GUIDANCE DOCUMENT: FORAGE FISH BEACH SPAWNING SURVEYS IN BRITISH COLUMBIA

Prepared by WWF-Canada and Archipelago Marine Research Ltd.

This "Guidance Document: Forage Fish Beach Spawning Surveys in British Columbia" was led by Jacklyn Barrs, with support from Brianne Kelly and Rachel Wang. This document is part of WWF-Canada's Food for All initiative.

Methodology, predictive maps and other supporting materials were contributed by the forage fish team from Mount Arrowsmith Biosphere Research Institute (MABRRI) at Vancouver Island University. This team included Alanna Vivani, Chrissy Schellenberg and Ryan Frederickson under the leadership of Haley Tomlin.

Thank you to Phillip Dionne (Washington Department of Fish and Wildlife) and Cliff Robinson (Fisheries and Oceans Canada) for their expert reviews and support of this document.

Special thanks to Pam Thuringer (WWF-Canada volunteer, M.Sc.). This guidance document could not have been developed without Pam's guidance, expertise and generous contributions.

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This "Guidance Document: Forage Fish Beach Spawning Surveys in British Columbia" was prepared as a resource to support the quality assurance and documentation of forage fish spawning beaches in British Columbia. Processes and recommendations are outlined to ensure consistent and approved methods are being used to produce data that can be applied in regulatory and policy decision-making.

The intended audience for this document ranges from the curious citizen scientist to Qualified Environmental Professionals (QEPs). This document should be used with its companion documents attached separately in Appendix A to E.

Appendix A: Using ShoreZone to Model Suitable Forage Fish Spawning Habitat in the Gulf Islands

Appendix B: British Columbia Forage Fish Spawning Habitat Monitoring: Citizen Science Methodology

Appendix C: British Columbia Forage Fish Spawning Habitat Monitoring: Academic and Qualified Environmental Professionals Sampling Methodology

Appendix D: Forage Fish Spawning Habitat Beach Survey: Citizen Science Datasheet

Appendix E: Forage Fish Spawning Habitat Beach Survey: Academic and Qualified Environmental Professionals Datasheet

These Appendices are an adaptation of existing methodologies used to conduct forage fish beach spawning surveys, including the Washington Department of Fish and Wildlife 'Vortex Methodology' – an addendum to 'Field Manual for Sampling Forage Fish Spawn in Intertidal Regions' (revised in 2006).

This guidance document should be reviewed and updated as new information, technology and methods develop.

INTRODUCTION

Forage fish refers to small, schooling fish that consist of many species, including sand lance, smelts, herring and anchovies. These are critical species in the ocean food web that connect the lower and upper trophic levels – they feed on phytoplankton and zooplankton and transfer this energy to marine fish, seabirds and marine mammals (Field 1988; Willson et al. 1999). Forage fish are often abundant in number and weight; however, cumulative effects from predation, poor water quality, habitat modification and degradation, overfishing and climate change can make these fish susceptible to dramatic population fluctuations (WWF 2016). Given their critical ecological role as prey species, these fluctuations also increase the vulnerability of important predators like Chinook salmon *(Oncorhynchus tshawytscha)* and marbled murrelets *(Brachyramphus marmoratus)* in British Columbia (BC MOE 2014; EC 2014).

