2016 WINTER SAMPLING

FOR

GULF OF MAINE NORTHERN SHRIMP

Photo by Robert Eckert, NH F&G, 2-10-16

Photo by Elaine Jones, ME DMR, 2-24-15

Maine Department of Marine Resources (DMR)
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SUMMARY

In the absence of a commercial fishery, four trawlers and two trappers participated in a cooperative winter sampling program to collect northern shrimp samples in the Gulf of Maine during January – April 2016 under the ASMFC's northern shrimp FMP RSA provision. They caught a total of 13.3 mt, or 60% of the 22 mt RSA. Sixty-one trawl and eleven trap samples were collected and evaluated for shrimp size and sex-stage, and the timing of egg hatch was estimated. Catches comprised mostly assumed 3-year-old female shrimp from the 2013 year class. The estimated time of 50% egg hatch was about March 7, 2016, which was slightly earlier than the previous year (March 11, 2015).

INTRODUCTION

Fisheries for northern shrimp (*Pandalus borealis*) in the Gulf of Maine (GOM) during the past thirty years have 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. The highest landings usually occur in the months of January and February (see Table 3 in Whitmore *et al.* 2015). Shrimp are caught by trawlers and trappers, with trawlers averaging about 86% of the Maine catch in 2009–2013 (Table 4 in Whitmore *et al.* 2015). Shrimp samples from commercial catches have been collected by member states (Maine, Massachusetts, and New Hampshire) each season for over thirty years, and have informed annual stock assessment updates.

The 2015–2016 GOM fishery was closed by the Atlantic States Marine Fisheries Commission (ASMFC) due to low stock abundance. This was the third consecutive year the fishery was closed. In the absence of a fishery, the ASMFC Northern Shrimp Technical Committee (TC) recommended a limited cooperative winter sampling project be implemented, like the previous year's project. 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 catches, estimating the winter size (carapace length) and sex-stage composition of the shrimp stock in traditionally fished areas, and
- 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 their December 7, 2015 meeting, the ASMFC Northern Shrimp Section established a 22 mt quota under the northern shrimp fisheries management plan (FMP) research set aside (RSA) program (ASMFC 2012) to support data collection during the winter of 2015–2016.

METHODS

Trawl samples: The traditional spatial range of the GOM northern shrimp commercial trawl fishery was divided into four regions: Massachusetts-New Hampshire, Western Maine (Kittery to Phippsburg), Midcoast Maine (Phippsburg to Monhegan Island), and Eastern Maine (east of Monhegan Island). Experienced GOM shrimp trawlers were solicited to participate in the project by e-mail and web announcements. One trawl captain for each of the four sampling regions was picked at random from among the qualified applicants from that region. The selected vessels were from Seabrook, NH (MA-NH region), Portland (Western ME region), New Harbor (Midcoast ME region), and Port Clyde (Eastern ME region) (Figure 1), and ranged in length from 42–57 feet (12.8–17.4 m). Each trawler was asked to fish about once every two weeks during the period in which northern shrimp migrate into inshore waters to hatch eggs (usually January through March), using their standard shrimp-fishing gear. Each trawler made no more than five trips. Trips were scheduled, weather allowing, on a mutually agreed upon date, after discussion between the captain and the state TC member. Participants were asked to conduct at least three tows per day in areas where they would normally fish for shrimp at that time of year. They provided their TC member with a 2-kg sample from the catch from each of three tows, and other information such as date, tow duration, location, begin and end depth, and estimated catch weight. The sample was chosen randomly from each tow's catch, and bagged and kept on ice (NH) or frozen (ME) for later delivery to NH Fish and Game or ME DMR. Similar 1-kg samples were also collected for further analysis by scientists at the University of Maine. U. Maine also provided temperature loggers (Onset Tidbit v2) to affix to each fisherman's net, which recorded temperature every five minutes continuously throughout the project, starting with each trawler's second or third trip. Trawlers were paid $500 per trip by ASMFC and were also allowed to keep or sell up to 1,800 pounds (817 kg) of shrimp per day to defray fishing expenses. The first trawl trip was made on January 25 and the last was on March 30, 2016.

Trap samples: Shrimp trappers were also invited to participate, and two were picked at random from among the qualified applicants; both were from Midcoast Maine (Boothbay Harbor and Friendship). The Midcoast area historically lands more than 90% of GOM trapped shrimp. The trappers were allowed to fish forty traps, tended as often as needed, landing no more than 100 lbs (45 kg) of shrimp per week, and were similarly allowed to keep or sell their landings to

offset fishing expenses. Each trapper was asked to combine the catches of all forty traps and collect one randomly chosen 2-kg sample from his day's catch about once every two weeks, also on a mutually agreeable schedule. Trappers also collected samples for U. Maine and were provided with a temperature logger to secure to one of their traps. The trappers used their standard shrimp traps and bait. The Boothbay Harbor trapper fished pairs (two traps per string) and the Friendship trapper fished triples (three traps per string). The first traps were set out on January 25 and the last ones were hauled April 13, 2016.

Sample work-up: At the labs, samples were analyzed following the usual procedures for commercial shrimp samples. Frozen Maine samples were thawed, and each trawl or trap sample was weighed, and then separated by shrimp species. *P. borealis* specimens were counted, measured (dorsal carapace length (CL)), 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 other shrimp species in the samples, usually *Pandalus montagui* or *Dichelopandalus leptocerus*, were counted and measured.

Calculations for trawl data: The numbers of northern shrimp of each sex, stage and size (CL in 0.5 mm categories) in each sampled tow were estimated ("raised" or "expanded") by multiplying the numbers in the sample by the tow catch weight divided by the sample weight. The pooled mean proportion of northern shrimp females that had carried and hatched off their eggs was calculated for each day as the estimated total female II shrimp in sampled tows divided by the sum of female II shrimp plus ovigerous females in sampled tows. Relative size-sex-stage frequency distributions for each day were calculated by dividing the number of northern shrimp in each sex-stage-size category by the total number in the sampled catches. Shrimp counts per pound (all species) for each sample were calculated by dividing the number of shrimp of all species in the sample by the total sample weight. The counts were then expanded to the tow to estimate the total number of shrimp of all species in the tow. The total number of shrimp in all the sampled tows was then divided by the total catch weights of all the sampled tows to give a pooled mean count per pound for each day and area. Pooled mean catch rates were calculated for each trip and area as the estimated total catch weight of shrimp of all species divided by the total number of hours towing for the trip or area. The mean tow depth was calculated by averaging the beginning and ending depths for each tow. Mean trip depth was calculated by averaging the trip's mean tow depths. Mean temperature for each tow was calculated by averaging the 5-minute temperatures, usually starting with the temperature recorded 5 or 10 minutes after the brake was set, until the last temperature recorded at or before haul back began. Mean trip temperature was calculated by averaging the trip's mean tow temperatures.

Calculations for trap data: The proportion of northern shrimp females that had carried and hatched off their eggs was calculated for each trapped catch as the total female II shrimp in the sample divided by the sum of female II shrimp and ovigerous females in the sample. Relative size-sex-stage frequency distributions for each catch were calculated by dividing the number of

northern shrimp in each sex-stage-size category by the total number in the sample. Shrimp counts per pound for each catch were calculated by dividing the number of shrimp of all species in the sample by the total sample weight. The numbers of shrimp in each trap sample were also expanded to the trip's catch by size-sex-stage category, for combining with the trawl samples in Figure 10.

Hatch timing: A 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 define 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 were weighted by the weight of the catch from which they were collected. Samples from both trawl and trap gear were included in all years, except hatch metrics for the 2013–2014 winter, when there also was no fishery, are from limited trawl samples collected off Pemaquid Point in Midcoast Maine (Hunter 2014).

RESULTS

Trawl Catches and Samples

The four trawlers fished from the ports of Seabrook (NH), Portland (Western ME), New Harbor (Midcoast ME), and Port Clyde (Eastern ME) (Figures 1–2). They each made five fishing trips. A summary of their results is in Table 1a-b. A total of 20,345 pounds (9.2 mt) were caught in trawls, or 42% of the 22 mt RSA. Nineteen samples were delivered to the NH F&G, and 42 to the ME DMR for a total of 61 samples collected and analyzed. Three of the captains mentioned having to relocate or take steps to avoid fixed gear in their traditional tows. Locations fished are charted in Figures 1–2. Fishing dates are listed in Table 1a. All trips were single day trips.

Size and sex-stage composition in trawl samples: Most of the shrimp were females, with a few males and transitionals caught during the last trips in late March (Figures 4-7), when most of the boats fished further off shore (Figure 2). The pooled mean number of shrimp of all species per pound (Number/Lb, Table 1a,b) was 43, and varied by trip from 39 (Midcoast ME, January 30 and February 15) to 55 (New Hampshire, Mar. 23) (Table 1a). In general, the *P. borealis* size-frequency distributions (Figures 4–7) showed a mode at about 23.5–24.5 mm CL, probably from the 2013 year class (3-year-olds). This is smaller than most GOM shrimp catch size modes historically, though not as small as the shrimp caught during the 2015 winter sampling project (Whitmore *et al.* 2015b); the GOM shrimp catch usually comprises mostly 4- and 5-year-olds,

although younger shrimp are caught if their year classes are strong or the fishery is conducted off shore (Figure 10 and Whitmore *et al*. 2015, text and Figure 3).

The assumed 2013 year class was first identified in the 2013 fall Maine-New Hampshire inshore trawl survey, and appeared again as a weak (about the ninth smallest in the summer survey time series) and unusually fast-growing year class in the 2014 summer shrimp survey (Age 1.5 in Table 10 in Whitmore *et al.* 2014). See Figure 11 for its progress as seen in recent surveys and cooperative winter sampling projects.

Some 2016 samples, particularly those from the New Hampshire boat, contained some very large shrimp (28–31 mm CL), probably from the 2010 and/or 2011 year classes. There were also a few shrimp in the 12–16 mm CL range, probably from the 2015 year class. In 20 of the 61 samples, species other than *Pandalus borealis* (mostly *Dichelopandalus leptocerus* and a few *Pandalus montagui*) made up more than 10% of the sample by count (in nine samples from New Hampshire, five from Western Maine, and six from Eastern Maine).

Egg hatch in trawl samples: Most of the female shrimp were still carrying eggs in late January and mid-February, and most had hatched off their eggs by the middle of March (Figures 4–7). Egg hatch rates from samples are plotted in Figure 12, and support past observations of egg hatch progressing chronologically from west to east. The approximate date of 50% egg hatch was day-of-the-year (DOY) 55 (February 23) off New Hampshire, about DOY 67 (March 7) in Western Maine, about DOY 74 (March 15) in Midcoast Maine, and about DOY 71 (March 11) in Eastern Maine. Note that the Midcoast and Eastern Maine boats fished within about 10 miles (16 km) of each other during their second, third, and fourth trips (Figure 1), so it is not surprising that their hatch dates were similar.

Trawl catch rates: Daily mean catch rates varied tremendously, from a low of 14 lbs/hr (Eastern Maine, March 30) to a high of 1,520 lbs/hr (Midcoast Maine, March 1) (Table 1a). The Western and Midcoast Maine boats consistently had the highest catch rates throughout the sampling season (Table 1b), and caught their 1,800 lb daily limit (or close to it) during 7 of their 10 trips. All boats had their highest catch rates during their third trip in late February or early March, and all had their lowest catch rates during their last trip near the end of March. The pooled mean catch rate for all regions and dates (total estimated pounds caught divided by total trawl hours) was 214 lbs/hr.

Trawl Depths: Mean trip depths varied from 34 to 45 fa (62–82 m) during the first four trips for all trawlers. During the last trip, all but the Eastern Maine boat moved to deeper waters (Figures 1-2, red points), averaging about 58 fa (106 m) (Table 1a).

Trawl Bottom Temperatures: Bottom temperatures are displayed in Table 1a and Figures 14a-d. Mean tow temperatures varied from 4.3 to 5.9°C. Highest temperatures were generally in the west, with an overall region mean of 5.4° in both New Hampshire and Western Maine, and 4.7° and 4.5° in Midcoast and Eastern Maine respectively. There were no obvious relationships

between temperature and catch rate or depth (Figures 14a-d, bottom). The most notable trend seems to be between catch rate and time, with a dome-shaped relationship indicating the highest catch rates during the middle of the project's timeframe (Figures 14a-d, top).

Trap Catches and Samples

The two trappers fished in the Boothbay Harbor and Friendship areas, both in Midcoast Maine (Figure 3). A total of 9,017 pounds (4.1 mt) were caught in traps, or 18% of the 22 mt RSA, and 11 samples were collected. Data collected on the days the traps were hauled are listed in Table 2. The Boothbay Harbor trapper hauled his traps 28 times for a total of 898 trap-hauls (the total number of times any trap was hauled) and caught a total of 5,778 lbs (2.6 mt). The Friendship trapper hauled his traps 20 times for a total of 696 trap-hauls and caught a total of 3,239 lbs (1.5 mt).

