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Summary of Coastal Intertidal Forage Fish Spawning Surveys: October 2012 – September 2013

by Mariko Langness, Phillip Dionne, Erin Dilworth, and Dayv Lowry

Washington Department of FISH and WILDLIFE

FPA 14-01

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Mariko Langness[1], Phillip Dionne[2], Erin Dilworth[1], and Dayv Lowry[3]

[1]Washington Department of Fish and Wildlife
Fish Program, Marine Resources Division
48 Devonshire Rd., Montesano, WA 98563

[2]Washington Department of Fish and Wildlife
Habitat Program, Science Division
1111 Washington St. SE, Olympia, WA, 98501

[3]Washington Department of Fish and Wildlife
Fish Program, Marine Resources Division
1111 Washington St. SE, Olympia, WA, 98501

to

Washington Department of Natural Resources
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Abstract

Marine spatial planning (MSP) involves the identification and mapping of marine resources in pursuit of developing long-term utilization plans for these resources after weighing costs and benefits to diverse stakeholders. As part of a coast-wide MSP process funded by the Washington State Legislature the Washington Department of Fish and Wildlife (WDFW), in collaboration with Makah, Quileute, Hoh and Quinault tribes, conducted a 12 month survey in an effort to document the presence of eggs deposited by forage fishes spawning in the intertidal. From October 2012 through September 2013, beaches along the Washington outer coast were surveyed for surf smelt *Hypomesus pretiosus*, night smelt *Spirinchus starksi*, and sand lance *Ammodytes hexapterus* spawn. The specific goals of the study were to: 1) subsample the breadth of the outer coast monthly; 2) identify any forage fish eggs found to the lowest taxonomic level possible; and 3) geo-reference all survey data to provide an easily accessible overview of sampling effort and egg detections to date. A comprehensive sampling strategy for the entire outer coast was designed, with 1003 sampling sites allocated over the 12 month survey. Of the 1003 total planned sites, 835 (83%) were sampled. Smelt eggs were present at 41 of these sites, while the remaining 794 sites were absent of forage fish eggs of any species. Of the sites where smelt spawn was present plus one non-random site, 32 met the WDFW 2+ egg standard and 28 became newly documented spawning sites. Spawn was documented in each month from February through September, one month earlier than suggested by previous sampling efforts. The number of documented spawning sites and number of eggs per site peaked in June and July suggesting a seasonal trend in spawn abundance. Spawning sites were documented in the northern central coast, ranging as far south as site 335 (south of Wreck Creek) and as far north as site 624 (near Ellen Creek). Analysis of the developmental stage of some eggs collected indicated the presence of multiple broods at the same site simultaneously. The presence of eggs at different sites during the late winter and the presence of multiple egg stages at one site suggest that several spawning events occurred during the season. We expect that further sampling would identify a broader spatial and temporal range of smelt spawning on the outer coast. Sampling over multiple seasons would likely increase egg detections as some sites may have only limited use on a seasonal or annual basis.

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Introduction

The process of Marine Spatial Planning (MSP) has developed over the past ten years to bring together stakeholders from diverse sectors that make use of the ocean, including governments, fishing and energy industries, conservationists, landowners, and recreationists, in order to identify, map, and allow for effective long-term utilization of the marine environment (Douvere 2008). Ultimately, this process is intended to minimize conflicts among sectors by spatiotemporally parsing both consumptive and nonconsumptive exploitation of the environment in such a way that the needs of all parties are met. Where contentious issues centering on incompatible activities arise, the MSP process allows for a mechanism by which competing uses can be weighed, the impact of trade-offs identified, and a data-driven compromise made (Douvere 2008; Lester et al. 2013; Samhouri and Levin 2012). In some cases, this optimized planning process has been shown to benefit numerous sectors in complex ways, such as increasing fishery profits by excluding fishing in target regions (e.g. Marine Protected Areas) while at the same time increasing ecotourism opportunities (Rassweiler et al. 2012).

As part of the first phase of a coast-wide MSP process funded by the Washington State Legislature and administered by the Washington State Department of Natural Resources (WDNR), the Washington Department of Fish and Wildlife (WDFW) was contracted to conduct surveys for eggs deposited by intertidal spawning forage fishes (surf smelt *Hypomesus pretiosus*, night smelt *Spirinchus starksi*, and Pacific sand lance *Ammodytes hexapterus*) along the Washington coast from the mouth of the Columbia River north to Cape Flattery. Knowledge of these species is critical because of the role they play as mid-level prey in the marine food web (Penttila 2007; Simenstad et al. 1979) and because they are exploited recreationally and commercially (surf smelt only) by fishers in Washington. Due to the local knowledge of smelt fisheries possessed by coastal Indian Tribes, and their role as co-managers of the natural resources of Washington State, surveys were collaboratively conducted with members and employees of the Makah, Quileute, Hoh, and Quinault Nations.

WDFW and its collaborators have collected extensive data on the location and timing of smelt and sand lance spawning in Puget Sound over the past 35 years (Penttila 1995, 2000, 2007; Quinn et al. 2012), including the strait of Juan de Fuca (Shaffer et al. 2003), however a comparative paucity of effort has been expended along the outer coast. Sampling in Puget Sound has also identified seasonal and tide height-specific patterns in spawning distribution and a variety of targeted studies have further identified key environmental parameters associated with use of beaches for spawning, and high egg hatching success (de Graaf 2008; Penttila 2001, 2001; Quinn et al. 2012; Rice 2006). As a result of these surveys and associated conservation efforts, the Hydraulic Code Rules of the Washington Administrative Code (WAC220-110) recognize intertidal forage fish habitat as a Saltwater Habitat of Special Concern and provide for a "no net loss" provision to protect these habitats. Additionally in order to protect both spawning adults and the eggs on the beach, certain seasonal windows have been designated "prohibited work times" (WAC220-110-271). A lack of knowledge about spawn timing and distribution along the outer coast has prevented the setting of prohibited work times relevant to intertidal spawning forage fish outside of Puget Sound.

The intertidal habitats in Puget Sound typically vary substantially from those along the outer Washington coast, being generally less exposed to high-energy wave regimes, especially during winter storms. In accordance with traditional tribal knowledge of smelt occurrence along the outer coast, a handful of beach surveys conducted from 1994-1998 identified five spawning areas utilized by forage fish, one of which was substantially inside Grays Harbor (WDFW, unpublished data). In addition to the sites identified by WDFW, surf smelt spawning is well known from Rialto Beach at the mouth of the Quillayute River, which has resulted in additional study of this locality because of the U.S. Army Corps of Engineers potential use of the site to dump dredge spoils (ICF International 2010). Additional surveys have been conducted along the shoreline of the Olympic National Park by Park staff (Steve Fradkin, pers. comm.), but these data have not been made widely available. Because so few locations have been sampled for forage fish spawning activity on the outer coast, the specifics of when, where, and in what particular environments these species spawn is not well understood.

The survey effort described here utilized aerial photography, shoreform information from DNR ShoreZone, LiDAR data, on-the-ground tribal knowledge, and fixed-length survey segments to develop a comprehensive sampling strategy for the entire outer coast. After identifying potential spawning beaches (i.e., any area not composed of solid rock) and taking into account several logistical considerations, including availability of access and sampler safety, we sought to survey 1000 beach segments over as broad a spatial-temporal scale as possible. During any given monthly survey frame, effort was distributed evenly along the outer coast with the goal of subsampling the entire geographic scope of the coast every thirty days. Though largely exploratory in nature, the specific goals of our study were to: 1) subsample the breadth of the outer coast monthly from October through September (and beyond); 2) identify any forage fish eggs found to the lowest taxonomic level possible; and 3) geo-reference all survey data to provide an easily accessible overview of sampling effort and egg detections to date for use in MSP activities, and to guide future survey efforts. The sampling design was constructed to allow use of an occupancy model to predict the likelihood of finding eggs at any given location during any given month, but sample sizes are not currently large enough to allow use of the model and results are not presented here.

Methods

Study Area and Design

Sampling sites were established along the Washington outer coast shoreline, from the Columbia River North Jetty to Cape Flattery, using a stratified random design. The shoreline (158 miles) was separated into 35 sampling “beaches” identified as “semi-exposed cobble-mixed coarse” and “exposed sandy” beach types based on Washington Department of Natural Resources (DNR) ShoreZone line feature GIS data and defined by breaks due to large estuaries (Willapa Bay or Grays Harbor), smaller estuaries and river mouths, or rocky headlands (Fig. 1). Extensive forage fish spawning surveys in Puget Sound (Penttila 1995, 2000, 2007), suggest that the chosen beach types have the potential to support spawning of surf smelt, night smelt, and sand lance. Each sampling “beach” was then subdivided into equal 1000 ft. long beach segments/sites, which is the current and historic mapping and sampling convention used by WDFW in Puget Sound, and assigned sequential beach segment ID/site numbers (Fig. 2). This site length allows sampling protocols to account for pocket beaches and heterogeneity in spawning environment without requiring sampling on a logistically unmanageable scale. “Beach zones” or “sampling regions” were created by an arbitrary grouping of beach segments into logistical sampling strata that roughly followed ownership or management of the land. Beach zones were named as follows: Long Beach, Twin Harbors, Copalis-Moclips, Quinault, Kalaloch-Hoh-Quil, and NW Coast.

The initial seven month survey, from October 2012 through April 2013, produced an expected sample size of 70% (588 sites) of potential spawning beaches, with 10% selected for sampling monthly (84 sites/month). To continue the survey, a new random draw of sites (498 sites) was allocated over an additional 6 month period, May 2013 through October 2013 (81-84 sites/month). As sites could potentially be resampled, sampling coordinates were shifted within the beach segment, using center coordinates from the initial 7 months, and south point coordinates for the additional 6 month period. In total, 1003 sites were allocated for the full year survey, October 2012 – September 2013. October 2013 surveys are not included in this report. Sites were sampled by WDFW, Quinault, Hoh, Quileute, and Makah staff, based on ownership, management, or ease of access to the land where sites were located.

Figure 1. Study area along Washington outer coast, showing 6 defined "beach zones" (Long Beach, Twin Harbors, Copalis-Moclips, Quinault, Kalaloch-Hoh-Quil, and NW Coast) and 35 sampling "beaches".

