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Nearshore Habitat Mapping of the Central and Western Strait of Juan de Fuca Phase 2: Final Report

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Nearshore mapping of the Strait of Juan de Fuca Phase II.

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Abstract

This report continues four years of mapping forage fish habitat along the central and western Strait of Juan de Fuca. From August 2002 to June 2003 we sampled a total of 43.1 miles of beach and documented three new forage fish spawning beaches and, for the first time, documented forage fish –likely long fin smelt- spawning in lower rivers of the Olympic Peninsula. We conducted 13 nearshore workshops with outreach to over approximately 300 local citizens and recruited over a dozen new volunteers, and continue to develop a workshop focusing on nearshore restoration of the Elwha dam removal. Results of our field work support findings of previous years: forage fish spawning along Strait beaches is highly variable, and may be attributed to high seasonal variation documented for Strait nearshore habitats. Timing of spawning along Strait shorelines may be delayed relative to other areas of Puget Sound, again possibly due to seasonal variation in nearshore habitats. Citizen involvement in understanding nearshore processes of the Strait is critical for wise long term management of our nearshore ecosystem. Results of this four year project are now being realized in citizen based nearshore restoration partnership projects including Dungeness Landing and Ediz Hook restoration.

Introduction

Coined as 'the fourth corner' of Washington state, the north Olympic Peninsula is best known for the mountains of Olympic National Park and the Olympic National Forest. We also have stunning shorelines that border the Strait of Juan de Fuca and the Pacific Ocean. The nearshore Strait of Juan de Fuca, which offers 294 kilometers (176 miles) of shoreline, is a critical component of a functioning Puget Sound ecosystem. *It is the conduit of migrating species to and from inland marine waters of Puget Sound and*

British Columbia. Our shorelines offer over 70% of the kelp beds of coastal Washington. The nearshore Strait (shorelines stretching from Neah Bay to Admiralty Inlet including Port Angeles, Dungeness, Sequim, and Discovery Bays, Kilsut and Port Townsend Harbors) provide critical feeding, refuge, and migration corridor for many species including three federally and or state listed salmon (Puget Sound Chinook, Strait of Juan de Fuca/Hood Canal Summer Chum, and Bull Trout), as well as sockeye, pink, and chum salmon, many rockfish species (including copper, quillback, and black rockfish), forage fish (including surf smelt, sand lance, and herring) (Miller et al 1980; Moriarty et al 2002; Penttila 2002, 1999,1995; Shaffer 2003; Sikes et al 2002; Simenstad et al 1988; Stick 1991). We also have numerous shellfish species including crab, shrimp, geoduck and oysters (Shaffer 2001). We have numerous wildlife assemblages that depend on forage fish as well. These include marbled murrelets, tufted puffins, rhinoceros auklets and other alcids, sea otters, Dahl's porpoise, Harbor porpoise, and killer whales (Sanquinetti, Wilson pers comm..).

While over 60% of our tideland is publicly owned, less than 12% of the adjoining upland is publicly owned. Thus local landowners will have a huge impact on the disposition of the nearshore, even if the tidelands themselves are well protected. The Puget Sound corridor has suffered sobering marine habitat and resource declines. In contrast, north Olympic Peninsula/Strait of Juan de Fuca nearshore habitats and resources are relatively intact. For example, while 10% of Clallam county shorelines have been armored, over 50% of central Puget Sound has been altered. Historically the Olympic Peninsula has been a geographically remote area dominated by multigenerational large landowners. So pressure on our marine resources and nearshore habitats has been relatively low and focused in targeted areas (such as Port Angeles Harbor, Sequim, Discovery, and Dungeness Bays). Times however, are changing. Large landholdings previously kept in forestry are being subdivided for development. Residential densities along the shoreline are increasing rapidly. Along with this development comes shifts to the nearshore environment (Pilkey and Wright 1998; Johannesen and Chase 2001; Johannesen 2001). This shift is already being seen in nearshore management. For example HPA permit applications by individual landowners in Clallam County for bulkheads, piers, docks, and storm water outfalls increased by approximately 200% between 1999-2001 (Shaffer unpublished data). Impacts to the environment are now being noted (Johannesen 2001; Shaffer 2002).

With funding from the Northwest Straits Commission we have therefore developed and implemented a strategy to educate local citizens on the importance of nearshore habitats. In this project we partner to understand how important our nearshore habitats are, where critical areas in the nearshore are located, and how as local stewards we can help ensure that they are managed wisely. The project includes a strong combination of education and fieldwork, via a successful citizens forage fish monitoring project, now in its fourth year (see Moriary et al 2002a&b; Sikes et al 2002; Shaffer 2000, 2001,2002; Shaffer in press.)

<u>Methods and Material</u>:

Surf smelt and sand lance spawning mapping was conducted using standard methods developed by Dan Penttila and published in Penttila 1995 and Moultin and Penttila 2000 (see Appendix A). These are the same methods used in the previous three years mapping studies. Long fin smelt sampling was conducted as outlined in Appendix B.

