

**Intertidal Forage Fish Spawning Site Investigation for
East Jefferson, Northwestern Kitsap,
and North Mason Counties**

2001-2004

**Final Report to:
Salmon Recovery Funding Board, Washington Department of Fish and
Wildlife, Jefferson County Marine Resources Committee, Jefferson
County, City of Port Townsend**

North Olympic Salmon Coalition
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June 30, 2005



Project Partners



NORTHWEST STRAITS
marine conservation initiative



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This report was funded in part through a cooperative agreement with the National Oceanic and Atmospheric Administration. The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA or any of its sub-agencies.

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ABSTRACT

Surf smelt, *Hypomesus pretiosus*, and Pacific sand lance, *Ammodytes hexapterus*, are fish critical as food for a variety of marine organisms. Both spawn in upper intertidal habitats that are often impacted by shoreline development. Protection of spawning habitat is vital to maintaining stable surf smelt and sand lance populations. The North Olympic Salmon Coalition (NOSC) conducted beach surveys for surf smelt and sand lance spawning grounds from September 2001 to November 2004 in east Jefferson, north Mason, and west Kitsap counties using Moulton/Penttila protocols. Funding sources included the Salmon Recovery Funding Board and the Jefferson County Marine Resource Committee (MRC). With an emphasis on public participation and education, this study demonstrates the work that can be accomplished with the involvement of local volunteers and strong partnerships. Project goals include the designation of unknown spawning sites and educating and involving the public by active participation during research and by providing educational activities, materials and lectures.

Locations where NOSC beach samples included more than one surf smelt or sand lance egg are included in the Washington Department of Fish and Wildlife's (WDFW) Priority Habitat and Species (PHS) Database. Surveys collected 2115 samples along 242 miles of beach that were sampled 1 to 4 times in varying years and seasons. 179 samples, 8.5%, of collected samples, turned up multiple eggs of surf smelt and/or sand lance. These samples designated new spawning areas in 102 locations. This documentation creates protection for approximately 17 miles of beach because Washington state laws include provisions for "no net loss" of forage fish spawning grounds.

Restoration recommendations by geographic area focus primarily on restoring sediment transport and hydrologic processes critical for viable forage fish spawning beaches. Future study recommendations suggest areas for continued forage fish sampling. Documented one-egg sites or areas with suitable substrate with documented spawning nearby are priorities for resampling.

INTRODUCTION

Surf smelt, *Hypomesus pretiosus*, and Pacific sand lance, *Ammodytes hexapterus*, locally known as "candlefish", are critical links in marine food webs in the Puget Sound Basin. A favorite food of salmon and other fishes, marine mammals and marine birds, they are included with Pacific Herring, *Clupea pallasii*, in a group of fish collectively called "bait" or "forage" fish. While herring spawn subtidally on submerged aquatic vegetation, sand lance and surf smelt spawn on upper intertidal sand-gravel beaches in the Puget Sound Region throughout the year (Penttila, 1999). Sand lance spawn from November through February. Surf smelt spawn most often in these winter months, but are known to spawn throughout the year in some Puget Sound areas (Penttila, 10/2000).

Nearshore areas of Puget Sound are subject to a variety of development impacts as human populations along the shoreline increase. Recognition and protection of spawning sites is critical to maintaining healthy forage fish populations. Once designated, forage fish spawning beaches are protected by the Washington Administrative Code (WAC) "Hydraulic Code Rules" (WAC 220-110) through WDFW's hydraulic permit application process.

The Washington Department of Fish and Wildlife conducted the "Intertidal Baitfish Spawning Beach Survey Project" (IBSBSP) throughout Puget Sound from 1991-1999. This project supplied the only formal information on spawning locations of sand lance and surf smelt in Puget Sound. Despite WDFW's efforts, many sampling gaps existed at the termination of their study. Many miles of beach in east Jefferson County and surrounding areas had not been surveyed sufficiently. Shorelines included in the inventory had received minimal sampling and needed carefully planned follow-up sampling. (Penttila, 1/2000) Given the lack of knowledge regarding specific timing of forage fish spawning in a given area, and the obvious difficulty of finding 1mm opaque fish eggs in beach sand, repeated sampling is necessary to find forage fish spawn sites.

In 2001 NOSC was awarded a Salmon Recovery Funding Board grant to conduct forage fish spawning surveys in eastern Jefferson County and portions of Hood Canal as a follow up to the IBSBSP. In partnership with the Northwest Straits Commission through a grant from the National Oceanic and Atmospheric Administration (NOAA), the Jefferson County MRC provided funding for project start-up activities including public outreach and education, landowner identification, sampling access, GIS support and volunteer recruitment and training.

The primary goal of the project was to document forage fish spawning beaches in east Jefferson County, north Mason County and northwest Kitsap County and make this information available to WDFW. A second, and complimentary, goal of the study was to involve and inform the public during the research. Contact with citizens at public outreach events made it clear that the general public had little or no understanding of what forage fish are, or why they are important. Once introduced, the topic generated enthusiastic interest and new understanding among volunteers, students, and landowners. Clearly, an improved understanding of forage fish and their habitat by shoreline landowners and public citizens is a critical component to their protection and continued reproductive success.

At the outset of the project outreach brochures were sent to every shoreline landowner (2300) in east Jefferson County. The brochures explained the importance of forage fish in a healthy marine environment, and the impacts of shoreline development on forage fish spawning. The brochures asked for volunteer involvement and beach access to private beaches. A total of 124 positive responses, and 5 negative responses were received.

NOSC targeted spawning surveys in areas of sand-gravel beaches with limited previous spawning survey information. Spawning surveys used the Moulton-Penttila sampling protocols (Moulton, Penttila, 2001). Habitat information collected at every sample site was entered in a standardized, GIS compatible spreadsheet provided by Friends of the San Juans and WDFW. NOSC's database has been provided to WDFW for inclusion in WDFW's Priority Habitat and Species Database that is used by WDFW habitat managers in assessing and conditioning hydraulic permit applications.

At the conclusion of the study all east Jefferson County shoreline landowners were sent maps documenting the location of known forage fish spawning sites in their shoreline segment or bay. Drift cell and bulkhead coverages were included with information about how they interact with forage fish spawning habitat. A second copy of the initial outreach brochure was also included.

During the project NOSC gave 15 forage fish presentations to community and civic groups. Elements from the outreach brochure and a forage fish project power point presentation are posted on the internet at nosc.org.

Partnerships:

The Jefferson County Marine Resource Committee has provided vital community and professional contacts that have helped in volunteer recruitment and facilitated our partnerships with the Navy and the Port Townsend Marine Science Center. The JCMRC was instrumental in acquiring shoreline landowner lists for initial landowner outreach and educational mailings at the project end.

The Jefferson County Conservation District (JCCD) donated use of Trimble GPS equipment and GIS computer. In addition, they have provided technical assistance with the GIS aspect of the project.

The Environmental Affairs Office at US Naval Magazine Indian Island partnered on several aspects of the study. The Navy provided biological staff and access for sampling Indian Island's shoreline. USN provided sampling supplies for the study as well as disposal of sample waste.

The United States Geological Survey Marrowstone Marine Station donated the use of two hooded dissecting scopes and lab space for the duration of the study.

Washington Department of Fish and Wildlife provided training, QA/QC and project guidance. WDFW donated staff and boat time for sampling in NE Kitsap county and areas of Jefferson County.

The Point No Point Treaty Council staff provided GIS consultation services and GIS coverages of shoreline bulkheads, drift cells, and aerial photos.

Northwest Watershed Institute contacted shoreline landowners in Dabob and Tarboo Bay to gain NOSC access in these areas. Previous landowner mailings received extremely low responses in this area.

Walt Blendermann loaned NOSC his 16-foot skiff for two years of the study, greatly increasing sampling efficiency and capabilities.