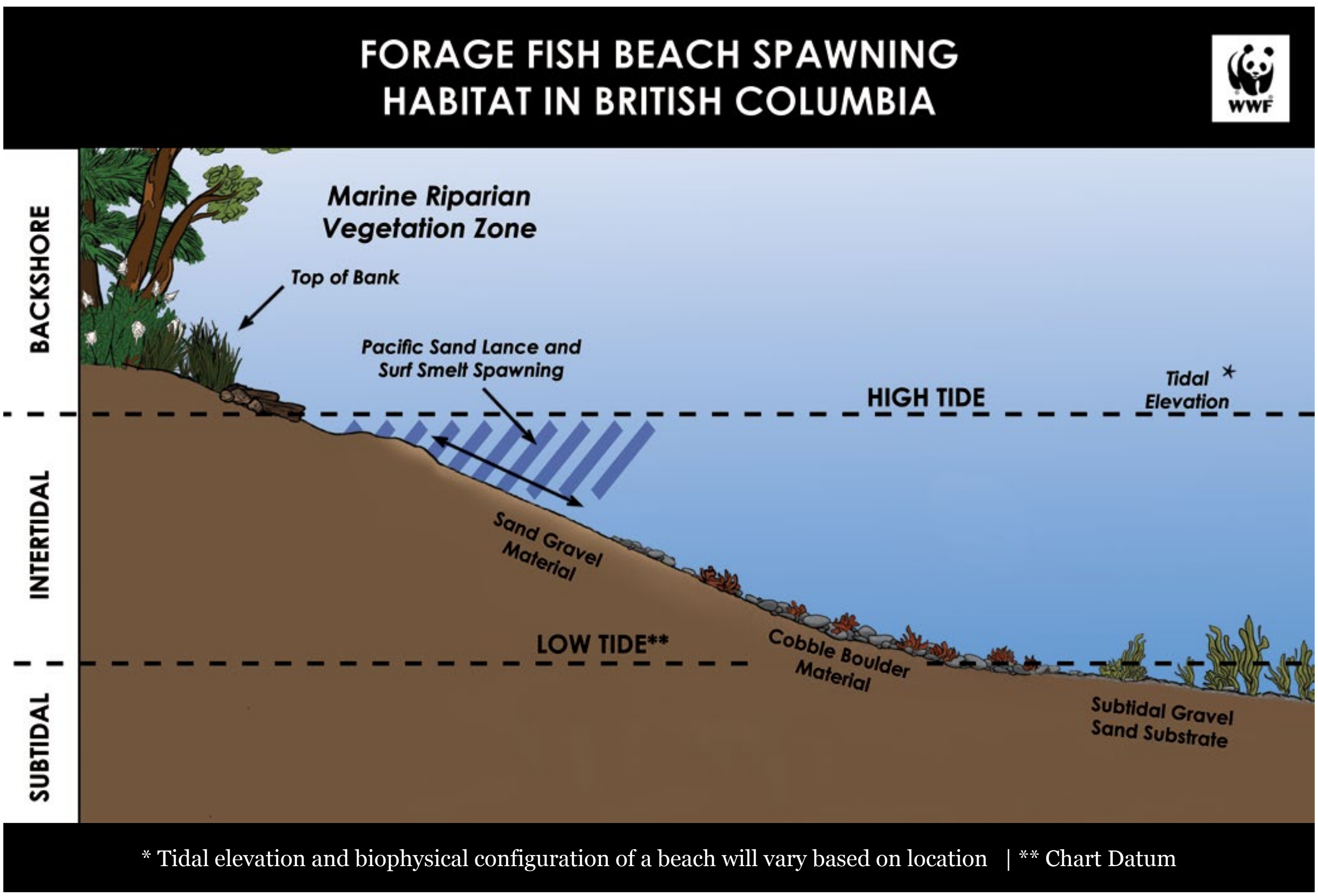


Figure 1. Illustration of forage fish beach spawning habitat in British Columbia (prepared by Core Creative Design).

Pacific sand lance *(Ammodytes personatus)* and surf smelt *(Hypomesus pretiosus)* utilize upper intertidal sand and pebble habitat for spawning, which has been extensively documented throughout Washington State. Non-systematic and systematic forage fish spawning surveys were carried out in Puget Sound from 1972 to 1990 and 1991 to 1995, respectively, to determine both spawning areas and spawning seasons for Pacific sand lance and surf smelt (Pentilla 1995a; 1995b; 1997). In Puget Sound, over 20,000 spawn assessment surveys have been conducted at more than 3,600 beaches; some beaches have been surveyed more than 40 times over the last several decades (Pierce et al. 2009).

In Washington State, surf smelt spawning activity occurs across different wave exposure regimes, from sheltered beaches in southern Puget Sound to the exposed pebble beaches on the outer coast of the Olympic Peninsula (Pentilla 2007). As of 2019, approximately 6 per cent of the Washington State shoreline was documented as Pacific sand lance habitat and 34 per cent as surf smelt, with some overlap in habitat use between species (WDFW 2019).

The waters of Washington State and British Columbia are connected by the Salish Sea – a biologically rich inland sea including Puget Sound, the San Juan Islands and the Strait of Georgia. The name is a step towards recognizing that this sea encompasses unceded territory of the Coast Salish nations.

While Washington State has carried out forage fish beach spawning surveys along their coastline in the Salish Sea since 1972, surveys and assessments in British Columbia are underdeveloped. As a result, knowledge is limited on Pacific sand lance and surf smelt abundance, distribution and use of intertidal beaches for spawning in British Columbia's portion of the Salish Sea (Therriault et al. 2002, 2009; Pentilla 2007). The eggs of Pacific sand lance and surf smelt have been found on beaches in British Columbia; therefore, it is hypothesized that they are intertidal spawners (Therriault et al. 2002, 2009; Blaseckie et al. 2002).

Forage fish spawning beaches are undergoing a 'coastal squeeze', where they experience both the impacts of shoreline development on land and climatic conditions from the sea. This is diminishing the quantity and quality of beach habitat for forage fish spawning (Martin 2015). For example, 53 kilometres of natural shoreline in Burrard Inlet (Vancouver, British Columbia) have been lost to coastal squeeze – yet the threats of urban and industrial development and sea level rise continue (Stantec 2009; Tsleil-Waututh 2017).

The conservation of Pacific sand lance and surf smelt populations are dependent on the availability of suitable spawning habitat. Long-term monitoring and data collection, as well as documented intertidal spawning (and potential spawning) habitats will begin to address the data gaps in British Columbia. Data and other knowledge forms can then be used to inform management decisions that impact intertidal areas, in addition to coastal processes and water quality. In moving towards an ecosystem-based approach, this data will also contribute to other on-going research projects in the nearshore environment and throughout the entire Salish Sea.

The purpose of this guidance document is to support the use of consistent forage fish beach spawning survey methodologies in British Columbia. Processes and recommendations are outlined to help organizations and individuals identify best practices for quality assurance and documentation.

Objectives

1) Outline the data collection process to simplify data flow and identify expertise required at each stage

2) Provide guidance – including standardized sampling methodologies – for individuals and organizations to conduct beach surveys

3) Compile a list of community contacts to facilitate connections with experts and other groups in the field

Expanding the monitoring network in British Columbia will provide data that can be used to inform nearshore policies and support evidence-based advocacy that push for the protection and restoration of forage fish beach spawning habitat. Most notably, this expansion presents the opportunity for a deeply collaborative approach that values iterative processes, as well as respectful and mutual knowledge exchanges *(see Figure 2)*.