Results

The citizen component of this work is impressive. We have presented 13 nearshore and forage fish workshops for and with local citizens groups over the last year. In total over 400 interested citizens have participated and approximately two dozen are active volunteers. Public awareness of wise management of nearshore has grown significantly and contributed to the restoration projects proposed along the Olympic Peninsula. The science component of this work is equally impressive. Over the last 12 months with one biologist, two interns (only one paid), and a growing list of volunteers we have sampled over 46 miles of shoreline and documented four new forage fish spawning areas including the documentation, for the first time, of forage fish spawning in the lower reaches of Olympic Peninsula creeks. Combining this with previous years work, over the life of the project we have sampled over 193 km (116 miles) of shoreline and documented no fewer than 12 new forage fish spawning areas, as well as made a number of significant discoveries on forage fish use of nearshore.As in previous years, data are incorporated into the WDFW forage fish database for habitat management. Clallam County, the local Native American Tribes, and NFMS are currently developing strategies to incorporate these data into Growth Management and zoning plans, as well as Essential Fish Habitat (EFH). Copies of data files will be provided to Clallam County and the tribes.

Results of the years work, by task, is as follows:

Task 1. Public education and outreach, forage fish and nearshore

Thirteen workshops and seminars were given to local stewards, including citizens groups, educational volunteer groups, and the local college (see table 1). In the first quarter (June-October) we gave nine nearshore presentations to local government and citizens groups (see below). Eight of these were oral presentations. A copy of the Powerpoint presentation of each is available on request. Audience size ranged from 5 to approximately 50. The last one was a series of poster presentations on forage fish and nearshore habitats of the Strait-complete with nearshore handout- for the Dungeness River festival. The festival had 3500 participants. In the second quarter (Oct-December) we held a half day forage fish workshop that netted a total of nine new volunteers and an evening nearshore and forage fish presentation that netted four. A copy of the Powerpoint presentation of each is available on request. Audience size ranged from 20 for the workshop to approximately 50 for the evening presentation.

In the third quarter we held a half day forage fish workshop for the Peninsula college Fisheries Ecology/Marine Conservation classes at Peninsula College on 20 March 2003. This resulted in two new fisheries intern volunteer candidates. A copy of the Powerpoint presentation of each is available on request. Audience size was 20 students. We are scheduled to hold another half day presentation on nearshore habitats and forage fish for local citizens on 3 May. Also, the 2001 WDFW-Clallam MRC co-sponsored work documenting juvenile salmon and forage fish use of nearshore paper was given at the Puget Sound Georgia Basin conference on 31 March 2003 Audience size was approximately 200 scientists, managers, and citizen's representatives from Canada and Washington state.

At project completion we had a minimum of 24 volunteers participating in forage fish surveys and nearshore work.A list of volunteers has been forwarded to Clallam County. A nearshore hand out was created and provided at each workshop. A copy of the handout has been provided to Clallam County. We are currently working on a citizens based nearshore workshop focusing on the central Strait and restoration elements of the Elwha dam removal.

Table 1. Synopsis of foragefish/nearshore presentations

Quarter	Date	Group	Presentation
I	17 June	Clallam County Commissioners	Forage fish work
	24 June	Audubon Society	Forage fish and you
	12 July	Friends of the Marine Lab	Nearshore, Forage fish, and you
	18 July	Soroptimist Jet Set	Nearshore, Forage fish, and you
	16 August	Pacific Woodrush	Nearshore, Forage fish, and you
	17 August	Pacific Woodrush	Nearshore, Forage fish and you field
	8 September	Streamfest	Nearshore, Forage fish and you
	21 September	Pacific Woodrush	Nearshore, Forage fish and you field II
	27 September	Dungeness River festival	Nearshore and forage fish posters (two); Nearshore fact sheet; Derelict gear poster (one)
II	9 November 2002	Local interested citizens- Forage fish workshop	Forage fish work
	15 January 2003	OP Audubon Society	Nearshore habitats and forage fish work
III	20 March 2003	Peninsula college, Fisheries Ecology/Marine Conservation	Nearshore habitats and forage fish work
IV	3 May 2003	City of PA/Peninsula College	Friends of the Marine Life Center

Task 2. Mapping spawning areas.

A. Surf smelt spawning. The contract between Clallam County and WDFW was finalized 1 August 2002. Seventeen beaches, totaling 6.5 miles, were sampled for surf smelt spawn two times between 1 August and 16 September 2002. Surf smelt spawn was found on two new beaches, just west of Jim Creek and One Half Mile beach located just west of Sekiu. A total of six eggs were found at Jim Creek, all of which were in gastrula stage. Four eggs were found at One Half Mile Beach, all of which were in blastula stage (see maps 1-4 for sampling sites and new spawn beaches). Surf smelt sampling for 2003 began in April and will conclude mid August. These results will be summarized in our August 2003 final report.

B. **Sand lance spawning**. We began sand lance sampling on 13 November 2002 and concluded sampling the last week of March 2003. In total we sampled 19 beaches six times and three beaches one time, for a total mileage of 36.6 miles (Table 1). In total we documented 3431 feet of new spawning beach at Clallam Bay. Table 2. summarizes egg stage from spawn collected at this beach.

Results of this year further support our findings of the last two years: forage fish spawning on Strait beaches is highly variable, likely due to high seasonal variability in the physical structure of our beaches. This work also indicates that sand lance spawning on Strait beaches may occur later than other winter spawning areas again due to our variable beach habitat and season transitions that occur during sand lance spawning season.