METHODS

Project Startup and Educational Outreach

Biologist/author Ron Hirschi and illustrator Debbie Cooper developed a brochure illustrating and explaining the vital role of forage fish in a healthy marine environment and their importance to salmon stocks (Appendix 1). The brochure also explained how coastal processes create and sustain healthy forage fish spawning habitat. The brochure's tear off mailer asked landowners for permission to access their property.

Over 2300 shoreline landowners in east Jefferson County were mailed one of these brochures in August 2001. Addresses were provided through a cooperative agreement with Jefferson County Assessor's office. Positive responses were received from 124 landowners. There were five negative responses. Overall response rate was 5%. In addition, many positive respondents talked to their neighbors who gave permission to access neighboring shoreline parcels. Additional landowner permission was gained by directly contacting landowners along the shoreline while surveys were in progress or through phone calls to landowners in targeted reaches. Also, through a partnership with the Northwest Watershed Institute, landowner permission was gained for nearly all of Dabob and Tarboo Bay. For surveys in northeast Kitsap and limited areas in east Jefferson County, WDFW provided assistance and shoreline access with donations of staff time and the use of a WDFW boat.

Some landowners accompanied staff and volunteers during the surveys and gained a greater understanding of shoreline ecology while helping with the study. Most people were surprised and fascinated to learn about the habits of these fish that live "in their backyards". A small network of trained shoreline landowners collected repeat samples on a regular basis.

During the course of the study, NOSC staff has provided lectures on forage fish to a variety of community groups and took informational forage fish displays to area events. Through this forum public awareness increased, additional shoreline access was gained and volunteers were recruited. Table 1 and Table 2 below summarize the educational events attended.

TABLE 1: FESTIVAL BOOTH DISPLAYS

Venue	Approx # of Contacts	# of Visits to venue
Jefferson County Fair	20, 20	2
Land Trust Tree Festival	10	2
PTMSC Low Tide Fest	10, 10	2
Trout Unlimited Expo	15	1
Port Townsend Farmers Market	10, 10	2
TOTAL	105	9

TABLE 2: LECTURES TO COMMUNITY ORGANIZATIONS

Community Group	Approx. # of Attendees	# of presentations given
Discovery Bay watchers	15, 15	2
Beckett Point Fisherman's Club	10	1
Port Ludlow Village Council	15, 15	2
Friends of Fort Flagler	25	1
Wild Olympic Salmon	20	1
Puget Sound Anglers	45,50	2
Discovery Bay Day	130	1
Discovery Bay Natural History Potluck	11	1
Discovery Bay Neighborhood Beach walks	8, 5, 20	3
WSU Waterwatchers	35, 35	2
Port Ludlow Fly Fishers	15	1
Bounty of the Sea Festival, Rotary	12	1
Port Townsend Marine Science Center Docent Class	20	1
Menzies Project Natural History Cruises	7, 5, 6	3
TOTAL	519	22

Volunteer Training

Volunteer involvement is considered vital in the educational and research goals of the project. The Port Townsend Marine Science Center sponsored a class by Dan Penttila, WDFW, in the winter of 2000 to help in the recruitment of volunteers for the study. As the study progressed, two seminars taught by Dan Penttila were held by NOSC to train staff and volunteers in the proper sampling protocol. These trainings included a presentation on the life history and biology of surf smelt, sand lance, and herring, and beach sampling at a variety of locations around Port Townsend Bay, processing of samples, and an introduction to the microscopic analyses of the samples. A total of 23 people attended the trainings. Of the 17 volunteers who attended, 12 actively participated in the study. Most study volunteers were recruited from press releases, forage fish talks, outreach booths at local festivals, and through recommendations by other volunteers. These volunteers received sampling training and forage fish education from NOSC staff before and during the study.

The study attracted new NOSC volunteers with a wide variety of backgrounds including law enforcement, commercial fishing, geology, and art. Eighty-six volunteers have participated in the spawning surveys to date donating 1262 hours of labor. Seventeen professional scientists, many with marine biology and geology experience, have participated as project volunteers. The additional knowledge brought to sampling expeditions by such professionals led to increased public education and created an exceptional communication network among volunteers and staff alike.

Sampling and Processing

NOSC used methods developed by the Washington Department of Fish and Wildlife for sample collection, processing and laboratory analysis (Moulton and Penttila, 2001). The methods in brief are described as follows: A bulk sample of surface substrate was collected from ~ +7 foot tide height on the beach by scraping the top 0.5-1 inch of sand from a 3-4 foot swath of beach parallel to the water line. This was repeated about every 15 feet at least three times until a gallon ziplock type bag was filled. When a sample (one bag) was taken, the beach location was marked on topographic maps and recorded with a GPS unit.

Substrate type, character of the uplands (development), location of sample zone, length and width of potential habitat and shading of the beach were also noted. A numbered waterproof tag was included in the sample bag. These bulk samples were then winnowed down by rinsing them through a series of screens to capture the 0.5-2 mm size fraction that would contain any spawn. This size fraction was then placed in a dishpan and agitated to bring the lighter, less dense egg material to the surface. This surface layer was then scraped off and preserved with Stockard's Solution for later lab analysis.

In the laboratory, at least 100 grams of the condensed, preserved fraction was scanned under 10X magnification. Embryological classification of forage fish eggs determined date of spawning, the number of broods present, and the level of egg mortality at the site. At least two eggs needed to be found in a sample for it to be counted as a positive sample. Sites where only one egg was detected in the condensed fraction were marked as priority areas for resampling (Penttila, 1995).

All lab analysis was conducted by trained, contracted lab assistants to assure quality. Sieving/winnowing operations were usually conducted by trained staff and contractors. When volunteers participated in sieving activities, trained staff or contractors always provided oversight of the processing to assure quality.

A Quality Assurance Project Plan (QAPP) was written at the beginning of the study to insure that participants followed the same set of protocols and had a standard operating procedure (Appendix 2). This plan covers sample collection, storage and processing. It also covers laboratory protocols and procedures for microscope use and stockard waste disposal. The plan was modified from the original format to include measures for Quality Assurance and Quality Control of databases associated with the project.

Selecting Sampling Locations

The study area includes all shorelines of east Jefferson County. Mason County shores were sampled from the Jefferson County line south to Liliwaup. Kitsap County shores were sampled from Point No Point around Foulweather Bluff to Coon Bay, from Salsbury Pt to the north side of Bangor Naval Submarine Station, and from the south side of Bangor Naval Submarine Station to Misery Pt. In Kitsap County, Port Gamble and Bangor Naval Submarine Station were not included as sample areas due to the large amount of documented spawning from WDFW surveys and limited time for sampling (Figure 1).

We initially targeted areas with substrate preferred by forage fish where previous sampling by WDFW was limited and no previous documentation of sand lance or surf smelt spawning existed. Initially, surveys were conducted on foot with access across private property. Foot surveys provided excellent opportunities for volunteer involvement and education; however, walking long reaches of shoreline can be labor intensive. Volunteers soon began to feel like packhorses, and recruitment of beach hikers became less and less fruitful as the study progressed.

In October 2003, a NOSC volunteer/board member provided his 16-foot aluminum boat for sampling. This greatly expanded the area that could be covered in a day, and allowed access to tidelands not accessible or difficult to access from the uplands. Easier sampling allowed NOSC to increase its scope of studied beaches to include those previously documented by WDFW's IBSBSP. Repeat sampling provides valuable information on the persistence of forage fish spawning beaches and yearly timing of spawning, and in many instances a different species of forage fish was documented than the species previously documented by WDFW.

Data Management

All sampling results were recorded in a Microsoft Access database using a format created by Jim Slocumb and the Friends of the San Juans. This database is the accepted format for recording and reporting forage fish beach spawning research for the 7 counties under the NW Straits Commission and SRFB coordinated forage fish project and the work performed by WDFW in Clallam County. All NOSC sampling results were delivered to WDFW, and new positive sample sites are currently included in WDFW's Priority Habitats and Species (PHS) Database. This information is available to WDFW habitat biologist for conditioning of Hydraulic Permit Applications, and may be obtained by any person or agency requesting it. Additionally, WDFW plans to create a GIS layer of sample points from historic and current forage fish surveys (Dale Gombert, pers. comm.). All positive and negative sample information will be included in this coverage. Shapefiles of known forage fish spawning beaches in Washington are available at <http://flavorj.com/~skysea/GIS>.