Size and sex-stage composition in trap samples: All northern shrimp in the trapped samples were female. The pooled mean number of shrimp of all species per pound (Number/Lb, Table 2) was 40, and daily means varied from 38 (Boothbay Harbor, March 10) to 67 (Friendship, April 13). In general, the *P. borealis* size-frequency distributions (Figures 8–9) showed a mode at about 24.0–24.5 mm CL, probably from the 2013 year class (3-year-olds).

Like the New Hampshire trawler, the trappers also caught a few very large northern shrimp (28–31 mm CL) probably from the 2010 and/or 2011 year classes. Unlike the trawlers, there were no small northern shrimp in the 12–16 mm CL range in the trapped samples. In 4 of the 11 samples, species other than *Pandalus borealis* (*Pandalus montagui* and *Dichelopandalus leptocerus*) made up more than 10% of the sample by count (in the earliest and latest samples collected from each area, Table 2).

Egg hatch in trap samples: Most northern shrimp caught in traps were still carrying eggs through the middle of February, and most had hatched off their eggs by the middle of March (Figures 8 and 9). Egg hatch rates from samples are plotted in Figure 13. The approximate date of 50% egg hatch was about DOY 61 (March 1) in both the Boothbay Harbor and Friendship trap samples, compared with about DOY 74 (March 15) in the Midcoast trawl samples, probably because trappers are more likely to catch shrimp after egg hatch than trawlers fishing at approximately the same time and place (Figure 3b in Whitmore *et al.* 2013 and Figure 10 in Whitmore *et al.* 2015b).

Trap Depths: Mean depths varied from 26 to 47 fa (48–86 m) for the Boothbay Harbor traps, with the deepest depths during the last two haul dates (Table 2). Depth varied very little (30-31 fa, 55–56 m) for the Friendship traps. Note that the Boothbay Harbor trapper moved his traps and covered a much larger area than the Friendship trapper (Figure 3).

Trap Bottom Temperatures: Bottom temperatures at 5 a.m. EST on the day the traps were hauled are displayed in Table 2, and continuously recorded temperatures are show in Figure 15,

along with shrimp catch rates. Haul date temperatures varied between 3.6 and 5.3 in Boothbay Harbor and between 3.7 and 4.8 in Friendship. There was no obvious relationship between catch rate and temperature, or temperature and depth. Like the trawl data, the most notable trend was between catch rate and time, with catch rates highest during the middle of the project period.

Size and Sex-Stage Composition for Trawl and Trap Samples Combined

When all samples were weighted by catch and combined (Figure 10), the northern shrimp mean size was 24.2 mm CL. The mean CL for females was 24.3, which was the seventh smallest in the 1985-2016 time series (from Whitmore *et al*. 2015, data for Figure 3). Ninety eight percent of the northern shrimp in the catch were female, most probably from the 2013 year class: 67% were ovigerous and 31% had carried eggs. This suggests that an unusually high proportion of the 2013 year class was composed of reproductive females (at only three years old) that were available inshore, and/or that females in the older year classes (2011 and 2012) were less abundant or less available inshore.

Hatch Timing for Trawl and Trap Samples Combined

In 2015 the estimated hatch initiation day was DOY 49 (February 18), the midpoint was DOY 70 (March 11) completion was DOY 92 (April 2), and duration of the hatch period was 44 days. The 2015 hatch occurred relatively late; the hatch midpoint was one of the latest in the time series (Figure 17). In 2016, the estimated midpoint of hatch was slightly earlier, at about DOY 67 (March 7) (Figure 16) and the duration of the hatch period was similar to 2015 (Figure 17).

DISCUSSION

The 2016 cooperative winter sampling program successfully provided winter length and sex-stage composition information and maintained the time series of egg hatch timing estimation for the Gulf of Maine northern shrimp stock, with 61 research samples analyzed from 20 trawl trips made in the MA-NH, Western ME, Midcoast ME, and Eastern ME regions, as well as 11 trap samples from Midcoast Maine. The expansion of geographic and temporal coverages, and the inclusion of trap samples in 2015 and 2016, compared to 2014 (Pemaquid Point, ME trawl samples only) were beneficial; however it is important to recognize that the effort was still limited in comparison to the resolution of data collected during a typical commercial fishing season. On average, over 200 fishery samples were collected annually over the last ten years (2004–2013) through the states' shrimp port sampling programs.

Differences among tows made on the same day within a few miles of each other suggest that the results could be influenced by moving even very short distances. The presence of fixed gear influenced tow operations in at least three of the four regions.

Nonetheless, the samples were useful for continuing the time series of hatch timing estimates and tracking the year classes currently in the population. Interesting findings emerged or were confirmed, foremost, that members of the 2013 year class were ovigerous (at only three years old) and available inshore, and more available than older year classes (2010–2012). Northern shrimp in the GOM generally transition from male to non-ovigerous females at about three-years-old, and carry eggs during their fourth winter (Clark *et al.* 2000), but there have been exceptions, notably the assumed 2001 year class which dominated catches as small ovigerous females in 2004 (Whitmore *et al.* 2015, Figure 3). The pattern of early maturing shrimp in 2016 is consistent with the 2015 summer survey results (Whitmore *et al*. 2015), where the 2013 year class (at age 2.5) appeared to be fast growing with most having transitioned to female (stage I and a few stage II). The high proportion of these shrimp may also to be an indication that early life survival (the number of shrimp surviving per spawning female) of the 2013 year class was higher than for the very poor 2010–2012 year classes (see Whitmore *et al*. 2014). However, the apparently higher survival should not be equated with high recruitment (the number of new shrimp entering the population), as recruit abundance of the 2013 year class was the ninth lowest in the 31-year summer shrimp survey time series (Whitmore *et al.* 2014).

Egg hatch trends observed in the 2016 winter sampling were consistent with historical regional trends of hatch, beginning and ending earlier in the western GOM and later in the eastern GOM. The 2016 hatch midpoint was about March 7 (DOY 67), one of the latest in the Maine time series. This is in contrast to the warm year of 2012, for example, where the midpoint of hatch occurred on February 13 (DOY 44). It appears that hatch metrics in 2014–2016 were similar to pre-2000 fisheries, when hatch duration was shorter and initiated later than post-2000 fisheries.

It is tempting to assume that the catch rates estimated here would be representative of a 2016 fishery had there been one. The Maine industry pooled mean catch rate for trawlers over the past 10 years is 350 lbs/hr (Whitmore *et al*. 2015, Table 8). But note that the purpose of this program was not to estimate catch rates. One fisherman fishing alone once every couple of weeks on unbroken aggregations of shrimp on his choice of day and place 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, and were lacking much opportunity to find or follow shrimp aggregations. The samples were collected successfully.

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Table 1a. Summary statistics for the trawl data: estimated total shrimp catch, number of tows, total towing time, mean bottom temperature, mean depth, pooled mean catch rate, number of samples collected for the ASMFC, pooled mean shrimp (all species) count per pound, percent of the shrimp catch that was *Pandalus borealis* (by count), and percent of *P. borealis* females whose eggs had hatched off, by area (west to east) and trip date.

Area	Date	Est. Total Catch Pounds	Tows Count	Tow Time Total hours	Avg Bottom Temp. °C	Avg Depth Fathoms	Avg Rate Lbs/Hr	Samples Count	Avg Count Number/Lb	*P.borealis* %	Egg Hatch %
MA-NH	28-Jan-16	875	4	6.1	na	39	145	4	44	94%	12%
	10-Feb-16	1,150	4	6.6	na	41	175	4	45	90%	21%
	23-Feb-16	1,425	3	6.5	4.8	39	219	3	42	97%	47%
	08-Mar-16	550	5	8.0	5.4	42	68	5	51	83%	96%
	23-Mar-16	40	3	1.4	5.7	61	28	3	55	96%	100%
Western ME	28-Jan-16	1,100	3	4.7	na	42	237	3	43	96%	1.4%
	11-Feb-16	1,800	3	3.7	5.9	37	484	3	41	95%	8.6%
	01-Mar-16	1,800	2	1.8	5.7	34	984	2	43	94%	22.7%
	16-Mar-16	1,900	3	3.8	5.1	39	496	3	48	90%	86.2%
	30-Mar-16	170	3	3.2	5.1	65	54	3	53	82%	99.6%
Midcoast ME	30-Jan-16	1,800	3	3.8	na	37	476	3	39	98%	1.7%
	15-Feb-16	1,850	2	2.1	na	39	889	2	39	100%	10.9%
	01-Mar-16	1,900	2	1.3	5.0	34	1520	2	40	98%	15.9%
	13-Mar-16	1,750	3	4.1	4.6	35	428	3	42	97%	45.0%
	30-Mar-16	245	3	4.8	4.6	48	52	3	50	91%	96.3%
Eastern ME	25-Jan-16	180	4	7.6	na	45	24	3	45	80%	0.2%
	18-Feb-16	640	4	7.3	4.6	35	88	3	40	96%	3.3%
	04-Mar-16	950	4	6.8	4.7	36	139	3	40	97%	30.9%
	18-Mar-16	140	3	5.6	4.3	40	25	3	47	87%	67.4%
	30-Mar-16	80	3	5.9	4.5	39	14	3	48	89%	96.2%
Totals & Avgs	**20 trips**	**20,345 Lbs, 9.2 mt**	**64**	**94.9**	**5.0**	**41**	**214**	**61**	**43**		

Table 1b. Summary statistics for the trawl data by area (west to east).

Area	Trips	Est. Total Catch Pounds	Tow Time Total hours	Avg Rate Lbs/Hr	Avg Count Number/Lb
MA-NH	**5**	**4,040**	**29**	**141**	**45**
Western ME	**5**	**6,770**	**17**	**394**	**44**
Midcoast ME	**5**	**7,545**	**16**	**473**	**40**
Eastern ME	**5**	**1,990**	**33**	**60**	**42**
Totals & Avgs	**20**	**20,345 Lbs, 9.2 mt**	**95**	**214**	**43**

Table 2. Summary statistics for the Maine trap data: estimated total shrimp catch, number of traps, number of set-over days, average depth, temperature, shrimp (all species) count per pound, percent of the shrimp catch that was *Pandalus borealis* (by count), and percent of *P. borealis* females whose eggs had hatched off, by area and haul day.

Area	Date	Est. Total Catch	Traps	Set Time	Avg. Depth	Temp.	Count	*P. borealis*	Egg Hatch
		Pounds	Hauled	Days	Fathoms	℃	Number/Lb	%	%
Boothbay Harbor	28-Jan-16	40	40	3	32		52	57%	1%
	29-Jan-16	18	40	1	35				
	30-Jan-16	19	40	1	32				
	02-Feb-16	27	40	3	32				
	06-Feb-16	50	40	4	36				
	09-Feb-16	165	40	3	34				
	11-Feb-16	156	40	2	33		40	91%	7%
	12-Feb-16	166	40	1	33				
	13-Feb-16	130	12	1	29				
	15-Feb-16	530	38	3	30	3.93			
	18-Feb-16	274	34	3	30	3.93			
	19-Feb-16	210	22	1	30	4.45			
	22-Feb-16	581	40	4	31	4.38			
	26-Feb-16	425	32	4	29	3.64	39	89%	46%
	01-Mar-16	477	19	5	29	4.95			
	04-Mar-16	377	18	3	29	5.33			
	06-Mar-16	342	19	2	30	4.84			
	10-Mar-16	325	40	4	32	4.53	38	94%	58%
	12-Mar-16	255	16	2	26	4.38			
	13-Mar-16	223	26	3	31	4.35			
	16-Mar-16	234	24	4	28	4.32			
	18-Mar-16	257	34	3	30	4.32			
	20-Mar-16	280	40	2	33	4.64			
	23-Mar-16	140	40	3	29	4.61			
	25-Mar-16	40	40	2	30	4.51			
	28-Mar-16	25	40	3	33	4.48			
	30-Mar-16	3	24	2	43	4.74			
	06-Apr-16	9	20	8	47	5.08	65	24%	100%
Friendship	25-Jan-16	66	30	2	31		48	66%	2%
	28-Jan-16	58	30	3	31				
	02-Feb-16	127	30	5	31				
	05-Feb-16	62	33	3	31				
	09-Feb-16	120	39	4	30		40	95%	12%
	15-Feb-16	138	39	6	30				
	18-Feb-16	182	39	3	30	4.09			
	22-Feb-16	308	39	4	30	3.85	40	98%	21%
	24-Feb-16	292	39	2	30	3.70			
	01-Mar-16	295	39	6	30	4.77			
	04-Mar-16	282	39	3	30	4.69			
	08-Mar-16	284	39	4	30	4.32	41	99%	71%
	10-Mar-16	199	27	2	31	4.32			
	12-Mar-16	123	21	3	30	4.09			
	14-Mar-16	217	39	2	30	4.22			
	17-Mar-16	186	39	3	30	4.19			
	20-Mar-16	194	39	3	30	4.27			
	24-Mar-16	92	39	3	30	4.30	42	96%	94%
	04-Apr-16	12	39	11	30	4.71			
	13-Apr-16	2	18	9	31	4.84	67	29%	100%
Totals & Avgs	**48 trips**	**9,017 Lbs, 4.1 mt**	**1,594**	**161**	**31**		**40**		

