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SUMMARY OF INFORMATION FOR DEVELOPMENT OF PLANS FOR RENEWED FORAGE FISH SPAWN SURVEYS (SURF SMELT AND PACIFIC SAND LANCE) IN ISLAND COUNTY, WA.

BY:

DAN PENTTILA

SALISH SEA BIOLOGICAL

5108 KINGSWAY

ANACORTES, WA 98221

TEL: (360) 293-8110

E-MAIL: depenttila@fidalgo.net

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B. Set of 4 charts of WDF/WDFW forage fish spawn sample sites in Island County, 1972-1991.

C. Moulton and Penttila (2001), rev.(2006) WDFW spawn survey protocol manual.

D. WDFW summary forage fish spawn survey reports to Island County MRC, 2001-2003.

E. G. Wood (2002) "Island Co. forage fish spawning habitat assessments", MRC report excerpts.

F. G. wood (2004) "Assessment of shoreline spawning habitats in the NW Straits, 2001-2004" MRC report excerpts.

G. Quinn, T., et al. (2012), "Patterns of surf smelt, *Hypomesus pretiosus*, intertidal spawning habitat use in Puget Sound", WDFW research paper on the 2007-10 "Camano I. Study".

H. Penttila (2013), "Forage fish spawn surveys, Cornet Bay beach restoration project site...June-August, 2013", summary report for Northwest Straits Foundation.

Introduction:

The following report has been prepared for Island County to aid the process of satisfying elements of the WDOE Grant No. SEANWS-2014-IsCOPH0002, Item 2.1, "Conduction of forage fish spawning surveys…". Summaries of the history of surf smelt (*Hypomesus*) and Pacific sand lance (*Ammodytes*) spawning habitat surveys within Island County, the spawning ecology of those beach-spawning forage fish species, specific details of beach-spawning forage fish spawn survey protocols and other considerations for the successful undertaking of such surveys by local volunteers, existing gaps in the current smelt/ sand lance spawning habitat survey database that might represent priority areas for renewed survey effort, application of forage fish spawn survey data to restoration projects in general, and the monitoring of the recent shoreline restoration project in Cornet Bay, Whidbey Island, will be presented. Attached appendices will feature various publications and information sources that may serve to expedite the forage fish habitat survey task noted above.

Forage fish spawning ecology:

Surf smelt:

The surf smelt, *Hypomesus pretiosus,* (Figure 1) is a common and widespread, near-shore dwelling, ecologically-important forage fish known to occur throughout the Puget Sound Basin/Salish Sea region. Since the species was first described in the scientific literature in 1855, it has been known to be an obligate upper intertidal beach-spawner, depositing and incubating its adhesive eggs on sandy-gravel beaches in the upper third of the intertidal zone, from Alaska to California (Figure 2). A small, short-lived, densely-schooling fish , it contributes to the prey base of the local near-shore marine ecosystem's foodweb, and also supports significant local sport and commercial fishery harvests in many areas of the state, including Island County (Penttila 2007).

The eggs of the surf smelt are about .8 mm in diameter and tightly adherent to particles of beach material (Figure 3). Spawning can occur at frequent time intervals at any given spawning site, resulting in a more or less continuously-occurring spawn deposit of egg of mixed age, that may persist at a site for the entire several-month length of the local spawning season. The eggs of the surf smelt are of such a small size and often in such low densities in the beach substrate that their visual detection by naked eye in the field is no-longer an acceptable method of spawning habitat documentation and mapping, especially by inexperienced volunteers. Thus was developed the "bulk substrate sampling " protocols for surf smelt/sand lance spawning habitat surveys.

Incubation periods of any particular brood of surf smelt eggs depends on the ambient seasonal terrestrial temperature at the site, and can vary from 2 weeks during warm summer weather to 6 weeks during freezing winter weather. Surf smelt spawn is vulnerable to mass-mortalities during sunny summer weather at sun-exposed spawning sites, where surface-exposed eggs are soon killed by thermal shock and desiccation. Smelt egg survival is greatly enhanced during the summer by the presence of overhanging shade from "marine riparian" trees lining a natural shoreline(Penttila 2001, Rice 2006).

The species is currently known to spawn on about ten percent of the shoreline of the greater Puget Sound Basin, with additional spawning sites still being found wherever suitably-detailed spawning habitat surveys are conducted in the region. Since the early 1970s, the Washington Department of Fisheries/Fish and Wildlife, the Washington Department of Natural Resources, suitably-trained NGOs and teams of volunteers have been undertaking surf smelt spawning habitat surveys in the Puget Sound Basin. The driving force for this effort has been the proper documentation of all existing surf smelt spawning sites, so as to protect them from any additional harm from human shoreline development activities of various sorts.

Regional surf smelt spawning seasons are complex and variable, depending on the geographic locale of observations. State-wide, spawning is year-round in some localities, including a subset of the known spawning areas in Island County. The majority of Island County surf smelt spawning beaches receive spawn in the "summer" (April through September). A few sites on southern Whidbey Island appear to receive spawn largely in the "winter" (October through March).

The customary location of the surf smelt's spawn deposition/incubation on fairly-specific types of mixed sand-gravel high on the beach near the MHHW line places its critical habitat in jeopardy of degradation/ destruction from almost any human development activity that intrudes seaward of the extreme high tide line. The species' vulnerability to development impacts, and its ecological/societal importance, has led, in recent decades, to inclusion of surf smelt-specific protective language in various regulatory frameworks governing land-use in Washington State, including the WAC Hydraulic Code Rules, the State Shoreline Management Act, and the State Growth Management Act, including that act's resultant local Critical Area Ordinances.

Pacific sand lance:

The Pacific sand lance , *Ammodytes hexapterus,* (often mistakenly referred to as the "candlefish" by local salmon anglers) is also a common and widespread, ecologically-important, near-shore-dwelling forage fish of the Puget Sound Basin/Salish Sea region (Figure 1). While it is an important element of the local marine foodweb, serving as prey for many species of birds, fish, and mammals, it has never supported significant human sport or commercial fisheries in our region.

While the species was scientifically described in 1811, details of its spawning habits were virtually unknown until it was serendipitously discovered to be an upper intertidal beach-spawner in late 1989 in and around Port Gamble Bay, Kitsap County, by the writer. Subsequent development of a new "bulk substrate sampling" survey protocol and the establishment of a Puget Sound-wide synoptic beach survey program by WDFW in 1991 soon led to the discovery that Pacific sand lance spawning activity was about as widespread in the Puget Sound region as that of the surf smelt (Penttila 1995a, 1995b).

While surf smelt and sand lance are taxonomically quite unrelated, they have apparently undergone a "convergent" evolution of their spawning habits and "preferred" habitats. Both species use fine-grained beaches in the upper third of the intertidal zone, with sand lance spawning tending to occur somewhat lower on the beach, on somewhat finer-grained material dominated by sand-sized particles (Figure 4). Unlike surf smelt, Pacific sand lance consistently spawn during November-February throughout the Puget Sound Basin.

If surf smelt eggs are difficult to visually detect in handfuls of beach substrate, those of the sand lance are virtually impossible to detect in that manner. The writer surveyed visually for surf smelt eggs on the beaches of the Puget Sound Basin for nearly 17 years before he stumbled upon deposits of what proved to be sand lance eggs, dense enough to detect visually on the beach surface, and in such numbers that they could be distinguished as "different" from surf smelt and in quantities sufficient to be reared-out to yield identifiable sand lance larvae. Sand lance eggs are about .6 mm in diameter, significantly smaller that surf smelt eggs, and acquire a coat of small adherent sand grains during deposition that render them virtually invisible to the naked eye (Figure 5). Details of their visual characteristics are such that, under magnification during routine lab analyses, they can be readily distinguished from surf smelt eggs in those many areas of Puget Sound where winter-spawning surf smelt and winter-spawning sand lances co-occur and use the same beaches at the same time.

Sand lance spawn deposits have been observed consistently and frequently on upper intertidal beaches throughout Puget Sound since 1989. The sand lance spawning act, creating the subsequently-observed "spawn pits", has been photo-documented on Island County beaches in mere inches of water at high tides on a number of occasions in 2009-2010. The persistent notion that sand lances spawn on subtidal sediment bottomlands, held by many from times before the 1989-onward intertidal spawn discoveries, remains unproven at this time.

Because Pacific sand lances spawn high in the intertidal, like surf smelt, their critical spawning habitats are as vulnerable to negative human shoreline development impacts as those of surf smelt are thought to be. Thus sand lance-specific language has also been added to the same set of Washington State land-use regulatory frameworks to prevent further net losses of spawning habitat for this species into the future.

As with surf smelt, site-specific spawning habitat protection is based on prior documentable observations of spawn in-situ on or near the site in question. Because so much of the outwardly "suitable looking" beach habitat in Puget Sound cannot be proven to be surf smelt or sand lance spawning habitat by observations of eggs on-site, steadfast no-net-loss protection cannot be based on "potential" habitat value at this time. In some permitting cases, potential negative impacts to "likely-looking" potential spawning sites may trigger one-time forage fish spawn surveys by trained consultants (hired by the permit applicant) prior to permitting. However, it is highly advisable for habitat managers to develop comprehensive spawning habitat databases for as much of the shoreline as possible prior to future resource-protection needs in vulnerable areas subject to development.

For the sake of completeness, it should be noted that two other important marine forage fishes occur throughout Island County. The Pacific herring (*Clupea*) spawns its eggs on marine vegetation beds at a number of sites during late winter and spring within the county. The northern anchovy, *Engraulis*, sheds its planktonic eggs into the local waters at a number of sites in the county during the summer months.

Brief History of Forage Fish Spawning Habitat Survey Effort in Island County:

WDF/M.B. Schaefer, 1930s:

In the early 1930s, WDF biologist M.B. Schaefer published a lengthy report on the biology and spawning ecology of the surf smelt in Puget Sound (Appendix A). This report included much information gathered on surf smelt spawning beaches within Island County, especially the beaches around Utsaladdy on northern Camano Island. The report included hand-drawn charts of then-known surf smelt spawning beaches, apparently based on the existence of sport or commercial smelt fishery harvests. These are depicted on figure 1 of Appendix A . Spawning seasons are also estimated. Note that this report did not depict any surf smelt spawning beaches in the south half of Island County. This 65-page report is probably long out-of-print, but I have a loose-leaf copy, if there is a need for modern-day Island County to have a copy for project files.

WDF/Penttila, 1972-1991:

Within months of the start of my forage fish-related career with WDFW/WDFW, I began my first surf smelt studies in the Puget sound Basin, based in the Schaefer (1936) report. Very little had been done regarding surf smelt by WDF in the interim, while a small number of surf smelt-related theses had been undertaken by graduate students at the University of Washington.

I used the Utsaladdy area as a surf smelt habitat training ground during the first years of my studies, accessing the beach west of Utsaladdy Point, via a county park that no longer exists. I gradually expanded spawn survey coverage as I became more familiar with the characteristics of surf smelt spawning habitat, and began using boats to access more of the shoreline than I could on-foot. About 280 individual sampling sites were undertaken within Island County during this period. Penttila (1978) summarizes surf smelt spawning habitat observations and biological sampling of spawning surf smelt on N. Camano Island and Penn Cove during this period.

Appendix B is a set of 4 charts outlining the summer/winter, north/south distribution of WDF surf smelt spawn survey sampling stations in Island County during the 1972-1991period. During all of this time, surf smelt spawning habitat mapping was undertaken using visual detection of eggs in the field as the only available method. Summer sampling was emphasized during most of this period, with only a small amount of winter sampling undertaken after late 1989, when it was considered that Island County shorelines might also support winter sand lance spawning activity. Sand lance spawning habitat documentation was limited by the continued usage of field-visual egg detection techniques.

WDFW/Penttila, 1991-1998:

At the beginning of this time period, the writer had developed the current "bulk substrate sampling" survey protocol, in response to the advent of the "Intertidal Baitfish Spawning Beach survey Project" (IBSBSP), a multi-year synoptic survey of all the sand-gravel upper intertidal beaches in the greater Puget Sound Basin, eastward from Neah Bay Penttila (1995a), and the clear need for a beach habitat/forage fish egg sampling methodology which would no longer depend on visual spawn detection in the field, given that it was now apparent that "invisible" sand lance eggs might be widespread within the survey area (Penttila 1995b). The new WDFW protocol was developed in-house in late 1991 and put to use. Some years later , it was formalized into a manual for use in San Juan County, which then was revised and put to use as a guide to all such studies elsewhere in Puget Sound (Appendix C: Moulton and Penttila, (2001) rev,. (2006).

Appendix D is a brief report produced in about 2000, with summer/winter, north/south charts of Island County illustrating the distribution of about 1100 forage fish spawn survey sampling stations undertaken by WDFW in the 1991-1998 period, all using the new protocol. Sampling coverage now was much more widespread over space and time within the county, as our surveys sought new sand lance spawning sites in the winter months.

WDFW/Penttila/Island Co. MRC, 2001-2003:

The WDFW's synoptic forage fish spawning habitat survey, IBSBSP, was de-prioritized out of existence in 1998. The 1991-1998 sampling site chart package also served to illustrate remaining forage fish spawn survey sampling gaps for the pending WDFW/Island Co. MRC "interlocal agreement" that was agreed-upon in 2001. This agreement allowed the writer, with MRC financial support, to resume forage fish spawning beach surveys within Island County for the purpose of completing the forage fish habitat inventory work that still remained.

Included in the balance of Appendix D are several seasonal reports that summarized forage fish spawning habitat survey work in Island County during the course of the interlocal agreement, which spanned three "summer" season and two "winter" seasons of sampling coverage. Charts indicate locations of new survey sampling sits, superimposed on the prior sampling coverages, with new spawning habitat documentations noted for each fish species in each season. All sampling was undertaken using the new survey protocols. A total of about 1780 individual sampling stations were undertaken during the interlocal agreement era.

Two comprehensive reports were produced by Gary Wood of the Island County MRC during the course of the interlocal agreement. Excerpts of these informative reports area included as Appendices E and F. In case these reports in their entirety are no longer able to be located within Island County, I have full copies which I could loan to county staff for the purposes of reproduction.

WDFW/Penttila/Camano Island Forage Fish Study, 2007-2010:

After 2003, directed forage fish spawning habitat surveys largely ceased within Island County, and the WDFW staff formerly involved in surf smelt/sand lance spawning habitat surveys were dispersed to other agency positions. In 2005, surf smelt/ sand lance spawning habitat surveys were again resurrected within WDFW, when the writer was transferred to the WDFW Habitat Science Division, with funding support from the Puget Sound Action Team. Spawning habitat mapping surveys then proceeded in areas of Puget Sound other than Island County, which it was felt had gotten sufficient survey coverage during the time of the MRC interlocal agreement, compared to other sectors.

In September 2007, it was decided that all such exploratory forage fish spawning habitat surveys in Puget Sound would be put "on hold", in favor of an intense concentration of field sampling effort, pertinent to forage fish spawning ecology questions, around the perimeter of Camano Island.

Fifty one fixed sampling sites were erected at about 1500' intervals around almost the entire perimeter of Camano Island. These 51 sites were to be sampled at two-week intervals for an entire calendar year. Bulk samples of beach substrate were to be collected at +8' and +10' in elevation, to investigate the distribution of spawn across the beaches. Over the course of the year, field data would also be taken on beach slope, LWD abundance and composition, overhead shade, sediment grain sizes, beach subsurface temperature profiles over time, and other factors, in far greater detail than had ever been routine during the course of previous forage fish spawning habitat surveys.

During the 2007-2008 period, a total of 2,225 individual substrate samples were collected for this project. In 2009-2010, a subset of the sites on the north end of Camano Island were sampled partially to gather more data for statistical applications. A summary report of this project, Quinn, et al, (2012) is included in full as Appendix G . Within this report, Figure 1, on page 1216, charts the locations of the sampling sites, virtually all of which had already been documented as forage fish spawning sites in previous years, as the cumulative spawning habitat data suggested that every sand-gravel beach around the perimeter of Camano Island had been documented as surf smelt and/or sand lance spawning habitat at one time or another.

Forage Fish Spawn Survey Protocols and Procedures:

Original IBSBSP protocols:

Surf smelt and sand lance spawning habitat surveys since 1991 have followed the existing protocols outlined in Appendix c ,Moulton and Penttila (2001) rev. (2006), which were developed with the advent of the WDFW's IBSBSP synoptic spawn survey program and the introduction of the "bulk substrate sampling" technique, to replace the documentation of forage fish spawning sites by naked-eye detection of eggs in the field, which in turn had been found to be totally ineffective in detecting sand-covered, visually cryptic sand lance eggs in the field. Screening and winnowing of the egg-sized portion of bulk sediment samples (.5 to 2 mm in diameter), and skimming of the lightest material of this size fraction would produce a preserved lab subsample. Microscopic examination at 10X of the lightest portion of the lab subsample enhanced the likelihood of detecting and identifying surf smelt/sand lance eggs when they occurred in typically low densities on the beaches after normal wind-wave dispersal of the incubating spawn after deposition.

The IBSBSP protocols were developed and used by already-very-experienced forage fish spawning habitat surveyors from the beginning. However, WDFW succeeded over the years in training a number of NGOs and volunteer groups in the application of these field and lab protocols for use in regional grant-funded forage fish surveys that supplemented the ongoing WDFW survey work, and many new forage fish spawning sites were documented by their efforts. The results of non-WDFW forage fish spawn surveys were accepted into the growing state-wide forage fish spawning habitat mapping database by arrangements to have all new non-WDFW spawning sites confirmed by WDFW lab egg/species identifications of picked-egg samples from the sites. In some cases, local forage fish surveys by NGOs received cooperative assistance from WDFW staff, through interlocal agreements, who did the original lab work-up of samples recovered from the field by the NGOs. In more recent years, the writer, as a sole-proprietorship consultant, undertook the lab work for several NGO surveys for a per-sample fee. So far in the history of Puget Sound forage fish spawning habitat survey programs, there has never been a case of an independent NGO having sufficient facilities and equipment to undertake all necessary phases of field and lab activities for a successful survey outcome, totally independent of WDFW participation in field training and/or lab QA/QC.

The key for NGO forage fish surveys is to have sufficient adherence to protocols and QA/QC of lab findings that the data can be vouched-for by credible forage fish experts, and thus be accepted into the 1972-present database, for use in land-use decisions and as expert -witness exhibits in sworn-testimony/legal settings.

Effective surf smelt/sand lance spawn surveys require a certain amount of experience in recognition of likely potential spawning habitats for the two species. They also require a knowledge of the likely elevation on the upper beach where eggs might most likely be found, given that each sampling site's habitat value on any given survey will likely be determined by the results of an analysis of a single several-pound bulk substrate sample. Ideally, the initial phases of a new forage fish spawn survey program staffed largely by inexperienced volunteers should allow for field training and sample processing training by experienced agency staff or consultants, with funding for these outside-experts.

Under certain special circumstances involving a single sampling site being targeted as goal for a project in the field, samples might be taken at multiple elevations on the beach, increasing the chances that the proper elevation for eggs might be found during the process. However, ordinary surveys are intended collect samples at many sites spaced-out along long reaches of shoreline per day, often to different shores day after day during opportune low-tide series. Thus there is usually only limited processing time and sample-container number and storage capacity for samples to allow accumulations of bulk and preserved lab samples over time.

New WDFW Forage Fish Survey Protocols Under Development:

For the past year, WDFW Habitat Science Team staff in Olympia has been developing some changes in the forage fish spawning habitat survey protocols. To the writer's knowledge, the new protocols are still being tested. They may involve a process for randomization of sample site placements in the field, and a new procedure for processing egg-sized fractions of bulk sediment samples for extraction of eggs and other light/low density material.

For information on the current protocol testing and future acceptance of data produced by the older protocols, survey organizers are urged to contact: Phillip Dionne, at: Phillip.Dionne@dfw.wa.gov, office tel.: (360) 902-2641. WDFW may also be able to offer field training in these new procedures.

Any pending forage fish spawn survey program in Island County may have to coordinate and cooperate with an on-going initiative to begin new forage fish habitat survey programs in the greater northern Puget Sound area as a whole. For more information on this new initiative, questions should be directed to Caroline Gibson, Northwest Straits Commission, Port Townsend, at: gibson@nwstraits.org .

WDFW state-wide forage fish spawn survey database:

For a number of years following the massive data entry process to prepare all known forage fish (surf smelt/sand lance)spawning habitat survey data collected in Washington State dating from 1972, the database and its attendant by-station survey records and spawning habitat distribution charts , were available to the public for downloading on the WDFW Salmonscape Database, available on the WDFW Habitat Program homepage.

Recently, this statewide forage fish survey database has been transferred to the Arc GIS system addressed below:

http://www.arcgis.com/home/webmap/viewer.html?webmap=19b8f74e2d41470cbd80b1af8dedd6b3

It appears that users now need arc-gis technology to access this new site. The writer would advise consulting with Phillip Dionne, WDFW, Olympia, if difficulties in access arise.

In the event that renewed forage fish spawning habitat surveys in Island County find wholly new spawning sites, a real possibility, arrangements should be made to transfer this new information to the WDFW Habitat Science Team in Olympia for inclusion in the state-wide forage fish survey database.

General Forage Fish Spawning Habitat Survey Issues:

Training of surveyors:

Issues of necessary training for field samplers and lab technicians has been mentioned above. Un-trained staff cannot be expected to undertake effective surveys, sample processing, nor production of acceptable data. All aspects of the survey procedures can be properly trained-for. There simply needs to be funding for outside experts to be able to impart appropriate knowledge, with refreshers as necessary through the span of the program.

Boat-based surveying:

The vast majority of the data currently residing in the state-wide forage fish database was acquired by wide-ranging boat-based surveys. By this method, long reaches of shoreline can be efficiently and effectively sampled on a daily basis, including vast areas that cannot be sampled from on-foot accesses. If programs are confined to on-foot surveys, then little more than spawn-monitoring programs can probably be undertaken. All the "easy" survey sites have already been sampled many times over the years.

Suitable low tides for forage fish spawn surveying:

Although forage fishes spawn in the upper intertidal zone, the tides have to be at a certain low elevation for effective sampling. During the summer months of surf smelt spawning activity, any tide as low as about +7' in elevation will expose most of the likely smelt spawning zone for sampling. Daylight tides of this elevation or lower are very common during the summer months, affording many workable field days.

During the winter months during the sand lance spawning season, suitable survey tides should ideally be about +5' in elevation, which occurs during daylight hours only a few days a month from November through January. Theoretically, easily and safely-accessible sites could be sampled during night hours during the winter, but such has never been routinely done by WDFW over the years.

Access to Private Properties:

The majority of the data currently in the state-wide database was collected by WDF/WDFW staff during an era when state agency staff were protected from liability for trespass on private shorelines by RCW laws while "on state business" (ie: resource data collection). Over the years, we had almost no complaints about our brief sampling visits to private shorelines. Most citizens are largely ignorant of any forage fish spawning activity that might be occurring on their properties. Once made aware of our purpose in visiting their beaches, they almost invariably become very interested in our documentation of fish spawning on their sites.

As for free access to private property by agency staff, such is no longer the case. A number of years ago, a particularly sensitive Director of Fish and Wildlife responded to a singular case of property-owner "outrage" over a state biologist attempting to assess salmon spawning on his property by declaring the trespass non-liability statute no longer applicable to agency staff. Since that time, WDFW forage fish spawn surveys have been ham-strung by the need to publicize upcoming forage fish survey programs in local newspapers, asking that anyone objecting to brief staff sampling visits to certain beach sites to send in their name and address, after which time, those sites would not be sampled. In reality, very few landowners objected to such visits when notified in advance.

Seeking express permission to visit each private shoreline land-holding in Island County for forage fish spawn surveys is impractical, especially if sampling sites are going to be randomized on short notice in the field. Perhaps announcements of pending spawn surveys in Island County's weekly community newspapers, and responding to those objecting to sampling visits might suffice. WDFW has been undertaking boat-based spawn surveys through broad areas of southern Puget Sound in the past year. Perhaps Phillip Dionne can explain how access to private beaches is being handled in the present day, although state agency rules would likely not apply to surveys being staffed by NGOs.

Forage Fish Spawn Survey Expenses:

Over and above hypothetical expenses arising from the use and maintenance of boats and tow-vehicles, there are a number of "consumable" items and products that will be necessary to purchase for effective forage fish spawn surveying:

- Wide-mouth plastic jars, screw- cap, 500ml capacity, surveys should probably have 100 or more on hand. Jars are available at any number of scientific supply companies

- Stockard's Solution Preservative: a 5% mix (each) of formaldehyde, glycerol, and glacial acetic acid. TOXIC. The routine preservative for forage fish eggs for 40+ years, it turns embryos white while leaving the yolk-sac translucent, aiding in egg aging. Added in small amount to the eventual lab subsample, one gallon will preserve about 30 samples. A stockpile of one gallon of each ingredient will make about 8 gallons of preservative. Local source: BBC Biochemical, in S. Mt. Vernon, WA, at: www.BBCus.com , tel.: (800) 635-4477.

- Plastic sample bags: 8"X 24"(tall) X 2 mil thickness, for collecting bulk sediment samples in the field, tied-shut, one-use only, should have about 1000 on hand. Local source: Aurora Plastics, Lynnwood, WA , at: info@auroraplasticbags.com , teL; 1-888-898-2247.

The survey manual in Appendix C has lists of field gear needed for surveys using the older protocols.

Data Gaps and Priority Island County Spawn Survey Areas:

Despite the fact that several thousand surf smelt /sand lance spawning habitat survey stations had been undertaken in Island County from 1991 through 2003 (not counting the array of fixed sites repeatedly sampled on Camano Island in 2007-2010), there still remains some sectors of shoreline that had been relatively infrequently sampled over that time. Given the nearly universal distribution of "potential" forage fish spawning substrates within the county, these sectors might be considered "priority" survey sectors for any future forage fish spawn survey program.

To generate a picture of total spawn sample site distribution, summer/winter, north/ south, the existing charts of sample site distribution from 1991through 2003 were overlain by blank charts of the county on a light table, and the distribution of site symbols marked. In the end, a number of relatively un-marked shoreline sectors, summer/winter, north/south could be discerned. These are described briefly below, and outlined on accompanying chart-figures.

North County/Summer: (Figure 6)

1. West NAS-Whidbey area: This sector will presumably require USN clearance and field escorts for sampling on-base. Such clearances and escorts were arranged for beach surveys on NAS property in 2003.
2. Ala Spit to central Dugualla Bay: Through a likely surf smelt spawning area, judging from known spawning to north and south. Sampling may involve monitoring of surf smelt spawning habitat damage? in recent years from the alteration of the south end of Ala Spit.
3. Maylor Point peninsula: This sector like also presumably need USN clearance and escort for shoreline access. Sampling should include any restored beaches on the north shore of the peninsula, on inner Oak Harbor.
4. North Camano Island: The area from central Utsaladdy Bay east to English Boom was heavily documented as surf smelt spawning a area prior to 1991, and during the 2007-2010 Camano project.

5. Livingston Bay- Juniper Beach: An area bounded by broad tide flats and thus difficult to approach by boat in the past.
6. Point Partridge south to Ebeys Landing: Far from launch ramps and subject to ocean swell from the Straits of Juan de Fuca, some of this sector may lie within the WDNR-sampled Smith-Minor Marine Reserve. None of the samples collected in the Reserve have been included in this analysis.

South County/Summer: (Figure 7)

1. Mutiny Bay east to central Useless Bay: Only 21 samples tallied. Convenient access for minus-tide summer sampling hikes.
2. Maxwelton south and east to Possession Point: Only 13 sites tallied. Mix of massive armoring, salt marshes and coarse feeder bluff beaches.
3. Sandy Point south to Clinton: Public accesses unknown. Launch boats at Langley Marina ramp.
4. Holmes Harbor: This very likely-looking potential surf smelt spawning beach/larval rearing area has yielded unusually sparse signs of smelt spawning amidst dense sand lance spawning activity in winter.

North County/Winter: (Figure 8)

1. NAS-Whidbey-Swantown area: This sector may lie partially within the Smith-Minor Island Marine Reserve.
2. East Polnell Point west to Blowers Bluff: Parts of this sector will likely require USN clearance and escort for beach access. Some sites, such as Oak Harbor Beach Park, have been adequately sampled.
3. Juniper Beach west to Triangle Cove: This sector would be somewhat easier to access by boat during the high low daylight tides of winter, but that leaves less time to travel along the beach.

South County/Winter: (Figure 9)

1. North Admiralty Bay South to Lagoon Point: Only 33 sites scattered over a long distance of entirely suitable-looking habitat.
2. Double Bluff east to Deer Lagoon: Access on-foot from the public park in the middle.
3. Glendale west to Maxwelton: Difficult to access by any means in the winter.
4. East Point west to NE Holmes Harbor: Should be able to extend the documented sand lance spawning beaches through here.

Much of Island County has not had forage fish spawning habitat surveys conducted through it for 10 or more years. In other parts of Puget Sound, it was not uncommon for surveys conducted at such long intervals would yield additional documented spawning habitat polygons between the previously documented spawning sites. Spawn-site discovery rates are entirely dependent on the relative abundance of the local spawning stocks. Both surf smelt and sand lance are relatively short-lived fish subject to marked variations in relative abundance over short periods of time. At any given time chosen for spawn survey programs, the relative abundance of stocks cannot be known ahead of time. Sampling at multi-year intervals increases the chances that at least some surveys will occur during periods of relatedly high abundance, thus increasing the chances of discovering more spawning sites more easily.

Forage Fish Spawn Monitoring:

From the above, it could be viewed that , after such a long period since the last spawn surveys on many of Island County's beaches, all of the county's shorelines may be deserving of some re-sampling during the course of the pending survey program. What forage fish "spawn monitoring" will not be able to do is provide data for the purposes of deducing stock abundance trends, over and above triggering am deep concern if spawn in a large number of frequently-used spawning sites disappears entirely. This would probably be a rare event, so far as we can know, given that smelt spawning beaches mapped in Puget Sound in the 1930s are still all still functioning where they are still largely intact. A few heavily- and consistently used spawning sites might be adopted as index areas, but there is no way at present to know if such sites would be representative of the spawning area as a whole.

Forage fish spawn densities found on beaches are vulnerable to many different unpredictable and largely undocumentable weather impacts that modify their densities greatly. Thus stock abundance information from spawn density monitoring data may be tenuous at best. There are presently no other sampling or analytical tools available to otherwise assess surf smelt or sand lance spawning population abundances in real time to give spawn density trend data meaning.

Major sudden environmental perturbations, such as massive oil spills, might trigger localized extinctions of beach-spawning forage fishes, as spawning beaches soak up oil and are contaminated with lethal substances for years on-end, beyond the maximum life span of the fish species. Then forage fish spawn data as we have collected should serve to form the basis for damage assessments.

Requests for non-herring forage fish spawn survey measures (or larval/fish surveys) that would yield relative abundance data have been voiced in recent years, but I see it as unlikely that such will be possible under present budget constraints. You may wish to consult with WDFW or other regional forage fish researchers to see if progress has been made in this investigative direction.

Monitoring of Restoration Project Sites for Forage Fish Spawning:

Both surf smelt and sand lance are known to use "restored" beaches for spawn deposition. Until recent years, beach restoration projects on Puget Sound shorelines were not designed with the intent of mitigating or enhancing forage fish spawning habitat. The fish seemed merely to move over onto restored beaches of the "preferred" grain size from adjacent natural spawning sites. In recent years, however, many restoration and mitigation actions are purposely attempting to restore forage fish spawning habitat, or mitigate for perceived potential damage to forage fish sites by project actions, often as a stipulation for permitting. Many of the restoration projects are still highly experimental, and long-term success is not assured. More is being learned all the time, but it should be realized by all concerned that restoring shorelines, at least by means of "beach nourishment", (ie: humans "becoming the feeder bluffs" otherwise incapacitated by armoring), is a long-term action in need of refurbishing from time to time in perpetuity.

There is still a great need for complete forage fish spawning usage data, both prior to and following, restoration actions, to gain knowledge in support of such actions, in the face of often considerable expense, or to adjust future designs for better results. In my view, if plans can be known far enough ahead of time, pre-project forage fish spawn monitoring should be undertaken at a prospective project site for at least two years in advance of the project action. It should be noted that forage fishes do not use their entire documented spawning area every year, and annual gaps in usage are to be expected. Two years of spawn monitoring increases the chances of encountering spawn, if in fact, the site is within a documentable spawning area.

In most of Puget Sound, where surf smelt stocks of mixed spawning season and sand lance stocks of winter spawning seasons are in close proximity of each other, it would not be unreasonable for restoration site spawn sampling to be undertaken monthly. If budgets were tight, then core spawn survey periods might be: June-August for summer-spawning smelt , and November-January for winter-spawning surf smelt and sand lance. Post-project monitoring periods depend somewhat on the size and scale of the project and its impacts, ranging up to 5 years of post-project monitoring in some recent cases.

Within a project site, standard forage fish spawn sampling protocols can be modified. Commonly, spawn sampling transects can be shortened and lateral spacing compressed, so as to allow for the collection of a number of individual samples scattered along the affected shoreline at few-hundred – foot intervals. There may also be a need to sample at a number of tidal elevations within the impact zone to discern details of the usage of the site by spawning forage fishes.

Given the distribution of known forage fish spawning beaches throughout the Puget Sound Basin, there is probably no project site that would not be within a few miles of a known forage fish spawning site, and often the distance may be just a few hundred feet. At distances of miles, it cannot be presumed that a perfectly "functional-looking" fine-grained restored beach will automatically attract spawning forage fishes merely by its sudden presence. Such a project should not be publically advertised as being in support of spawning forage fishes prior to actual spawn observations on-site. How forage fish have chosen those beaches they now spawn upon is unknown.

However, at the other end of the distance spectrum, a suitably fine-grained restored beach established amidst nearby documented spawning habitat polygons will almost assuredly be found and used by spawning fish within a shore period of time (from hours to months). Where funding and geomorphic parameters permit, it should generally be the case that a beach restoration project proposed for anywhere in Puget Sound should routinely be designed to include establishment of an upper intertidal zone of fine-grained sediments, just in case heretofore undocumented forage fishes are in need of spawning habitat. Project sites where there is a probability of summer surf smelt spawning should also be designed to establish a zone of marine riparian trees (not low shrubs) that might provide shading canopies extending over the spawning habitat.

Cornet Bay Restoration Project:

Pre-project forage fish spawn monitoring of the Cornet Bay beach restoration project was initiated in 2009. The writer conducted on-site forage fish spawn sampling training for a select group of Island County Beachwatchers in April 2009, while still with WDFW. An interlocal agreement between Island County and WDFW supported the writer's lab analyses of the monthly set of bulk substrate samples from 6 fixed sites in the project area from July 2009 through August 2011.

Sand lance eggs had been found at the sampling site #3, just north of the State Park maintenance pier on a single occasion in about 1993. While surf smelt were caught in abundance off the State Park moorage pier just offshore of the project site, no surf smelt eggs were ever found during the pre-project spawning habitat sampling. The closest surf smelt spawning habitat known was at Hoypus Point, about ¾ miles north of the project site. No smelt eggs were ever found at sampling site #1, a quite suitable-looking natural beach north of the area impacted by the project's restoration actions.

Restoration actions at Cornet Bay, including removal of the then-existing creosote timber bulkheads from the upper intertidal zone, with subsequent re-grading and beach nourishment with potential surf smelt spawning substrate occurred on the full length of former creosote bulkhead during September-October, 2012.

At the end of the restoration actions on the site, the writer was contracted by the Northwest Straits Foundation to undertake post-project forage fish spawn surveys at the same 6 fixed sampling sites in the project area. Three forage fish spawn surveys were conducted from June through August of 2013. A summary report was produced in September 2013, and distributed to the Northwest Straits Foundation. It is reproduced in full as Appendix H .

NWSF-funded post-project forage fish spawn surveys continued with four "winter' surveys conducted between November 2013 and February 2014, and a second "summer" series of three spawn surveys conducted in July-August, 2014. No forage fish eggs were found on any of these surveys.

The Cornet Bay beach restoration project enhanced near-shore habitat values and more human-user-friendly beach, regardless of whether or not it produced evidence forage fish spawning activity on the project site.

The Cornet Bay restoration site is amenable to continued sampling by Island County volunteers if that is thought to be advisable. The 2013 report includes GPS lat-lons for the fixed sample sites, if they need to be re-established for use by future sampling teams.

Conclusion:

To the best of my knowledge and records, I believe I have addressed the various questions and comments regarding pending forge fish spawning habitat survey programs planned for Island County. I can make myself available, *pro bono*, to address any further questions or comments that might arise form Island County staff review of this document.

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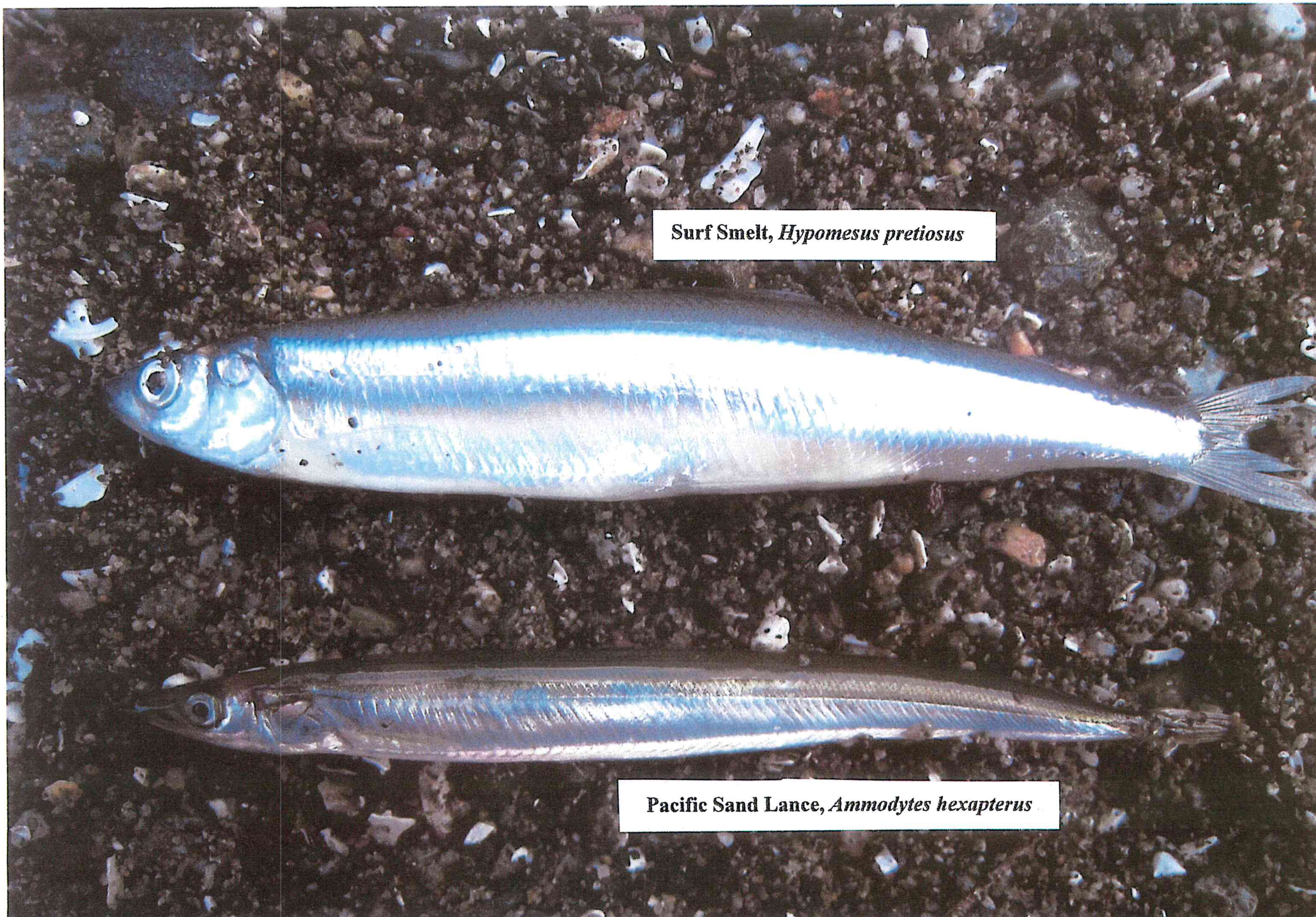


Figure 1. **Common Beach-Spwning Forage Fishes of Puget Sound. Photos About 25% Larger Than Life-Size.**

M. Humling, WDFW, Photo

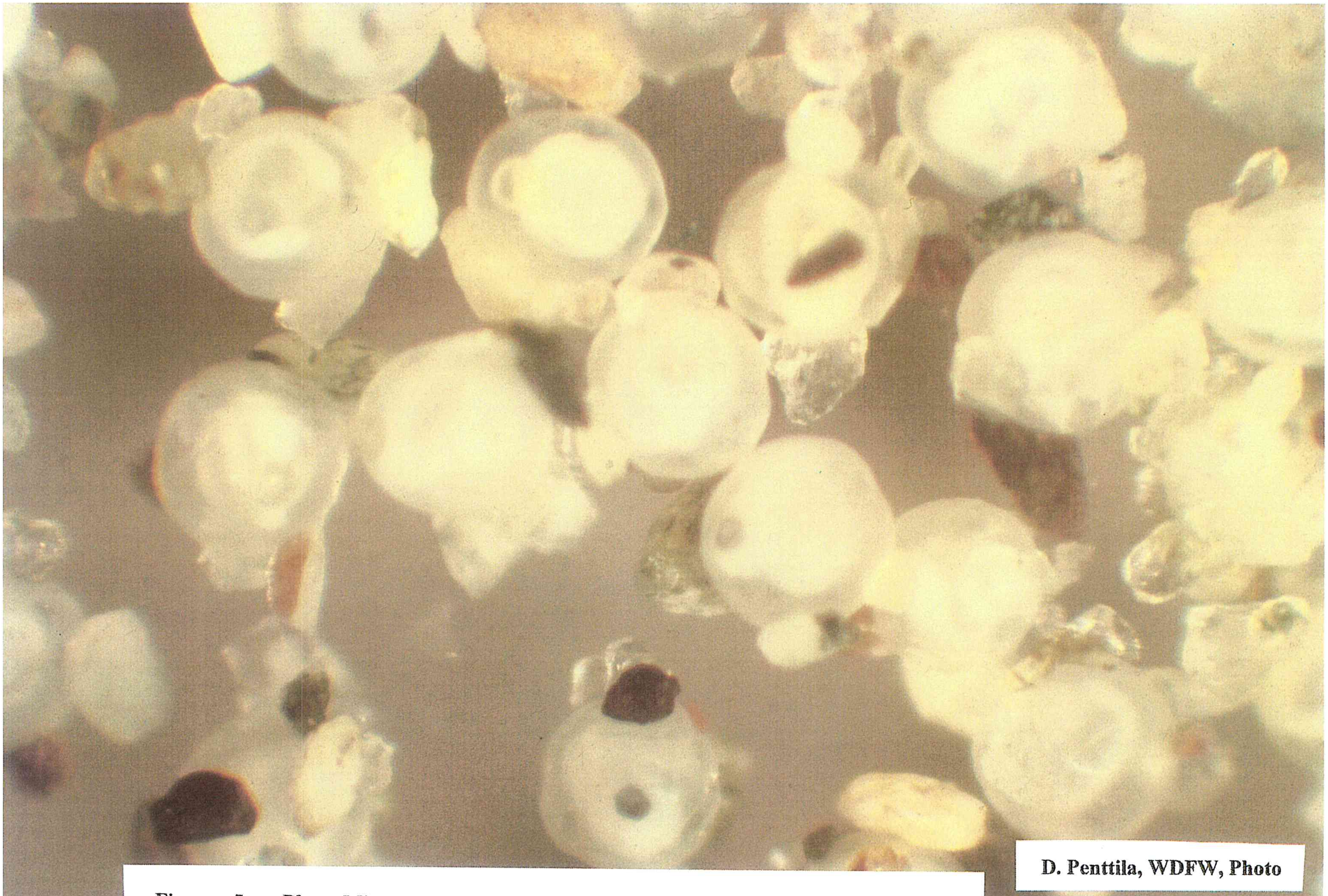
Figure 2. Fresh, Intact Surf Smelt Spawn Deposit (Outlined in White) onUpper Intertidal Fine-Grained Beach, NW Camano Island.

K. Perry, WDFW, Photo

Figure 3. Close-up of Live Surf Smelt Eggs on Spawning Substrate.

Figure 4. Fresh, Intact, Sand Lance "Spawn Pits" (Outlined) On Upper Intertidal Sand Beach, E. View Toward Monroe's Landing County Park, N. Shore, Penn Cove, Whidbey I.

D. Penttila, WDFW, Photo



D. Penttila, WDFW, Photo

Figure 5. Photo-Micrograph of Preserved Sample of Mixed-Age Sand Lance Eggs.