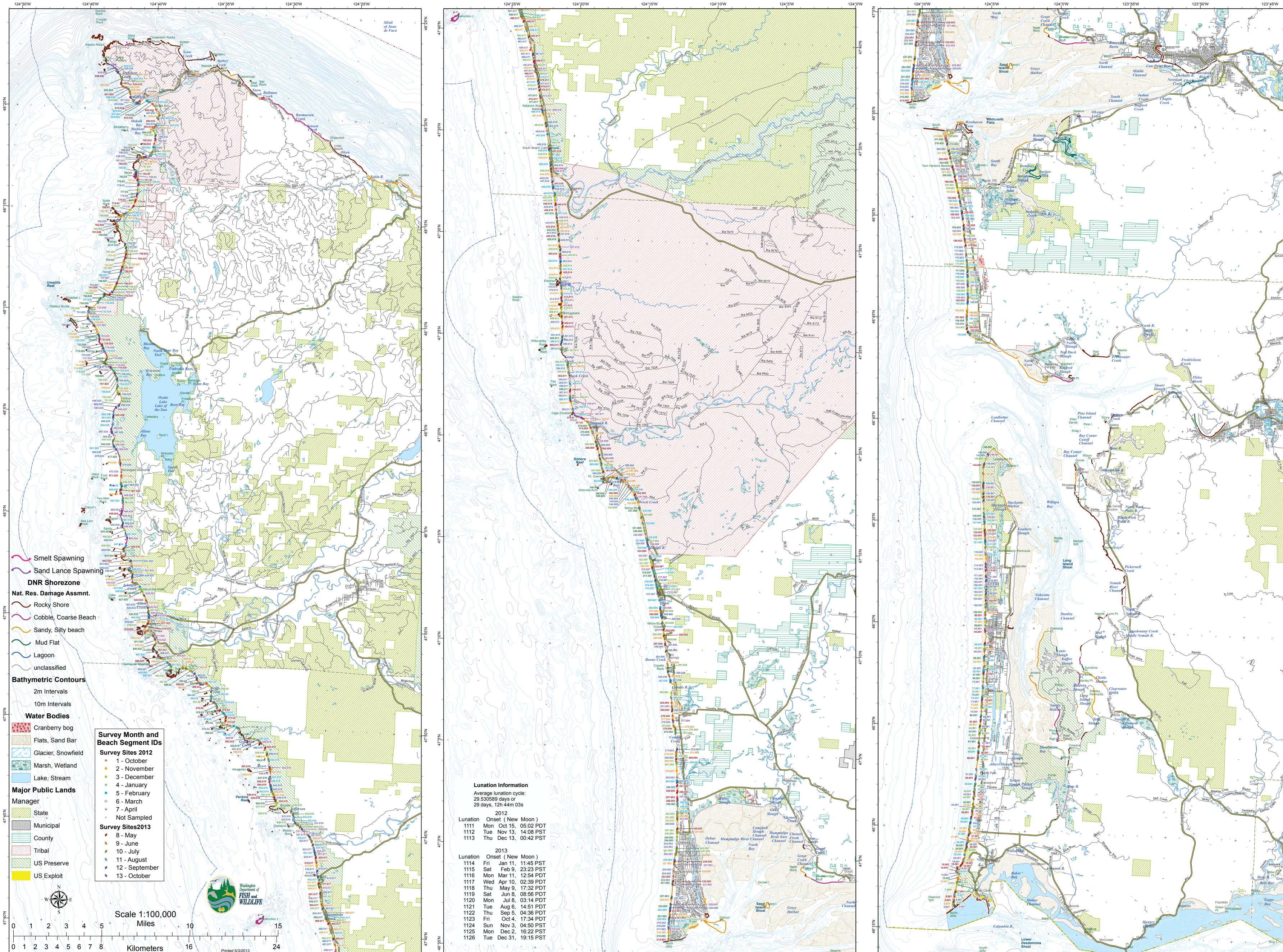

Figure 2. Planned sampling sites from October 2012 to October 2013.

Sampling Approach

Sample Collection

Sampling occurred monthly, beginning the week of 16 October 2012 and ending 30 September 2013 (12 sampling months). Within a month, days during or after the highest tides and with the broadest temporal sampling windows were chosen. There is evidence from Puget Sound surveys that surf smelt and Pacific sand lance spawn during high tide events, depositing eggs along the upper third of the intertidal range (+7 to +9 feet MLLW) (Moulton and Penttila 2006; Penttila 1978, 1995). Therefore, we aimed to sample on days that would allow for access near the upper tidal limit for an extended period of time, maximizing collection capacity for a given date.

Estimation of the upper third of the daily high tide range was determined using NOAA tide prediction charts (Fig. 3). Using these charts we were able to determine the approximate time at which only the upper third of the beach (~+6 to daily high tide) was exposed. If possible, we arrived at the site at this time, sampling from the high tide mark down to the water's edge. This allowed us to take a linear measurement of the beach face as an index of tidal height and for use as an estimate of the upper third of the beach for that particular sampling day and location. This method was particularly effective for estimating the upper third of broad, flat, sandy beach sites at Long Beach, Twin Harbors, and Copalis-Moclips (Fig. 4A). At steep cobble-course beaches (Fig. 4B), the linear distance of the upper third was shorter, and often sampling occurred from the upland toe or log line (if high tide mark unidentifiable) down to the estimated lower edge of the upper third.

This study used a variant of the bulk beach substrate sampling protocol used for spawning beach surveys in Puget Sound, standardized in the late 1990s by Dan Penttila and later codified into a manual (Moulton and Penttila 2006; Penttila 1995). The only major deviation from this standard protocol was that sediment samples were taken perpendicular to the beach face rather than parallel to the high tide line (Appendix; Protocol FF-01-C). This allowed us to survey the entire upper third of the recent tidal range in a single sample, circumventing a lack of knowledge about the specific tidal height at which eggs are deposited on the outer coast. While our results do not allow us to isolate the specific tidal height of egg deposition, additional surveys to collect these data are planned for the future.

The modified protocol has since been further augmented to accommodate specific circumstances encountered only on the outer coast. Specific changes include: 1) addressing that a range of beach sediment particle sizes may be encountered within the upper third of the tidal range (unlike Puget Sound where sampling occurs at a known tidal elevation and band of similar sediment character); and 2) rewording the meaning of the "width" and "sample zone" data fields, with width representing the width from the “upper most” to “lower most” scoop on a transect, and sample zone representing the distance to the lowest sample scoop of a transect taken perpendicular to a landmark (Appendix; Field Data Sheet). For most sampling sites, the width and sample zone are the same distance unless extra samples are taken in the lower 2/3 of the tidal range (extra samples procedure further detailed below). In addition, many of the landmark codes have been eliminated since they did not apply well to coastal sampling. Only two landmark codes are used: 1 – down beach from high tide mark, and 2 – down beach from upland toe.

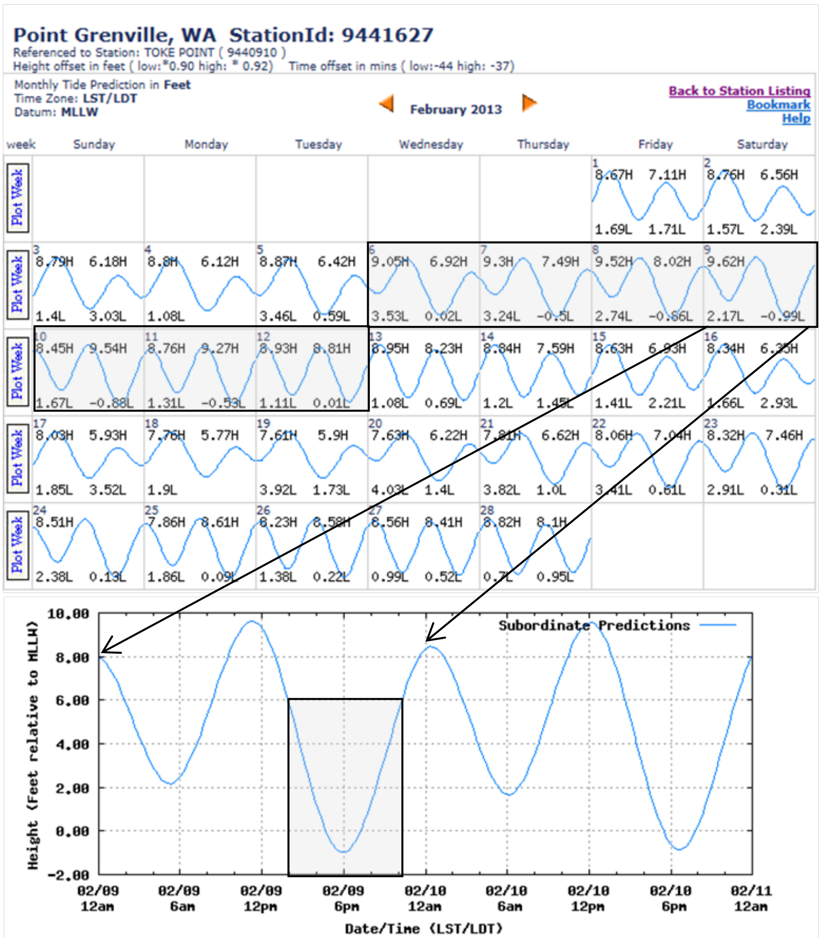

Figure 3. February 2013 tide chart of NOAA central coast site Point Grenville, WA. Highlighted days are preferable sampling days, allowing for access to the upper third of the beach for an extended period of time. On February 9, the time range is highlighted showing a potential 8 hour window for sampling between 2pm and 10pm.

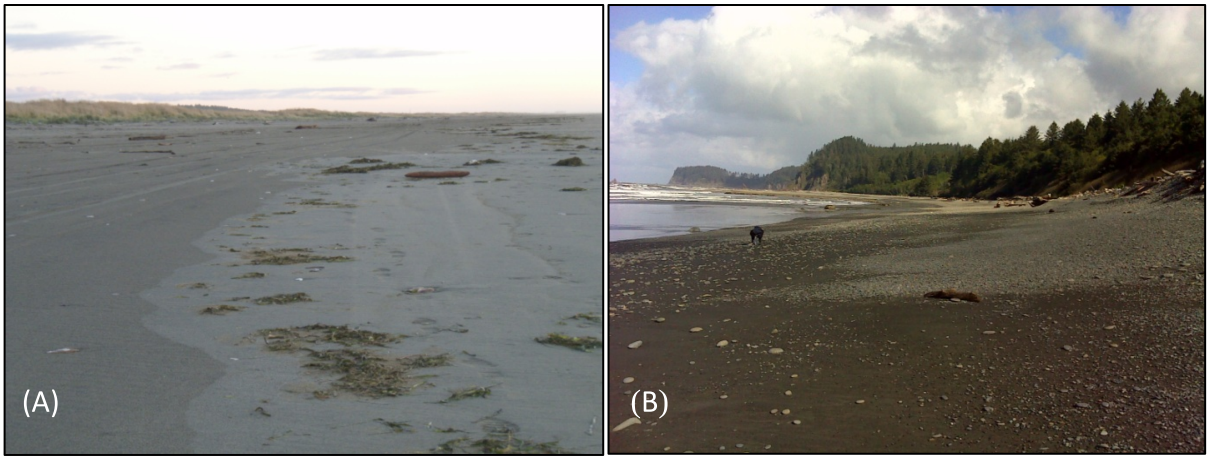

Figure 4. (A) Copalis Beach, a flat, broad, exposed, sandy beach type, showing high tide mark/wrack line; (B) Rialto Beach, a steep, semi-exposed, cobble-mixed course beach type.