Table 1. Summary of beaches sampled for sand lance spawn 2002-2003. * Indicates spawn found. Many beaches were sampled repeatedly

Beach number	Beach Name	Distance(ft)	Total Distance Sampled	Total 2002-03
1	Mitigation Beach	986	1972	5916
2.	Bullman Cr.	1000	2000	6000
3.	Rasmussen Cr.	650	1300	3900
4.	Jansen Cr.	400	800	2400
5.	Shipwreck Pt.	1450	2900	8700
6.	Hoko/Sekiu	5649	11299	34164
7.	Mouth Hoko	800	1600	4800
8.	1 Mile Beach	4475	8950	26850
9.	½ Mile Beach	750	1500	4500
10.	Olsens Pocket	200	400	1200
11.	Clallam Bay W.	2750	5500	16500
12.	**Clallam Bay C. ***	**3431**	**6862**	**20586**
13.	Deep Cr.	1580	3160	9480
14.	Twin R.	1200	2400	7200
15.	Salt Cr.	625	1250	3750
16.	Hollywood B	200	400	1200
17.	D. Oyster Hse.	650	1300	3900
18.	E. Travis Spit	4000	8000	24000
19.	Diamond Point	800	1600	4800
20.	First Beach	600	600	600
21.	Second Beach	1100	1100	1100

22.	Third Beach	1657	1657	1657
	Total for 2002-2003	**34953**	**66550**	**193203**

Table 2. Egg stage of sand lance spawn collected at Clallam Bay, 6 February 2003.

		Stage					
	Total	**1cell-morula**	**blastula**	**gastrula**	**1/2-1coil**	**1 coil**	**dead**
Number of eggs	68	14	9	9	32	1	3
Percent		20.6	13.2	13.2	47.1	1.5	4.4

B. **Long fin smelt spawning.** Long fin smelt are referenced as one of the most abundant forage fish on western Strait shorelines (Miller et al 1980). Long fin are documented to spawn in the Nooksak river and Lake Washington. There are repeated local reports of forage fish in lower creeks along the western Strait during winter months, but long fin spawning in Strait creeks has not been documented. We therefore conducted a pilot assessment of long fin smelt spawning along lower creeks and river mouths of the central and western Strait. Sampling methods are provided in Appendix B.

Table 2 and Figures 1-4 summarize our long fin smelt sampling sites. Spawn was collected at one site, Deep Creek, on 26 February, 4 March, and 11 March 2003. Eggs were verified as osmerid eggs (Penttila, WDFW memo 3 March 2003). A total of 41 eggs were collected. Most were in the early development stage (from the 26 February sampling, 37% -7 eggs- were blastula, 5%-1 egg- was ½-1 coil, and 58%-11 eggs- were dead. Peninsula college interns attempted to grow out a subset of eggs at the aquaculture lab at the college for species verification, but the samples were lost.

Table 3. Development stage of long fin* spawn collected at Clallam Bay, 6 February 2003 (*pending confirmation)

				Stage			
	Total	**1cell-morula**	**Blastula**	**Gastruala**	**1/2-1coil**	**1 coil**	**Dead**
Number of eggs	19		7		1		11
Percent			36.8		5.3		57.9

Table 4. Long fin smelt sampling sites

Creek	# samples	Distance from sampling station to creek mouth (feet)	Spawn detected
Valley Creek	2	600	None
Salt Creek	4	1000	None
Lyre River	4	300	None
East Twin	4	1200	None
West Twin	4	340	None
Deep Creek	**7**	**800**	**41 eggs and two larval fish**
Clallam River	4	145	None
Sekiu River	4	200	None
Bullman Creek	4	280	None

Task 3. Public outreach, derelict gear
A derelict gear poster was created for the Dungeness River Festival booth. The festival had 3500 participants.

We dialoged with the local dive shop on interest and availability for partnering with the derelict gear project, and with SeaGrant staff about local partnering opportunities. We had the derelict gear project coordinator come and present to the MRC. We assisted with the writing of the next Clallam EAG, which has a large derelict gear focus.

Task 4. Information to Website
Provided 2002/2003 quarterly reports to Susan Hindle for newsletter and website update (http://www.teamwatermark.com/ClallamMRC/) as well as to regional forage fish web page.

Discussion
At the conclusion of our fourth year, our work continues to be premiere and unique- we focus not only on documenting spawning sites using standard WDFW techniques, but also on defining more detailed use of nearshore, including kelp beds and lower rivers. This work is biologically comprehensive, complementary to, and in complete partnership

with,other forage fish mapping efforts underway in the Puget Sound and San Juan Islands. Our ongoing contribution of Strait forage fish use completes the regional focus intended with the Northwest Straits Commission.

We have made many important discoveries over the life of this project. We now know that forage fish, likely long fin smelt, spawn in our lower rivers. This is important when noting that long fin smelt are the most abundant forage fish on our western shoreline (Miller et al 1980). We also now know that our surf smelt spawning egg mortality is high, around 30%, and that this mortality is independent of beach and month (Shaffer 2001). This mortality is consistent with mortality documented in other studies, which also showed that shoreline alterations can result in significant increases in mortality of forage fish eggs (Penttila 2001). This is extremely important from a management perspective. Activities on Strait beaches should be thoughtfully designed and conducted to avoid increasing egg mortality beyond the already high natural level.