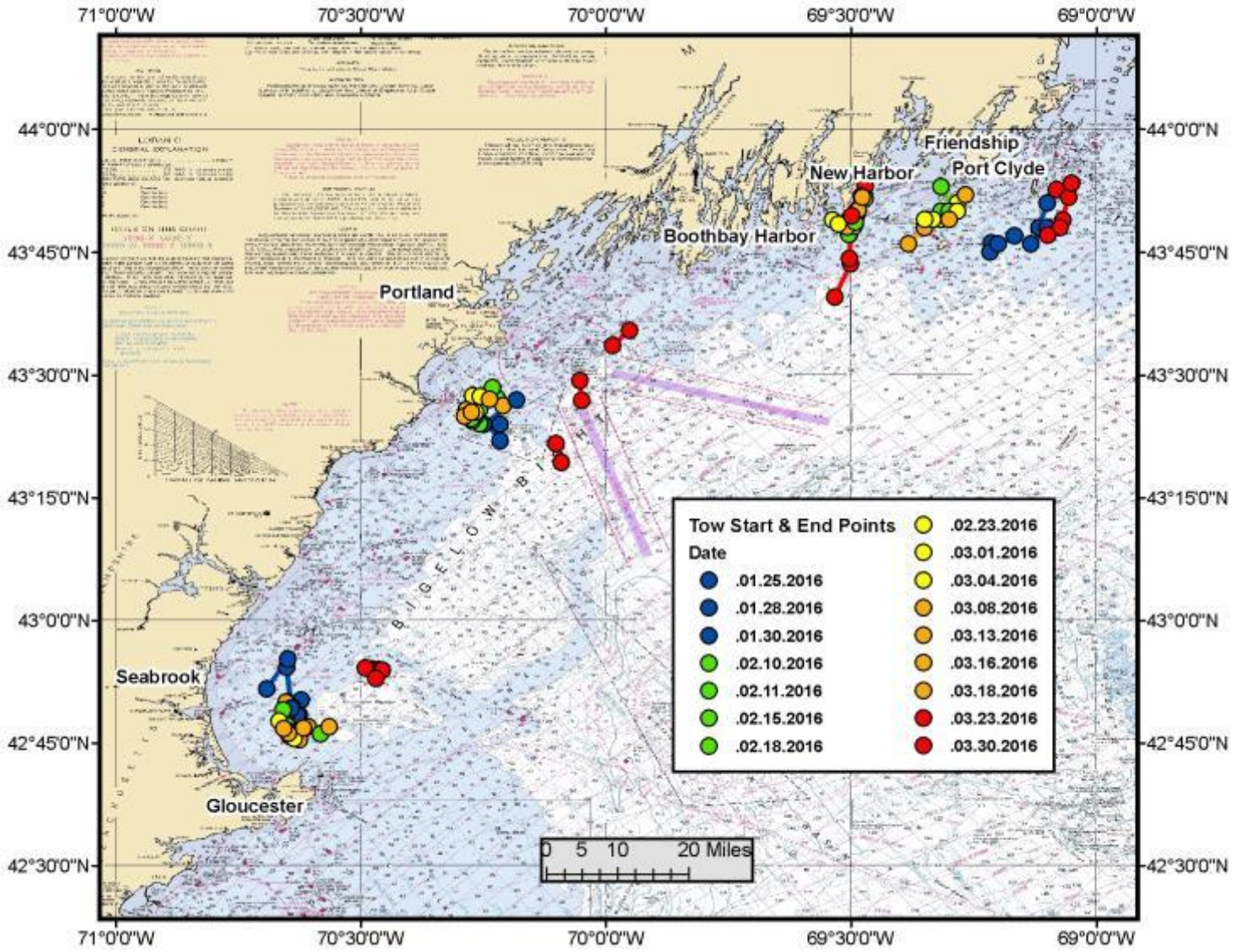

Figure 1. Locations of 2016 Gulf of Maine northern shrimp sampling tows. Color palette (blue to red) indicates fishing date: First trip for each trawler is indicated in blue, second is green, third is yellow, fourth is orange, and fifth is red.

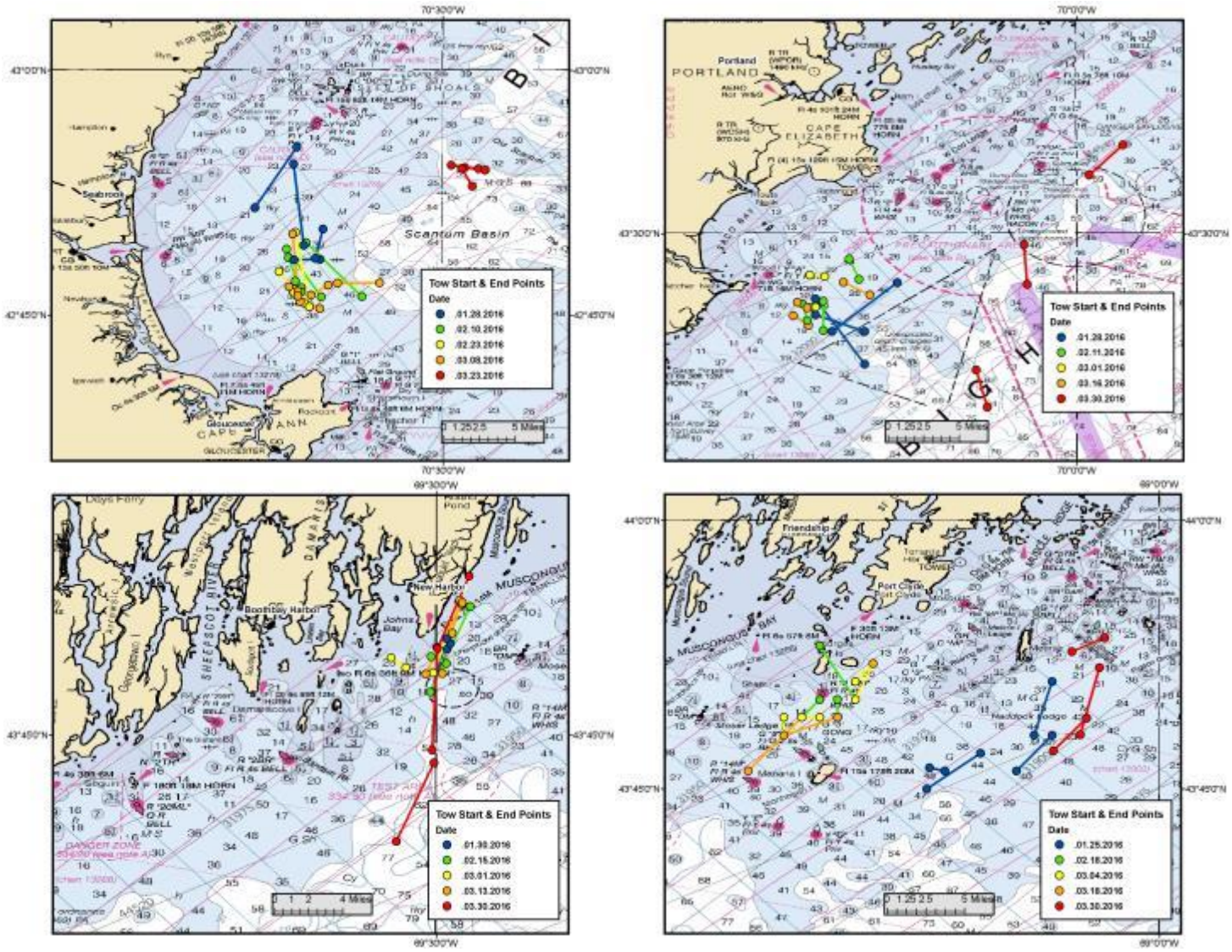

Figure 2. Locations of 2016 Gulf of Maine northern shrimp sampling tows by region:
New Hampshire (top left), Western Maine (top right), Midcoast Maine (bottom left), and Eastern Maine (bottom right).

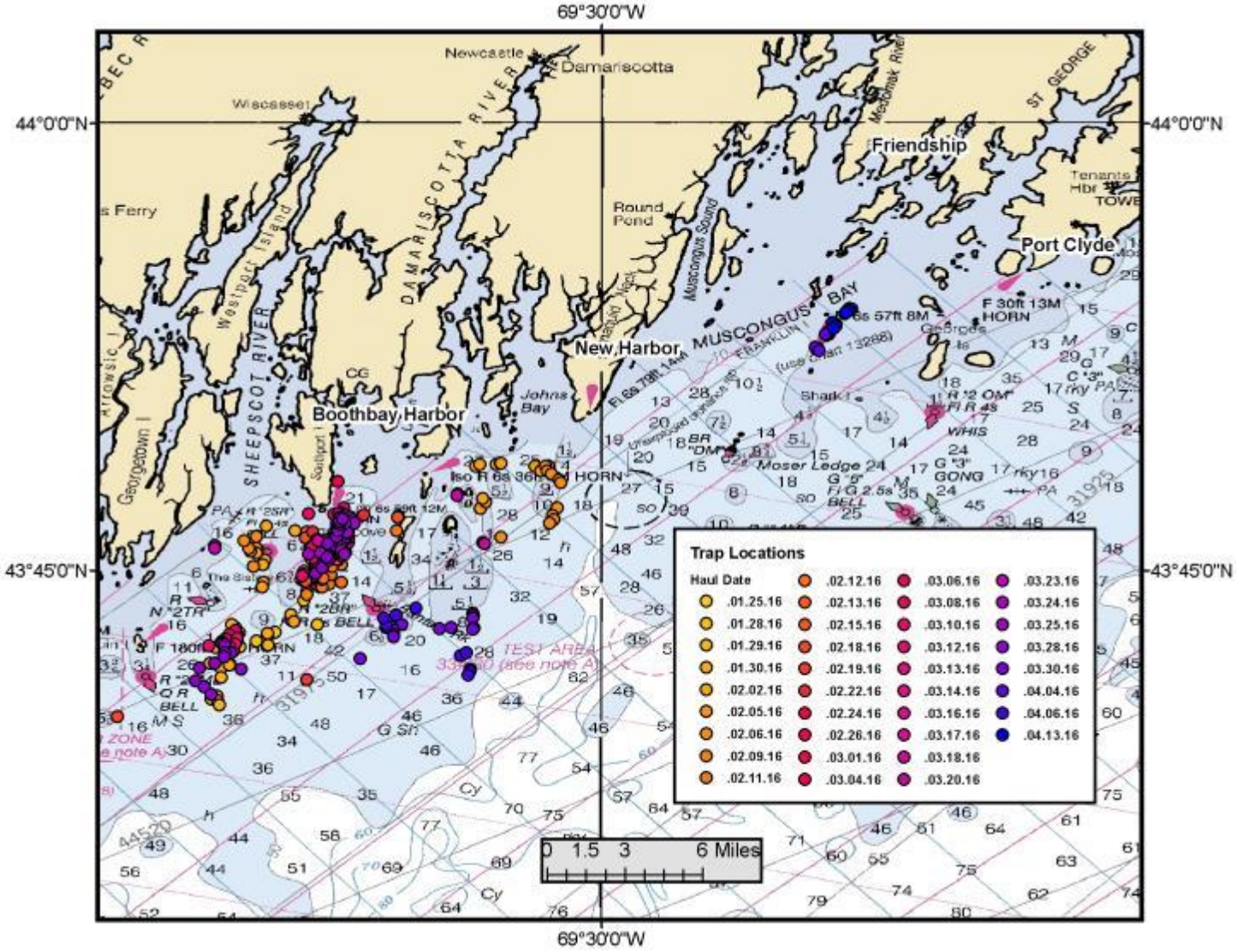

Figure 3. Locations of 2016 Gulf of Maine shrimp sampling traps. Color palette (yellow to blue) indicates fishing date. Boothbay Harbor traps are to the west of the 69°30" longitude line; Friendship traps are in Muscongus Bay.