The sampling sites were located using provided beach segment center or south point coordinates from DNR GIS data. Upon arrival at the provided coordinates of the site, the last high tide mark or wrack line was identified and actual sampling center coordinates recorded. Pertinent habitat data were recorded, including the sediment character (particle size range), character of the uplands, and shading of the spawning substrate zone. Additionally, a subjective field assessment of spawn intensity apparent to the naked eye was conducted. When possible, photos were taken of the survey area at the site center facing each cardinal direction. The time of collection for each subsample was recorded and allowed us to determine tidal height with NOAA verified historic tide data (parameters: 6 minute water level intervals, MLLW, feet, LST/LDT) from the nearest harmonic tide sites on the outer coast (sites: Toke Point, Westport, and LaPush).

At each sampling site, three bulk sediment samples were collected; at the site center of the beach segment, 100 ft. north of the center, and 100 ft. south of the center. For each bulk sediment sample, four evenly spaced scoops of sediment were collected within the estimated upper third of the tidal range. The first scoop was collected at the high tide mark/wrack line and the fourth at the lower edge (water side) of the upper third (Fig. 4A; Fig. 5). Each scoop was collected using a 16 oz. sample jar or large scoop to remove the top 5-10 cm (2-4 in) of sediment and placed in a plastic bag for later wet sieving and winnowing. Deviation from the sampling protocol occurred at 82 sites in the NW Coast beach zone, where samples were collected 60-100 ft. apart, and only 3 scoops were collected within the upper third, starting approximately 10 ft. below the high tide mark. Spawn was not detected at any of these sites and due to the deviation from sampling protocol; samples will likely be excluded from any attempts to model occupancy.

When time and tides permitted, extra samples were taken in the lower two-thirds of the daily tidal range. During low tide, four additional evenly spaced scoops were taken below the lower edge of the upper third down to the edge of the water (Fig. 5). These extra samples were collected to determine if eggs could be detected in the lower elevations of the beach and because the gentle slope of southern beaches often made determining the exact extent of the upper third of the intertidal zone difficult.

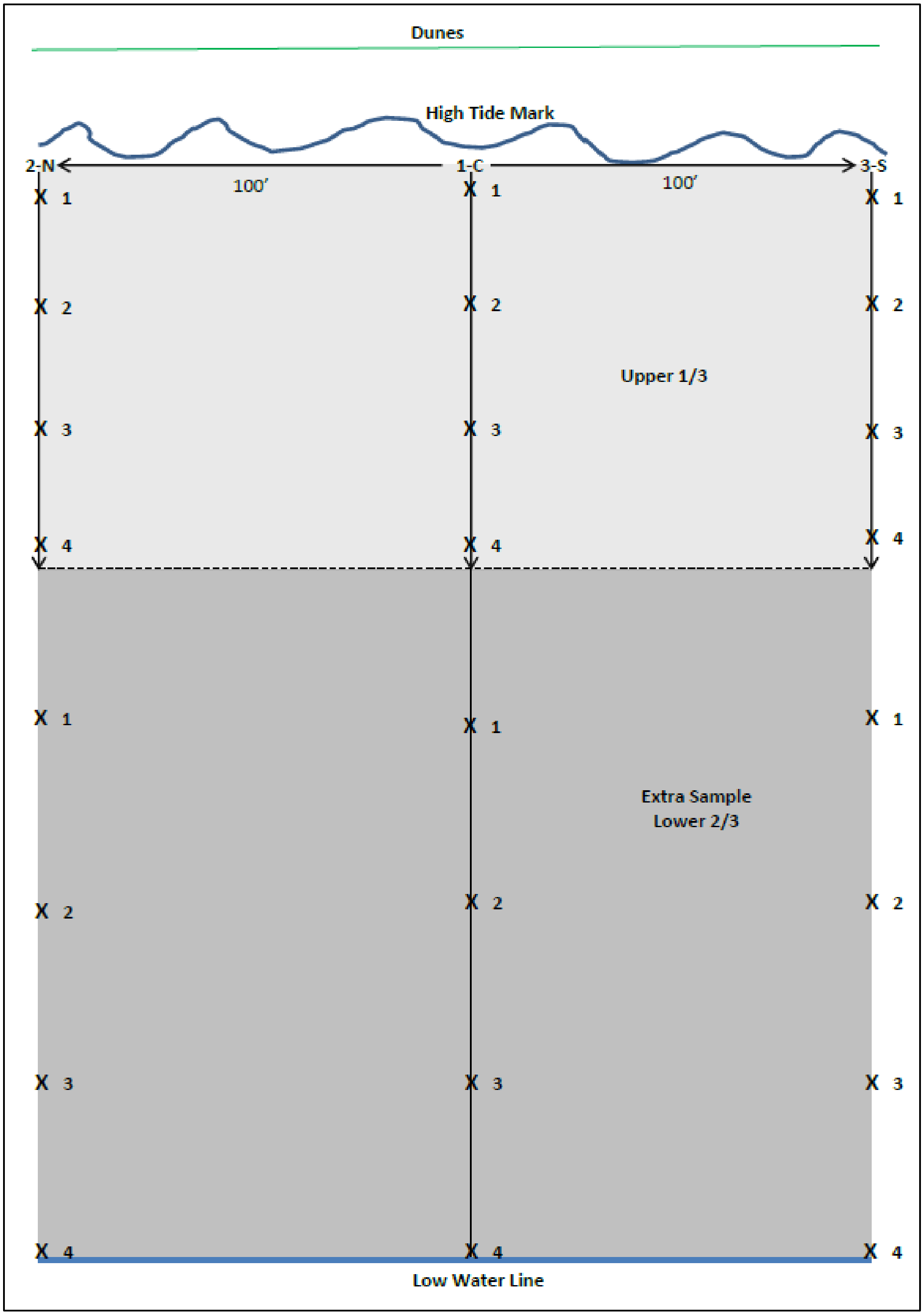

Figure 5. Sampling diagram. 1 – C = Sample 1 taken at site center or south point coordinates, 2 – N = Sample 2 taken 100 ft. north of center, 3 – S = Sample 3 taken 100 ft. south of center. 1, 2, 3, 4 = scooped sediment.

Sample Processing

Bulk beach substrate samples were condensed in the field or lab to remove most of the sand and reduce the volume of sediment following Moulton and Penttila (2006) (Appendix; Protocol FF-02). The bulk sediment sample was run through a set of nested 4-mm, 2-mm, and 0.5-mm sieves, using buckets of shore water in the field or freshwater from a sink/hose setup in a lab. Materials from the 4-mm and 2-mm sieves were discarded and material from the 0.5-mm sieve (egg-sized material) was placed into a rectangular dishpan and covered with 1-2 in. of water. Eggs were then winnowed to the surface by swirling, rocking, and bouncing the dishpan for 1-2 minutes. Light material accumulated toward the center of the pan and was then worked to one corner. Tipping the pan, water was slowly drained away, drying up and exposing the lighter fraction, which was skimmed from the surface using a spoon and placed into an 8 oz. jar. This winnowing process was repeated twice more or until the sample jar was roughly two-thirds full, completing a "winnowed light fraction sample" (Fig. 6). Samples were stored in a refrigerator for up to two weeks and, if left unexamined for eggs, preserved in 200 proof (90.48%) denatured ethanol. For sites within the Long Beach, Twin Harbors, and Copalis-Moclips beach zones, we maximized field collection on a given day by collecting bulk sediment samples (up to 99 samples) and bringing them back to the lab for storage in a refrigerator or outside in a cool shaded environment. These samples were condensed, and examined or preserved, within two weeks.

Figure 6. Sieving and winnowing process. Numbers to the lower left of each frame indicate the sequential process of sieving and washing (1-4), agitating (5), and winnowing the light fraction (6-8).

Winnowed light fraction samples were examined for forage fish egg presence/absence using the adopted Puget Sound forage fish egg presence/absence laboratory protocol, with the WDFW standard for documenting a spawning site for a given species at 2+ eggs (live or dead) per single "winnowed light fraction" sample (Appendix; Protocol FF-03). However, the standard for documenting a spawning site was altered so that for a given species 2+ eggs (live or dead) could be found in any of the three "winnowed light fraction" subsamples at a single site. Winnowed light fraction samples were analyzed by scooping an undetermined amount of evenly mixed sediment into a glass petri dish and thoroughly examined for eggs using a dissecting microscope with 10-20x power.

The abundance of forage fish eggs in all the collected samples was low enough so that complete analysis of the entire winnowed light fraction occurred. However, there was the option to subsample in cases of high spawn density. Up to half of the sample could be subsampled. All eggs found were removed and, if time permitted, the development stage of smelt eggs was determined using embryological stage categories created by Dan Penttila (Appendix; Protocol FF-04). All eggs were archived for future genetic testing aimed at identifying demographically independent stocks of forage fish on the Washington outer coast.

Sample processing deviated from these methods for the 133 samples collected in the Quinault beach zone. The winnowing process was altered so that all the light sediment agitated to the surface was poured directly into the 8 oz. jar. The 8 oz. light sediment was then winnowed again and the remaining sediment examined for eggs using the dissecting microscope. While detection of spawn from these samples is included in this report, and will be included in the list of documented spawning sites, these samples will likely be excluded from any attempts to model spawning beach occupancy in subsequent statistical treatments planned after further data collection.

Results

Of the 1003 total planned beach sites from October 2012 to September 2013, 835 (83%) were sampled. Monthly sampling percentages ranged from 65-94% (Table 1). Further detail on the total number of sites sampled per month by collaborating entity, and overall sampling percentages are provided in Table 1.

Of the 835 sites sampled, 81 involved collections outside the boundaries of the planned sites. Sampling outside of an allocated site occurred due to limited time to reach the site (i.e. tide was coming in and sampled nearest location) or inaccuracy in locating sites via GPS. As these sites were collected randomly, data may be included for analysis to complete future occupancy models.

The loss of planned sampling was primarily due to difficult site access in parts of the Quinault, Kalaloch-Hoh-Quil and NW Coast beach zones. The NW Coast beach zone was the least sampled, with 61% of planned sites sampled for the year (Table 2). Additional sampling percentages per year and month by beach zone are provided in Table 2. Sites located north of Johnson Creek up to Yellow Banks – Ozette were especially challenging to reach, particularly north of Cape Johnson and the area south of Yellow Banks to Norwegian Memorial. Poor weather conditions also reduced overall sampling efforts due to safety concerns, especially in remote locations. Sites that fell directly on a rocky headland (North Head or Taylor Point) were not sampled due to unsuitable habitat not identified by the GIS data layers. Additionally, stream outflows would sometimes be impassible and access to sites prevented or limited by these barriers.

Table 1. Total sites sampled per month by collaborating entity, and overall sampling percentages.

Month	WDFW	Quinault	Hoh	Quileute	Makah	Total Sampled	Percent Sampled
October	30	10	12	5	5	62	74%
November	31	13	0	6	5	55	65%
December	33	13	7	11	9	73	87%
January	32	10	8	8	10	68	81%
February	31	10	9	9	8	67	80%
March	33	7	12	8	5	65	77%
April	33	12	15	6	11	77	92%
May	32	13	14	8	9	76	94%
June	33	10	12	15	0	70	84%
July	33	12	12	7	6	70	84%
August	33	12	11	14	9	79	94%
September	32	11	11	14	5	73	87%
Year 1 Total	**386**	**133**	**123**	**111**	**82**	**835**	**83%**

Table 2. Sampling percentages per month by beach zones; Long Beach, Twin Harbors, Copalis-Moclips, Quinault, Kalaloch-Hoh-Quil, and NW Coast.