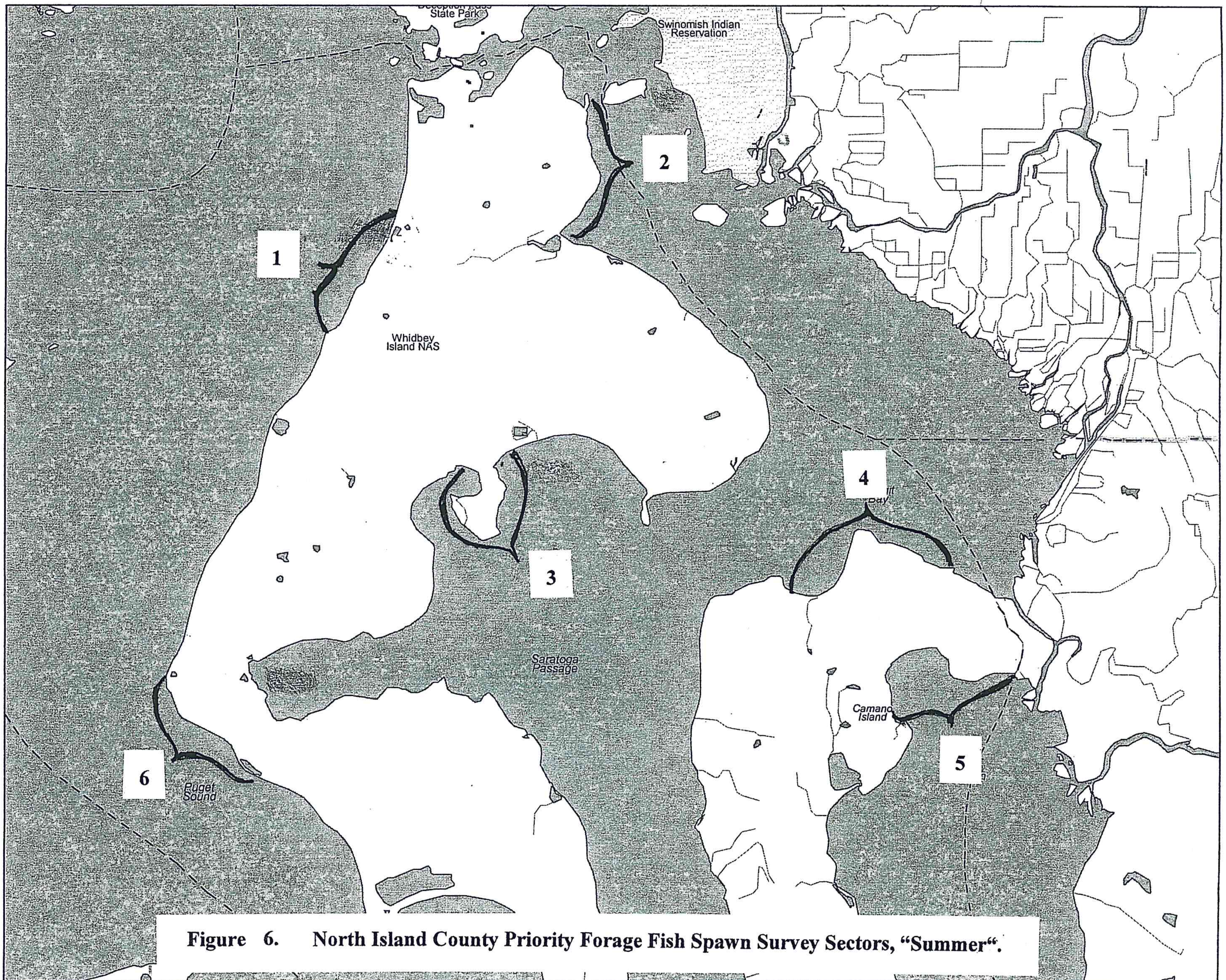


Figure 6. North Island County Priority Forage Fish Spawn Survey Sectors, "Summer".

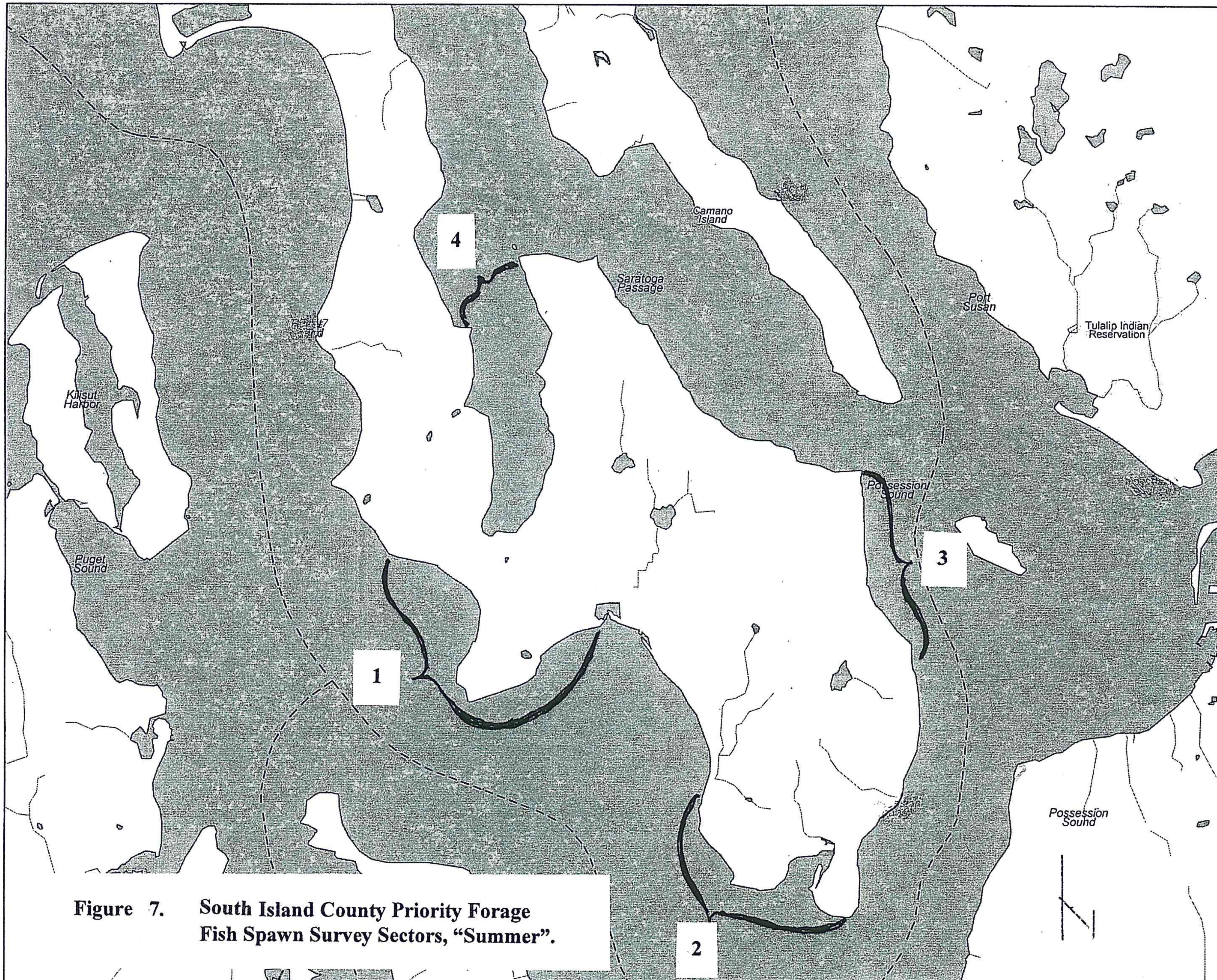


Figure 7. South Island County Priority Forage Fish Spawn Survey Sectors, "Summer".

3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 1 mi Scale: 1 : 162,500 Detail: 10-0 Datum: WGS84

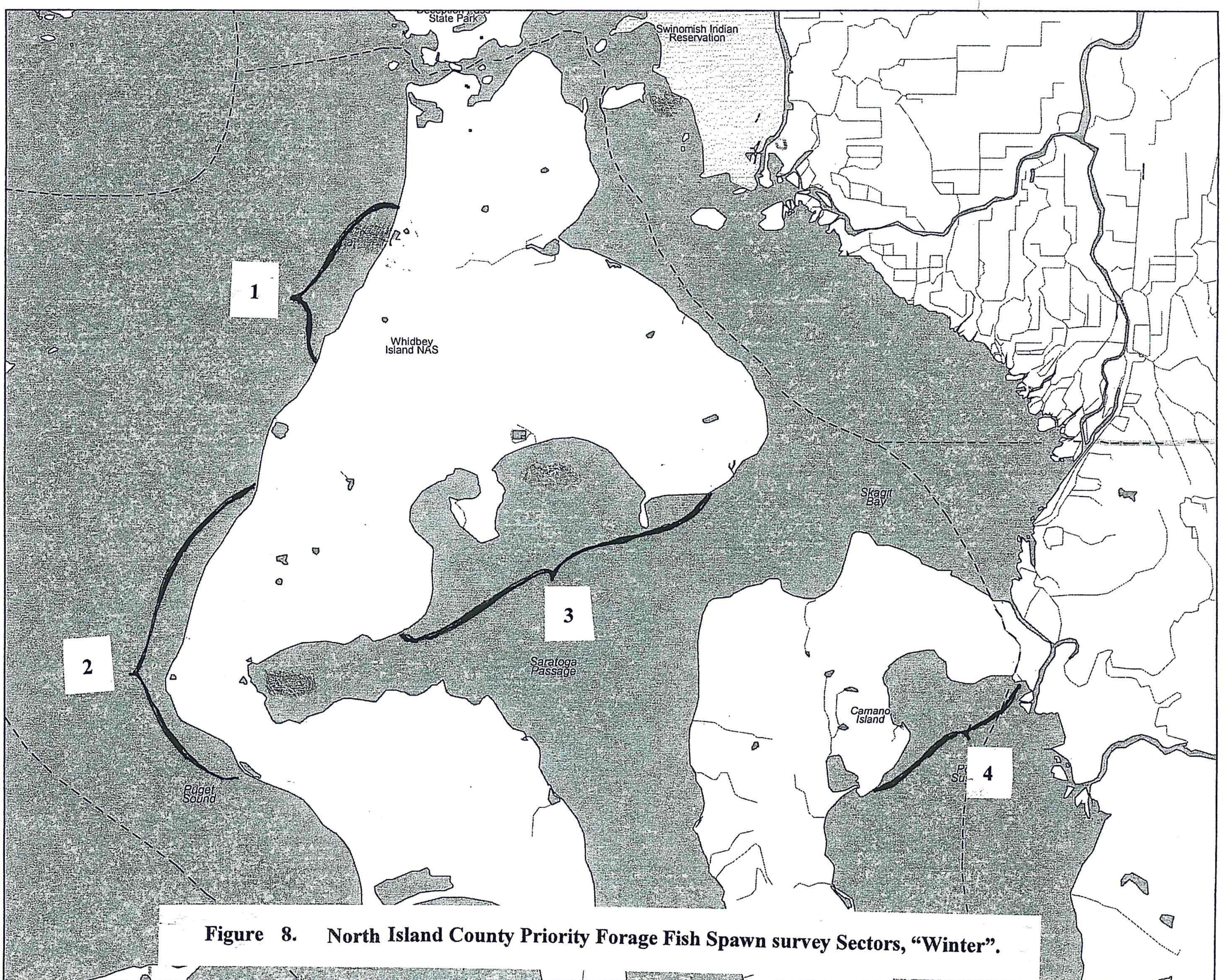


Figure 8. North Island County Priority Forage Fish Spawn survey Sectors, "Winter".

 1 mi Scale: 1 : 162,500 Detail: 10-0 Datum: WGS84

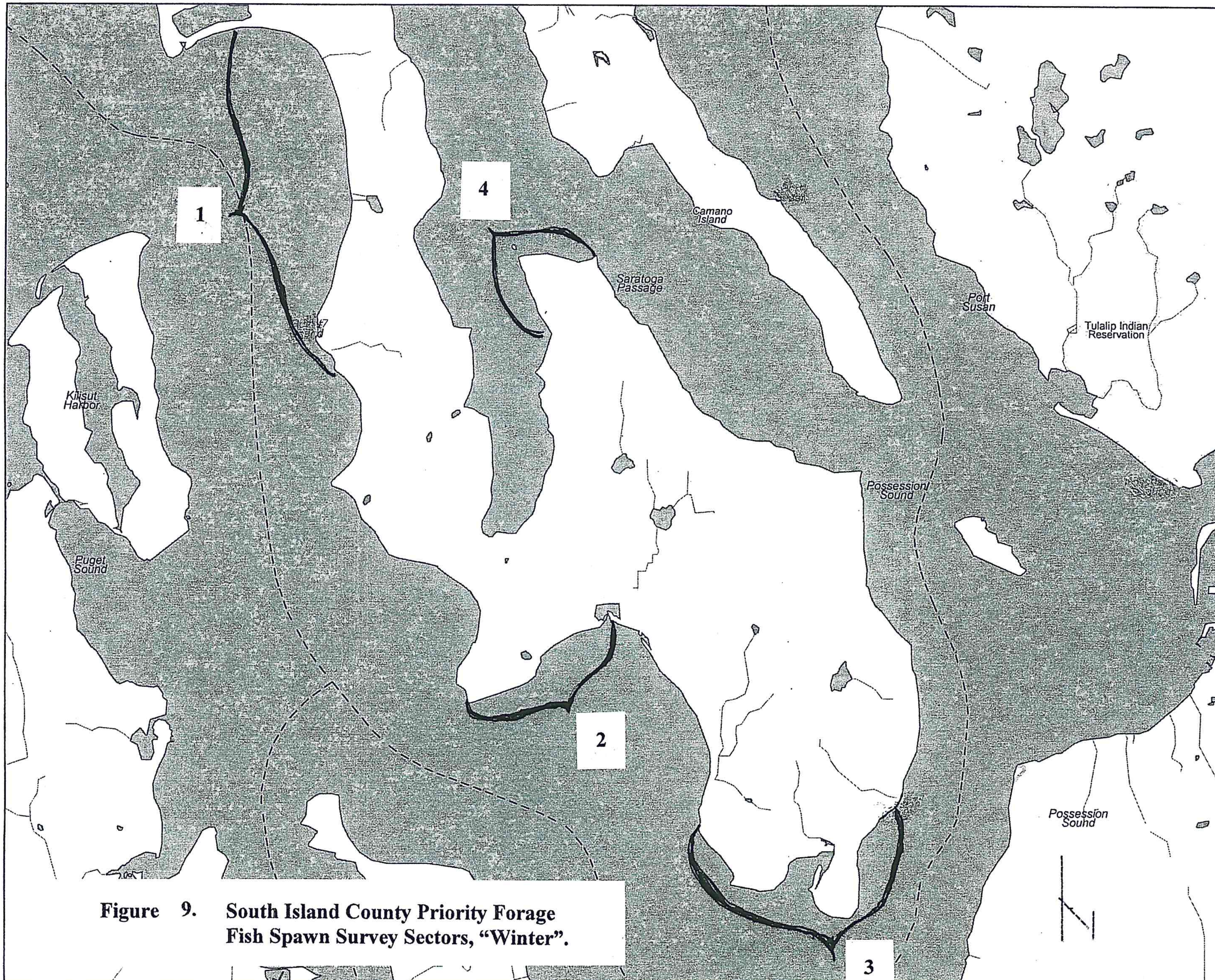


Figure 9. South Island County Priority Forage Fish Spawn Survey Sectors, "Winter".

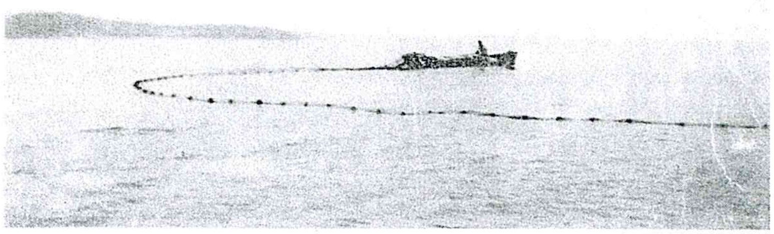
 1 mi Scale: 1 : 162,500 Detail: 10-0 Datum: WGS84

APPENDIX A

DEPARTMENT OF FISHERIES

State of Washington

Contribution to the Life History of the Surf Smelt, Hypomesus Pretiosus, in Puget Sound



Drag Seining for Smelt at Utsaladdy Beach

Biological Report No. 35B

Prepared for
B. M. BRENNAN, Director of Fisheries

July, 1936

STATE OF WASHINGTON
DIVISION OF SCIENTIFIC RESEARCH
DEPARTMENT OF FISHERIES

B. M. BRENNAN, DIRECTOR

LOYD A. ROYAL, BIOLOGIST

Biological Report
No. 35B

CONTRIBUTION TO THE LIFE HISTORY OF THE SURF SMELT (*HYPOMESUS PRETIOSUS*) IN PUGET SOUND

by

MILNER B. SCHAEFER

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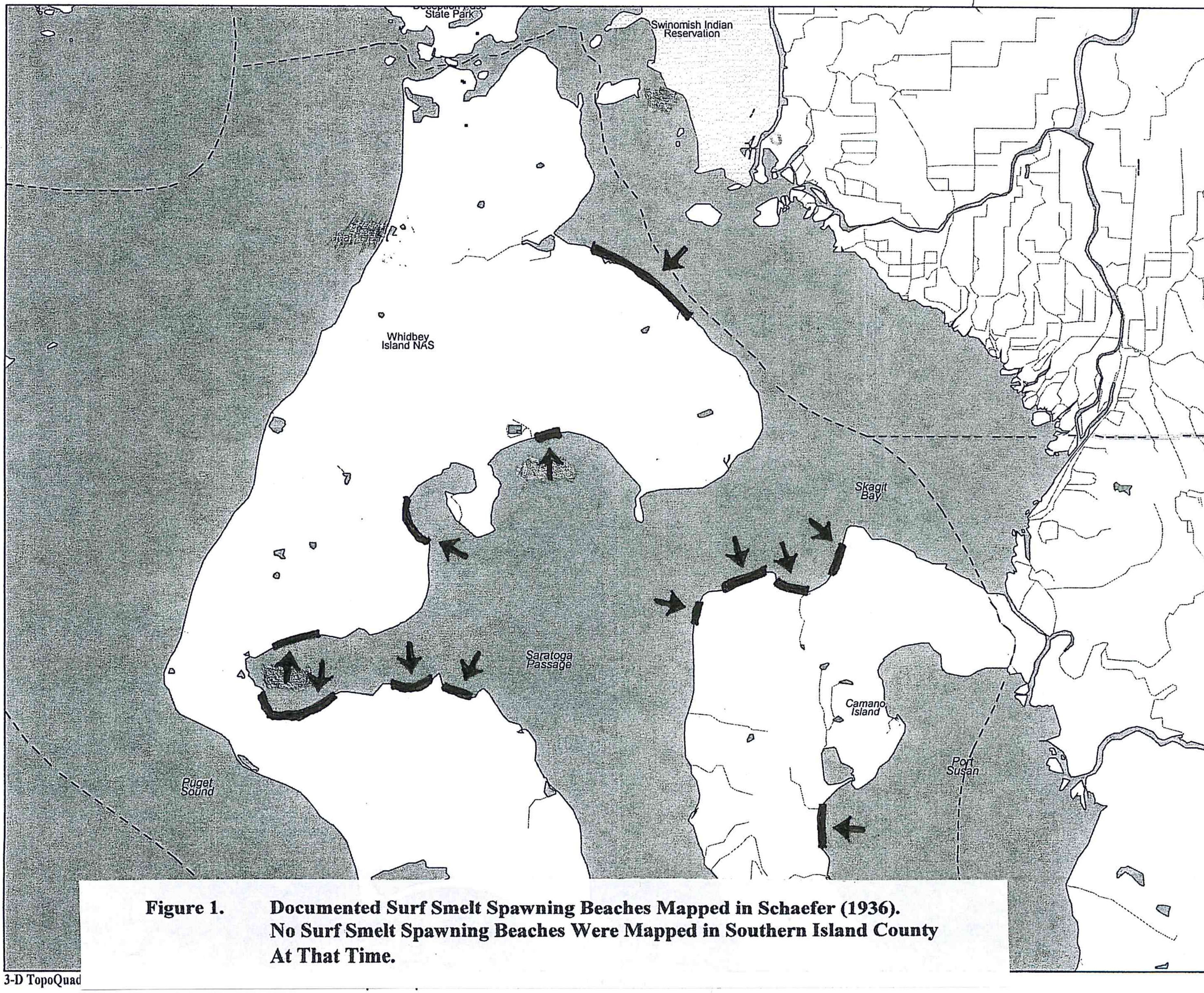


Figure 1. Documented Surf Smelt Spawning Beaches Mapped in Schaefer (1936). No Surf Smelt Spawning Beaches Were Mapped in Southern Island County At That Time.

APPENDIX B

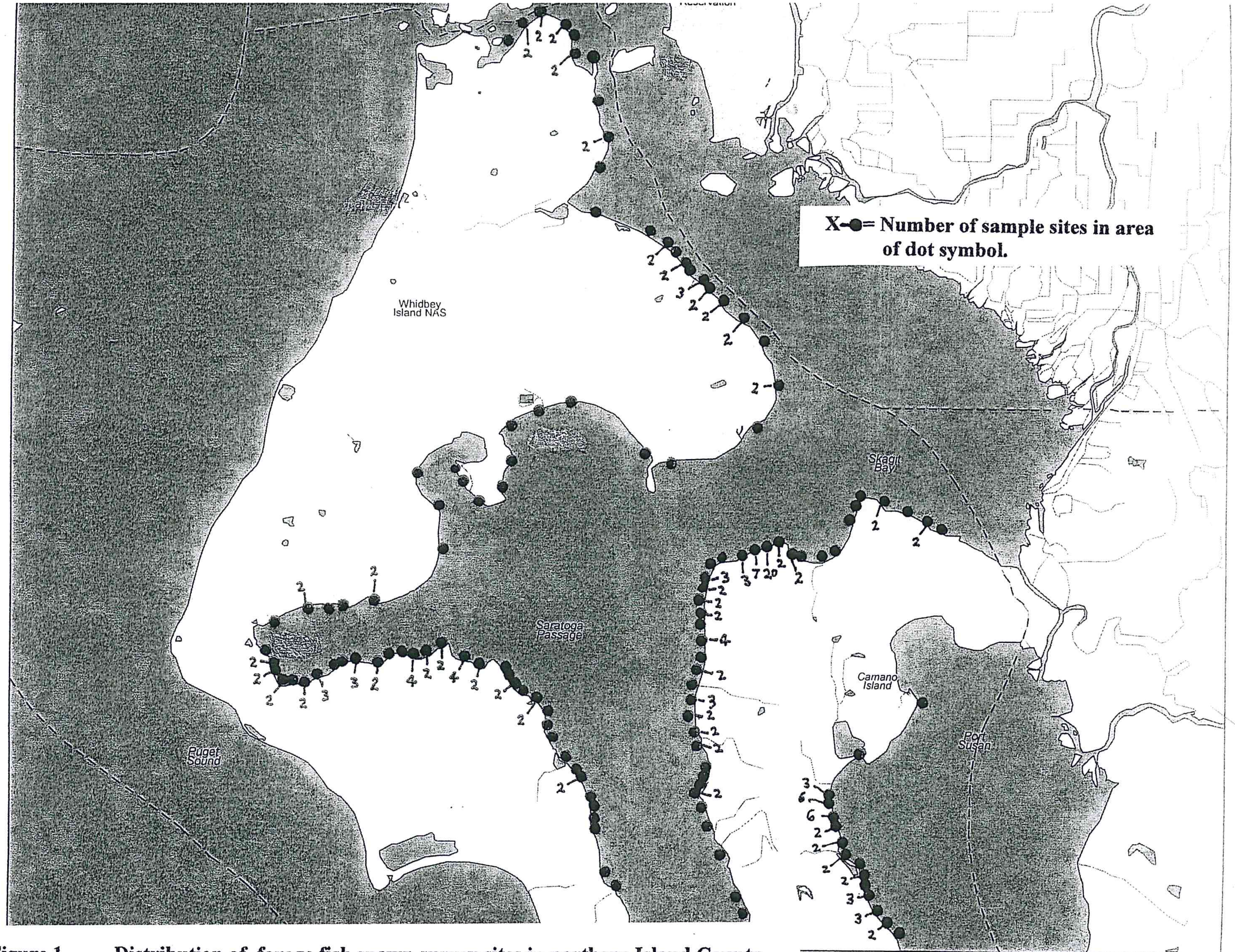


Figure 1. **Distribution of forage fish spawn survey sites in northern Island County, during "Summer" (April-September) by WDF/WDFW, 1972-1991, using visual spawn detection in the field.**

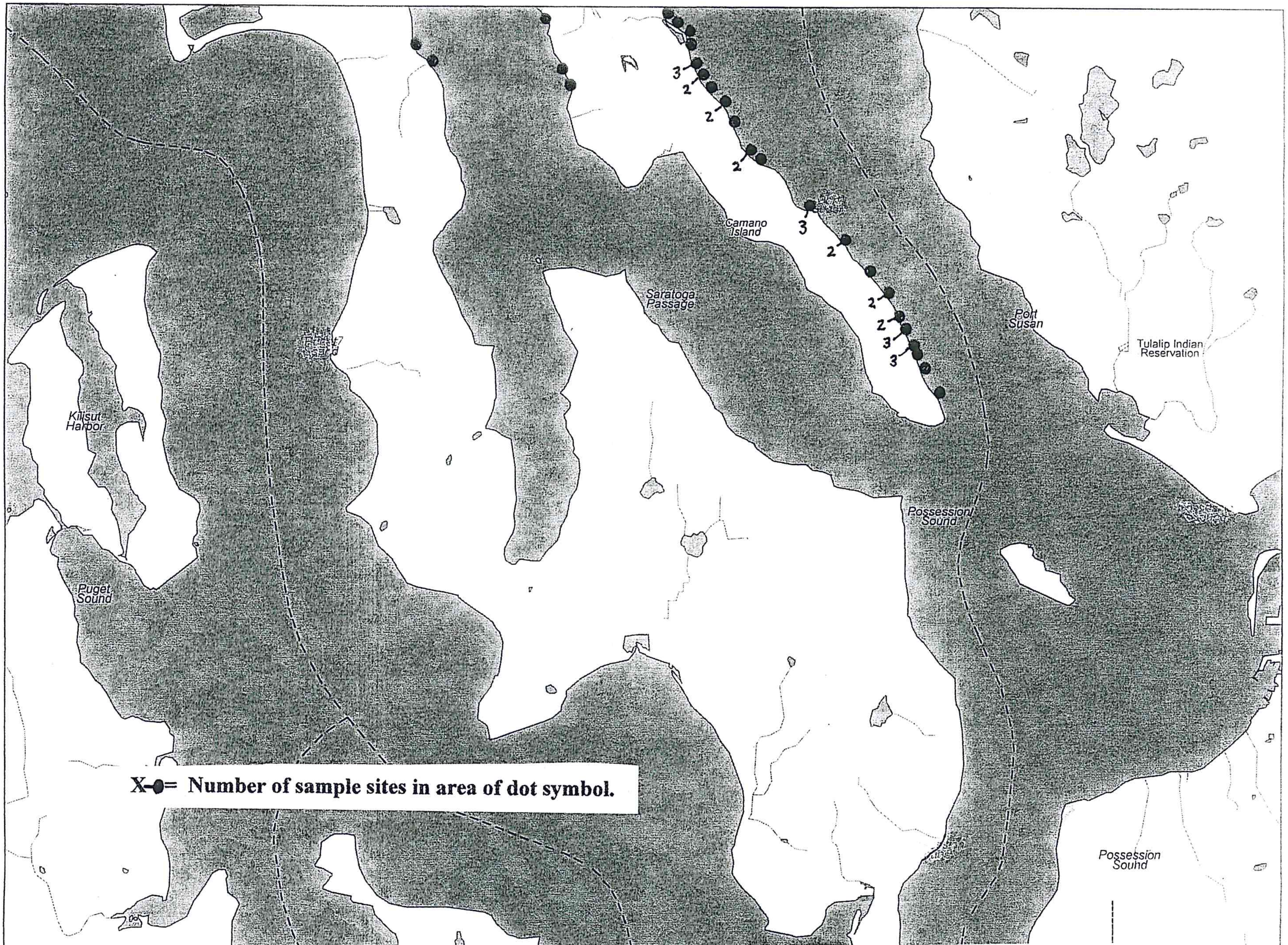


Figure 2. Distribution of forage fish spawn survey sites in southern Island County during "Summer", (April-September), by WDF/WDFW, 197201991, using visual spawn detection in the field.

3-D T

Figure 3. **Distribution of forage fish spawn survey sites in northern Island County during "winter", (October-March) by WDF/WDFW, 1972-1991, using visual spawn detection in the field.**

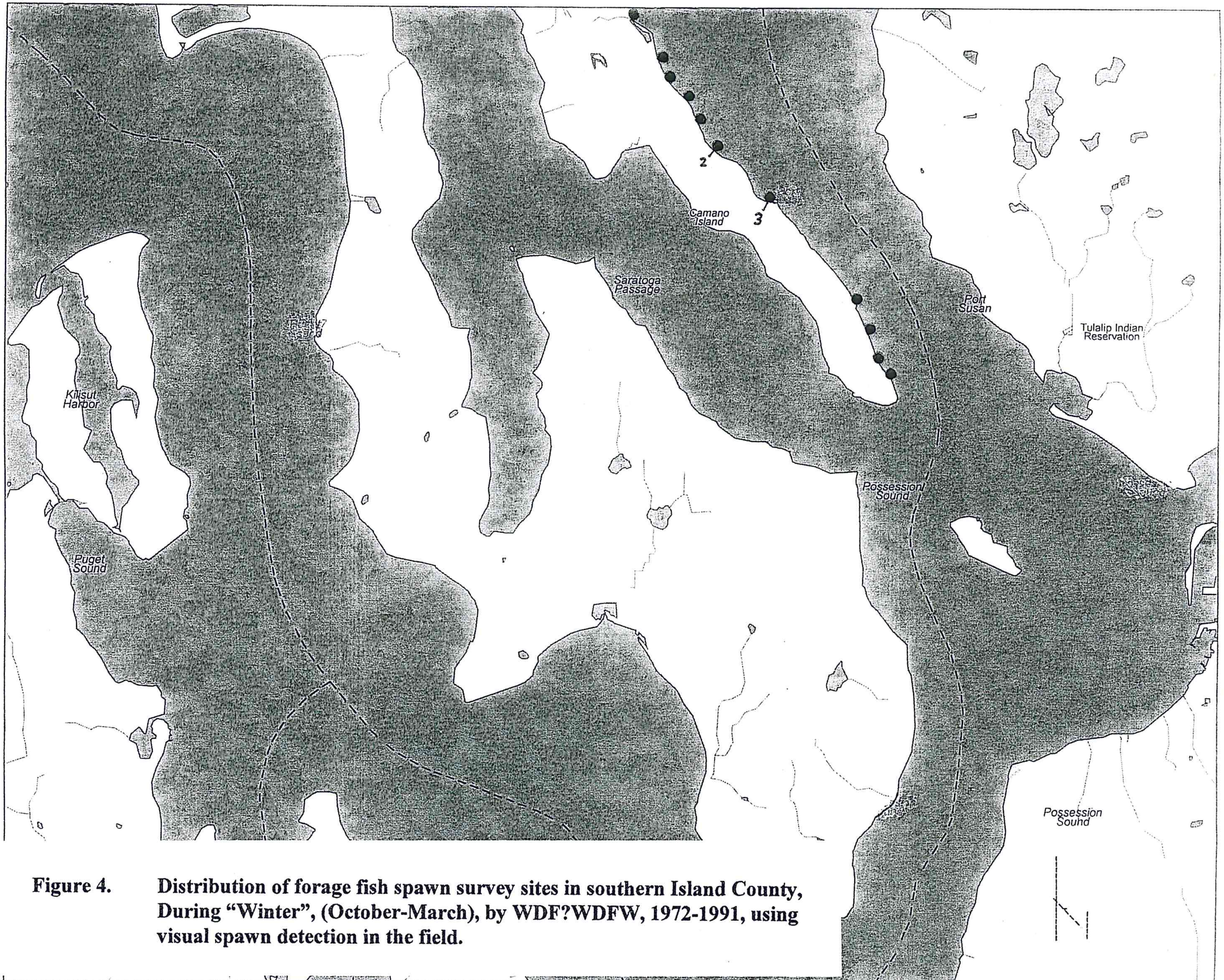


Figure 4. **Distribution of forage fish spawn survey sites in southern Island County, During "Winter", (October-March), by WDF?WDFW, 1972-1991, using visual spawn detection in the field.**

 1 mi Scale: 1 : 162,500 Detail: 10-0 Datum: WGS84

APPENDIX C

SAN JUAN COUNTY FORAGE FISH ASSESSMENT PROJECT

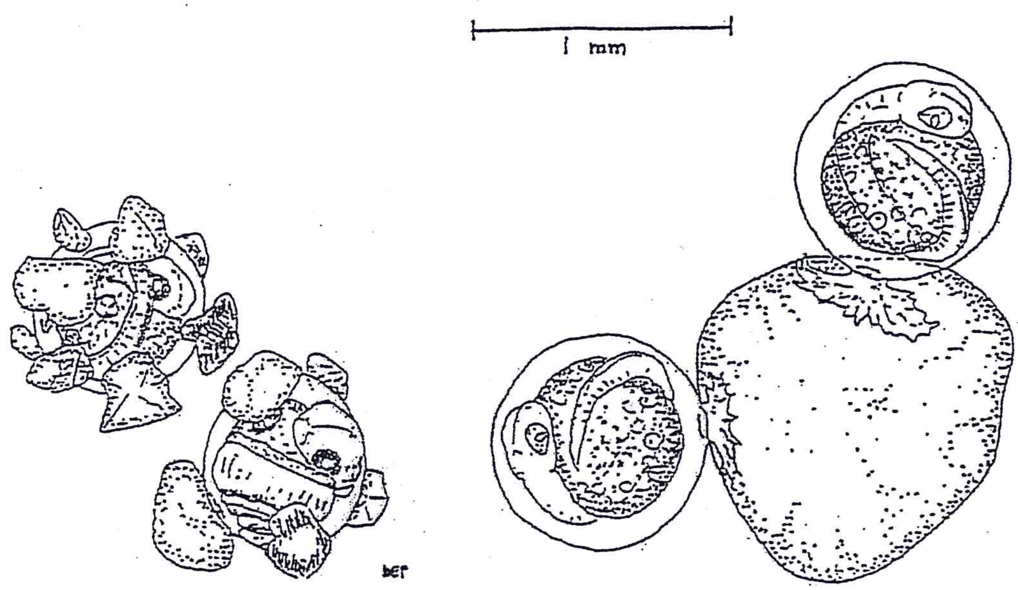
FIELD MANUAL

FOR SAMPLING FORAGE FISH SPAWN IN INTERTIDAL SHORE REGIONS

FIRST EDITION

MARCH 2001

(REVISED 2006)



Lawrence L. Moulton
MJM Research
1012 Shoreland Drive
Lopez Island, WA 98261

Daniel E. Penttila
Washington Dept of Fish and Wildlife
PO Box 1100
LaConner, WA 98257

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MJM Research
1012 Shoreland Drive
Lopez Island, WA 98261

and

Daniel E. Penttila
Washington Department of Fish and Wildlife
PO Box 1100
LaConner, WA 98257

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FIELD MANUAL FOR SAMPLING FORAGE FISH SPAWN IN INTERTIDAL SHORE REGIONS

INTRODUCTION

With the listing of many Puget Sound salmon stocks as threatened or endangered, the issue of maintaining salmon forage fish stocks has been identified as a high priority by the San Juan County Marine Resources Committee (SJC MRC). All the important forage fishes, i.e. surf smelt, Pacific sand lance, and Pacific herring, depend on nearshore habitats for spawning and rearing. Protection of nearshore habitats utilized as spawning and rearing areas for forage fish will be needed if salmon recovery is to be successful. Recovery of bottomfish within SJC was also identified in 1996 as a key priority by the SJC MRC. These species have since become a high priority throughout Puget Sound because six stocks have been identified for potential listing as threatened or endangered species. The same forage fish species of interest in salmon recovery will be vital for the success of any program to restore bottomfish stocks.

Washington Department of Fish and Wildlife (WDFW) presently attempts to protect all known, documented Pacific herring, surf smelt, and Pacific sand lance spawning sites from impacts of shoreline development. "No net loss" regulations for the protection of known spawning sites of these species are included in the wording of the Washington Administrative Code "Hydraulic Code Rules" (WAC 220-110), which are applied by WDFW marine habitat managers during considerations for granting Hydraulic Permits for in-water shoreline development proposals. However, the forage fish habitat protection regulations only apply to shorelines where spawn has actually been detected by WDFW or other qualified surveyors. Thus it is critical for overall protection of these habitats that spawn deposition site inventories be complete and comprehensive. Not all outwardly suitable-appearing shorelines seem to be used by spawning forage fishes. On the other hand, large areas of formerly productive spawning habitat have been degraded or destroyed by shoreline practices in the absence of a database (or concern) regarding forage fish spawning activity.

Surveys to identify spawning areas were conducted by WDFW between 1989 and 1999, which documented 14 surf smelt spawning beaches, and 8 Pacific sand lance spawning beaches (Penttila 1999). WDFW was conducting a systematic survey of forage fish spawning beaches from 1991-1996 throughout Puget Sound, but lost funding for the effort in 1997, just as the San Juan County beaches were to be surveyed. As a result of the diminished program, only a small portion of the potential beach spawning habitat has been surveyed (Penttila 1999).

Surf smelt in the San Juan area spawn year-round, with no particular spawning season more dominant than another (Penttila 1990, 1999, Figure 1). Eggs, about 1 millimeter in diameter, are deposited in the upper intertidal zone on mixed sand and gravel beaches (Figure 2). After spawning, the eggs are dispersed across the beach by wave activity, so more of the beach is used for incubation than is used for actual spawning. Surf smelt can spawn on the same beach through the year, so eggs are likely to be present at any time. For example, at Hunter Bay and N. Shaw Island index sites, smelt eggs were found during 13 of 16 visits from February 1989 to May 1990 (Penttila 1990).

WDFW conducted field surveys of spawn visible to the eye from 1989 to 1990 and "bulk sampling" (i.e., composited sediment samples from potential spawning beaches) from 1993 to 2000 to identify surf smelt spawning areas within San Juan County. The bulk sampling method consists of collecting beach samples and subjecting the sample to laboratory examination for egg presence. This method is considered a much more accurate measure of spawning activity than the visual method. A total of 208 visual samples and 286 bulk samples were taken during the survey periods. Most of the visual surveys were on Orcas, Lopez and Shaw islands, while bulk sampling was primarily on San Juan, Orcas and Lopez islands (Penttila 2000). The distribution of sampling is illustrated in Figure 3. As presented above, fourteen beaches within San Juan County have so far been identified as supporting spawning by surf smelt (Penttila 1999, Figure 4). The visual sampling method is considered relatively inefficient for identifying spawning locations, thus WDFW recommends that the locations surveyed in 1989-1990 that did not yield eggs should be re-surveyed using the bulk method (Penttila 2000).

Results of bulk sampling indicate that not all beaches with appropriately-sized sand and gravel are used for spawning. Usage appears greatest on beaches with over-hanging vegetation. Over-hanging vegetation provides shade, which reduces egg mortality caused by desiccation. The shading is likely to be particularly important for the portion of the stock that spawns from late spring to early fall, when low tides are during the day and exposure to warm, dry air is greatest.

The intertidal nature of Pacific sand lance spawning was not known until 1989 (Penttila 1999). Pacific sand lance appear to use the same spawning substrate as surf smelt, as eggs from both species are often in the same sample. Pacific sand lance, however, will also use pure sand beaches that are not utilized by surf smelt. Fresh spawn appears as shallow, circular pits on the upper beach (Figure 2). The pits disappear rapidly after spawning as wave action re-works the beach sediment. Spawning by Pacific sand lance is during the winter, from early November through February (Figure 1). Development of the 0.6-0.8 mm eggs takes about 4 weeks, depending on temperature, thus incubating eggs could be present into late March.

The bulk sampling method described for assessing surf smelt spawning is also used to document Pacific sand lance spawning. The visual method is virtually useless for detecting Pacific sand lance eggs because these eggs are covered with sand grains and are essentially undetectable with the naked eye. Eight Pacific sand lance spawning areas were found during the bulk sampling conducted from 1993 to 2000, with the distribution as depicted in Figure 5.

STUDY DESIGN CONSIDERATIONS

Project Objectives

The primary objective of the SJC forage fish assessment is to identify county beaches that are utilized as spawning areas by surf smelt and Pacific sand lance. A secondary objective is to identify subtidal regions supporting Pacific herring spawning.

Sampling Schedule

Planning for surveys needs to consider spawning time when designing surveys intended to identify spawning locations (Figure 1). In the San Juan Islands, surf smelt spawn year-round (Penttila 1999). Pacific sand lance begin spawning in November, continuing through February.

SURF SMELT AND PACIFIC SAND LANCE SPAWN ASSESSMENT

Sampling for surf smelt and Pacific sand lance eggs consists of 1) obtaining a bulk sample of mixed sand and gravel from the upper intertidal region of an appropriate beach, 2) condensing the bulk sample to a manageable volume, and 3) examining the condensed sample under a dissecting microscope to determine the presence or absence of eggs.

Site Selection

Not all beaches represent potential surf smelt or Pacific sand lance spawning areas. Potential spawning areas are composed of a mixture of sand and small gravels, usually with fine shell fragments mixed in. Spawning and incubation areas are normally in the +7 to +9 foot MLLW tide zone. Areas that are shielded from direct sunlight by over-hanging vegetation are often more heavily used than areas where vegetation has been removed. Examples of spawning areas are shown in Figure 6. Note that in Blind Bay, only a portion of the potential habitat appears to be actually used for spawning and that the utilized area corresponds to the area with most over-hanging vegetation. Close-ups of areas containing appropriate substrate are in Figure 7. Eggs can sometimes be seen through a visual assessment (Figure 8).

Field Equipment

Equipment needed for collecting bulk beach samples to assess surf smelt and Pacific sand lance:

- 16 ounce plastic jar
- 8 inch x 24 inch polyethylene bags (to hold bulk sample)
- waterproof labels
- Pencil w/#2 lead
- Waterproof marker (fine tip)

- Electrical tape

Equipment needed for condensing samples:

- Rack of sediment screens, size 4, 2, and 0.5 mm, preferably Nalgene instead of the more traditional brass screens,
- 2 - 5 gallon buckets modified to act as drain for screen rack,
- 2 Wash buckets,
- Plastic dishpan,
- 16 ounce plastic sample jar
- Stockard's Solution:
  50 ml formalin (37% formaldehyde)
  40 ml glacial acetic acid
  60 ml glycerin
  850 ml fresh water

Equipment needed to establish sample location:

- Chart or map of beach to be sampled, 1:24,000 scale
- Integrated digital camera/GPS system
- 100 ft fiberglass tape for measuring distances

Field Records

Environmental characteristics of the sampled location are recorded to help analyze results of sampling. These records are entered on the field data sheet, which is completed at the time of sampling (Figure 14). Personnel involved in sampling need to be listed on the bottom of the sheet in case there are questions regarding the data. The data sheet will be reviewed after the crew has returned from the field. The reviewer will indicate that the sheet has been completed by signing the space labeled "Reviewed by".

The data fields should be filled in as follows:

Last High Tide: time and elevation of the last high tide – can be obtained from a current tide chart.
Island: Island Sampled
Date of Sampling
Beach Number: Assigned Number for Beach being sampled.
Sample Number: Sample number from Sample Label.
Time: time sample label is removed from the beach (0000-2400 hr)
Latitude/Longitude: latitude and longitude in degrees, minutes, seconds
Beach: Character of the upper beach:
0 = mud,
1 = pure sand,
2 = pea gravel (fine gravel) with sand base,

3 = medium gravel with sand base,
4 = coarse gravel with sand base,
5 = cobble with sand base,
7 = boulder with sand base,
8 = gravel to boulders without sand base,
9 – rock, no habitat

Uplands: Character of the uplands (up to 1,000 ft):
1 = natural, 0% impacted (bulkhead, rip-rap, housing, etc.);
2 = 25% impacted; 3 = 50% impacted; 4 = 75% impacted, 5 = 100% impacted

Sample Zone: Distance of collection parallel from a land mark in feet to the nearest ½ foot. Used to determine the tidal elevation of the spawn deposit

Land Mark: Land mark for sample collection:
1 = down beach from last high tide mark
2 = up beach from last high tide mark
3 = down beach from second to last high tide
4 = down beach from upland toe
5 = up beach from waterline at the time noted

Tidal Elevation: This is determined in the office using the location and time data.

Smelt, Sand Lance, Rock Sole, Herring: subjective field assessment of spawn intensity:
0 = no eggs in field,
1 = very light, observed in field,
2 = light, observed in field
3 = light medium, observed in field
4 = medium, observed in field
5 = medium heavy, observed in field
6 = heavy, observed in field
7 = very heavy, observed in field
8 = eggs observed in the winnow

Width: Width of the potential spawning substrate to the nearest foot

Length: Length of the beach up to 1,000 feet (500 feet on either side of the station) or "C" if continuous.

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

Comments: additional information to be entered into the computer, evaluated on a station by station basis.