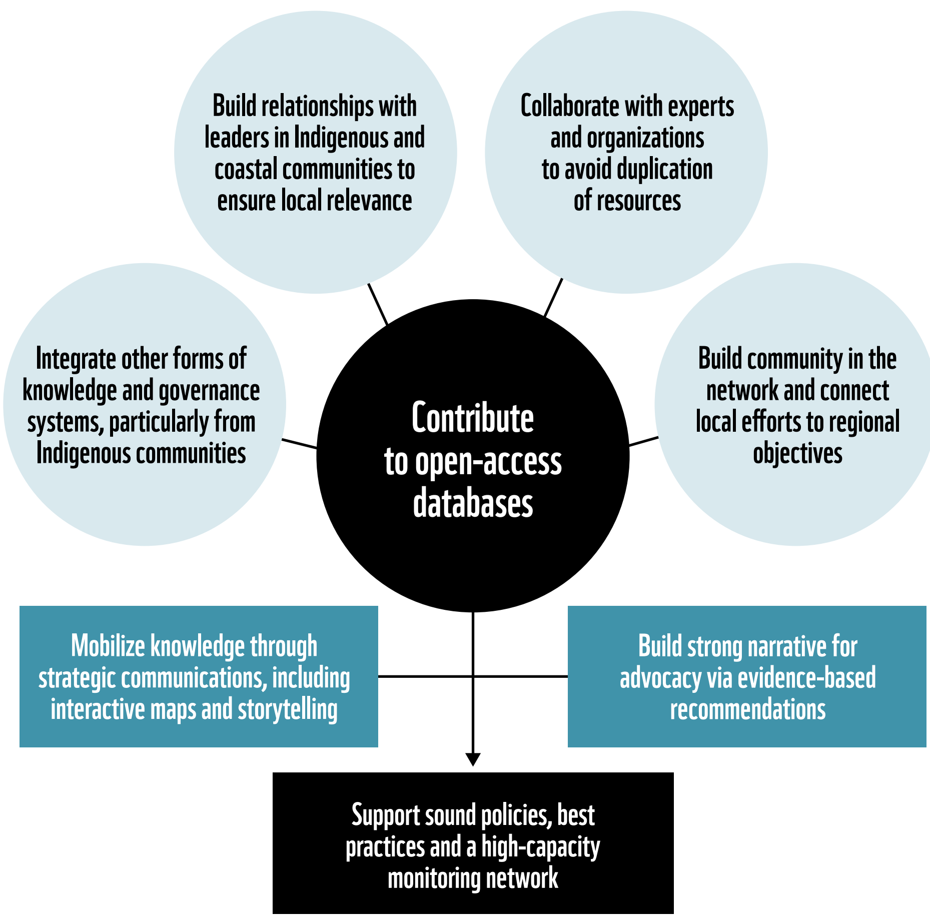


Figure 2: Collaborative steps needed to achieve an expanded monitoring network in British Columbia

The data collection process may vary depending on the individual or organization. For instance, academic institutions may have more technical capacity and resources than citizen science groups. The diagram below identifies what expertise is required at each stage and offers options to determine the most appropriate process for each individual or group *(Figure 3)*.

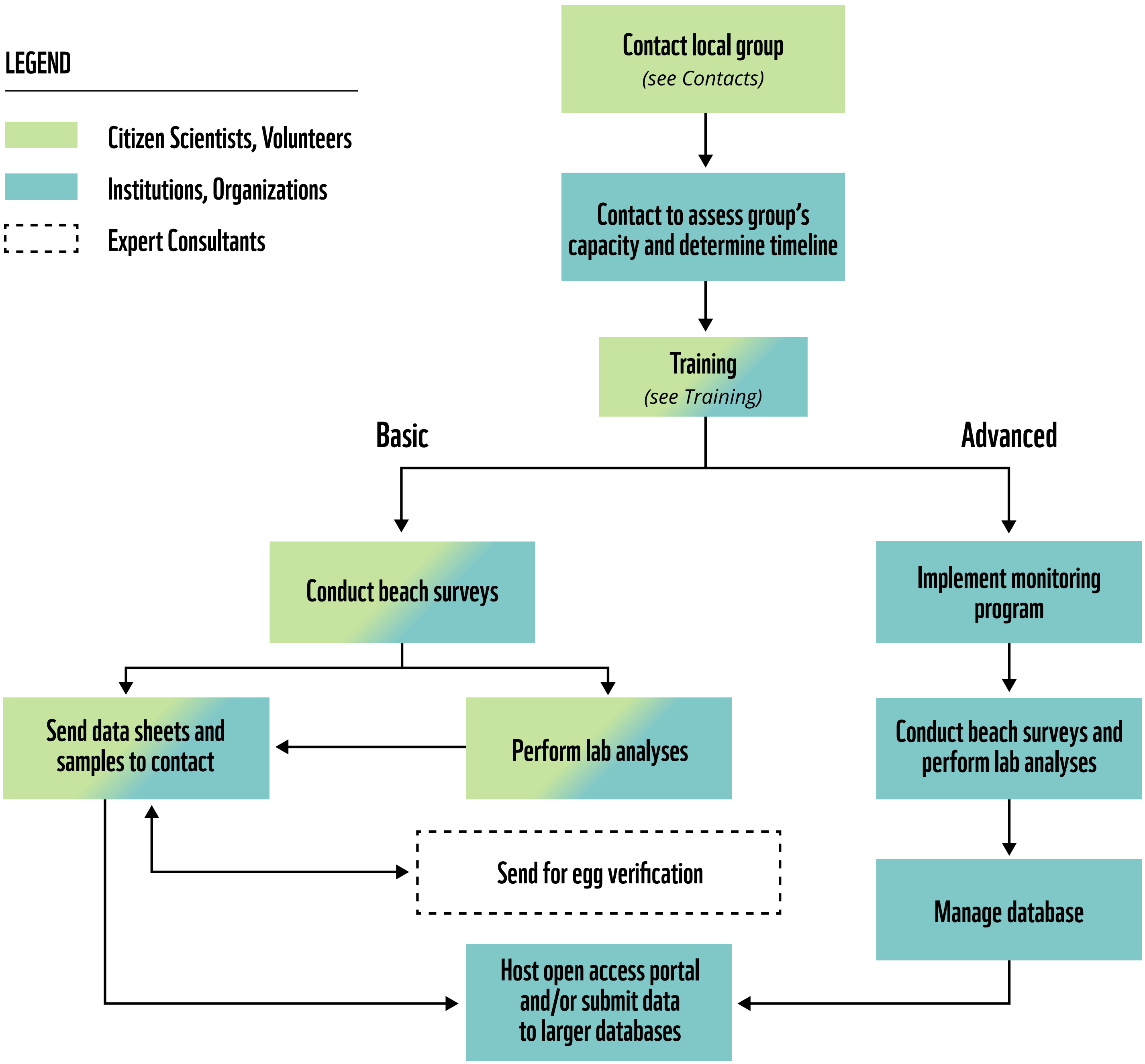


Figure 3. Data collection process options for individuals, organizations and experts.

