Herring Spawning Areas of British Columbia

A review, geographic analysis and classification.

by

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Revised edition: 2013

Original edition: Hay, D.E., P.B. McCarter, R. Kronlund and C. Roy. 1989. Spawning areas of British Columbia herring: a review, geographical analysis and classification. Volumes 1-6. Can. MS Rep. Fish. Aquat. Sci. 2019.

Abstract

The geographical distributions of Pacific herring (*Clupea pallasii*) spawning sites have been estimated each year since 1928. The analysis was based on approximately 30,000 spawning events recorded mostly by fishery officers and diver teams in six regions of the British Columbia (BC) coast. For each of 101 geographical sections of BC, time-series maps were constructed to delineate annual herring spawn depositions along each kilometre of shoreline from 1930 to 2001. Total cumulative egg deposition from 1928 to 2013 was also mapped using proportionately sized, multi-coloured, bubble plots which rank and classify each kilometre of herring spawning habitat according to the long-term frequency and magnitude of spawns over time. Cumulative spawn analysis was conducted coast-wide so that any kilometre on the BC coast could be easily compared with any other BC coastal kilometre. Approximately 5,285 km (or 18 %) of British Columbia's extensive 29,500 km coastline have been ranked and classified as herring spawning habitat. An estimated 300 to 600 kilometres of BC coastline or about 1.8 % of BC's total shoreline length is intensively utilized by spawners in a typical season.

The approximate shapes of some herring spawn depositions were digitized over a 1:20,000 scale, Terrain Resource Information Management (TRIM) map for the years, 1930 to 2002. Composite spawn maps for 101 sections of BC were created by chronologically overlaying polygons of annual, spawning beds. In 2005, Arcview shape files of individual, spawning beds comprising a period of over 70 years were published on the worldwide web. A series of plots and histograms summarize the magnitude, frequency and timing of herring spawning over all years and distinguish shoreline kilometres with highly repetitive spawning activity from those shorelines with less frequent activity. A statistical summary of herring spawn and catch records, including mean, minimum and maximum spawning dates and measured, sea-surface temperatures from nearest lighthouse stations are also presented in a series of tables for each herring section,

statistical area, region and for the entire British Columbia coast. The accuracy and completeness of records is discussed.

Key words: herring, spawning, British Columbia

Introduction

In recent years there has been increased awareness and concern by industry, government and the public about the environmental protection of Pacific herring spawning grounds. An increasing number of nearshore developments, such as log booming activities and mariculture establishments could affect some intertidal and shallow, subtidal spawning areas utilized by herring. The impacts of oil spills, pollution, various inshore fisheries and ocean climate regime shifts on herring spawning distributions is also a concern. A problem with the identification of nearshore areas as herring spawning habitat is that much of the British Columbia (BC) coast, perhaps 19% or more, has been utilized as a spawning site at least once during the last 75 years. However, much less of this coastline (1-2%) is used for repetitive spawning over a number of years. The locations that support large and repetitive spawnings deserve the most attention and consideration from possible environmental impacts. This report provides the basis for identifying significant herring spawning areas and locations which support major herring fisheries.

Herring Spawning Records

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Detailed records of herring spawns in British Columbia have been collected annually by fishery officers and diver teams (Hay and Kronlund 1987). Usually, an estimate of the location, length, width and density of each spawn deposition has been recorded. A total of approximately 30,000 spawning events at 1,392 locations have been recorded since 1928. These herring spawning locations were entered into a database using geographic names and numeric codes. The geographical areas represented by location names, however, can vary from small islands or coves measuring only 100 m in length or breadth, to bays or inlets more than 50 km in length. Also, these herring spawning locations were frequently clustered, so that many geographical names were used to describe the same general vicinity (some names represented subsets of each other). In 1983, to resolve these database problems, we began to develop a shoreline kilometre system to represent discrete, herring spawning locations. This was the first step in a deviation from an earlier location naming and coding system developed by Issacson and Hourston (1972) and Hourston and Hamer, M. (1979). Additional location codes were subsequently compiled by Haist and Rosenfeld (1988) and Midgley (2003) as "new" spawning locations were recorded and more permanent location boundaries established. Other Fisheries and Oceans Canada (DFO) report series also document spawning activity and these are listed here by principle author and fishery periods (see references)

1. Humphreys, R.D. 1970-1973
2. Webb, L.A. 1974-1978
3. Chalmers, D.D. 1979-1992

4. Hamer, L. 1999-2002
5. Webb, R. 2003-2009
6. Spence, B. 2010-2012

These reports document the details of annual herring fisheries and spawn abundance from a management perspective.