Based on our four years work we also now know that surf smelt and sand lance spawning along the Strait of Juan de Fuca is extremely variable. For example, WDFW has sampled Clallam Bay beaches for over a decade, but only documented spawning here by both sand lance and surf smelt within the last two years. Also, over four years we have repeatedly noted that surf smelt and sand lance spawning appears to occur later along the Strait of Juan de Fuca than other areas of Puget Sound (Moriarty et al 2002, Penttila pers comm.). This variability may be due to a number of factors including the seasonal variability in habitat as documented along the Strait of Juan de Fuca (Moriarty et al 2002, Shaffer 2000). The Strait is a wind dominated system (see Shaffer 2000 for a discussion). Beaches profiles and substrate composition here change from week to week.. In this study we repeatedly noted that optimal spawning habitat became most prevalent for surf smelt later in the summer (August-September), and later in the spring (March) for sand lance. This is also when we consistently found new spawning sites. The high intra- and inter-annual variability of habitat use along the Strait is an important point for habitat management. It may be difficult to accurately predict when spawning may be occurring along Strait beaches within a surf smelt or sand lance spawning season. Field sampling is the definitive tool for assuring no impact to resources.

Finally, four years of field work with local citizens has clearly shown us that our shorelines function in a number of ways, all of which are linked. Restoration actions should be developed with this in mind. Excellent examples of where these fuctions are being brought together in a restoration context -as a result of this project- include the Dungeness Landing project, which includes both a boat ramp redevelopement and a beach restoration. Another is the Ediz Hook restoration partnership which includes a 1500 foot stretch of shoreline that is being restored via citizen, Port, Tribal, DoT, and WDFW partnership. Both of these projects will be to the benefit of both local citizens that use the area for recreation and for juvenile forage fish and salmonids that depend on the area for spawning and migration. Future restoration partnerships to focus on include the Elwha dam removal and it's relationship to the nearshore habitats and shoreline so important for local citizens and our marine ecosystem.

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Appendix A (NOTE: reprinted from Penttila citations: cite as Penttila 1995 or Moulton and Pentilla 2000)

Materials and Methods

Surf Smelt and Sand Lance Spawn Assessment

Sampling for surf smelt 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 spawning habitat. Suitable sites are composed of a mixture of sand and small gravels. The spawning and incubation areas are normally in the +7 to +9 foot Mean Lower Low Water tidal zone. Areas that are shielded from direct sunlight by overhanging vegetation are often more heavily used than areas where vegetation is non-existent or has been removed. Potential spawning sites along the Strait of Juan de Fuca were identified with the use of aerial photographs, and personal communication with local residents possessing knowledge of forage fish.

Once potential sites had been identified, a sampling schedule was generated, taking into consideration that spawning times may differ between areas. Because the purpose of this study was to determine the extent to which spawning occurs in the Strait, all selected beaches were sampled at least three times to ensure that spawn was not overlooked due to timing.

Field Equipment

Equipment needed for collecting bulk beach samples to assess surf smelt:

- 8 ounce plastic jar or scoop
- 1 gallon or larger plastic storage bag
- Waterproof labels

Equipment needed for condensing samples:

- Rack of sediment screens, sizes 2 and 0.5 mm
- One five gallon bucket modified to act as a drain for screen rack
- Wash bucket
- Plastic dishpan
- 8 ounce plastic sample jar
- Stockards Solution (preservative) 50 ml formalin(37% formaldehyde), 60 ml glycerin, 40 ml glacial acetic acid, 850 ml distilled water

Field Records

Certain physical characteristics of the sampled location were recorded to help analyze the results of the sampling. These records were entered on a field data sheet at the time of sampling (Figure 14). The data fields are as follows:

Date of Sampling
Station: Station number, starting with 1 each area, each day
Sample: Sample number.
Latitude/Longitude: Listed 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

6 = boulder with sand base
7 = gravel to boulders without sand base
8 = rock, no habitat

Uplands: Character of the uplands (to 1000 feet):
1 = natural, 0% impacted
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 the sample collection:

1 = down the beach from the last high tide mark
2 = up the beach from the last high tide mark
3 = down beach from second to last high tide mark
4 = down beach from upland toe
5 = up beach from waterline at 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.

Smelt, Sand Lance, Rock Sole, Herring: subjective field assessment of spawn intensity:
0 = no eggs 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 1000 feet, or "C" if continuous.

Shading: Shading of the spawning substrate zone, averaging over the 1000 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 observations, evaluated on a station by station basis.

General Protocol for Collecting Bulk Beach Samples

Each beach was examined to determine the area(s) most likely to contain spawn. This zone is typically in the upper third of the beach, near the upper tidal limit. For surf smelt eggs, the zone is characterized by mixed sand and small gravel. Mud or muddy sand are not acceptable substrates. Larger gravel, cobble or solid rock are also unacceptable.

The sample is composed of four scoops of gravel, evenly spaced along a 100 foot stretch of beach:

- Identify an approximately 100 foot of beach to be sampled
- Obtain location information from a GPS or map of area
- Prepare a label identifying location of sample
- Start at one end of the transect, fill scoop with sand from the top 0.5 inch of beach and dump into the plastic storage bag. The scooped area should be 3-4 feet long
- Move 10 paces along the transect, obtain another scoop sample and place in the storage bag

- Repeat until the four scoops have been obtained. This constitutes a bulk sample for one location

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. However, in this study, all such work was done at Peninsula College, where there was access to a hose. This separation was 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 upwards during this washing process, allowing them to be skimmed from the surface material. The washing procedure is as follows:

- Assemble the screens on top of the drain bucket, with the larger mesh on top.
- Remove the sample label and place it in the 8 ounce storage jar
- Add a portion of the sample to the top screen, thoroughly wash the sediment through the screen set with fresh water
- Discard the sediment in the top screen, retaining only the material in the lower (0.5mm) screen
- Dump the material retained in the smaller 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
- 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

Final separation was performed under a dissecting microscope at 10-20x, where the eggs became quite visible. Eggs found were separated once identified. Embryology was conducted at this time, and recorded on the examination data sheet (Figure 16). Due to the relatively long incubation periods, it was common to see two or more different stages in the sample. If possible, a random sample of 100 eggs was selected for the embryological examination.

