SAN JUAN COUNTY FORAGE FISH ASSESSMENT PROJECT

FORAGE FISH SPAWNING DISTRIBUTION IN SAN JUAN COUNTY AND PROTOCOLS FOR SAMPLING INTERTIDAL AND NEARSHORE REGIONS

FINAL REPORT

JUNE 2000

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TABLE OF CONTENTS

Introduction1
Summary of Existing Information 2
    Distribution of Forage Fish in San Juan County 2
        Surf Smelt 2
        Pacific Sand Lance 3
        Pacific Herring 4
        Longfin Smelt 4
Field Protocols 6
    Study Design Considerations 6
    Project Objectives 6
    Sampling Schedule 6
    Surf Smelt and Pacific Sand Lance Assessment 6
        Site Selection 6
        Field Equipment 7
        Field Records 7
        General Guidelines for Collecting Bulk Beach Samples 9
        Condensing Bulk Samples 10
        Laboratory Examination 10
    Pacific Herring Assessment 11
        Site Selection 11
        Field Equipment 11
        Field Records 11
        General Guidelines for Collecting Vegetation Samples 12
        Laboratory Examination 12
    Quality Assurance/Quality Control 13
        Surf Smelt and Pacific Sand Lance 13
        Pacific Herring 13
    Data Reporting 13
References 14
Appendix A. Records of forage fish distribution in the San Juan Islands. A-1

LIST OF FIGURES

Figure 1. Historical records of surf smelt in San Juan County (from Miller and Borton 1980). 15

Figure 2. Spawning time of forage fish species in San Juan Islands. 16

Figure 3. Fresh surf smelt and Pacific sand lance spawn deposits. 17

Figure 4. Distribution of intertidal sampling by WDFW to identify surf smelt and sand lance spawning beaches, 1989-2000. 18

Figure 5. Results of WDFW sampling for evidence of intertidal spawning by surf smelt, 1989-2000. 19

Figure 6. Historical records of Pacific sand lance in San Juan County (from Miller and Borton 1980). 20

Figure 7. Results of WDFW sampling for evidence of intertidal spawning by Pacific sand lance, 1989-2000. 21

Figure 8. Historical records of Pacific herring in San Juan County (from Miller and Borton 1980). 22

Figure 9. Distribution of known Pacific herring spawning areas and prespawner holding area in San Juan County. 23

Figure 10. Historical records of longfin smelt in San Juan County (from Miller and Borton 1980). 24

Figure 11. Representative surf smelt spawning beaches in San Juan County. 25

Figure 12. Examples of surf smelt spawning beaches in San Juan County. 26

Figure 13. Examples of surf smelt eggs in field conditions. 27

Figure 14. Field data form used to record data associated with surf smelt and Pacific sand lance bulk sampling. 28

Figure 15. Sampling mixed sand/gravel beach for surf smelt and Pacific sand lance eggs. 29

Figure 16. Screening bulk sediment sample to separate egg-bearing sediments from larger material. 30

Figure 17. Winnowing bulk sediment sample to separate egg-bearing sediment from barren sand. 31

Figure 18. Marine vegetation rake used to sample herring spawn. 32

Figure 19. Pacific herring spawn intensity classifications. 33

Figure 20. Examples of Pacific herring spawning areas in San Juan County. 34

Figure 21. Field data form used to record data associated with Pacific herring egg sampling. 35

Figure 22. Embryonic developmental stages of Pacific herring. 36

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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.

The Washington Department of Fish and Wildlife (WDFW) presently endeavors 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.

The Northwest Straits Commission (NWSC) was established in 1998 to provide an ecosystem focus on marine resources of the Northwest Straits as a whole, to help mobilize science to focus on key priorities, to provide resources to the MRCs, and to serve as a forum for coordination and consensus-building. Working within the NWSC framework, the goals of the MRCs are to:

1. Encourage strong county participation in MRCs.

2. Consistent with a scientifically-based regional system of Marine Protected Areas, identify local candidate sites and urge their inclusion at the appropriate level.

3. Help ensure a net gain in highly ecologically productive nearshore, intertidal, and estuarine habitat within the county, as well as no significant loss of existing, high-value habitat. Work with

State, Tribes, and local authorities to help map, assess, and protect nearshore habitat and prevent harm from upland activities through local and state ordinances and shoreline plans.

4. Help ensure a net reduction in shellfish harvest areas within the county closed due to contamination.

5. Contribute to measurable increases in factors supporting bottom fish recovery - including numbers of fish of broodstock size and age, average fish size, and abundance of prey species - as well as sufficient amounts and quality of protected habitat.

6. Contribute to increases in other key marine indicator species.

7. Use and contribute to a scientific data pool on marine resources, including a scientific baseline, common protocols, unified GIS, and sharing of ecosystem assessments and research.

The NWSC recognized the importance of maintaining forage fish stocks in northern Puget Sound by funding this effort to 1) document existing information on forage fish within SJC and 2) develop protocols for assessing forage fish spawning habitats throughout the NWSC area.

SUMMARY OF EXISTING INFORMATION

DISTRIBUTION OF FORAGE FISH IN SAN JUAN COUNTY

Distribution information for forage fish is sporadic because the fish are small and, except for Pacific herring, have not been the target of major directed fisheries. Miller and Borton (1980) summarized the distribution of fishes in Puget Sound, including the San Juan Islands, based on all identifiable records through 1975, including published records, University of Washington School of Fisheries and Friday Harbor Laboratories log books, and miscellaneous records from other sources. As fisheries investigations have progressed, it has become apparent that surf smelt and Pacific sand lance, in particular, are much more abundant than indicated by earlier records. Pacific sand lance are under-represented in samples because the thin fish readily passes through most nets traditionally used for sampling.

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).

The status of Pacific herring is better known than the other forage fish species because the species has historically been commercially harvested within Puget Sound. Annual surveys are conducted on the spawning areas of the major stocks, with frequent surveys on some minor stocks (Lemberg et al. 1996).

Surf Smelt

Surf smelt have been sporadically reported in the San Juan Islands in the historical record (Miller and Borton 1980). Most of the records are from Argyle Spit and False Bay, with scattered reports from other locations around the county (Figure 1). A complete listing of surf smelt records in the county through 1975 is provided in Appendix A.

Surf smelt in the San Juan area spawn year-round, with no particular spawning season more dominant than another (Penttila 1990, 1999, Figure 2). Eggs, about 1 millimeter in diameter, are deposited in the upper intertidal zone on mixed sand and gravel beaches (Figure 3). 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 and 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 4. As presented above, fourteen beaches within San Juan County have so far been identified as supporting spawning by surf smelt (Penttila 1999, Figure 5). The visual sampling method is considered relatively inefficient in 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 the 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. The over-hanging vegetation provides shade, which reduces 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.

Pacific Sand Lance

Pacific sand lance have been reported from various locations around San Juan Island, with most records from night light sampling at the Friday Harbor Labs dock. Other areas with more than three records include Argyle Spit and False Bay (Miller and Borton 1980; Figure 6).

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 3). 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 2). 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 7.

Pacific Herring

Pacific herring are widely distributed through the county, as is evident from the historical record (Miller and Borton 1980, Figure 8). Many of these reports are from early records of spawning areas and from around popular salmon fishing areas.

Two stocks are recognized by WDFW in San Juan County. One stock spawns in Westcott Bay, while the other spawns at scattered locations on Lopez, Orcas, and Shaw islands (Lemberg et al. 1996, Figure 9). Spawning surveys on these stocks have been sporadic over the last twenty years, with insufficient data to evaluate population trends. Early reports indicate there may be additional spawning along Waldron and Sucia islands, but these reports have not been verified in recent years (Chapman et al. 1941, Penttila 1999).

Herring spawn from the upper intertidal region to a depth of 40 feet, but most spawning is between 0 and –10 ft MLLW (WDFW Puget Sound herring fact sheet). In San Juan County, spawning is generally on eelgrass or a fibrous red alga known as *Gracilariopsis* (Penttila 1999). Other substrates may be used on occasion. Spawning occurs from late January through April (Figure 2). In 1990 and 1991, herring spawned in the following range of dates (Stick 1990, 1991):

Location	1990	1991
Westcott Bay, San Juan	Jan 31-Apr 10	Jan 29-Mar 28
Mud-Hunter Bay, Lopez	Feb 13-Apr 11	NA
Blind Bay , Shaw	Mar 1-31	NA
East Sound, Orcas	NA	Feb 27-Mar 27

Eggs incubate for about two weeks, depending on water temperature, so eggs can be present at the spawning sites into late April.

Longfin Smelt

Longfin smelt are an anadromous smelt found in many Puget Sound rivers, but little is known of them. The populations do not appear to be large and spawning is in the fall, both of which may contribute to the lack of directed fisheries on this species. Lake-resident populations are in Lake

Washington and Harrison Lake, British Columbia. In San Juan County, longfin smelt appear to have an established population in East Sound, Orcas Island (Miller and Borton 1980, Figure 10). They may also be established in West Sound, but existing information is insufficient to substantiate this conclusion.

Longfin smelt spawn in sand and gravel areas in the lower reaches of rivers and streams, but so far spawning areas in San Juan County have not been identified. Small streams entering East Sound and the eastern shore of West Sound are likely spawning areas.

FIELD PROTOCOLS

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. The spawning areas for longfin smelt should be identified, if possible, but are not a high priority under this project.

Sampling Schedule

Planning for surveys will need to consider spawning time when designing surveys intended to identify spawning locations (Figure 2). In the San Juan Islands, surf smelt spawn year-round (Penttila 1999). Pacific sand lance begin spawning in November, continuing through February. Pacific herring in this region spawn from late January to late April. Longfin smelt likely spawn in November-December.

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. The 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 11. 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 the most over-hanging vegetation. Close-ups of areas containing appropriate substrate are in Figure 12. Eggs can sometimes be seen through a visual assessment (Figure 13).