The level of training needed will depend on the capacity and objectives of the individual or group. Generally, two types of training may be provided: Basic and Advanced *(Table 1)*. See Contacts for a list of available experts that may be able to provide training.

Table 1. Training components under the Basic and Advanced training.

ADVANCED	BASIC	1. Site Assessment 2. Filling out Data Sheets 3. Sample Collection 4. Sample Processing
		5. Lab Analysis
	6. Egg Verification 7. Data Management	

The timing of forage fish beach spawning surveys along the coast of British Columbia in the Salish Sea should coincide with the spawning period for the targeted species.

Surf smelt have been documented to spawn year-round in Puget Sound, with some stocks spawning during the summer (May to August) and others in the fall and winter (September to March) (Penttilla 2007; Pierce et al. 2009; Quinn et al. 2012). Information on the timing and location of surf smelt spawning in British Columbia is limited (Therriault et al. 2002), though spawning has been observed during the summer and fall (deGraff 2007; DFO 2012). Surf smelt egg incubation lasts up to 56 days depending on season and air and water temperature (Therriault et al. 2002). Several egg batches from distinct spawning events can incubate together within the substrate.

Pacific sand lance egg incubation is approximately one month (Pentilla 1997). In Puget Sound, Pacific sand lance spawn in the upper intertidal zone from November through February, with most spawning occurring earlier in this period (November and December) (Pentilla 1995b, 1997; Pierce et al. 2009). Repeated spawning events by Pacific sand lance have been documented in Puget Sound at the same beach during one season and perennially. In Baynes Sound (central east coast of Vancouver Island), Pacific sand lance have been documented to spawn between November and February (Thuringer 2004).

Spawning of Pacific sand lance and winter-spawning surf smelt can co-occur during the winter season, with eggs from both species incubating together (Penttilla 1995b; 2001). In Puget Sound, extensive beach surveys were initially conducted between November and February to capture this overlap in spawn timing (Penttilla 1995a, 1995b; Pierce et al. 2009). Currently, sampling is more evenly split between winter and summer months (Dionne, pers. comm. 2020).

The planning for forage fish beach spawning surveys will need to include consideration of spawning times, including seasonality. These surveys require sufficiently low tides to access the upper intertidal zone – this may be a limiting factor at some beach sites in the winter because of limited daylight hours.

Recommended timing for scheduling surveys along the coast of British Columbia in the Salish Sea:

1) **November to February** – the Pacific sand lance late-fall and winter spawning window – with emphasis on targeting the earlier part of this window (November and December). This timing aims to capture most of the sand lance spawning events, as well as the spawning overlap between sand lance and surf smelt.

2) **June to September –** the surf smelt summer and early-fall spawning window. Peak surf smelt spawning has been documented in north Puget Sound in the summer, and in the San Juan Islands in August and September.

Given the limited information on spawning beaches in British Columbia, year-round surveys would be the ideal scenario to determine the spawning seasonality of surf smelt and Pacific sand lance. However, it is recognized that survey timing and frequency will be defined by specific sampling objectives and feasibility – including capacity, access and cost.

Beach Characteristics

Surf smelt and Pacific sand lance will spawn on the upper areas of intertidal beaches that contain specific sediment grain-size distributions of sand and pebble (Pentilla 2007; Quinn et al. 2012). Spawning individuals can enter an area on a high tide and deposit adhesive eggs on sand and pebble sediments in less than 10 centimetres of water (Moulton and Pentilla 2000; Thuringer 2004).

Spawning and incubation occur on the beach typically within 2 to 3 metres above mean low tide level – this is approximately the upper third of the tidal range (Moulton and Pentilla 2000; Thuringer 2004; Pentilla 2007). Surf smelt usually spawn at slightly higher elevations than Pacific sand lance. The preferred elevation for spawning is likely a tradeoff between exposure to high temperatures and desiccation at higher elevations, and increased humidity and predation risk at lower elevations (Quinn et al. 2012).

In Washington, surf smelt spawn is typically scattered and patchy in spawning areas (1-to-3-metre diameter patches), while Pacific sand lance spawn can be patchy or in bands of spawn 10 metres wide and > 200 metres long (Pentilla 1997). After spawning occurs, eggs can disperse along the beach with tidal and wave activity (Moulton and Pentilla 2001, revised 2006; Pentilla 2007).

Each species has specific substrate grain size preferences for spawning. Surf smelt prefer a coarse sand to fine pebble mix ranging from 1 to 7 mm in diameter. Pacific sand lance typically spawn in medium-sized sand sediments ranging from 0.25 to 0.5 mm in diameter, with spawning also »

Figure 4. Photos showing potential beach spawning sites for Pacific sand lance and surf smelt.

Beach Characteristics

« documented in coarse sand and fine pebble sediments (1 to 7 mm) (Pentilla 1997; Thuringer 2004; Pentilla 2007). Both species require spawning substrate with minimal silt (< 0.063 mm) to prevent smothering of eggs (Pentilla 1978; 2001; 2007; Thuringer 2004).

Beaches at the depositional ends of sediment drift cells[1] commonly support both surf smelt and Pacific sand lance spawning habitat (Pentilla 2007). This is where accretionary shore forms occur, such as sandy spits (see *Figure 5*). Surf smelt spawning beaches can also be found in coarser substrate at the erosional start of a sediment drift cell (Pentilla 2007).