Month	Long Beach	Twin Harbors	Copalis-Moclips	Quinault	Kalaloch-Hoh-Quil	NW Coast
October	87%	100%	91%	77%	88%	33%
November	93%	86%	100%	100%	24%	33%
December	100%	100%	100%	100%	65%	76%
January	93%	100%	100%	77%	82%	57%
February	87%	100%	100%	77%	76%	62%
March	100%	100%	100%	54%	94%	43%
April	100%	100%	100%	92%	88%	81%
May	93%	100%	100%	100%	65%	78%
June	100%	100%	100%	85%	100%	50%
July	100%	100%	100%	92%	76%	60%
August	93%	100%	100%	92%	94%	90%
September	100%	100%	91%	85%	88%	71%
Year 1 Total	**96%**	**99%**	**98%**	**86%**	**78%**	**61%**

Of the 835 sites sampled to date, smelt eggs were detected at 41 sites, and were absent from the remaining 794 sites. Because surf smelt and night smelt eggs cannot be distinguished morphologically, the species of smelt spawning at these beaches cannot be definitively stated. Eggs were retained for future species identification using genetic tools. Thirty-one of the 41 “smelt positive” sites met the WDFW 2+egg standard to document as a spawning site (Fig. 7).

Forage fish spawning was detected starting in February and ending in September. In February, one site was documented as a spawning site near the mouth of the Hoh River. In March, three sites were documented, all in the Kalaloch region. In April, four sites were documented, one south of the Queets River, two in the Kalaloch region, and one near the mouth of the Hoh River. In May, 3 sites were documented, one near the Quinault River, one in the Kalaloch region and one at First Beach, LaPush. June and July had the greatest number of documented spawning sites for the year, with 7 sites documented each month. In June, one site fell near the Quinault River, one at Camp Creek, two south of the Queets River, two in the Kalaloch region, and one near Ellen Creek. In July, one site fell near Wreck Creek, one at Cape Elizabeth, one at Camp Creek, one at Raft River, two south of Whale Creek, and one south of the Queets River. In August, four sites were documented, one near Duck Creek, one in the Kalaloch region, one at the Hoh River, and one at Jefferson Cove. In September, three sites were documented, two near Whale Creek and one in the Kalaloch region (Fig. 7).

The 10 remaining “smelt positive” sites did not meet the WDFW 2+egg standard and were not identified as newly documented spawning sites. These “single egg” sites were detected in March, May, July, August, and September (Fig. 7, Table 4). These sites will be prioritized for visits during future surveys.

In addition to determining egg presence, several of the eggs were further examined to determine the development stage of the embryo using standardized stage categories (Moulton and Penttila 2006, see Appendices). Table 3 further details the documented (2+ egg) spawning sites, number of samples with smelt eggs, total number of smelt eggs at each site, and smelt egg stage/condition. Table 4 details single egg sites, general location, and stage/condition if determined.

Twenty-seven of the 31 sites where eggs were found are newly documented spawning sites (Fig. 7). Three sites (487 sampled twice, 485, and 425) were previously documented smelt spawning sites sampled in July 1998 by Dan Penttila. Although spawning at site 487 was previously documented, the current survey allowed the documented spawning area to be extended north by 700 ft. Also, site 425 was extended north by 725 ft.

Seven extra sites were sampled from March to August and were targeted based on likelihood of encountering forage fish eggs (i.e. adult smelt observed spawning at location). As these sites were not randomly selected they are not part of the sampling design and will not be included in pending occupancy model work. However, site 608, collected in May, met the 2+ egg standard and will be documented as a new spawning site, bringing the total number of newly documented spawning sites to 28 (Fig. 7).

Over 60 additional samples were collected in the lower 2/3 of the intertidal and were all absent of forage fish eggs. Sampling effort in the lower 2/3 was minimal, conducted only at a few sites in the Long Beach, Twin Harbors, and Copalis-Moclips zones from November 2012 – March 2013, and in the Kalaloch-Hoh-Quil and NW coast zones in June 2013.

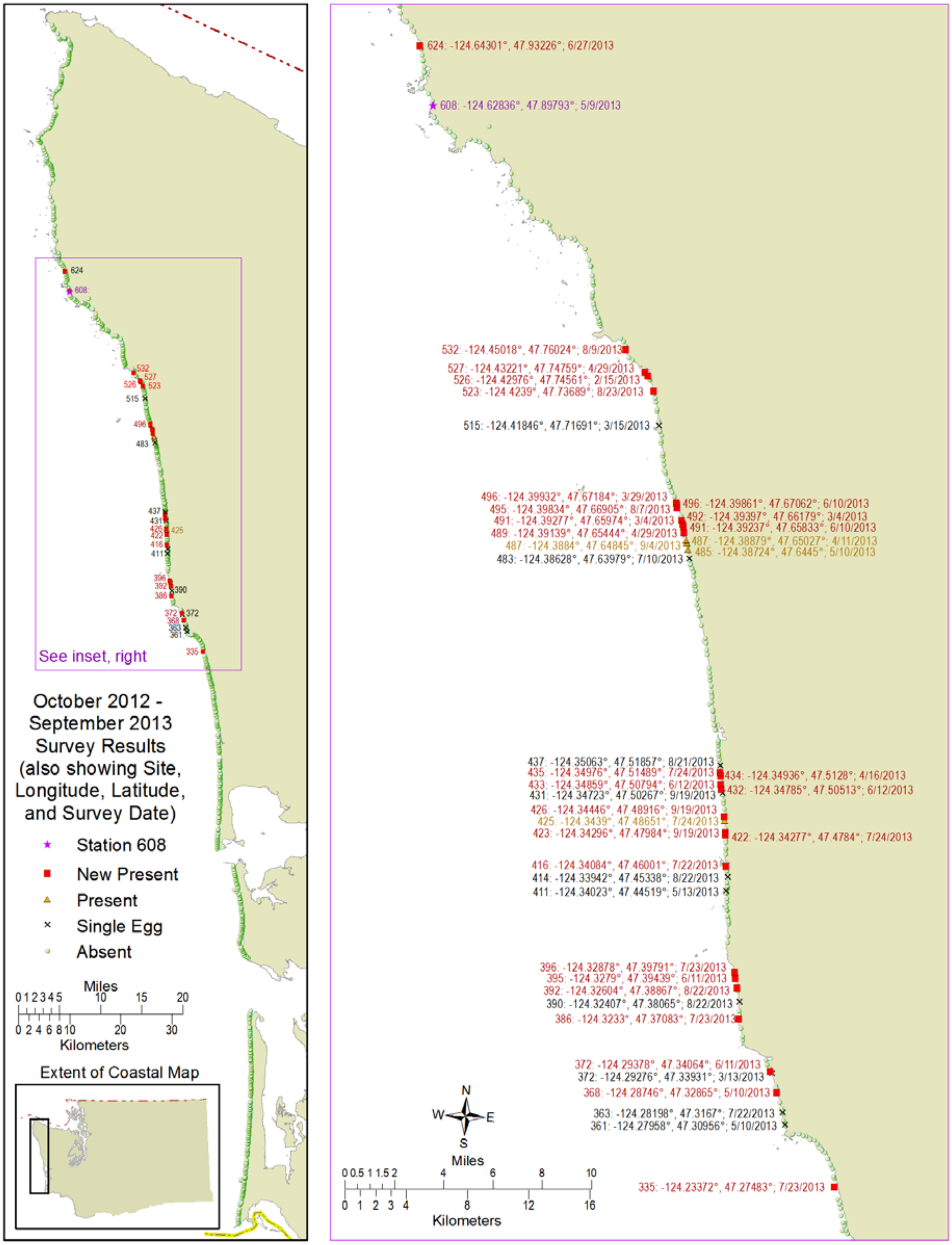

Figure 7. Locations of all sites sampled from October 2012 – September 2013. Documented smelt spawning sites (2+eggs), both previously (present) and newly documented (new present), as well as single egg sites are indicated. Newly documented extra sample site 608 is marked separately as it was a non-random sample.

Table 3. Documented smelt spawning sites by month of sample collection, general location, number of samples with smelt eggs (of 3 samples collected per site, of 6 for #433), total number of smelt eggs at site, and egg stage/condition. * Sites that fell within a previously documented smelt spawning site sampled in July 1998 by Dan Penttila.

Month	Documented Spawning Site #	General Location	Number of Samples with Smelt Eggs	Total Number of Smelt Eggs at Site	Smelt Egg Stage / Condition									
					Dead	1-Cell-Morula	Blastula	Gastrula	0.5 coil	1 coil	1.5 coil	>1.5 coil	Late-Eyed	Not Determined
February	526	Hoh Shoreline	1	2	1									1
March	491	Kalaloch	1	7	2			4				1		
	492	Kalaloch	1	3										3
	496	Kalaloch	2	3										3
April	434	S. Queets River	3	13							1		2	10
	*487	Kalaloch	2	5			1					4		
	489	Kalaloch	3	52	8		7	3	4	10				20
	527	Hoh Shoreline	1	2								2		
May	368	Quinault River	3	10										10
	*485	Kalaloch	3	18	4					2	5	5		2
	608	First Beach	3	6	1									5
June	372	Quinault River	3	60										60
	395	Camp Creek	3	28										28
	432	S. Queets River	3	81										81
	433	S. Queets River	5	97										97
	491	Kalaloch	2	2	2									
	496	Kalaloch	1	4	1									3
	624	Ellen Creek	1	4	3									1
July	335	Wreck Creek	1	4					4					
	386	Cape Elizabeth	1	3	2									1
	396	Camp Creek	3	54	7	1				21	3	11	2	9
	416	Raft River	1	7	1						4			2
	422	S. Whale Creek	3	73	24		1	3	1		2	36	1	5
	*425	S. Whale Creek	3	81	31			4			17	12		17
	435	S. Queets River	3	43	5			4		20	2	7		5
August	392	Duck Creek	3	25	22						2	1		
	495	Kalaloch	2	2	1									1
	523	Hoh Shoreline	2	14	11		3							
	532	Jefferson Cove	3	20	13							6		1
September	423	S. Whale Creek	3	54	14									40
	426	Whale Creek	3	36	11									25
	*487	Kalaloch	3	32	10					11	5	3		3

Table 4. Single egg sites by month of sample collection. Single egg sites do not meet the WDFW 2+ egg standard to document as a new spawning site.