Field Equipment

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

- 8 ounce plastic jar
- 1 gallon ZipLoc or other sealable freezer bags
- waterproof labels

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,
- Wash bucket,
- Plastic dishpan,
- 8 ounce plastic sample jar
- Stockard's Solution:

  50 ml formalin (37% formaldehyde)
  40 ml glacial acetic acid
  60 ml glycerin
  850 ml distilled water

Field Records

Environmental characteristics of the sampled location are recorded to help analyze results of the sampling. These records are entered on the field data sheet, which is completed at the time of sampling (Figure 14). The data fields are as follows:

Sector: Island Sampled
Date of Sampling
Station: Station number, starting with 1 each area, each day.
Sample: Sample number. Blank for bulk samples, letter for scoop samples.
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 the last high tide mark
2 = up beach from last high tide mark
3 = down beach from second to the last high tide
4 = down beach from upland toe
5 = up beach from the waterline at the time noted in comments

Tidal Elevation: This is determined in the office by using the data from "land mark", the average beach slope for the sector, and the height of the tide on the previous tide exchange.

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 the 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.

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 the appropriate sample number so that the exact site can be re-visited, if needed. If possible, 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 15).

- 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 label to allow identifying the location and collection time of the sample, deposit the label in the plastic bag.
- Start at one end of the transect, scoop a jar full of sand from the top 0.5 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.

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. 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 (Figures 16 and 17). 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 an 8 ounce sample jar.
- 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.

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 the eggs from the sand. Final separation is performed under a dissecting microscope at 10-20x, where the 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 found during the smelt/Pacific sand lance spawn assessment should be archived for confirmation of species and spawn age analyses. Up to 100 random eggs of each species present should be labeled and preserved in Stockard's Solution in a small 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 the forage fish eggs in the samples should be recorded in some manner, as these provide information of the relative frequency and density of spawning.

PACIFIC HERRING ASSESSMENT

Sampling for herring spawn consists of obtaining a sample of subtidal vegetation and examining it for attached herring eggs. Pacific herring stocks in the San Juan Islands generally spawn on eelgrass, although a fibrous red alga known as *Gracilariopsis* is also used in some locations. Other marine algae that may be used for herring spawning substrate in SJC are Laminaria, Agarum, Ulva, and Agardhiella.

The vegetation is sampled with a metal rake that is deployed from a boat and dragged across the substrate to grapple a vegetation sample (Figure 18). The vegetation is examined for eggs; if eggs are found, the density of eggs is assessed and assigned a density category (Figure 19). The density category and area covered by spawn can be used to estimate the size of the spawning stock.

Site Selection

In the San Juan Islands, Pacific herring generally spawn in bays, as indicated in the spawn deposition map (Figure 9). Within the bays, spawning is generally between 0 to –10 feet MLLW. This can result in a very narrow or widely spread spawning area, depending on the configuration of the bay. Examples of spawning areas are shown in Figure 20.

Field Equipment

Equipment needed for collecting subtidal vegetation to assess herring spawning:

- Shallow draft boat/motor and appropriate safety equipment
- Vegetation Rake, 60-80 feet of tow line
- Plastic tub for retaining collected vegetation
- Small depth sounder or other means to measure water depth
- Field guide for identifying marine vegetation
- 8 ounce plastic sample jar
- waterproof sample labels
- Stockard's Solution (see composition above under smelt and sand lance sampling)

Field Records

Records describing the details of each sample are retained to document the sample. These records are entered on the field data sheet, which is completed at the time of sampling (Figure 21). The data fields are self-explanatory: station number, depth of sample, spawn intensity and type of marine vegetation present (identified as present with a check mark). The spawn intensity code is illustrated in Figure 19.

As with the surf smelt and Pacific sand lance samples, prepare a map of each location sampled using a 1:24,000 scale USGS topographic sheet or 1:25,000 scale NOAA nautical chart. Mark each sample location on the map with the appropriate sample number so that the exact site can be re-visited, if needed. If possible, use a GPS to obtain latitude and longitude of each sampled location, but priority should be placed on an accurate map. Appropriate maps and charts are listed above under the surf smelt and Pacific sand lance protocols.

General Guidelines for Collecting Vegetation Samples

Herring spawn is generally found from the 0 to –10 foot MLLW tide level. The sample is taken by locating the desired sample location along the beach, dragging the vegetation rake perpendicular to shore for approximately 10 yards, then retrieving the rake. The vegetation is identified and examined for herring eggs.

- Identify the specific location to be sampled.
- Find the 0 foot tide level.
- Deploy the rake and drag perpendicular to shore for approximately 10 yards.
- Retrieve rake, place attached vegetation in plastic sorting tub.
- Identify vegetation, estimate percent of sample by type.
- Search eelgrass and algae (if any) for herring eggs.
- If eggs are found, preserve representative samples of the eggs in Stockard's solution in a labeled sample jar.

Laboratory Examination

Preserved samples of Pacific herring spawn from the spawn surveys should be inspected at 10-20x, and the array of embryological stages present in the sample recorded, using Figure 22 as a guide. Given the 14-day incubation period for herring eggs in this region, a spawn deposition date can be estimated for each egg brood present. This is critical information for the basic biological database for the herring populations, planning of future spawn surveys in the area and determination of seasonal work windows for permittable in-water development activities.

As with the surf smelt/Pacific sand lance spawn samples, it is advisable to archive labeled herring spawn samples for inspection by WDFW, or other knowledgeable experts, to confirm identification and development stages. There are a number of types of non-egg objects that may be misidentified as herring eggs or empty herring egg shells, including the egg masses of a few other species of demersally-spawning fishes, egg masses of a number of gastropod species, and decalcified worm tubes and bryozoan colonies.

QUALITY ASSURANCE/QUALITY CONTROL

Surf Smelt and Pacific Sand Lance

The primary concerns for quality control include:

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

The best way to ensure the quality of the data is to make sure the samplers are appropriately trained and understand the importance of careful sample processing and complete recording of sample-related information. The accuracy of the 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.

Pacific Herring

The primary concerns for quality control include:

- sampling the appropriate habitat,
- accurate identification of the sample location,
- accurate identification of marine vegetation,
- careful searching of the vegetation to ensure that herring spawn is detected

Again, the best way to ensure data quality is through training in sample documentation and sample collection. Training in identification of marine vegetation is also important.

DATA REPORTING

Data reporting should include all information collected during the sampling. Usually, this reporting is in the form of summary tables that present the information recorded on the 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 the number of eggs by species found in each sample.

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Stick, K. 1991. Summary of 1991 Pacific herring spawning ground surveys in Washington State waters. Washington Department of Fisheries Progress Report 292 Olympia, WA. 49p

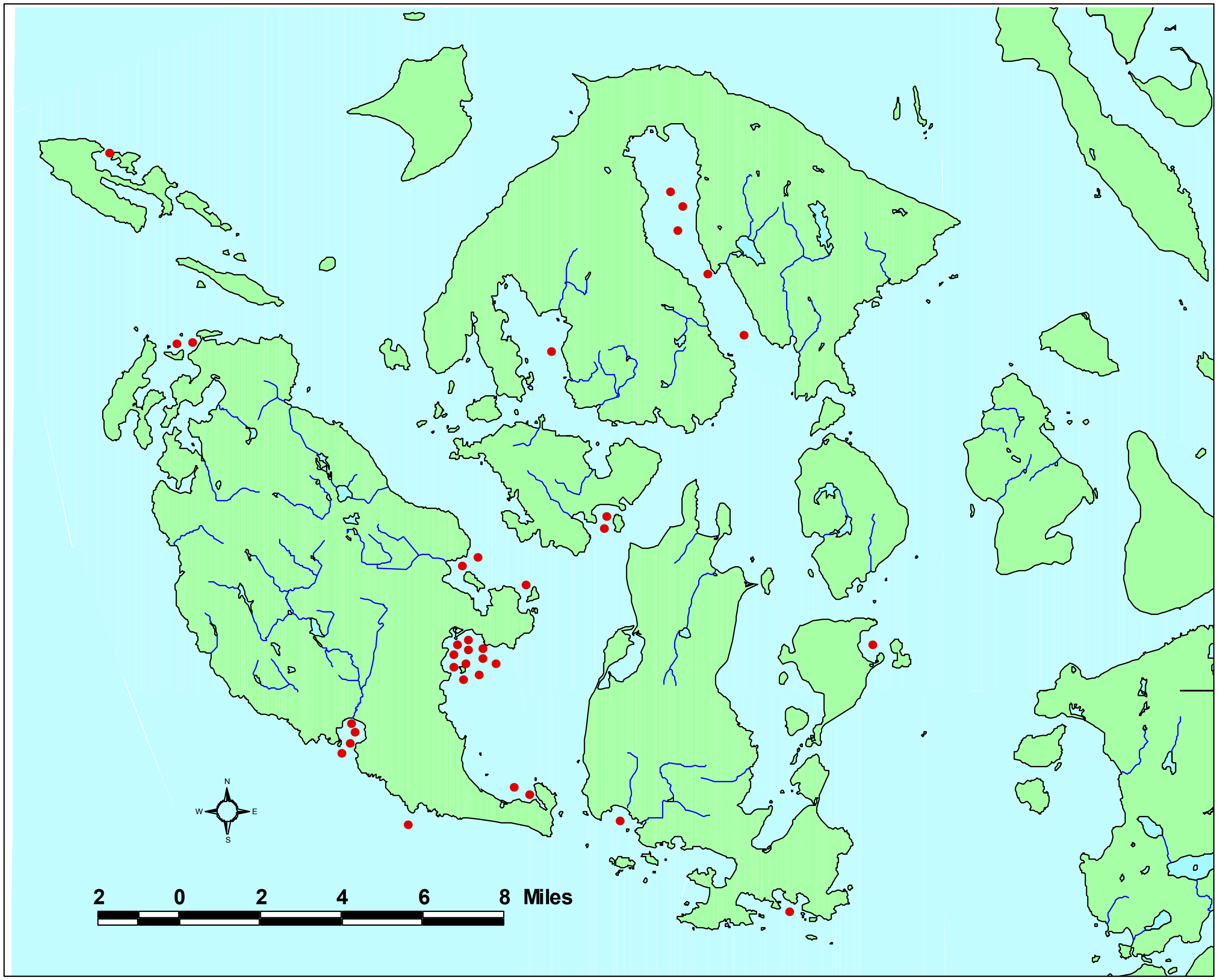


Figure 1. Historical records of surf smelt in San Juan County (from Miller and Borton 1980).