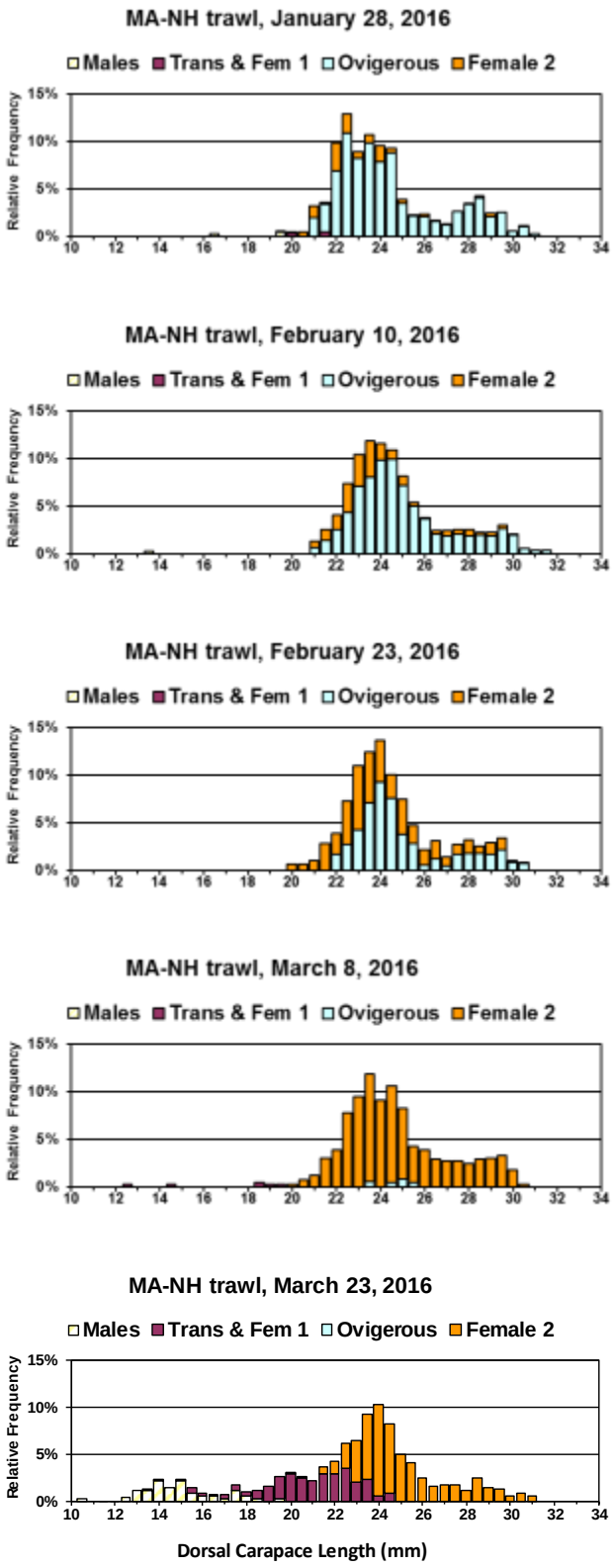

Figure 4. Northern shrimp relative size-sex-stage frequency distributions from New Hampshire (Seabrook) trawl samples.

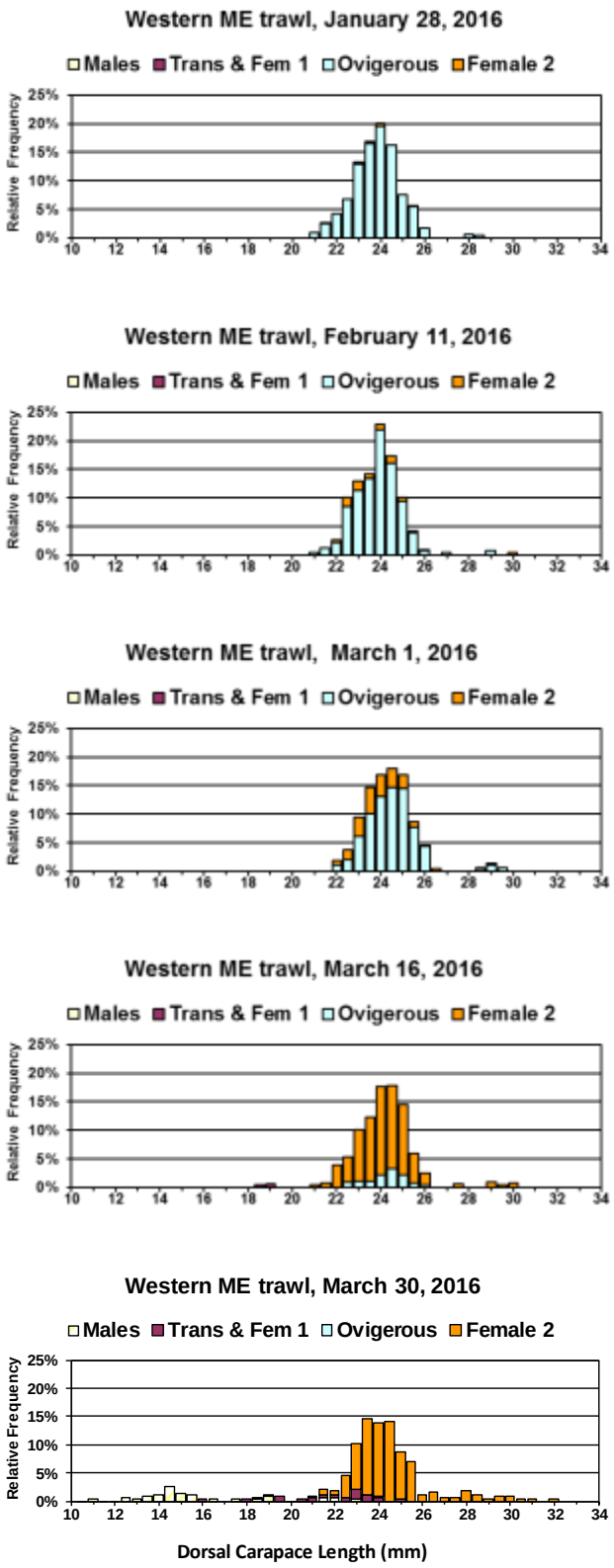

Figure 5. Northern shrimp relative size-sex-stage frequency distributions from Western Maine (Portland) trawl samples.

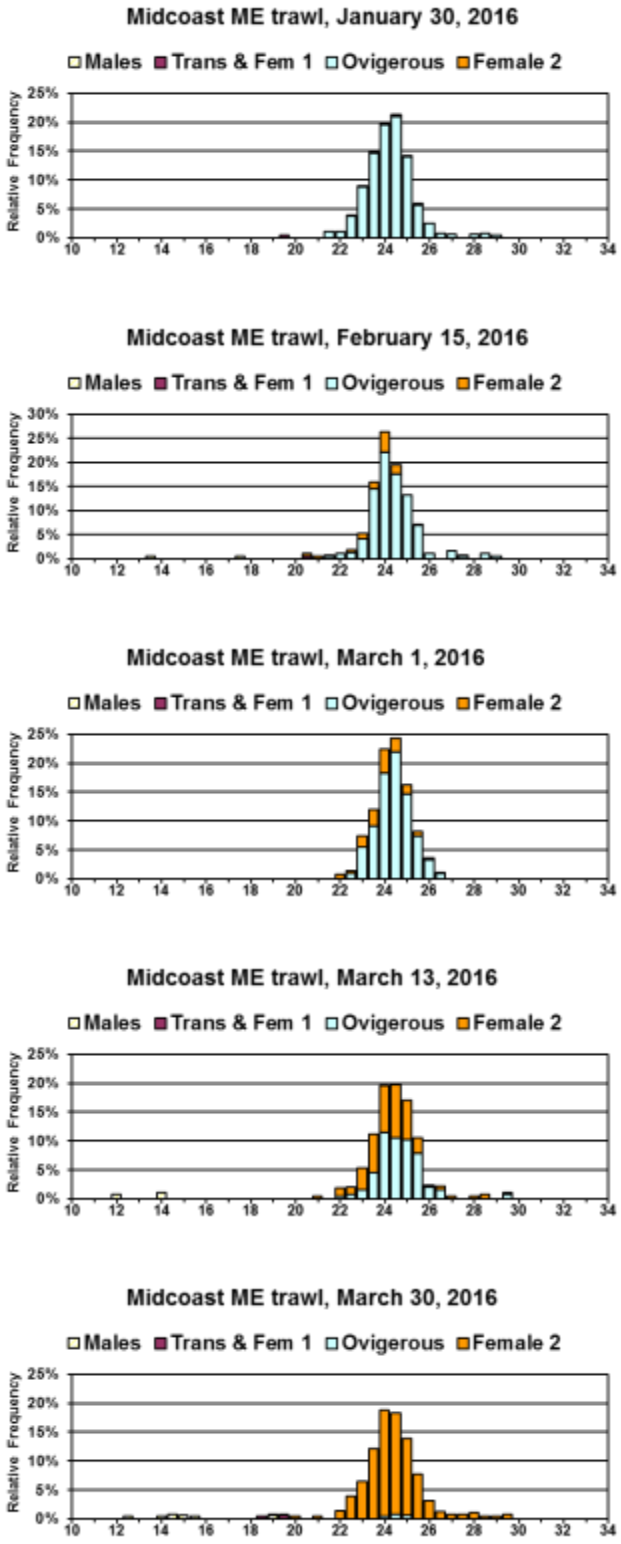

Figure 6. Northern shrimp size-sex-stage frequency distributions from Midcoast Maine (New Harbor) trawl samples.

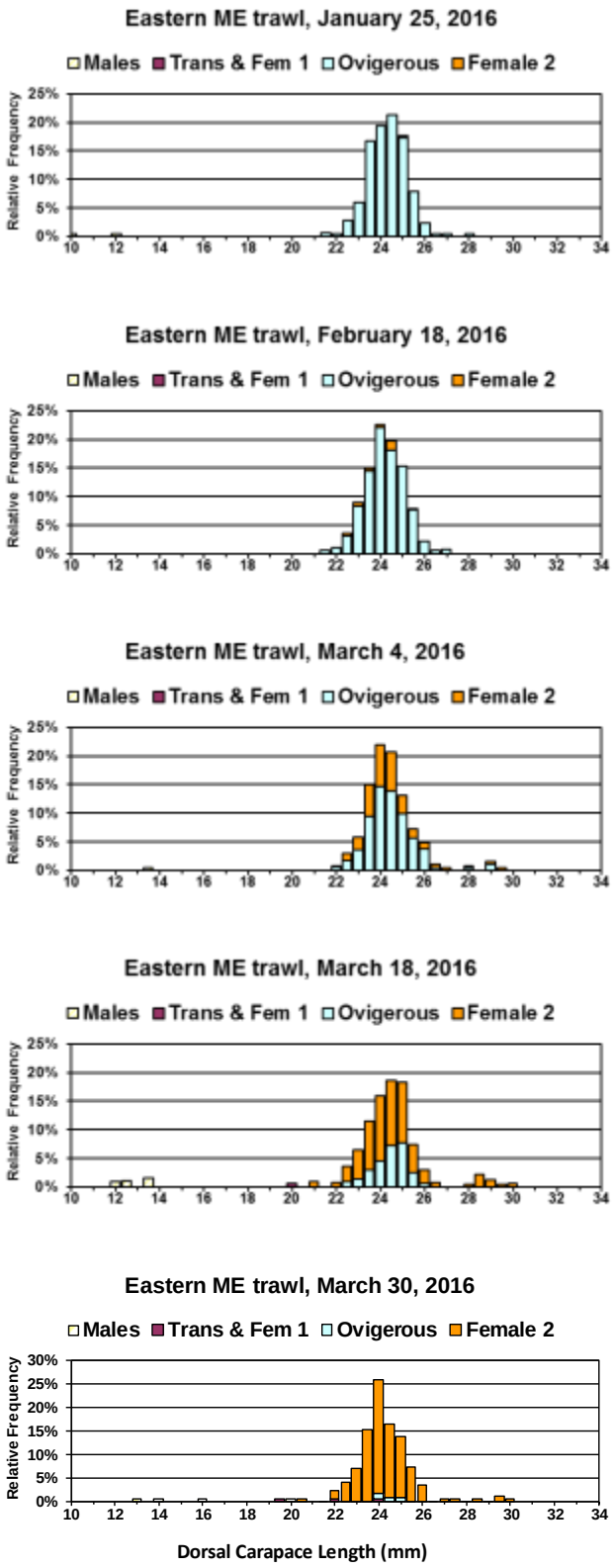

Figure 7. Northern shrimp relative size-sex-stage frequency distributions from Eastern Maine (Port Clyde) trawl samples.