End of Project Outreach Materials

All shoreline landowners in east Jefferson County were mailed a report of forage fish spawning on their local bays and shorelines (Appendix 2). NOSC results and historical WDFW information from the PHS Database were presented on 2000 aerial photos. Net sediment transport derived from Department of Ecology drift cell layers and bulkhead coverage from the Point No Point Treaty Council (Hirschi et al., 2003) were also shown on the maps. A cover letter explaining the maps and the initial outreach brochure were included to explain the interrelationships between forage fish, shoreline processes and bulkheads. Artwork by Deborah Cooper and Mudra Bergan paired with forage fish natural history information is included on the maps and letter.

RESULTS

From September 2001 to November 2004 NOSC forage fish surveys collected 2115 samples. Of these, 179 samples (8.5% of all the samples collected), contained multiple eggs of surf smelt and/or sand lance. These samples designated new spawning areas in 102 locations. 5.78 miles of new sand lance habitat and 10.84 miles of new surf smelt habitat has been designated in WDFW's PHS database from NOSC sample stations. 12.02 miles of this habitat had no previous record of use by any forage fish species. On approximately 4.6 miles of beach, we found a second species of forage fish spawning in areas previously documented to support spawning of another forage fish species.

In addition to documenting spawning by surf smelt and sand lance, we documented the presence of spawn from two other fish species. 11 samples recorded multiple rock sole, *Lepidopsetta bilineata*, eggs, a demersal spawner known to use intertidal areas on occasion (Penttila, pers. comm.) but with no previous record of beach spawning in Jefferson County. Through our sampling effort 1.64 miles of rock sole spawning habitat has been designated in the WDFW PHS database. 3 samples recorded herring eggs. Herring eggs found on the beach are assumed to have detached from subtidal vegetation and are not included in the WDFW PHS database.

The following table provides a “bay by bay” summary of sampling results. “New Sand Lance Sites” and “New Surf Smelt Sites” are locations where no previous record of that species of forage fish spawning existed. “Second Species” are sites where the beach was previously known to be used by one forage fish species, but a second species was encountered in samples from the site. “Redocumented Sites” are locations where NOSC sampling found forage fish spawn on beaches known to be used by that species by WDFW. “One-egg Sites” are only noted in this report when they were encountered at sites previously unknown to be used by that species of forage fish.

TABLE 3: SAMPLING RESULTS BY AREA

Shoreline Region, Figure #	Miles (approx.)	# of Samples	New Sand Lance Sites	New Surf Smelt Sites	Second Species	Redocumented Sites	One- egg Sites
Discovery Bay, 3	22	195	1	3	0	2	3
N Quimper Peninsula, 4	4	91	0	0	0	1	0
Port Townsend Bay west, 4	12	245	7	2	0	8	4
Indian Island, 5	12	138	7	15	13	23	6
Marrowstone Island, 5	17.5	227	2	6	6	11	2
Oak Bay, 6	5.5	70	1	1	0	0	0
Port Ludlow, 7	15	170	3	10	1	11	4
Squamish Harbor, 8	6.5	60	0	1	0	2	3
Thorndyke Bay, 8	4	79	0	0	0	1	3
E. Coyle Peninsula, 9	10	105	0	1	1	2	3
Dabob Bay, includes W Coyle, 9, 10	20	215	13	14	7	6	3
Quilcene Bay, 10	10	59	0	5	1	8	1
Pulali Pt to Quatsap Pt, 11	10	82	3	1	0	0	1
Quatsap Pt to Liliwaup, 12	20	86	0	0	0	0	0
Pt No Pt to Coon Bay, 13	8.5	68	0	0	0	0	3
Salsbury Pt to Bangor, 14	8.5	132	1	0	0	0	2
Bangor to Seabeck, 9	10	94	0	2	0	2	1
	195.5	2115	38	61	29	77	39

Spawn Timing

Any sample with one or more eggs detected was classified by the month in which it was collected to demonstrate months in which spawn is most likely to be collected in the study area. No samples were collected in April or June.

CHART 1: SAND LANCE AND SURF SMELT SAMPLES WITH SPAWN

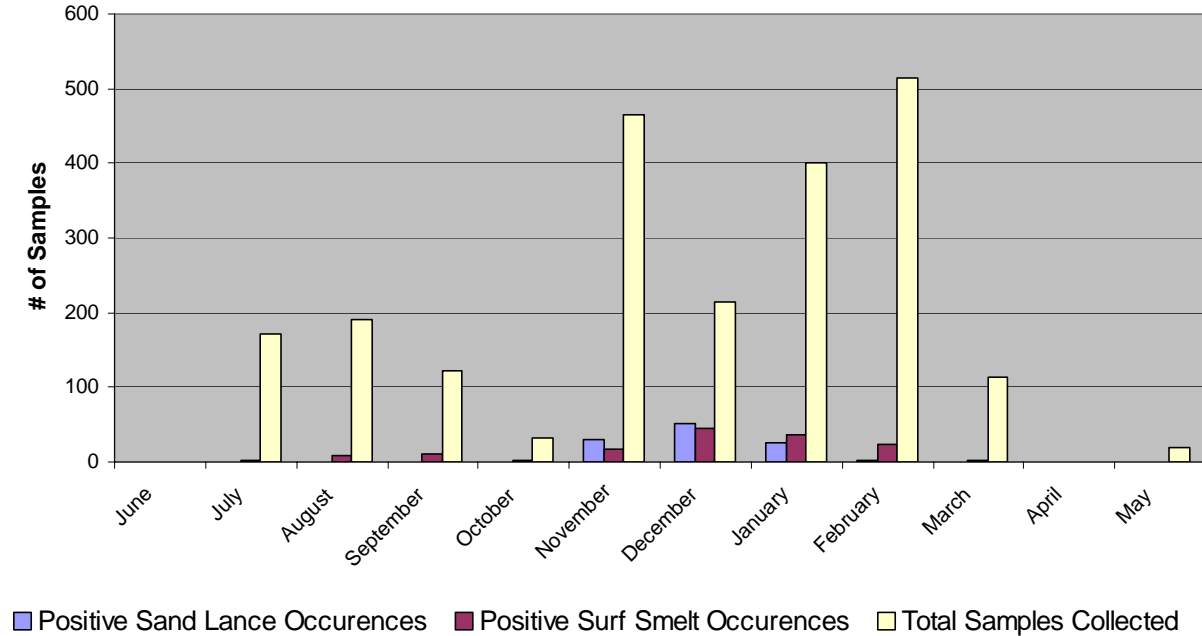
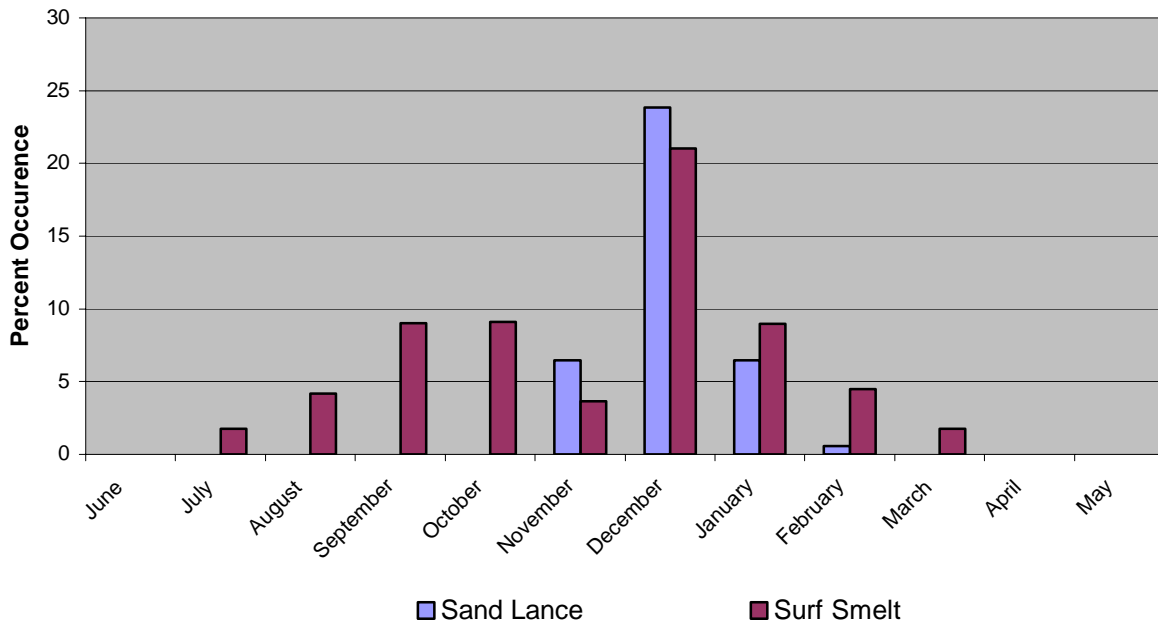