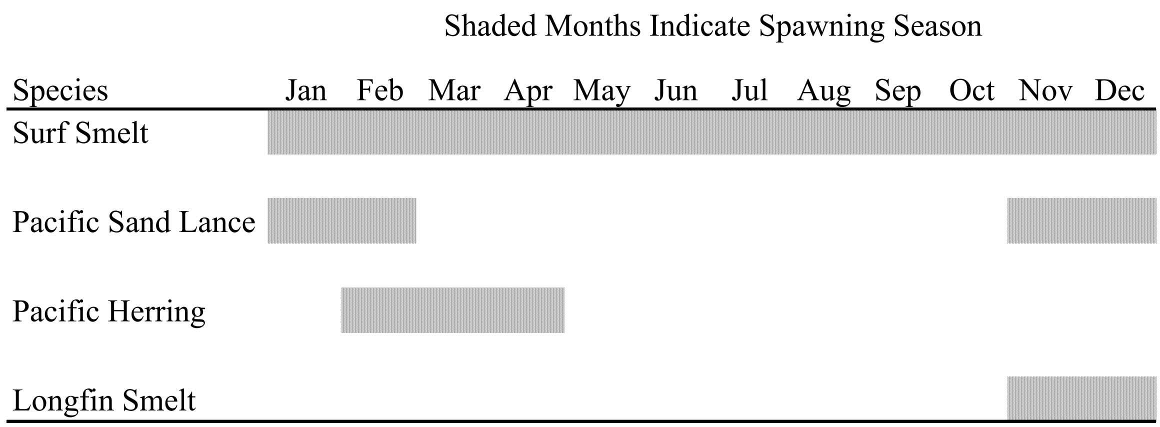


Figure 2. Spawning time of forage fish species in San Juan Islands.

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 3. Fresh surf smelt and Pacific sand lance spawn deposits.

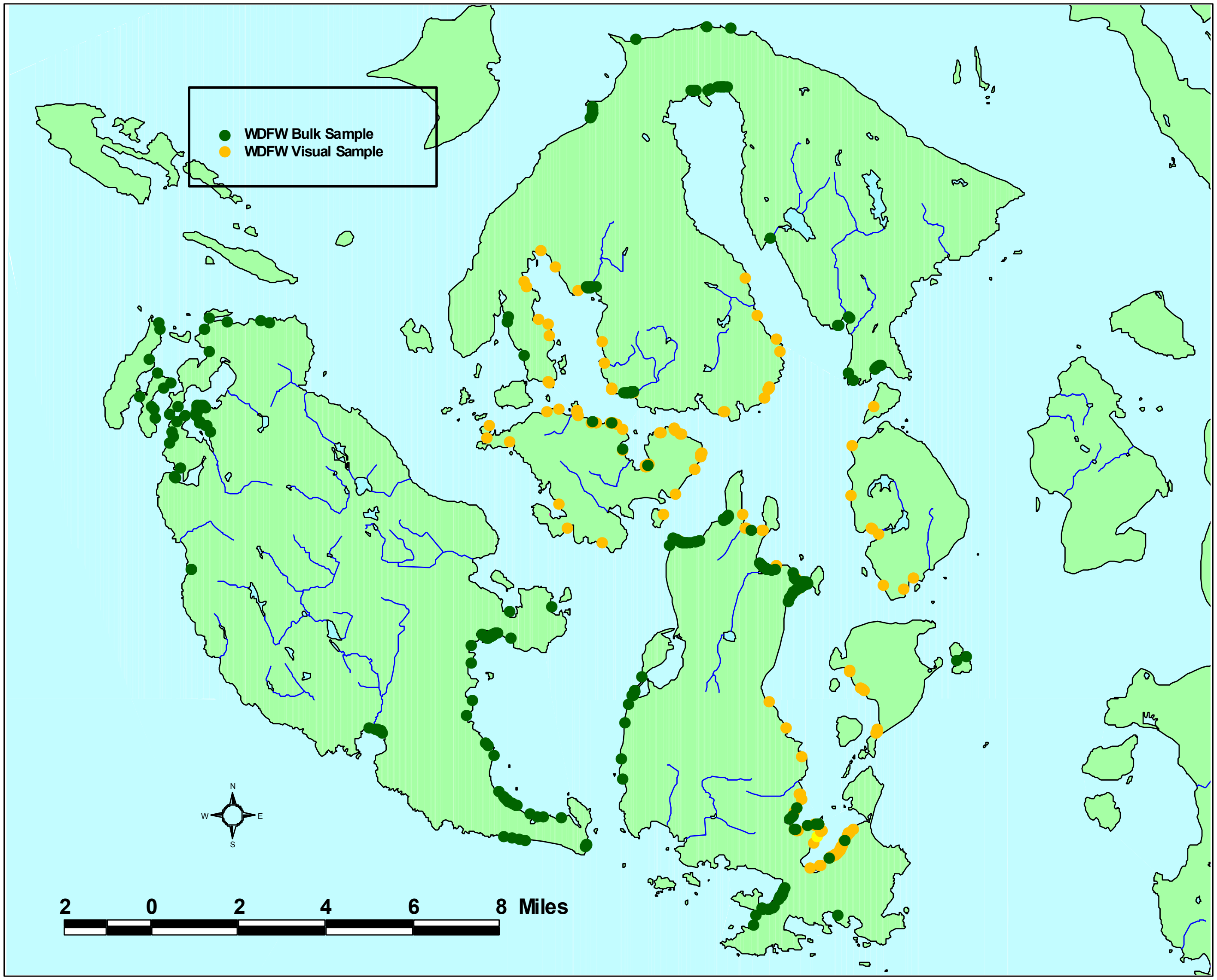


Figure 4. Distribution of intertidal sampling by WDFW to identify surf smelt and sand lance spawning beaches, 1989-2000.

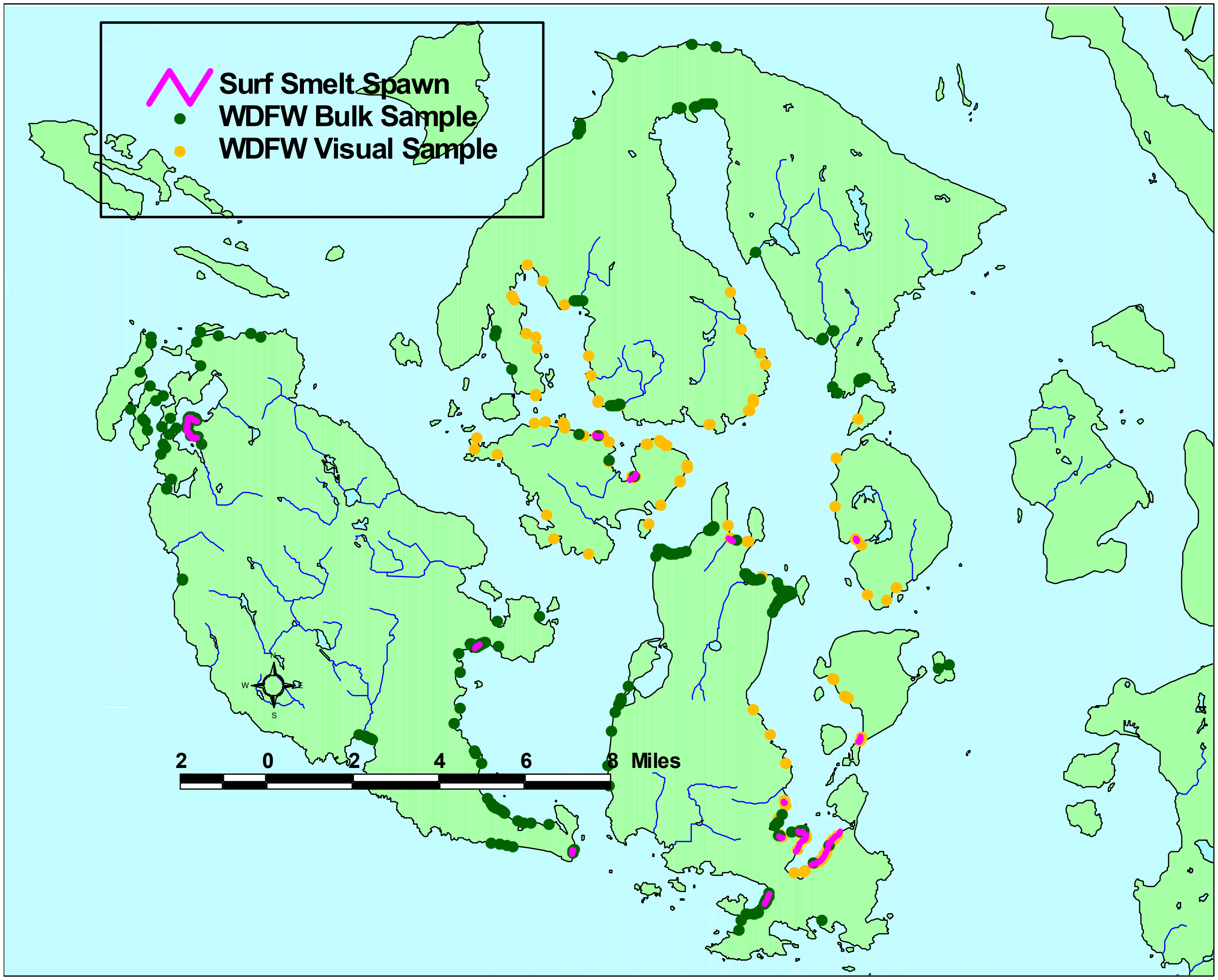


Figure 5. Results of WDFW sampling for evidence of intertidal spawning by surf smelt, 1989-2000.