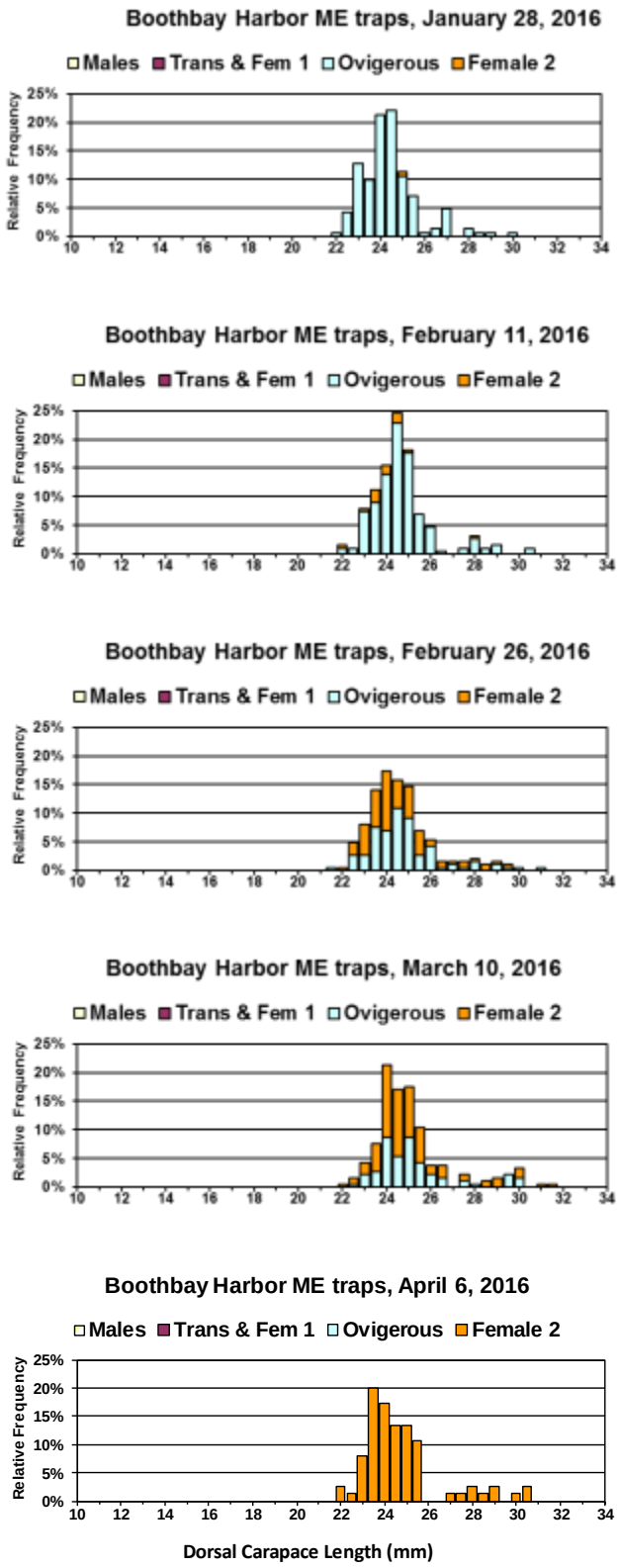

Figure 8. Northern shrimp relative size-sex-stage frequency distributions from Midcoast Maine (Boothbay Harbor) trap samples.

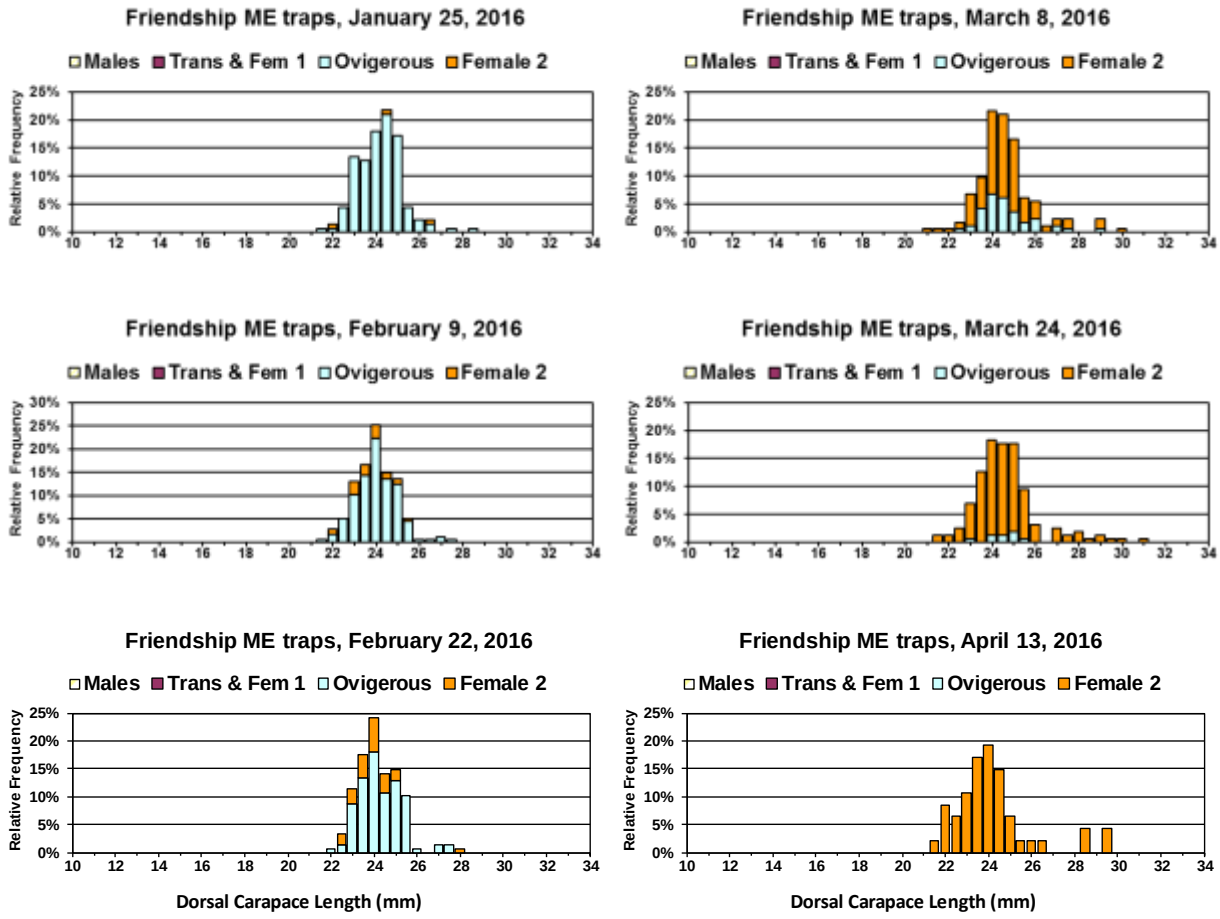

Figure 9. Northern shrimp relative size-sex-stage frequency distributions from Friendship, Maine trap samples.

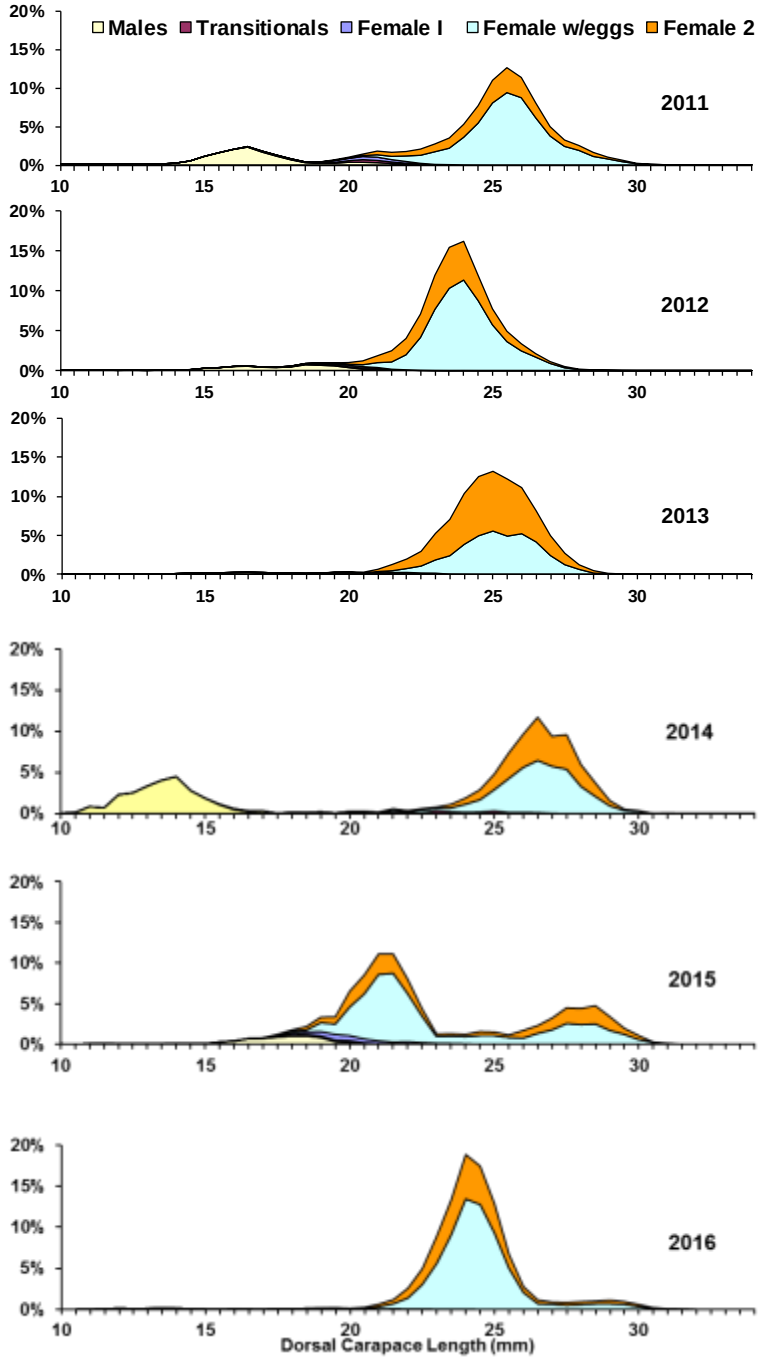

Figure 10. Northern shrimp relative size-sex-stage frequencies from winter sampling with data from 2011–2013 GOM fishery samples expanded to landings, 2014 Pemaquid Point, Maine samples, and 2015 winter samples (modified from Whitmore *et al.* 2015), and 2016 winter samples expanded to sampled catches.

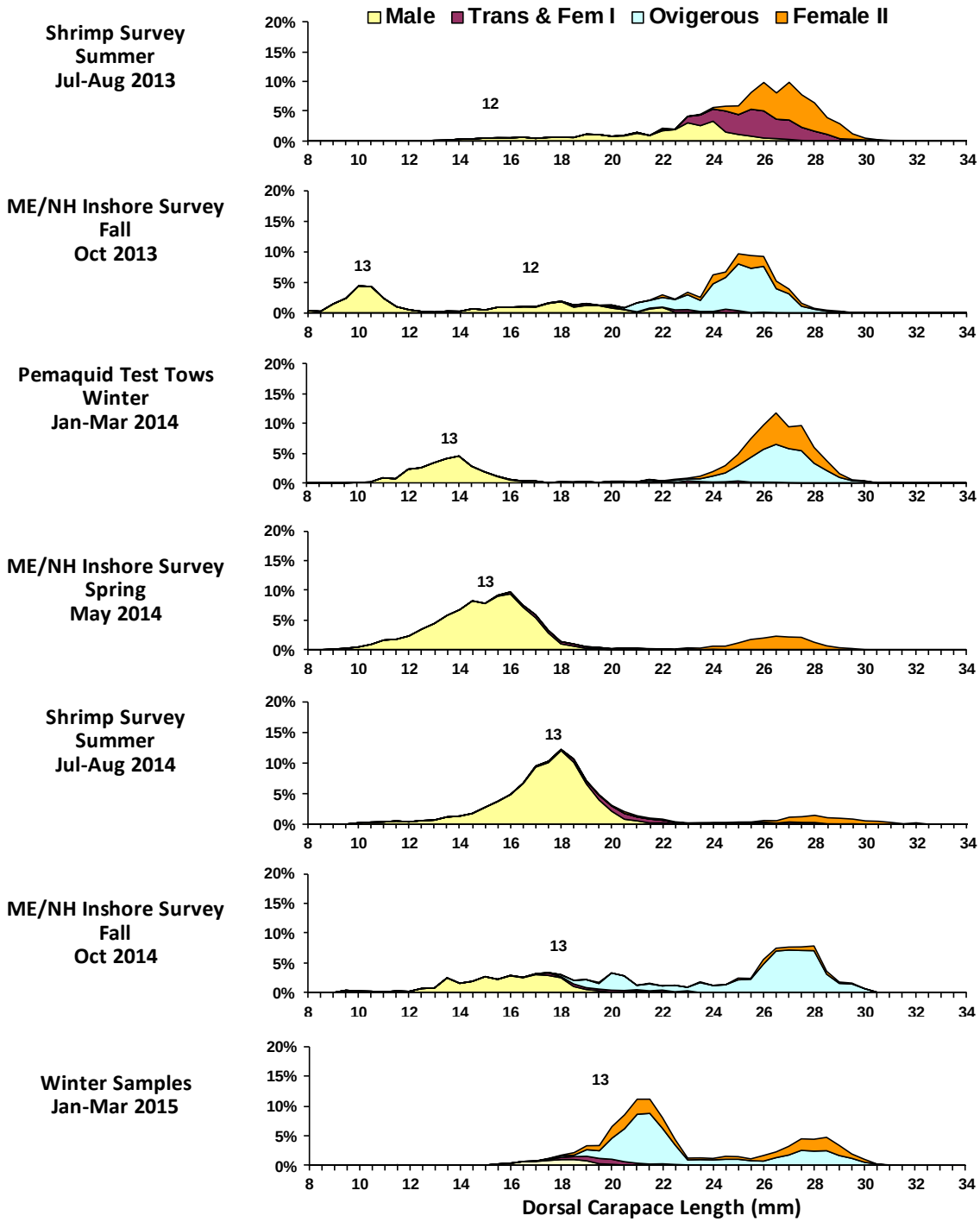

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Figure 11. Northern shrimp relative size-sex-stage frequencies from 2013–2016 GOM surveys and sampling programs. Two-digit years denote the mode of assumed 2012–2015 year classes.