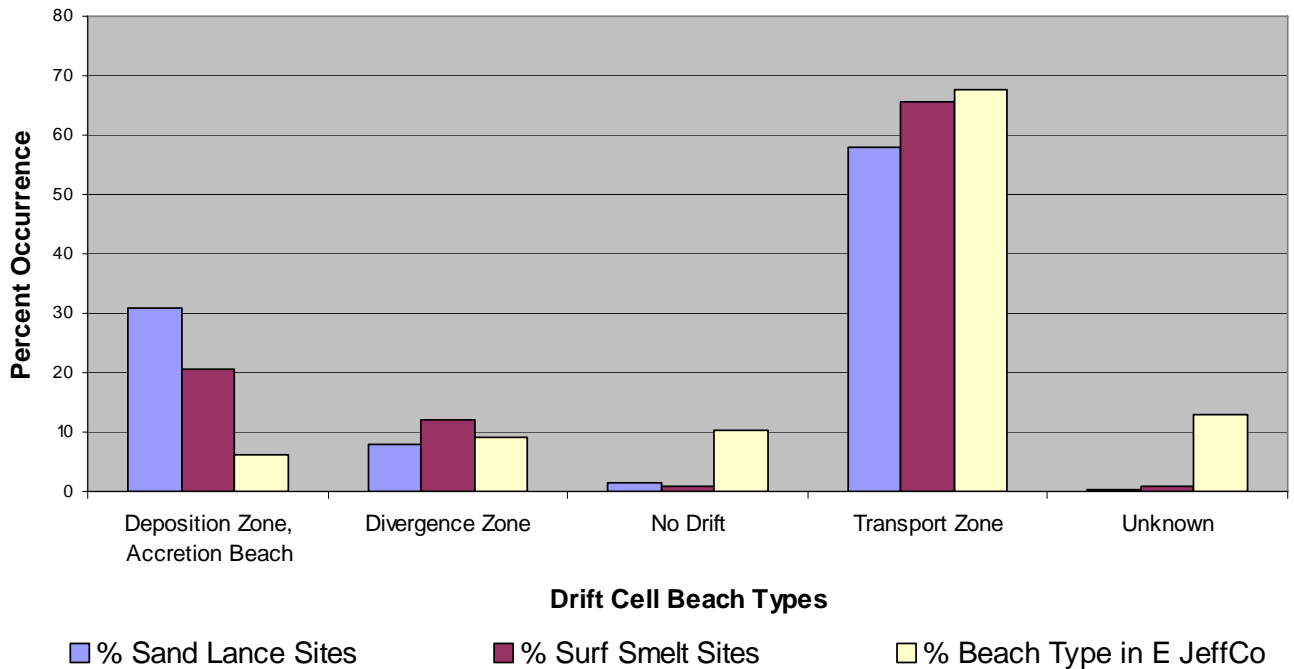
CHART 2: PERCENTAGE OF SPAWN OCCURRENCES IN BEACH SAMPLES



Beach Type Preferences

By consulting Department of Natural Resources shorezone shapefiles and Department of Ecology drift cell shapefiles it was noted that approximately 31% of known sand lance spawning and 21% of known surf smelt spawning in east Jefferson County takes place in deposition zones, areas known as accretion beaches. Accretion beaches make up only about 6% of the shoreline in east Jefferson County. So, 31% of sand lance spawning and 21% of surf smelt spawning takes place in just 6% of the habitat. It is possible that accretionary beaches accumulate preferred spawning substrate leading to this trend.

CHART 3: PERCENT OCCURRENCE OF SPAWN IN DIFFERENT ACCRETION ZONES



One-egg Sites

39 one-egg samples were collected by NOSC in areas previously unknown to support spawning of the detected species. These and historic one-egg sites are areas for the concentration of future study (Penttila, 2000) (Figures 15, 16). During NOSC’s sampling efforts, sampling at historic WDFW one-egg sites often resulted in the confirmation of the beach as a spawning site by the species detected by WDFW or by a second species of forage fish (Table 4).

TABLE 4: ONE EGG SITE SAMPLING SUMMARY

WDFW One-egg Sites in E JeffCo	Original species usage confirmed by NOSC resampling	Alternate species usage confirmed by NOSC resampling	Percentage one-egg sites confirmed as spawning grounds
25	6	5	44%

Substrate Selection

Substrate was classified in the field by the predominant substrate visible in the sampling location. Categories were 1) Mud <0.125mm 2) Pure Sand 0.125mm to 2mm 3) Pea gravel with sand base 2-4mm 4) Medium gravel with a sand base 4-8mm 5) Coarse gravel with a sand base 8-16mm 6) Cobble 16-256mm 7) Boulders >256mm. It should be noted that classification stressed the substrate visible on the surface. Scooping into the substrate usually resulted in the capture of many finer grained sediments not readily visible.

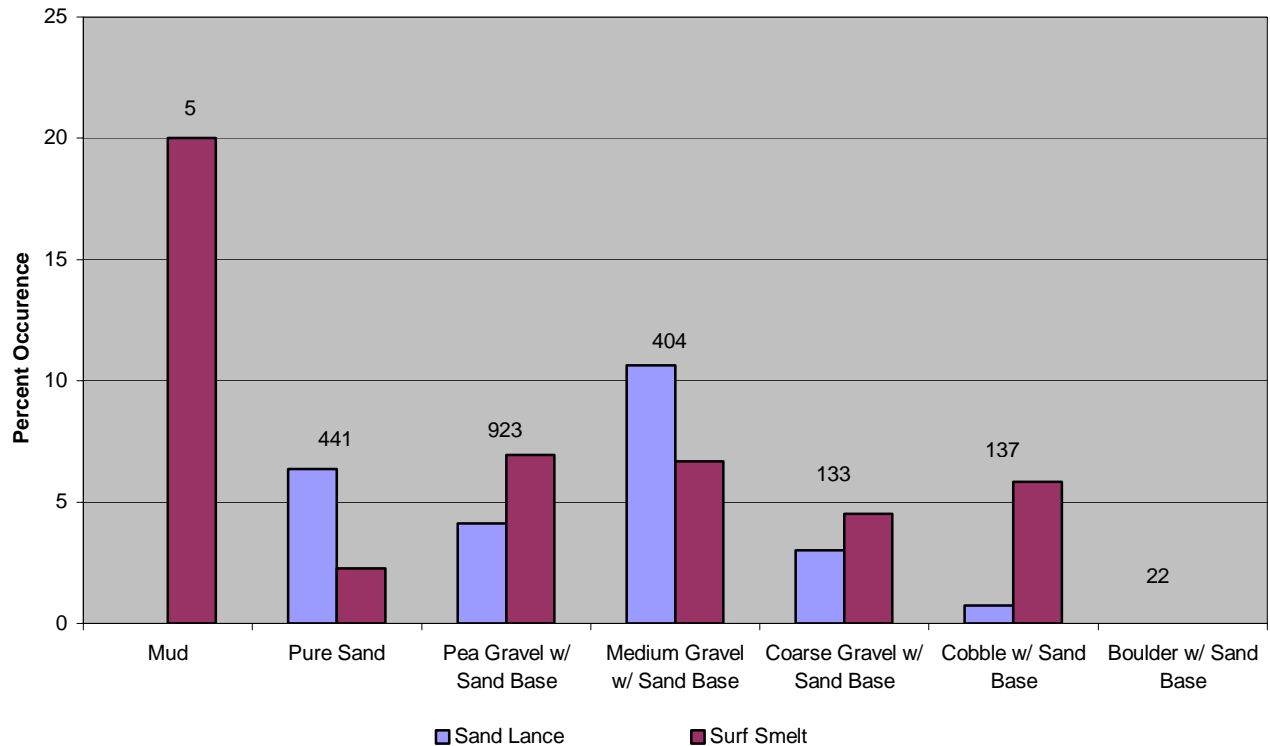
Surf smelt eggs were most often found in a pea gravel like substrate mixed with sand, with medium sized gravel mixed with sand as the second most common substrate. Sand lance eggs were most often found in a pea gravel like substrate mixed with sand, with pure sand as the second most common spawn substrate. These substrates constituted the greatest proportion of chosen sample sites based on previous research results which suggest these are the best spawning substrates (Penttila, 1995), and based upon in the field training from Dan Penttila. However, surf smelt and sand lance eggs were found in substrates other than these archetypal spawn substrates (Chart 4).