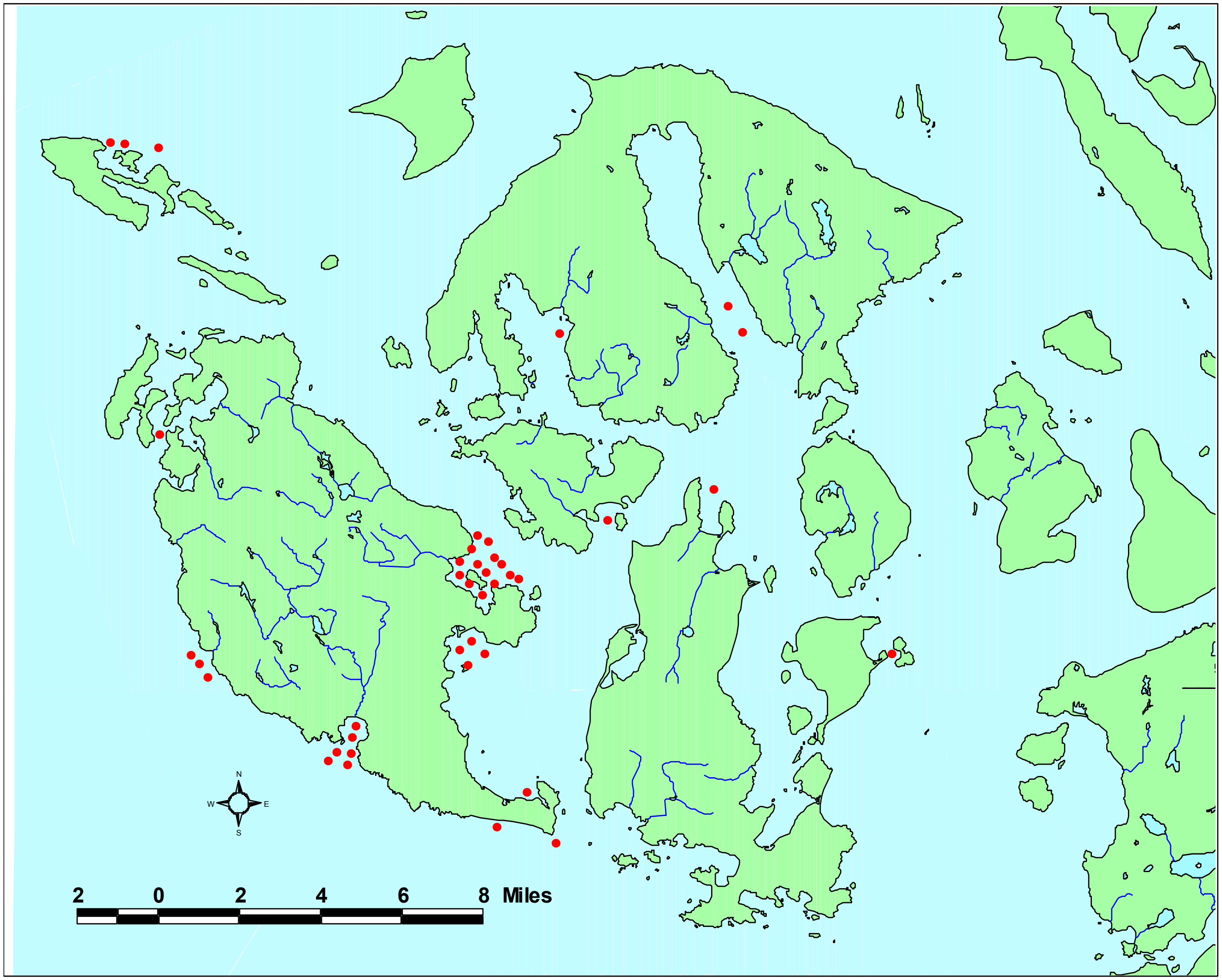


Figure 6. Historical records of Pacific sand lance in San Juan County (from Miller and Borton 1980).

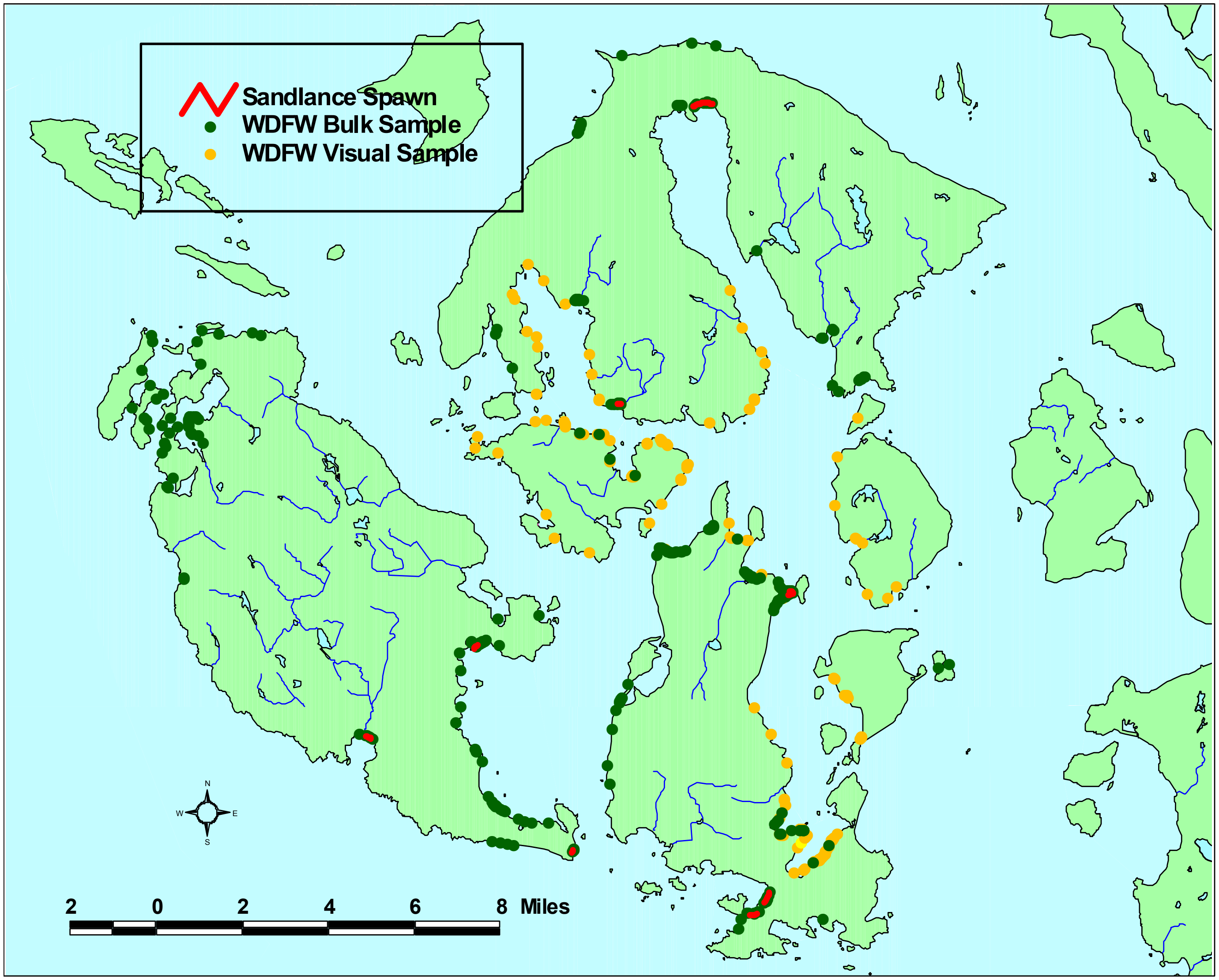


Figure 7. Results of WDFW sampling for evidence of intertidal spawning by Pacific sand lance, 1989-2000.