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 shells. These objects include certain invertebrate eggs, algal fruiting bodies, and flatworms and their egg cases.

Quality Insurance/Quality Control

The primary concerns for quality control are:

- Sampling the appropriate habitat
- Accurate identification of sample habitat
- Careful screening and winnowing of the bulk sample to retain the maximum number of eggs
- Accurate identification of the sampled eggs

Adequate training of the samplers may be the best way to ensure good data. To check accuracy, a sample known not to contain eggs may be seeded with a known number of eggs, and then processed to see how many of the eggs are detected.

Appendix B:

Long fin smelt Materials and Methods

Eight rivers and creeks between Port Angeles and Neah Bay were sampled bi-weekly from mid January thru March 2003. All were sampled within 0.25 mile of the river mouth. A 0.5 meter diameter, 0.25mm mesh plankton net, which when submerged sampled a volume of 8.3 cubic feet was used for sampling. The net cod end had a hard, plastic, removable catch container with 0.5 millimeter mesh. Sampling consisted of hanging the net from bridges that crossed the main channel near the mouth of each site, with the exception of the Lyre River, which was sampled from streamside access points. The net was submerged until the top of the mouth was underwater, and fished for five minutes. The sample was preserved with Stockard's solution. To prevent cross contamination the net was thoroughly rinsed with tap water before sampling the next creek. In the lab, samples were visually examined with a dissection scope and all fish larvae collected saved and later identified by Dan Penttila, WDFW.