Samplers: Names of personnel participating in the sample collection

Photo Taken: indicate number and direction of photographs

Prepare a map of each location sampled using a 1:25,000 scale NOAA nautical chart or 1:24,000 scale USGS topographic sheet. Mark each sample location on the map with appropriate sample number so that the exact site can be re-visited, if needed. Use a GPS to obtain latitude and longitude of each sampled location, but priority should be placed on an accurate map.

Relevant nautical charts are:

18429 - Rosario Strait – Southern Part
18430 - Rosario Strait – Northern Part
18432 - Boundary Pass
18433 - Haro Strait – Middle Bank to Stuart Island
18434 - San Juan Channel

Relevant USGS topographic sheets are:

Blakely Island, Wa.	48122-E7-TF-024
Eastsound, Wa.	48122-F8-TF-024
False Bay, Wash.	N4822.5-W12300/7.5
Friday Harbor, Wa.	48123-E1-TF-024
Lopez Pass, Wash.	N4822.5-W12245/7.5
Mt. Constitution, Wa.	48122-F7-TF-024
Richardson, Wash.	N4822.5-W12252.5/7.5
Roche Harbor, Wa.	48123-E2-TF-024
Shaw Island, Wa.	48122-E8-TF-024
Stuart Island, Wa.	48123-F2-TF-024
Waldron Island, Wa.	48123-F1-TF-024

General Guidelines for Collecting Bulk Beach Samples

Examine the beach to evaluate the most likely zone to contain eggs (+7 to +9 feet MLLW). This zone will be in the upper third of the beach, near the upper tidal limit. Typically, this zone is 1 or 2 vertical feet below the log line. For surf smelt eggs, the zone is characterized by mixed sand and small gravel. For Pacific sand lance eggs, the zone is similar, but can extend into pure sand. Mud or muddy sand are not acceptable substrates, nor are larger gravels, cobbles or solid rock and talus shores.

The sample is composed of four (4) scoops of gravel evenly spaced along a 100 ft stretch of beach (see Figure 10).

- Identify an approximately 100 ft stretch of beach to be sampled.
- Obtain location information for the transect by reading position information from a GPS or marking the location carefully on a large scale (1:24,000) USGS topographical sheet.
- Prepare a Sample Label to allow identifying the location (Beach Number) and collection time of the sample, deposit the label in the plastic bag (Figure 11).
- Start at one end of the transect, scoop a jar full of sand from the top 1-2 inch of beach and dump the sand into the plastic bag. The scooped area will likely be 3-4 ft long – the idea is to skim the eggs developing in the surface one-inch of substrate.

- Move 10 paces along the transect, obtain another scoop sample and place in the bag with the previous scoop.
- Repeat pacing and scooping until the four scoops have been obtained – this constitutes the bulk sample for the chosen transect.
- Seal the bag securely and place in a cool location. This is particularly important in warmer weather because high temperatures can cause mortality and decomposition in the eggs.
- Store in a secure location to ensure that the bags are not damaged during transit from the field.
- Take one or more photographs of the sampled beach. The photograph should be taken from one end of the sampled transect, looking towards the other end, so that the view is parallel to the beach. The photograph should show the sample relative to the last high tide line, if possible, and any other land marks that will help to establish the sample location. The direction of view (looking north, south, etc.) should be recorded on the field data sheet.

Condensing Bulk Samples

The bulk egg samples can be processed in the field to remove most of the sand and reduce the volume of the sample. This is done by washing the eggs from the sand and discarding the barren sediment (Figure 12). The eggs are lighter than the sand and gravel and will move upward during the washing process, allowing them to be skimmed from the surface of the material (Figure 13). The washing is conducted as follows:

- Assemble the Nalgene screens on top of the drain bucket, with the largest mesh on top, grading to the smallest mesh on the bottom.
- Remove the sample label and place it in a 16 ounce sample jar.
- Mark the Beach Number and Sample number on the outside of the jar with the fine-tip marker pen.
- Add a portion of the sample to the top screen, thoroughly wash the sediment through the screen set with either salt or fresh water, which ever is readily available.
- Discard the sediment in the top screens, retain only the material in the bottom (0.5 mm) screen.
- Dump the material retained in the 0.5 mm screen into the dishpan.
- Add water until the material is covered by 1-2 inches of water.
- Swirl the water around the pan, adding rocking and bouncing motions to allow the eggs to migrate to the top of the sediment. The idea is similar to gold panning, try to winnow the eggs to the surface of the material.
- After swirling for 1-2 minutes, work the lighter fraction of material to one corner of the pan. Carefully dry up the lighter fraction by tipping the pan so that the water drains away, and skim the lighter fraction from the surface of the sand with the sample jar.
- Repeat the winnowing process two more times.
- Process the remainder of the sample in a similar fashion, each time adding the retained lighter fraction to the sample jar.
- Fill the sample jar with Stockard's Solution to preserve the eggs. Seal the jar securely, invert carefully several times to ensure that the preservative reaches all the eggs.

- Tape the jar shut with electrician's tape so that the preservative does not evaporate during storage.

Laboratory Examination

Laboratory examination begins with a further condensing of the sample. The winnowing process conducted in the field is repeated using a shallow tray to separate eggs from sand. Final separation is performed under a dissecting microscope at 10-20x, where surf smelt eggs become quite visible. Pacific sand lance eggs are surrounded by sand grains, thus it is necessary to search for clumps of sand grains, then tease off the sand with fine-tipped forceps or dissecting needles to reveal the egg.

Eggs will be counted by species and the counts entered on the lab data form (Figure 13). The lab data form will only be used by those individuals specially trained in lab processing of samples and identifying eggs.

Eggs found during the smelt/Pacific sand lance spawn assessment will be archived for confirmation of species and spawn age analyses. Up to 100 random eggs of each species present will be labeled and preserved in Stockard's Solution in a vial, to be forwarded to WDFW staff, or other knowledgeable experts, for inspection. A number of non-egg objects may be encountered in preserved upper intertidal substrate samples that may be misidentified as forage fish eggs or empty egg shells, including invertebrate eggs, algal fruiting bodies, flatworms and their egg cases, certain thecate or arenaceous foraminifera, decalcified gastropods, and fragments of annelid worm tubes. Relative abundance and ages of forage fish eggs in the samples will be recorded, as these provide information of the relative frequency and density of spawning.

QUALITY ASSURANCE/QUALITY CONTROL

Primary concerns for quality control include:

- sampling appropriate habitat,
- accurate identification of sample location,
- careful screening and winnowing of the bulk sample to retain the maximum number of eggs, and
- accurate identification of sampled eggs.

The best way to ensure quality of the data is to make sure samplers are appropriately trained and understand the importance of careful sample processing and complete recording of sample-related information. Accuracy of screening and winnowing procedure can be measured by seeding a sand-gravel sample barren of eggs with a known number of eggs, then processing the sample to see how many eggs are actually detected.

DATA REPORTING

Data reporting should include all information collected during sampling. Usually, this reporting is in the form of summary tables that present information recorded on field and lab data sheets. The format of the tables can be similar to that of the data sheets to simplify reporting. Reporting should include:

1. a listing of all sites sampled, whether eggs were found or not,
2. detailed location information so that any site can be re-sampled, if necessary,
3. a summary of sampling at each site, including environmental conditions and number of samples taken,
4. a summary of findings for each site, including number of eggs by species found in each sample.

REFERENCES

Penttila, D.E. 1990. Summary report, San Juan Co., surf smelt spawning beaches, February 1989 through May 1990. WDF Memorandum to Greg Hueckel, July 3, 1990. Seattle, WA. 7p.

Penttila, D.E. 1999. Documented spawning areas of the Pacific herring (*Clupea*), surf smelt (*Hypomesus*), and Pacific sand lance (*Ammodytes*) in San Juan County, Washington. Washington Dept. of Fish and Wildlife, Marine Resources Division. Manuscript Report. LaConner, WA. 27p.

Penttila, D.E. 2000. Previous surf smelt/sand lance beach sampling sites in San Juan County. Washington Dept. of Fish and Wildlife, Marine Resources Division. WDFW Memorandum to L. Moulton, February 14, 2000. LaConner, WA. 1p.

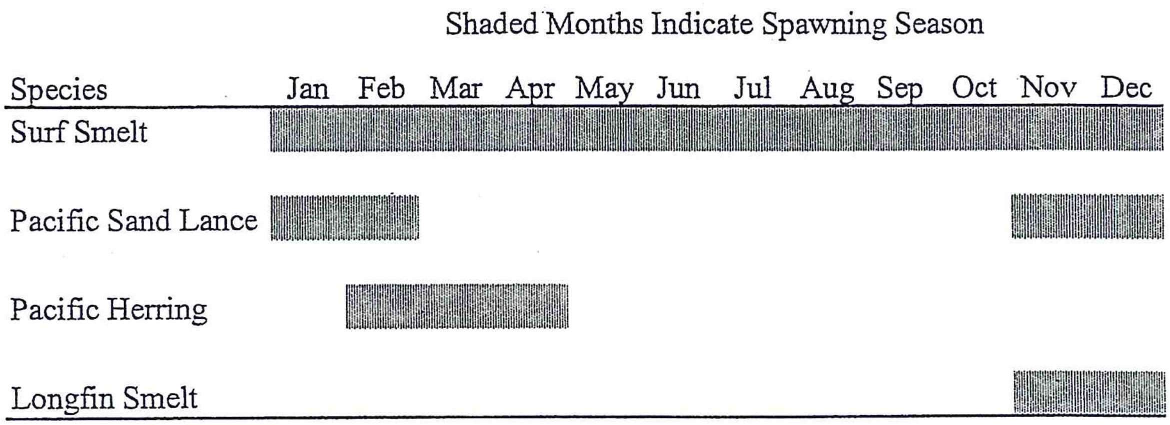
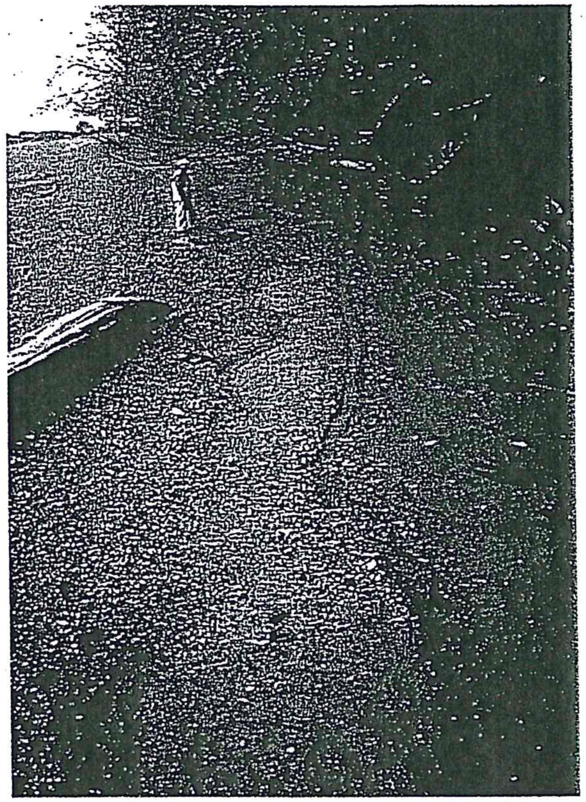


Figure 1. Spawning time of forage fish species in San Juan Islands (data from WDFW).



a. Surf smelt spawn deposit outlined to show extent of spawning activity – note proximity of spawn deposit to the high tide mark.

b. Pacific sand lance spawn deposit with characteristic pitting (pits are circled to highlight).

Figure 2. Fresh surf smelt and Pacific sand lance spawn deposits (photos by D. Penttila, WDFW).

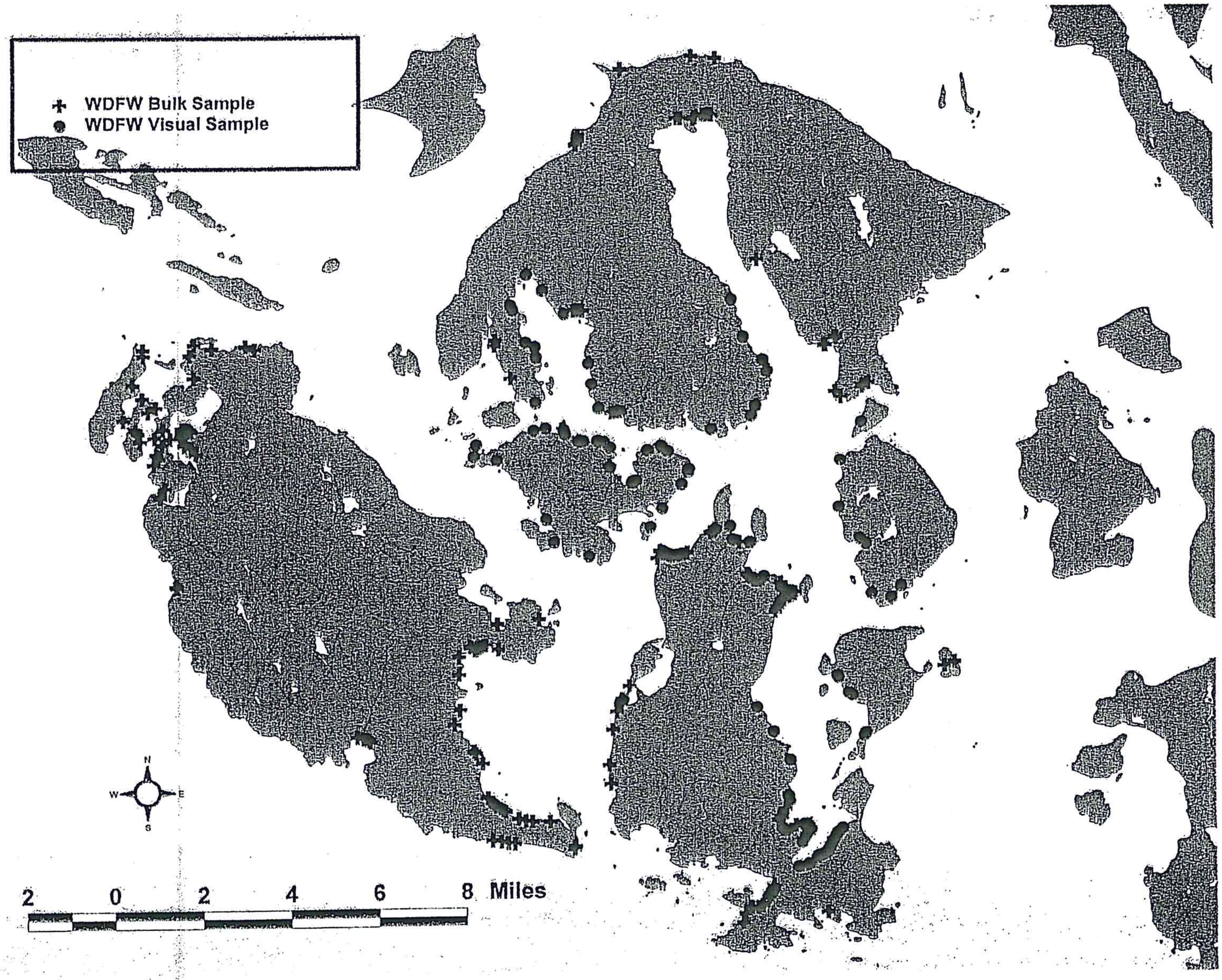


Figure 3. Distribution of intertidal sampling by WDFW to identify surf smelt and sand lance spawning beaches, 1989-2000.

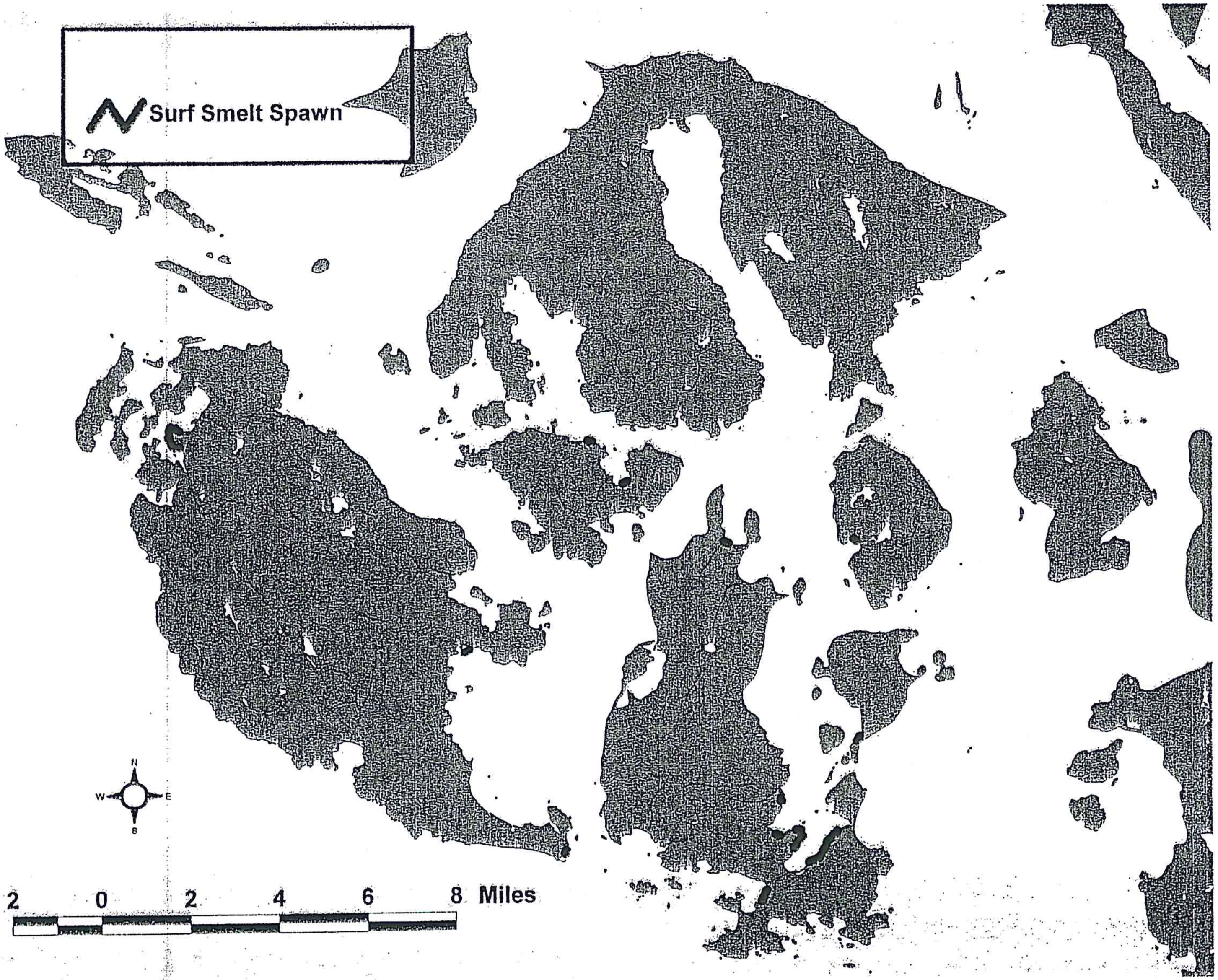


Figure 4. Results of WDFW sampling for evidence of intertidal spawning by surf smelt, 1989-2000.

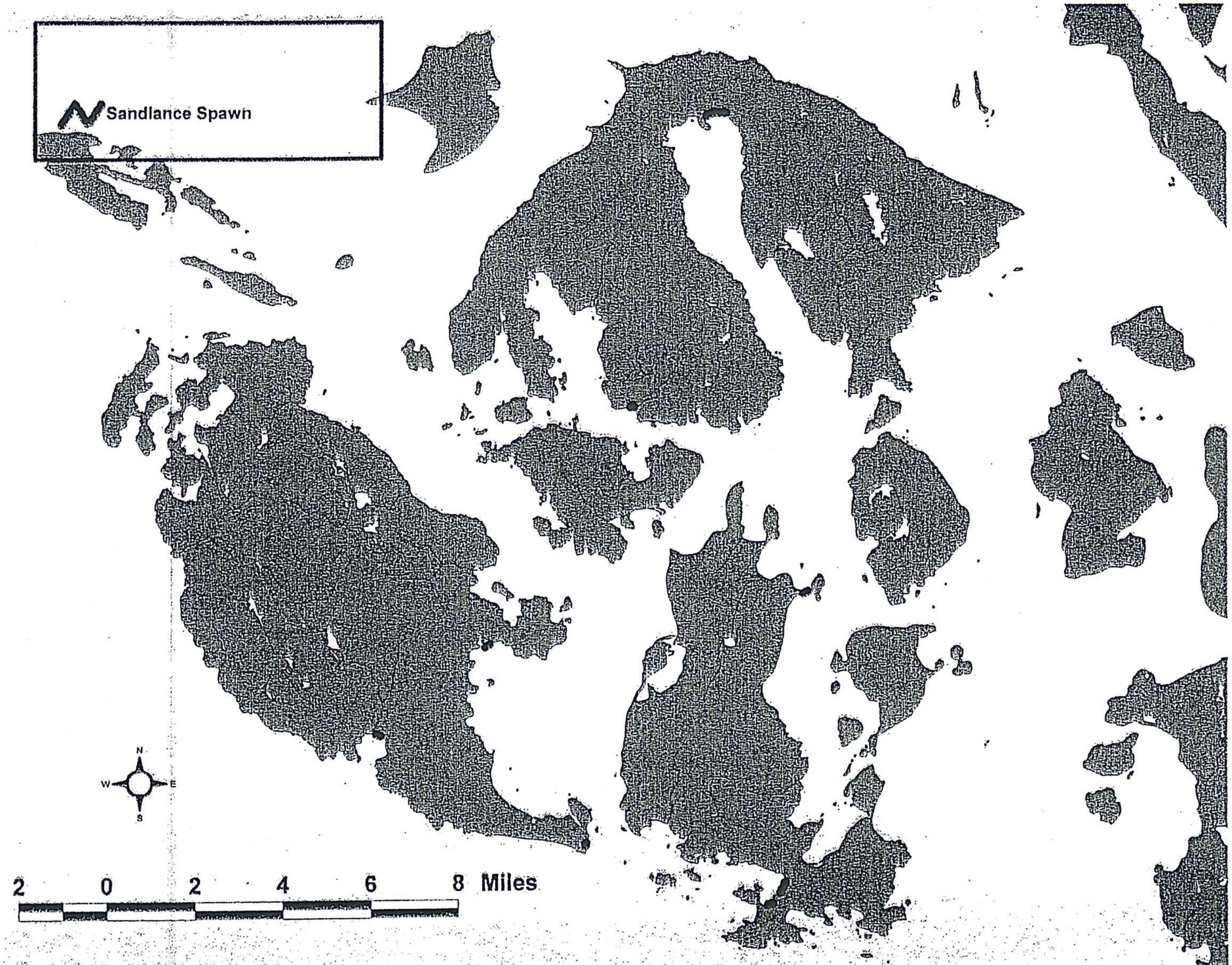
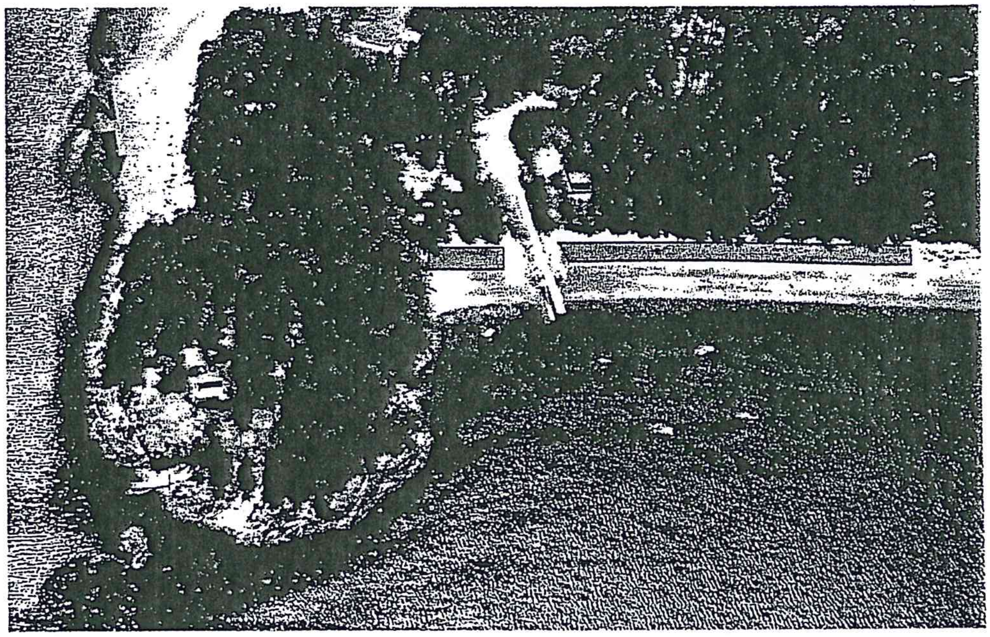
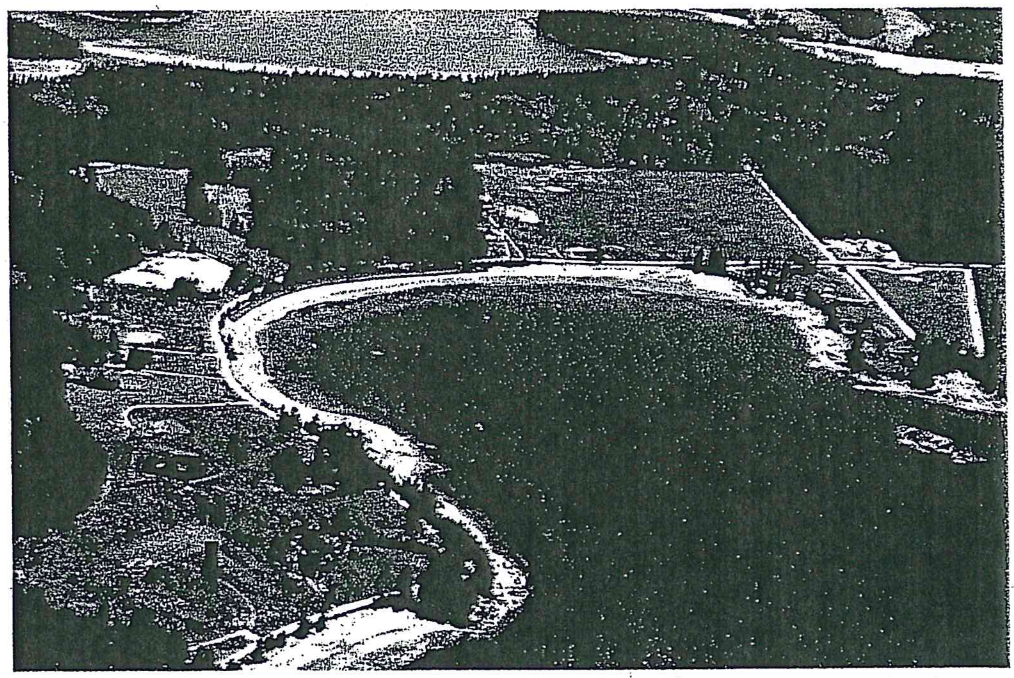


Figure 5. Results of WDFW sampling for evidence of intertidal spawning by Pacific sand lance, 1989-2000.

54

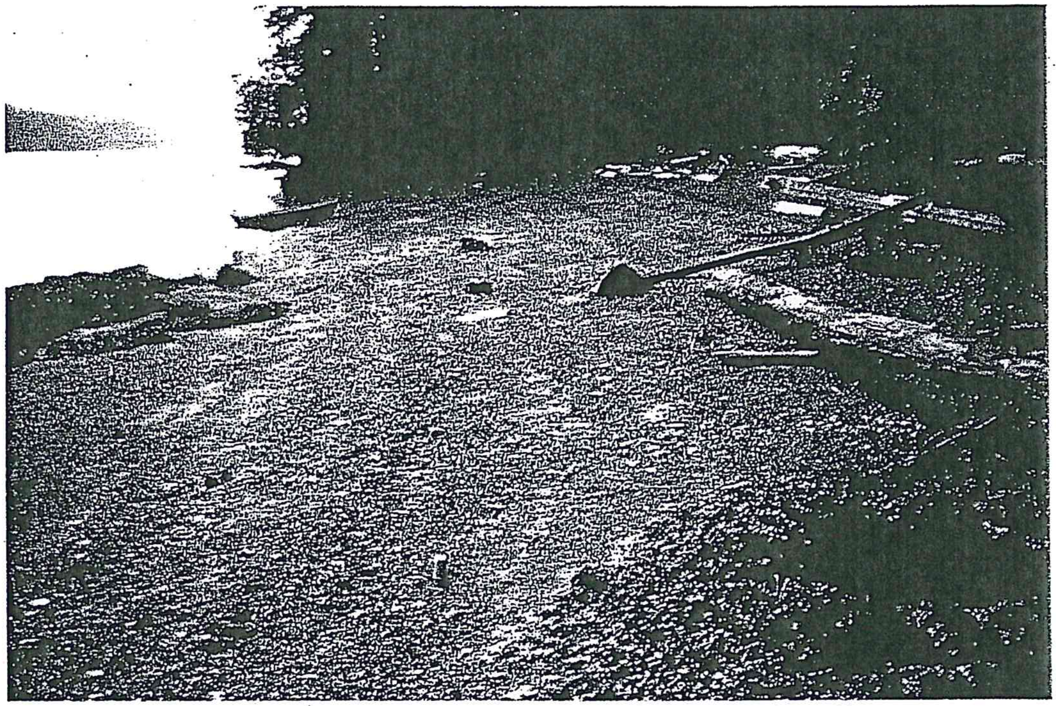


a. Surf smelt spawning area (patterned area) at Hunter Bay, Lopez Island (note that spawning area has been reduced by dock and launch ramp construction).



b. Surf smelt spawning area (arrow to patterned area) in Blind Bay, Shaw Island (note relationship of spawning area to over-hanging vegetation).

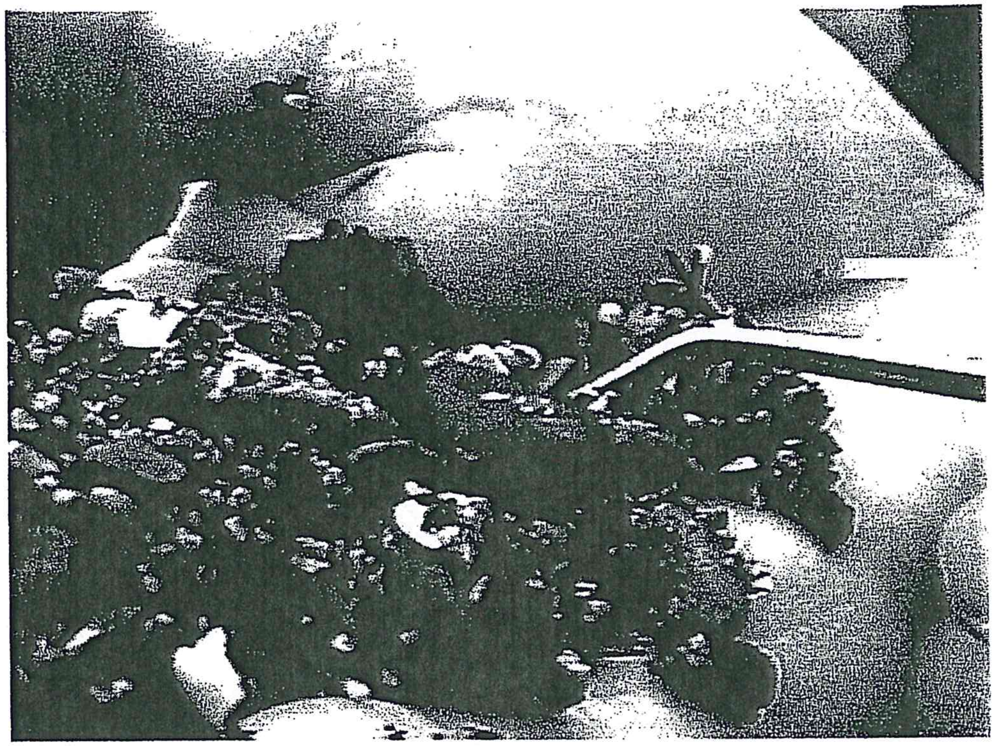
Figure 6. Representative surf smelt spawning beaches in San Juan County (aerial photos from WDOT, 1986).



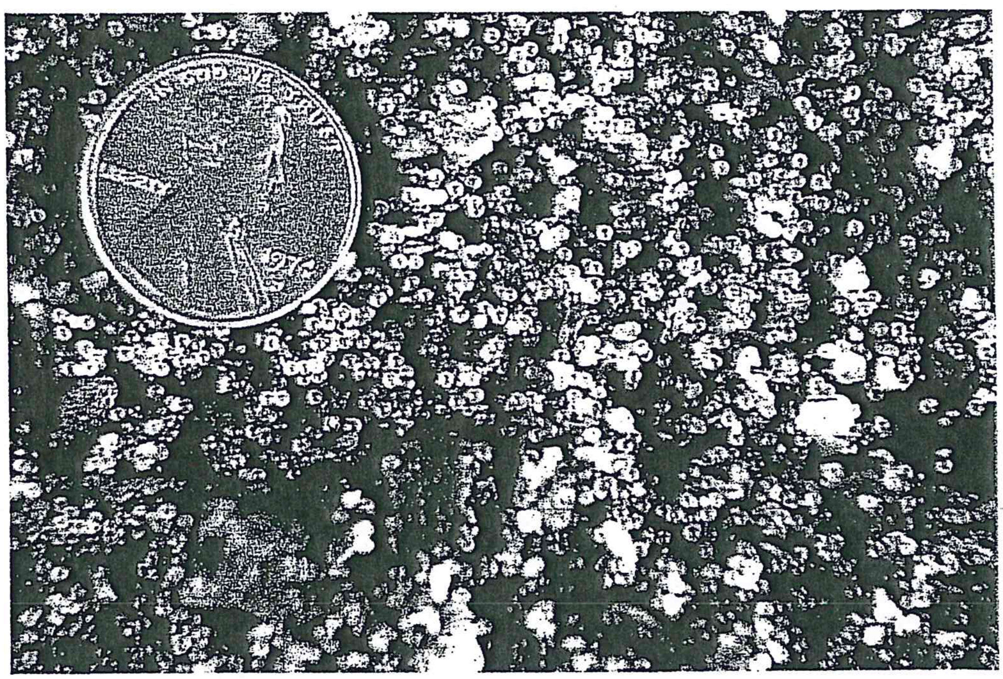
a. Pocket beach west of Blind Bay on Shaw Island, surf smelt spawning area.

b. Mud Bay, Lopez Island, surf smelt spawning area.

Figure 7. Examples of surf smelt spawning beaches in San Juan County (photos by D. Penttila, WDFW).



a. Surf smelt eggs - 2 eggs are on the large black stone at the tip of the forceps. Eggs are approximately 1 mm in diameter (photo by L. Moulton).



b. Heavy deposition of surf smelt eggs *in situ* (photo by D. Penttila, WDFW).

Figure 8. Examples of surf smelt eggs in field conditions.

last high tide	
time	elevation

second effective high tide	
time	elevation

Island

day	month	year

SJC Forage Fish Spawning Surveys

Page ____ of ____

Reviewed By:____________________

Beach Number	Sample Number	Time	latitude			longitude			beach	uplands	sample zone	land mark	tidal elevation	smelt	sand lance	rock sole	herring	width	length	shading	comments
			°	'	"	°	'	"													

Samplers:____

Figure 9. Field data form used to record data associated with surf smelt and Pacific sand lance bulk sampling.

a. Obtaining beach subsample to examine for eggs.

b. Adding subsample to composited sample in bag.

Figure 10. Sampling mixed sand/gravel beach for surf smelt and Pacific sand lance eggs (photos by L. Moulton).

San Juan County MRC
FORAGE FISH PROJECT

SAMPLE NO:
FFP-000 1

DATE: __________ TIME: __________

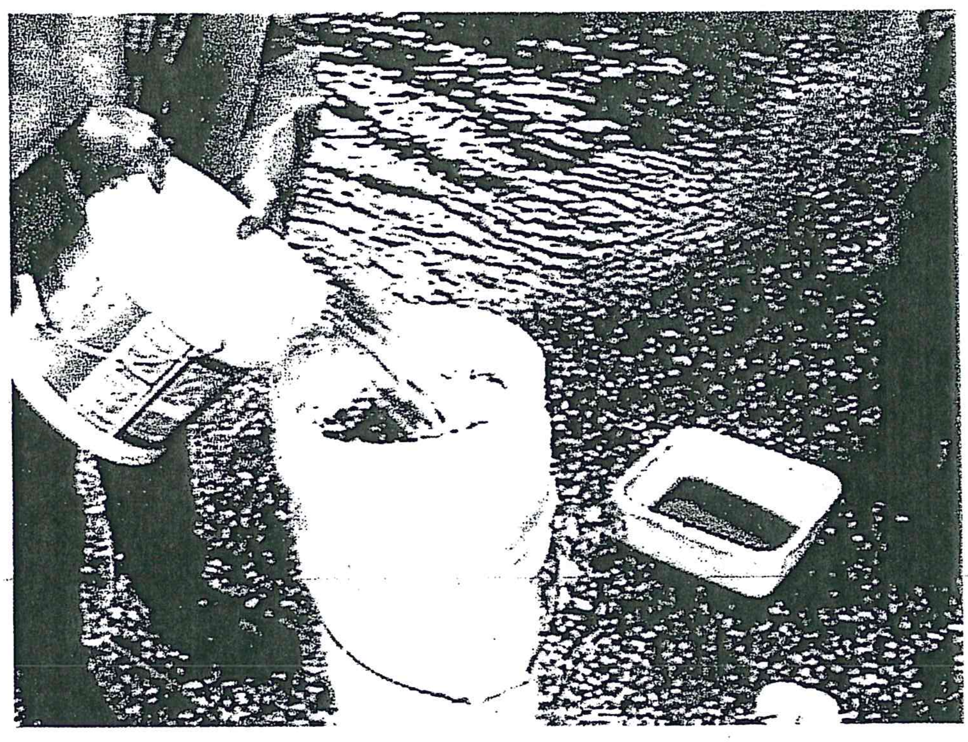
BEACH NO: ____________________

SAMPLER: ____________________

Figure 11. Label used to identify each bulk sample

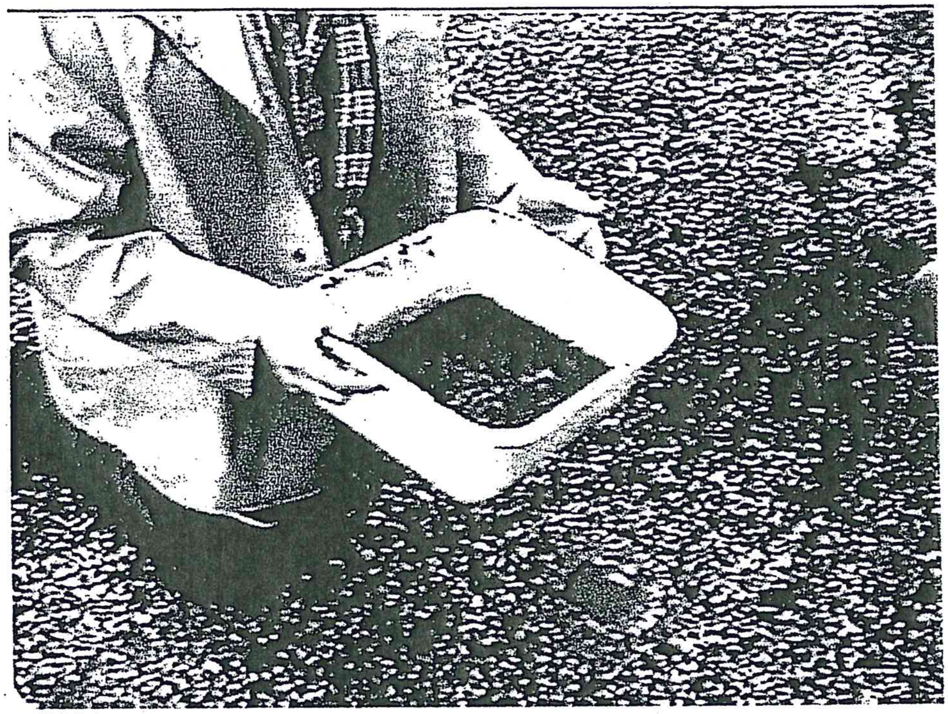
6'

a. Standardized screens (4 mm, 2 mm, and 0.5 mm) are used to remove excess large material from the sample.



b. Sample is washed carefully to ensure eggs are removed from the large gravels and are deposited in the smallest material.

Figure 12. Screening bulk sediment sample to separate egg-bearing sediments from larger material (photos by L. Moulton).



a. Pan is swirled to separate eggs from sediment.

b. Lighter fraction of egg-bearing sediment is collected in a sample jar.

Figure 13. Winnowing bulk sediment sample to separate egg-bearing sediment from barren sand (photos by L. Moulton).

SJC Forage Fish Spawn Sample Analysis

Page _____ of _____

Recorder____________________

Island	month	day	year

Beach Number	Sample Number	species	1 cell to morula	blastula	gastrula	1/2-1 coil	1 coil	11/2 coil	>11/2 coil	late eyed	dead	# eggs	% dead	est. # broods	wt. substrate	eggs/ gram	remarks

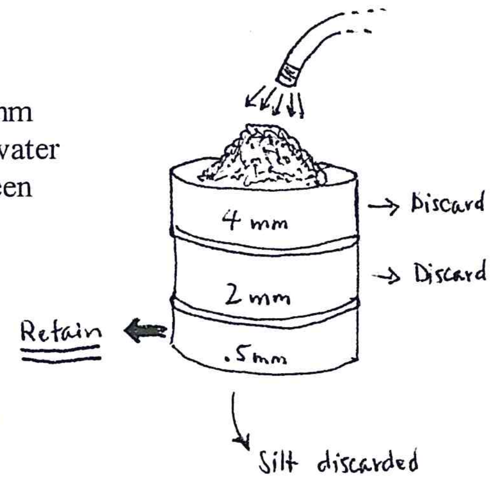
Figure 14. Lab data form used to record data associated with surf smelt and Pacific sand lance bulk sampling.

WDFW Forage Fish Spawning Habitat Survey Protocols:

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

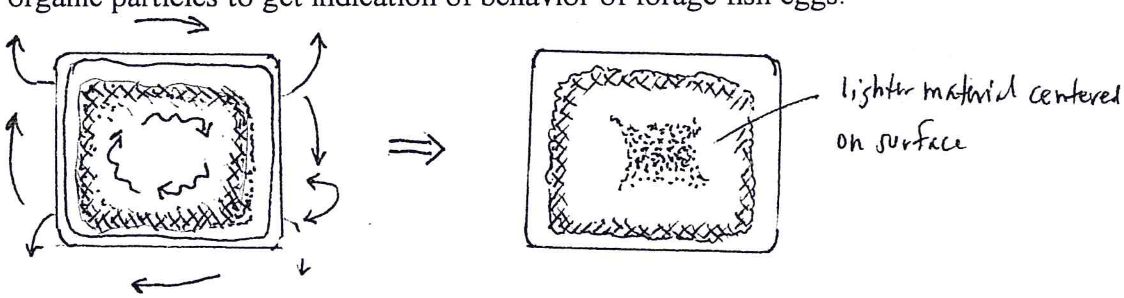
1. Wet-screen material through set of nested 4 mm/2 mm/.5 mm screens, using buckets of shore-side water at site or fresh-water hose elsewhere. Screens should be carefully cleaned between samples

2. Discard material retained in 4 mm and 2 mm screens.

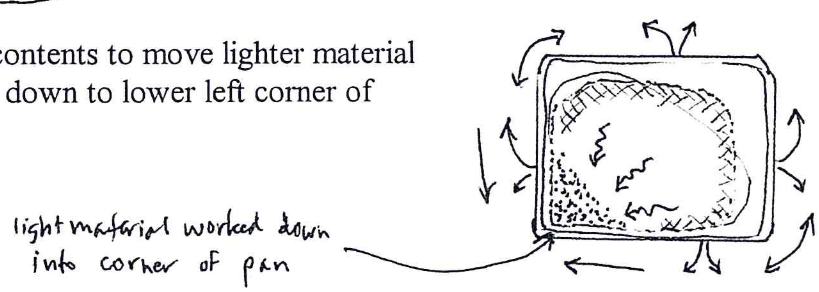


3. Place material from .5 mm screen ("egg-sized material") in rectangular dish-pan, and cover with 1 inch of water.

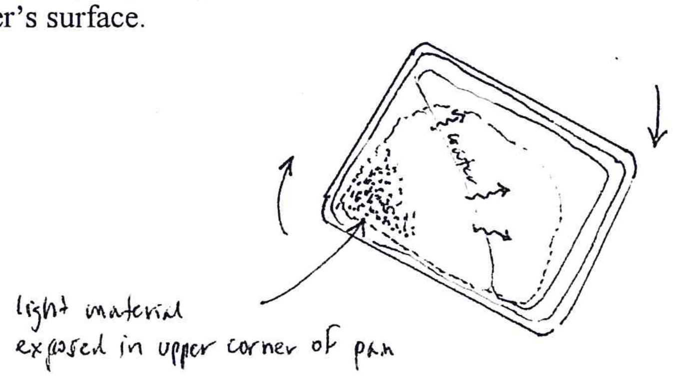
4. Rotate/tilt/yaw dish-pan of material to impart rotation to water, and cause lighter material to rise to surface and accumulate toward center of deposit in pan. Observe behavior of shell fragments and organic particles to get indication of behavior of forage fish eggs.