Beach spawning and egg development can occur across a range of diverse conditions[2] (Pentilla 1995a, 1995b, 1997, 2007; Thuringer 2004). Areas that are shielded from direct sunlight by over-hanging vegetation are more suitable for spawning, due to lower desiccation risk. Areas where vegetation has been removed are less suitable, especially during the warmer summer-spawning period (Pentilla 2001, 2002; Rossell and Dinnel 2006; Lee and Levings 2007).

Surf smelt have been observed to spawn in environments with low salinity, such as the lower reaches of rivers on the Olympic Peninsula (Shaffer et al. 2003). On Camano Island in Puget Sound, spawning beaches that were highly used by surf smelt were characterized by medium-to-high-wave exposure and low solar exposure[3] (Quinn et al. 2012).

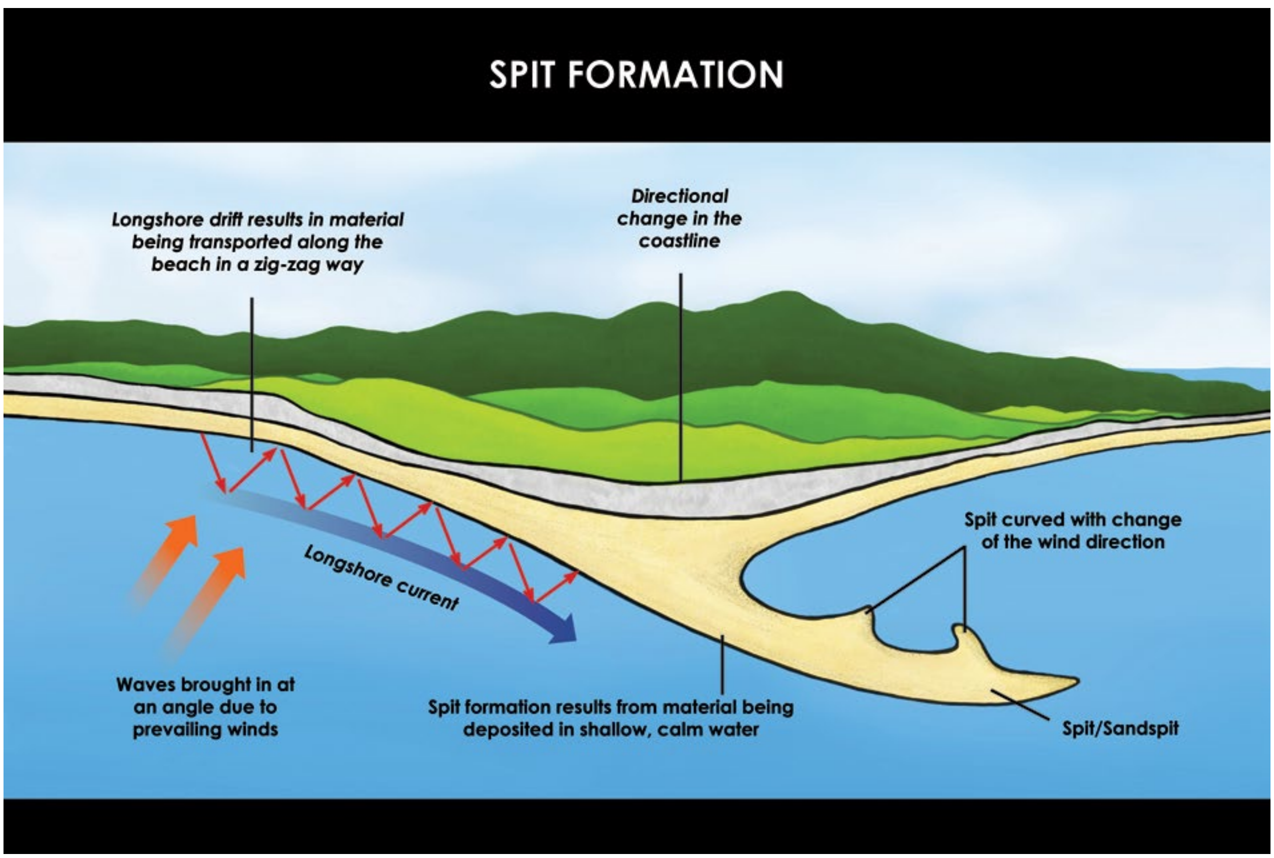


Figure 5. Illustration showing the formation of a spit (prepared by Core Creative Design).

[1] Sediment drift cells: sections of coastline that exhibit a sediment source, a zone of net directional sediment transport and an area of sediment deposition.
[2] Diverse conditions include: temperatures, salt-levels, wave exposures, beach widths, beach slopes, beach aspects, over-hanging riparian vegetation and modified upland.
[3] A north-facing direction will likely result in lower solar radiation and lower temperatures.
[4] llustration adapted from “Forming of a Spit,” by GeograPhonic. Retrieved from https://www.purposegames.com/game/forming-of-a-spit-quiz

Tools and Technology

A few different tools can be used to help identify survey locations before going out into the field. These include ShoreZone models, aerial imagery, hydrographic charts and other ground surveys conducted within the area of interest.

ShoreZone

ShoreZone is a standardized system that maps coastal habitats, including the supratidal, intertidal and some subtidal areas. This mapping uses oblique, low-altitude imagery to segment a digital shoreline into relatively homogenous units based on geomorphology (CORI 2017). Physical[5] and biological[6] attributes are mapped across different across-shore components of these units.

The Washington State ShoreZone dataset was used to identify attributes that were consistently associated with known beach spawning sites in Puget Sound. These attributes were then used to predict potential suitable upper intertidal beach spawning habitat in areas not yet inventoried in Washington State (Harper and Borecky 2003).