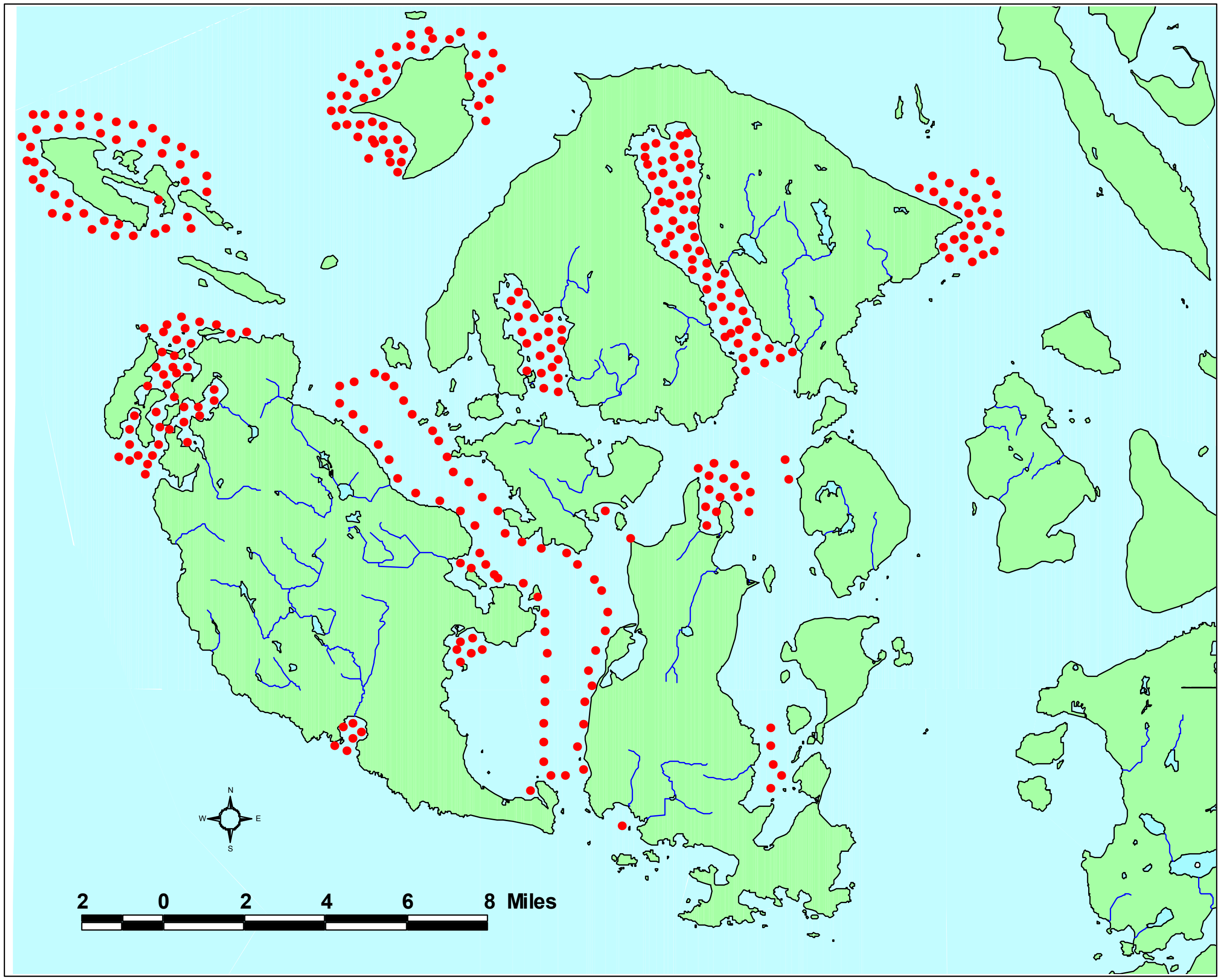


Figure 8. Historical records of Pacific herring in San Juan County (from Miller and Borton 1980).

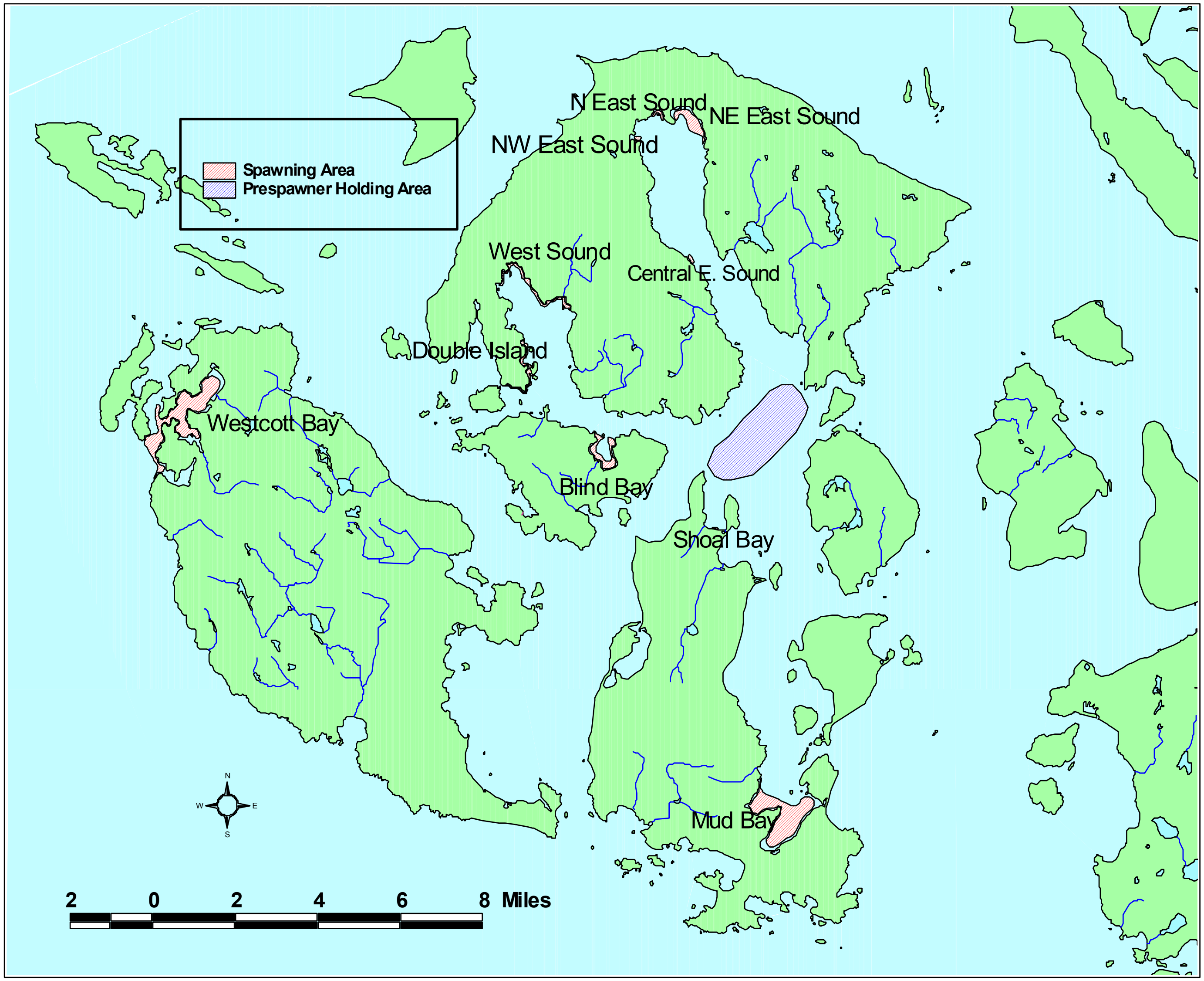


Figure 9. Distribution of known Pacific herring spawning areas and prespawner holding area in San Juan County.

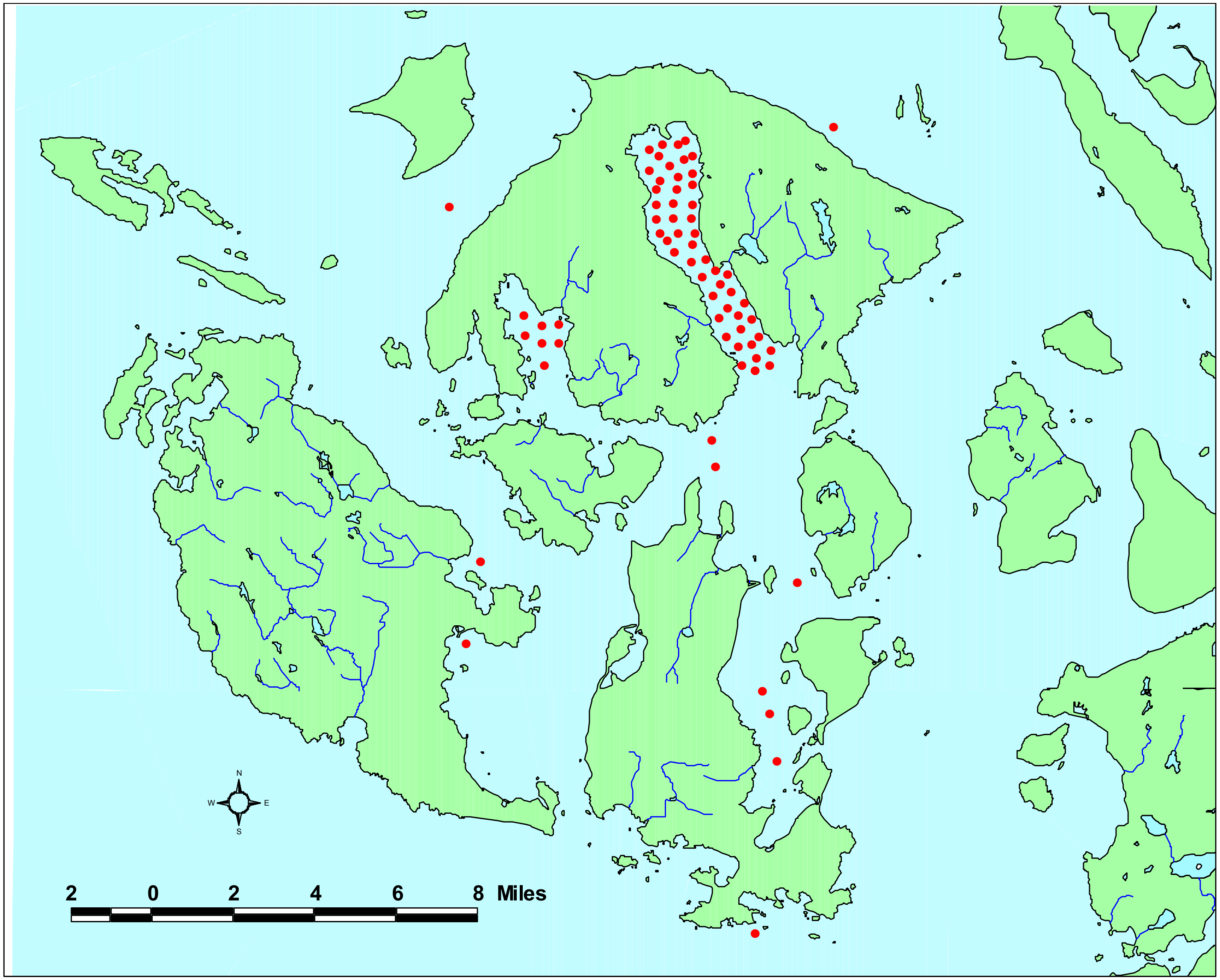


Figure 10. Historical records of longfin smelt in San Juan County (from Miller and Borton 1980).