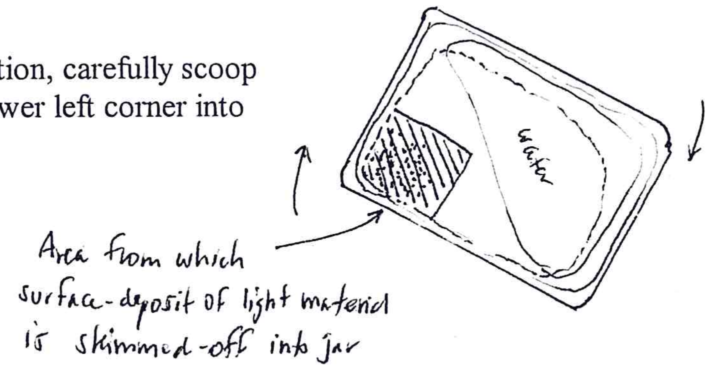
5. Tilt/swirl/agitate pan contents to move lighter material accumulated at center down to lower left corner of pan deposit.



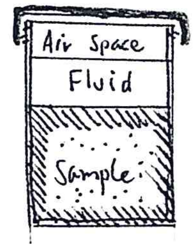
6. Carefully tilt pan to decant water to opposite corner of pan, slowly exposing lower left corner material above water's surface.



7. Holding pan in this tilted position, carefully scoop surface 1" of material from lower left corner into wide-mouth sample jar.



8. Repeat steps 4-7, about 3 more times, until sample jar is about 2/3 full of material.



9. Top- off sample jar with Stockard's Solution preservative, and shake well to distribute preservative to all material.

10. Preserved samples will emit carbon dioxide as acidic preservative dissolves shell material in the samples. Lids should be loosely-fitted initially to allow escape of gas.

11. Escaping gas will also result in preservative escaping jars. Samples should be stored in leak-proof containers, and stored in well-ventilated areas to prevent accumulation of carbon dioxide in enclosed spaces.

12. Preserved samples may be archived for 10+ years without loss of data.

Bulk substrate sample processing materials:

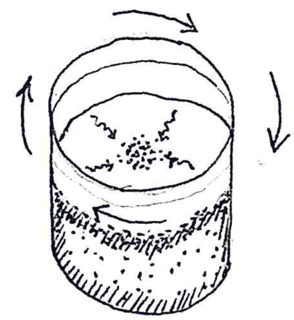
Nested set of 4 mm/2 mm/.5 mm screens (Nalgene preferred over brass which bends/distorts over time)
buckets for discarded gravel
1-2 gallon plastic dish-pans
400 ml wide-mouth sample jars
Stockard's Solution preservative (one gallon will preserve about 30 winnowed-light-fraction samples
freshwater hose work-area with sufficient drainage
area to discard waste gravel

WDFW Forage Fish Spawning Habitat Survey Protocols:

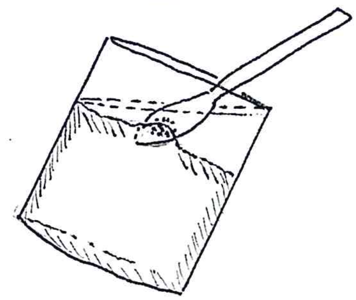
Laboratory procedures for recovering forage fish eggs from preserved "winnowed light fractions"(screened beach substrate subsamples).

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 material in jar.

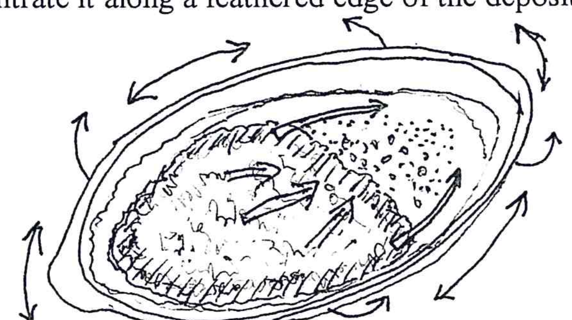


3. Carefully tilt jar, slowly scoop center-mound of light material with spoon into oval microscope dish.

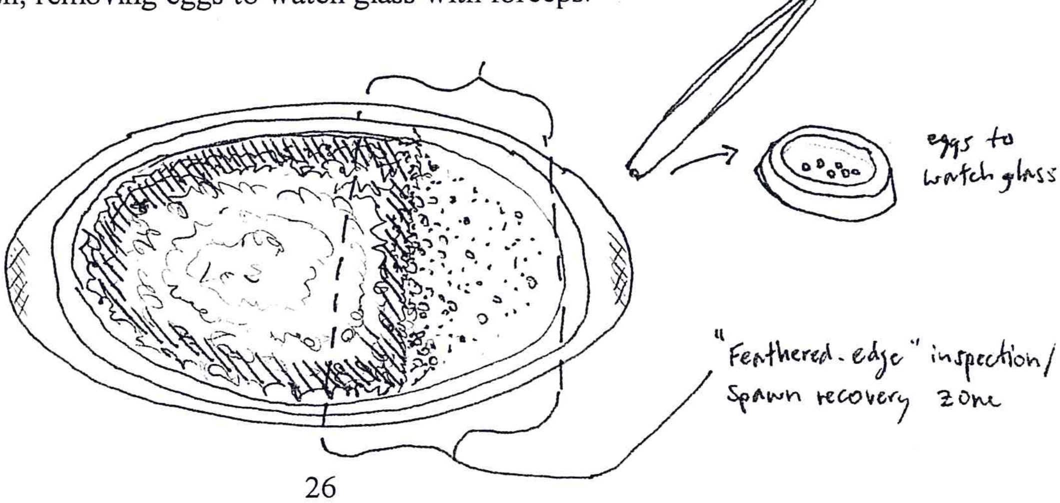


4. Repeat steps 1-3 four times, accumulating about 400 grams of light material in microscope dish.

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



6. Carefully place dish on microscope stage, inspecting zone around feathered edge of deposit of material in dish, removing eggs to watch glass with forceps.



7. Reverse dish, repeat steps 5-6 three times or until eggs cease to be detected around feathered-edge of deposit of material in dish.

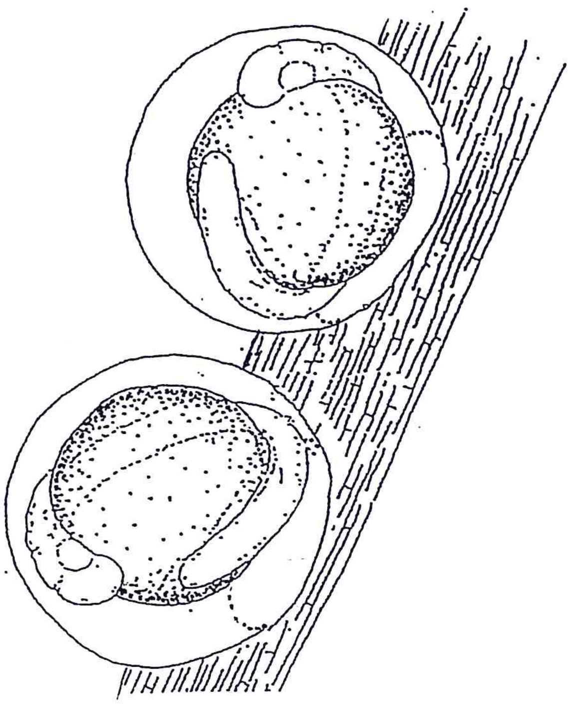
8. If single egg is recovered in steps 1-7, repeat with second sample of material from jar of winnowed light fraction.

9. Identify eggs accumulated in watch-glass, count and/or record number of eggs in each embryological-stage category on data sheet

Lab materials:

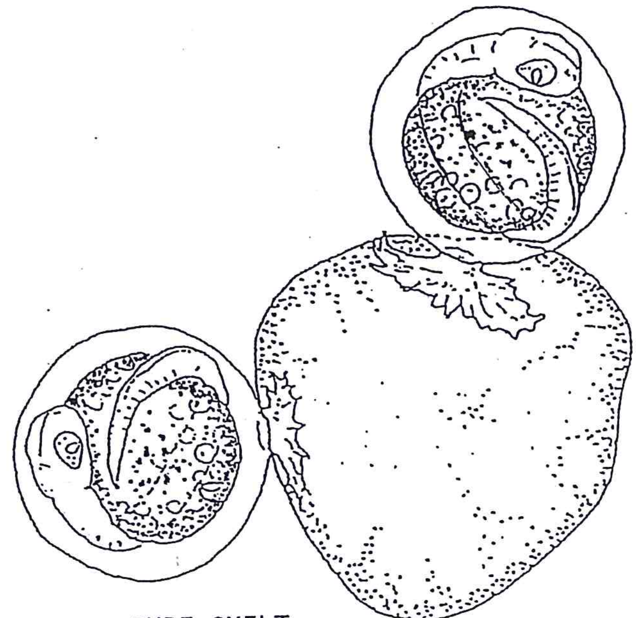
Fume hood (alternatively, carefully rinse preservative from winnowed light fraction samples before processing).
Paper-towels
lab-gloves (keeps preservatives off skin)
Microscope with 10-20X
buckets/pans (to catch drips, accumulate completed samples, etc.)
Oval microscope dish
watch-glasses/small petri dishes
fine-point (watchmakers) forceps
table-spoon
tally sheets/multi-place counter

1 mm



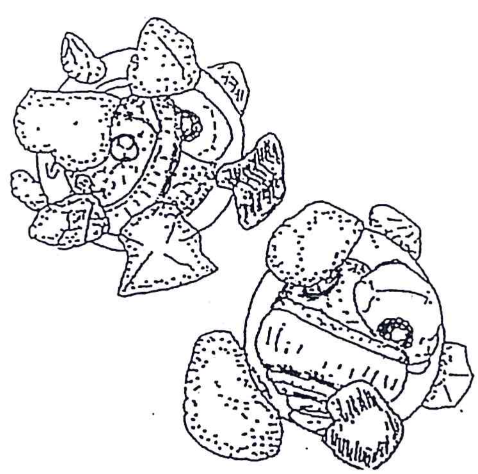
PACIFIC HERRING

almost entirely deposited on marine vegetation; distinct shell attachment sites; self-adhesive in layers or clumps.



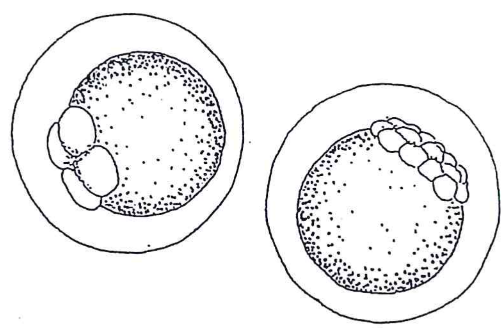
SURF SMELT

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

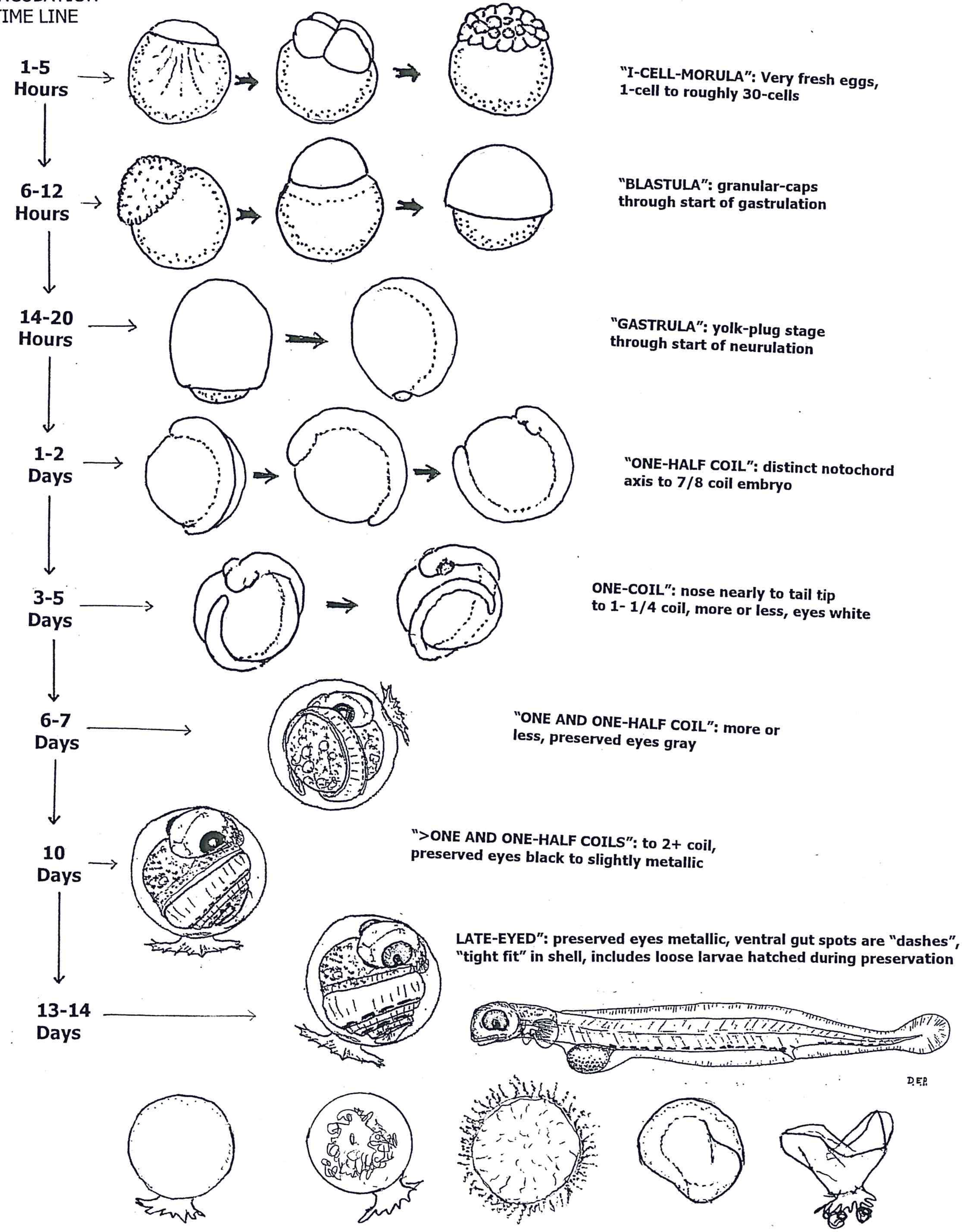
egg perfectly spherical; very clear; no visible attachment sites; non-self-adhesive.

D.E.P.

CHARACTERISTICS OF THE EGGS OF FOUR SPECIES OF INTERTIDAL-SPAWNING MARINE FISHES FROM THE PUGET SOUND BASIN.

WDFW SURF SMELT EMBRYOLOGICAL-STAGE CATEGORIES

TWO-WEEK
SUMMER
INCUBATION
TIME LINE



"DEAD": opaque-white/without discernable embryo/ fungus-covered eggs/ collapsed egg-shells/ empty egg-shells

"NON-FORAGE FISH EGG-LIKE" OBJECTS ENCOUNTERED IN PUGET SOUND BEACH SUBSTRATE SAMPLES

These objects may be mis-identified as forage fish eggs with the naked eye, but can be easily distinguished from them under microscopic examination.

Gromia protozoan: benthic protozoan with 1-4 mm spherical , soft shell, contents granular and brown in color, no attachment sites.

Worm? egg cases: wrinkled-ovoid, 1 mm in length, purple/brown transparent in color, filled with round eggs or oval larvae, may have sand grains attached, could be mistaken for sand lance egg shells when empty.

Sand-covered beach worms: a 1-2 cm annelid, plain in form and white in color, is common in gravel beaches; when disturbed, they may coil-up tightly and secrete mucus, collecting coats of sand grains and thus resembling sand lance eggs to the naked eye.

Annelid sand-tube fragments: irregular fragments or sections of chitinous worm tubes with sand grains attached, could be confused with sand lance eggs.

Coiled-up flatworms: a 2-4 mm white flatworm may be common on Hood Canal beaches: when disturbed, it may coil-up into a globular shape resembling a loose, dead smelt egg to the naked eye.

Plant seeds/flower parts: a variety of shore-zone plant seeds and miscellaneous parts find their way onto the beach, none closely resemble forage fish eggs under a scope.

Conifer pitch droplets: often perfectly spherical, variable in size, clear to red-brown in color, no embryo-like internal structure, either deform un-elastically or shatter into fragments when forcepped.

Algal fruiting bodies and fragments: certain red algae shed fragments, ovoid-roundish in shape, variable in size, pink/green in color, no embryo-like internal structure under scope.

Coiled-up sphaeromiid isopods: can common on estuarine beaches, juveniles can be 1-2 mm in diameter when tightly coiled, gray in color, obviously a segmented arthropod under a scope.

Ostracods: 1-2 mm ovoid crustaceans with "bivalved" carapaces, light-brown in color, a central eye-spot and swimming legs are distinguishable under a scope.

Mites: 2-3 mm arachnids, light brown in color, body segmentation and walking legs obvious under a scope.

Assiminia snails: a globular gastropod, 1-3 mm in size, common in upper intertidal gravel. The decalcified protein "ghost" of the shell with the coiled animal, can be distinguished from fish eggs under a scope.

Lacuna snail egg masses: 1-3 mm hemispherical jelly masses, white to yellow in color, commonly clustered at tips of eelgrass blades and other marine vegetation: distinguished from herring eggs by shape, texture, and presence of large numbers of tiny eggs imbedded in them under magnification.

Slag pellets/agates: Some eroding rock formations will yield tiny spherical translucent-quartz inclusions onto beaches; beaches in the area of old mills may have spherical slag-droplets formed when burning material was dumped into the water, obviously neither will deform when forcepped.

Carbonized spheres: spherical solid objects of unknown origin, flat-black in color, no internal structure, shatter to fragments when forcepped.

Invertebrate? fecal pellets: variety of ovoid/cylindrical brown objects, shatter to earthy fragments when forcepped.

"Non-forage" marine fish eggs: a few other marine fish species deposit benthic adhesive eggs on marine vegetation and other solid surfaces in the near-shore zone. While they may not be identifiable to species themselves, all are distinguishable from forage fish eggs by density or area of total deposit, size, color, embryo structure, or occurrence context.

Dan Penttila
WDFW Habitat Program
LaConner

APPENDIX D

Washington Department of FISH and WILDLIFE

Washington Department of Fish and Wildlife
Marine Resources Division
LaConner, Washington 98257

SURVEYS FOR SURF SMELT AND SAND LANCE SPAWNING HABITAT IN ISLAND COUNTY, WA, BY WDF/WDFW, 1991-1998.

PLUS:

Memos summarizing results of additional WDFW-led forage fish spawning habitat inventory surveys undertaken on the shorelines of Island County during the following periods:

June-September, 2001
November 2001-February 2002
April-September 2002
November 2002-February 2003
May – September 2003

The surf smelt, *Hypomesus pretiosus*, and Pacific sand lance , *Ammodytes hexapterus*, are common and widespread nearshore marine forage fish species in the Puget Sound basin, including the waters of Island County. These species are unique among Puget sound marine fishes in their usage of upper intertidal sand-gravel beaches upon which to deposit and incubate their eggs.

The position of these critical spawning habitats near the high water mark Sound-wide, their apparent vulnerability to a variety of shoreline development activities, and these species' importance in the local marine food webs led the Washington Department of Fisheries/Fish and Wildlife to include them in the Washington Administration Code Hydraulic Code Rules as "salt water habitats of special concern", with no-net-loss rules governing development activities on those beaches where surf smelt and/or sand lance spawn have been found. These enhanced habitat protection rules do not apply to beaches where WDFW or other bone fide spawn sampling survey effort have not found spawn, or where no sampling effort has been under taken at all by WDFW or other properly trained personnel.

Virtually the entire marine shoreline of Island County includes an upper intertidal zone comprised of the type of sand-gravel beach commonly used by spawning surf smelt and/or sand lance. Only those shorelines comprised of salt marsh/mud flat or solid rock outcrops would be unlikely to include potential surf smelt/sand lance spawning habitat.

The shorelines of Island County have been known to support spawning of surf smelt populations since "time immemorial" , and this fact was documented scientifically when the species was first studied in Puget Sound in the early 1930s. Sand lance spawning activity was first documented in Island County in 1991, shortly after the species' intertidal spawning habits became known locally.

During the 1991-1998 period, WDF/WDFW marine resources program staff undertook a systematic survey, the "Intertidal Baitfish Spawning Beach Survey Project" (IBSBSP), of sand-gravel beaches throughout the Puget Sound basin in an attempt to map all existing surf smelt and sand lance spawning beaches, for purposes of documenting them and protecting them from inadvertent loss through shoreline development. During the course of that time, a considerable amount of beach survey effort was undertaken within Island County.

A total of over 1,100 beach survey stations were undertaken on Island County's beaches. These sampling stations were generally comprised of the collection of a single 10-pound sample of upper intertidal beach substrate, which was process and analyzed for the presence, relative density and age distribution of any surf smelt and sand lance spawn present. During the course of these surveys, many miles of previously unknown surf smelt and sand lance spawning habitat were discovered.

It was the intent of the IBSBSP to place sampling stations at at least one-quarter-mile intervals along the shoreline during the probable local forage fish spawning seasons, in an attempt to document all existing spawning sites. Figures 1-4 illustrate the cumulative distribution of all sampling sites undertaken on Island County shorelines. As can be seen on the charts, not all Island County shorelines were adequately sampled by IBSBSP, which lost the funding support of WDFW in mid-1997. A considerable percentage of the beaches of Island County either received only 1-2 sampling surveys or none at all. It is presumed from the distribution of spawning sites that were in fact documented by the IBSBSP that significant additional spawning sites exist on the County's shorelines. Lack of knowledge of their existence precludes application of the Hydraulic Code rules' enhanced protection measures during the course of HPA applications on those shorelines.

Island County forage fish spawning habitat survey effort is complicated by the fact that the beaches are used most of the calendar year by one species or the other. The attached figures illustrate IBSBSP sampling effort separated into the "summer", April-September, at which time summer-spawning surf smelt are frequenting beaches throughout the County, and "winter" months, October through March, during which time the summer smelt spawning season winds down and the sand lance spawning season (November-February) occurs.

During both seasonal periods, large gaps exist in the previous WDFW spawning habitat survey coverage within island County. Any proposal to close these data gaps would afford additional habitat protection to these marine forage fish species that form an integral part of the diets of ESA-listed salmonids in the Puget Sound basin.

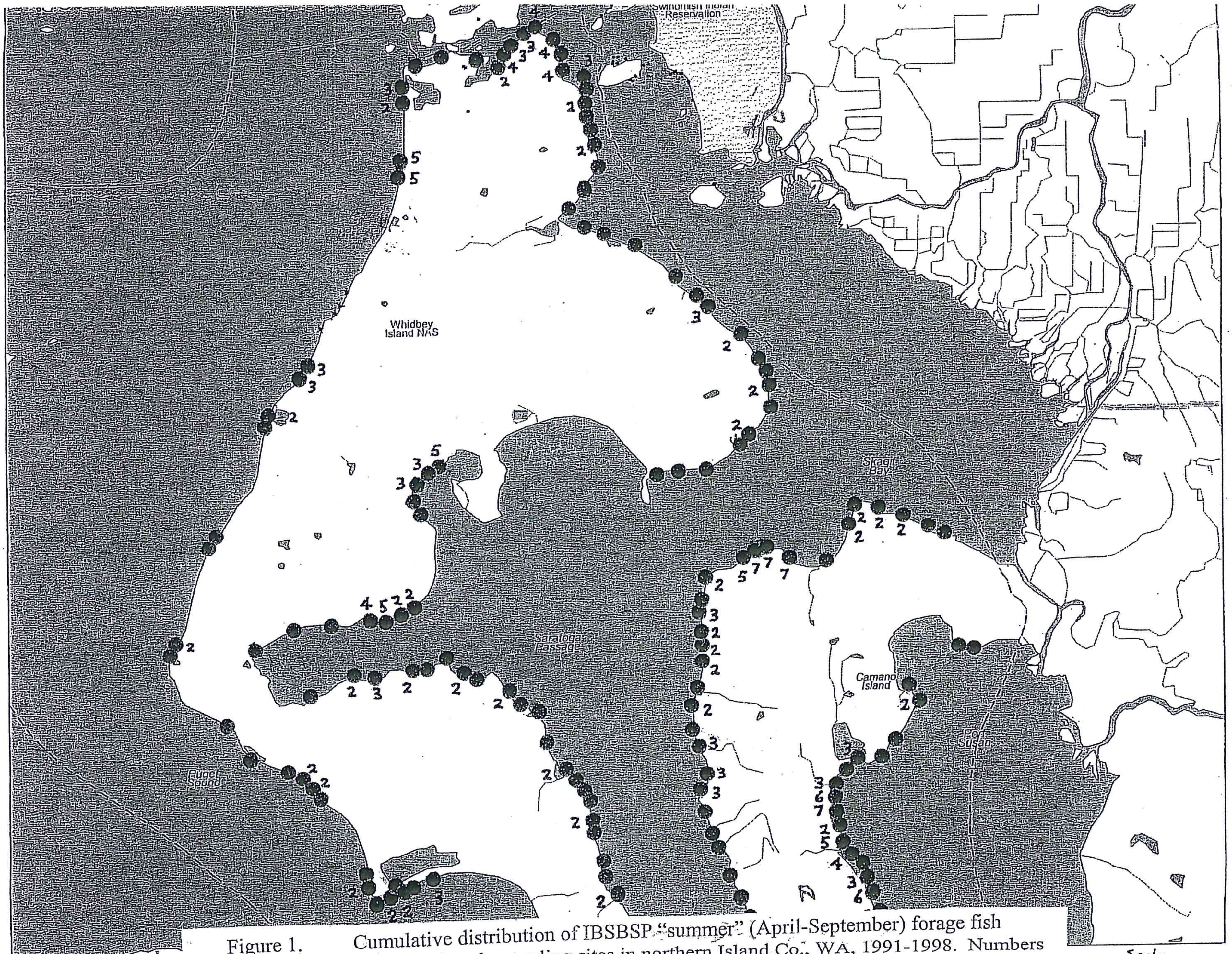


Figure 1. Cumulative distribution of IBSBSP "summer" (April-September) forage fish spawning beach sampling sites in northern Island Co., WA, 1991-1998. Numbers beside dots indicate the number of stations undertaken within the quarter-mile of shoreline occupied by the symbol.

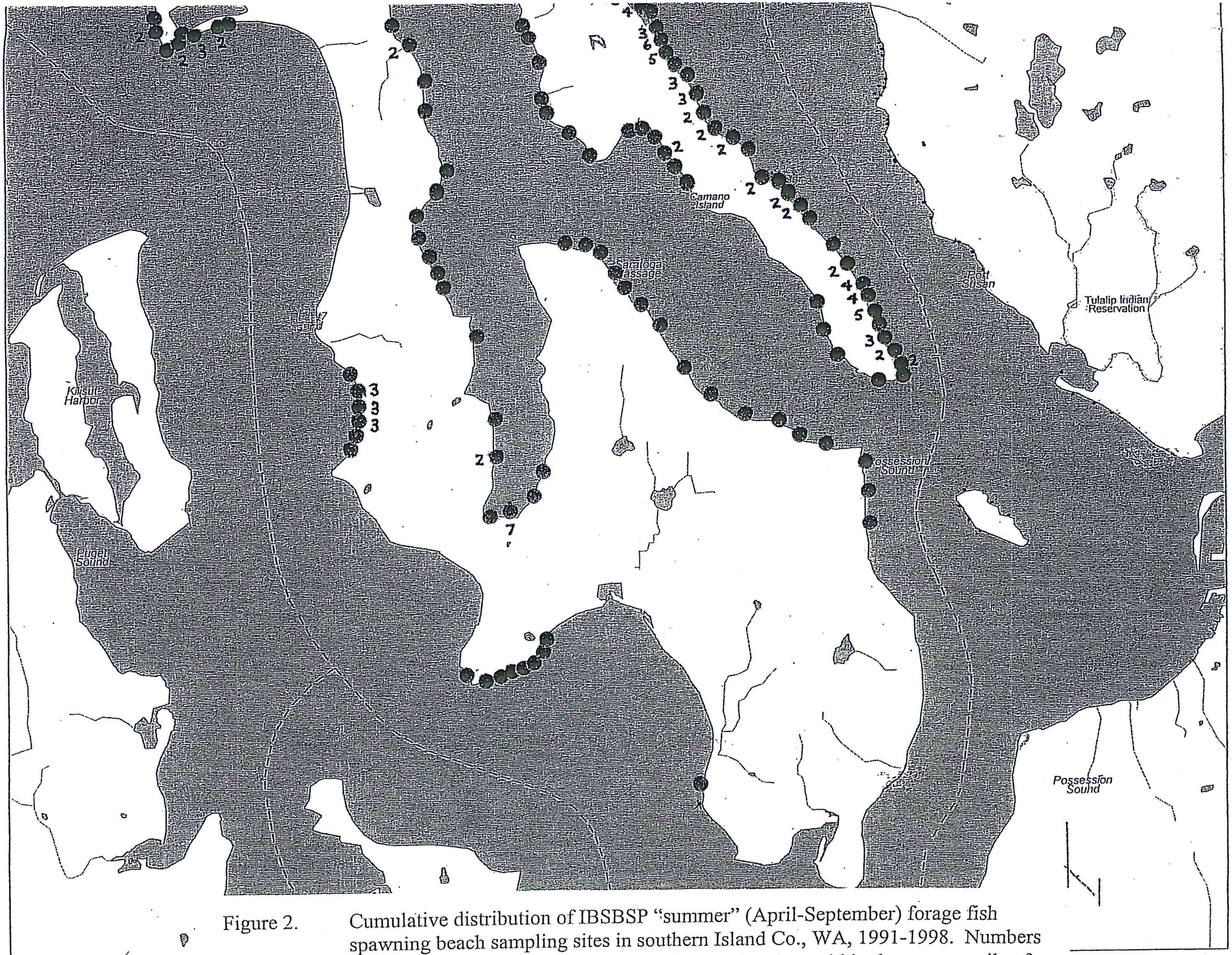


Figure 2. Cumulative distribution of IBSBSP "summer" (April-September) forage fish spawning beach sampling sites in southern Island Co., WA, 1991-1998. Numbers beside dots indicate the number of stations undertaken within the quarter-mile of shoreline occupied by the symbol.

Scale
1 cm = 1 mile

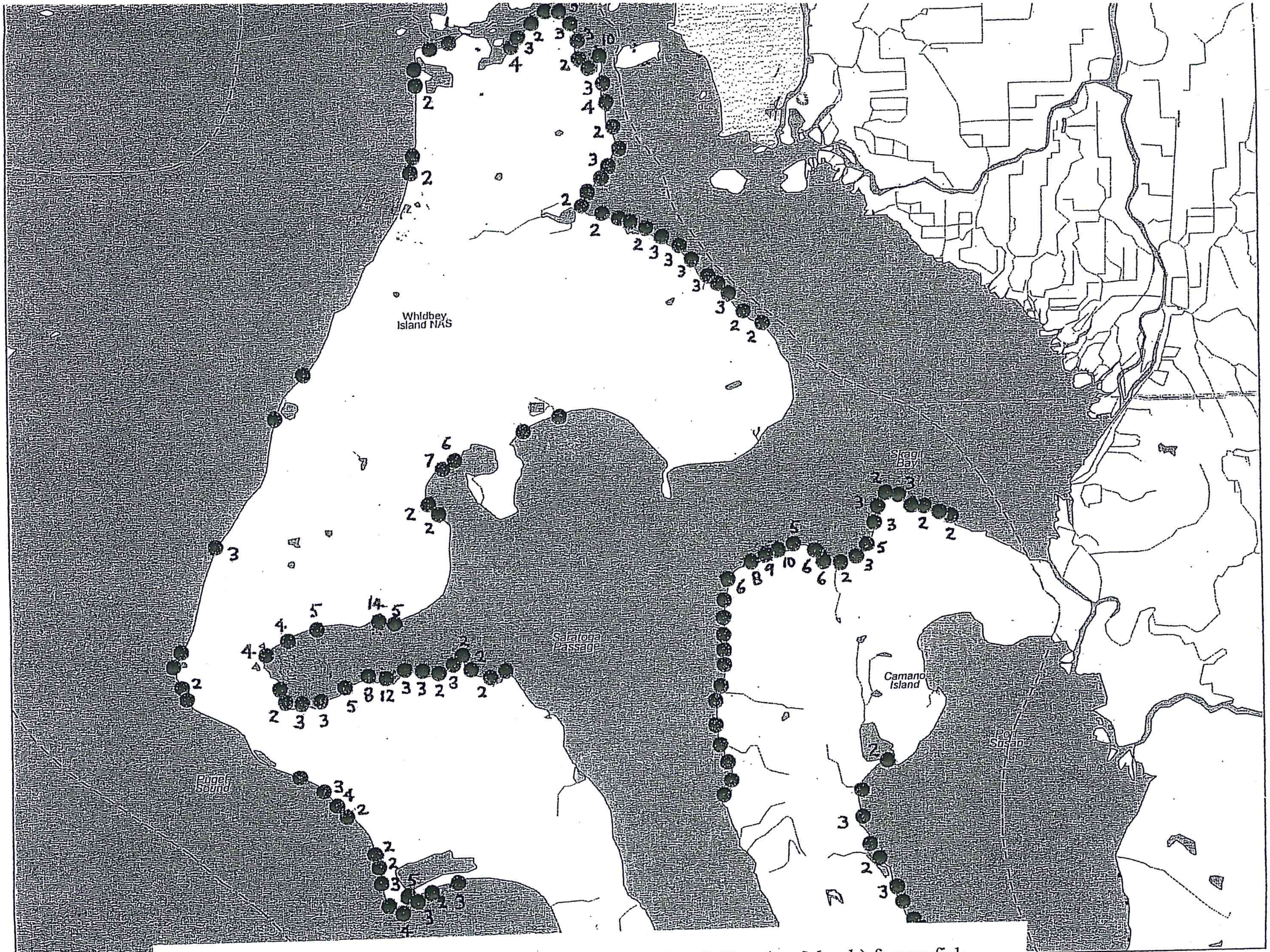


Figure 3. Cumulative distribution of IBSBSP "winter" (October-March) forage fish spawning beach sampling sites in northern Island Co., WA., 1991-1998. Numbers beside dots indicate the number of stations undertaken within the quarter-mile of shoreline occupied by the symbol.

Scale
1cm = 1mile

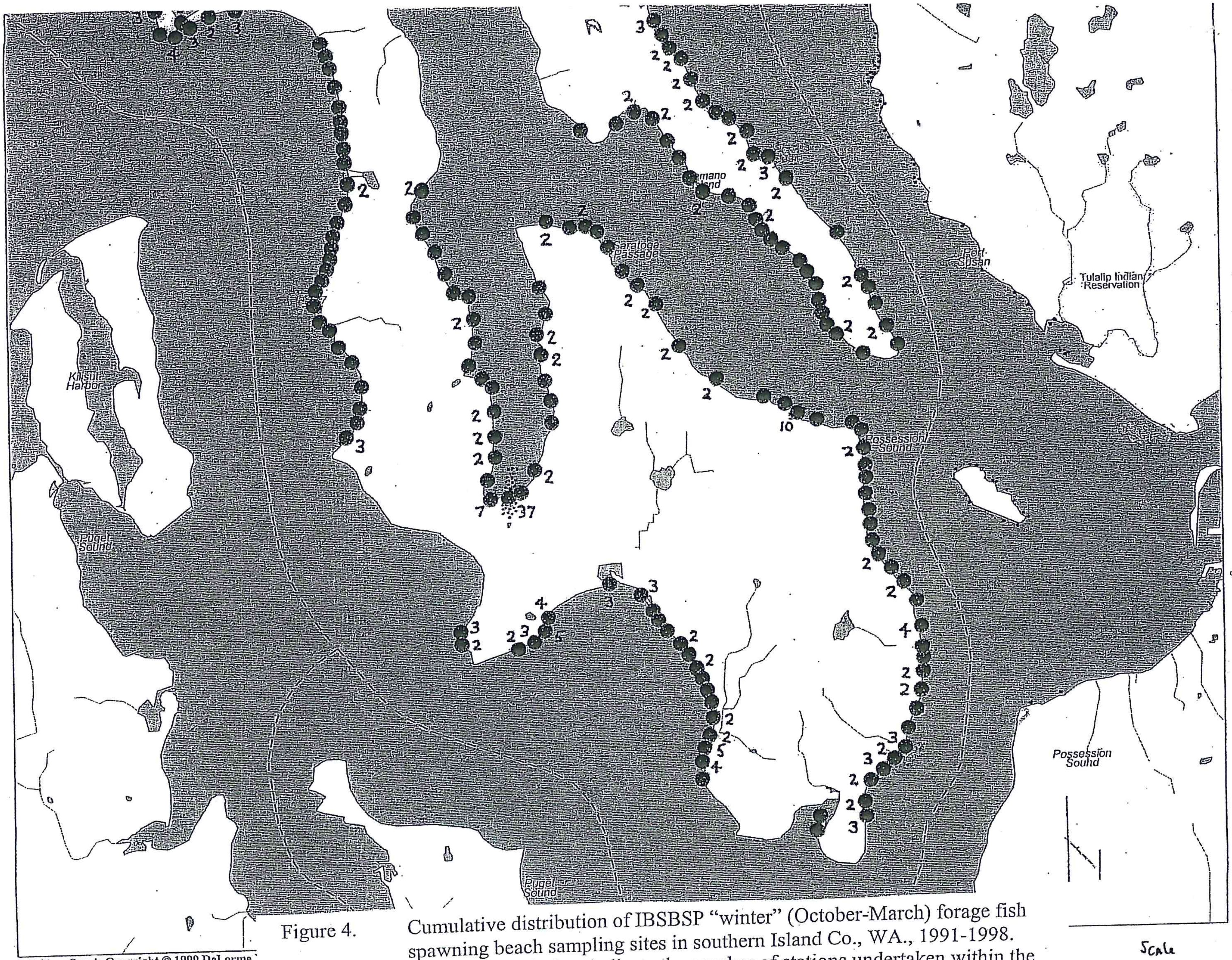


Figure 4. Cumulative distribution of IBSBSP "winter" (October-March) forage fish spawning beach sampling sites in southern Island Co., WA., 1991-1998. Numbers beside dots indicate the number of stations undertaken within the quarter-mile of shoreline occupied by the symbol.

State of Washington
DEPARTMENT OF FISH AND WILDLIFE
P.O. Box 1100 • 111 Sherman Street • La Conner, WA 98257-1100
(360)466-4345 • Fax: (360)466-0515

DATE: October 10, 2001

TO: Island County MRC

FROM: Dan Penttila DEP.

SUBJECT: SUMMARY OF RESULTS, FORAGE FISH SPAWNING BEACH SURVEY PROJECT, JUNE-SEPTEMBER 2001

Following is a summary of survey results from the June-September 2001 "summer" surf smelt spawning habitat surveys undertaken cooperatively by WDFW and local volunteers, under the auspices of the Island Co. MRC forage fish survey project. Incorporating data derived from the lab analyses of all Island County survey sample material archived from the summer 2001 survey period, this report supercedes my September 11, 2001 memo summarizing preliminary results.

Survey Effort:

Fifteen field surveys:
- Four surveys conducted on-foot from land access points
- Eleven surveys conducted by boat, requiring 9 volunteer days

332 beach substrate sampling stations undertaken
- 70 sample stations (21.1%) yielded evidence of surf smelt spawn

(See Figures 1 and 2 for areal coverage)

Survey Results:

8.1 lineal statute miles of newly-documented surf smelt spawning beach
- *15,000 feet in the Onamac Point-Camano I. St. Pk. sector
- *19,500 feet in the southwestern Camano Island sector

*smaller sites at Elger Bay, west and north Crescent Hbr., Blowers Bluff, W. Penn Cove, Lona Beach, and north and south of Swantown
* smelt spawning confirmed on N. Crescent Harbor, not surveyed since 1930s

(See Figure 3 for old and new smelt spawning sites in Island County)

Sites of Interest:

The sites below were encountered during the course of the field surveys, and offer some potential for acquisition an/or habitat restoration for the benefit of public recreation and forage fish habitat conservation.

* NE Penn Cove: acquire heavily-used sand lance spawning beach/wetland west of Monroe's Landing Co. Pk. for habitat and public recreation.

* W. Penn Cove WDFW property site: removal of derelict bulkhead, restoring full extent of surf smelt spawning habitat.

* Inner Oak Harbor: reconstruct degraded beach west of marina to forage fish spawning habitat and public recreation.

* N. Powell Road access: acquire/protect undeveloped dune-swale habitat/public recreation site.

* Race Lagoon Spit: acquire intact spit/berm/lagoon /marsh system for habitat and public recreation site.

* SE Penn Cove/Iron Springs: acquire/protect feeder bluff/marine riparian forest/last-best smelt beach in Penn Cove.

* Elger Bay Spit: acquire for-sale shoreline for habitat and public recreation values.

Future Work:

* Additional forage fish survey training sessions with North Olympic Salmon Coalition and Friends of the San Juans field volunteers, as requested.

* November-January, full field survey schedule of sand lance spawning habitat surveys.

DEP

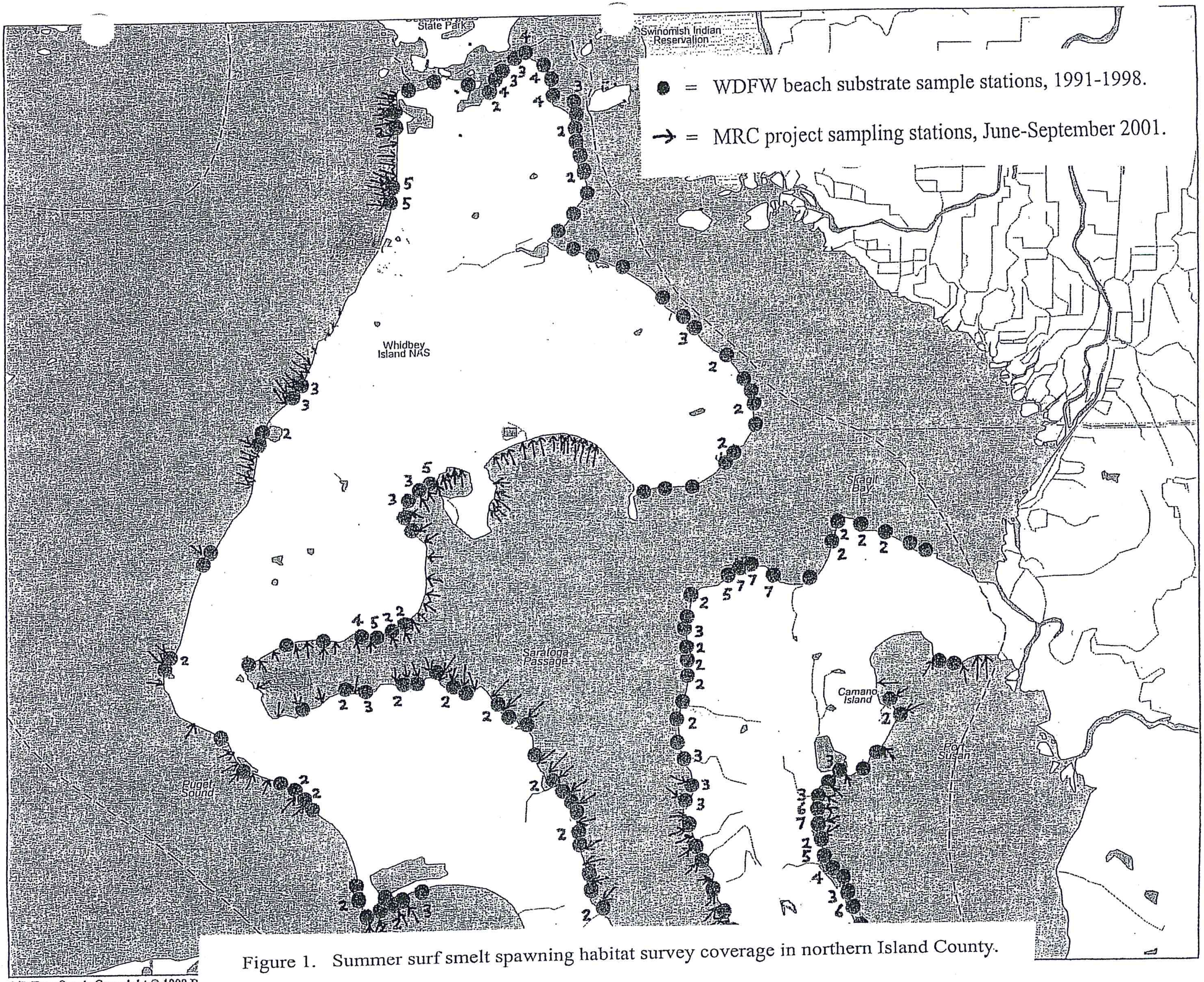


Figure 1. Summer surf smelt spawning habitat survey coverage in northern Island County.