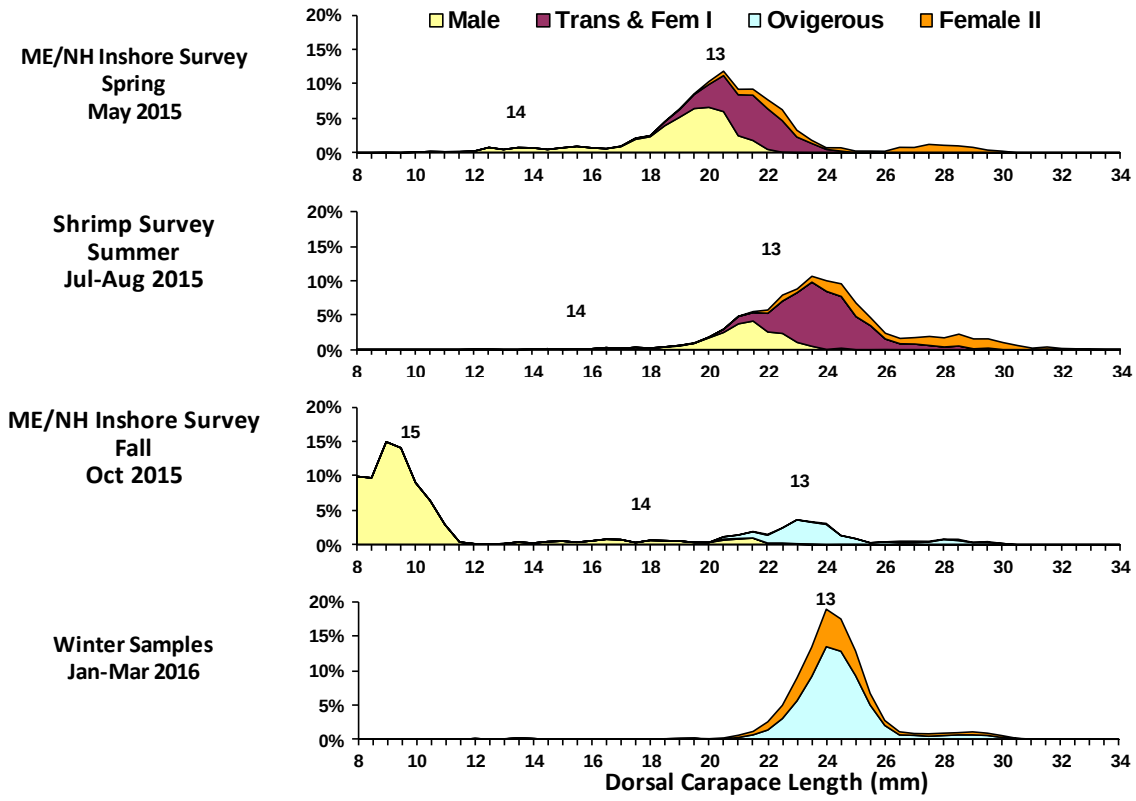


Figure 11. Continued

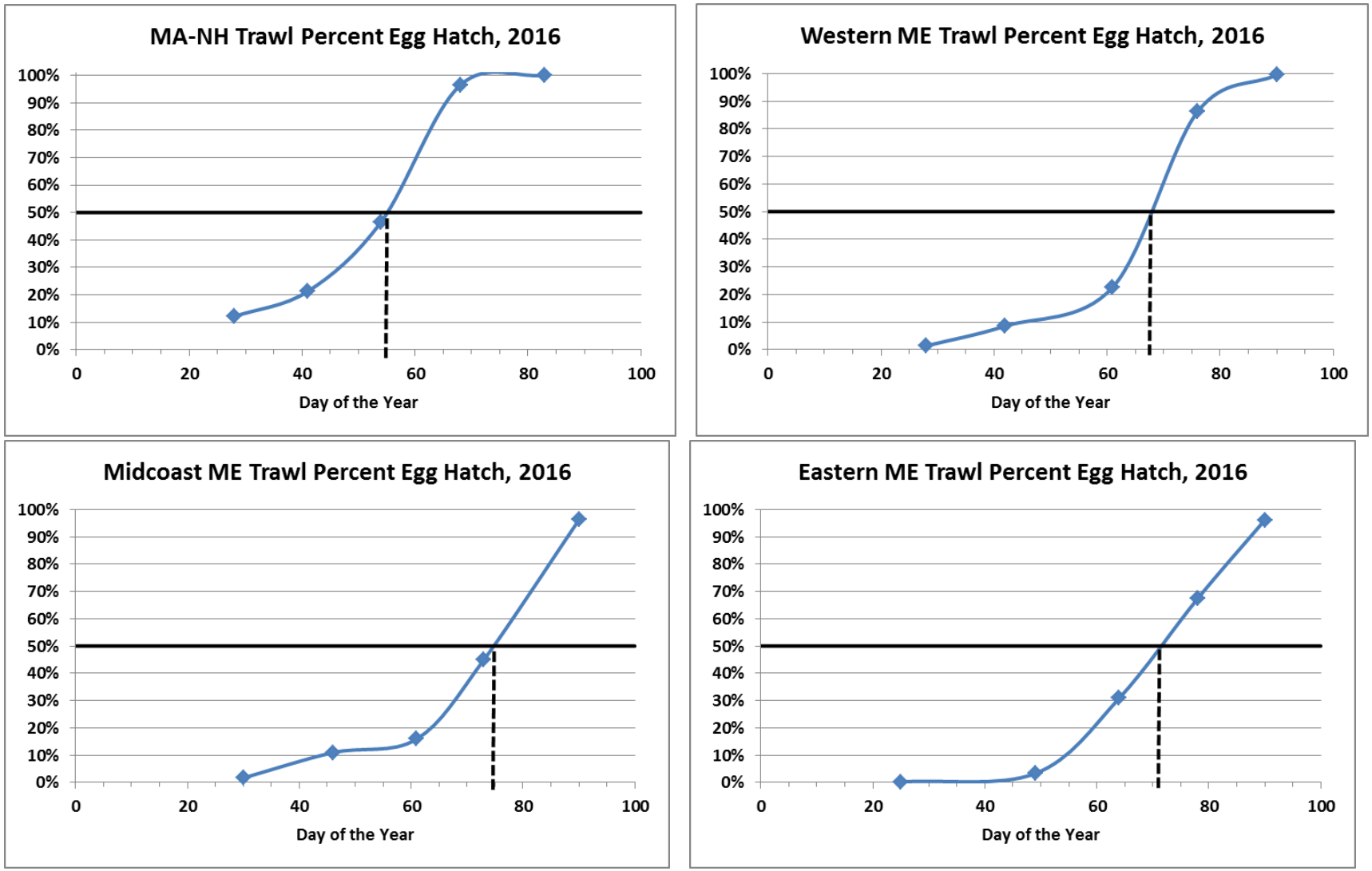
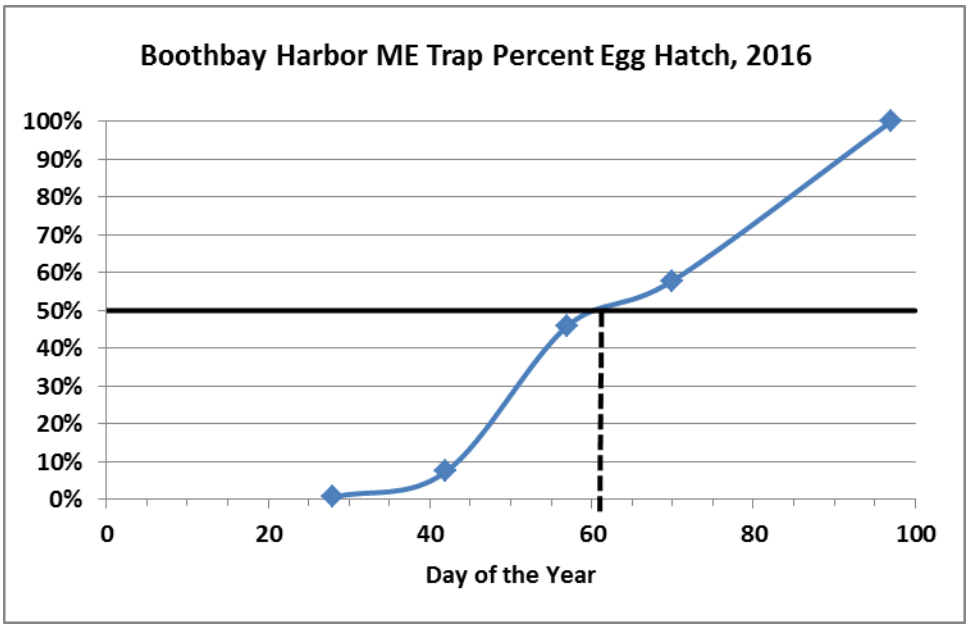


Figure 12. Mean percentage of egg hatch by day of the year (2016) for northern shrimp, for New Hampshire trawl samples (top left), Western Maine trawl samples (top right), Midcoast Maine trawl samples (bottom left) and Eastern Maine samples (bottom right). Dotted line indicates approximate day of 50% hatch.



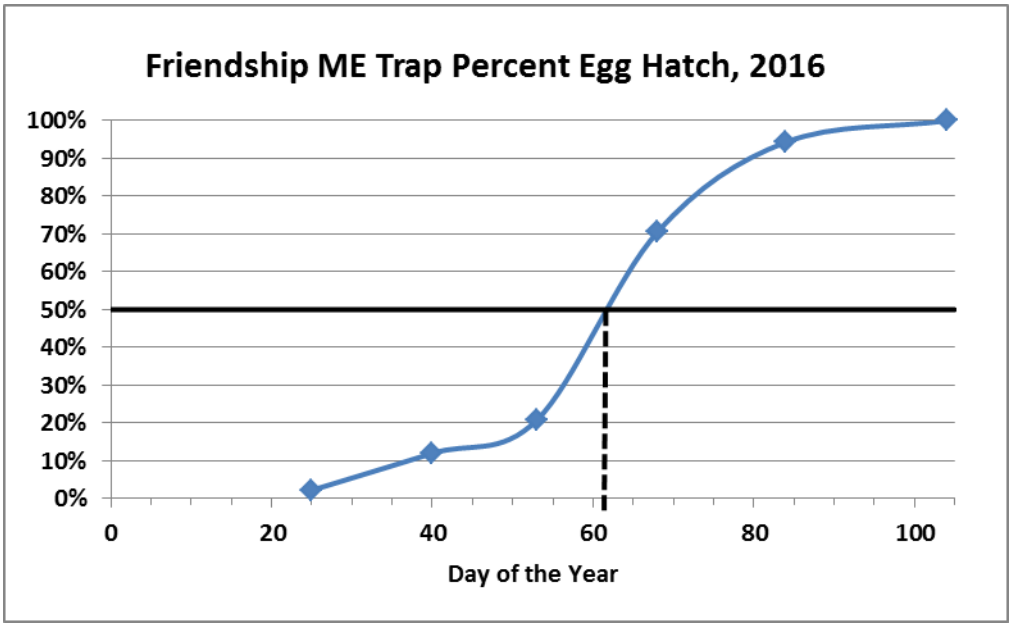


Figure 13. Mean percentage of egg hatch by day of the year (2016) for northern shrimp, for Boothbay Harbor, Maine trap samples (above) and Friendship, Maine trap samples (below). Dotted line indicates approximate day of 50% hatch.