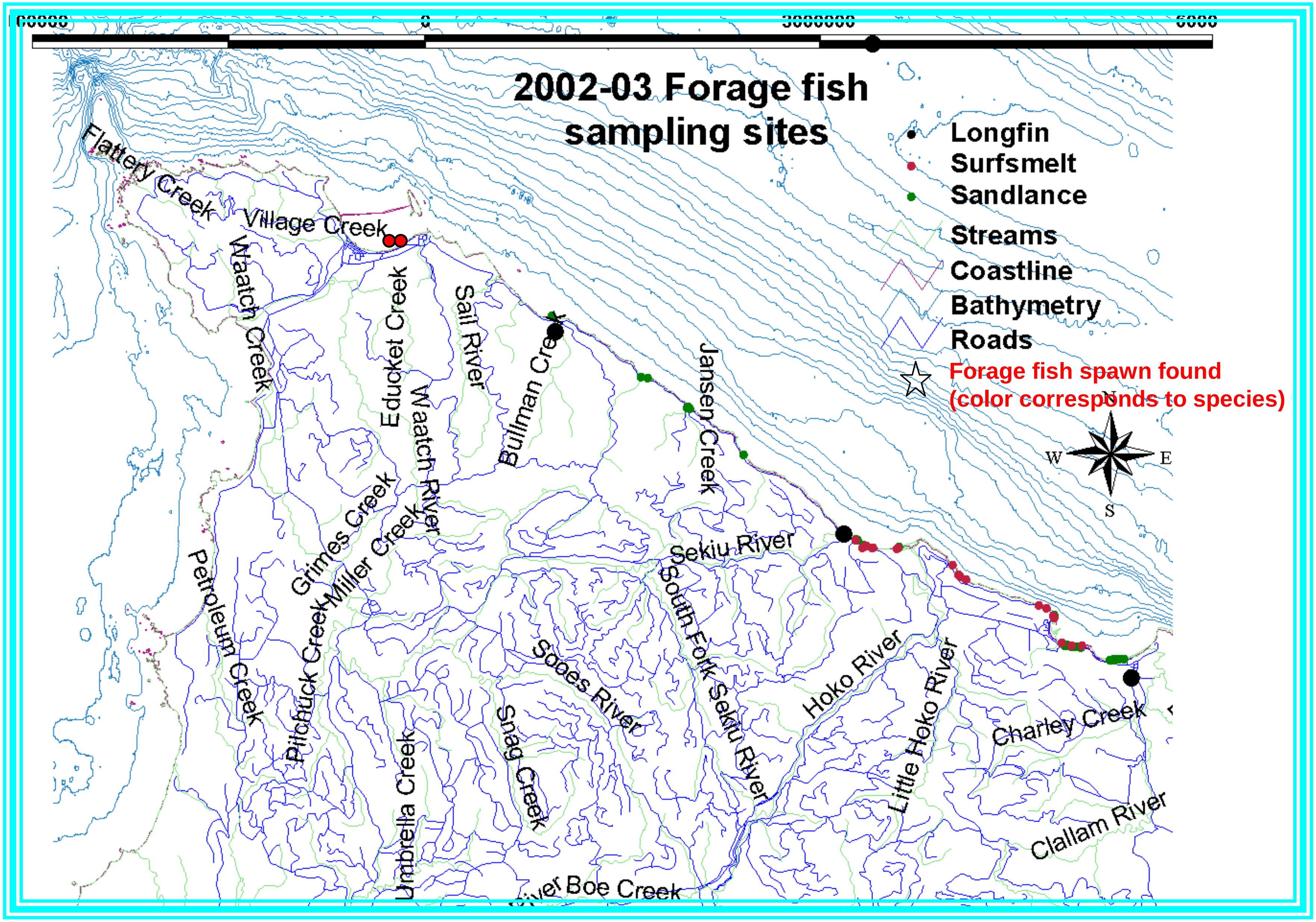

Figure 1. Forage fish sampling sites

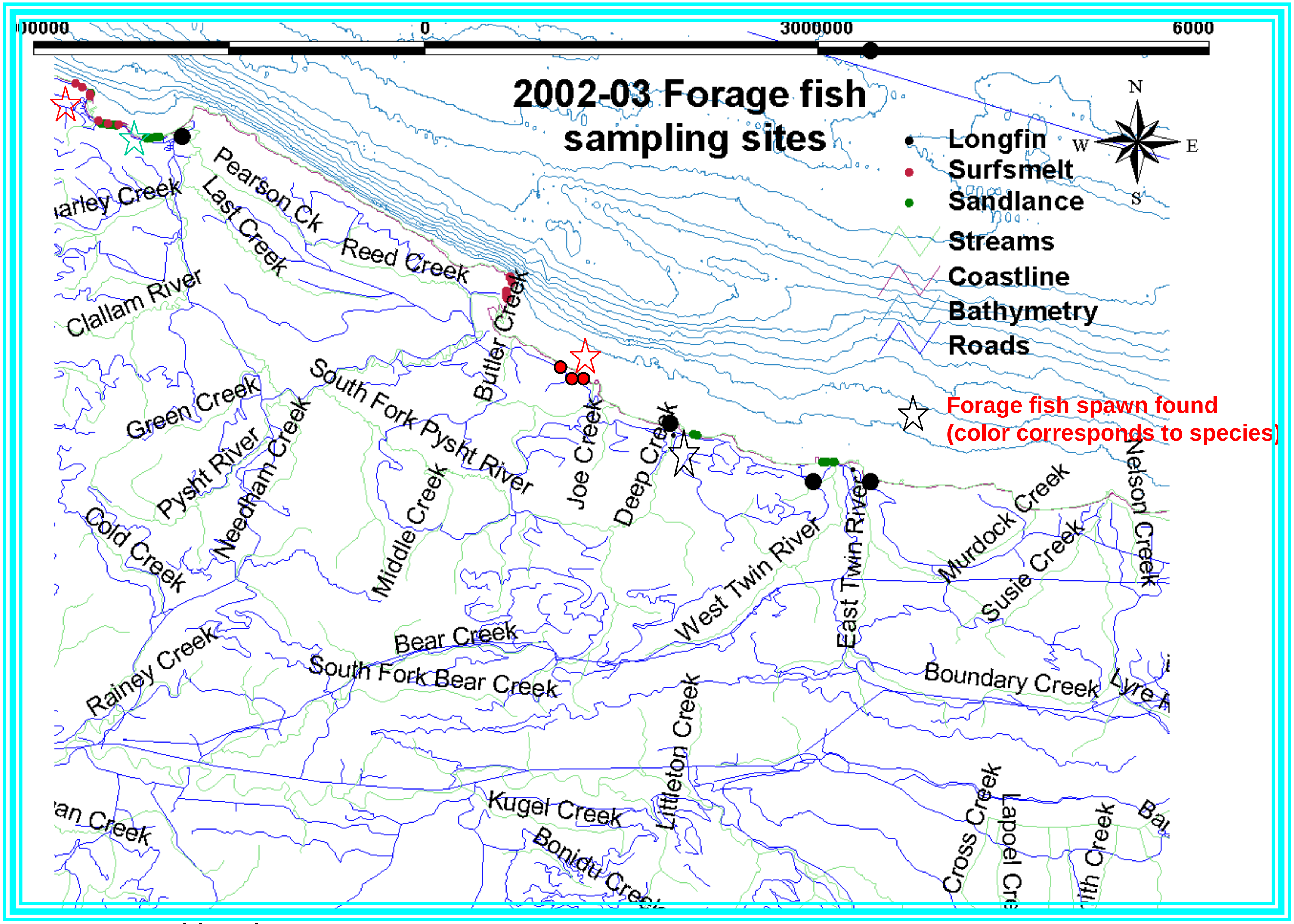