Month	Single Egg Site #	General Location	Egg Stage
March	372	Quinault River	Not Determined
	515	Ruby Beach	Gastrula
May	361	Pt. Grenville	Not Determined
	411	Raft River	Not Determined
July	363	Pt. Grenville	1.5 coil
	483	Kalaloch	Not Determined
August	390	Duck Creek	Dead
	414	Raft River	1 coil
	437	S. Queets River	Dead
September	431	S. Queets River	Dead

Discussion

This study was designed to inform the Marine Spatial Planning process with regard to the presence and timing of forage fish spawning on coastal beaches. The goals of our study were to: 1) subsample the breadth of the outer coast monthly for 1 year, October 2012 – September 2013; 2) identify any forage fish eggs found to species; and 3) geo-reference all survey data to provide an easily accessible overview of sampling effort and egg detections to date for use in MSP activities, and to guide future survey efforts. Despite limited site access that in some cases reduced sample size, we were able to achieve our goals and documented 28 new (and three known) smelt spawning locations. All survey data have been compiled into an ArcGIS geodatabase for easy integration with other resource distribution and exploitation data when proceeding with MSP activities on the outer coast.

Earlier survey efforts to document intertidal spawning forage fish on the outer coast of Washington State have been sparse relative to the efforts in the Puget Sound region. Previous sampling efforts on the outer coast have preferentially not sampled during winter months, presumably due to the logistical challenges of sampling during winter, and because previous winter sampling efforts on the outer coast had detected no spawn between the months of November and February (Fradkin 2001; Penttila 2007). Despite the results of previous efforts, we conducted surveys from November through February because: 1) previous sampling was not geographically comprehensive; 2) we were using a modified sampling technique that covered a broader portion of the intertidal than has been previously sampled; and 3) the window in which funding was available meant that developmental test sampling was not practical and that significant data must be collected prior to June 30, 2013. By coordinating with tribal collaborators and having dedicated staff available to conduct surveys during the “off” season we had a substantial chance of documenting spawning in previously unconsidered locations and at novel times of the year.

The results of samples collected during November through January were consistent with the results of previous studies, with no spawn detected. However, spawn was documented in each month from February through September at 28 previously undocumented sites, one month earlier than suggested by previous sampling efforts. Though the numbers of eggs collected in February was generally low, it indicates that the spawning season on some beaches of the outer coast is longer than previously thought. No spawn was detected in October 2012. However, spawn was documented at one site in October 2013 (complete data not presented in this report). The number of documented spawning sites and number of eggs per site peaked in June and July suggesting a seasonal trend in spawn abundance. This coincides with the results of a previous study in which peak egg densities occurred from May through September (Fradkin 2001).

Spawning sites are located in the northern central coast, ranging as far south as site 335 south of Wreck Creek and as far north as site 624 near Ellen Creek. Most of the spawning locations are clustered within the Quinault and Kalaloch-Hoh-Quileute beach zones. At this time, the results of this study do not allow us to definitively state the mechanisms influencing this spatial distribution. Surf smelt likely demonstrate some annual migration/movement along the coast and may simply spawn where they are present and ready. Additionally, spawn timing may be related to water temperature and forage exposure that promotes egg development. Also, given that our detection rates are unknown, it's possible that eggs were present at sampled sites but not detected. This may be of particular concern given the deviations in sampling protocol for some samples collected in the NW coast beach zone.

Interestingly, many of the spawning locations are within close proximity to freshwater outflows, small streams or large river mouths. Freshwater outflows to the intertidal zone may provide eggs with the needed moisture to prevent egg desiccation, heat stress, and mortality. This could be particularly important on the exposed beaches of the outer coast where there is often little marine riparian cover to provide shade. The interaction of freshwater outflows with nearshore waves resulting in the accumulation of sediment near the mouths of rivers and streams and the local attenuation of wave energy may also influence the ability of forage fish to utilize intertidal habitat, and influence the retention of spawn in that habitat. In Puget Sound, surf smelt are known to be highly tolerant of variable salinity regimes and immersion in freshwater outflows is not uncommon (Penttila 1978). In California, the most favored surf smelt spawning beaches are coarse sand pea-gravel beaches, with some freshwater seepage (Leet et al. 2001). Perhaps, feeding adult smelt are attracted to these nutrient rich sandflats, an area that would also provide desirable habitat for rearing juvenile smelt. Although an interesting observation, additional investigation is needed to assess this potential affinity to freshwater outflows.

Analysis of the developmental stage of a subset of the eggs collected indicates the presence of multiple stages at the same site, suggesting overlapping broods and multiple spawning events. Surf smelt eggs may hatch as soon as two weeks after being spawned and spawning events in Puget Sound are commonly superimposed on each other, and it is not uncommon for an area to contain two to five individual broods of eggs (Penttila 2007). The presence of eggs at different sites during the late winter and the presence of multiple egg stages at a site indicate that several spawning events occurred during the season. However, multiple sites were sampled where only one egg was found indicating that as comprehensive as our sampling was, bi-weekly as opposed to monthly sampling may be justified to document additional spawning sites.

Because surf smelt and night smelt eggs cannot be distinguished morphologically, the species of smelt spawning at these beaches cannot be definitively stated. Most documented spawning sites in Puget Sound have been documented as surf smelt spawning sites. However, night smelt have been recently documented in the Salish Sea and northern Puget Sound. An egg specimen collected near Discovery Bay, WA (Salish Sea) was misidentified as a longfin smelt but based on a study using molecular markers to distinguish smelts found in the gut contents of fishes, the specimen was identified as a night smelt (*Spirinchus starski*) (Paquin et al., in press). Additionally, night smelt have been observed spawning on coastal beaches during early spring by tribal fishermen. Although not officially documented it provides some insight into the possibility that observed smelt spawn may be night smelt. In California, night smelt are known to spawn earlier (before June) in the season than the spawning of surf smelt, predominately in the summer (Leet et al. 2001). Further genetic identification of the eggs is planned in the near future and will allow for positive identification of surf and/or night smelt.

No sand lance eggs have been discovered in our sampling to date. Sand lance generally spawn in the winter in Puget Sound and on beaches with grain sizes smaller than those favored by surf smelt, and generally spawn lower on the beach than surf smelt (Penttila 1995; 2001b). Given this predilection, we anticipated that the detection probability for sand lance eggs in the Long Beach, Twin Harbors, and Copalis-Moclips beach zones might be higher than for surf smelt. In the few surveys that have historically occurred on the outer coast, sand lance have been documented to spawn in December inside Grays Harbor and in June in Grenville Bay just south of the mouth of the Quinault River. Our lack of sand lance egg detections could be a result of our sampling protocol, a lack of spawning occurrence altogether, or our focus on exposed beaches on the outer coast, as opposed to more protected beaches inside Grays Harbor, Willapa Bay, etc. Additionally, though we sampled hundreds of beaches, our sample size could have simply been insufficient. Pending funding, sampling may eventually be expanded inside of major inlets, which may help alleviate these issues.

Based on our success in documenting spawn in previously undocumented times and areas, we expect that further sampling would identify a broader spatial and temporal range of smelt spawning on the outer coast. Continued sampling will likely increase the number of sites where we encounter eggs. As we detect eggs at more sites, our sample design will enable us to estimate error rates and further refine sampling methods. Improved methods may enable higher detection probability and greater efficiency in sampling, which could provide the opportunity to sample a greater number of sites with little change in staff and funding needs. Also, previous work on Rialto Beach and in Puget Sound has shown both seasonal and annual variability in egg density even during peak months of spawning activity (Fradkin 2001; Penttila 2007). This suggests that given the opportunity to continue sampling over multiple seasons, the potential to document spawning sites would increase, as some sites may have only limited use on a seasonal or annual basis.

Future Work

Spawning beach surveys will continue for another full year, October 2013 - October 2014. If future funding is available, we would propose to learn more about the fisheries for these species and continue to monitor spawning activity. The number of spawning beach surveys may be reduced and effort could focus on specific uncertainties that are identified by analyses of data collected in the first two years. We would propose these activities continue to be collaborative efforts with tribal managers and biologists.

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Appendices

Protocol FF-01-C

WDFW Intertidal Forage Fish Spawning Habitat Survey Protocols

Procedures for obtaining bulk beach substrate samples -- Coastal

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<u>Field materials needed</u>:

Measuring tape (100+ feet)
16-ounce plastic jar or large scoop
8 inch x 24 inch polyethylene bag (or large, sturdy ziplock)
Handheld GPS device
Tide table
Digital camera (optional)
Hypsometer (if available)
Data sheet (preprint on Write-in-the-Rain paper if possible)

<u>Note</u>: Sampling should occur on the lowest tide practicable. Prior to sampling any site consult tide tables to ensure you will be able to access the upper third of the daily tidal range. It may also be necessary to obtain **permission to access the beach** from private or corporate landowners.

<u>Procedure</u>:

1. Upon arriving on the beach, fill out the header information on the attached data sheet. *Do not* fill in "Reviewed by." Before conducting the first sample, describe the character of the upland and beach environment using the codes provided on the back of the data sheet. For additional details on sample codes see Moulton and Penttila (2001)*.

2. Identify a landmark from which you will measure the distance to the bulk substrate sample tidal elevation. Typical landmarks include the upland toe of the beach, the last high tide mark or wrack line, the vegetated edge of the upland dune, and the edge of the water.

3. Measure the distance from the landmark to the water side of the upper third of the daily tidal range. Note that linear measurements along the beach face serve as an index of tidal height but do not directly quantify *vertical* tidal height. The goal is to sample across the upper third of the daily tidal range.

4. Standing at a randomly selected location at the water side of the proper tidal range, record a GPS fix on the data sheet.

5. Using a 16-ounce sample jar or large scoop remove the top 5-10 cm (2-4 in) of sediment from the location recorded in Step 4 above. Place the sediment in an 8 inch x 24 inch polyethylene bag or

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large, sturdy ziplock. You may need to take two scoops to get sufficient sediment, depending on the coarseness of the beach.

6. Walk several paces away from the water, repeat the sediment scooping action, and place the sediment in the bag. Move an additional several paces up the beach and repeat. Move an additional several paces, approximately to the high tide mark, and repeat. The bag should now have sediment from four locations in the upper third of the daily tidal range and be at least ⅔ full.

7. Using the measuring tape, move 100 ft along the beach, record a GPS fix, and repeat steps 5 and 6 **using a new collection bag.** Repeat this process again, filling a total of three bags at a given site.

8. Once three samples are collected at a site either: a) move on to wet sieving and winnowing the sample as described in the companion protocol "Procedures for recovering "winnowed light fractions" subsamples of forage fish egg-sized material from bulk beach substrate samples;" or b) continue on to the next sample site in order to maximize collection capacity for a given date.

9. If you have a camera, take several photos of the survey area showing sampling locations. Be sure to take photos from several perspectives (i.e., both up and down, as well as along, the beach). For each photo, record the cardinal direction you are facing on the data sheet in the comments field.

* Moulton, L.L., and Penttila, D.E. 2001. Field manual for sampling forage fish spawn in intertidal shore regions. Field Manual, MJM Research and Washington Department of Fish and Wildlife, Lopez Island, WA. PDF available on request from Dayv Lowry at WDFW (dayv.lowry@dfw.wa.gov).

Original protocol by Dan Penttila, WDFW. Reformatted by Dayv Lowry, WDFW.