About 70% of spawn records have an accompanying map or chart showing the geographical locations of each spawning event. Records without charts consist of narratives or tables describing the location of each spawn deposition relative to a fixed reference point, such as a bay, inlet or island. In order to standardized and increase the number of fixed reference points, we plotted a series of kilometre positions on charts, at one kilometre intervals along shorelines using nautical chart calipers. We then estimated, to the nearest 0.1 kilometre, the geographical "start" positions of each spawning event relative to these geo-referenced shorelines. Spawn depositions extended from a "start" position (x.x) to an "end" position (x.x + length) where length was measured as the distance (km) of the spawn deposition along the shoreline. This system was made to work in all sections of the BC coast where herring were known to have spawned. Herring sections or sub-areas comprising each statistical area (Haist and Rosenfeld 1988 or Midgley 2003) were utilized for mapping and data aggregation purposes as these convenient boundaries encompassed clusters of shoreline spawning beds. Most herring sections have a zero starting kilometre position which increases to a maximum of 400 km, so as to include all of the shorelines where herring spawning events have been reported. In several cases, spawning activity can overlap between adjacent sub-areas or sections. In these instances, the kilometre positions were made contiguous between sub-areas. The kilometre segments were not defined for the entire coastline but rather only for the general vicinity of herring spawning sites. Therefore, there are geographical gaps in the position numbers. Kilometre positions were defined in each herring *section* on the BC coast that had a sufficient number of records for analysis. Consequently, they are a few recently recorded and peripheral spawning locations that do not have assigned kilometre positions.

Kilometre start positions were approximated for 30% of the records where only a location name was recorded (no charted positions). A median kilometre position was calculated for each of these spawning locations using the remaining 70% of records which did have charted positions. Most records where spawning positions had to be approximated, occurred prior to 1951. A few locations were never charted or there were insufficient records to make a reasonable approximation. In these relatively few instances we assigned a general, kilometre position to some location names to facilitate computer mapping.

Geographic Organization

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The Herring Geographical Bulletin CD-ROM or Web site is organized into 6 regions, 30 statistical areas and 101 herring sub-areas or sections compatible with the stock assessment regions defined by Fisheries and Oceans, Canada (Haist and Rosenfeld 1988, Midgley 2003). There have been several changes in the boundaries and geographical names applied to regions, sections and locations since this mapping work began in 1983. These changes, however, do not interfere with the geographical analysis presented in this report as the relational database has been regularly updated and linked since 1994 to a separate geo-referenced dataset. This dataset consists of latitude and longitude coordinates of approximately 7,800 reference positions located approximately one kilometre apart, along BC's shorelines. Digital mapping of herring spawns and cumulative spawn analysis became feasible after entering and/or updating more than 28,000 spawn "start" positions (to the nearest 0.1 km) in the database. To display some of the details of these spawns, approximately 100 sub-area or section maps were created from a single, seamless BC coastal map. We used SYSTAT and MINITAB to create spawn maps, plots, tables and image files suitable for electronic publication. The original seamless base map was prepared by digitizing and then digitally combining several 1:40,000 scale Canadian Hydrographic Service (CHS) charts. The chart digitization was completed by Geo-Spatial Systems Ltd. over a period of several years during the early 1990s. Some of the larger section maps were geographically partitioned further and labelled: N=north, S=south, E=east and W=west due to their broad and expansive areas. This procedure was done in order to display section maps at similar scales as some herring sections (or spawning bed clusters) were considerably larger in geographical area that others. Associated spawn and catch statistics shown in the website tables, however, remain aggregated by whole sections, statistical areas and stock assessment regions.

In the late 1990s the availability of geographical information systems (GIS) permitted intensive digitization of the approximate shapes (or polygons) of many, previously recorded spawn depositions. This work was conducted over a 1:20,000 scale, TRIM (Terrain Resource Information Management) base map. Eventually more detailed, composite maps of major spawn depositions from 1930 to 2002 in each herring section were compiled using ARCVIEW. Region and section boundaries, originally defined on the basis of spawning bed clusters in the early 1970s (or during a period of stock rebuilding) were applied in this geographical analysis but these boundaries do not imply delineations of separate herring stocks. Currently, there are a total of 147 herring sections in BC. Only 101 of these sections, however, have a history of spawning within their boundaries. The remaining sections consist mostly of offshore areas and undefined spawning or fishing locations bounded within statistical areas. Herring catches have been recorded in 143 of the 147 herring sections and are summarized in tables by catch season and gear type. The following table lists the 101 geographical sections and 6 regions examined in this herring spawn analysis and classification.