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

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

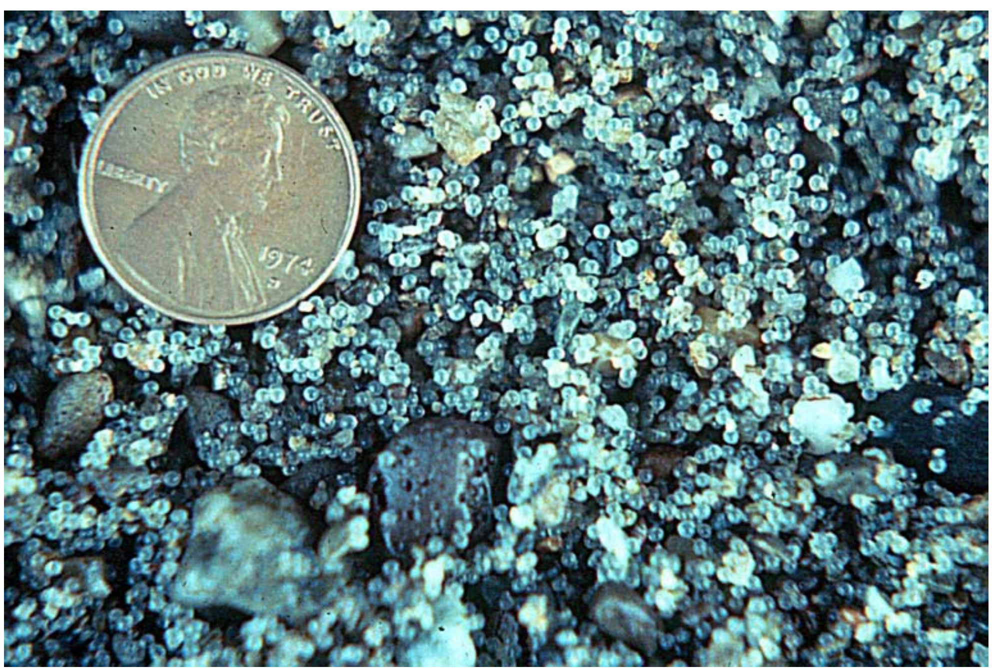
Figure 11. Representative surf smelt spawning beaches in San Juan County.

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

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

Figure 12. Examples of surf smelt spawning beaches in San Juan County.

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.



b. Heavy deposition of surf smelt eggs in situ.

Figure 13. Examples of surf smelt eggs in field conditions

last high tide		second effective high tide	
time	elevation	time	elevation

Intertidal Baitfish Spawning Beach Surveys

sector	month	day	year

Station	sample	latitude			longitude			beach	uplands	sample zone	land mark	tidal elevation	smelt	sand lance	rock sole	herring	width	length	shading	comments

Figure 14. 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.

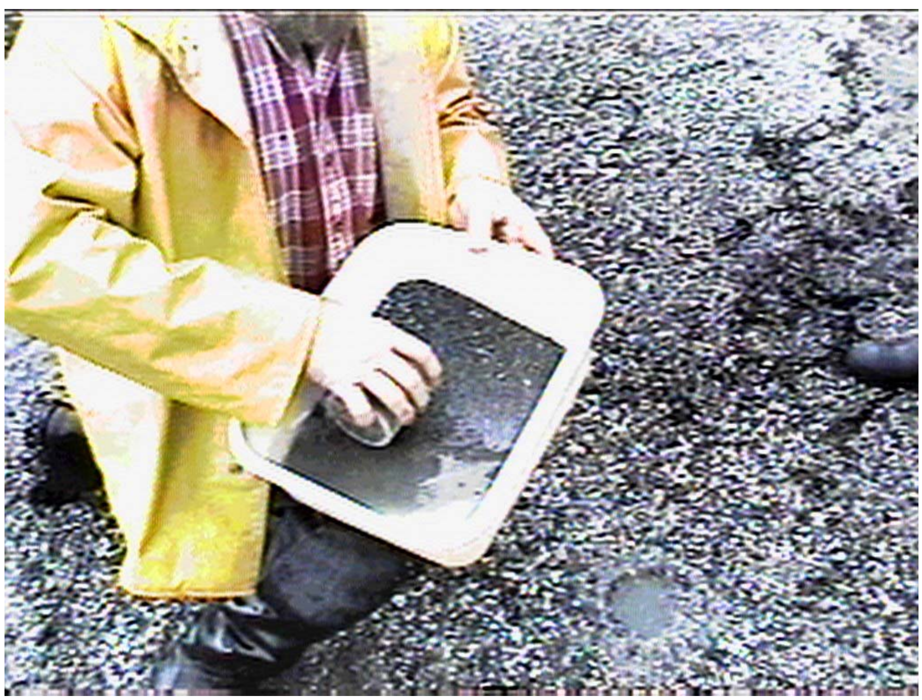
Figure 15. Sampling mixed sand/gravel beach for surf smelt and Pacific sand lance eggs.

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 16. Screening bulk sediment sample to separate egg-bearing sediments from larger material.

a. Pan is swirled to separate eggs from sediment.



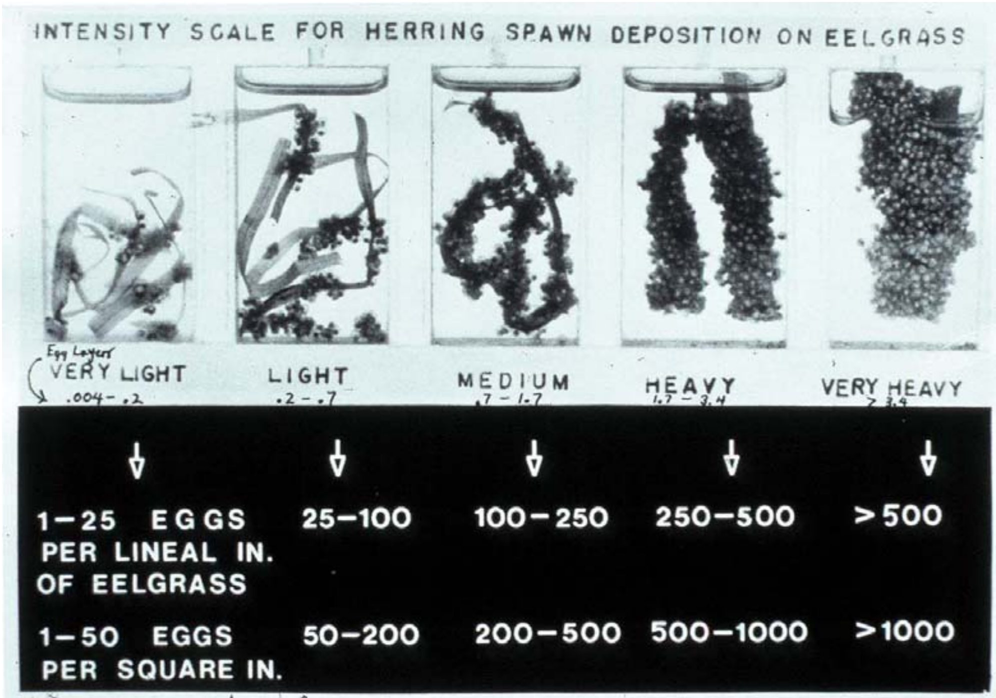
b. Lighter fraction of egg-bearing sediment is collected in a sample jar.

Figure 17. Winnowing bulk sediment sample to separate egg-bearing sediment from barren sand.

a. Marine vegetation rake is deployed from a small boat in shallow water.

b. Marine vegetation rake with light herring spawn on Gracilariopsis.

Figure 18. Marine vegetation rake used to sample herring spawn



a. Scale used to classify intensity of herring spawn.

b. Very light herring spawn on eelgrass – this is the typical classification and spawning substrate seen in the San Juan County spawning areas.

Figure 19. Pacific herring spawn intensity classifications.

a. Herring spawning area (in red) in East Sound, Orcas Island.

b. Herring spawning area (in red) in Blind Bay, Shaw Island.

Figure 20. Examples of Pacific herring spawning areas in San Juan County.

WASHINGTON STATE DEPARTMENT OF FISH AND WILDLIFE

HERRING SPAWN DEPOSITION SURVEY LOG

AREA____ DATE__________________

PERSONNEL____

BOAT______________ MOTOR__________ TIME LAUNCHED___________ TIME RETURNED__________

SPAWN INTENSITY: VL,L,LM,M,MH,H,VH

Sta. No.	Depth (ft)	Spwn Int.	Eelgrass	Agardhiella	Gracilariopsis	Ahnfeltia	Alaria	Botryoglossum	Callophyllis	Constantinia	Desmerestia	Fucus	Gelidium	Gigatina	Hydroids	Iridiea	Laminaria	Laurencia	Microcladia	Nereocystis	Odonthalia	Plocamium	Polyneura	Prionitis	Rhodymelia	Rhodymenia	Sargassum	Ulva	Urospora	Worm tubes	Terr. Debris			No vegetation	Eyed eggs	% mortality

Figure 21. Field data form used to record data associated with Pacific herring egg sampling.