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WDFW Intertidal Forage Fish Spawning Habitat Survey Protocols

Procedures for recovering "winnowed light fractions" subsamples of forage fish egg-sized material from bulk beach substrate samples

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Field materials needed:

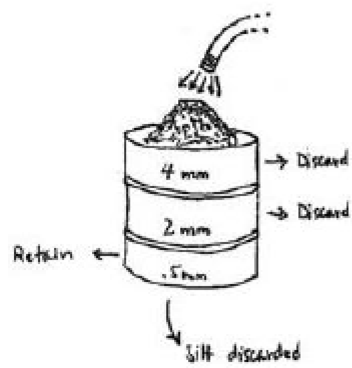
Nested set of 4-mm, 2-mm, and 0.5-mm sieves/screens (Nalgene or stainless steel preferred over brass, for durability)
Buckets for discarded material (2-4), may have several large holes drilled near lip as rinse water outlets
1-2 gallon plastic dishpans
400-ml wide-mouthed sample jars
Freshwater hose work area with sufficient drainage (or extra buckets for saltwater rinsing)
Area to discard waste gravel
Ethyl alcohol or Stockard's solution† (only needed when samples will not be analyzed immediately)
Pencil and Rite-in-the-Rain paper (cut into small squares for labeling samples)

Procedure:

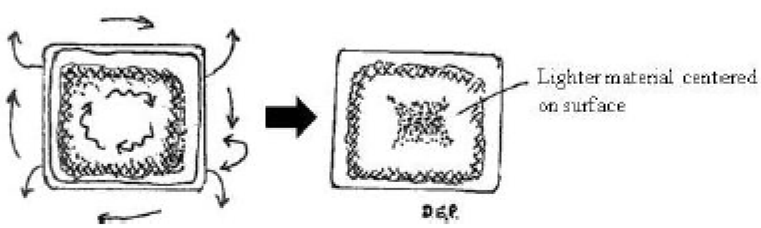
1. Thoroughly wet-screen material through set of 4-mm, 2-mm, and 0.5-mm sieves/screens, using buckets of shore-side water at site or freshwater hose elsewhere. Screens should be carefully cleaned between samples.

2. Discard material retained in 4-mm and 2-mm sieves/screens.

3. Place material from 0.5-mm sieve/screen ("egg-sized material") in rectangular dishpan and cover with ~1 inch of water.



4. Rotate/tilt/yaw dishpan of material to impart rotation to water and cause lighter material to rise to the surface, where it should accumulate toward the center of the pan. Observe behavior of shell fragments and organic particles to get indication of behavior of forage fish eggs.



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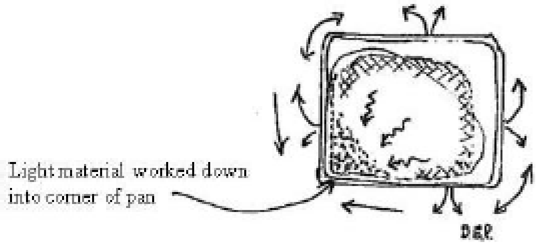
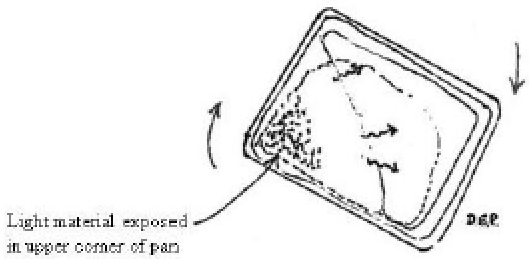
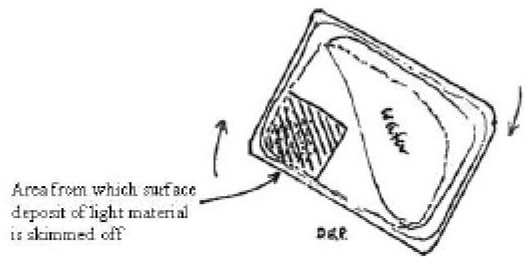
5. Tilt/swirl/agitate pan contents to move lighter material accumulated at center down to lower left corner of pan.



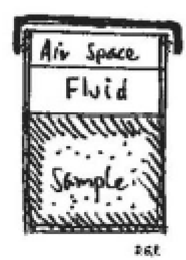
6. Carefully tilt pan to decant water to opposite corner of pan, slowly exposing lower left corner material above water's surface.





7. Holding pan in the tilted position, carefully use a wide-mouthed sample jar to skim the surface 1 inch of material from the lower left corner of the deposit.

8. Repeat steps 4-7 approximately three more times, or until the sample jar is ~⅔ full of material.



9. If sample will not be analyzed within a few days in the laboratory, top-off sample jar with ethyl alcohol or Stockard's solution† and shake well to distribute fluid. Note that long-term storage is also possible with these preservatives. If genetic samples are desired 95% nondenatured ethyl alcohol should be used.

10. Fit lid loosely onto sample jar to allow gas to escape (preserved samples will emit carbon dioxide as the acidic preservative dissolves shell material in the sample).

11. Store sample jars in leak-proof containers in well-ventilated area to prevent accumulation of carbon dioxide in enclosed areas. Note: both gas and some preservative, if present, will escape.

† Stockard's solution contains formaldehyde, which is carcinogenic. 1 l Stockard's solution = 50 ml formalin (37% aqueous formaldehyde), 40 ml glacial acetic acid, 60 ml glycerin, 850 ml fresh water (1 l = 0.2642 gal; 1 gal = 3.785 l).

Original protocol by Dan Penttila, WDFW. Reformatted by Dayv Lowry, WDFW.

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WDFW Intertidal Forage Fish Spawning Habitat Survey Protocols

Laboratory procedure for determining forage fish egg presence/absence from preserved "winnowed light fraction" beach substrate samples

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Laboratory materials needed:

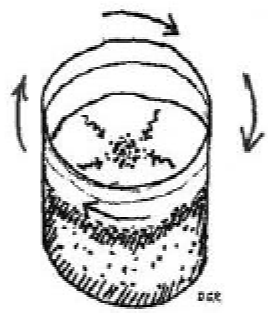
Fume hood (alternatively, winnowed light fraction samples can be carefully washed before analysis)*
Latex or nitrile gloves*
Spoon
Oval microscope dish
Dissecting microscope with 10-20x power
Watchglasses/small Petri dishes
Fine-point (watchmakers) forceps
Data/tally sheets
Paper towels
Buckets/pans/sample jars (to collect waste, accumulated samples, etc.)

*Depending on the preservative used, samples may be toxic or carcinogenic. Take proper precautions.

Note: This procedure describes a second reduction of bulk substrate material collected during field sampling and is best used for determining spawn presence/absence. If detailed egg stage counts are needed, use the associated document "Laboratory procedure for counting and staging forage fish eggs."

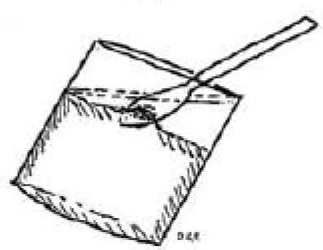
Procedure:

1. Stir "winnowed light fraction" sample jar contents with spoon.



2. Swirl jar in clockwise manner to impart rotation to fluid and surface layer of contents, causing light material to move to center of jar.

3. Carefully tilt jar. Slowly scoop center mound of light material with spoon into oval microscope dish.



4. Repeat steps 1-3 four times, accumulating about 400 grams of light material in microscope dish.

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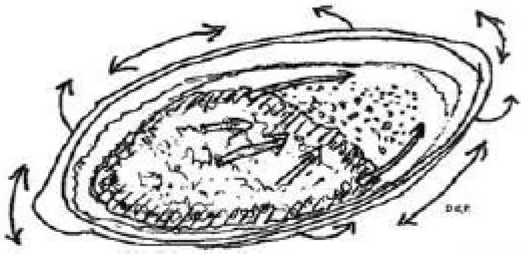
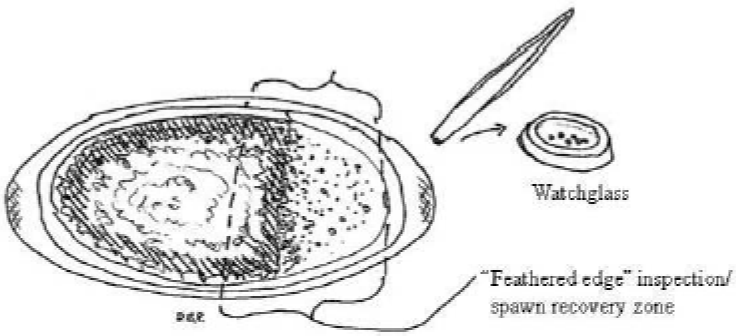
5. Add water to microscope dish. Swirl/tilt/yaw dish to suspend lightest material and concentrate it along feathered edge of the deposit in the dish.



6. Place dish on microscope stage. Inspect zone around feathered edge of deposit. Remove eggs to watchglass with forceps.



7. Reverse dish to redistribute sediment. Repeat steps 5+6 three more times, or until eggs cease to be detected around feathered edge of deposit. Species assignment may be made at this time or after completing processing (see attached egg identification guide).

8. If steps 1-7 produce zero eggs, or only a single egg, repeat the procedure with a second sample of material from the same jar of "winnowed light fraction." The WDFW standard for documenting a spawning site for a given species is 2 eggs in a single "winnowed light fraction" sample.

9. Either preserve eggs for future counting and staging, or identify eggs in watchglass (see attached egg identification guide) to determine the species present.

10. Complete survey findings, as well as preserved egg samples if taken, should be sent to Dayv Lowry at Dayv.Lowry@dfw.wa.gov and/or WDFW, Habitat Program, 1111 Washington St SE, Olympia, WA 98501.

Original protocol by Dan Penttila, WDFW. Reformatted by Dayv Lowry, WDFW.

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Protocol FF-04

WDFW Intertidal Forage Fish Spawning Habitat Survey Protocols

Laboratory procedure for counting and staging forage fish eggs obtained from processed "winnowed light fraction" field samples

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Laboratory materials needed:

Petri dishes/measuring plates
Spoon
Balance or scale
Disposable pipette
Paper towels
Dissecting microscope with 10-20x power
Fine-point (watchmakers) forceps
Watchglasses
Data/Tally sheets

Note: This procedure describes the analysis of "winnowed light fraction" sediment samples and is best used for quantifying spawn abundance/intensity by species. If spawn presence/absence is needed, use the associated document "Laboratory procedure for determining forage fish egg presence/absence."

Procedure:

1. Thoroughly mix the contents of the condensed "winnowed light fraction" sample obtained from field processing of bulk sediment samples. Place a Petri dish or measuring plate on a balance/scale and tare (i.e., zero) the device.

2. If preservative is present, pour off as much liquid as possible into the appropriate waste container and fill the Petri dish ~½-⅔ full with sediment. Use a pipette to remove any residual preservative or other liquid then use a paper towel to blot the subsample dry. Record the weight.