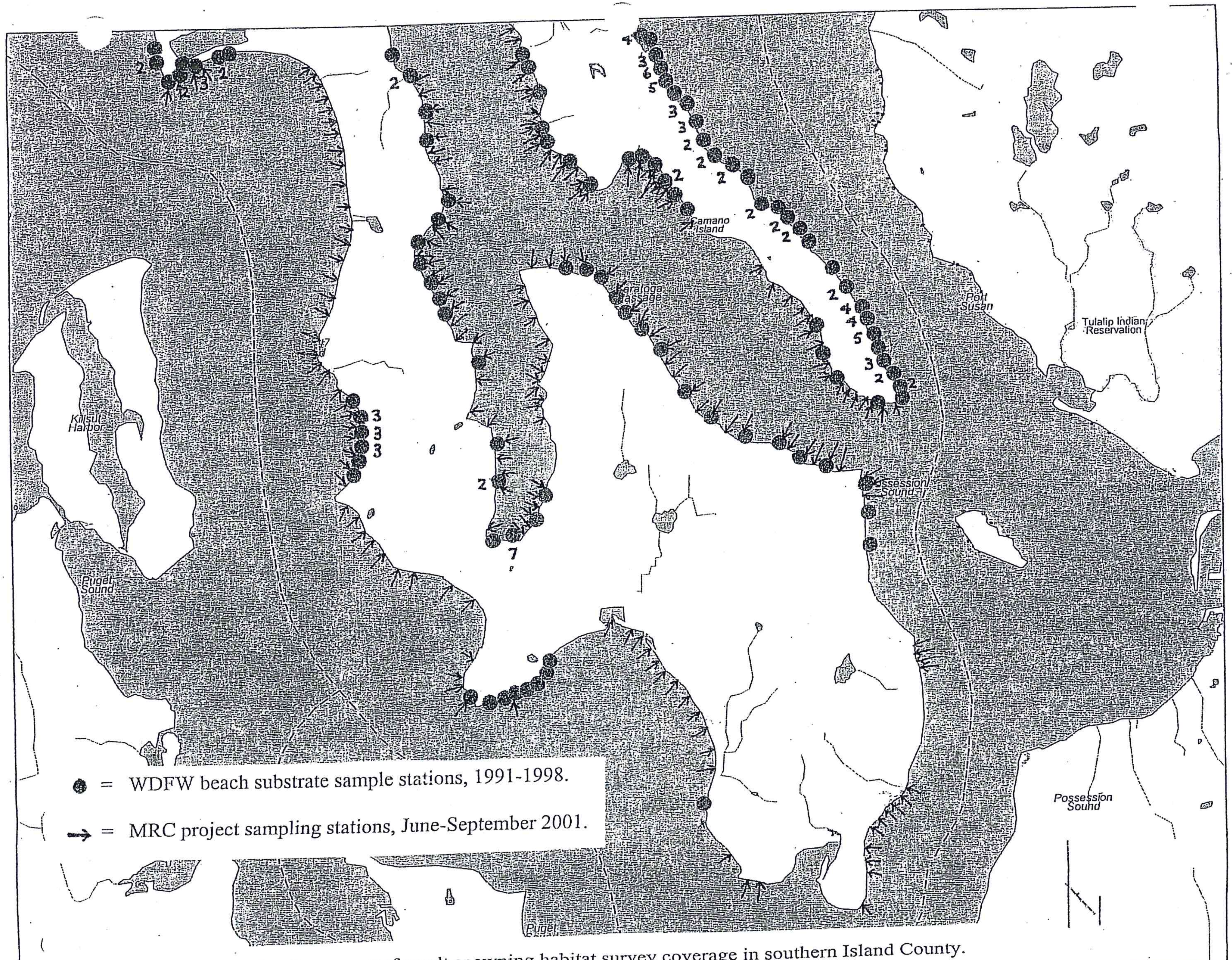


Figure 2. Summer surf smelt spawning habitat survey coverage in southern Island County.

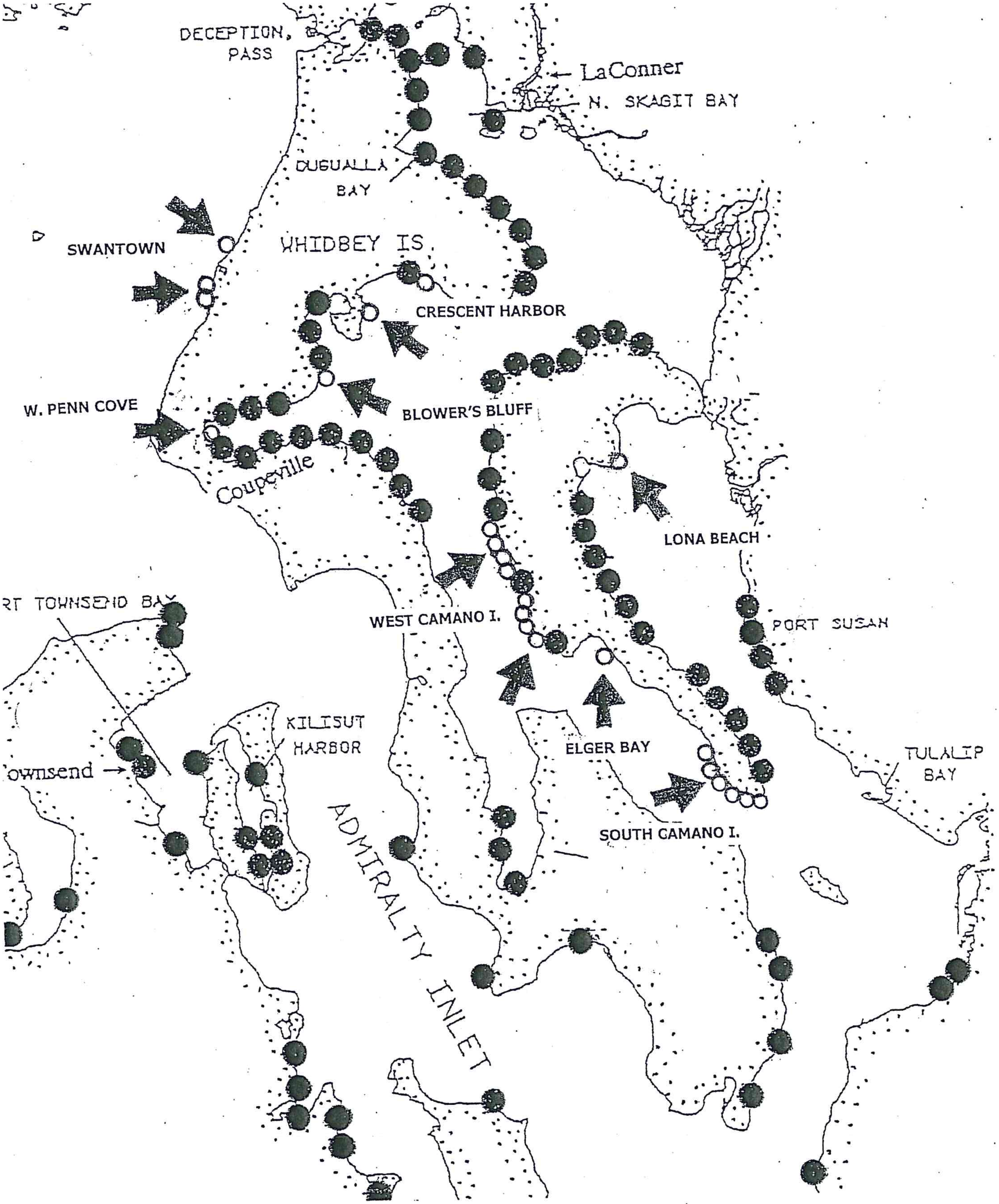


Figure 3. Documented surf smelt spawning beaches in the Island County region.

● = Documented by WDFW, 1972-1998.

➡ ○ = Newly documented by MRC surveys, June-September 2001

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DEPARTMENT OF FISH AND WILDLIFE
P.O. Box 1100 • 111 Sherman Street • La Conner, WA 98257-1100
(360)466-4345 • Fax: (360)466-0515

DATE: April 17, 2002

TO: Island County Marine Resources Committee

FROM: Dan Penttila DEL

SUBJECT: SUMMARY OF RESULTS, FORAGE FISH SPAWNING BEACH SURVEY PROJECT, NOVEMBER 2001-FEBRUARY 2002.

Following is a brief summary of results of forage fish spawning habitat surveys during the "sand lance spawning season", undertaken from November 2001 through February 2002, along the shorelines of Island County.

Survey Effort:

Twenty Two Field Days:
- Eight surveys days conducted on-foot from land access points
- Fourteen boat-survey days, requiring 10 days of volunteer time and 4 days of additional WDFW staff time.

339 Beach Substrate Sampling Stations undertaken:
- 108 sample stations (32%) yielded evidence of forage fish spawn
- (See Figures 1 and 2 for areal coverage)

New Sand Lance Spawning Habitat Discoveries:

3.2 lineal statue miles of new sand lance spawning habitat found:

N. shore, Oak Harbor:	500'
S. shore, Penn Cove:	2,000'
NW Port Susan:	1,000'
N. Mutiny Bay:	1,000'
N. Greenbank:	1,600'
S. Holmes Harbor:	1,000'
E. Elger Bay:	1,000'
Langley region:	8,600'

(See Figures 3 and 4 for locations of Island County sand lance spawning habitat.)

Discussion:

Two of the on-foot survey days noted above involved field training of staff of the Friends of the San Juans and a team of students from Camosun College (Victoria, BC) regarding sand lance spawning habitats and survey techniques at well-used spawning sites in Penn Cove and Holmes Harbor. During this report period, the writer also contributed to a forage fish habitat project demonstration field trip and "media-day" on San Juan Island with Friends of the San Juans staff, delivered a forage fish presentation lecture/lab session for the public on Camano Island for the Beachwatchers, delivered forage fish spawn sample lab analysis training to staff of the Friends of the San Juans and the North Olympic Salmon Coalition for their respective projects, contributed a forage fish habitat project oral presentation and poster display for the Island County "Sound Waters" public workshop, delivered a full-day marine fish class for minorities-in-science students at the WWU's Shannon Point Marine Center, and participated in the City of Port Townsend's marine shoreline data workshop.

A surprising majority of the forage fish spawn observations made during the course of this survey season were actually of surf smelt eggs. Surf smelt spawn persisted on Island County beaches through late January. While it had been previously known that surf smelt spawning activity, primarily a May-October phenomenon in Island County, sometimes also occurred through the winter in this region, the widespread nature of winter spawning was not previously known. No new surf smelt spawning habitat sites were found during this survey season, however.

The 3.2 miles of "new" sand lance spawning beach found this season adds to the approximately 24 miles of sand lance habitat known in Island County prior to this season. In addition, sand lance spawning activity was "confirmed" on a number of local spawning beaches that had not been re-surveyed since the time of their initial discovery by WDFW staff in the 1990s.

Future Work:

A majority of the scheduled boat survey field trips in Island County this past season were curtailed in various degrees by poor weather conditions, as should be expected during this time of year. During the course of the season, new arrangements were developed for the clearing of various launch ramps for our winter use on-request by local public-works staff. Certain sectors of Island County shoreline not able to be properly surveyed this winter season, i.e. southern Camano Island, southern-most Whidbey Island, Bush Point-Mutiny Bay, Admiralty Bay, and NE Whidbey Island, will be given priority if sand lance spawning habitat surveys are able to be undertaken for a second season under the auspices of the MRC. The Crescent Harbor-Polnell Point area needs to be surveyed if arrangements can be made with USN security.

In the more immediate future, Island County surf smelt spawning habitat surveys will commence again in April, and will begin to fill in the remaining gaps in local survey coverage for that species and season.

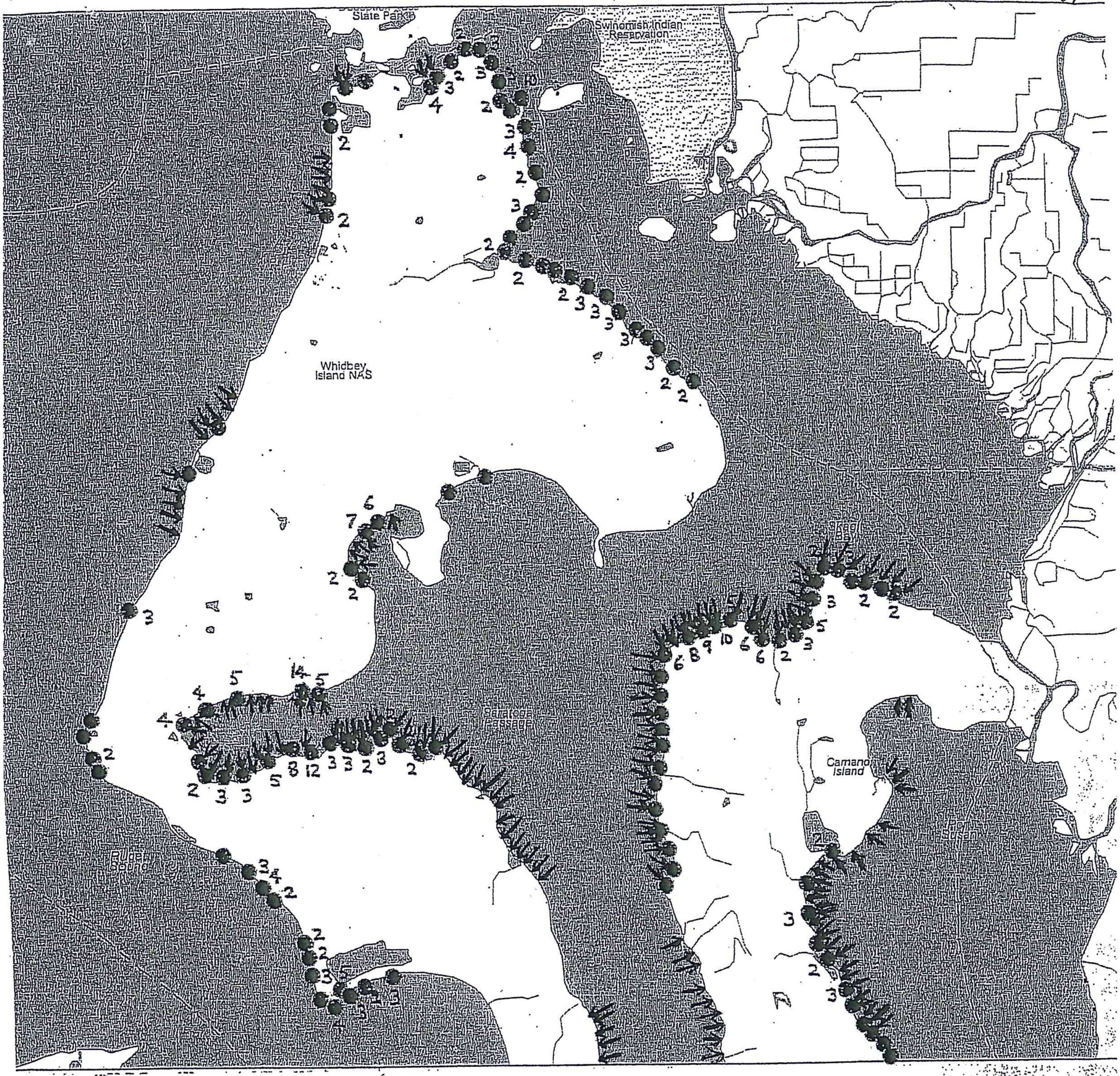


Figure 1. Cumulative distribution of winter-season forage fish spawning habitat sampling stations in northern Island County.

● ● ● = WDF/WDFW sampling stations undertaken prior to 2001

⟶ = sampling stations undertaken November 2001-February 2002

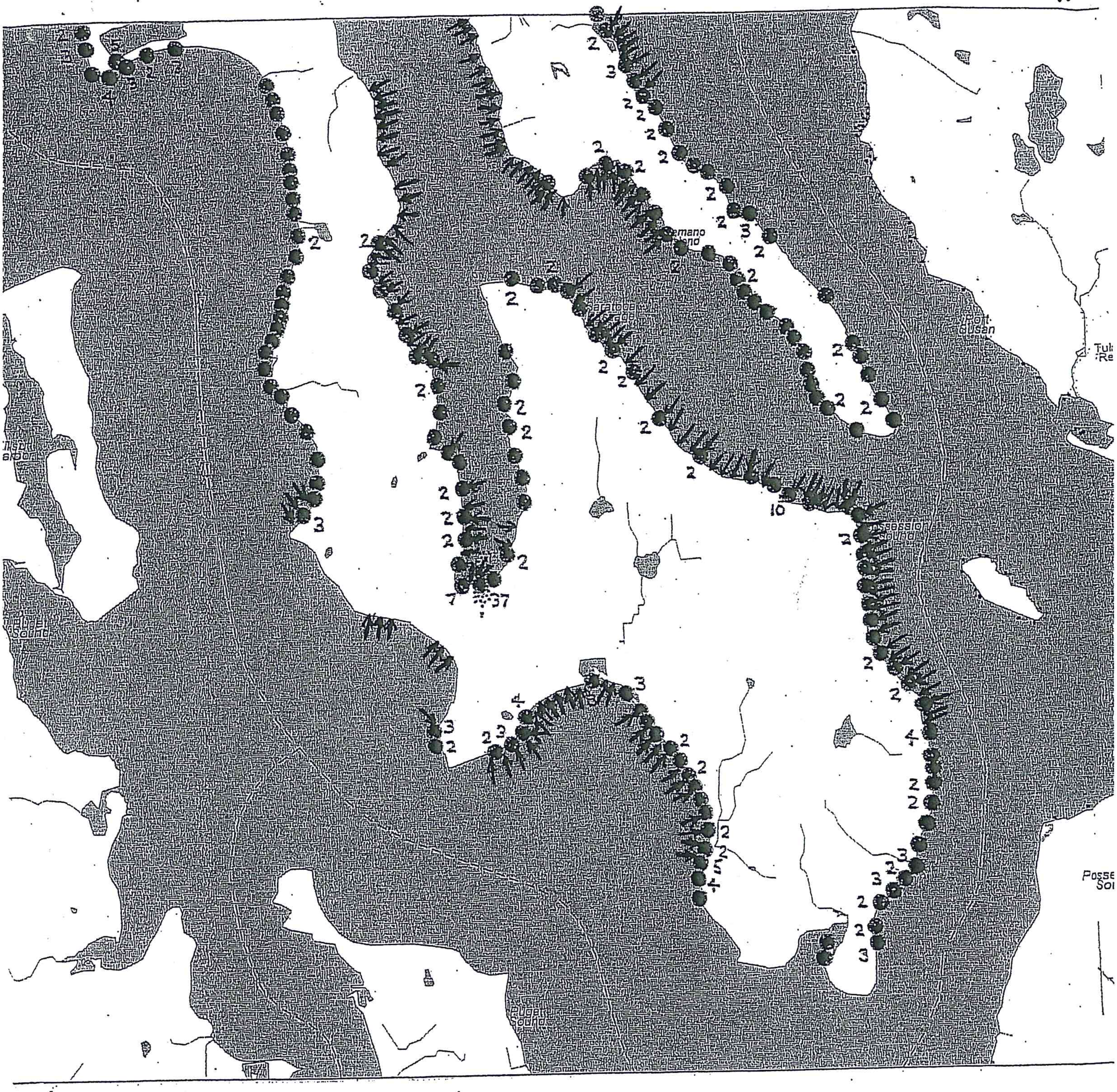


Figure 2. Cumulative distribution of winter-season forage fish spawning habitat sampling stations in southern Island County.

● ● ● = WDF/WDFW sampling stations undertaken prior to 2001

→ = sampling stations undertaken November 2001-February 2002

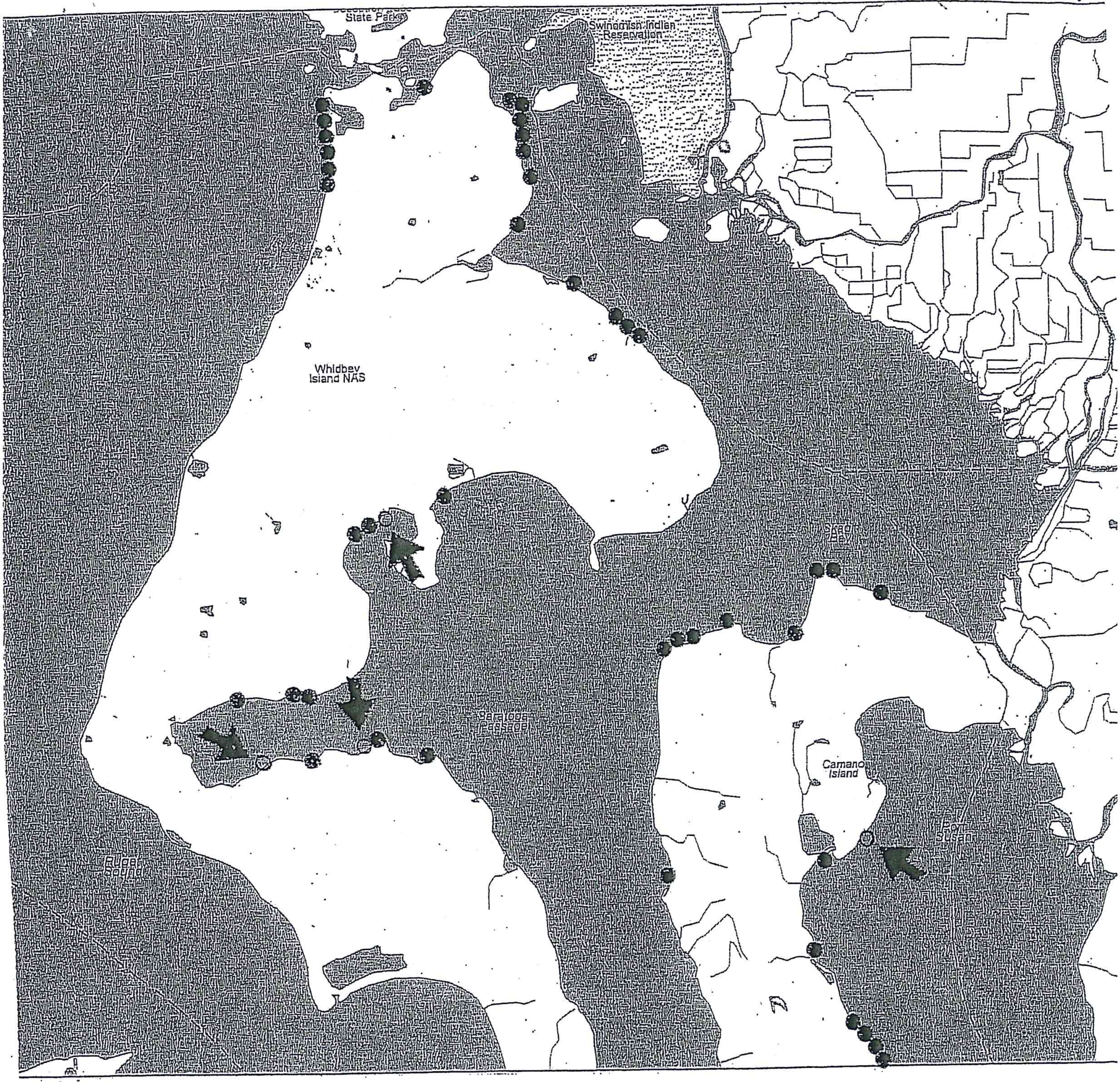
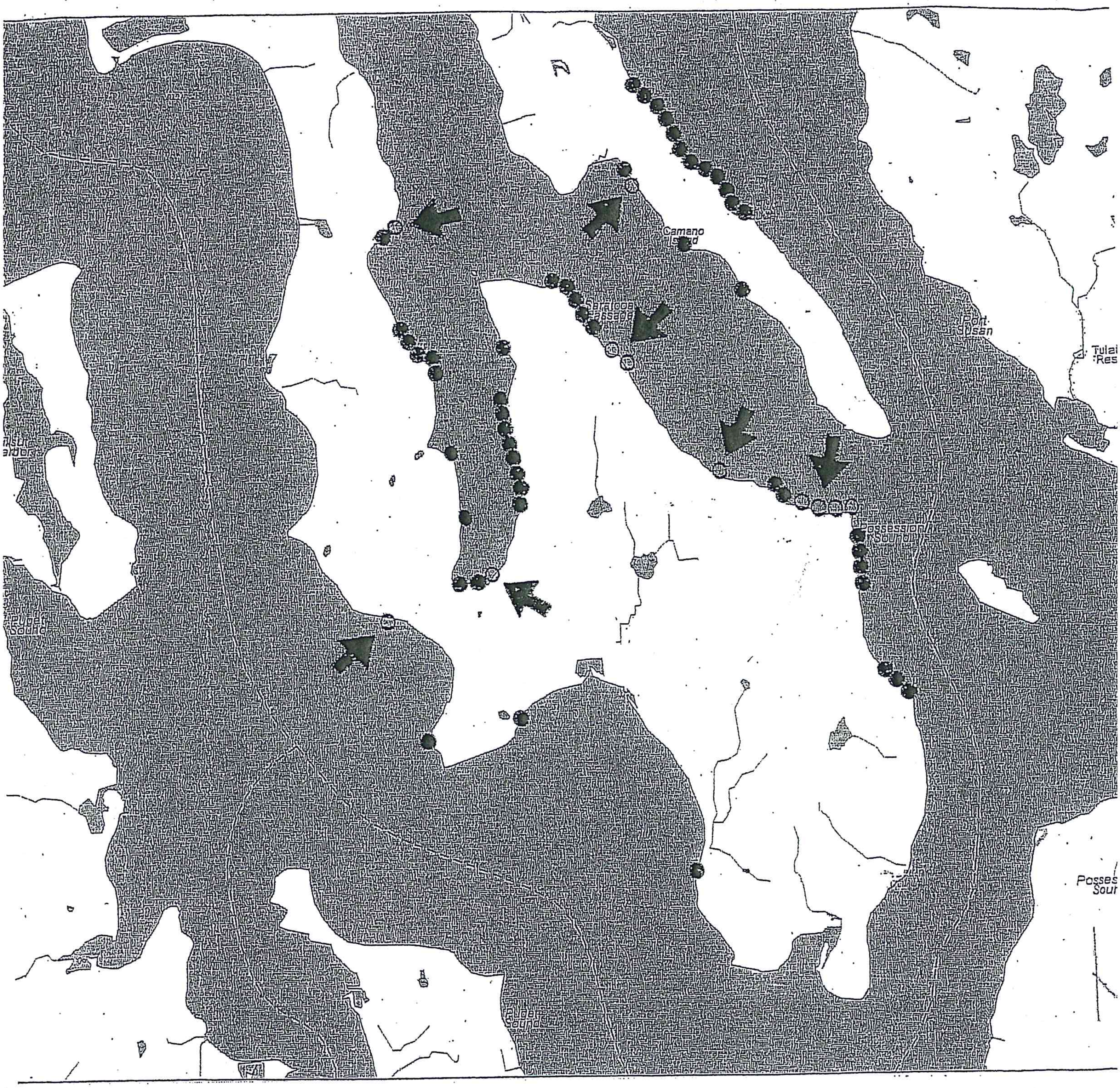


Figure 3. Documented Pacific sand lance (*Ammodytes*) spawning beaches in northern Island County.

●●●● = Spawning beaches documented by WDF/WDFW prior to 2001

➡ ○ = Additional spawning sites documented November 2001-February 2002



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State of Washington
DEPARTMENT OF FISH AND WILDLIFE
P.O. Box 1100 • 111 Sherman Street • La Conner, WA 98257-1100
(360) 466-4345 • Fax: (360) 466-0515

DATE: January 31, 2003

TO: Island County Marine Resources Committee

FROM: Dan Penttila DEP

SUBJECT: SUMMARY OF RESULTS, ISLAND COUNTY FORAGE FISH SPAWNING BEACH SURVEY PROJECT, APRIL-SEPTEMBER 2002.

Following is a summary of results of my forage fish spawning habitat surveys and related activities undertaken during the "summer surf smelt spawning season", from April through September 2002, along the shores of Island County under the auspices of the MRC-sponsored forage fish project.

SURVEY EFFORT:

Twenty eight field survey days:
- 16 boat survey days
- 12 on-foot survey days

500 beach substrate sample collected:
- 139 (27.8%) yielded evidence of forage fish spawn

NEW SURF SMELT SPAWNING HABITAT DISCOVERIES:

A total of 6.4 lineal statute miles of "new" surf smelt spawning beach was found:

Admiralty Head:	1000'
E. Camano Island:	11,500'
Mabana, Camano I.:	1,000'
Barnum Pt., Camano I.:	1,500'
Swantown, Whidbey I.:	6,300'
NW Camano I.:	3,600'
Blower's Bluff, Whidbey I.:	9,100'

The distribution of sampling stations, and new surf smelt habitat discoveries, are illustrated on attached figures 1 and 2.

DISCUSSION:

Surf smelt spawning habitat areas in Island County newly-documented in the summer of 2001 were confirmed in 2002 along the western and southwestern shores of Camano Island. Significant gaps in the pre-MRC-project distribution of documented surf smelt spawning beaches on the east-central shore of Camano Island and in the Blower's Bluff area south of Oak Harbor were closed by discoveries made during the summer of 2002.

The newly-documented surf smelt spawning area around Swantown, west of Oak Harbor, was quite significantly expanded in 2002. For some reason, this area is the only one on the entire west shore of Whidbey Island that appears to receive consistent and widespread summer surf smelt spawning activity, in spite of the fact that there are many miles of similar-looking sand-gravel beach along much of the rest of that shore.

An "exploratory" herring spawning habitat survey was conducted in early April 2002, following anecdotal reports of "ripe" herring in Oak Harbor Marina in the past, and a new knowledge of large eelgrass beds in the area of southeastern Penn Cove. We succeeded in finding several thousand feet of "wholly new" herring spawning habitat on the native eelgrass beds at and south from Snatelum Point. Although the eggs were moderately dense on the substrate plants, the spawning site was within sight of a number of beach residences, and marked by a dense flock of scoter ducks feeding on the spawn in their customary manner, there is no historical, anecdotal, or technical record of herring spawning activity at this location. Additional exploratory herring spawning habitat surveys will be undertaken in Island County waters in the late-winter-spring of 2003.

Regarding my continuing efforts at public outreach and education within Island County during this report period, oral forage fish presentations were made to the Whidbey Lyceum series, the Camano Island section of the Island County Beachwatchers, and WA State Parks managers at their annual training session at Cornet Bay ELC. I participated in a UW/PRISM work group meeting regarding future research uses of the Cama Beach St. Pk. property. Forage fish display and informational handout materials were supplied to the WSU Extension staff for use at a booth at the Island County Fair. I spent a day at the Cornet Bay ELC with the combined fifth grade classes from Lowell Elementary School in Seattle beach-seining for nearshore marine organisms. I escorted a reporter and photographer from the Seattle Post-Intelligencer on a low-tide beach walk of a well-used surf smelt spawning beach on northern Camano Island as they gathered material for a subsequent series of features on the "health of Puget Sound".

I assisted staff of the Island County Parks and Recreation Department with technical information and a oral presentation before the ALEA panel in Olympia in an (unsuccessful) attempt to secure a grant to acquire 300+ lineal feet of good surf smelt spawning beach from a willing seller adjoining the existing Utsaladdy County park property on northern Camano Island. A similar attempt by WDFW to IAC funding to acquire this same property, for the same public-access enhancement reasons, several years ago had also been unsuccessful. Such an acquisition would have increased the available public-access smelt beach in the historically-important smelt-harvest area of northern Camano Island several-fold.

FUTURE WORK:
A full season of surveys for winter-spawning surf smelt and sand lance spawning habitat is planned for Island County shorelines. The Island County work will have to accommodate the staff and volunteer training and coordination needs of additional new forage fish spawning habitat inventory completion projects that are getting underway in Whatcom, Skagit, Snohomish, Mason and Thurston Counties.

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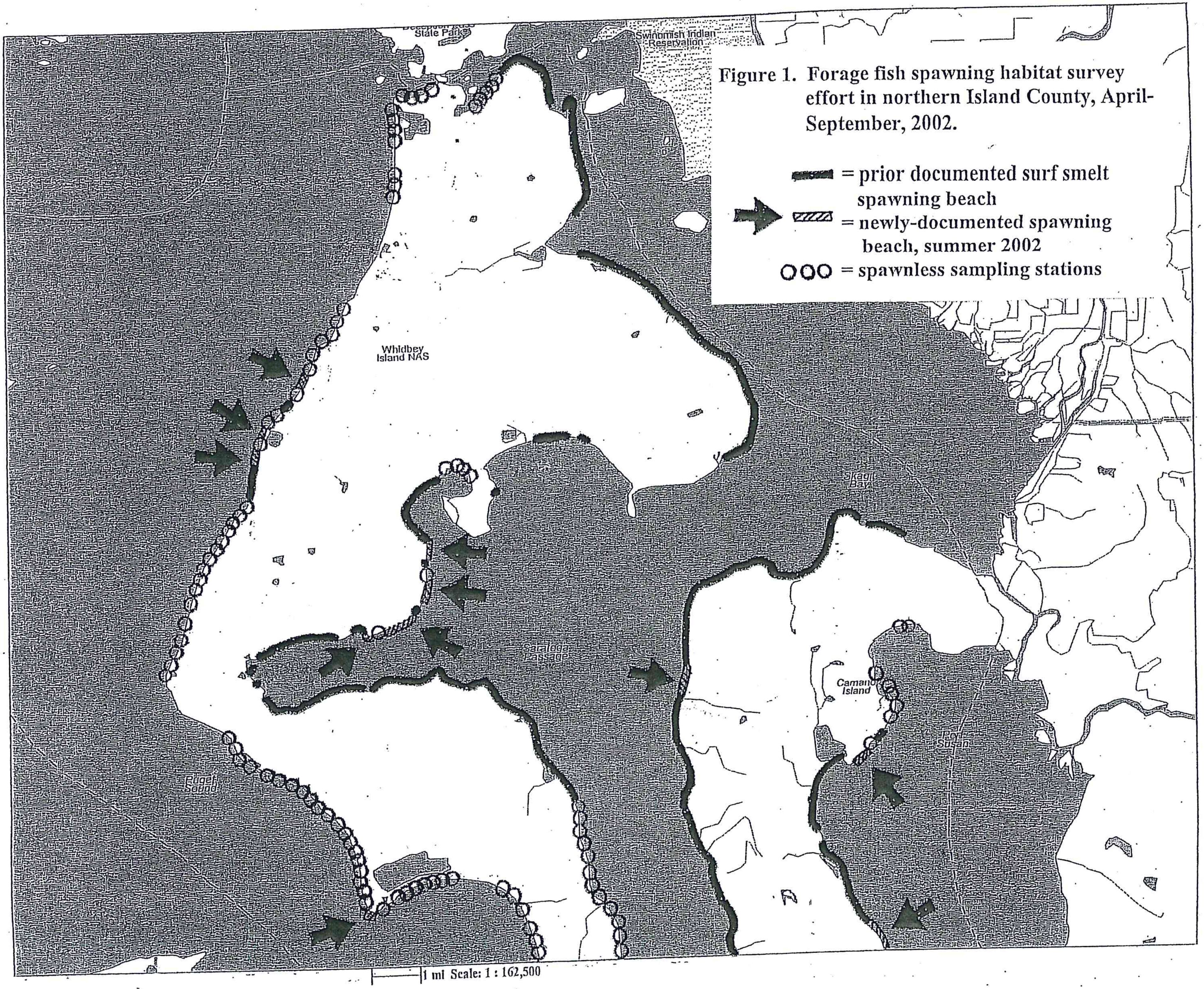

Figure 1. Forage fish spawning habitat survey effort in northern Island County, April-September, 2002.

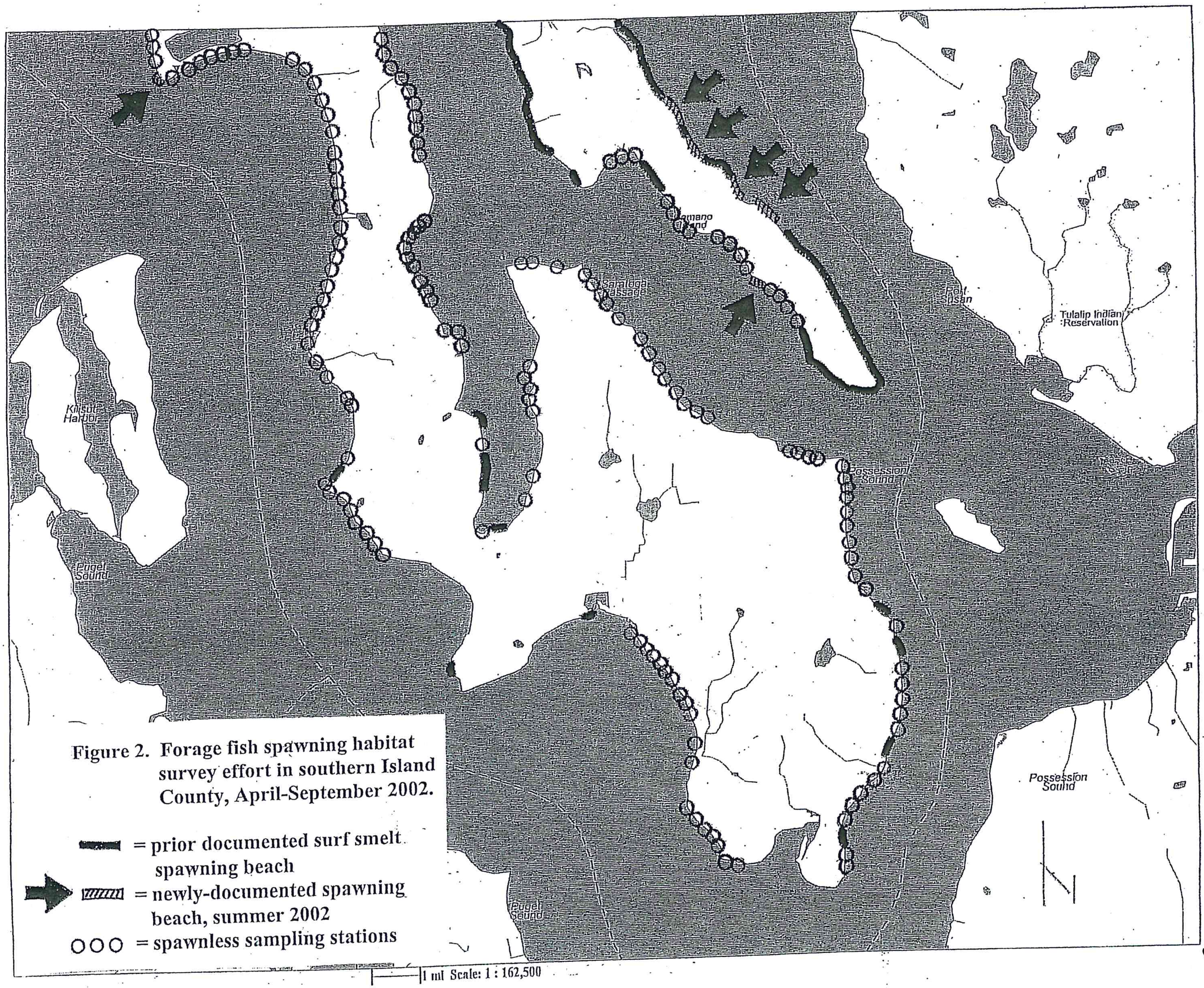

Figure 2. Forage fish spawning habitat survey effort in southern Island County, April-September 2002.

▬ = prior documented surf smelt spawning beach

➔ ▨ = newly-documented spawning beach, summer 2002

OOO = spawnless sampling stations

State of Washington
DEPARTMENT OF FISH AND WILDLIFE
P.O. Box 1100 • 111 Sherman Street • La Conner, WA 98257-1100
(360) 466-4345 • Fax: (360) 466-0515

DATE: June 12, 2003

TO: Gary Wood, Island County Marine Resources Committee

FROM: Dan Penttila DEP.

SUBJECT: SUMMARY OF RESULTS, ISLAND COUNTY FORAGE FISH SPAWNING BEACH SURVEY PROJECT, OCTOBER 2002-APRIL 2003.

Following is a brief summary of results and activities pertaining to the Island County forage fish spawning habitat inventory completion project during the winter of 2002-03, supported by the Island County MRC.

SURVEY EFFORT:

Eighteen field sampling days (surf smelt/sand lance beaches)
- 14 boat-based surveys
- 4 on-foot surveys

377 beach substrate sampling stations:
- 27.9% yielded forage fish eggs

Five exploratory herring spawning habitat surveys
- 177 vegetation-sample sites
- No new herring spawning sites found

NEW FORAGE FISH SPAWNING HABITAT DISCOVERIES:

Surf smelt: (see Figures 1 and 2)

800'	west side of "Mariner's Cove" waterway entrance, NE Whidbey I.
2,600'	on SE Camano island
1,000'	on NE Useless Bay
1,000'	east of Polnell Point Spit

Total: 5,400' (1.02 statute miles)

Sand Lance: (see Figures 3 and 4)
9,200' on SW Camano Island
2,800' in Holmes Harbor area
1,000' NE of Cornet Bay
2,000' NW of Langley

Total: 15,000' (2.84 statute miles)

DISCUSSION:

Significant amounts of new surf smelt and sand lance spawning habitat were discovered within island County during the second winter season of the project. Surf smelt spawn was again found in detectable amounts through the winter season, further indication that Island County supports virtually year-round surf smelt spawning activity at many sites, although the area is still characterized by a summer peak of spawning activity. The estimated mileage of documented surf smelt spawning habitat within Island County now stands at about 62 miles, roughly 29% of the total county shoreline. Camano Island, in particular, is rich in surf smelt spawning habitat. Virtually anywhere around the perimeter of the Island where the upper intertidal is mixed sand-gravel, and not marsh, pure sand nor cobble, surf smelt eggs have been found.

With the documentation of 2.8 additional miles of new sand lance spawning habitat found during this report period, the total sand lance spawning habitat for island County has reached approximately 30 miles, 14% of the shoreline (of all types) in the county. The criteria by which spawning sand lances select their spawning sites remains a puzzle. Many suitable-looking protected sandy shorelines within the survey area have not yet yielded evidence of sand lance spawning.

A number of exploratory herring spawning habitat surveys were undertaken within the County during February-April, during the time of year when herring spawning activity is on-going in the county's several already-known herring spawning areas (Figure 5 and 6). The standard WDFW marine-vegetation sampling techniques were used. In most cases, these surveys were the very first time that experienced WDFW forage fish unit staff had ever undertaken spawn surveys along these reaches of shoreline. Healthy eelgrass/algae beds were found in all the surveys undertaken, and it is not readily apparent why the local herring spawning stocks have evolved to spawn consistently where they presently do, "ignoring" the intervening vegetated shorelines. Nevertheless, no evidence of "new" herring spawning habitat was found, nor were we able to detect herring spawn in the area on the east side of Snatelum Point (SE Penn Cove), where a herring spawning site was newly-documented in April 2002.

PUBLIC OUTREACH:

Dispensation of public forage fish information continued to be a significant duty in the northern Puget Sound/NWSC region during the report period. During this time, new forage fish spawning habitat completion projects were commenced in Whatcom, Skagit, and Snohomish Counties. Two additional WDFW forage fish biologists were hired and trained in the protocols of the project. QA/QC lab analyses continued for a portion of the samples generated by forage fish habitat survey projects in Sand Juan and Jefferson Counties. Forage fish project volunteer orientation presentations were held in Whatcom and Snohomish Counties. The Whatcom Count MRC-sponsored "marine resource summit" as attended. The Whatcom County MRC and its video producers were assisted, with field and lab demonstrations, in the production of a public-informational video on the local forage fish spawning habitat survey project. A series of four forage fish/nearshore habitat workshops were attended at the Port Townsend Marine Science Center. A forage fish session was presented for the Island County MRC's "Soundwaters" program. The year's new class of Island County Beachwatchers were given a forage fish presentation/field trip. The proposed Bush Point public launch ramp site, and its attendant smelt spawning habitat mitigation site on west Penn Cove, were visited with project engineers and habitat managers.

A meeting of local residents and land-use managers concerning the marine resource science of Discovery Bay was attended. A combined group of marine habitat managers from several federal agencies were given an informational forage fish spawning ecology presentation at NOAA-Sand Point. The annual group of minority science students attending the WWU's Shannon Point lab were given an all-day lecture and lab on marine fishes. One day of the Georgia Strait/Puget Sound Research Conference was attended in Vancouver, BC, and found to be high in interest in forage fish matters. Elsewhere in the Puget Sound basin, field work commenced on contracted forage fish spawning habitat inventory completion projects within Mason and Thurston Counties.