Figure 1. Forage fish sampling sites

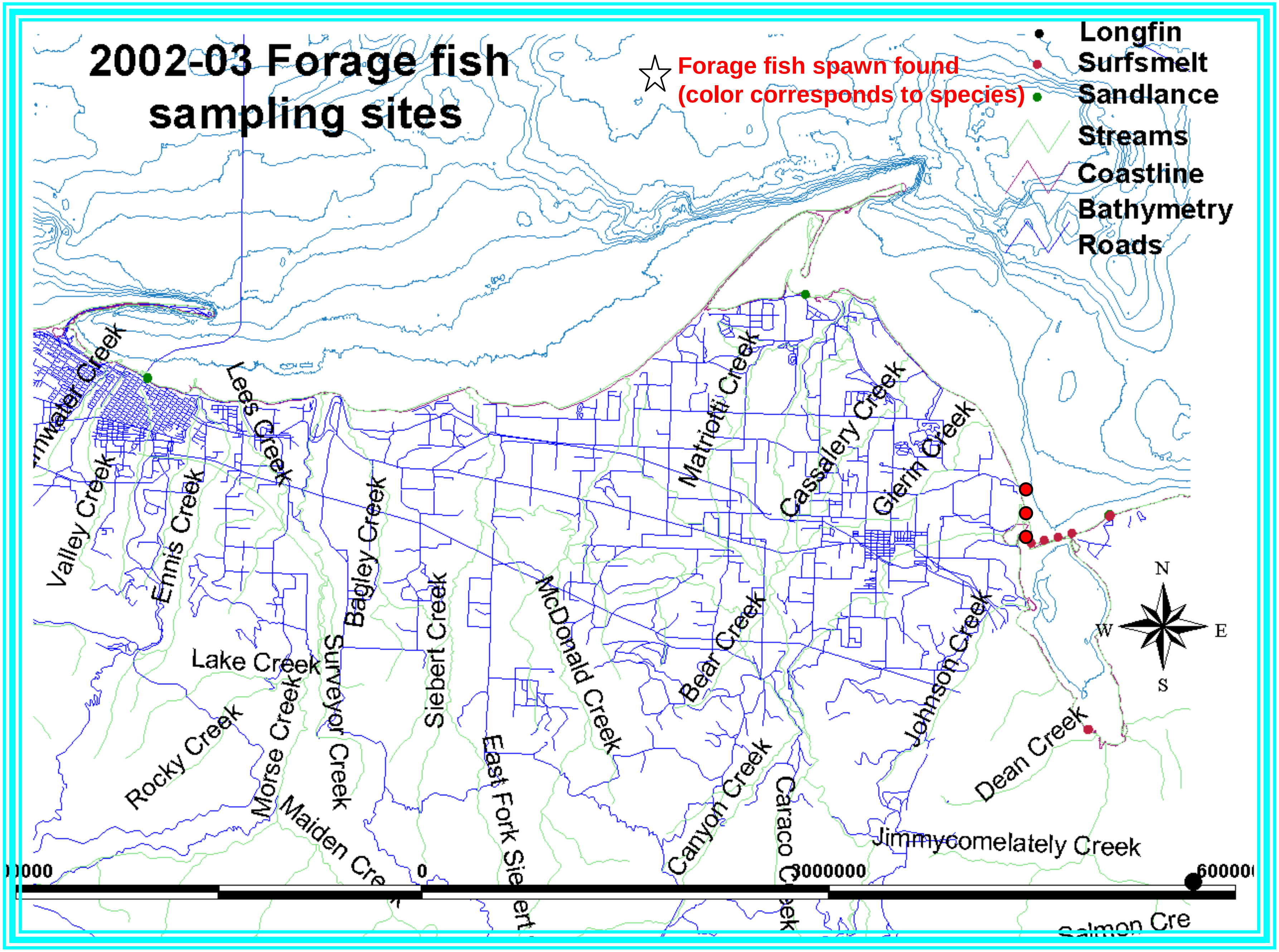

Figure 1. Forage fish sampling sites

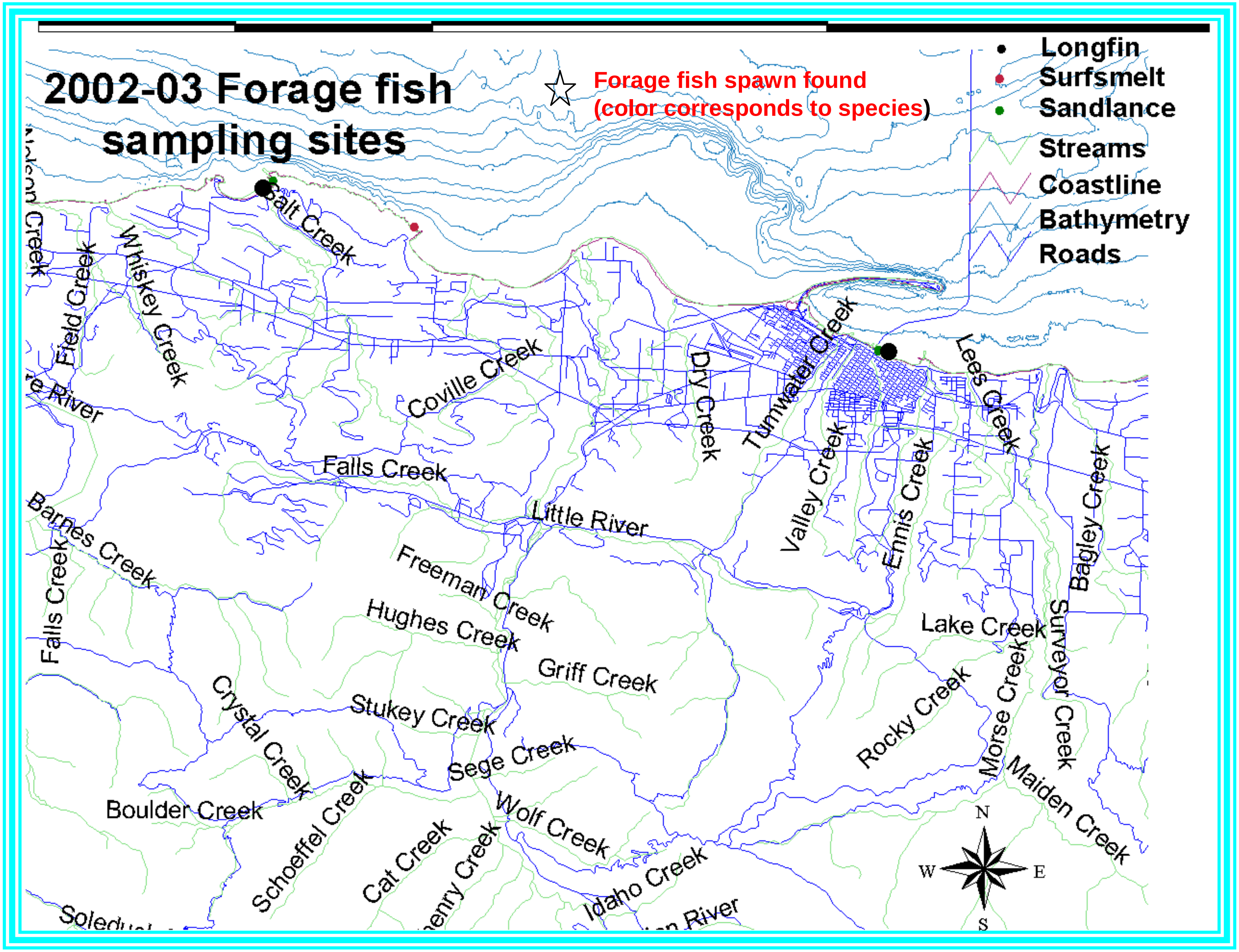

