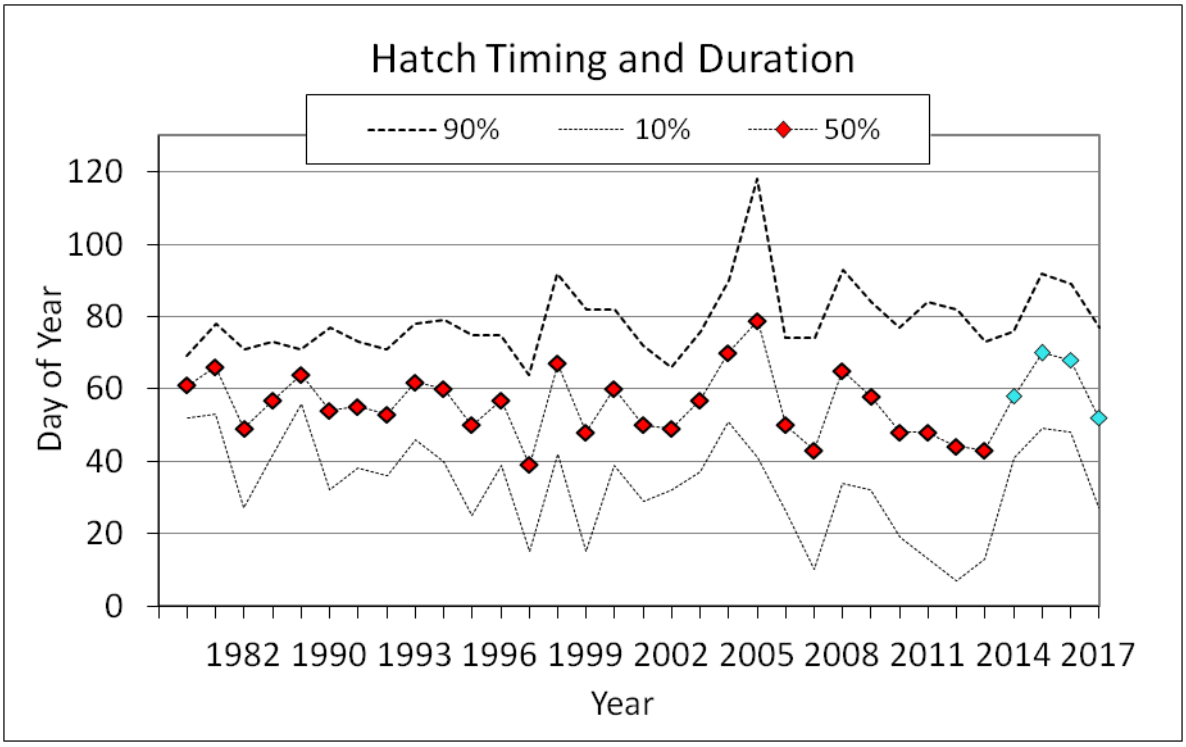


Figure 7. Time series of hatch timing estimates from sampling of the Maine commercial fishery (1980–1984, 1989–2013) (red), and NSTC winter sampling in Maine (2014–2017) (blue).