FUTURE ACTIVITIES:

As of this writing, it is understood that forage fish spawning habitat inventory field work will continue within Island County through the balance of 2003, another summer smelt spawn survey season, and the greater part of the following sand lance spawning season. There will also be contributions to the second annual forage fish project review report being prepared by Island County MRC staff.

DEP

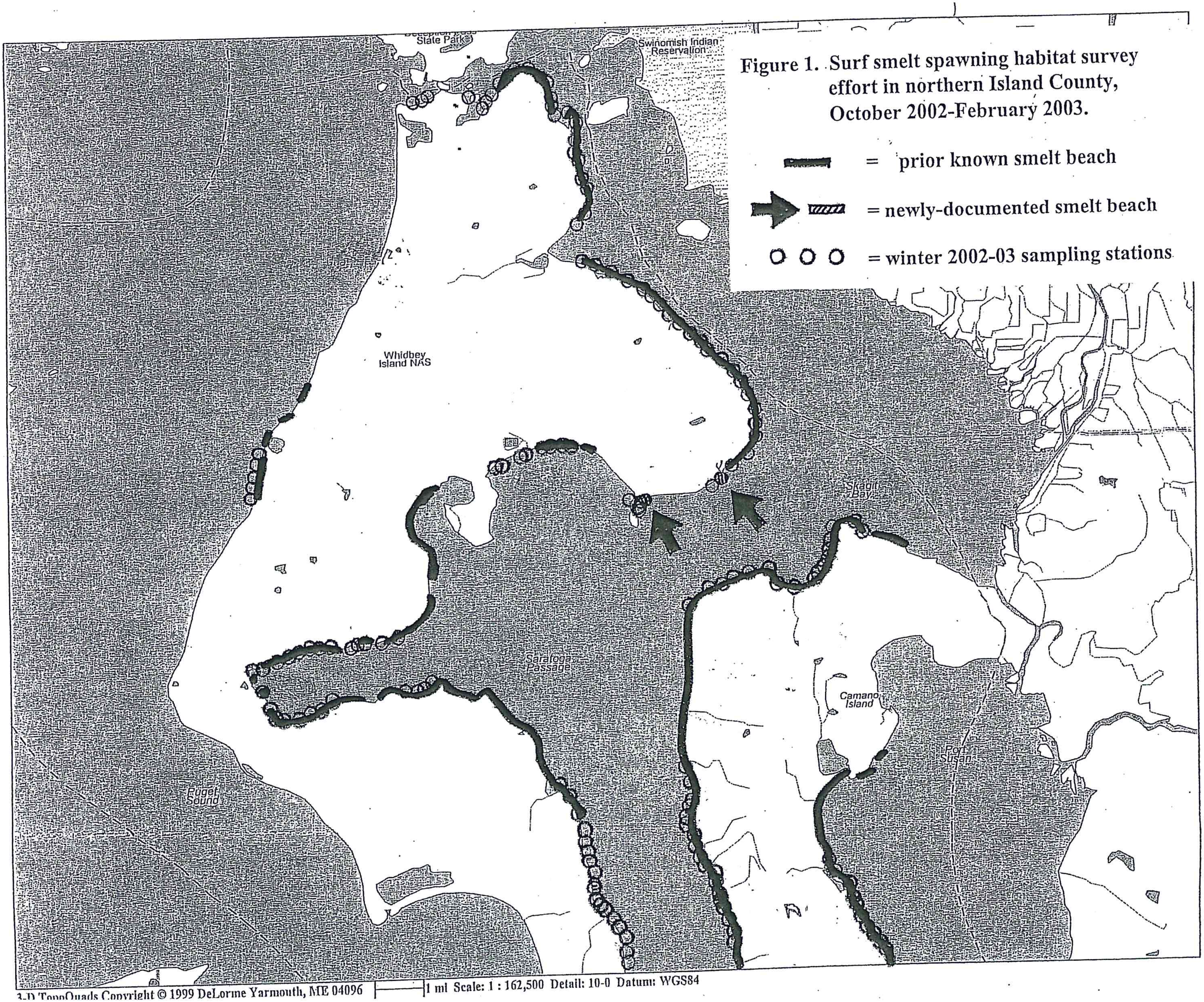

Figure 1. Surf smelt spawning habitat survey effort in northern Island County, October 2002-February 2003.

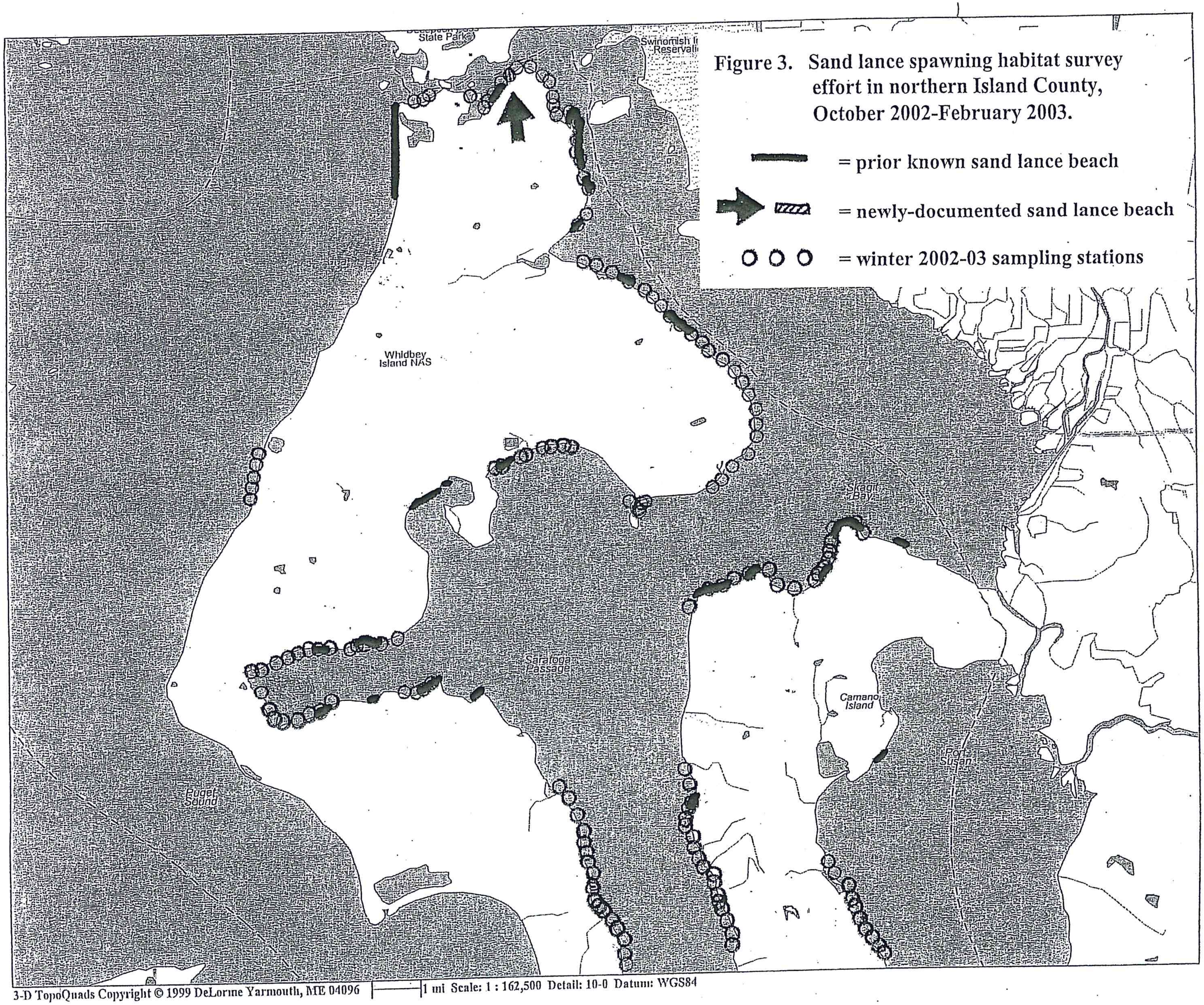

Figure 3. Sand lance spawning habitat survey effort in northern Island County, October 2002-February 2003.

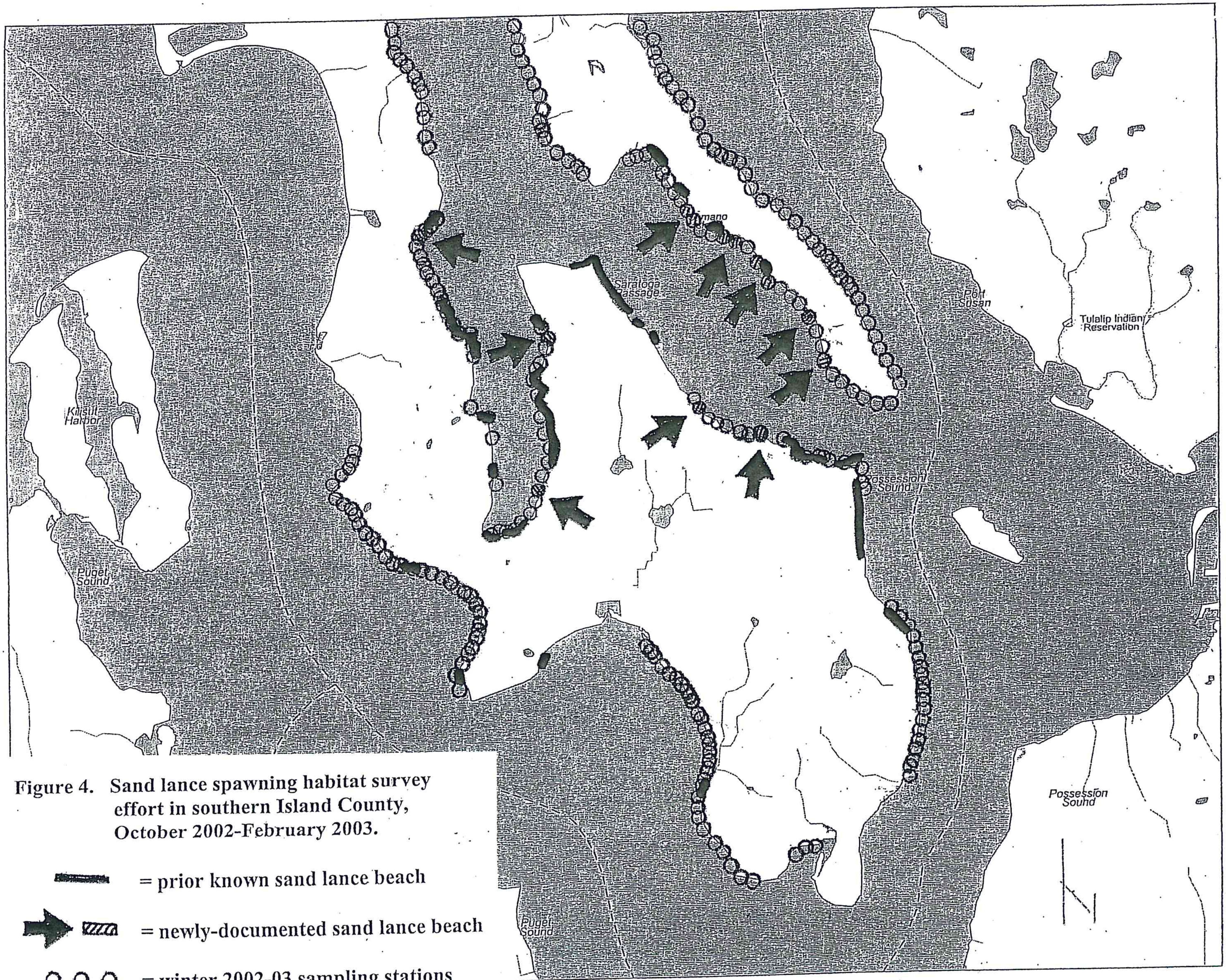

Figure 4. Sand lance spawning habitat survey effort in southern Island County, October 2002-February 2003.

= prior known sand lance beach

= newly-documented sand lance beach

= winter 2002-03 sampling stations

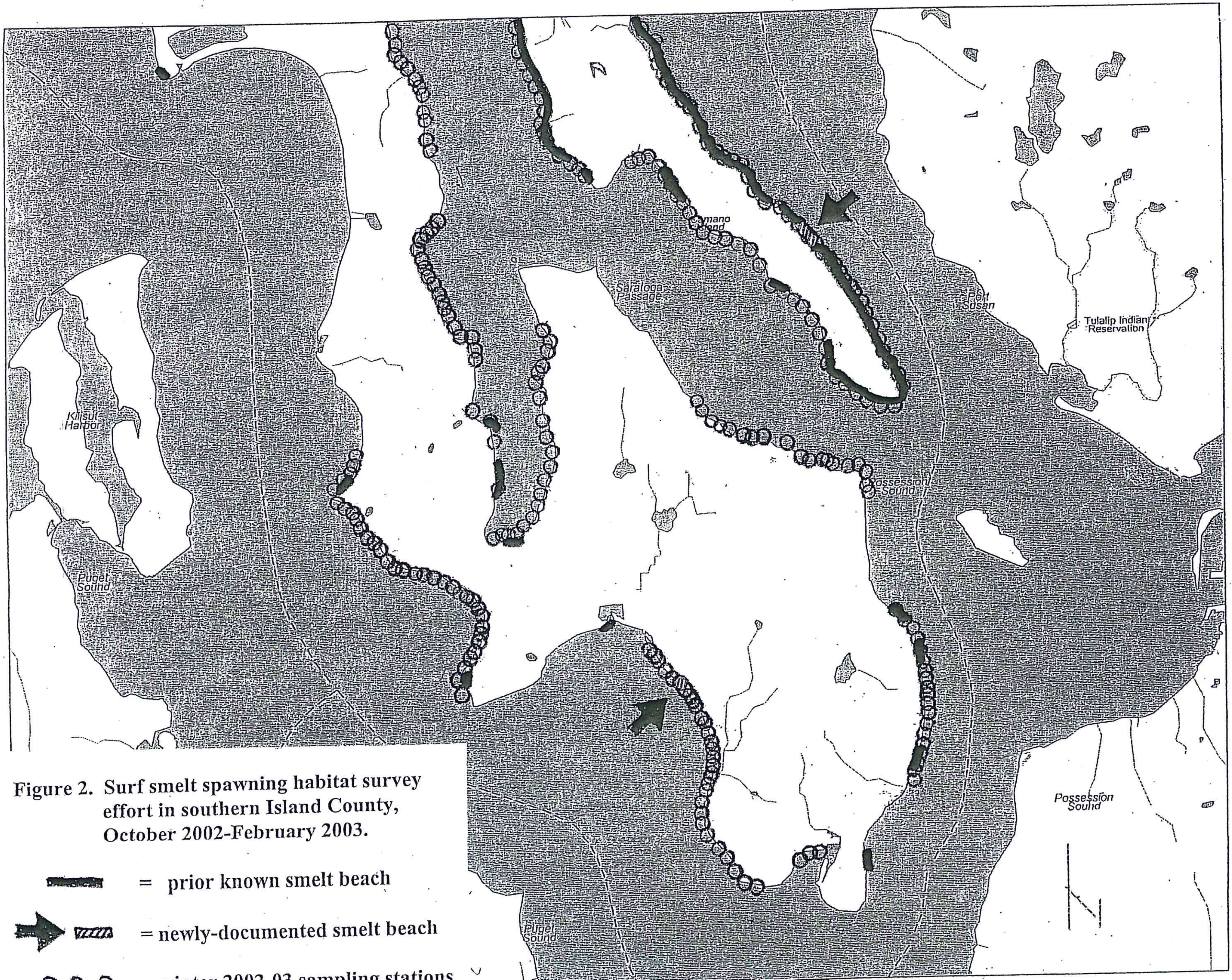

Figure 2. Surf smelt spawning habitat survey effort in southern Island County, October 2002-February 2003.

= prior known smelt beach

= newly-documented smelt beach

○○○ = winter 2002-03 sampling stations

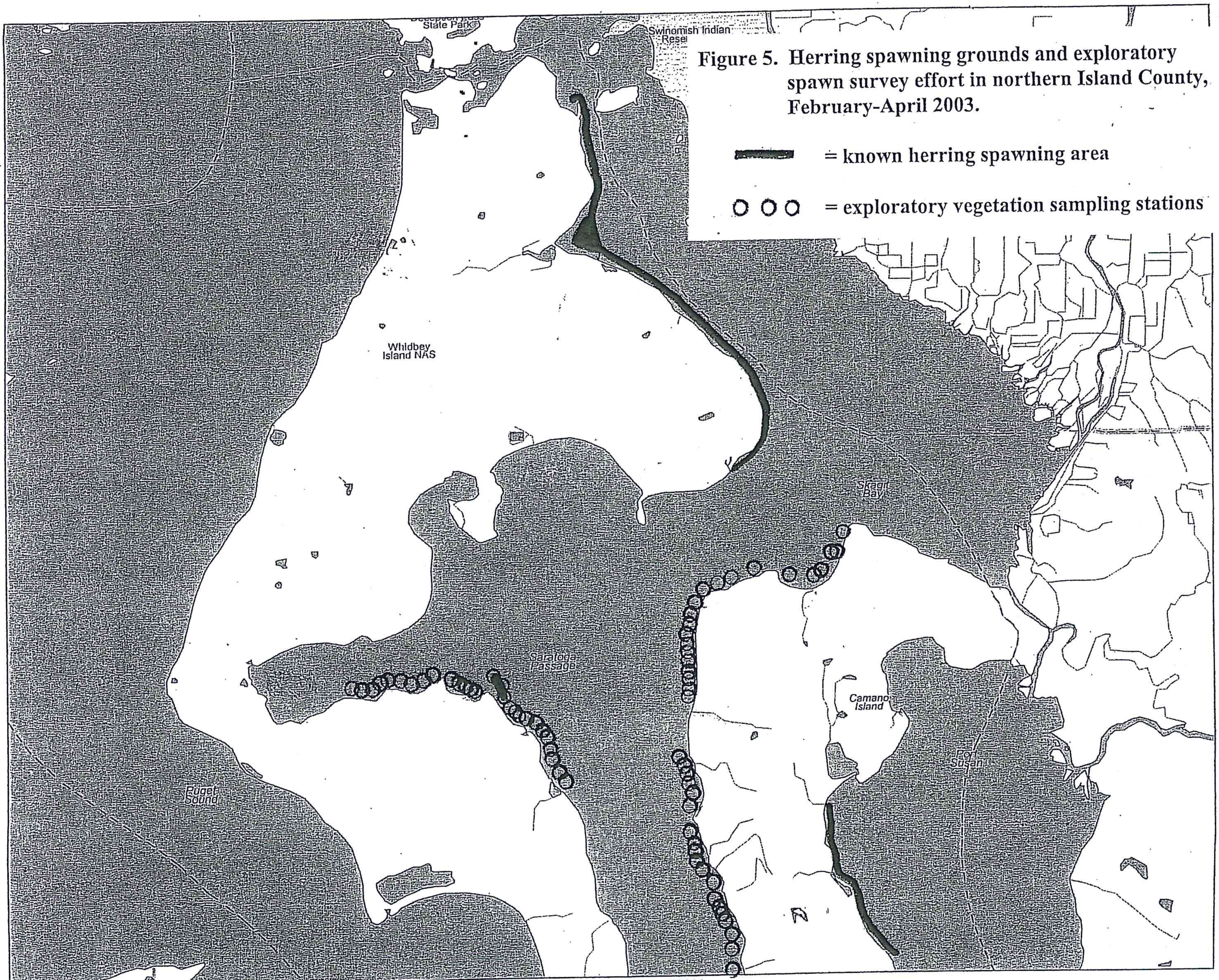

Figure 5. Herring spawning grounds and exploratory spawn survey effort in northern Island County, February-April 2003.

= known herring spawning area

O O O = exploratory vegetation sampling stations

 1 mi Scale: 1 : 162,500 Detail: 10-0 Datum: WGS84

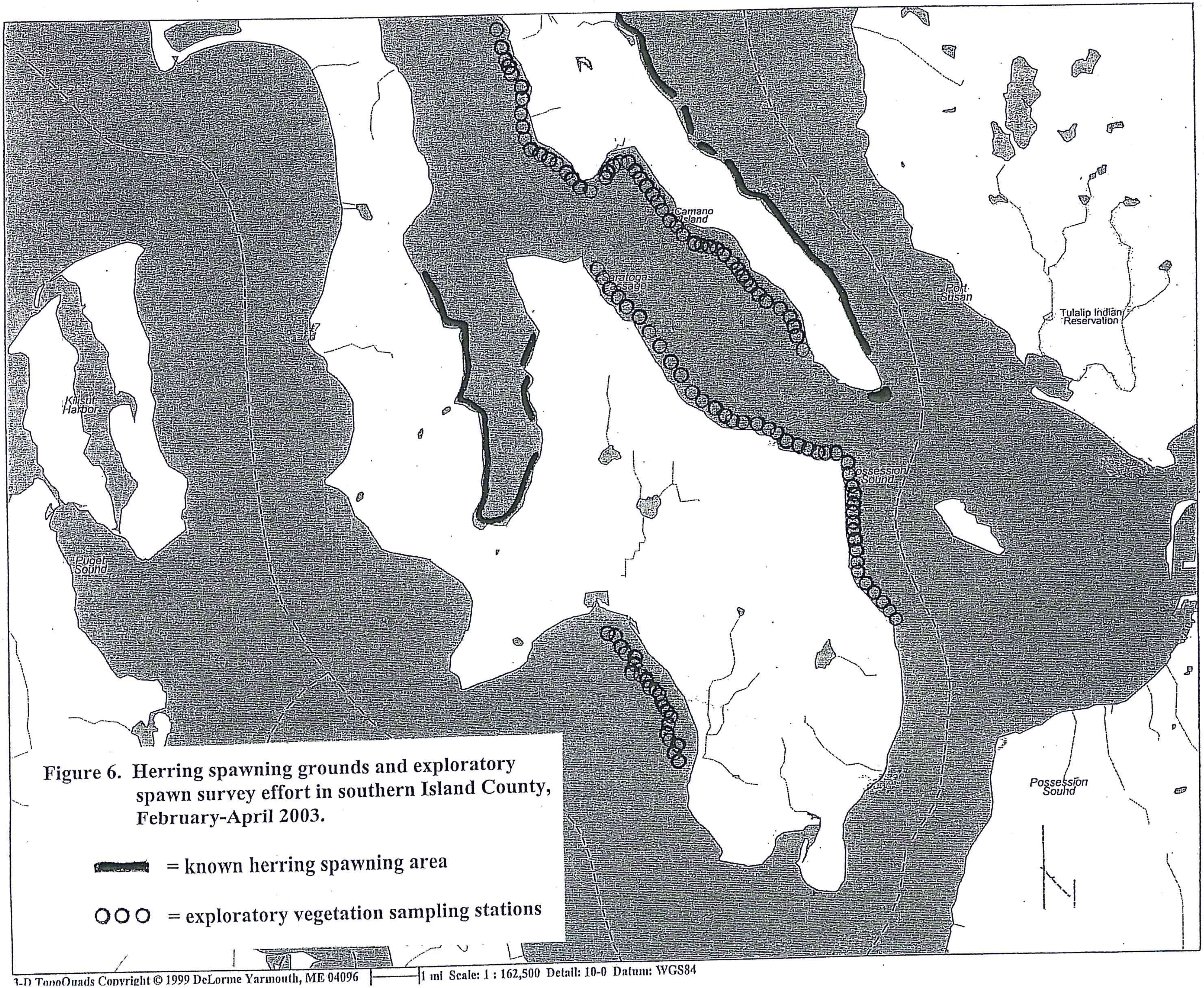

Figure 6. Herring spawning grounds and exploratory spawn survey effort in southern Island County, February-April 2003.

▬ = known herring spawning area

OOO = exploratory vegetation sampling stations

State of Washington
DEPARTMENT OF FISH AND WILDLIFE
P.O. Box 1100 • 111 Sherman Street • La Conner, WA 98257-1100
(360) 466-4345 • Fax: (360) 466-0515

DATE: October 24, 2003

TO: Island County Marine Resources Committee

FROM: Dan Penttila DEP.

SUBJECT: SUMMARY OF RESULTS, ISLAND COUNTY FORAGE FISH SPAWNING BEACH SURVEY PROJECT, MAY-SEPTEMBER, 2003.

Following is a brief summary of WDFW staff's field survey results and other activities undertaken during the summer of 2003 that were associated with the Island County forage fish spawning habitat inventory completion project being supported by the Island County MRC.

FIELD SURVEY EFFORT AND NEW DISCOVERIES:

Thirteen field survey days: 231 beach substrate sampling stations, 34.6% of which yielded surf smelt eggs. (see Figure 1).

A total of **1,786** sampling stations have now been completed in Island County during the course of the MRC project.

New summer surf smelt spawning sites:

1,400 feet in SE Camano Island
1,900 feet east of Polnell Point, Whidbey Island
1,000 feet west of Polnell Point
500 feet NE of Barnum Point, Camano Island

4,800 feet (.9 statute miles) Total

Forage fish spawning habitat survey effort in Island County during the summer of 2003 emphasized those areas that had been least-sampled by WDFW in previous years. With the shores of Camano Island and Saratoga Passage already largely documented as forage fish spawning habitat, survey emphasis was placed on the west shore of Whidbey Island. Although summer surf smelt spawning activity was again documented on the beaches south of Swantown, (first discovered in 2001), no additional evidence of spawning was found elsewhere on similar-appearing beaches from Deception Pass to Possession Point. Long reaches of summer surf smelt spawning habitat, previously documented by WDFW in the 1990s, between Strawberry Point and Ala Spit on NE Whidbey Island and from Camano Head north to Triangle Cove on eastern Camano Island, were re-visited, and extensive present-day smelt spawning activity was confirmed. This summer's surveys included a day in the security areas of Crescent Harbor and western Ault Field beaches, escorted and assisted by NAS-Whidbey environmental office staff.

CONVERSIONS OF HISTORICAL FORAGE FISH HABITAT DATA:

During this report period, considerable effort was devoted to a review of the WDF/WDFW's "historical" surf smelt/sand lance spawning habitat survey database, accumulated from undertaken during the 1972-1993 period. A search was made for all survey sampling stations that might have occurred within Island County, and for which there was a documentable effort to detect and record the occurrence of forage fish spawn in some manner, and for which a sampling location could be identified with some precision.

Nearly 600 such sampling sites and spawn presence/absence records were recovered for Island County shorelines. Original field notebooks and field reports were reviewed so as to glean as much information as possible from them for entry onto currently-used data forms. All survey charts were converted to 1:24,000 topo charts, with original station locations re-produced as accurately as possible, and from which after-the-fact latitude-longitude locations were assigned to them. The historical sampling stations were given county-specific grand-station numbers chronologically, beginning at the very first beach the writer visited on his very first forage fish-related field trip of 1972, in a manner that will link them with the stations undertaken during the current project. The data is being entered by WDFW-LaConner staff in a manner compatible with data entry activities that have been underway for the current array of forage fish habitat mapping projects in Island and other north-Sound counties.

Most of the historical sample stations consisted only of visual observations of beach substrate in the field, at a charted site, coupled with a qualitative assessment of the relative density of the spawn. Occasionally, the spawn would be sampled quantitatively, with sets of "scoop" samples of visibly-spawn-bearing substrate. Microscopic examination of eggs from a weighed substrate sample, with embryo aging, would yield data of much the same character as is done collected when field-visible egg deposits are encountered on current surveys.

The current "bulk-substrate sampling" method was not adopted until late 1991, and the current data format and recorded station character element array was not adopted until late 1993. However, inclusion of these historical sampling stations into the eventual overall county database will add greatly to the total forage fish spawning habitat distribution view. For a few beach reaches, in-situ visual spawn observations made during the 1972-1991 period remain the primary basis by which certain sectors of those beaches are documented as forage fish spawning habitat and subsequently given no-net-loss regulatory protection by state and federal resource agencies.

PUBLIC OUTREACH ACTIVITIES:

During the report period, the writer took part in a variety of forage fish/nearshore habitat-related environmental outreach/education activities within the northern Puget Sound counties that are involved in the NWSC. The Camano Island class of new Island County Beachwatchers was given a forage fish training session: lecture/lab/ forge fish spawning beach field trip, as part of their training program (Island Co.). The five-workshop series pertaining to forage fishes and the near-shore environment, sponsored by the Port Townsend Marine Environmental Center, was completed (Jefferson Co.). I also delivered an oral presentation on Puget Sound forage fishes, staffed a forage fish poster display, and headed up an informational beach walk at PTMSC's "Low-Tide Fest" (Jefferson Co.). The volunteer beach-steward class from RE Sources (Bellingham) was given a forage fish presentation and beach walk as part of their training to augment local State and local park staff during the summer of 2003 (Whatcom/Skagit Cos.). I participated in two field trips and a multi-group workshop on the matter of the recent near-total disappearance of dense beds of native eelgrass in Westcott-Garrison Bays, a herring spawning ground on San Juan Island (San Juan Co.). FOSJ was assisted by WDFW-LaConner by the undertaking of a standard forage fish spawning beach survey of the SW shores of Rosario Strait, a sector of San Juan Co. shoreline that had been difficult for them to reach from their base of operations in Friday Harbor (San Juan Co.). I led a multi-agency field trip to the Fidalgo Bay DNR Marine Reserve, as part of DNR's program to re-evaluate their marine reserve system (Skagit Co.). Science classes from Lowell Elementary School (Seattle) and Anacortes High School were given beach seine demonstrations and marine organism life-history discussions at a site in Cornet Bay, Deception Pass St. Pk. (Island Co.).

Elsewhere in the Puget Sound basin, the writer led a forage fish habitat sampling demonstration field trip to Seahurst Park (King Co.), where a sector of surf smelt spawning beach is slated for de-armoring and restoration. A presentation on the forage fishes of southern Puget Sound was delivered to the APHETI local community group, they being concerned about the impact of expanding shellfish aquaculture on the marine resources of Totten and Eld Inlets (Thurston Co.). A day-long forage fish spawning habitat sampling training session, including lecture/field trip/substrate sampling/ screening/winnowing/microscopic analyses, was delivered to a group of consultants and agency staff, for the second year, responding to agency needs for additional "certifiable" sampling expertise at shoreline project sites.

FUTURE WORK:

Forage fish spawning habitat surveys will continue in priority areas during the fall-winter of 2003, completing the current Island County project. Efforts to incorporate pre-MRC-project WDFW Island County forage fish habitat survey data into the Sound-wide database will continue. This effort should be more straight-forward, since WDFW's 1993-2000-era forage fish survey data had all been collected in formats and protocols virtually identical to those in use at present.

DEP

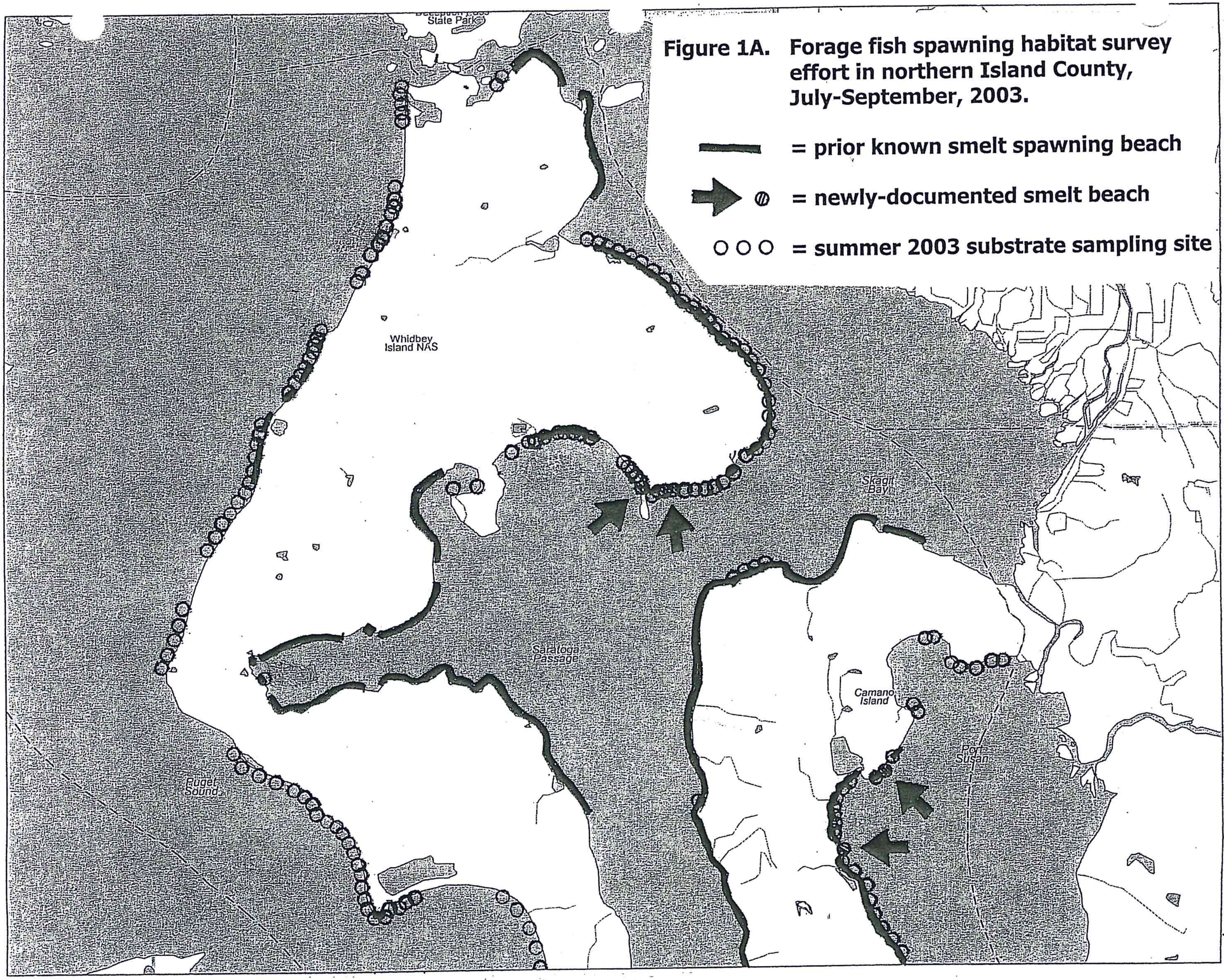

Figure 1A. Forage fish spawning habitat survey effort in northern Island County, July-September, 2003.

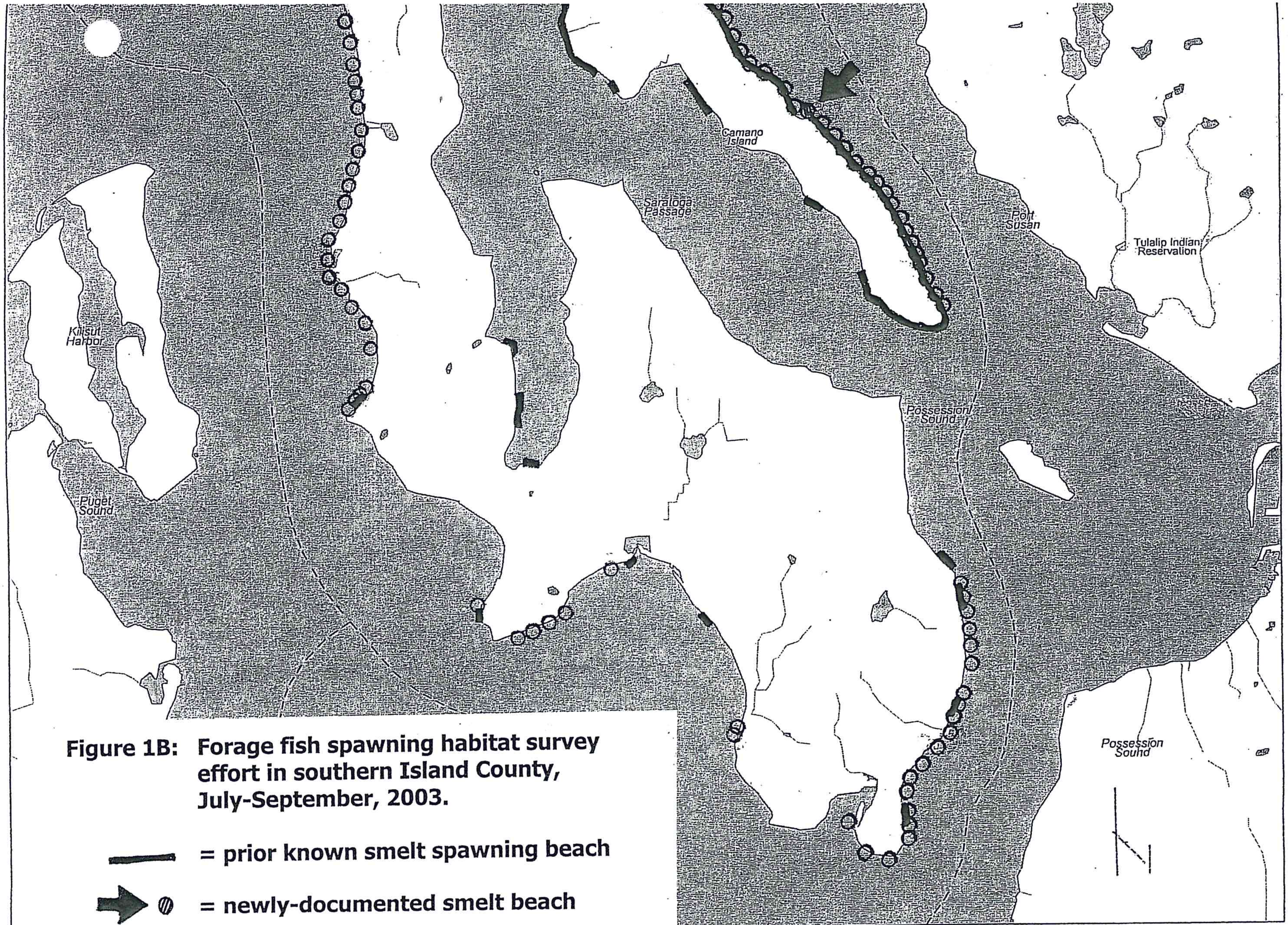

Figure 1B: Forage fish spawning habitat survey effort in southern Island County, July-September, 2003.

= prior known smelt spawning beach

= newly-documented smelt beach

○○○ = summer 2003 substrate sampling site

APPENDIX E

NORTHWEST STRAITS
marine conservation initiative

ISLAND COUNTY FORAGE FISH SPAWNING HABITAT ASSESSMENTS

PROJECT SPONSOR'S FIRST ANNUAL REPORT

JUNE 2002

ISLAND COUNTY MARINE RESOURCES COMMITTEE

Tom Campbell Chair
Don Meehan MRC County Lead

Reported by Gary Wood MRC Executive Director
and Dan Penttila, WDFW Project Lead Biologist

Sponsored by Grants from NOAA and the Salmon Recovery Funding Board [SRFB], Northwest Straits Commission [NWSC], National Fish & Wildlife Foundation [NFWF], Marine Ecosystem Health Program [MEHP], in partnerships with Friends of the San Juans, Washington Departments of Fish and Wildlife and Ecology; and Northwest Straits Marine Conservation Initiative

A NORTHWEST STRAITS INITIATIVE PROJECT

Unified report for submission to all project partners, co-sponsors, and stakeholders

Join the Project at www.foragefish.org

>>CONTENTSCONTENTS>>

APPENDIX F

ISLAND COUNTY MARINE RESOURCES COMMITTEE
101 6th Street, P.O. Box 5000
Coupeville, WA 98239-5000
360.679.7327 Fax: 360.240.5503
donme@co.island.wa.us
www.islandcountymrc.org

Assessment of Shoreline Spawning Habitats in the Northwest Straits (2001 - 2004)

with accompanying GIS Database/CD-Rom

Three years of biologic field investigations at a regional scale yield GIS databases to map forage fish spawning depositions in Puget Sound: Surf smelt/*Hypomesus pretiosus*, Pacific sand lance/*Ammodytes hexapterus and* Pacific herring/*Clupea pallasi*

Reported by:
Gary Wood JD, MRC Executive Director
Forage Fish Projects Coordinator

Principal Investigator:
Daniel E. Penttila, Fisheries biologist
Washington Department of Fish and Wildlife/WDFW

Sponsoring Grant Awards:

FORAGE FISH SPAWNING HABITAT ASSESSMENTS
Salmon Recovery Funding Board/SRFB
Grants 00-1086, 01-1673N and 01-1252N (2001-04)
to Island County Marine Resources Committee; and
SEADOC SOCIETY, Island County surveys (2001-02)

REGIONAL FORAGE FISH ASSESSMENTS
National Fish and Wildlife Foundation/NFWF
Challenge Grant 2002-0241-00 (2002-03),
Whatcom, Skagit, Snohomish & Island Counties

COORDINATION OF FORAGE FISH PROJECTS
SRFB Grants 00-1086 and 01-1252N (2002-03); and
Northwest Straits Commission /NWSC
Department of Ecology CZM 310 Grants to MRC (2001-04)

NORTHWEST STRAITS
marine conservation initiative

www.nwstraits.org

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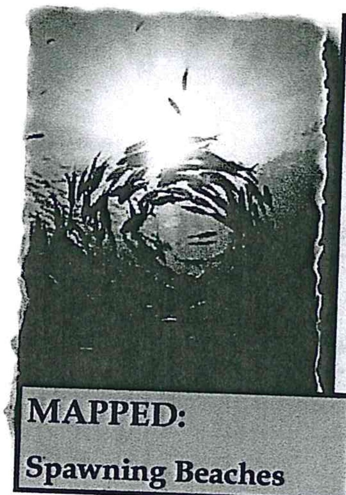
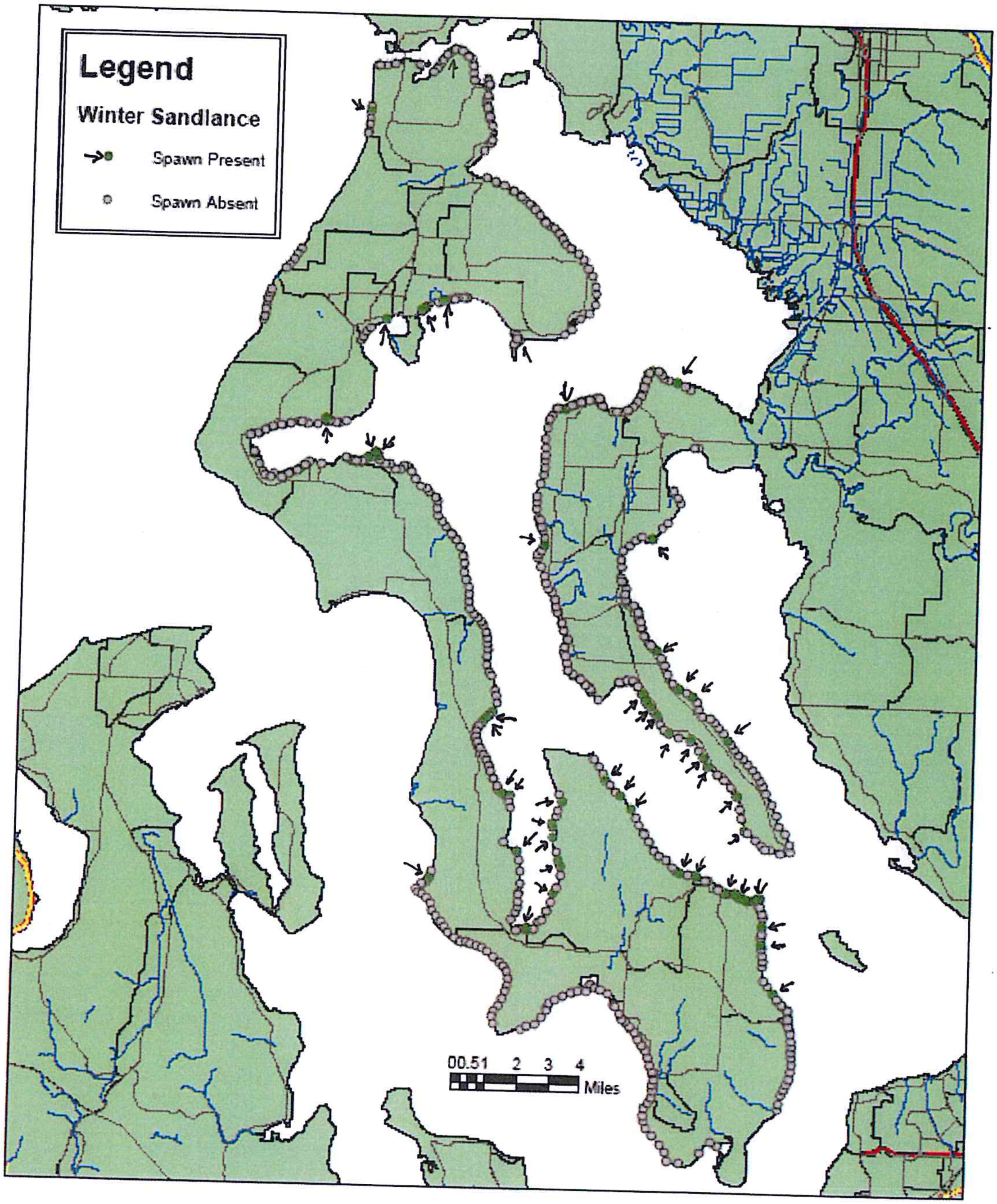