A beach of compacted pea gravel/clay substrate with small cusps of loose pea gravel/sand on the north shore of Port Ludlow bay yielded surf smelt eggs in 2003 and sand lance eggs in 2002. The beach might have been classified as unsuitable by visual characters only. Surf smelt spawn was found at two similar sites in Mystery Bay and at one site at the head of Quilcene Bay. Other “nonconformers” included beaches with a substrate of pebbles lacking much sand or smaller particles. Though not often selected for spawning, samples from these beaches did occasionally yield surf smelt eggs. The standard data sheet did not include any options “without a sand base” which made it difficult to quantify these areas using assigned codes.

These samples demonstrate that caution is needed when making sampling judgments regarding suitable forage fish spawning habitat. Researchers have a limited amount of time for surveys, and usually target highest quality/most likely to be used habitats first and most frequently. This often leaves lower quality habitats unexamined and prevents studies from detecting deposits in these areas. This can skew data from reflecting true percentages of habitat types being utilized by sand lance and surf smelt (Penttila, pers. comm.). Whenever possible, NOSC surveys were inclusive of all beach habitat types, although a preference was given to sampling “more suitable” areas more often.

CHART 4: PERCENT OCCURRENCE OF SPAWN IN DIFFERENT SUBSTRATES

* Numbers above bars indicate # of samples collected in given substrate.



The relatively high occurrence in mud above is an artifact of a small sample size. Also, the one beach of mud that showed surf smelt eggs (2) in laboratory examination was located in a small bay between two reaches of pea gravel beach with known surf smelt spawning. It is possible the eggs drifted or were washed to the mud area from neighboring beaches.

QA/QC Results

As outlined in the QA/QC plan, one-third of all negative samples were sent to Dan Penttila for his examination. In all, 646 negative samples (30.5%) were checked. Of those, 5 positive samples had been missed and 10 one-egg samples had been missed. Conversations with Mr. Penttila indicate that some missed eggs are expected, and that NOSC’s numbers were within tolerances and not cause for concern. Additionally, he noted an improvement in NOSC’s lab egg detection after our first season of lab work. In fact, 4 of the 5 positive samples missed were from the first seasons laboratory work. In the following two seasons laboratory analysis only 1 unidentified positive sample was found.

Dan Penttila also confirmed lab technicians egg identifications at the projects outset and conclusion to assure proper identification. No identification errors were noted.

A mistake was noted in the QA/QC plan in January of 2003. Screen sizes were incorrectly entered in the plan causing NOSC to use 2mm, 1mm and .5mm screens instead of 4mm, 2mm, and .5mm screens. The mistake came to the attention of NOSC after Dan Penttila noticed the relatively small size of substrate in NOSC samples sent to him for QA/QC in January 2003. The procedural error was corrected beginning with sample number 02KRL750. Dan Penttila ran a series of trials to determine the effects of the accidental inclusion of the 1mm screen (Penttila, 2004). Trial results suggest that the inclusion of the 1 mm screen

actually increases detectability of surf smelt eggs and decreases detectability of sand lance eggs in a given sample. Dan Penttila concluded that the net results of NOSC surveys were not significantly impacted by the mistake and that NOSC data could be incorporated into WDFW spawning habitat databases.

OBSERVATIONS AND RECOMMENDATIONS

Each shoreline region broken out in Table 3 is further quantified below with: 1) general observations 2) months in which NOSC found forage fish spawn in the region 3) future intertidal baitfish spawning study recommendations and 4) suggested restoration actions to improve/maintain habitat qualities necessary for intertidal forage fish spawning.

Discovery Bay, Gardiner Boat Ramp to Cape George, Figure 3

Observations: Compared to the rest of the study area, Discovery Bay sampling turned up surprisingly few positive samples during NOSC sampling. Historic data reflects that much of the Discovery Bay shoreline supports sand lance spawning; however, in 200 NOSC samples only 3 sites had sand lance eggs (two of these were at historic sites and one bordered a historic site). Two new surf smelt sites were noted, and one historic beach was confirmed. Despite sampling in many of the same months as historic studies conducted in 1993-1994, NOSC surveys were rewarded with only a few positive sites. Such sampling discrepancies may be attributed to fluctuations in stock abundance (Penttila, pers. comm.) and demonstrate the challenges associated with forage fish beach surveys.

Beckett Point is one of two areas in E Jefferson County where neighboring drift cells converge, a “convergence zone”, where there is no documented forage fish spawning. NOSC surveys did turn up one surf smelt egg and previous WDFW sampling has found 2 one-egg sand lance sites bordering the point.

Beaches at the SE end of Discovery Bay from Woodman’s Beach south about 2.3 miles are impaired by railroad rip rap bulkheading extending below ordinary high water (OHW). The railroad grade is no longer in use and the bulkhead is slowly degrading. Spawning substrate is very patchy through this reach, and most of the tidal elevation used by beach spawners is buried in rip rap. NOSC sampled along the face of this bulkhead on two seasons. One sample collected November 2003 yielded 2 surf smelt eggs. This sample was collected in an area where the bulkhead has eroded almost completely, exposing the upper beach for a stretch of approximately 250 feet. This forms a small “pocket beach” with excellent spawning substrate at appropriate tidal elevations. This demonstrates the positive response of intertidal spawners to the removal of a structure previously impeding their ability to spawn by burying spawning habitat.

NOSC Positive Samples: surf smelt-Dec 01, Nov 03, Feb 03; sand lance-Dec 01

Future Study Recommendations: Beckett Point and the beaches bordering to the N and S should be considered areas of high priority for further sampling efforts. Most of the Bay exhibits substrates appropriate for beach spawning and reaches without known forage fish spawning should be targeted.

Restoration Action: Removal of railroad bulkheading along the abandoned railroad grade in southeast Discovery Bay would enhance about 1.6 miles of highly impaired beach with known forage fish spawning in the area. Bulkhead education and possible removal at Beckett Point. Proper deposition of Cape George marina entrance dredge spoils on the down drift side of the marina.

North Quimper Peninsula, Cape George to Pt Wilson, Figure 4

Observations: Despite excellent spawning substrate for the majority of this reach, NOSC and WDFW surveys have not found forage fish spawn except for one summer surf smelt site on Point Wilson's north side. Summer surveys were limited to the area from Point Wilson to North Beach in the NOSC study.