In 2017, WWF-Canada commissioned Coastal & Ocean Resources (CORI) – a key developer of the ShoreZone mapping system – to build a similar predictive model using the British Columbia ShoreZone dataset (CORI 2018; Appendix A). ShoreZone attributes were updated based on comparisons between beach spawning forage fish habitat assessment surveys (de Graaf 2013; 2014; 2017) and the ShoreZone imagery collection and mapping conducted between 2004 and 2010. The attributes in the updated predictive model included substrate in the upper intertidal zone (all combinations of sand, pebble and cobble) and exposure type (very protected, protected and semi-protected) (CORI 2017).

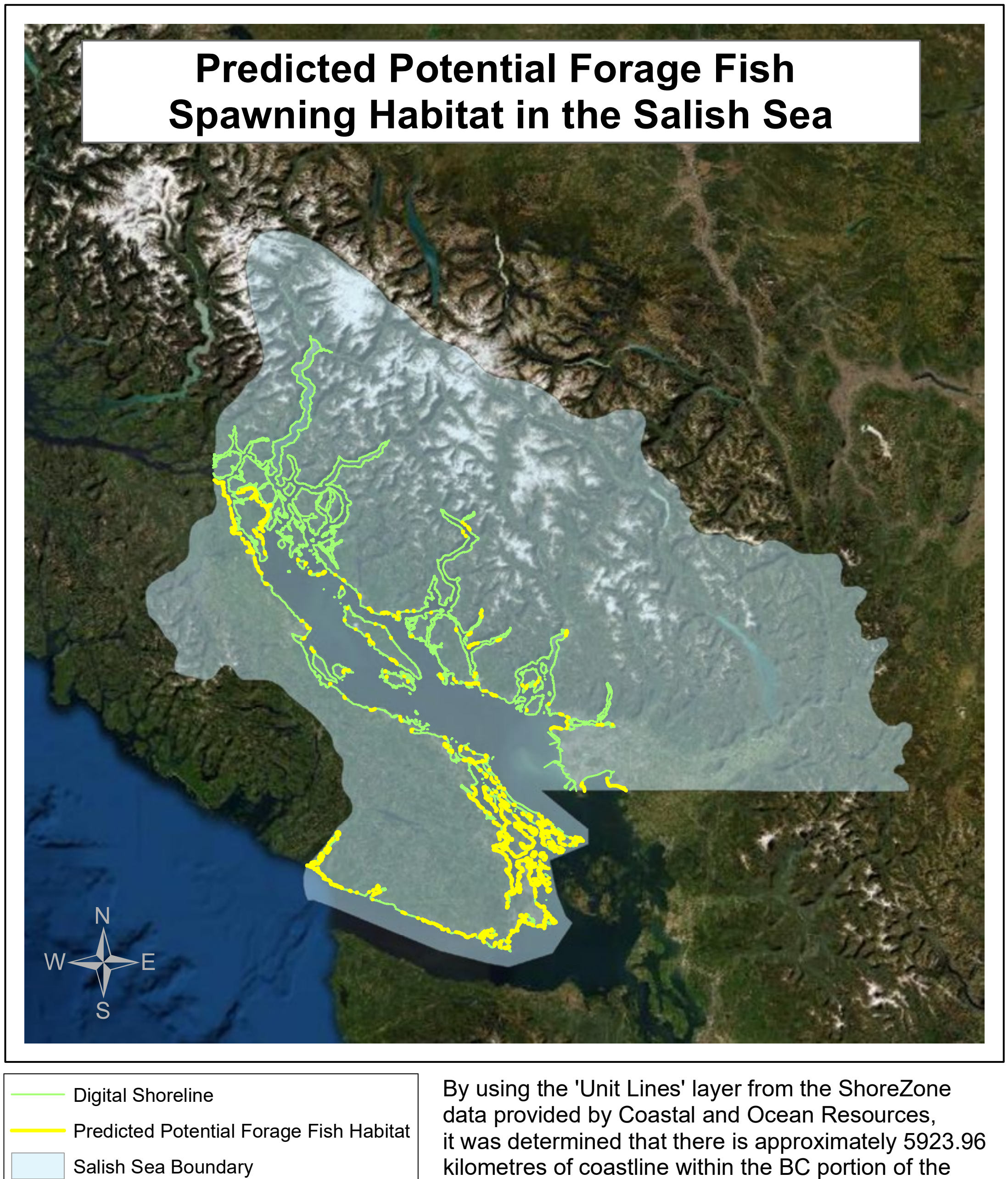
To assess the accuracy of the British Columbia ShoreZone model, the predictions were compared to habitat ground surveys conducted on the Gulf Islands. The model correctly predicted potential suitable upper intertidal spawning habitat 75 per cent of the time (CORI 2017). As a result, this ShoreZone model may be used to help direct future ground-based research around coastal British Columbia. The model can also be re-evaluated and improved as more ground truth data is collected for suitability and the presence of spawn.

Figure 6 illustrates the total percentage of predictive potential suitable spawning habitat for Pacific sand lance and surf smelt along the coast of British Columbia in the Salish Sea. It should be noted that the utility of the ShoreZone model declines in areas with imagery and mapping that are three or more decades old due to poor or old imagery resolution. As ShoreZone data gets updated throughout the province (i.e. more recent collection of higher resolution video with updated classification) the more predictive strength the model will have.

ShoreZone imagery (photos and video) can also be accessed on the CORI website[7] for some of the British Columbia coastline. Field crews should review imagery before conducting ground surveys as a tool to better target their survey sites. However, it is important to note that some sites can be very dynamic – they may change seasonally and/or episodically, or over the years from the time imagery was collected.

[5] Examples: substrate type and slope
[6] Examples: prominent biobands of vegetation and invertebrate species
[7] CORI website: http://www.coastalandoceans.com

Tools and Technology



By using the 'Unit Lines' layer from the ShoreZone data provided by Coastal and Ocean Resources, it was determined that there is approximately 5923.96 kilometres of coastline within the BC portion of the Salish Sea. There is approximately 732.92 kilometres of predicted potential forage fish habitat within the Salish Sea region.