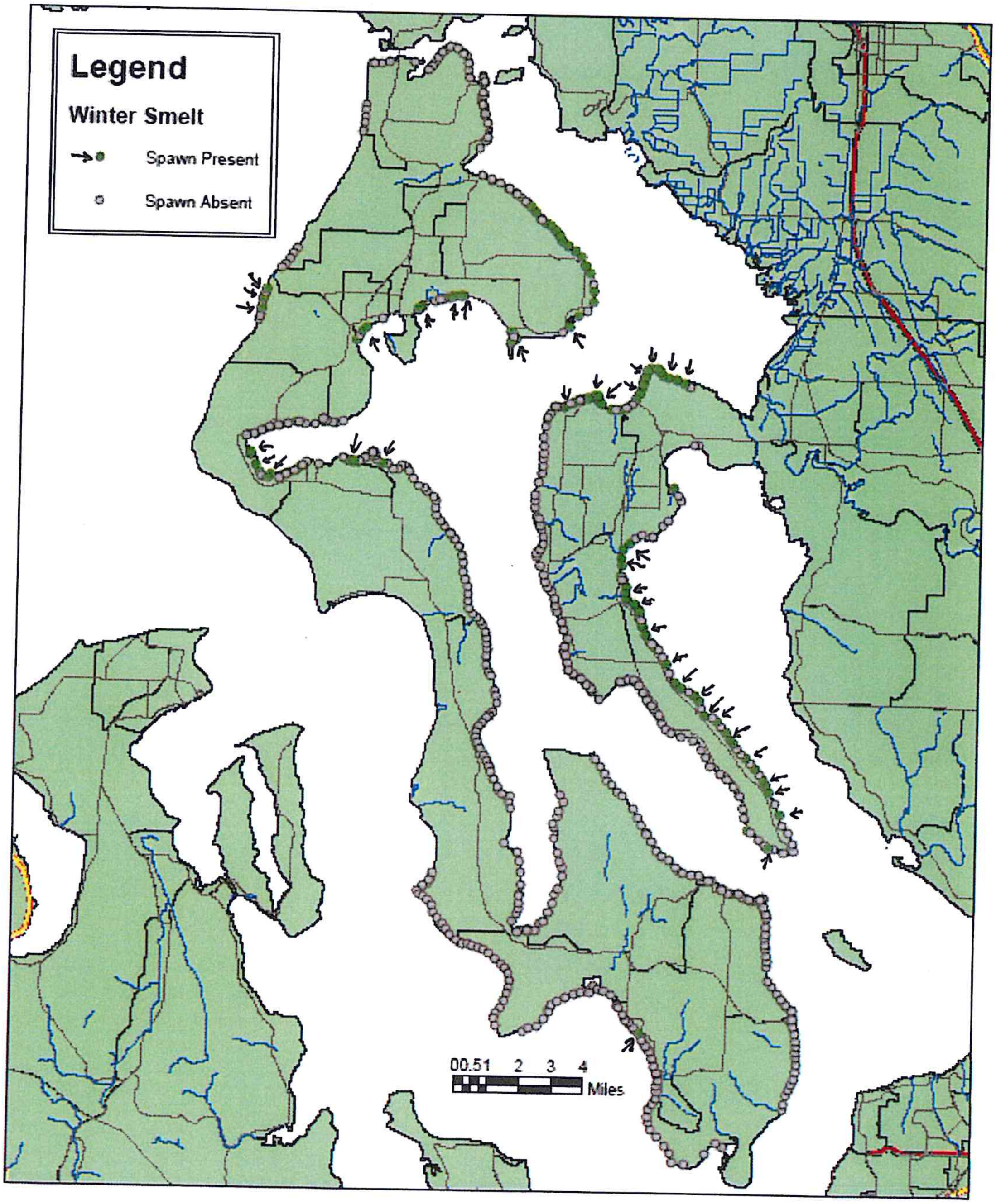
IN SEARCH OF 'INVISIBLE EVIDENCE'

Forage Fish Spawning Habitat Surveys

A three year project is complete, 12/03



Island County Forage Fish



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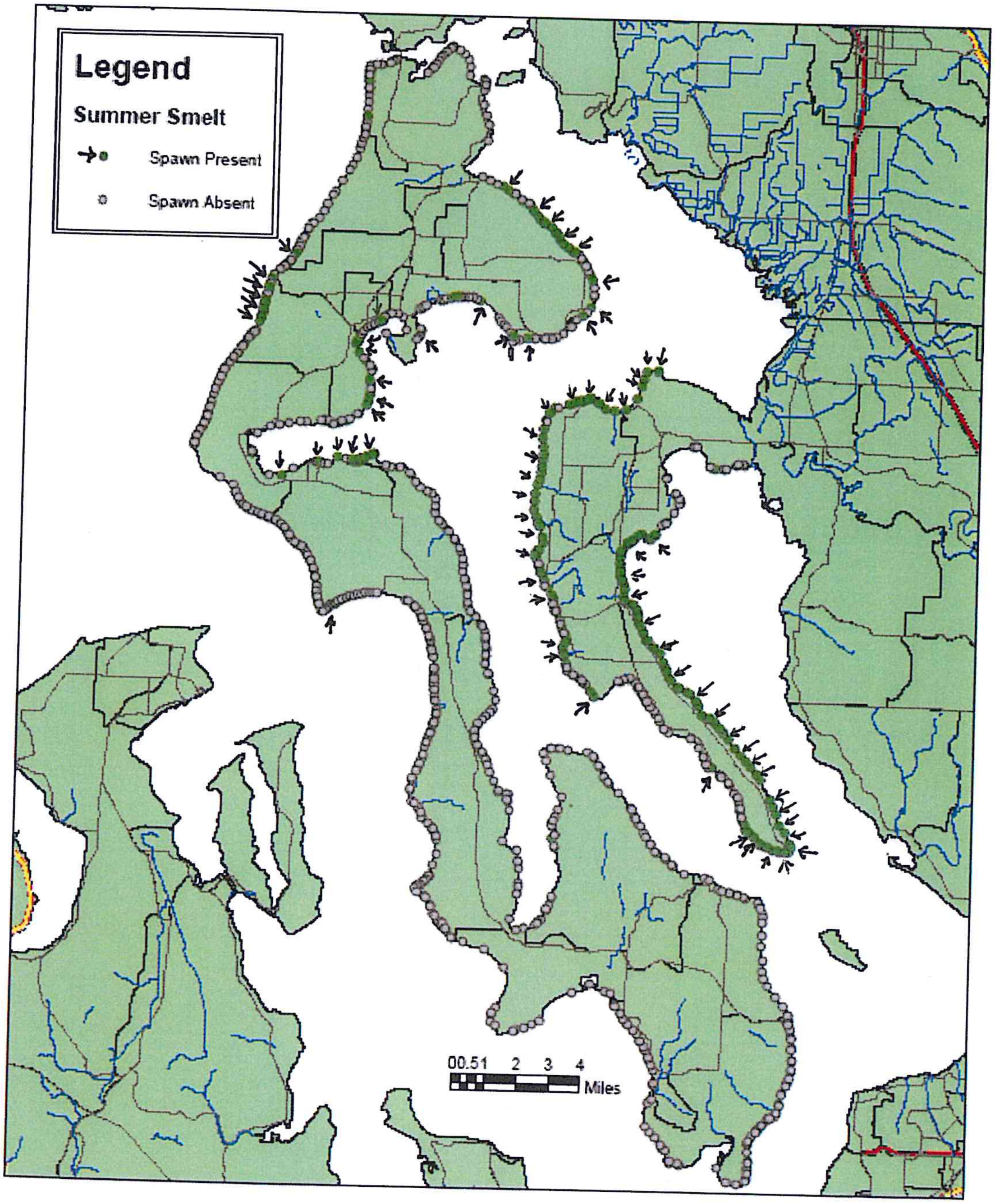


Island County Forage Fish

APPENDIX G

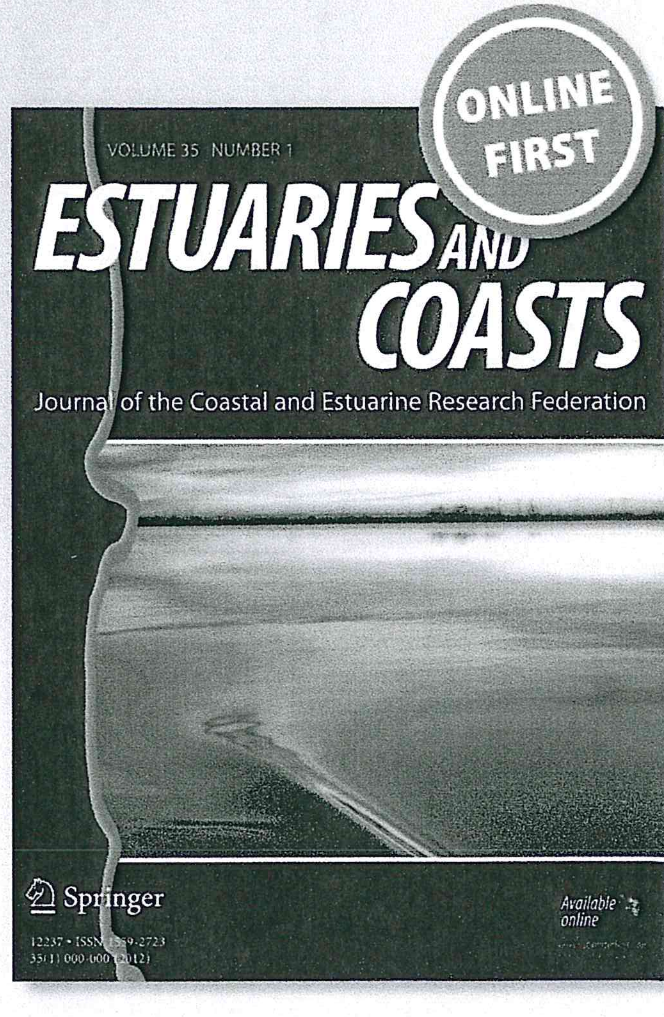
Patterns of Surf Smelt, Hypomesus pretiosus, *Intertidal Spawning Habitat Use in Puget Sound, Washington State*

Timothy Quinn, Kirk Krueger, Ken Pierce, Daniel Penttila, Kurt Perry, Tiffany Hicks & Dayv Lowry

Estuaries and Coasts
Journal of the Coastal and Estuarine Research Federation

ISSN 1559-2723

Estuaries and Coasts
DOI 10.1007/s12237-012-9511-1



Springer

Estuaries and Coasts
DOI 10.1007/s12237-012-9511-1

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Patterns of Surf Smelt, *Hypomesus pretiosus*, Intertidal Spawning Habitat Use in Puget Sound, Washington State

Timothy Quinn · Kirk Krueger · Ken Pierce · Daniel Penttila · Kurt Perry · Tiffany Hicks · Dayv Lowry

Received: 27 June 2011 / Revised: 16 April 2012 / Accepted: 26 April 2012

Abstract Surf smelt *Hypomesus pretiosus* are an important part of the Salish Sea food web and obligate beach spawners, yet little is known about the spatiotemporal distribution of spawning and beach characteristics related to spawning success. We counted smelt eggs at 51 sites around Camano Island, Puget Sound, Washington every 2 weeks for 1 year and at 13 of those 51 sites each month in the following year. At each site, we measured beach characteristics hypothesized to affect spawning habitat suitability as measured by egg abundance and mortality. Eggs were collected at 45 sites and pooled by month for analyses. Few sites (N=10, 19.6 %) contributed 87 % of total eggs and 89 % of all live eggs collected. Mean total egg counts at sites were higher ($p<$ 0.019) in Jul–Sep (1,790.7, SE=829.5) than in Jan–Mar (26.1, SE=10.2). Principal component and regression analyses suggested that aspect, fetch, solar radiation, and beach temperature predicted egg abundance but not mortality. Because a small proportion of sites appear to support most spawning activity, a conclusion consistent with year 2 egg counts, impacts to relatively few beaches could greatly affect surf smelt production.

T. Quinn (✉) · K. Krueger · K. Pierce · D. Penttila · K. Perry · T. Hicks · D. Lowry
Science Division, Washington Department of Fish and Wildlife Habitat Program,
600 Capitol Way N,
Olympia, WA 98501, USA
e-mail: Timothy.Quinn@dfw.wa.gov

Present Address:
D. Penttila
Salish Sea Biological,
5108 Kingsway,
Anacortes, WA 98221-3018, USA

Published online: 19 June 2012

Keywords Osmeridae · Forage fish · Beach spawning · Egg survival

Introduction

Marine nearshore and intertidal environments are used for spawning and early rearing by diverse fishes (Moffatt and Thomson 1978; Carscadden et al. 1997; Nakashima and Taggart 2002) and invertebrates (Brousseau et al. 2004; Jackson et al. 2005). Intertidal spawning by fish occurs on coastlines of four continents and several species representing at least six families spawn on beaches, including silverside (Atherinopsidae), killifish (Fundulidae), puffer (Tetraodontidae), smelt (Osmeridae), righteye flounders (Pleuronectidae), and stickleback (Gasterosteidae) (Penttila 1995, 2007; Martin and Swiderski 2001). The nearshore environment of the Salish Sea (Puget Sound and Georgia Basin) is spawning and rearing habitat for several fish and wildlife species (Simenstad et al. 1979; Kozloff 1983; Kruckeberg 1991; Thuringer 2003; Townsend et al. 2006). At least three species of fish, surf smelt *Hypomesus pretiosus*, sand lance *Ammodytes hexapterus*, and rock sole *Lepidopsetta bilineata*, spawn in the intertidal zone of the Salish Sea (Schaefer 1936; Penttila 1995, 2007). Sand lance burrow into intertidal sediment during winter months (Quinn 1999), presumably as an energy conservation strategy (Winslade 1974), and Pacific herring *Clupea pallasii*, spawn on shallow subtidal macrophyton beds of the region (Gonyea et al. 1982; Penttila 1995). These species, commonly referred to as forage fish, are crucial components of marine food webs (Therriault et al. 2009) that are increasingly threatened by nearshore development from a growing human population (Penttila 2007; Anderson et al. 2009). Insufficient knowledge of the use of nearshore habitats by forage fish limits our ability to guide development while conserving forage fish habitat.

Marine coastal areas, which comprise some of the most intensively developed landscapes throughout the world, are subjected to two frequent and important anthropogenic disturbances: shoreline armoring and removal of terrestrial vegetation (Fletcher et al. 1997; Griggs 2005; Dugan and Hubbard 2010; Krueger et al. 2010). Armoring to protect shorelines from erosion has a long history (Charlier et al. 2005), and armoring is expected to be more frequent and extensive because of rapid human populations growth near coasts (Crossett et al. 2004) and the perceived need to protect shorelines and developed areas from the effects of climate change (Scavia et al. 2002). Several recent studies in Puget Sound suggest that these disturbances can impair nearshore processes, including sediment delivery and transport and shading by riparian vegetation, which in turn affects species richness, abundance, and productivity (Romanuk and Levings 2006; Dethier and Berry 2010).

Better understanding of the spatiotemporal spawning patterns of forage fish will facilitate the conservation of their habitat as development along shorelines intensifies. We examine spatiotemporal patterns of surf smelt spawning because this species receives special protection from development, their behavior is relatively well understood, and conservation and research effort directed toward surf smelt might benefit other species. The obligate intertidal spawning behavior of surf smelt (hereafter smelt) in the Salish Sea is one of the best-documented aspects of their life history (Penttila 1995, 2007). Smelt spawn in the upper third of the tidal range in Puget Sound and appear to be tolerant of a wide range of salinities and wave energy regimes (Penttila 1978; 2001, 2002, 2007). However, recent research confirms that loss of nearshore vegetation reduces the suitability of smelt spawning habitat (Penttila 2001, 2002; Rice 2006; Rossell 2006; Lee and Levings 2007; Toft et al. 2007; Slack et al. 2010). We use suitability here to describe habitat quality, where quality can range from non-habitat to optimal habitat with maximal carrying capacity for a life stage (sensu USFWS 1981). Although smelt eggs appear to be somewhat resistant to thermal and desiccation stress, the eggs of fish spawning in summer and early fall suffer higher egg mortality on exposed beaches than on beaches with overhanging vegetation (Rice 2006; Lee and Levings 2007; Slack et al. 2010). In laboratory experiments, surf smelt eggs developed most successfully in a narrow relative humidity range (80–93 %) (Lee and Levings 2007) that on beaches is strongly dependent upon vegetative shading, sediment grain size (Penttila 2001, 2002), and both sediment and atmospheric temperature in the intertidal zone.

The effects of shoreline armoring on smelt spawning habitat is less clear, but shoreline armoring can decrease beach nourishment from eroding (feeder) bluffs and increase reflected wave energy, which lowers elevation and coarsens sediments of beaches in the upper intertidal zone (Baldwin and Lovvorn 1994; Toft et al. 2007). Spawning habitat in Puget Sound is typically found where waves and currents sort the available substrate into a sand–gravel mix with most sediment between 1 and 7 mm in diameter (Penttila 2001, 2002, 2007). Changes in the distribution of sediment to size ranges outside this window are expected to affect surf smelt spawning site selection and, perhaps, egg and larval mortality. In laboratory studies, small quantities of both suspended and settled silt were found to dramatically decrease larval smelt survival (Morgan and Levings 1989). On the other hand, Penttila (2007) suggested that most apparently suitable beaches in Puget Sound, based on substrate characteristics, do not support spawning activity, and population density, behavioral or environmental factors almost certainly also determine whether a beach supports spawning. As a result, in any given year, only approximately 30 % of the known smelt spawning beaches in Puget Sound support spawning (D. Penttila, unpublished data). While spawning seasons are coarsely known for some locations in Puget Sound; little is known about the temporal distribution of egg abundance or viability due to a lack of comprehensive temporal sampling.

The Washington Department of Fish and Wildlife (WDFW) protects fish life and habitat by administering the "Hydraulic Code" (Revised Code of Washington 77.55), which regulates work that uses, obstructs, diverts, or changes the natural flow or bed of state waters. The WDFW implements the law via the hydraulic project approval (HPA) permit process. Permits issued by the WDFW include provisions unique to the project type and physical setting that attempt to avoid, minimize, or mitigate for activities that may affect fish life in Washington's lakes, streams, rivers, and marine environments. Given our relatively rudimentary understanding of beach spawning fish ecology, provisions to protect forage fish are typically limited to work timing windows that determine when construction activities can occur. Further, all forage fish spawning sites as determined solely by presence of eggs are currently treated equally in the permitting process and in WDFW guidance to local governments.

Our objectives were to (1) characterize the annual spatiotemporal distribution of smelt spawning over a wide variety of physical conditions in a region of Puget Sound in an effort to improve the hydraulic permitting process and technical guidance to local governments involved in development and conservation planning; (2) investigate how variation in characteristics of the beach environment affect the suitability of spawning habitat, as measured by egg abundance and mortality rates; and (3) use statistical models to quantitatively explore relationships between habitat characteristics that we postulated might dictate the suitability of smelt spawning habitat. Finally, we conducted an exploratory analysis of interannual correlations within and among sites and the consistency of spawn abundance across years.

Materials and Methods

Study Area

Camano Island is located in Puget Sound, Washington State, between Whidbey Island and the mainland (study area; Fig. 1) and is connected to the mainland by a bridge. It has an area of approximately 103 km^2 and a shoreline length of approximately 84 km based on the Washington Department of Natural Resources ShoreZone inventory data (http://128.208.23.127/website/DNR_Shorezone/DNR_SZ/szdoc/sz_hdr.htm), of which 31 % is armored (Puget Sound Nearshore Ecosystem Restoration Project 2009). We established 51 sampling sites along the shoreline of Camano Island (study area; Fig. 1) using a stratified random design. We selected study sites by calculating the total length of marine shoreline, excluding marshy wetland habitat along the northeast portion of the island. We excluded this habitat type because it has been consistently devoid of forage fish eggs in repeated sampling (D. Penttila, unpublished data) and because it has extensive low tide terraces composed of fine-grain sediments (silt) that are dangerous to traverse. We randomly established the first sampling site adjacent to the marsh in the first 300 m of the northeast end of the study area and, using ArcMAP (Version 9.3.1, ESRI, Redlands, CA, USA), located additional sampling sites clockwise at ~1.2 km intervals along the shoreline until we reached the northern end of the study area (Fig. 1). Sample site locations were transferred to Washington Department of Ecology oblique aerial photographs (http://apps.ecy.wa.gov/shorephotos/links.html) so that they could be located by boat using easily identifiable shore topographic features.

Sampling Approach

We visited all sampling sites by boat once every 2 weeks (referred to as a sample session) during each month beginning the week of 10 Sep 2007 and ending the week of 18 Aug 2008 (24 sample sessions). All sites were permanently assigned to one of three sampling routes. A two-person crew typically required 3 days to complete a sample session, with the crew sampling one route each day. We attempted to sample over consecutive days within a sample session, to space sample days between sessions as close to 12 days as possible, and to change route sampling order among sample sessions. The total number of sites sampled during a session and the sample schedule was based on logistical and ecological considerations. Sampling was performed on the lowest available daytime tides within each sample session. Given a two-person crew and the availability of suitable daytime tides, it was determined that the 51 sites could reliably be surveyed over the course of a year.

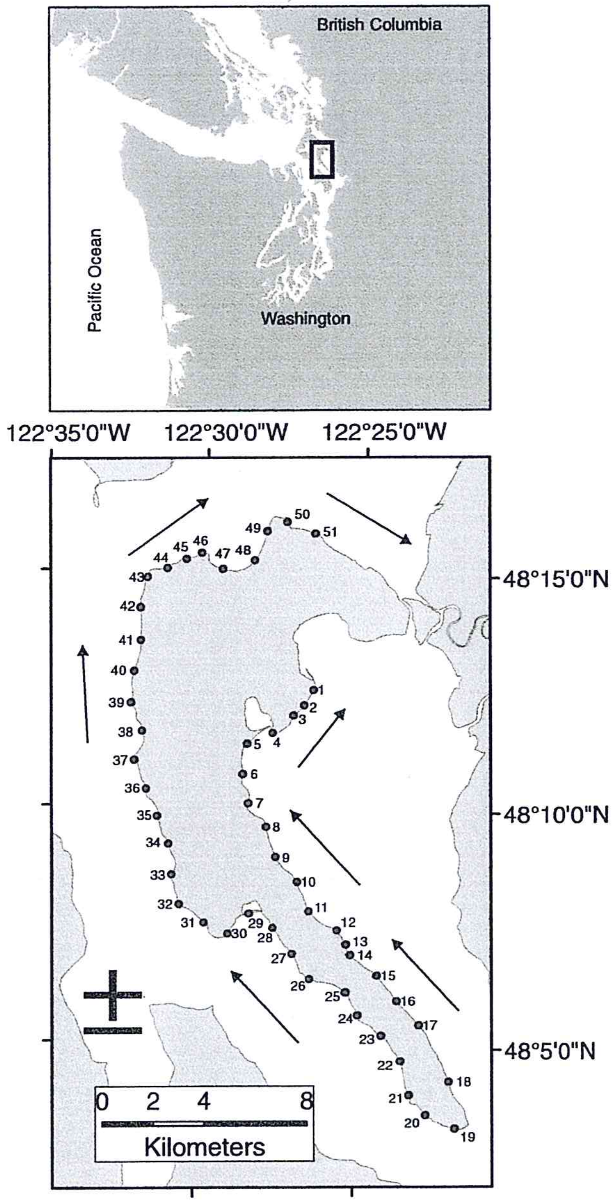

Fig. 1 Map of Camano Island, Puget Sound, Washington showing distribution of 51 sampling sites. **a** The geographic context of Puget Sound relative to the Pacific Ocean and British Columbia. **b** Camano Island with sampling sites labeled. *Arrows* indicate dominant sediment drift flow direction, not including small back eddies and interactions with shore features

At each sampling site, we placed markers to establish two permanent, 30-m transects parallel to the waterline, one at +2.6±0.2 m and the other at +3.2±0.2 m above mean lower low water (MLLW). At each site, the permanent transect elevation was determined by marking the water elevation at a specific time (during calm weather) for which tidal elevation was known. Hereafter, all beach elevations are in reference to MLLW and measured from the elevation of the two permanent transects.

Sampling for forage fish eggs consisted of taking a 500-ml scoops of surface sediment to a depth of approximately 5 cm at four locations (3, 11, 19, and 27 m) along each 30-m permanent transect (Moulton and Penttila 2001, 2006; Penttila 1995). Sediment and eggs from all subsamples for a given permanent transect were combined, transported to the laboratory, and processed on the day they were collected. Samples were processed by wet-screening them through a stacked series of sieves (4, 2, and 0.5 mm), progressively removing sediment while retaining eggs and egg-sized sediment. The remaining light fraction (fine sediment and eggs) was decanted into a washbasin, covered with 3 to 5 cm of water, and agitated to suspend lighter material, following Penttila (1995). After hydraulic winnowing, the surface 0.5–1 cm of the resulting deposit was skimmed off using a wide-mouthed sample jar. This winnowing process was repeated at least three times per sample to ensure adequate egg discovery probability (Moulton and Penttila 2001, 2006). The light fraction sub-sample was preserved in Stockard's Solution (aqueous mix of 4 % glacial acetic acid, 5 % formaldehyde, and 6 % glycerol). This preservative renders fish embryos opaque while leaving the yolk sac and other egg contents translucent, thus aiding in egg sample analyses. Using a dissecting microscope, eggs were identified to species, sorted into different cohort or age classes based on developmental stage, and scored as either live or dead (Penttila 1995). Live and dead eggs are treated as count data as opposed to density data since expanding them to the entire beach area would require egg distribution data that we did not collect and because we assumed that counts from standardized samples at each site were directly comparable. Our sampling method was developed based on over 30 years of sampling and analysis of more than 10,000 samples. Our previous work has shown that the collection of the top 5 cm of beach sediment collects virtually all smelt eggs and that collection, and processing of eggs on the same day as collection does not result in significant mortality.

In addition to the sampling described above, from August 2009 through July 2010, we sampled the upper permanent transect of 13 sites (sites 38–50, northwest portion of Camano Island) once per month. These sites were selected because, together, they exhibited a large range in annual egg counts during the first year of sampling. The intent of this additional sampling was to assess interannual correlations within and among sites and the consistency of high spawn abundance across years (i.e., 2007–2008 vs. 2009–2010).

Characterizing Sampling Sites

A suite of physical characteristics of all surveyed beaches were quantified once during the summer of 2009 to identify characteristics correlated with egg abundance and survival. Physical characteristics were selected based on a review of the literature describing intertidal spawning by fish and invertebrates and processes that affect the structure and function of beaches. Site-specific physical characteristics were measured in the field, whereas beach-scale physical characteristics were calculated using a geographic information system. Beach-scale physical characteristics were expected to change more slowly than, and affect the structure of, site-specific physical characteristics. We recognize that we did not measure some physical characteristics that may affect smelt spawning, but we expected to identify appropriate spatial scales and characteristics worthy of further study. At each sampling site, two temporary transects were established perpendicular to, and intersecting each end of, the 30-m permanent transect described above. Along these temporary transects, we measured beach slope between 1.3 and 3.2 m tidal elevation (Low_slope), between 3.2 m and mean higher high water (MHHW) (Mid_slope), and between MHHW and ordinary high water (OHW) (High_slope). The OHW was defined as that elevation where aquatic or semi-aquatic vegetation is replaced by terrestrial vegetation, or where terrestrial vegetation begins. At sites with no apparent physical evidence of the OHW (majority of sites), we estimated OWH to be MHHW +0.5 m. For each site, we then determined the (1) type of backshore control structure (berm, bulkhead, or bluff face); (2) elevation (Ele_control) of the toe of the bulkhead or bluff face, or in the case of a berm, the elevation of the slope break between the upper beach and berm; (3) elevation of the seaward (Ele_sea) and landward (Ele_land) edge of the drift wood zone; (4) width of the area where driftwood zone (Wood_width); and (5) volume of wood (Wood_vol) in the driftwood zone (i.e., 30 m×Wood_width). The driftwood zone was measured only where driftwood was present. Wood volume was determined during the summer of 2008 by tallying all wood pieces by 5-cm-diameter classes starting at a minimum of 10 cm at the thickest end and 60-cm-length classes starting at a minimum of 60 cm. Midpoints of diameter and length classes were used to calculate wood volumes at each site.

During the late summer period of high smelt egg abundance in 2008, additional sediment samples were collected along the upper transect at each site to evaluate beach sediment characteristics. Samples were spread out on shallow, plastic-lined trays and completely air dried in a protected alcove within a storage facility at the WDFW La Conner office. Drying typically took 3–7 days and was facilitated by gentle stirring and occasional transfer to a

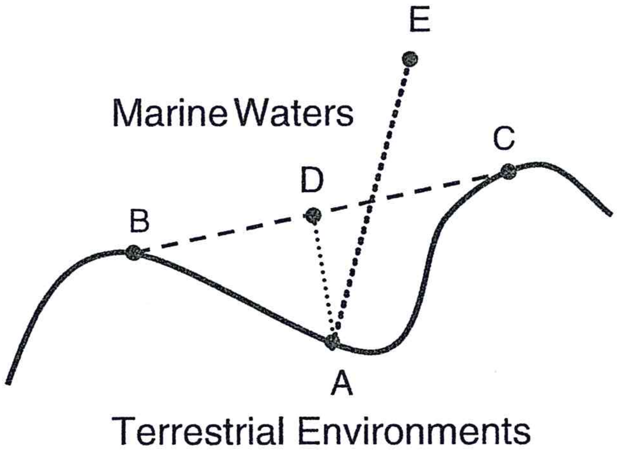

Fig. 2 For each of the 51 beach sample sites (e.g., site *A*), we calculated a number of characteristics. Beach sinuosity is the ratio of the shoreline length (*BAC*) to the straight-line (*BC*) length between two points (*B* and *C*) on the shoreline, equidistance from, and located on either side of the sample site. Concavity is the distance from the midpoint of the chord to the shoreline (DA) measured at a right angle to the chord. Sinuosity and concavity were determined at two scales, 500 and 5,000 m. Concavity was negative when the sample site was exposed and positive when protected (shown here). Aspect was determined at the sample site (represented here by *AE*), and Loc_10 and Fetch were distances measured from the sample site in the direction of *AE* to the 10-m depth contour and nearest land, respectively

50 for 2008–2009 and 2009–2010. For all statistical tests, we chose $\alpha=0.05$ (Table 1).

Regression Analyses

We employed an information theoretic approach to explore the relationship between egg counts and physical characteristics of the shoreline. Following the methods described by Burnham and Anderson (2002) and based on extensive literature review and our field observations, we assembled eight candidate models a priori to explain variation in egg counts on the upper transect as a function of shoreline characteristics. We calculated Pearson correlations between egg count variables (i.e., Total_eggs, Live_eggs, and Dead_eggs) to determine the most appropriate response variables. We selected predictor variables and determined the structure of the candidate models to allow comparison of predictor importance as measured at the spatial extent of sites and beaches. Before conducting the analyses, we examined the data to address regression assumptions (Beaudreau and Essington 2007). We removed beach characteristics for which we were missing relatively large amounts of data because this would reduce the sample size (number of sites) of the analysis. For pairs of predictor variables that were highly correlated ($r \geq 0.7$), we eliminated one and retained the characteristic deemed most interpretable. We then constructed a model containing the following characteristics, Northness, Fetch, Concav_5000, GSF, Max_temp, Wood_vol, and D_{50}, followed by construction of seven nested subset models using combinations of these characteristics (see Table 2). Before running regression models, we examined scatter plots of all individual shoreline characteristics (predictor) versus egg counts (potential response variable). When plots of residuals versus fitted values indicated a non-linear relationship, we attempted to linearize the relationship by systematically applying various transformations to the predictor variable until we maximized the r^2 of the simple regression. We used t tests to evaluate the null hypothesis that slope was equal to zero (Table 3).

The "best" models were based on corrected Akaike's information criterion (AIC_c), which indicates the best compromise between goodness-of-fit and model parsimony (Burnham and Anderson 2002). Models with delta AIC_c less than 7 were regarded as supported by the data (Burnham and Anderson 2002, p. 70).

Table 1 Pearson correlation coefficient matrix between variables describing surf smelt egg counts from 51 sites around Camano Island, Washington during 2007–2008

	Total_eggs	Live_eggs	Dead_eggs	Mort_rate
Total_eggs	1.000			
Live_eggs	0.972	1.000		
Dead_eggs	0.773	0.604	1.000	
Mort_rate	−0.289	−0.345	−0.049	1.000

Principal Component Analysis

We conducted a principal component analysis (PCA) to condense the suite of beach characteristics measured/calculated in situ and from DNR ShoreZone data into a smaller set of compound components. We used PCA to help describe covariance patterns in beach characteristics for descriptive rather than confirmatory purposes (Tabachnick and Fidell 1989, p. 599). We hypothesized that beach characteristics were likely to respond to a few dominant environmental gradients, such as exposure to storm patterns, wave energy, and shoreform and that we could describe variation in beach characteristics in simpler ways by identifying these gradients.

Similar to the regression modeling above, we first removed variables describing beach characteristics for which we were missing relatively large amounts of data. For pairs of predictor variables that were highly correlated ($r \geq 0.7$), we eliminated one and retained only the variable deemed most interpretable. Although not strictly necessary for PCA, removing correlated variables increases the ratio of sample size to the number of observed variables. We examined univariate stem and leaf, box, and normality plots for each attribute to identify suspected outliers and, when they were

Table 2 Mean and range of response and predictor variables quantified in situ (site-specific) or derived from DNR ShoreZone data (beach scale)

Name	Scale	Description	Units	Mean	Range	r^2	p
Response variables							
Live_eggs		Mean live eggs per month	Eggs/month	3,967	0–93,374		
Dead_eggs		Mean dead eggs per month	Eggs/month	2,405	0–21,880		
Total_eggs		Mean total eggs per month	Eggs/month	6,372	0–113,643		
Predictor variables							
Vis_sky	Site	View to sky	Proportion	0.67	0.31–0.87	0.015	0.389
GSF	Site	Global site factor	Proportion	0.77	0.06–0.99	0.213	0.001
D_{50}	Site	Median sediment size	mm	6.4	0.6–30.3	0.068	0.067
D_{50}_SD	Site	Standard deviation of sediment size distribution	Phi	2.0	0.6–3.9	0.017	0.364
Low_slope	Site	Slope of lower beach	%	9.6	3.6–15.3	0.255	0.000
Mid_slope	Site	Slope of mid beach	%	13.7	3.3–132.0	0.074	0.054
Ele_control	Site	Elevation of the tidal control structure	m	3.7	2.6–4.4	0.058	0.089
Wood_width	Site	Width of the zone where drift wood collects	m	4.4	0.3–7.9	0.128	0.010
Wood_vol	Site	Volume of drift wood	m^3	6.0	0–77.3	0.012	0.442
Northness	Beach	Shoreline aspect: north (+1) to south (−1)	Index	−0.05	−0.96–0.99	0.574	0.000
Fetch	Beach	Distance to nearest land	m	6,218	1,692–14,446	0.120	0.013
Loc_10	Beach	Distance to depth of 10 m	m	1,303	66–10,599	0.034	0.194
Sinu_500	Beach	Sinuosity of 500 m segment	Index	1.0	1.0–1.6	0.022	0.320
Sinu_5000	Beach	Sinuosity of 5,000 m segment	Index	1.3	1.0–2.9	0.046	0.129
Concav_500	Beach	Concavity of 500 m segment	Index	−26.7	−430–229	0.007	0.569
Concav_5000	Beach	Concavity of 5,000 m segment	Index	−859	−4,615–3,463	0.000	0.995
Max_temp	Site	Mean of 27 max daily temps	°C	27.2	18.1–34.9	0.124	0.016
Min_temp	Site	Mean of 27 min daily temps	°C	18.6	15.5–21.5	0.233	0.001

We systematically applied various transformations to the predictor variable to meet normality assumptions and until we maximized the r^2 of the simple regression between that variable and log(Live_eggs + 1); p values were based on t tests to evaluate the null hypothesis that slope was equal to zero. Variables D_{50}, D_{50}_SD, Mid_slope, Ele_control, Fetch, Loc_10, and Min_temp were Log_{10}-transformed, and Northness and Max_temp were square root transformed. Wood_vol was transformed by (SQRT(Wood_vol) + SQRT(Wood_vol + 1))

not normally distributed, transformed variables to improve normality as determined by Lilliefors test (Systat 12). We conducted our PCA (Systat 12) using the correlation matrix of 20 beach characteristics (see Table 2 for list of variables) with no component rotation. To explore potential relationships among egg abundance and mortality rate, and principal components, we regressed log(Total_eggs +1) and mortality rate from the upper transect at each site against each of the most important principal components. We used data from the upper transect alone because these data were more complete, i.e., included a larger number of sample sites than the lower transect data set.

Results

Sampling was occasionally curtailed due to winter weather conditions, especially at a few sites. We completed sampling during 1,131 and 1,094 of 1,224 possible site visits (51 sites × 24 visits) at the upper and lower transects, respectively. When summarized by month, we sampled 607 and 592 of 612 possible site visits (51 sites × 12 visits) at the upper and lower transects, respectively. By excluding December samples, we fully populated egg count data for all other site × month combinations for the upper transect. Likewise by excluding samples for December and for sites 14 and 44, we fully populated egg count data for all other site × month combinations for the lower transect.

Eggs were found at least once on 45 of 51 sites over the course of the study. The spatial distribution of egg counts around the island was clumped with about 20 % of sites contributing the vast majority of eggs (Fig. 3). Few sites (N=10, 19.6 %) contributed 87 and 89 % of Total_eggs and Live_eggs collected, respectively. Two relatively discrete areas of the shoreline, one on the eastern shore and another on the northwestern shore, had the highest egg abundance. Site 45 (Fig. 1) had the highest average eggs counts and over twice as many eggs as any other site. Annual counts of Total_eggs on upper transects ($mean_{sites}$=516.7, SE=225.4) were correlated (r=0.71, $t_{0.05(2), 47}$=6.856, p<0.001) with, but not

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Table 3 Models considered in the information theoretic approach

Model	Variables	r^2	AIC_C	ΔAIC_C	$Exp(0.5\times\Delta AIC_C)$	Rank
L1	Northness, Fetch, Concav_5000, GSF, Max_temp, Wood_vol, D_{50}	0.612	133.46	1.46	0.482	3
L2	Northness, Fetch, Concav_5000, GSF	0.611	138.47	6.47	0.039	7
L3	Northness, GSF, Max_temp	0.519	135.28	3.28	0.194	5
L4	Northness, Fetch, GSF, Max_temp, Wood_vol	0.596	133.10	1.10	0.578	2
L5	GSF, Max_temp, Wood_vol, D_{50}, Northness, Fetch, Concav_5000	0.612	133.46	1.46	0.482	3
L6	GSF, Max_temp, Wood_vol, Northness	0.561	133.98	1.98	0.371	4
L7	GSF, Wood_vol, Northness, Fetch, Concav_5000	0.632	138.44	6.44	0.040	6
L8	GSF, Max_temp, Northness, Fetch	0.580	132.00	N/A	N/A	1
M1	Northness, Fetch, Concav_5000, GSF, Max_temp, Wood_vol, D_{50}	0.024	51.69	2.95	0.229	4
M2	Northness, Fetch, Concav_5000, GSF	0.024	54.19	5.44	0.066	6
M3	Northness, GSF, Max_temp	0.011	48.74	N/A	N/A	1
M4	Northness, Fetch, GSF, Max_temp, Wood_vol	0.038	53.03	4.29	0.117	5
M5	GSF, Max_temp, Wood_vol, D_{50}, Northness, Fetch, Concav_5000	0.024	51.69	2.95	0.229	4
M6	GSF, Max_temp, Wood_vol, Northness	0.038	50.21	1.46	0.481	2
M7	GSF, Wood_vol, Northness, Fetch, Concav_5000	0.054	55.37	6.62	0.036	7
M8	GSF, Max_temp, Northness, Fetch	0.016	51.19	2.45	0.294	3

Models use either live egg (L1–8) or mortality rate (M1–8) as the response variable. AIC_C was used to determine the best model and other models in the subset were ranked for validity relative to the best model. For descriptions of variables and how they were transformed to improve normality, see Table 2

significantly different ($t_{0.05(2),\ df=48}=1.94$, $p<0.059$) from, annual counts of Total_eggs at lower transects ($mean_{sites}=125.6$, SE=35.3). Egg counts varied seasonally, with peak abundance in late summer and early fall, though Live_eggs (albeit often in small number) were found during all months of the year at both transects (Fig. 4). Summer counts of Total_eggs ($mean_{sites}=1,790.7$, SE=828.5) were significantly higher ($t_{0.05(2),\ df=48}=2.13$, $p<0.019$) than winter counts of Total_eggs ($mean_{sites}=26.1$, SE=10.2), but summer counts of Live_eggs ($mean_{sites}=955.8$, SE=632.2) were not significantly different ($t_{0.05(2),\ df=48}=2.13$, $p<0.069$) from winter counts of Live_eggs ($mean_{sites}=4.3$, SE=1.7). Mortality rates peaked in summer at around 75 % just before egg counts reached their seasonal maximum and then declined to less than 20 % in late September at both transects (Fig. 4). Egg mortality rates on upper transects ($mean_{sites}=0.589$, SE=0.031) were significantly higher ($t_{0.05(2),\ df=33}=-3.21$, $p<0.003$) than mortality rates at lower transects ($mean_{sites}=0.458$, SE=0.031).

Egg counts at 13 sites were fairly consistent between years. Counts of Live_eggs on upper transects in 2009–10 were correlated ($r=0.756$, $t_{0.05(2),\ 11}=8.78$, $p<0.001$) with counts of Live_eggs in 2008–09 suggesting interannual stability in spawning site usage.

Regression Analyses

All potential response variables were correlated with each other, though some weakly (Table 1). Live_eggs and Total_eggs were highly correlated ($r=0.972$), but r^2 values for regression models were generally higher for Live_eggs; thus, we concentrated modeling efforts on Live_eggs and Dead_eggs as response variables.

Seven predictor variables (GSF, Low_slope, Wood_width, Northness, Fetch, Max_temp, Min_temp) exhibited significant linear relationships with Live_eggs, with Northness having the highest r^2 (0.574). Nine predictor variables had significant linear relationships with Dead_eggs including the same seven variables as Live_egg regressions plus D_{50} and Sinu_5000. The best models for Live_eggs and Dead_eggs both contained GSF, Northness, and Max_temp (Tables 2 and 4). Additionally the best model for Live_eggs included Fetch. Concav_5000 and D_{50} were not included in the top models for either response variable or inclusion of Wood_vol varied (Tables 2 and 4).

Principal Component Analysis

We computed eigenvectors utilizing 16 beach characteristics and retained the first three principal components for interpretation (Table 5) based on the broken stick criterion (Jackson 1993). These first three components explained 23.83, 15.01, and 10.60 % of the total sample variance, respectively (Table 5). Based on the relative percent variance criterion alone, which suggests that the cumulative percent variance of the first one to three components should be greater than 70 %, this PCA does not dramatically reduce the dimensionality of the beach variation. Nevertheless, each of the first three components explains significantly

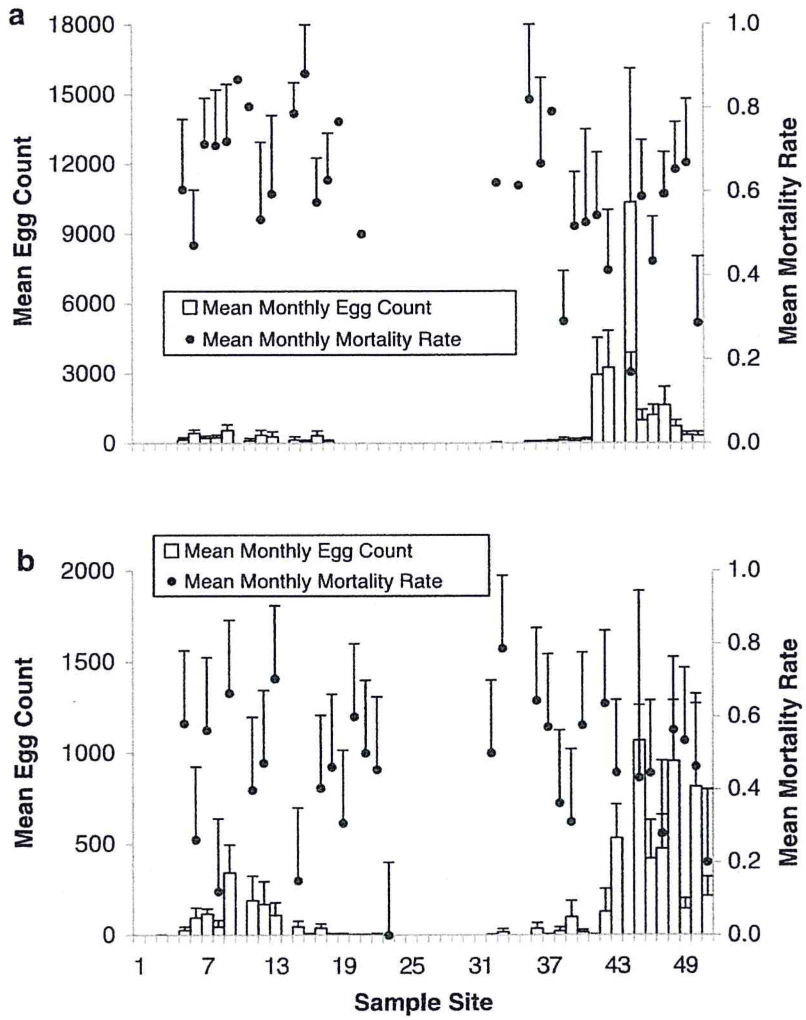

Fig. 3 Mean monthly egg counts (and mortality rates) calculated by summing egg counts (and mortality rates) across all months at each site and dividing by the number of months sampled. *Error bars* represent 1 standard error. **a** Upper transect, **b** lower transect. Note difference in scales of the first *y*-axis of **a** and **b**

more variation than would be expected if there were no structure to the dataset. We based our interpretation of each component on variables with loadings > |0.45| with more emphasis placed on higher loadings, particularly those > |0.60| (Table 5).