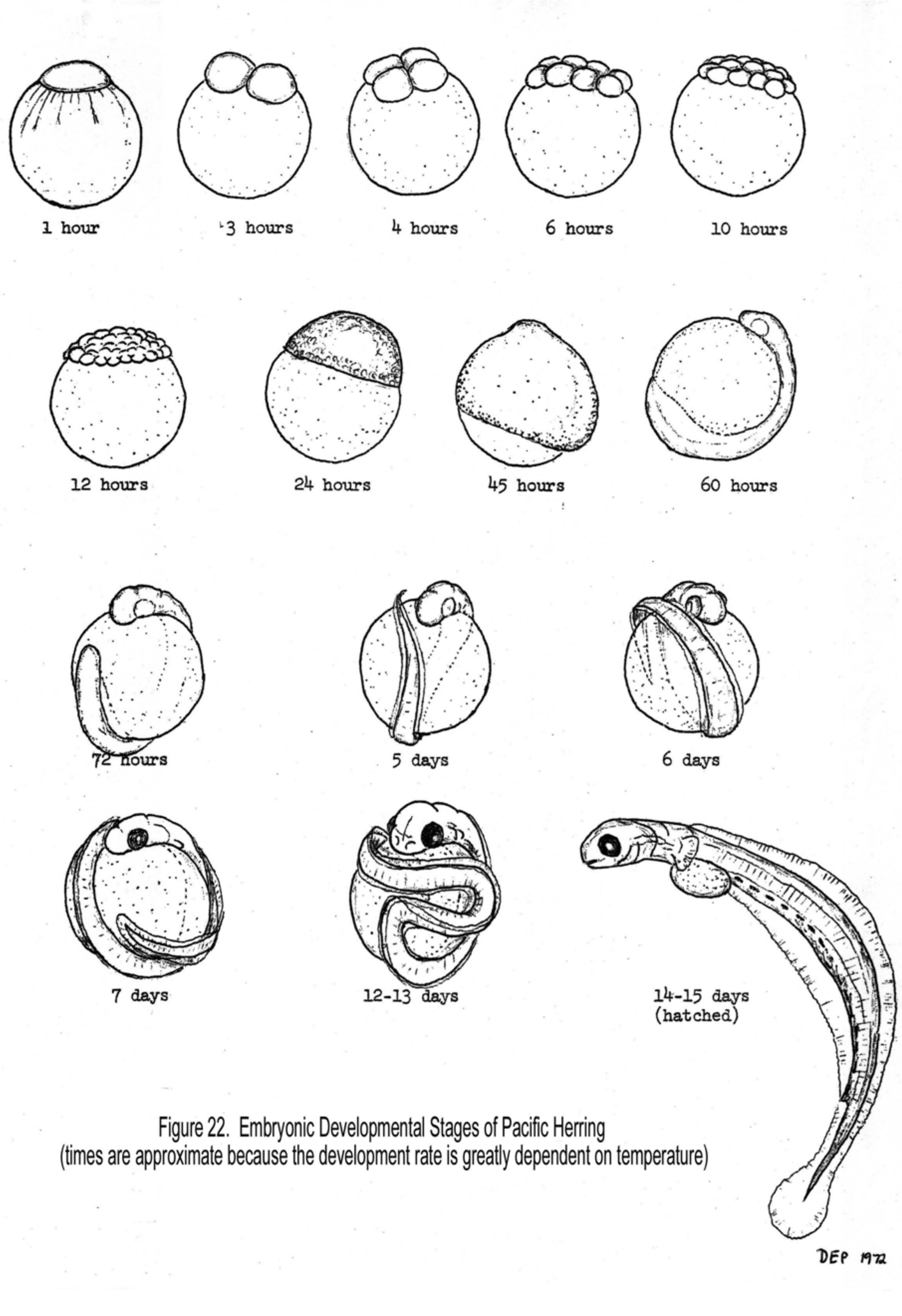


Figure 22. Embryonic Developmental Stages of Pacific Herring
(times are approximate because the development rate is greatly dependent on temperature)

APPENDIX A.

RECORDS OF FORAGE FISH DISTRIBUTION IN THE SAN JUAN ISLANDS

APPENDIX A. RECORDS OF FORAGE FISH DISTRIBUTION IN THE SAN JUAN ISLANDS (FROM MILLER AND BORTON 1980).

KEY TO SOURCE RECORDS

The listed entries contain the number of records for a particular location and the source of the information. For example, the following entry:

14 Friday Harbor: Powers, 1921

contains the number of records reported (14), the location (Friday Harbor) and the source of the information (Powers, 1921). The number of records refers to the number of occurrences for the species, not the number of individuals reported.

If the location is identified as "San Juan Islands," a record for the region was reported, but there was not a more specific location given by the source.

If the number of occurrences is 50+- (Fishing areas, etc.) then all locations listed would be 50+ each.

EXPLANATION OF SOURCE CATEGORIES

Published Records

This includes a broad spectrum of printed material, including technical reports.

University of Washington Museum Collection

These records are from notebooks listing the specimens preserved in the School of Fisheries Museum. The notebooks are kept in the museum.

Friday Harbor Laboratory Log

These logs are of collections made largely in the San Juan Islands and in connection with class or research work at the University of Washington, Friday Harbor Laboratories and/or the School of Fisheries.

University of Washington Boat Log

These logs list collections made using some of the research vessels (mainly the COMMANDO) of the School of Fisheries. Also listed are many of the class beach seine trips. The logs are available through the Dean's Office at the School of Fisheries.

Miscellaneous Logs

This is a potpourri of any legitimate record or set of records that cannot be classified by the above categories. They range from logs of various research institutions to verified phone calls and photographs from marine scientists. The following is an alphabetized listing and explanation of the abbreviated citations of important logs in the miscellaneous category that need further explanation.

NIH (date or collection number). Records from trawl and beach seine collections made under the direction of Dr. Bruce S. Miller as part of various National Institute of Health grants.

NMFS, COBB - (cruise or date of cruise). Records from trawl collections of the R/V COBB made by the U.S. Department of Commerce, National Marine Fisheries Service.

U.W. Oceanography, 1964-67. Records from research collections made under the direction of Dr. T. Saunders English of the University of Washington, Department of Oceanography. Most collections were made by beam trawl from the R/V HOH.

Records of surf smelt (*Hypomesus pretiosus*) in San Juan County

Published Records

1 San Juan Islands: Starks, 1911.
1 San Juan Islands: Shelford et al., 1935.

University of Washington Museum Collection
2 Squaw Bay: 558; 2348.
1 Davis Bay: 604.
2 East Sound: 697; 744.
3 False Bay: 1124;1171;2984.
1 San Juan Islands: 2347.
1 Roche Harbor: 2989.

Friday Harbor Laboratory Log
1 Jackles Lagoon, Cattle Point: 6/29/51.
1 off Fish Creek, Cattle Point: 6/21/52-1.
1 Roche Harbor: 8/19/52.
10 Argyle Bay., 8/16/55-2; 7/5/60; 8/11/60-2,3,4; 6/22/61; 7/8/67; 7/12/61-1; 7/18/61-2; 7/15/63.
1 Prevost Harbor: 7/10/50-4.
1 Eagle Point: 7/13/50-3.
1 West Decatur Head: 7/24/50-1.
2 Friday Harbor Lab: 7/19/60; 8/4/61-2
2 Argyle Lagoon 8/11/60-1; 7/10/69-3.
1 White Beach: 8/16/60-4.
2 North Bay: 8/18/60-1,2.
1 McArdle Bay: 8/22/60-3.
1 False Bay: 6/29/61.
1 Turn Island: 7/30/61.
1 San Juan Island: 5/62.
1 Squaw Bay or West Sound: 6/30/67.
1 Argyle Lagoon: 7/9/73.

University of Washington Boat Log
3 training cruise area: East Sound; north of Rosario Point: 6603H; 6614H; 7118H.

References:

Starks, E. C. 1911. Results of an ichthyological survey about the San Juan Islands, Washington. Annals of the Carnegie Museum 7:162-213.

Shelford, V. E., A. 0. Weese, L. A. Rice, D. I. Rasmussen, and A. Maclean. 1935. General survey of the communities. Pages 251-332 in Some marine biotic communities of the Pacific Coast of North America. Ecological Monographs 5.

Records of Pacific sand lance (*Ammodytes hexapterus*) in San Juan County

Published Records
1 Sucia Island: Evermann and Goldsborough, 1907.
1 San Juan Islands: Starks, 1911.
1 East Sound: Smith, 1937.

University of Washington Museum Collection
1 Upright Head and Shoal Bay: 676.
1 East Sound: 691.
2 False Bay: 1132; 1160.
1 Kanaka Bay: 1154.
3 Friday Harbor: 2106; 3704; 11328.
1 Deadman Bay: 17961 also Friday Harbor Log, 8/2/63.

Friday Harbor Laboratory Log
1 Jackles Lagoon, Cattle Point: 6/29/51.
3 north side of Stuart Island: 7/10/50-7,8,9.
1 American Camp: 7/6/52.
18 Friday Harbor Lab: 7/30/52; 7/6/52; 7/7/52; 7/8/52; 6/13/52; 7/31/52; 6/14/52; 6/15/52; 6/16/52; 7/29/55; B/l/52; 8/2/52; 8/4/52; 8/9/52; 7/30/55; 7/50; 8/4/61-2; 6/67.
1 Friday Harbor: 6/21/55-2.
1 White Point: 5/25/55-1.
4 Argyle Bay: 8/16/55-3; 7/5/60; 7/12/61-4; 7/15/63.
1 James Island: 7/24/50-5.
1 Squaw Bay: 7/10/61-1.
1 San Juan Island: 5/62.
1 Deadman Bay: 6/22/63.
1 Cattle Point: 6/23/67-1.
3 False Bay: 7/18/67; 7/l/69-4,7.
1 night light, Friday Harbor Lab: 1969.

Miscellaneous Logs
50+ Sucia Island: Allyn Johnson, personal communication, 1972.
1 Friday Harbor: Bruce Miller, Diving Log, 9/10/65.
1 Edwards Reef, west-central San Juan Island: Bruce Miller, Diving Log, 8/16/66.

References:

Evermann, B. W., and E. L. Goldsborough. 1907. The fishes of Alaska. U.S. Bureau of Fisheries, Bulletin 26:219-360.

Smith, R. T. 1937. Observation on the shrimp fishery in Puget Sound. Washington State Dept. Fisheries, Biological Report 36D. 19 pp.

Starks, E. C. 1911. Results of an ichthyological survey about the San Juan Islands, Washington. Annals of the Carnegie Museum 7:162-213.

Records of Pacific herring (*Clupea harengus pallasi*) in San Juan County

Published Records
1 San Juan Islands: Shelford, 1935.
1 San Juan Islands: Starks, 1911.