That equates to 12.37% of the Salish Sea coastline being predicted potential forage fish habitat, based on the ShoreZone data.

Figure 6. Percentage of predicted potential forage fish beach spawning habitat in British Columbia (prepared by Ryan Frederickson, Mount Arrowsmith Biosphere Region Research Institute).

Tools and Technology

Aerial Imagery and Hydrographic Charts

Aerial imagery – from orthophotos, Google Earth, ESRI and drone surveys – can be used to obtain useful information about beach size, vegetation type and coverage, substrate type and shoreline modification. It is recommended to review aerial imagery obtained on a low tide event to identify potential spawning habitat. However, like ShoreZone imagery, aerial imagery should be used with caution, especially for dynamic sites that may change seasonally or interannually.

Unmanned Aerial Vehicle (UAV or drone) aerial imagery combined with ground truthing surveys is emerging as a useful tool for collecting habitat data and monitoring change over time.

Reviewing hydrographic charts can also provide information on fetch distances, beach aspect, substrate type and beach elevations that can be useful before conducting ground surveys for forage fish spawning sites.

Other Field Surveys and Local Knowledge

Potential forage fish beach spawning habitats may have historic datasets with information on substrate type and previous spawning presence. For example, Indigenous communities, local environmental groups and government organizations may provide additional information on potential areas to target for spawning surveys. When Traditional Ecological Knowledge is offered, it provides valuable insight into spawning habitats and changes that may have occurred over time. It should be a priority to build relationships with local knowledge holders, and to integrate diverse forms of knowledge that may not fit within the confines of quantitative science.

Ground Truthing

Once potential forage fish spawning sites have been determined using a combination of the predictive tools above, sites will need to be assessed on the ground for their suitability. The physical area of suitable spawning substrate can vary from a continuous band of material – both several meters wide and kilometers long – to an array of discontinuous smaller patches. Site suitability can also change across seasons depending on the erosional and depositional environment.

In Washington State, eggs are usually found within the upper third of the beach. This area is generally located 30 to 60 centimetres (or 1 to 2 vertical feet) below the log line, and/or 2 to 3 metres above the mean low low water mark. For surf smelt eggs, substrate in this area is characterized by a mix of sand and small pebble. For Pacific sand lance eggs, this substrate is similar, but can extend into pure sand.

In British Columbia, surveys for surf smelt and Pacific sand lance eggs should be conducted within the upper third of the beach. Pacific sand lance spawning substrate ranges from medium sand to small pebbles, while surf smelt spawning substrate is coarse sand to small pebbles. Target substrate is medium to coarse sand (0.25 to 2 mm) and small pebbles (2 to 7 mm), respectively.

A grain size comparator card can be a good tool to identify suitable substrate in the upper third of the beach. Another useful reference is the high tide line, demarked by washed up beach wrack (or seaweed); suitable spawning substrate can be targeted ~1 metre (vertical elevation) below the high tide line (Robinson pers. comm. 2020). Mud or muddy sand are not acceptable substrates, nor are cobbles or solid rock and talus shores. Note that the key is to target potential patches of suitable sediment in the upper one-third of a beach rather than focus strictly on tidal elevation.

Spawning areas cannot be easily identified by visual observations. This is due to the small size of the eggs (0.8 - 1 mm for Pacific sand lance and 1.0 - 1.2 mm for surf smelt) and the tendency for these eggs to adhere to sand grains and disperse after spawning (Robards et al. 1999; DFO 2002). If egg density is high on a beach, it may be possible to see through a visual assessment.

Failure to detect eggs at a site does not conclude definitively that spawning does not occur there, especially when there are limited surveys for that site. There can be significant seasonal or interannual variability in forage fish egg density observed on a beach (Moriarty et al. 2002; Quinn et al. 2012; Parks et al. 2013). Therefore, surveys should occur at a site across different seasons and several years – ideally 1-3 times within a possible spawning period – to assess its importance as a spawning area.

The Washington State beach spawn sampling protocol recommends that beaches are consecutively sampled for two years before ruling out the presence of spawning (Moulton and Pentilla 2001, revised 2006). Longer term monitoring of beaches will also improve baseline information about spawning beaches and potential patterns or trends around beaches.

Other Considerations

Collection Permit

A scientific collection licence from Fisheries and Oceans Canada is required to harvest fish for experimental, scientific, educational or public display purposes[8]. It could take up to 30 days to process, approve and receive a licence.

Site Access

Site access to potential spawning beaches may be restricted due to private residences, reserve land, protected areas and/or commercial and government operations. Obtaining necessary permissions from landowners is required before accessing these sites.

Disturbance Events

Storm surge, wave activity and substrate scour during large storm events can alter a beach and disperse incubating eggs – in some cases they can completely remove eggs from the spawning area. Conducting forage fish beach spawning surveys after large storm events may reduce the probability of finding eggs, even if spawning has occurred at the site recently.

Recreational and commercial harvesting of beach wrack in the upper intertidal areas of beaches can also affect egg dispersion.

[8] Fisheries and Oceans Canada. Scientific licences. Retrieved from: http://www.pac.dfo-mpo.gc.ca/fm-gp/licence-permis/scientific-scientifique-eng.html

Survey Guidelines

The sampling methodology for surf smelt and Pacific sand lance spawning habitats in British Columbia follows the Washington Department of Fish and Wildlife (WDFW) methodology (Moulton and Pentilla 2001, revised 2006) – this includes the recent use of a vortex method to process samples (Dionne 2015).

Surveys for surf smelt and Pacific sand lance eggs consists of:

1) Obtaining a bulk sample of mixed sand and pebble from the upper intertidal area of a beach site

2) Using sieves and a vortex to condense the bulk sample for lab analysis

3) Examining the condensed sample under a dissecting microscope to determine the presence or absence of eggs and to differentiate between forage fish species

Appendix B and C provide specific sampling methodologies to conduct forage fish beach spawning surveys – including necessary field equipment, collection and processing methods for samples, and identification diagrams for different forage fish species. Appendix D and E provide data sheet templates. These guidelines and data sheet templates were prepared by Mount Arrowsmith Biosphere Region Research Institute, with support from the WDFW, WWF-Canada and Archipelago Marine Research Ltd.