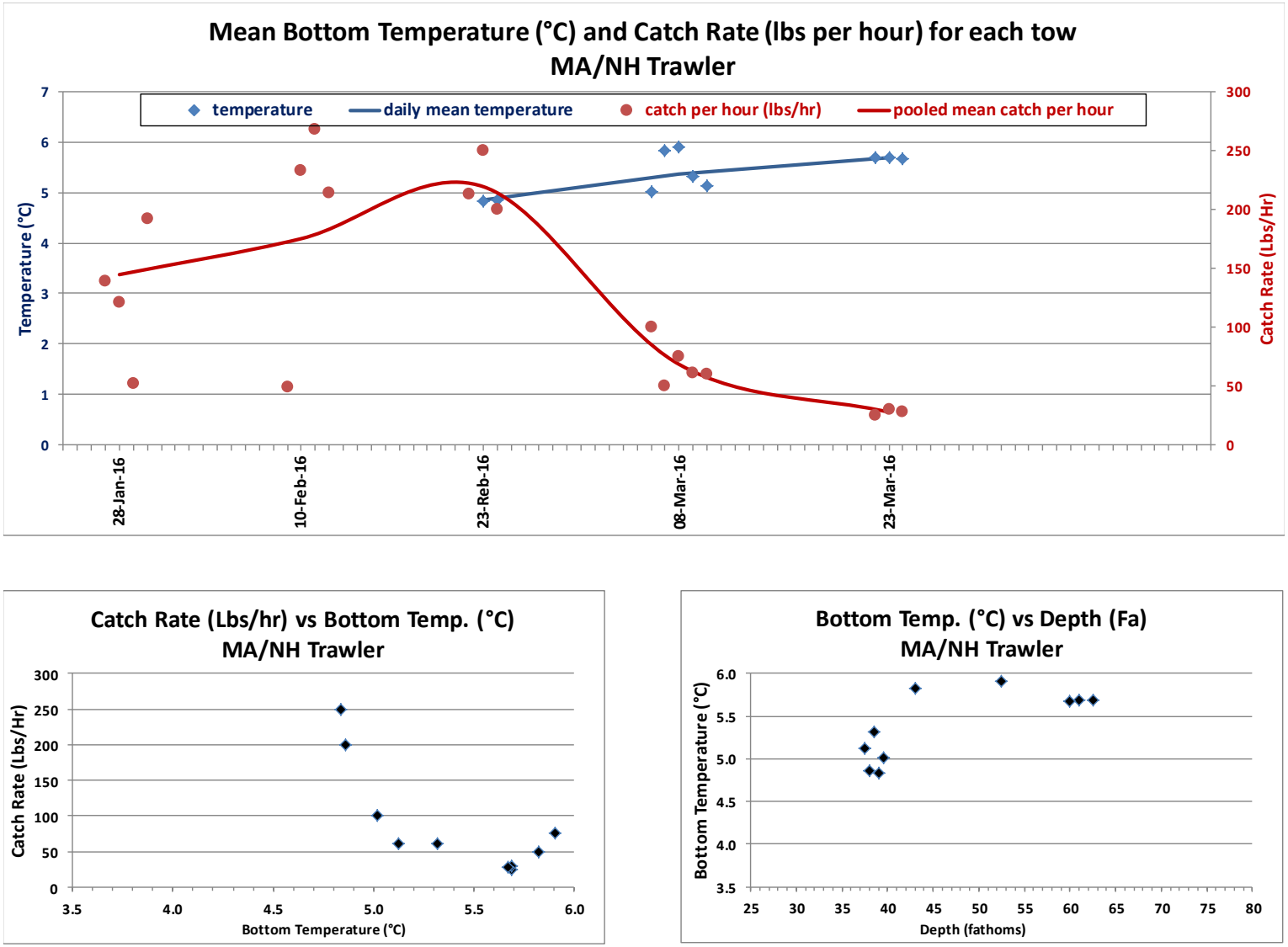


Figure 14a. Mean bottom temperatures and northern shrimp catch rates for each tow by date (top, points) with daily means (top, lines), catch rates vs. temperature (bottom left), and temperature vs depth (bottom right) for New Hampshire tows.

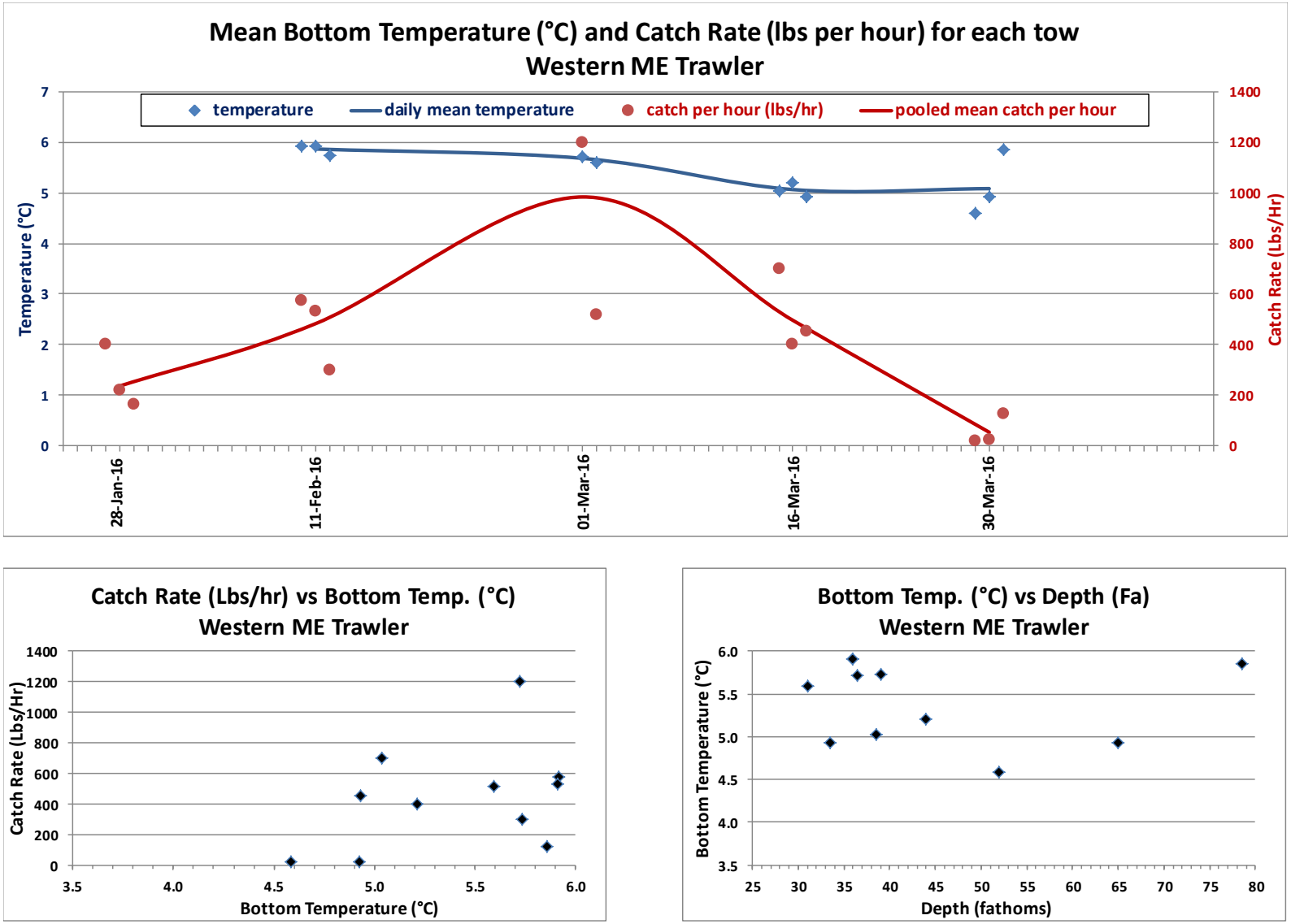


Figure 14b. Mean bottom temperatures and northern shrimp catch rates for each tow by date (top, points) with daily means (top, lines), catch rates vs. temperature (bottom left), and temperature vs depth (bottom right) for Western Maine tows.

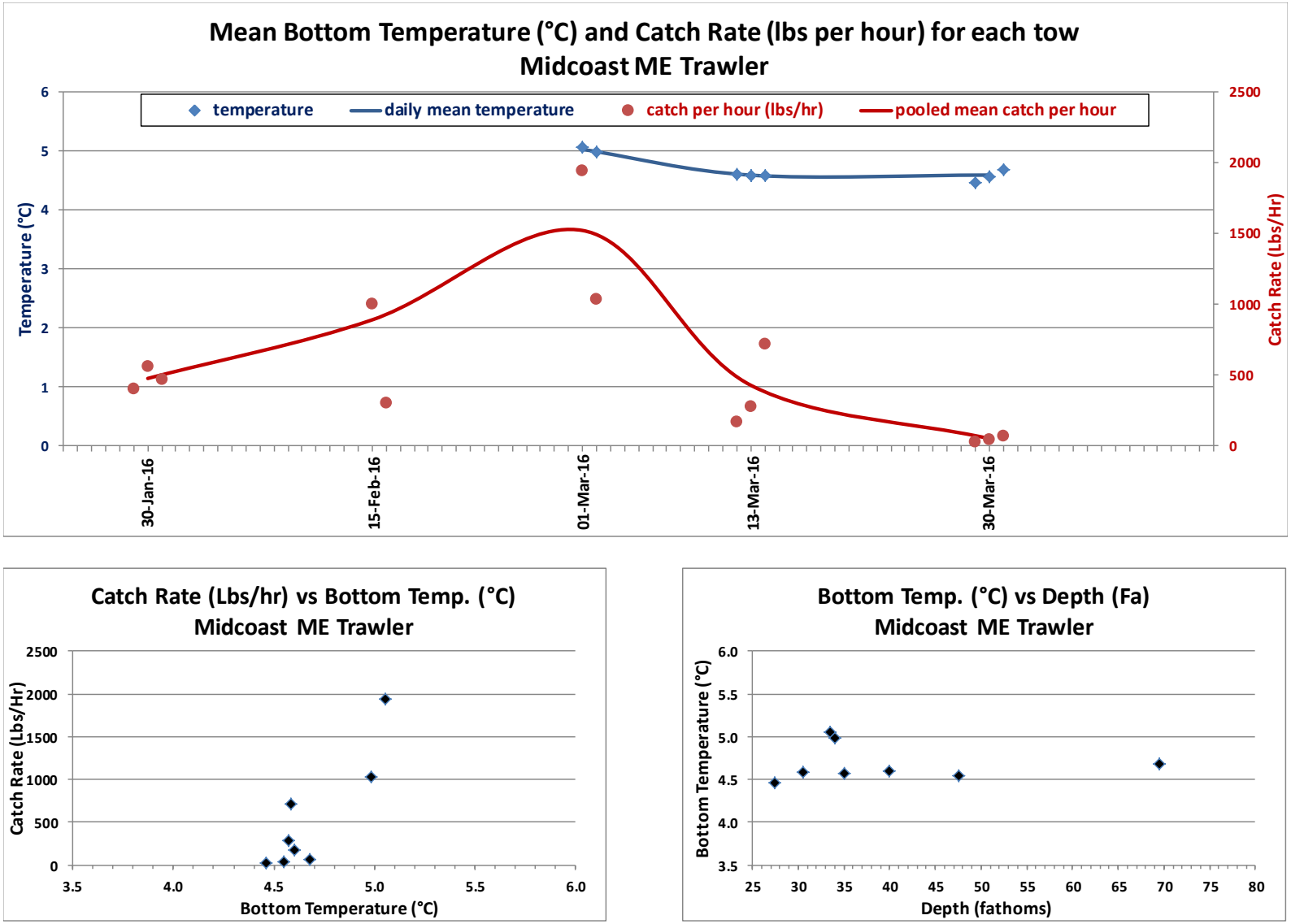


Figure 14c. Mean bottom temperatures and northern shrimp catch rates for each tow by date (top, points) with daily means (top, lines), catch rates vs. temperature (bottom left), and temperature vs depth (bottom right) for Midcoast Maine tows.