3. Using a dissecting microscope and forceps, count and record the developmental stage of all eggs in the subsample, using the diagrams below. Eggs may be removed to a watchglass and separated by species (using diagrams below) prior to staging. Record counts on data sheet provided below.

4. Repeat steps 1-3 until all sediment in the sample jar has been examined. When counting and staging is complete, preserve the collected and separated eggs along with the entire sample, appropriately labeled with collection date, location, sampler, and other information.

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5. Combine the weight of all sediment subsamples to obtain a total weight for the sample. Record this value in the comments field of the data sheet. This will be used to calculate egg density by species.

6. The abundance of sand lance, role sole, and other eggs is typically low enough that complete analysis of the "winnowed light fraction" can occur. For surf smelt subsampling may be required due to high spawn density. If this is the case, steps 1-3 should be repeated at least 3 times. The remaining "winnowed light fraction" sample must then have residual liquid poured off, be blotted dry, and be weighed. The total number of eggs in the original sample may then be estimated by dividing the combined weight of all subsamples by the total sample weight (remaining plus all subsamples), and then dividing the number of eggs in the combined subsamples by this value. Specifically:

   (Weight of combined subsamples) / (Weight of **total** sample) = (decimal conversion factor)

   then,

   (# eggs in combined subsamples) / (decimal conversion factor) = (# eggs in total sample)

   Example: From a wet "winnowed light fraction" sample you remove and dry three sediment subsamples weighing 10 g each. You count 200 eggs in the first subsample, 150 in the second, and 250 in the third. You then dry and weigh the remaining sediment in the sample jar and find it weighs 270 g. You have sampled 0.10 of the total sample:

   (10+10+10) / (10+10+10+270) = 30/300 = 0.10

   To get the number of eggs in the total sample, divide the number of eggs you counted (200+150+250 = 600) by 0.10 to get 6000 total eggs. The egg density is 20 eggs/g.

7. Complete survey findings, as well as preserved egg samples if retained, should be sent to Dayv Lowry at Dayv.Lowry@dfw.wa.gov and/or WDFW, Habitat Program, 1111 Washington St SE, Olympia, WA 98501.

Original protocol by Doris Small, WDFW. Reformatted by Dayv Lowry, WDFW.

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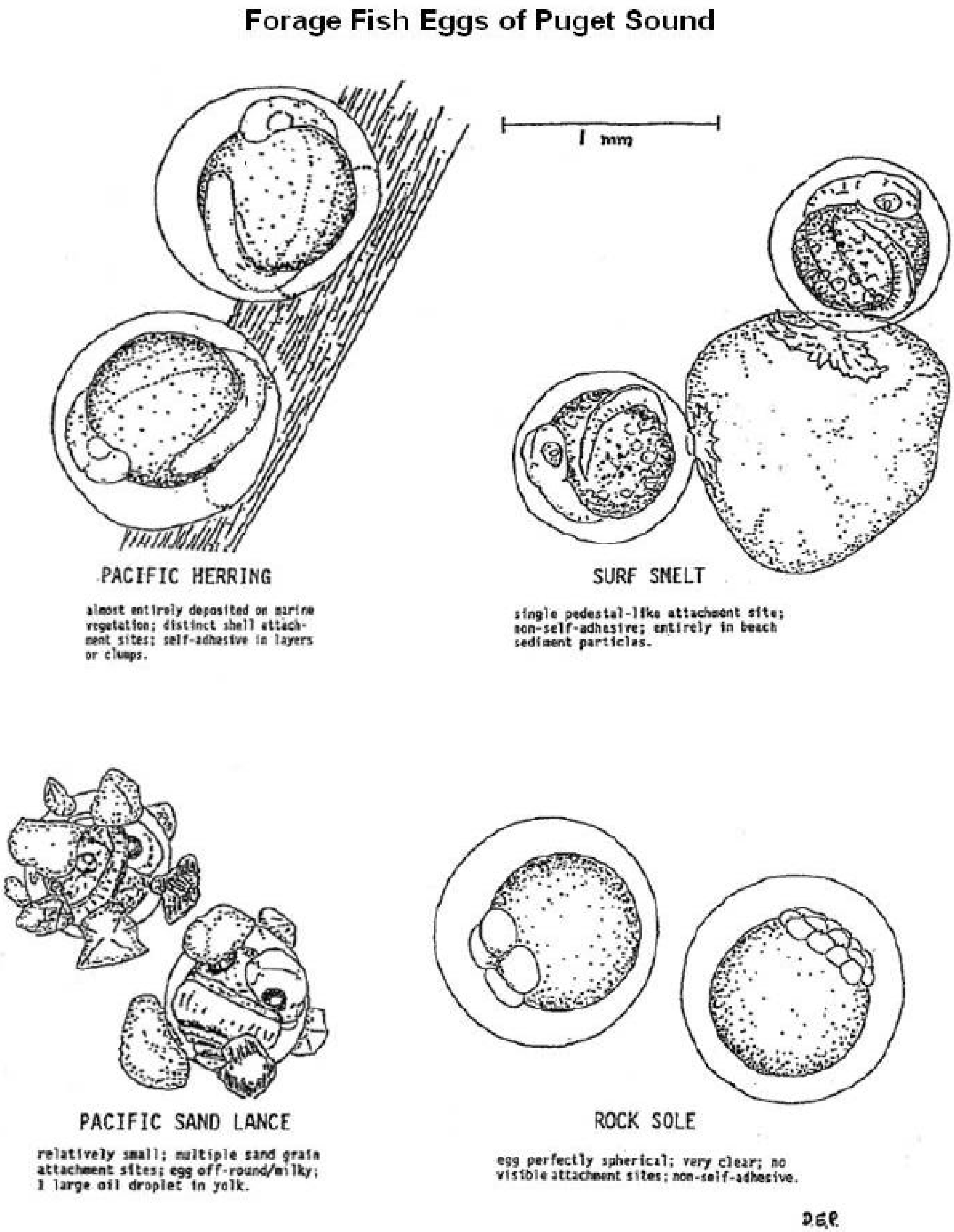
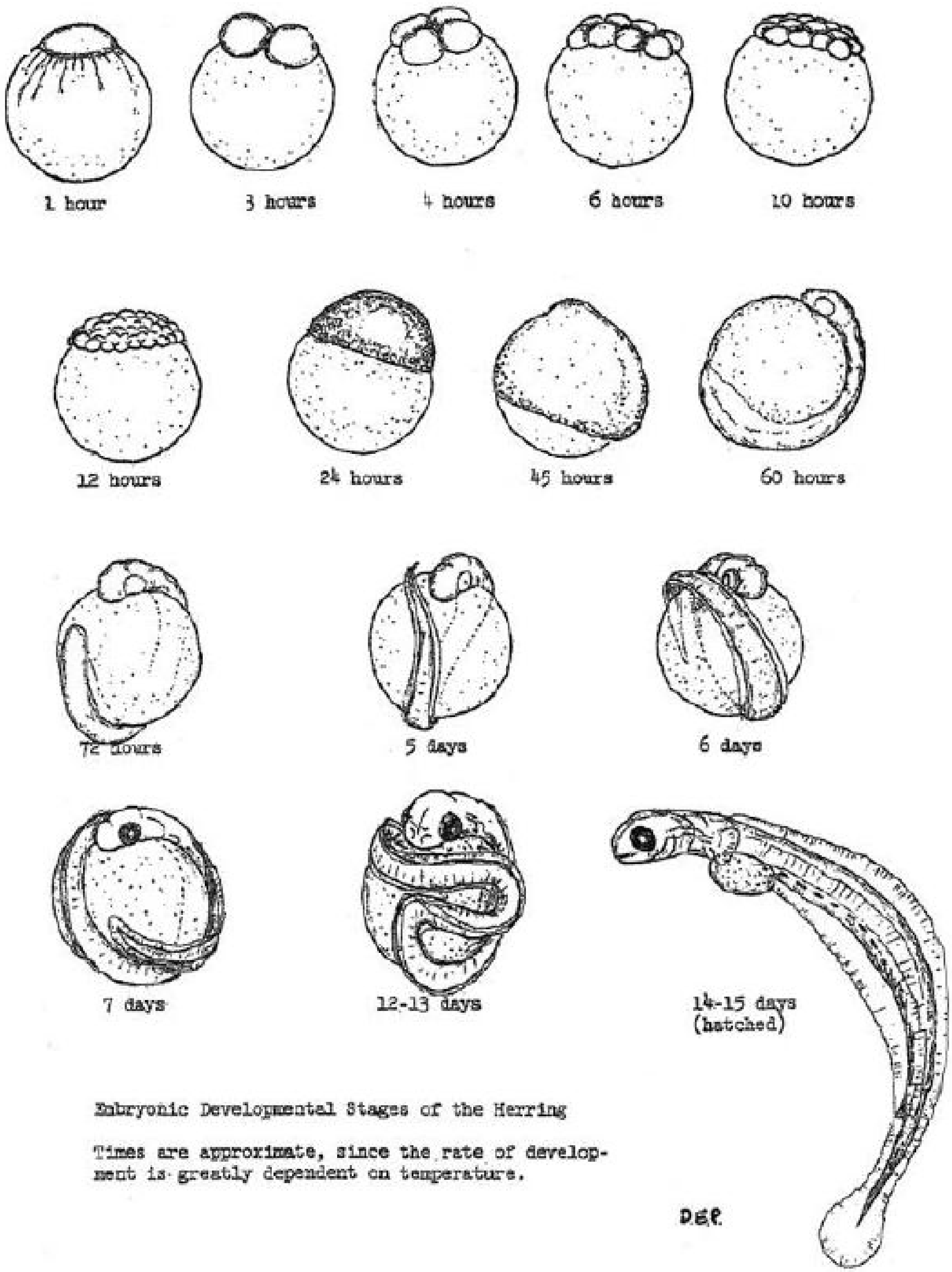

Forage Fish Eggs of Puget Sound
1 mm
PACIFIC HERRING
almost entirely deposited on marine vegetation; distinct shell attachment sites; self-adhesive in layers or clumps.
SURF SMELT
single pedestal-like attachment site; non-self-adhesive; entirely in beach sediment particles.
PACIFIC SAND LANCE
relatively small; multiple sand grain attachment sites; egg off-round/milky; 1 large oil droplet in yolk.
ROCK SOLE
egg perfectly spherical; very clear; no visible attachment sites; non-self-adhesive.
D.E.P.