Figure 1. Forage fish sampling sites

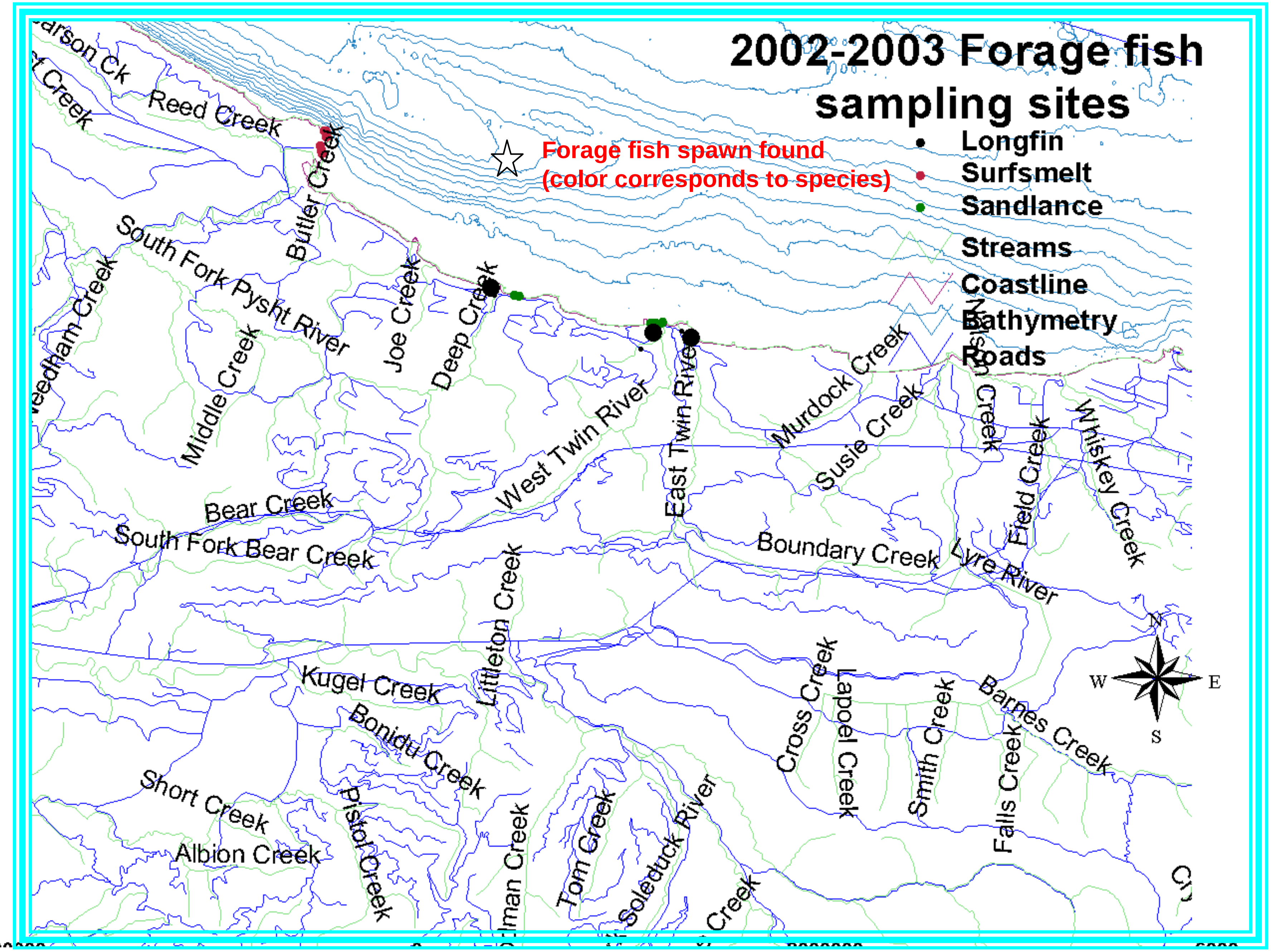

Figure 1. Forage fish sampling sites