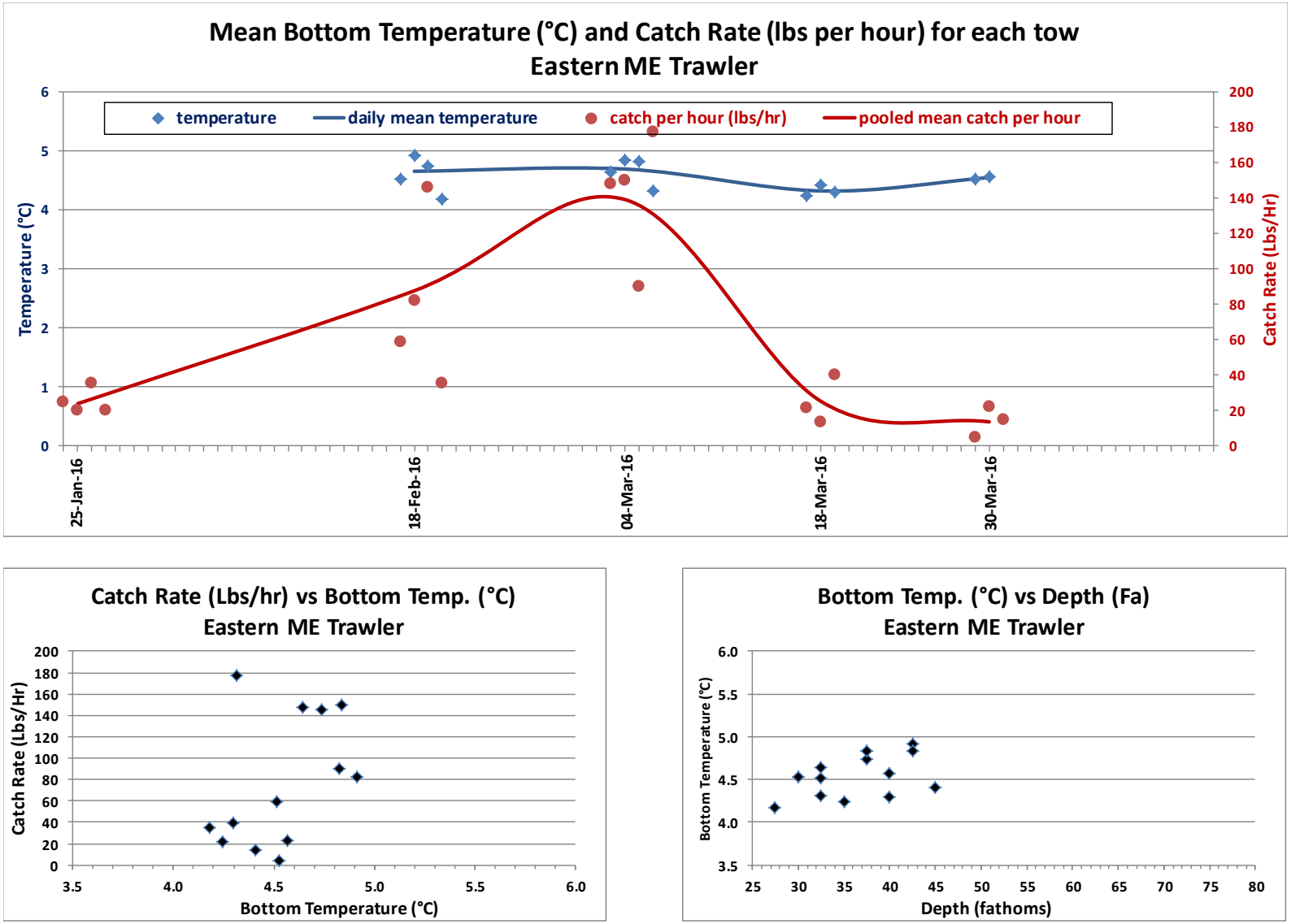
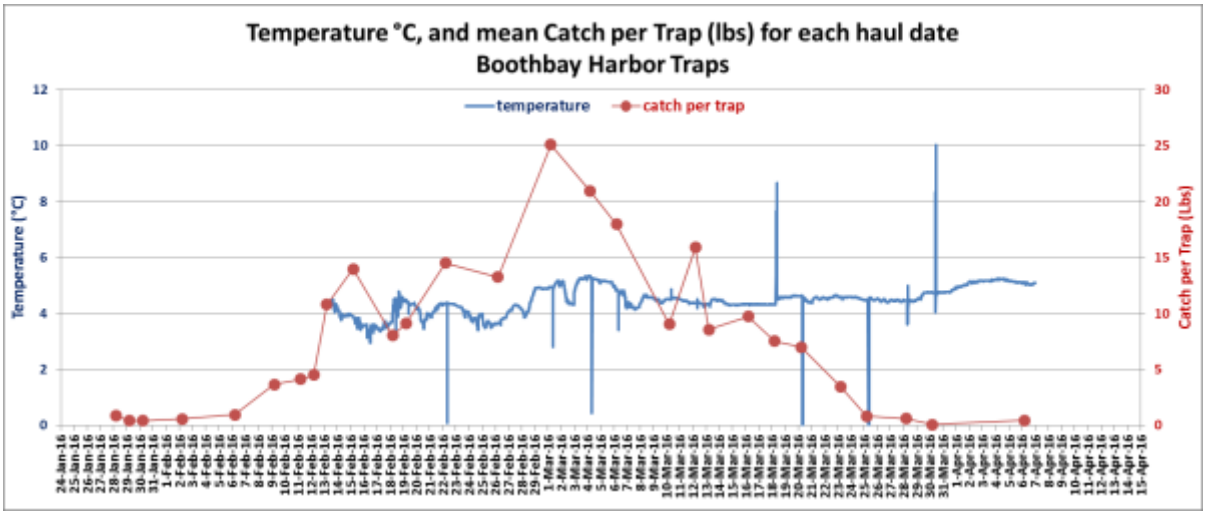


Figure 14d. Mean bottom temperatures and northern shrimp catch rates for each tow by date (top, points) with daily means (top, lines), catch rates vs. temperature (bottom left), and temperature vs depth (bottom right) for Eastern Maine tows.



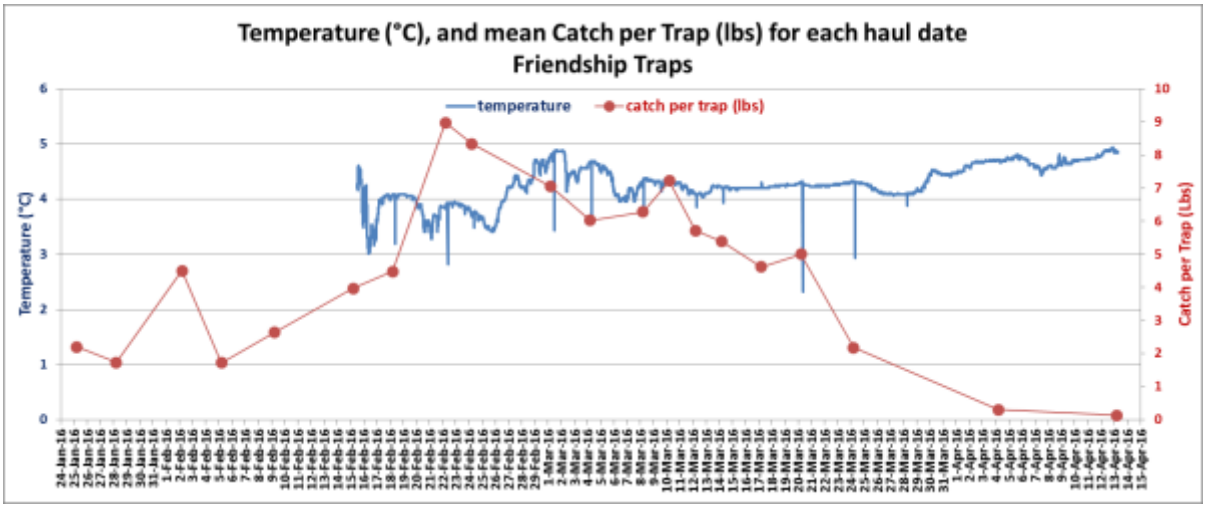


Figure 15. Continuous bottom temperatures (every 5 minutes) and mean northern shrimp catch rates (lbs per trap) for Boothbay Harbor (top) and Friendship (bottom) traps by haul date. Note temperature spikes and valleys on days the trap with the temperature logger was brought to the surface.

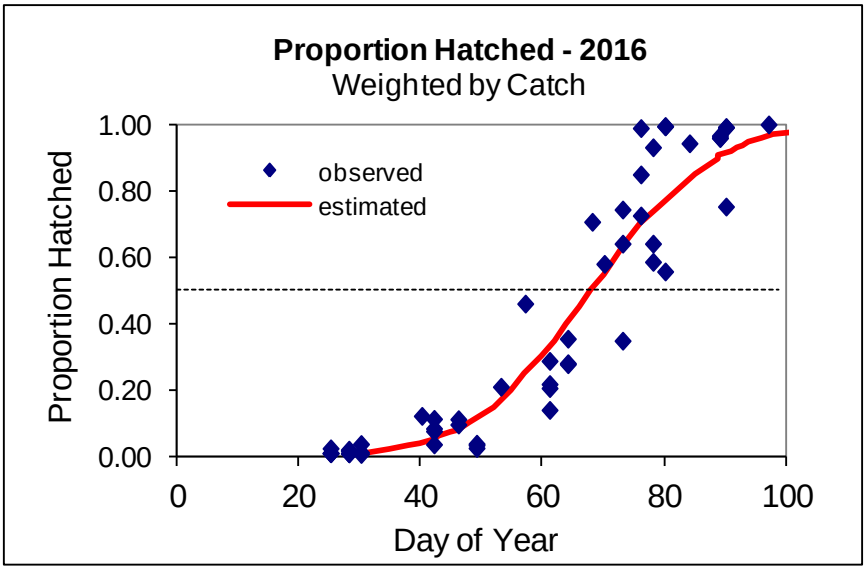


Figure 16. Proportion hatched over time in all Maine samples during 2016. Blue dots are observed proportions in samples; red line is fitted estimate from probit analysis.

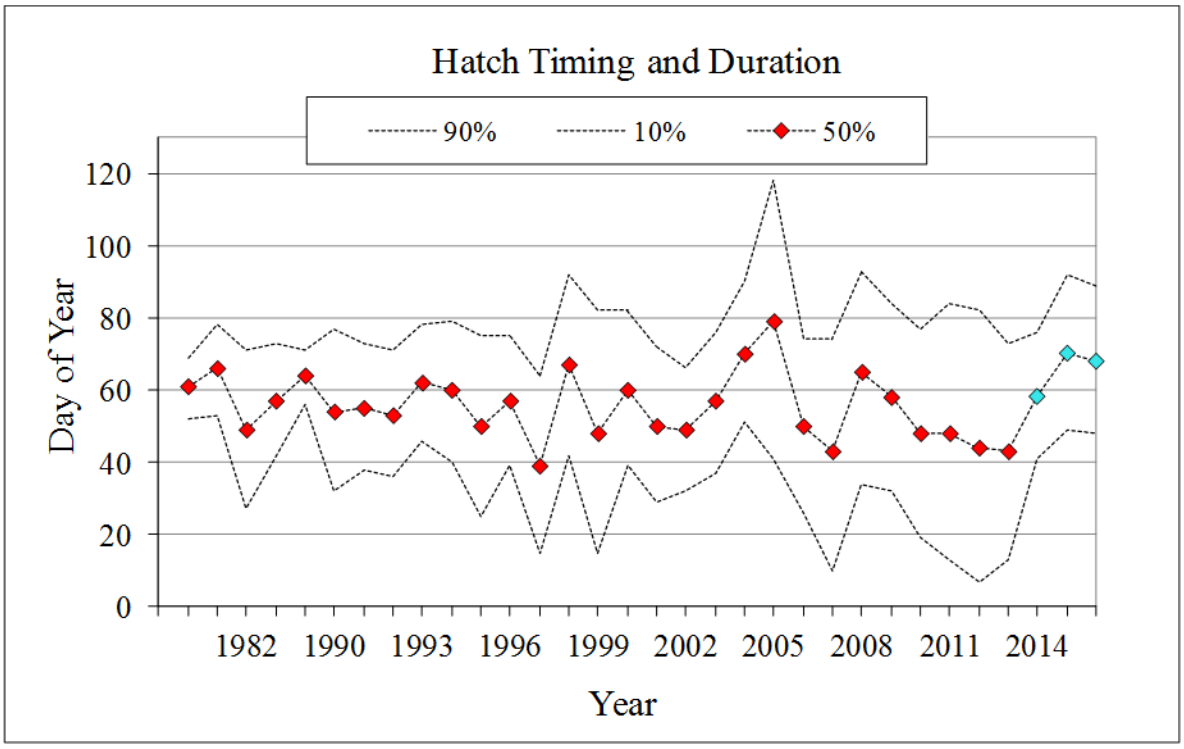


Figure 17. Time series of hatch timing estimates from sampling of the Maine commercial fishery (1980–1984, 1989–2013) (red), and NSTC winter sampling in Maine (2014–2016) (blue).