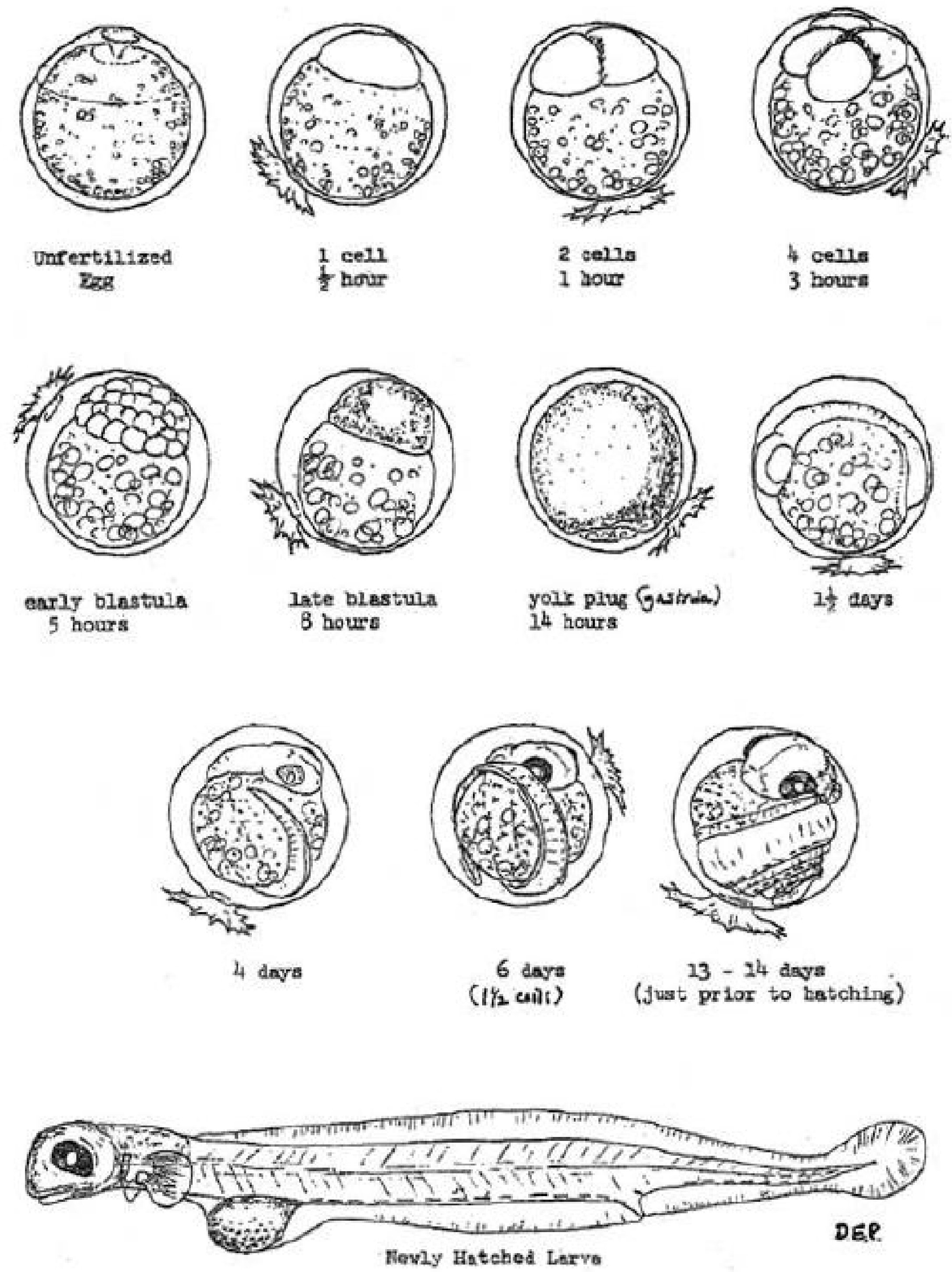
Embryonic Development Stages – Pacific herring



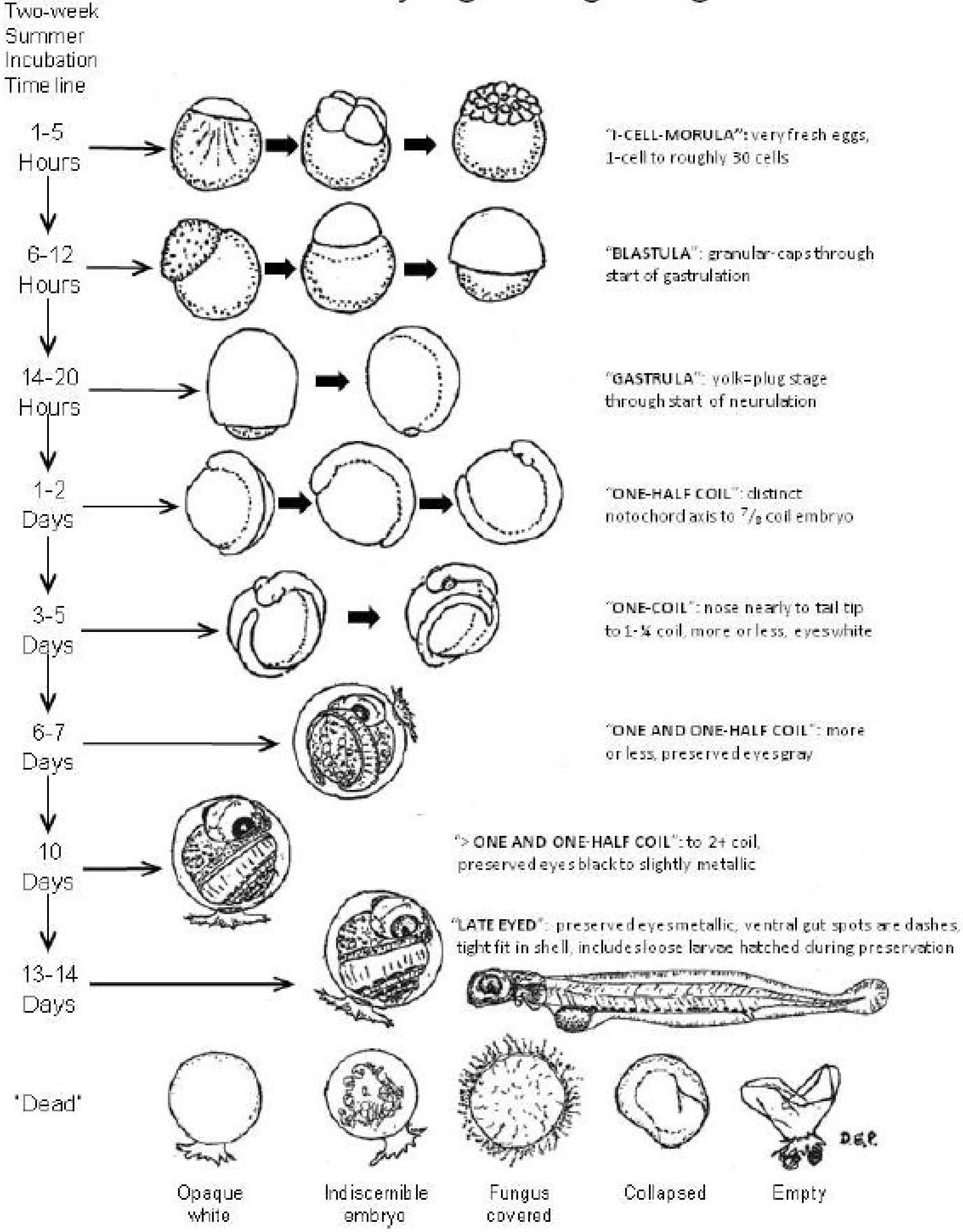
Embryonic Developmental Stages of the Herring

Times are approximate, since the rate of development is greatly dependent on temperature.

Embryonic Development Stages – Surf smelt



Surf Smelt Embryological Stage Categories



Last High Tide	
Time (24-hr):	
Elevation:	

Location:		
Day	Month	Year

Forage Fish Spawning Beach Survey

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Samplers:____

	Beach Station #	Latitude (decimal degrees)	Longitude (decimal degrees)	Beach	Uplands	Width	Length	Sample #	Time (24-hr)	Landmark	Sample zone	Tidal elevation	Shading	Smelt	Sand lance	Rock sole	Comments
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	

Field Observation Sampling Code

Beach: Sediment character of the upper third of beach (particle size range in inches)
0 = mud (<0.0025)
1 = pure sand (0.0025-0.079)
2 = pea gravel (0.079-0.31, "fine gravel") with sand base
3 = medium gravel (0.31-0.63) with sand base
4 = coarse gravel (0.63-2.5) with sand base
5 = cobble (2.5-10.1) with sand base
7 = boulder (>10.1) with sand base
8 = gravel to boulders without sand base
9 = rock, no habitat
Note: Record code that depicts the dominant substrate for the station. If there is no dominant substrate, record all substrate codes observed in the comments.

Uplands: Character of the uplands (up to 1,000 ft from high water mark)
1 = natural, 0% impacted (no bulkhead, rip-rap, housing, etc.)
2 = 25% impacted
3 = 50% impacted
4 = 75% impacted
5 = 100% impacted

Width: Width from upper most to lower most sample scoop on a transect; in feet to the nearest ½ foot.

Length: Length of beach segment up to 1,000 feet (500 feet on either side of the station center).

Sample #: Unless otherwise noted, it is assumed that for a given station with three samples:
1 = Center sample (Recorded coordinate)
2 = North sample (100 ft. north of center)
3 = South sample (100 ft. south of center)

Landmark: landmark for determining sample zone where collection occurs
1 = down beach from last high tide mark
4 = down beach from upland toe

Sample Zone: Distance to lowest sample scoop of a transect taken perpendicular to the landmark; in feet to the nearest ½ foot.

Tidal Elevation: Determined in the office using NOAA verified historic tide data and location/ time data provided.

Shading: Shading of spawning substrate zone, averaged over the 1,000 ft. station and best interpretation for the entire day and season
1 = fully exposed
2 = 25% shaded
3 = 50% shaded
4 = 75% shaded
5 = 100% shaded

Smelt, Sand Lance, Rock Sole: Subjective field assessment of spawn intensity apparent to the naked eye:
0 = no eggs visible
VL = very light, sparse
L = light, but apparent
LM = light medium, visible
M = medium, readily visible
MH = medium heavy, abundant
H = heavy, broadly abundant
VH = very heavy, widespread
W = eggs observed in the winnow

Forage Fish Spawning Beach Survey Sample Analysis

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	Recorder Name	Beach Station #	Sample #	Collection Date	Analysis Date	Species	Total Eggs counted	Dead eggs	Denominator of portion sampled*	Comments
1			1			Surf smelt				
						Sand lance				
						Rock sole				
2			2			Surf smelt				
						Sand lance				
						Rock sole				
3			3			Surf smelt				
						Sand lance				
						Rock sole				
4			1			Surf smelt				
						Sand lance				
						Rock sole				
5			2			Surf smelt				
						Sand lance				
						Rock sole				
6			3			Surf smelt				
						Sand lance				
						Rock sole				
7			1			Surf smelt				
						Sand lance				
						Rock sole				
8			2			Surf smelt				
						Sand lance				
						Rock sole				
9			3			Surf smelt				
						Sand lance				
						Rock sole				

Reviewed by:______________________

*The "*Denominator of portion sampled*" is the value to multiple by to expand to the whole sample. For example, if you analyze 1/4 of the whole sample, this value would be 4. This value must be an integer, therefore if more than 1/2 of the sample is processed, then the whole sample must be processed and reported as 1.