The first component represents a gradient from south facing, relatively flat beaches with high GSFs, high elevation controls, large wood collection zones, large volumes of wood, and higher maximum sediment temperatures, to north facing, relatively steep beaches located in concave shoreforms with low GSFs and cooler maximum sediment temperatures. Note the strongly inverse relationship between Northness and GSF, as well as between Northness and Max_temp (Table 5). Beaches with southerly aspects would be expected to have higher sediment temperatures consistent with higher GSF. The second component represents a gradient of beaches within concave shoreforms, with large fetches, and large volumes of drift wood, to beaches in sinuous shoreforms, with small fetches, and small volumes of wood. Three of the 16 original variables (Loc_10, Sinu_5000, and D_{50}_SD) did not load on either of the first two components and apparently do not contribute to the beach site gradient. Live_Egg counts were significantly associated ($F_{1,43}$=22.49, p<0.000) with PC1 scores (Log (Live_egg+1)=−8.50×PC1scores+2.20; r^2=0.34), but not PC2 scores (p=0.23).

Discussion

We found pronounced and consistent spatiotemporal patterns of surf smelt spawning on Camano Island, and these patterns can inform improved conservation efforts. The spatial distribution of egg occurrence was highly continuous, with smelt eggs found at nearly every site sampled over the course of a year, including many beaches where previous, less-intensive sampling failed to document smelt spawning. Although surveys to detect smelt spawning have been

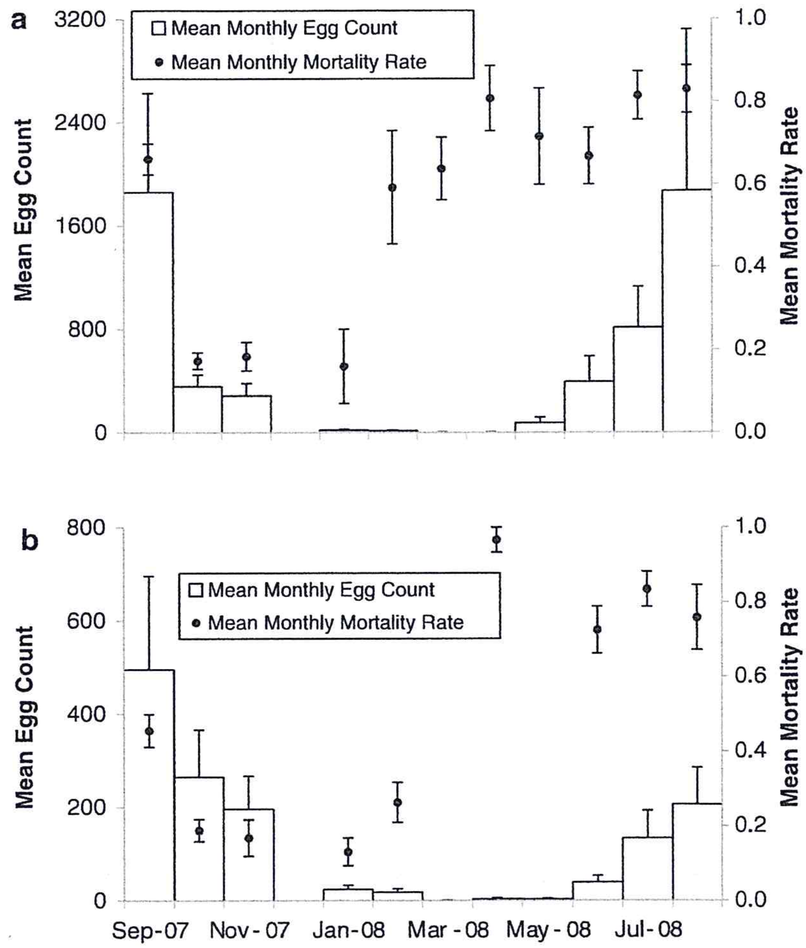

Fig. 4 Mean monthly egg counts (and mortality rates) calculated by summing egg counts (and mortality rates) across all sites each month and dividing by the number of sites sampled. *Error bars* represent 1 standard error. **a** Upper transect, **b** lower transect. Note difference in scales of the first *y*-axis of **a** and **b**

conducted throughout much of Puget Sound (Penttila 2007), our knowledge of spawning locations and their relative importance both intra- and inter-annually remains incomplete. Spawning beaches likely differ dramatically in production of smelt and their value for maintaining population abundance. The spatial distribution of egg abundance was nonuniform; sites on the northwestern edge of the study area (sites 42–48) contained up to several orders of magnitude more eggs than other regions of the island, a pattern that was consistent between years. This marked dominance in usage as spawning sites existed despite broad variation among these sites in some beach characteristics, including median sediment particle size, beach slope, backshore control type and height, wood band width, sinuosity, and concavity. However, in addition to being located in the northwest region of the study area, these sites were united by comparatively low maximum sediment temperatures, substantially greater fetch, narrow wood bands, and (except site 42) a north-facing beach aspect. The results of both our information theoretic approach and PCA support this overall trend toward high-use spawning beaches being characterized by medium to high potential wave action (e.g., high fetch, narrow wood bands) and low solar exposure (e.g., north facing, low GSF, lower maximum temperature).

The results of our study are consistent with studies of capelin (*M. villosus*), suggesting that processes affecting spawning usage are likely similar among species and locations. Use of spawning beaches by capelin, as well as egg abundance on spawning beaches, has been linked to beach aspect (orientation) and the degree of substrate size sorting in Conception Bay, Newfoundland, Canada (Nakashima and Taggart 2002; Taggart and Nakashima 1987). The dominant orientation of high-use spawning beaches was northeasterly for capelin, which matches the geophysical context of spawning beaches in the current study with respect to fetch, prevailing wave action, and solar exposure. Additionally, Nakashima and Taggart (2002) noted that sediment size profiles within a beach may change seasonally as a consequence of changes in prevailing winds and resultant wave action. We only quantified sediment profiles during summer months so the degree to which those profiles change by season, and the resultant effects on egg retention and

Table 4 Standardized regression coefficients and p values for each independent variable describing beach characteristics used to explain live eggs counts (models L1–8) and mortality rate (models M1–8)

Effect	Model L1		Model L2		Model L3		Model L4		Model L5		Model L6		Model L7		Model L8	
	Coef	p	Coef	p	Coef	p	Coef	p	Coef	p	Coef	p	Coef	p	Coef	p
Northness	0.619	0.000	0.564	0.000	0.635	0.000	0.606	0.000	0.619	0.000	0.695	0.000	0.629	0.000	0.549	0.000
Fetch	0.248	0.048	0.288	0.006			0.211	0.075	0.248	0.048			0.238	0.028	0.260	0.022
Concav_5000	−0.192	0.117	−0.133	0.184					−0.192	0.117			−0.164	0.104		
GSF	−0.205	0.098	−0.249	0.020	−0.187	0.121	−0.220	0.056	−0.205	0.098	−0.202	0.085	−0.256	0.016	−0.215	0.062
Max_temp	−0.018	0.878			0.008	0.944	0.039	0.733	−0.018	0.878	0.051	0.662			0.011	0.923
Wood_vol	0.144	0.240					0.143	0.223	0.144	0.240	0.215	0.062	0.168	0.122		
D_{50}	−0.032	0.785							−0.032	0.785						
Effect	Model M1		Model M2		Model M3		Model M4		Model M5		Model M6		Model M7		Model M8	
	Coef	p	Coef	p	Coef	p	Coef	p	Coef	p	Coef	p	Coef	p	Coef	p
Northness	0.033	0.876	0.127	0.455	0.015	0.934	−0.025	0.900	0.033	0.876	−0.034	0.853	0.049	0.786	0.040	0.831
Fetch	−0.020	0.918	−0.122	0.449			−0.021	0.908	−0.020	0.918			−0.061	0.715	−0.077	0.646
Concav_5000	0.024	0.902	0.072	0.646					0.024	0.902			0.109	0.495		
GSF	0.074	0.700	0.042	0.797	0.067	0.695	0.080	0.642	0.074	0.700	0.079	0.644	0.051	0.758	0.075	0.664
Max_temp	−0.079	0.677			−0.090	0.595	−0.123	0.482	−0.079	0.677	−0.124	0.471			−0.090	0.596
Wood_vol	−0.094	0.623					−0.166	0.355	−0.094	0.623	−0.173	0.300	−0.200	0.246		
D_{50}	−0.089	0.636							−0.089	0.636						

For descriptions of variables and how they were transformed to improve normality, see Table 2

Table 5 Component loadings for six principle components derived from analysis of beach attributes measured on 46 beaches around Camano Island in Puget Sound

Beach attribute	PC1	PC2	PC3	PC4	PC5	PC6
Northness	**−0.770**					
Max_temp	**0.654**					
GSF	**0.625**					
Ele_control	0.577	0.462				
Min_temp	0.577					
High_slope	−0.574					
Mid_slope	−0.499		0.489			
Concav_500	−0.453	0.469				−0.475
Concav_5000		**0.615**				
Fetch		0.591				
Wood_vol		0.580				
Sinu_500		−0.542				
D_{50}		−0.468				
Loc_10			**0.714**			
Sinu_5000			0.485	−0.541		
D_{50}_SD					−0.573	−0.464

Loadings with absolute values < | 0.45 | were considered unimportant (Tabachnick and Fidell 1989) and not included here. Loadings > | 0.60 | are shown in bold for emphasis. For descriptions of variables and how they were transformed to improve normality, see Table 2

viability, cannot be directly evaluated. In addition, other factors such as predation on and off the beach and larval transport and rearing undoubtedly contribute to the suitability of surf smelt spawning sites. These factors were beyond the scope of our work but clearly warrant further study.

We postulate that the suitability of a beach for spawning by smelt is due primarily to characteristics of the beach and adjacent beaches. Beach characteristics are in turn determined by sediment source, exposure, and the energy available to shape beach morphology. Wave action influences beach form through erosion, transport, and deposition of sediment and organic matter (Dugan and Hubbard 2006, 2010; Patsch and Griggs 2006). Puget Sound is populated by numerous feeder bluffs composed of glacial till that contribute sediment to beaches. Due to limitations in fetch and the predominant direction of storms relative to the north south orientation of shorelines, wave action is typically oblique to shore in Puget Sound (Finlayson 2006; Johannessen and MacLennan 2007; Shipman 2008, 2010). This geomorphic setting produces sediment drift cells along which wave action and sediment turnover are relatively stable and predictable, barring storm events and human disturbance of the shoreline. The suitability of beaches for smelt spawning is likely related to its position within a drift cell. We suggest that on beaches where wave action has sorted the sediment appropriately, water percolation and retention may be balanced such that smelt eggs in the upper intertidal remain damp but not continually immersed. Moderation of relative humidity in a narrow window (80–93 %) is critical to surf smelt egg development (Lee and Levings 2007). As the prevailing winds in Puget Sound are strong and come from the southwest in winter and weaker and northerly in summer (Overland and Walter Jr. 1983; Finlayson 2006), it is possible that beaches on southern Camano Island have, over geologic time, developed into suboptimal smelt spawning habitat through wave action (but see comments on seasonal beach reconditioning above). This is borne out in the nearly complete lack of eggs in sites 23–32 along southwest Camano Island and the prevalence of finer sediments along these beaches as compared to the high-use beaches (D_{50}=6.73 vs. 4.70). However, the small number of drift cells identified on Camano Island precludes meaningful statistical analysis.

The suitability of a beach for spawning by smelt is also related to its exposure to incident solar radiation, which is the greatest on south-facing beaches. As a consequence of exposure, the average temperature of intertidal sediments on south-facing beaches can, all other characteristics being equal, be expected to be higher than on north-facing beaches. Recent studies have shown that smelt egg mortality increases with increasing exposure to solar radiation, sediment temperature, and desiccation (Penttila 2001, 2002; Rice 2006; Rossell 2006; Lee and Levings 2007). These findings are consistent with the pattern of smelt egg abundance across the gradient represented by PC1. Two other lines of evidence in our data suggest that high summer temperatures and associated effects (e.g., low humidity) may be related to poorer spawning habitat suitability. First, smelt eggs at lower elevation transects generally had lower mortality rates than eggs at higher transects, although egg abundance was also lower. This suggests that thermal and desiccation stress were both minimized lower on the beach. Furthermore, egg mortality declined markedly after August at both upper and lower egg transects with the seasonal decrease in atmospheric temperature and the return of regular precipitation. The preferred tidal height for placement of eggs at a given spawning site is likely a tradeoff between thermal and desiccation stresses at higher intertidal elevations and increased relative humidity and predation stresses at lower elevations.

Beaches are commonly armored with concrete or rock revetments to prevent erosion or to gentrify yards (Kraus and McDougal 1996; Holsman and Willig 2007; Shipman 2010). When revetments are placed within the marine intertidal zone, they can have cascading effects resulting in changes to the beach profile, coarsening of beach sediments, loss of large woody debris, and increased wave energy to the foreshore (Holsman and Willig 2007; Dethier and Berry 2010; Dugan and Hubbard 2010). Humans can also increase exposure to solar radiation of the beach as a result of clearing the land of vegetation for construction and to provide an unobstructed view of the water. The direct detrimental effects on gross habitat characteristics and microclimate, exacerbated by sea level rise as a consequence of climate change (Krueger et al. 2010), indicate that shoreline armoring and marine riparian zone elimination represent two important threats to the continued reproductive capacity of surf smelt in Puget Sound (Penttila 2007; Rice 2010).

Management Implications

The challenge of conservation is finding ways to minimize the loss of biodiversity with limited financial and human resources (Bottrill et al. 2009). Thus, natural resource managers are commonly confronted with three fundamental questions: (1) what needs protection, (2) where should it be protected, and (3) how should it be protected (Primack 2010, p. 351). While substantial scientific uncertainty remains regarding the characterization of suitability of surf smelt spawning habitat and the processes that create and maintain them, our results along with other important work on beach ecology cited herein suggest a number of immediate actions that could improve conservation of surf smelt spawning habitat. First, given the high demand for additional shoreline development and the fact that nearly 30 % of Puget Sound marine shoreline and 31 % of Camano Island is currently armored (Puget Sound Nearshore Ecosystem Restoration Project 2009), the most important spawning beaches should be identified and afforded more protection and restoration effort. That is, beaches in northwest Camano Island and those with low summer temperature, north-facing aspect, and relative large fetch are more important for smelt spawning than other beaches and thus should receive additional consideration during the HPA and other shoreline construction permitting processes. In addition, the drift cells in which these beaches occur should also be considered as important conservation targets, particularly in terms of maintaining sediment delivery and transport processes. Where development will occur, armoring should be permitted only where it is critically necessary to protect capital investments and then placed above the ordinary high water mark based on future sea level rise predictions. All shoreline vegetation should be maintained, especially trees that shade the intertidal region of the beach. While spawning sites with northerly aspects may currently be more resilient to high temperatures than sites with southerly aspects, increasing sea and air temperatures associated with climate change may diminish the suitability of all beach sites.

Finally, while the value of providing best available science is clear in cases involving imminent and permanent change, such as human development of the nearshore, we also urge commitment to better use of scientific information especially where we have learned from past mistakes. For example, the importance of spawning during seasons with low egg abundance should not be discounted. Although total smelt egg abundance and the number of live eggs were the highest in summer, eggs were often found in abundance during winter when mortality was relatively low; suggesting that smelt that spawn in winter might substantially contribute to the population, at least during years or at locations when summer mortality is especially high. Conserving sufficient habitat quantity and suitability for expression of such variations in life history might facilitate species persistence in highly variable environments (Caswell 1983), or serve as locations of bet-hedging (Helfman et al. 1997), that ensure the long term survival of smelt faced with disturbance. These conservation actions might be especially important as environments become more variable due to human actions and climate change (Reed et al. 2010).

We have two concluding thoughts relative to information needs. First, given the high demand for additional shoreline development, there is a tremendous need to better understand how typical shoreline development affects beaches as smelt spawning habitat both at the site and larger (e.g., drift cell) scales. Second, although widespread surveys to detect smelt spawning have been completed throughout much of Puget Sound (Penttila 2007), our knowledge of spawning locations and their relative importance both intra- and interannually remains incomplete over much of Puget Sound. Failure to detect eggs in a few samples remains poor evidence of absence of smelt spawning just as relatively low abundance of eggs in a few samples at a site may not be indicative of the importance of that site over an annual cycle. We encourage a more thoughtful approach to permitting new shoreline armoring projects in Puget Sound given existing survey data. Specifically, projects with potential to affect site or drift cell characteristics should receive forage fish spawning surveys for at least 1 year similar to the surveys we conducted on Camano Island. Data from these surveys would increase the probability of avoiding false negative results and begin to test the applicability of the

Camano Island spawning suitability model outside of our study area.

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APPENDIX H

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FORAGE FISH SPAWN SURVEYS

CORNET BAY BEACH RESTORATION PROJECT SITE,

DECEPTION PASS STATE PARK, WHIDBEY ISLAND, WA,

JUNE-AUGUST, 2013

SUMMARY REPORT

IN PARTIAL FULFILLMENT OF ISLAND COUNTY WSU EXTENSION

MARINE RESOURCES COMMITTEE

PURCHASE ORDER # 9428

BY

DAN PENTTILA

SALISH SEA BIOLOGICAL

5108 KINGSWAY, ANACORTES, WA 98221

TEL: (360) 293-8110, E-MAIL: depenttila@fidalgo.net

SEPTEMBER 2013

INTRODUCTION:

With the completion of the beach restoration project in the area of the Cornet Bay sector of Deception Pass State Park in late 2012, it was determined by project sponsors that post-project monitoring of the restored beaches and environs to detect usage (for spawning) of the area by the shore-spawning forage fishes, surf smelt (*Hypomesus pretiosus*) or the Pacific sand lance (*Ammodytes hexapterus*) would be an important part of the overall assessment of the project's environmental impact.

This report will summarize observations made during the first regional summer surf smelt spawning season following the completion of the beach-restoration action.

BACKGROUND:

Surf smelt and Pacific sand lance are known to spawn at many sites in the general area of northern Whidbey and adjacent Fidalgo Islands. The Washington Department of Fisheries and, after agency merger, Fish and Wildlife undertook numerous spawning habitat surveys for these species in the general area of the Cornet Bay restoration project in the decades leading up to the restoration action. During that time, the shoreline within the subsequently-restored shoreline was documented to be used by spawning Pacific sand lance on November 17, 1993 (Figure 1)(Penttila 1999). Eventually, this site of sand lance egg collection would be incorporated into the project site's forage fish spawn sample array as site #3.

While the state park piers in the immediate vicinity of the project site were known to be the sites of successful surf smelt sport-jig fishery harvests for several months each year, spawning habitat surveys did not ever detect surf smelt eggs within the project site in its pre-restoration condition. The reasons for this are unknown, except to note that the pre-project shoreline armoring did, in fact, intrude significantly seaward from the high tide line, burying the landward portions of the hypothetical surf smelt spawn deposition zone, in terms of tidal elevation and substrate type. This intrusion of armoring structures into the intertidal zone was to be remediated by the restoration action, in part for the enhancement of surf smelt spawning habitat quality.

The presence of a surf smelt sport-jig fishery in the immediate area of the pre-project shoreline in Cornet Bay could not be construed as indicating that surf smelt must spawn on the beaches around the piers. Sport-jig-caught surf smelt in Puget Sound are almost entirely of actively-feeding smelt in a non-spawning/recovering-spent condition, as judged by biological data taken from similar jig-fishery smelt catches at nearby LaConner in previous years (Penttila 1982). Surf smelt spawning activity has been documented approximately one statute mile northeast of the Cornet Bay project site, on the west side of Hoypus Point, northernmost Whidbey Island (Figure 2)(Penttila 1999). It is likely that the surf smelt caught on the Cornet Bay piers are attributable to the fish spawning on the extensive summer-time surf smelt spawning areas known to occur throughout the Skagit Bay-Saratoga Passage region.

After the Cornet Bay shoreline was proposed for a restoration project, the Island County Beachwatchers organization was tasked with collecting pre-project data on the site to document the degree to which the project area was being used by spawning surf smelt and Pacific sand lance. In mid-2009, the volunteers were provided with on-site training by WDFW in the collection and processing of beach substrate sampling protocols then in use for forage fish spawning habitat surveys, so that their pre-project data could be added to the state-wide forage fish survey database (Moulton and Penttila 2001, rev. 2006). WDFW provided the volunteer group with sample bags, lab-sample jars, and preservative. Six fixed sample sites were located within the project area from which monthly samples would be collected in the prescribed manner. WDFW staff (the writer) analyzed the preserved lab sampled generated by the volunteers for the presence and character of any forage fish eggs that might be found within them.

The Beachwatcher volunteers steadfastly proceeded with their monthly sampling from July 2009 through April 2011, during which time no surf smelt or sand lance eggs were found within the project area.

2013 POST-PROJECT METHODOLOGY:

The collection of beach surface substrate samples for the possible detection of incubating forage fish eggs generally followed the current field protocols that have been used by WDF/WDFW and other suitably-trained NGOs for such spawning habitat surveys in Washington State since late 1991 (Penttila 1995, Moulton and Penttila 2001, rev. 2006). The only departure from the WDFW protocols was the adoption of a 50-foot length for the sampling transect along which the bulk sample of beach material was collected, rather than the routine 100-foot sampling transect normally used on such surveys. A similarly shortened transect length had been used by the Island County Beachwatchers during their 2009-2011 pre-project sampling in Cornet Bay.

The processing of the bulk beach substrate samples down to the "winnowed light fraction" preserved lab subsamples also followed existing WDFW protocols, as did the laboratory analyses of the preserved sub samples (Moulton and Penttila 2001, rev. 2006).

POST-PROJECT ACTIVITIES AND OBSERVATIONS:

Prior to the development of the existing contract, the writer visited the Cornet Bay beach restoration project site on October 16, 2012, shortly after the restoration action had been completed, for the purposes of taking a set of digital photographs of the project area in its freshly-restored condition. Eighteen photos were taken of the existing condition of the site, the restored portions of which now looked outwardly to be very suitable potential forage fish spawning habitat.

In anticipation of the project contract, the Cornet Bay project site was visited by the writer on May 15, 2013 for the purposes of re-locating the six fixed forage fish spawn sampling stations previously established in 2009 for the pre-project spawn monitoring activities. Using a Garmin 76H hand-held GPS unit, the sampling sites were relocated as closely as possible to their pre-project positions, and marked with discretely-flagged stakes above the high tide line. Table 1 listed the GPS coordinates of the sampling locations as established in 2009 and relocated in 2013.

During the course of the May 15, 2013 visit, each of the fixed spawn sampling sites was digitally photographed with eye-level oblique views of the sample sites from opposite ends of their likely sampling transects, a total of 12 photos in the set.

Immediately after the PO #9428 contract was finalized, the Cornet Bay project site was visited on June 25, 2013 for the first of three monthly sample-sets. Appendix 1 is a copy of the field/lab report for that survey. No evidence of surf smelt spawning activity was found, although the restored sector of beach, represented by sample sites #2, #3, and #4, looked outwardly suitable. Evidence of sand lance spawning activity was not expected during the summer months, since that species' spawning season Puget Sound-wide is November-February (Penttila 2007).

The Cornet Bay project site was next visited on July 12, 2013 (Appendix 2). No evidence of surf smelt spawn deposition was found on or around the project site.

The Cornet Bay project site was visited on August 22, 2013 for the final forage fish spawn survey of the contract period (Appendix 3). Again, no evidence of surf smelt spawn deposition was found, during a time when smelt spawning was presumably wide-spread in the region to the east.

CONCLUSIONS:

The results of forage fish spawn sampling during the first summer following the restoration of more natural upper intertidal beach habitat at the Cornet Bay project site indicated that summer-spawning surf smelt were not using the site for egg deposition. Given that no evidence of surf smelt egg deposition had been found during previous forage fish spawn surveys by WDFW and the Island County Beachwatchers' pre-project survey, the results are not surprising, in spite of the project's obvious success in restoring very suitable-looking potential habitat to the site.

Surf smelt spawning activity has been documented on about 10% of the shoreline of the Puget Sound Basin (Penttila 2007). Most of the "outwardly suitable-looking beaches" in the Puget Sound basin, as suggested by the present of the proper texture of beach substrates at the proper tidal elevations, have not yielded evidence of smelt spawning activity using the current survey protocols. There appears to have been a "natural selection" of perennially-used surf smelt spawning sites during the last approximately 5000 years since the last Ice Age glaciers retreated from the region, and the combination of isostatic rebound upland of the formerly glaciated land surface and the rise of sea level with the world-wide melting of those Ice Age glaciers stabilized sea level and evolving shorelines in their present positions. The precise mechanisms of this spawning-site selection process are as yet unknown.

Whether or not surf smelt will ever be found to use the restored beaches at Cornet Bay for spawning remains an open experimental question. Surf smelt are known to spawn within about one mile of the site at present. Non-spawning surf smelt are known to occur in very close proximity to the restored area seasonally in large numbers, as judged by the on-going pier-based sport-jig fishery. The degree to which surf smelt "home" back to their beaches of hatching, if at all, is unknown, as is the rate at which surf smelt spawning activity "roves" over the outwardly suitable post-glacial habitat landscape over time, if at all. It is obvious that this species (along with all the rest of the local marine/estuarine species of plants and animals) had to have some capacity for "exploration" of new spawning sites, to have re-populated the entire length and breadth of the Puget Sound Basin in the geologically-short period of time since the glaciers most-recently retreated.

While several recent beach restoration projects in the Puget Sound Basin have succeeded in enhancing surf smelt spawning on beaches where it was still persisting on degraded habitat, projects like the Cornet Bay restoration action, producing suitable potential habitat at varying physical distances from existing spawning sites, are important experiments within the still-youthful realm of forage fish beach restoration. Periodic monitoring for surf smelt eggs over coming years may provide important answers to the question of how soon spawning surf smelt will find their way to adjacent "wholly new" beaches of outwardly suitable quality.

Regardless of the surf smelt usage questions, it is clear that the Cornet Bay restoration action conserved the existing documented Pacific sand lance spawning site (sample station #3) in a suitable condition for future spawning usage. The expansion of upper intertidal mixed sand-gravel beach substrate coverage in adjacent sectors of the project site suggests that the potential sand lance spawning habitat may have been increased in physical area and quality. Proposed additional sampling at the Cornet Bay project site during the winter of 2013-2014 will monitor the site for evidence of both sand lance spawning activity and that of winter-spawning surf smelt.

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Table 1. GPS coordinates of fixed forage fish spawn sample sites, Cornet Bay beach restoration project area, N. Whidbey Island , WA.

Site	2009 (pre-project)	2013 (post-project)	Remarks
1	N 48 deg., 24,114'	N 48 deg., 24.115'	natural /suitable beach,
	W 122 deg., 37.271'	W 122 deg., 37.296'	NE of launch ramps
2	N 48 deg., 24.051'	N 48 deg., 24.051'	armored/restored beach,
	W 122 deg., 37.379'	W 122 deg., 37.383'	SW of launch ramps
3	N 48 deg., 24.028'	N 48 deg., 24.025'	armored/restored beach,
	W 122 deg., 37.419'	W 122 deg., 37.429'	Just S of St. Pk. moorage pier
4	N 48 deg., 23.989'	N 48 deg., 23.988'	armored/restored beach,
	W 112 deg., 37.467'	W 122 deg., 37.467'	S of St. Pk. maint. pier
5	N 48 deg., 23.951'	N 48 deg., 23.950'	natural/ suitable beach,
	W 122 deg., 37.517'	W 122 deg., 37.515'	SW of restored project site
6	N 48 deg., 23.919'	N 48 deg., 23.919'	natural marginal habitat,
	W 122 deg., 37.559'	W 122 deg., 37.561'	SW of restored project site

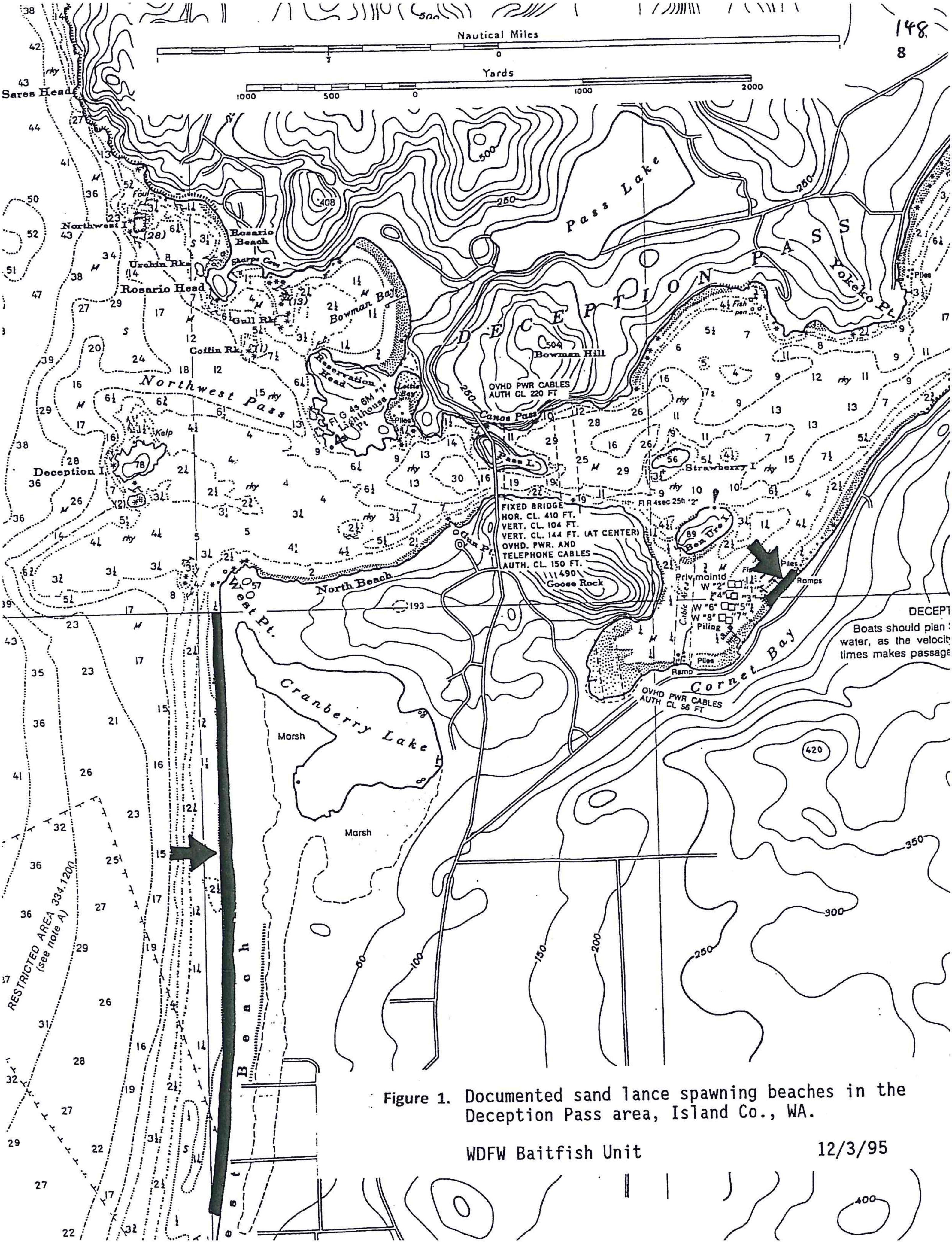

Figure 1. Documented sand lance spawning beaches in the Deception Pass area, Island Co., WA.

WDFW Baitfish Unit 12/3/95

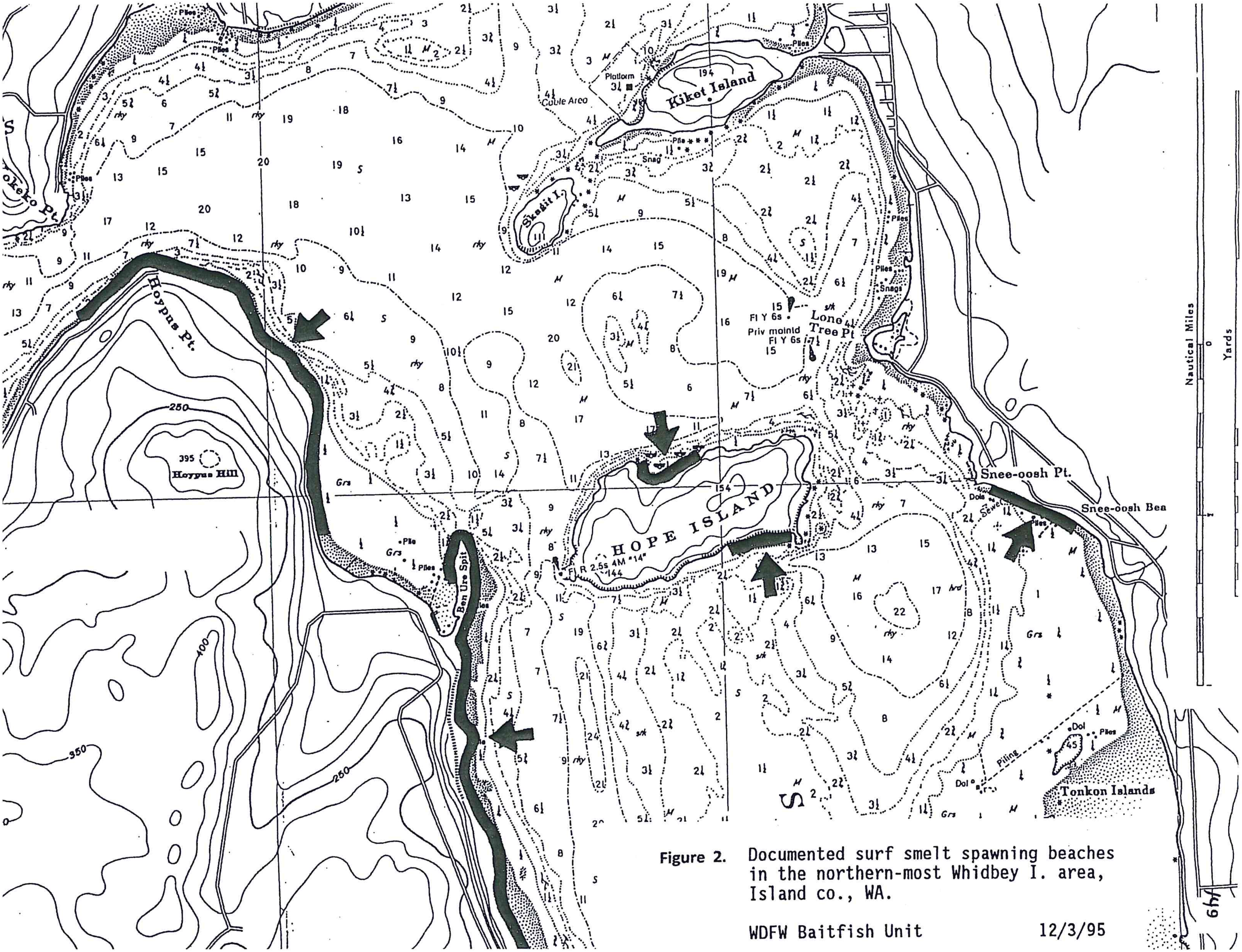

Figure 2. Documented surf smelt spawning beaches in the northern-most Whidbey I. area, Island co., WA.

WDFW Baitfish Unit 12/3/95

APPENDIX 1:

SALISH SEA BIOLOGICAL

FIELD REPORT

AREA: Cornet Bay State Park

DATE: June 25, 2013

PERSONNEL: Dan Penttila

REPORT:

The intent of this field trip was to undertaken the collection of a second set of forage fish spawning substrate samples along the length of the restored beach at the Cornet Bay State Park beach extending south of the launch ramps, for a contract with Island County to monitor the new beach for the presence of surf smelt eggs during the summer of 2013.

The site was surveyed first in mid-May to relocate the pre-project forage fish spawn sampling sites, and collect a first set of samples, but the contract was only finalized and officially signed yesterday.

I found all the stakes marking my 6 fixed sampling sites in their original positions, and the array of sites was sampled from north to south during the course of about an hour. In a few cases, the tidal elevation of today's sample transects differed somewhat from the positions of the samples in mid-May (in numbers of feet down-beach from the fixed stakes), as the beach had generated bands of suitable gravel higher on the beach, and within the typical surf smelt spawn deposition/incubation zone during the period between my visits.

The bulk samples of beach material were processed down to preserved lab subsamples later on this day. During the course of winnowing and collecting the lab material, no visual sign of surf smelt spawn was seen.

The Cornet Bay project area had been visited briefly on the afternoon high tide of 6/22/13, at which time a large number of sport smelt jigger fishermen were found on the state park moorage piers and the finger piers of the launch ramps. They seemed to be having moderate success catching forage fishes. This morning's high ebb tide found only a few fishermen on these jigging docks, having little success.

DEP

Last Revised: 3/25/2001

SJC Forage Fish Spawning Surveys

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last high tide: time ______ elevation ______

Reviewed By: ____________

Island: Cornet Bay S.P.

day: 25 month: 6 year: 13

Beach Number	Sample Number	Time	latitude * °	'	"	longitude °	'	"	beach	uplands	sample zone	land mark	tidal elevation	smelt	sand lance	herring	width	length	shading	comments
1		0905	48	24	.115	122	37	.296	3	1	10	1					25		2	20' ds of stake*
		Sampled near upper edge of gravel, below [illegible]																		new 16' ds of stake
2		0914	48	24	.051	122	37	.383	3	3	10	1					35		1	10' ds of Stake*
																				≈ [illegible]
3		0928	48	24	.025	122	37	.429	3	3	12	1					35		1	20' ds of stake*
		Sampled new gravel band [illegible] above where [illegible] in May																		≈ [illegible]
4		0935	48	23	.988	122	37	.467	3	3	8	stake					40		1	14' ds of Stake*
		beach still "hard" w/ brown dirt 1.5" deep																		[illegible] not visible
5		0950	48	23	.950	122	37	.515	3	1	9	1					12		2	13' ds of stake*
																				[illegible] 4' ds of stake
6		0958	48	23	.919	122	37	.561	3	1	18	stake					12		1	18' ds of Stake*
																				[illegible] not visible

Samplers: * 5/16/13 values D. Penfold

Forage Fish Spawn Sample Analysis

Page 1 of 1

post-restoration spawn survey

Recorder Penttila

Island	month	day	year
Cornet Bay	6	25	13

Beach Number	Sample Number	species	1 cell to morula	blastula	gastrula	1/2-1 coil	1 coil	11/2 coil	>11/2 coil	late eyed	dead	# eggs	% dead	est. # broods	wt. substrate	eggs/ gram	remarks
	1											0					
	2											0					
	3											0					
	4											0					
	5											0					abundant rolled-up. isopods
	6											0					abundant worms, isopods

APPENDIX 2:

SALISH SEA BIOLOGICAL

FIELD REPORT

AREA: Cornet Bay, N. Whidbey Island

DATE: July 12, 2013

PERSONNEL: Dan Penttila

REPORT:

The intent of this field trip was to collect the contracted July sample-set of upper intertidal beach substrate samples from the six fixed sites in and around the Cornet Bay beach restoration project site, in search of evidence of post-project surf smelt spawning activity.

I left home at 1100 and began sampling at site #1, north of the Cornet Bay launch ramps. at 1130. For most of the sites. I used the same measurements down-beach from my marking stakes to determine the tidal elevation of the substrate sampling transects. Only at site #3 did I have to sample a few feet lower than the sample elevation of the June sample set, in order to sample a surf smelt habitat-suitable band of mixed sand-gravel, instead of the present featureless sand band further up-beach.

I finished the field sampling in about one hour, and proceeded home where the substrate sample set was processed down to the preserved winnowed-light fraction subsamples. No visual sign of surf smelt spawn had been seen anywhere in the project site, despite the continued "suitable-looking" nature of the restored beach. Nor were there any smelt eggs visible in the screening/winnowing process.

DEP

Forage Fish Spawning Surveys

Reviewed By: Penttila

last high tide: time ___ elevation ___

second effective high tide: time ___ elevation ___

Island: Cornet Bay

day 12 month 7 year 13

X= stake

Beach Number	Sample Number	Time	latitude °	'	"	longitude °	'	"	beach	uplands	sample zone	land mark	tidal elevation	smelt	sand lance	rock sole	herring	width	length	shading	comments 6/25/13
											16	X									distance dl of stake
1		1130																			16', dl of stake. lhtl not visible
2		1137									6 10	1 X									10', lhtl 4' dl of stake
3		1145									15 16	1 X									12', new gravel zone at 16' dl of stake
4		1155									4 8	1 X									8'
5		1207									13	X									13' lhtl not visible
6		1214									18	X									18', lhtl not visible

Samplers: D. Penttila

Forage Fish Spawn Sample Analysis

Page 1 of 1

Recorder Penttila

Cornet Bay (Island) 7 (month) 12 (day) 13 (year)

~ post-project spawn survey

Beach Number	Sample Number	species	1 cell to morula	blastula	gastrula	1/2-1 coil	1 coil	11/2 coil	>11/2 coil	late eyed	dead	# eggs	% dead	est. # broods	wt. substrate	eggs/ gram	remarks
	1											0					
	2											0					
	3											0					
	4											0					
	5											0					
	6											0					
												balled-up [illegible]					common

APPENDIX 3:

SALISH SEA BIOLOGICAL

FIELD REPORT

AREA: Cornet Bay, Whidbey Island

DATE: August 22, 2013

PERSONNEL: Dan Penttila

REPORT:

The intent of this field trip was to undertaken the last of three contracted summer forage fish spawn surveys of the new beach restoration project site in Cornet Bay.

I left home at about 1000, and began the sampling of the fixed sites in the project area at site #1 at about 1040. Sampling proceeded in the usual manner from north to south through the 6 fixed sampling sites.

The restored beach has remained in a very suitable-looking condition for forage fish spawning activity since the last survey. The most recent higher high tide line, for a predicted tidal elevation of +11.9 in Seattle, coincided with the seaward edge of the netting protecting the shore-side plantings at sites #2, #3, and #4. A crew was spot-spraying herbicide on weeds within the netted plantings.

At site #3, there was some sign of a steepening of the upper beach, and a scouring of the beach surface material down to a layer of compact clay/soil beneath. The pocket beach here just north of the state park maintenance pier , documented in the past as a sand lance spawning site, remained in a pure-sand condition.

I finished the field sampling at about 1130. The day's samples were processed down to preserved winnowed-light-fraction lab subsamples at home later on this day. During the course of processing, there was no visual sign for forage fish eggs noted.

DEP

Forage Fish Spawning Surveys

Reviewed By: ____

last high tide	
time	elevation

second effective high tide	
time	elevation

Island: Cornet Bay

day	month	year
22	8	13

X = stake loc.

July stake distance down-beach ↓

Beach Number	Sample Number	Time	latitude °	latitude '	latitude "	longitude °	longitude '	longitude "	beach	uplands	sample zone	land mark	tidal elevation	smelt	sand lance	rock sole	herring	width	length	shading	comments	
1		1040							3	1	2	1						20		2		16'
											13	X										
2		1047							3	1	4	X						40		1	[illegible] at wetting	10'
3		1054							3	2	15	X						27		1	Some sign of scour on upper-most beach	16'
4		1103							3	2	6	X						30		1	[illegible] at wetting	8'
5		1113							3	1	12	X						11		2		13'
6		1120							3	1	15	X						13		1		18'

Samplers: D. Penttila

Forage Fish Spawn Sample Analysis

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Recorder Penttila

Island	month	day	year
Cornet Bay	8	22	13

Beach Number	Sample Number	species	1 cell to morula	blastula	gastrula	1/2-1 coil	1 coil	11/2 coil	>11/2 coil	late eyed	dead	# eggs	% dead	est. # broods	wt. substrate	eggs/ gram	remarks
	1											0					
	2											0					
	3											0					
	4											0					
	5											0					common isopods worms
	6											0					abundant isopod and [illegible] worms