NOSC Positive Samples: surf smelt-Aug 04.

Future Study Recommendations: Further summer sampling and some winter sampling of this reach.

Restoration Action: Removing the unused Coast Guard lighthouse from the tip of Point Wilson would allow for removal of massive bulkheading at Pt Wilson's tip which is bordered on both sides by summer surf smelt spawning beaches. Removal of the unused boat ramp at North Beach County Park. The Port Townsend Shoreline Inventory (Nightingale, 2002) references these and other nearshore impairments.

Port Townsend Bay, Pt Wilson to Ship Canal, Figure 4

Observations: This reach is heavily used for spawning by forage fish. Sampling of historic sites and undocumented beaches often turned up forage fish spawn. Most of the reach exhibits excellent spawning substrate, except where shoreline development has covered the spawning elevations.

NOSC Positive Samples: surf smelt-Mar 02, Oct 02, Aug 04, Nov 04; sand lance-Jan 02, Nov 02, Dec 02, Dec 03, Jan 04

Future Study Recommendations: Any areas not currently designated as forage fish spawning should receive further sampling. A concentration of one-egg sites at Pt. Hudson and neighboring downtown beaches are a high priority for resampling.

Restoration Actions: Removal of concrete waste pile well below OHW at Pope Marine Park in Port Townsend would expose over 100 feet of beach with excellent substrate and forage fish spawning in the area. Removal of unused pilings/dolphins/ferry ramps in Port Townsend area. Removal of Larry Scott Trail bulkheading would reconnect a feeder bluff to its beaches. An elevated rail boat ramp at Port Hadlock would alleviate the need to clear beach sediment from the current ramp during winter months in known sand lance spawning habitat. Remove the unused creosote railroad trestle in Port Townsend Boat Haven. Also refer to Port Townsend Shoreline Inventory (Nightingale, 2002).

Indian Island, Figure 5

Observations: Nearly every Indian Island beach is now known as spawning grounds for surf smelt and/or sand lance. Samples along the east shore confirmed WDFW's results of heavy sand lance usage, and also found surf smelt to be using the beaches synchronously with the sand lance. Extremely dense sand lance spawn deposits mixed with surf smelt eggs were detected along Indian Island near the head of Scow Bay in early December 2003.

Indian Island's forest cover is relatively intact. Besides the crane site at Walan Pt and boat/seaplane ramps near Crane Pt, the shoreline is undeveloped and holds many nearly pristine saltmarshes.

NOSC Positive Samples: surf smelt-Jan 02, Dec 03; sand lance-Jan 02, Dec 03, Jan 04

Future Study Recommendations: Given the frequent usage of this area by surf smelt and sand lance, the island would lend itself well to ancillary studies of forage fish life histories. Future sampling of undesignated reaches are very likely to locate forage fish spawn.

Restoration Actions: Remove unnecessary parking lot bulkheads at South Indian Island County Park.

Marrowstone Island, Figure 5

Observations: Few new sites were located on Marrowstone Island. The detection of one sand lance egg on the east side of Marrowstone led to the discovery of sand lance spawn in subsequent samples. Despite excellent substrate and relatively pristine beaches, the east, north, and northwest sides of Marrowstone did not reveal many spawning sites.

One surf smelt egg was located in a sample from the head of Mystery Bay. The substrate here is patches of coarse sand with a mud base throughout. It is a site that doesn't fit the "normal" expectations of forage fish spawning habitat, but demonstrates the need to be inclusive of such habitats in future survey efforts.

A volunteer on Marrowstone collected frequent samples at his beach in Kilisut Harbor. The beach was previously known by WDFW to be a sand lance beach. 10 samples at this site through the studies course turned up 5 samples positive for surf smelt spawn. Positive samples were collected during Nov 01, Feb 02, Jan 04, Feb 04, Nov 04. 3 samples collected during the summer season revealed no spawn.

NOSC positive samples: surf smelt-Nov 01, Feb 02, Jan 04, Feb 04, Sept 04, Nov 04.
sand lance-Jan 04

Future Study Recommendations: One-egg site investigations at Marrowstone Point and Mystery Bay. Resampling of east, north and northwest beaches.

Restoration Action: Replace current concrete boat ramp at Fort Flagler with a raised rail boat ramp. The current ramp serves as a groin, which collects beach sediments and pushes them further off the beach than is normal. Remove old Army pier on northeast Marrowstone as it interferes with longshore drift, is constructed with creosote pilings and is unused. Remove bulkhead on northwest Marrowstone point that disconnects an estuary from the shoreline. Improve water quality in Kilisut Harbor and Mystery Bay to ensure future forage fish spawning in this heavily utilized area. Low water quality has been shown to increase ulvoid blooms which may impede intertidal forage fish spawning (Shaffer, 2001)

Oak Bay, Ship Canal to Mats Mats Bay, Figure 6

Observations: Good sampling coverage in time and space resulted in only 2 new sites. A new sand lance site at the north end of this reach borders previously known sand lance spawning to the south and is of interest due to the complex interactions of bulkheads and a county boat ramp to the south, the ship canal jetty to the northwest, and a newly formed (Nov 04) tidal channel from the saltmarsh through the beach berm to its south. Interacting with the drift cell coming from the south, the bulkheading and boat ramp appear to be depleting the beach north of them of transported sediments by pushing them farther offshore (Hirschi, pers. comm.). The creation of the tidal channel into the large salt marsh was likely sped by this accretion theft paired with winter storm events. Monitoring this sites future forage fish usage and beach characteristics would offer additional insight into the effect of shoreline alterations on spawning grounds.

NOSC Positive Samples: surf smelt-Nov 01; sand lance-Nov 02

Future Study Recommendations: Resample reaches without known forage fish spawning. Mats Mats Bay was not surveyed in this study, and though dominated by muddy substrates, pockets of suitable habitat may hold unknown forage fish spawning sites.

Restoration Action: Remove County bulkhead and unusable boat ramp at Oak Bay County Park. Remove parking lot bulkhead at Jefferson County's South Indian Island Park.

Port Ludlow area, Mats Mats Bay to Termination Point, Figure 7

Observations: The reach directly north of Ludlow Bay was newly identified as summer surf smelt spawning grounds by repeated sampling by a local shoreline landowner and volunteer. This reach is characterized by medium gravel on a sand base and interspersed cobbles. Shoreline vegetation overhangs much of the shoreline in this area creating full shade most of the day except during the early morning. WDFW IBSBSP did not conduct summer sampling in this reach (Penttila, 1999). Surf smelt spawn was also detected in this reach during the winter months by WDFW and NOSC surveys.

The north side of Hood Head also revealed one site utilized in the summer by surf smelt. This beach is a pea gravel/sand beach. It is about 75% shaded by shoreline vegetation. This is a new site for any surf smelt documentation.

3 positive samples of special interest were found on Ludlow Bay's north shore near the marina. Samples in two different winters revealed surf smelt and sand lance utilizing a small section of beach characterized by patches of loose pea gravel and coarse sand on a compacted pebble/clay base. The marine plant *Salicornia europaea* is interspersed at spawning tidal elevations and creates a border along the areas OHW line.

NOSC Positive Samples: surf smelt-Dec 01, Jan 02, Sept 02, Nov 02, Jul 03, Aug 03, Sept 03, Nov 03; sand lance-Dec 01, Jan 02, Nov 02, Nov 03

Future Study Recommendations: Additional summer sampling in this reach may locate more summer spawning grounds.

Restoration/Protection action: Port Ludlow marina expansion may adversely affect forage fish sites on Ludlow Bays north shore. Bulkhead education and possible removal demonstrations by willing landowners is recommended. Protect and improve water quality that is currently degraded by excess nutrient loads in Ludlow Bay and mining activities near Mats Mats Bay (Shaffer, 2002).