Databases

In British Columbia, the Strait of Georgia Data Centre (SGDC) is a collaborative program between the Pacific Salmon Foundation (PSF) and the Institute for the Ocean and Fisheries (University of British Columbia). The goal is to build a secure data archive for marine ecosystem information on the Strait of Georgia in the Salish Sea. Data sharing agreements have been and/or will need to be established with PSF to house and maintain forage fish data collected by citizen scientists, academics, Qualified Environmental Professionals (QEPs), biologists and environmental non-government organizations. The SGDC allows for all the collected data to be housed in a centralized and open-access database. Data collected from forage fish beach spawning surveys should be submitted to the Strait of Georgia Data Centre.

Islands Trust Conservancy also manages a database with suitable spawning habitat assessment data, as well as a MapIT online tool for their trust area. Given their capacity to host larger amounts of data, data collectors surveying in this area are also encouraged to share their data with Islands Trust Conservancy.

Data Quality Assurance and Quality Control

Appendix B and C provide guidance on completing datasheets with all the required information. Some groups are also using mobile apps in the data collection process – this helps to improve data flow between the data collector and database.

Survey coordinators need to review site photos to verify that the information on the data sheets is consistent with the site conditions seen in the photos. Survey locations should be mapped to ensure that they correspond with the expected location of the surveys (e.g. using Google Earth, ArcGIS, qGIS). Additional protocol review and refresher training should also occur prior to intensive field monitoring programs (i.e. species-specific spawning windows) to help maintain good QA/QC of the data and samples collected in the field.

When eggs are found within samples, they should be identified and recorded accordingly. To validate these records, species identification will need to be verified by an expert (e.g. Fisheries and Oceans Canada scientists, taxonomy laboratory specialists, professional biologists).

Before entering data into a larger database, survey coordinators should review all datasheets and/or datasets to ensure there are no errors or missing data.

For more information about this guidance document, please contact:

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CONTACTS

Table 2. Relevant contacts with expertise around forage fish beach spawning surveys.

ORGANIZATION	LOCATION	SITE	AREA OF EXPERTISE
WWF-Canada	Victoria, BC, Canada	http://www.wwf.ca/	• Prepared "Guidance Document: Forage Fish Beach Spawning Surveys in British Columbia." • Predictive model • Data sharing agreement support • Policy expertise • Capacity building support
Archipelago Marine Research Ltd.	Victoria, BC, Canada	https://www.archipelago.ca/	• Prepared "Guidance Document: Forage Fish Beach Spawning Surveys in British Columbia." • Technical expertise – site selection, data management, and mapping
Mount Arrowsmith Biosphere Region Research Institute (MABRRI)	Vancouver Island University - Nanaimo Campus, Nanaimo, BC, Canada	https://mabrri.viu.ca/	• Prepared Appendix B to E • Training – basic and advanced (excludes egg verification) • Beach monitoring surveys • Coordinator expertise – access to labs for egg verification
Peninsula Streams Society (PSS)	Sidney, BC, Canada	https://peninsulastreams.ca/	• Beach monitoring surveys • Beach nourishment expertise • Coordinator expertise – access to labs for egg verification • Training capabilities for volunteers
Ruby Lake Lagoon Society	Pender Harbour, Sunshine Coast, BC, Canada	https://www.lagoonsociety.com/	• Beach monitoring surveys • Training capabilities for volunteers • Access to microscopes • Mobile apps – online data collection expertise
Friends of Forage Fish – Sunshine Coast	Sunshine Coast, BC	http://www.friendsofforagefish.com/	• Beach monitoring surveys • Access to microscopes
Project Watershed	Courtenay, BC	https://projectwatershed.ca/	• Beach monitoring surveys • Coordinator expertise – access to labs for egg verification • Training capabilities for volunteers
Pacific Salmon Foundation	BC Salish Sea	http://sogdatacentre.ca/ https://www.psf.ca/	• Host Salish Sea Marine Survey database with UBC – the Strait of Georgia Data Centre
Coastal and Ocean Resources Inc.	Victoria, BC, Canada	http://www.coastalandoceans.com/	• Prepared "Using ShoreZone to Model Suitable Forage Fish Habitat in the Gulf Islands"
Islands Trust Conservancy	BC Gulf Islands	http://www.islandstrustconservancy.ca/	• Gulf Islands – habitat suitability assessments • MapIT online tool – contains suitable site locations on Map
Sea Watch Society (BC Shore Spawners Alliance)	Mill Bay, BC, Canada	https://www.facebook.com/foragefish/ https://www.cmnbc.ca/atlasgallery/forage-fish-atlas-and-data-management-system/	• Beach monitoring surveys/volunteer training • Habitat suitability assessments • Other technical expertise

Table 2. Relevant contacts with expertise around forage fish beach spawning surveys.

ORGANIZATION	LOCATION	SITE	AREA OF EXPERTISE
Washington Department of Fish and Wildlife (WDFW)	Olympia, WA	https://wdfw.wa.gov/fishing/management/marine-beach-spawning	• Training expertise within Washington State • Beach monitoring in Puget Sound • Mapping of suitable habitat for forage fish in Washington State
SeaChange Marine Conservation Society	Brentwood Bay, BC, Canada	https://seachangesociety.com/	• Coastal restoration expertise
Green Shores	Vancouver, BC, Canada	http://stewardshipcentrebc.ca/Green_shores/	• Technical expertise in sustainable shoreline development
Smart Shores	BC Salish Sea	https://www.smartshores.ca/	• Technical expertise in mapping and data services

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PERSONAL COMMUNICATIONS

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