14 Friday Harbor: Powers, 1921.

2 False Bay; Brown Island: Powers, 1921.

50+ northwest coast of San Juans: Kelly, 1946.

50+ Mosquito Pass; Waldron Island; and Stuart Island, spawning areas: Williams, 1959.

50+ Orcas Island near Point Lawrence, fishing area: Williams, 1959.

50+ nearshore areas of San Juan Channel, West Sound, and East Sound; west of Waldron Island; northwest Orcas Island; Roche Harbor through Mosquito Pass; fishing areas: Washington Marine Atlas Vol. 1, 1972.

50+ San Juan Islands spawning areas: West Sound; East Sound; west of Waldron Island; south of Henry Island; Upright Head to Humphrey Head: Washington Marine Atlas Vol. 1, 1972.

50+ s San Juan Islands spawning areas: Echo Bay and Shallow Bay of Sucia Island; bay on east side of Waldron Island; Roche Harbor; bays on both sides of Mosquito Pass especially Mitchell Bay and Westcott Bay; West Sound; Pole Pass: Chapman et al., 1941.

50+ spawning area: East Sound, heaviest in front of the town of East Sound: Chapman et al., 1941; Katz, 1942.

50+ great schools seen along northwest side of Waldron Island near Fisher Point and along the northwest shores of San Juan Island: Chapman et al., 1941.

University of Washington -Museum Collection
1 Squaw Bay: 568.
4 False Bay: 576; 583; 1123; 1170.
1 Davis Bay: 603.
6 East Sound: 693; 742; 2294; 17127; 17061 also Friday Harbor Log, 6/20/63; 18692 also NIH, 1964-66.
1 mid East Sound: 18693 also Friday Harbor Log, 6/5/64.
1 Flat Point, Lopez Island: 716.
3 Friday Harbor: 2094; 3703; 5122.
l West Sound: 2222.
1 Roche Harbor: 2947.

Friday Harbor Laboratory Log
8 West Sound: 6/23/51; 7/g/52-3 also boat log, 5220I; 7/26/60-1; 8/13/60-2; 6/26/61; 6/27/63-B; 6/20/69-2; 7/6/71-2.
1 off Rocky Bay: 6/30/51-2.
1 Satellite Island: 7/5/51-3.
1 south of Satellite Island: 8/15/55-1.
1 south of Orcas Island: 6/24/52.
2 Lopez Sound or East Sound: 7/l/52; 7/11/63.
1 White Point: 6/25/55-1.
1 Reid Harbor, Stuart Island: 7/g/52-2 also boat log, 5220H.
1 Fish Creek, Cattle Point: 7/21/52-1.
12 Friday Harbor Lab: 8/2/52; 7/13/52; 7/14/52; 7/15/52; 7/16/52; 7/10/55; 7/29/55; 7/50; 8/4/61-2; 7/17/69-2; 7/21/69-2; 7/22/69-2.
8 East Sound: 8/11/52; 7/6/60-2; 7/26/60-1; 8/13/60-1; 6/20/61; 5/11/62; 6/29/71; 7/6/71-1.
3 mouth of East Sound: 7/28/55-2; 8/11/55-3; 6/20/50-2 also boat log, 5033I.
6 mid East Sound: 1/17/64; 2/17/64; 4/3/64; 7/11/64; 6/20/69-1; 6/21/71-1.
1 Roche Harbor: 8/19/52.
1 Garrison Bay: 6/25/55-3.
1 East Sound or West Sound: 7/25/55.
3 Lopez Sound: 7/28/55-1; 7/6/60-1; 6/21/71-2.
1 Trump Island to Decatur Head: 8/11/55-2.
6 Argyle Bay: 8/16/55-2; 7/5/60; 8/11/60-2,4; 6/22/61; 7/15/63.
3 north side of Stuart Island: 7/10/50-7,8,9.
1 West Sound or Lopez Sound: 6/27/60.
1 Squaw Bay: B/l/60-1.
1 Mitchell Bay: 8/16/60-1.
2 Upright Head to Olga: 8/l/60-2; 7/10/61-2.
4 Argyle Lagoon: 8/11/60-1; 7/12/61-2; 7/10/69-2,3.
1 Westcott Bay: 8/16/60-2.
1 North Bay: 8/18/60-1.
1 False Bay: 6/29/61.
1 Mosquito Pass.: 7/17/61-1.
1 San Juan Island: 5/62.
1 Squaw Bay or West Sound: 6/30/67.
1 West of Neck Point: 7/31/69.
1 lower East Sound: 6/26/73-1.
1 Argyle Lagoon: 7/9/63.

University of Washington Boat Log
1 East Sound: 5033M.
12 training cruise area: north end of East Sound, north of Rosario Point: 6603H; 6614H; 6620H; 6630H; 6717H; 6722H; 6815H; 6819H; 6908H; 7118H; 7010H; 7313H.
1 training cruise area: southwest of Center Island, Lopez Sound: 7118I.
1 training cruise area: Lopez Sound, southwest of Center Island: 7017I.
1 training cruise area: East Sound, north of Rosario Point: 7017H.
1 East Sound: DeLacy's Log, 6/20/69.

3 East Sound: U.W. Ocean., Hoh, S.J., 1966.

Miscellaneous Logs
10+ Sucia Island: Allyn Johnson, personal communication, 1972.
10 Friday Harbor: NMFS, Cobb-21.
1 West Sound: NMFS, Cobb-21.
21 East Sound: NIH, 1964-66.
1 East Sound: NIH, 1968-71.
1 Friday Harbor: Miller, Diving Log, 1963-71.
1 Argyle Bay: Miller, Diving Log, 1963-71.

References:

Chapman, W. M., M. Katz, and D. W. Erickson. 1941. The races of herring in the State of Washington. Washington State Dept Fisheries, Biological Report 38A. 35 pp.

Katz, M. 1942. The herring races of Washington, with a note on the fecundity of the Seal Rock population. M.S. Thesis, Univ. Washington, Seattle.

Kelly, T. K. 1946. The commercial fisheries of Washington. Ph.D. Dissertation, Univ. Washington, Seattle.

Powers, E. B. 1921. Experiments and observations on the behavior of marine fishes toward the hydrogen-ion concentration of the seawater in relation to their migratory movements and habitat. Puget Sound Biological Station Publication 357:1-22.

Shelford, V. E., A. 0. Weese, L. A. Rice, D. I. Rasmussen, and A. Maclean. 1935. General survey of the communities. Pages 251-332 in Some marine biotic communities of the Pacific Coast of North America. Ecological Monographs 5.

Starks, E. C. 1911. Results of an ichthyological survey about the San Juan Islands, Washington. Annals of the Carnegie Museum 7:162-213.

Williams, R. W. 1959. The fishery for herring Clupea pallasii on Puget Sound. Washington State Dept. Fisheries, Fisheries Research Papers 22:5-30.

Records of longfin smelt (*Spirinchus thaleichthys*) in San Juan County

Published Records
1 San Juan Islands: Shelford, 1935.
1 East Sound: Smith, 1937.
1 San Juan Islands: MacPhee and Clemens, 1962.

University of Washington Museum Collection
1 Friday Harbor: 398.
5 East Sound: 2339; 14976 also Friday Harbor Log, 8/11/52; 6031; 17073 also Friday Harbor Log, 6/20/63; 17125.
1 West Sound: 2340.
1 north end of East Sound: 5757 also boat 491M.
1 west side of Orcas Island: 15994.
3 East Sound, south of Rosario Point: 19461; 19582; 19583 all also NIH, 1964-66.

Friday Harbor Laboratory Log
1 off Orcas Island opposite Barnes Island: 6/20/50-3.
1 south of Orcas Island: 6/24/52-1-3.
2 Lopez Sound and East Sound: 7/l/52; 7/11/63.
5 West Sound: 7/9/52-3 also boat 5220I; 7/26/60-2; 6/26/61; 6/20/69-2; 7/6/71-2.
7 East Sound: 7/6/60-2; 7/26/60-1; 8/13/60-1; 6/20/61; 7/8/63; 6/29/71-1; 7/6/71-1.
1 East or West Sound: 7/25/55.
2 Lopez Sound: 7/28/55-1; 6/16/61.
2 lower East Sound: 8/11/55-3; 6/26/73-1. 1 West Sound and Lopez Sound: 6/27/60.
2 Upright Head to Olga: B/l/60-2; 7/10/61-2.
1 San Juan Islands: 5/62.
1 south of Lopez Island: 6/27/63-A.
6 mid East Sound: 1/17/64; 2/21/64; 4/3/64; 6/5/64; 7/11/64; 6/20/69-1.

University of Washington Boat Log
14 training cruise area: East Sound, north of Rosario Point: 6603H; 6614H; 6620H; 6717H; 6722H; 6815H; 6819H; 6908H; 7118H; 7307H; 7010H; 7017H; 7110H; 7313H.
1 training cruise area: Lopez Sound, southwest of Center Island: 7307I.

Miscellaneous Logs
17 south of Rosario Point in East Sound: NIH, 1964-66.
1 East Sound: NIH, 1968-71.
1 Argyle Spit: NIH, 1968-71.
1 East Sound: A.C. DeLacy, personal communication, 6/20/69.
1 West Sound: U.W. Ocean., Hoh, San Juans, 1966.
2 East Sound: U.W. Ocean., Hoh, San Juans , 1966.

References:

MacPhee, C., and W. A. Clemens. 1962. Fishes of the San Juan Island Archipelago, Washington. Northwest Science 362:27-38.

Shelford, V. E., A. 0. Weese, L. A. Rice, D. I. Rasmussen, and A. Maclean. 1935. General survey of the communities. Pages 251-332 in Some marine biotic communities of the Pacific Coast of North America. Ecological Monographs 5.

Smith, R. T. 1937. Observation on the shrimp fishery in Puget Sound. Washington State Dept Fisheries, Biological Report 36D. 19 pp.