Squamish Harbor, Termination Point to south Bridgehaven, Figure 8

Observations: One surf smelt egg was found on Bridgehaven Spit in an area previously documented as sand lance spawning habitat. This area is eroding from the affects of Bridgehaven bulkheading and old ferry terminal wing walls updrift (Hirschi, 2003).

The head of Squamish harbor is one of two convergence zones in east Jefferson County with no documented forage fish spawning.

NOSC positive samples: surf smelt-Jan 04

Further Study Recommendations: Two one-egg sand lance samples were collected from this area, good spawning substrate is present in most of the reach, and most east Jefferson County convergence zones exhibit forage fish spawning, suggesting this as a priority area for further sampling.

Restoration Actions: Restore sediment transport processes by removing unused ferry terminal pilings, dolphins and wing walls. Discontinue dredging of Bridgehaven harbor entrance, or assure proper placement of dredge spoils downdrift.

Thorndyke Bay area, south of Bridgehaven to south Thorndyke Bay, Figure 9

Observations: One-egg site documentation early in the study made the reach E of Thorndyke Creek an area of interest for further sampling. Further site investigations did not find usage by forage fish, except in one known WDFW reach. A rapidly eroding bluff east of the creek contributes major amounts of sediment in this area. Abundant sediment creates wide beaches with numerous nearshore bars (Johannessen, 1992) this makes it difficult to know where to collect forage fish samples because likely tidal elevations and substrates exist on multiple bars.

NOSC Positive Samples: sand lance-Nov 03

Further Study Recommendations: Additional sampling efforts on the expansive beaches east of Thorndyke Creek in areas of one-egg sites. Also, excellent shaded habitat with pea gravel on a sand base exists through much of the Bay south of the creek mouth and should be a target for future sampling.

Restoration Action: Except for a few private bulkheads, this reach is relatively pristine. Future actions that would interfere with forage fish spawning or longshore drift should be avoided.

East Coyle Peninsula, south Thorndyke Bay to Fisherman's Harbor, Figure 10

Observations: Positive samples in this reach bordered on or were directly within WDFW known reaches. Many small streams enter Hood Canal in this reach. A series of small spits occur along the shoreline, most with known sand lance spawning.

NOSC Positive Samples: surf smelt-Feb 03; sand lance-Dec 02, Nov 03

Further Study Recommendations: As suggested by the number of one egg sites encountered in undocumented reaches, continued sampling of gaps in known habitat will likely result in confirmation of forage fish spawning.

Restoration Action: Protect this relatively pristine shoreline from development impacts.

Dabob Bay, Fishermans Harbor to Bolton Peninsula tip, Figure 9, 10

Observations: 20 completely new forage fish spawning sites made Dabob sampling the project's most fruitful. Additionally, resampling of WDFW known reaches redocumented 6 sites and found a second species on 7 beaches. Much of this shoreline is pristine with excellent spawning substrate.

The area was blanket sampled in December/January 02/03 and in February 04. Interestingly, while 30 positive sites were found during December/January 02/03, only 2 samples from the bay revealed spawn on the February 04 sampling. Such dramatic sampling differences during different years and months demonstrates the difficulty of finding surf smelt and sand lance spawning grounds. Scheduling sampling days with considerations for weather and tides over a large geographic region leads to areas receiving sampling during short windows, possibly with the result of completely missing spawning events.

NOSC Positive Samples: surf smelt-Dec 02, Feb 04; sand lance-Dec 02, Jan 03

Further Study Recommendations: The one egg site at the tip of the Bolton Peninsula turned up one surf smelt egg on two occasions on NOSC surveys, and was recorded as a one-egg site in WDFW surveys (Penttila, 2000) and should be revisited. Excellent spawning substrate and nearly pristine backshore through much of this area justifies resampling any gaps in documented forage fish spawning.

Restoration actions: Seek conservation easements to preserve this relatively pristine shoreline. Restore Camp Discovery Creeks lower reaches and interaction with nearshore processes and reduce sediment loads from upland management practices.

Quilcene Bay, Bolton Peninsula to Pulali Pt, Figure 10

Observations: Sampling revealed surf smelt spawn on the west side of Quilcene Bay in addition to confirming surf smelt utilization of most of the east shore. One surf smelt egg was noted in a patch of sand along an otherwise muddy stretch of beach near the head of Quilcene Bay.

NOSC Positive Samples: surf smelt-Jan 03, Jan 04; sand lance-Jan 03

Future Study Recommendations: Most of the bay's shores are now known forage fish spawning habitat. Conduct additional surveys on beaches north and south of Frenchman's Pt and south of Pt Whitney.

Restoration Actions: Remove string of railroad pilings in northwest Quilcene Bay waters. Restore lower reaches of Big and Little Quilcene rivers to encourage natural delta formations.

Pulali Pt to Quatsap Point, Figure 11

Observations: NOSC surveys documented four times as much spawning habitat as had been previously known in this reach.

Sand lance spawn was detected on the Dosewallips River delta. Here river channels carve the beaches in different ways on nearly every tidal cycle. The eggs were found between two delta channels on an island of fine-grained sand mixed with small pea gravel.

NOSC Positive Samples: surf smelt, Feb 03; sand lance Jan 03, Nov 04

Future Study Recommendations: Conduct additional surveys from Dosewallips delta to Quatsap Point.

Restoration Actions: Remove private bulkheads and over beach structures on creosote piles, which are common in this reach. Address water quality issues in Pleasant Harbor. Restore natural Dosewallips River delta by restoring historic lower river processes currently constricted by dikes and subject to channelization.

Quatsap Point to Liliwaup, Figure 12

Observations: No new sites were found in this reach. Only two WDFW historical sand lance sites are known in this reach. Reach substrate is dominated by large gravels to cobbles with or without a sand base. Much of the reach is heavily impacted by Highway 101 bulkheading at or below ordinary high water.

Future Study Recommendations: Resample beaches with quality spawning habitat. Ayock Pt has good substrate and may be a good location for repeated landowner/volunteer sample efforts.

Restoration Actions: Restore lower Duckabush River and nearshore connection processes, remove unused log dump pilings and associated fill south of Eldon that disrupt longshore transport.

Foulweather Bluff Area, Pt No Pt to Coon Bay, Figure 13

Observations: 3 one-egg sand lance sites were located in this reach. Excellent spawning substrate exists through most of the area.

NOSC One-egg Sites: Sand lance-Feb 03, Jan 04

Future Study Recommendations: Resample the area to document suspected spawning grounds.

Restoration Actions: Preservation of unbulkheaded beaches and education of landowners about forage fish.

Lofall Area, Salsbury Pt to Bangor Naval Submarine Base, Figure 14

Observations: Despite many areas of excellent substrate and shoreline vegetation only 1 new beach was documented in this reach.

NOSC Positive Samples: Sand lance-Nov 02

Future Study Recommendations: Two one-egg sites, favorable habitat, and development pressures make this an important reach for resampling.

Restoration Actions: Bulkhead education. Remove creosote bulkhead at Kitsap Memorial State Park as a demonstration project. Remove old ferry infrastructure at Lofall.

Bangor Naval Submarine Base to Seabeck, Figure 9

Observations: Despite excellent substrate and good riparian vegetation through much of this reach, only 2 positive samples were collected in new locations. One sample detected summer spawning surf smelt near Misery Point in Sept 04.

NOSC Positive Samples: Surf smelt-Jan 03, Feb 03, Sept 04; Sand lance-Nov 02

Future Study Recommendations: Favorable habitat characters, development pressures and a one-egg site make this an important area for resampling.

Restoration Actions: A high percentage of the shoreline (about 90%) is armored from Misery Pt to 0.5 miles NE of Big Beef Harbor. Bulkhead education and possible removal demonstrations by willing landowners is recommended.

DISCUSSION

Resampling Strategy

Perhaps the most important lesson learned from our surveys is that in order to locate spawning areas, sampling needs to take place over several seasons in several different months. Even then, it is very likely that spawn events will be missed, and beaches used by forage fish will remain undocumented. This is consistent with initial IBSBSP work in east Jefferson County (Penttila, 1/2000) and more recent work conducted in Clallam County (Moriarty et al, 2002). Future study of surf smelt and sand lance spawning should include monthly sampling in areas where no spawning is currently designated, but seems probable based on habitat conditions or the previous detection of a single forage fish egg (Figures 15,16). This intense monitoring could be accomplished with local trained citizens assigned reaches of beach that receive monthly sampling over a course of 3-5 years.

It is our experience that sampling beach reaches with suitable habitat that are located between known spawning beaches is likely to result in the collection of positive samples. Resampling efforts that attempt to sample during months when forage fish spawn has been found in neighboring areas may meet with the most success. However, because so little is known about the year-to-year timing of forage fish spawning, the most important factor is simply that samples are taken and examined for forage fish spawn on a wide variety of dates. We believe that undetected spawning sites exist in nearly all sampled reaches.

It is possible that most reaches of Puget Sound shorelines with suitable substrate serve as a host for spawning events at some point. However, as noted in Findings: Substrate Selection, quantifying which substrates fish find “suitable” is not a simple task. Also, given the movement of sediment through driftcells and driftcell interactions with existing and future shoreline modifications, it is possible that areas with habitat unlikely for spawning today may one day prove suitable and vice versa. Thus, given the difficulty of detecting spawn, the difficulty of delineating usable habitat, and the movement of sands along area shores, the argument could be made that all nearshore areas are critical for forage fish spawning success.

Shoreline Development Impacts and Regulations

To maintain healthy forage fish stocks, preventing negative impacts to their spawning habitat is important. The impacts to forage fish spawning habitat from shoreline modifications (bulkheads, groins, piers, ramps, docks) can be broken down into two basic types: direct impacts and indirect impacts. Direct impacts occur at the modifications site. Examples include: 1) loss of shoreline vegetation, 2) burying of habitat by structures, 3) damage from equipment working in an area while eggs are incubating on the beach, and 4) substrate coarsening and lowering of the beach profile in front of bulkheads (MacDonald, et al 1994). Indirect impacts may occur by: 1) the disruption of sediment transport to another area caused by a structure impounding upland sediment behind it (bulkheads), 2) by impeding shore sediments movement along the shore (groins, piers, ramps docks), or 3) by the alteration of habitat that is not currently designated as spawning habitat but may be used at some point in the future.

Current WAC's allow WDFW to apply conditions to permits affecting direct impacts to forage fish spawning grounds. However, the single-family residence bulkhead law (RCW 77.55.200) makes it extremely difficult for WDFW to completely deny an application for a bulkhead even with the proven existence of forage fish spawning on the beach directly impacted. (Carman and Small, 2005). WDFW can require compensatory mitigation for hard structures placed below mean higher high water (MHHW) on a known spawning beach. However, if landowners choose to design and build a “soft” bulkhead (i.e. one constructed with logs, gravels, cobbles and plantings instead of rock or concrete) which protrudes below MHHW, WDFW considers the friendlier design to be adequate mitigation and does not require compensatory mitigation for direct impacts to forage fish spawning habitat (Thurston, pers. comm.). If

there is no known forage fish spawning at a site where a Hydraulics Permit Approval (HPA) has been requested, WDFW encounters difficulty in conditioning permits to mitigate for indirect impacts to forage fish habitat. Current regulations do not protect important shoreline processes by allowing continued armoring of sediment sources and allowing six feet of bulkhead encroachment in designated and non-designated intertidal baitfish spawning habitat. (Carman and Small, 2005). By continuing to allow direct and indirect impacts to forage fish habitat by bulkheads and other shoreline structures, WDFW's "no net loss" standard regarding forage fish spawning habitat might be more accurately portrayed as "less net loss". Only with more stringent regulations regarding the impacts of shoreline modifications might forage fish spawning beaches receive adequate protection. However, because of the difficulty in passing such regulations and the difficulty of then implementing them, education of shoreline landowners about the effects of bulkheads, alternatives to bulkheads and the effectiveness or need of bulkheads is a critical part of shoreline process and habitat preservation.

Impacts to water quality from shoreline development, marinas and moorages are other factors that can affect beach spawning forage fish. Civic stormwater outfalls, single-family stormwater outfalls, and runoff from cleared neighborhood shorelines laden with pesticides, septic effluent and other pollutants likely affect spawning success by altering beach salinities, temperatures, and nutrient and pollutant load. Increased algal blooms associated with increased nutrient loads can negatively impact forage fish spawning success (Shaffer, 2001). Adequate regulation and education are needed to address such stressors.

Public Outreach and Education

This project is an excellent example of citizen science creating usable data for direct use by resource managers. Not only was a vast amount of information generated that will be useful to planners for decades to come, but because the public was allowed to actively participate and learn while conducting the work an immeasurable amount of protection of forage fish resources was accomplished through public awareness. The extensive mailings have touched an audience of over 2300 people at the projects outset and conclusion. Active project participation has included 86 volunteers donating 1262 hours of work. Experiences on the beach with project volunteers and at outreach events with the general public demonstrate that once people know about forage fish, most show immediate interest and concern for the fish. Citizens voiced concerns ranging from whether they should be walking on the beach during spawning seasons, to concerns about the effects of their own or their neighbors bulkheads, and effects of the removal of marine riparian vegetation.

Education efforts concerning bulkheading and drift cells were often met with curiosity and intrigue. Most of the citizens contacted had little to no understanding of what bulkheads might do to a beach or that beaches are dynamic "rivers of sand". The concepts are simple enough, that once explained, they made an immediate impact on one's perception of a beach or a bulkhead. Beach walks are not the same once shoreline processes are explained to the beach walkers! Increased public awareness of forage fish, their importance to the Puget Sound food web and their habitat requirements encourages improved stewardship of our coastline.

The initial outreach and training effort was determined a success. It served as an excellent base step for securing access to shoreline study sites while educating the public about shoreline processes and human impacts to the food web. It provided the secondary benefit of volunteer recruitment and increasing citizen and landowner involvement in marine science. This effort can serve as a model for non-profits conducting large-scale ecological studies on a mix of public and private land ownerships. Seeking landowner permission via initial outreach mailings was complicated by low responses. In future mailings it would be wise to note that not replying to the request for access would be considered consent to beach sampling.

Continued efforts to involve and inform the public about nearshore processes, human caused disruption of these processes and their overall importance to forage fish, salmon and Puget Sound ecosystems are critical. An informed public actively involved in stewardship of our shorelines is an important component to shoreline resource protection and restoration.

ACKNOWLEDGEMENTS

Mike Ramsey, Salmon Recovery Funding Board; Dan Penttila, Doris Small, Randi Thurston, Anne Shaffer, Chris Waldbillig, Dale Gombert, WDFW; Phil Dinsmore, Dinsmore GIS Services; Mudra Bergan, Betsy Howell, Beth MacBarron, for outstanding laboratory work; Jerry Proutt for the use of his property, water and continued volunteer help; Howie Barnhouse, Chanoane Hart, Alisa Meany, John Loughlin-Presnal, Kalina Radon, Erron Kellner WCC interns; Al Latham, JCCD; Nancy Elder Carruthers, Paul Hershberger, USGS Marrowstone Marine Lab; Bill Kalina, United States Navy at Indian Island; Ray Lowrie, Dick Schneider for diligent sampling efforts; Ron Hirschi, project design; Peter Bahls, Northwest Watershed Institute; Steve Todd, Nick Fitzpatrick, Point No Point Treaty Council; Neil Harrington, Jeff Miller, Jefferson County; Jefferson County MRC; Pat Pearson, WSU/JeffCo MRC; Debbie Cooper and Mudra Bergan for the beautiful artwork; Paula Mackrow, Alisa Meany, Audrey Miles Cherney, Sarah McNulty, Craig Isenberg, NOSC staff for all the support throughout this lengthy and complicated study; Volunteer John Snyder for inspiration, and all the fantastic NOSC volunteers who offered help, advice, and laughs throughout the project. Thank you all!

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