Haida Gwaii	Prince Rupert District
Section 001 Tasu Sound	Section 032 Portland Inlet
Section 002 Port Louis	Section 033 Port Simpson
Section 003 Rennell Sound	Section 041 Area 4 West (Dundas Island)
Section 004 Cartwright Sound	Section 042 Area 4 North (Prince Rupert)
Section 005 Englefield Bay	Section 043 Area 4 South (N. Porcher Is.)
Section 006 Louscoone Inlet	Section 051 Other Area 5 (Banks Island)
Section 011 Masset Inlet	Section 052 Kitkatla Inlet
Section 012 Naden Harbour	Section 053 Principe Channel
Section 021 Juan Perez Sound	

Section 151 Redonda Islands
Section 152 Powell River
Section 161 Sabine Channel
Section 162 Hotham Sound
Section 163 Malaspina Strait
Section 164 Jervis Inlet
Section 165 Sechelt Inlet
Section 172 Nanoose Bay
Section 173 Yellow Point
Section 181 Swanson Channel
Section 182 Plumper Sound
Section 191 Saanich Inlet
Section 192 Cordova Bay
Section 193 Victoria Harbour
Section 202 Sooke Harbour
Section 220 Nitinat Lake
Section 280 Howe Sound
Section 291 Fraser Foreshore
Section 292 Sechelt
Section 293 Boundary Bay

Section 241 Tofino Inlet
Section 242 Hesquiat Harbour
Section 243 Sydney Inlet
Section 244 Millar Channel
Section 245 Vargas Island
Section 251 Tahsis Inlet
Section 252 Nootka Sound
Section 253 Esperanza Inlet
Section 261 Tahsish Inlet
Section 262 Clannick Cove
Section 263 Checleset Bay
Section 271 Quatsino Sound
Section 272 Brooks Bay
Section 273 Forward Inlet
Section 274 Holberg Inlet

A series of linkage maps, summary tables, plots and spawn maps for each sub-area (e.g., region, statistical area or herring section) can be explored with a web browser. Major features are described below:

MAP 1. A British Columbia map that shows the locations of six regions. Any region map can be displayed by clicking a region name (hotspot or hyperlink) on the British Columbia map.

MAP 2. A region map that shows the locations and boundaries of statistical areas and herring sections within each region. Summary tables, plots and maps of herring spawners and catches can be displayed by clicking a section number (hotspot or hyperlink) on a region map.

FIGURE 1. A cumulative spawn map (or bubble plot map) of each herring section that shows shoreline reference points or kilometre (km) positions. Long-term cumulative spawn (from 1928 to the present year) is depicted along each kilometre of coastline by the proportional size of each bubble. The bubbles are coloured to represent six classifications of cumulative spawn. Red indicates the top 5%, brown the next 10%, yellow the next 15%, green the next 20%, blue the next 25% and violet the last 25% of ranked shoreline kilometre segments.

Herring Spawn Classification	Colour of Each Map Circle	Percentage of Ranked KM	Range of Percentages

Vital	Red	Top 5 %	95-100 %
Major	Brown	Next 10 %	85-95 %
High	Yellow	Next 15 %	70-85 %
Medium	Green	Next 20 %	50-70 %
Low	Blue	Next 25 %	25-50 %
Minor	Violet	Next 25 %	0-25 %

Spawn habitat maps are based on indices calculated in cumulative spawn tables. These maps are updated annually from data archived in DFO's herring spawn database. The cumulative Spawn Habitat Index (SHI) is utilized as a measure of "habitat sensitivity" as this index takes into account, both the long-term frequency and magnitude of recorded spawns over time. The index is calculated by the sum of the product of each measured length of spawn (metres along the shoreline) and the median of the product of spawn width and egg layers adjusted by percent cover and pooled geographically. This index (described more fully below) should not be confused with the "spawn index" utilized in catch-age, age-structured or escapement stock assessment models (Haist et al. 1984-1992 or Schweigert et al. 1993-2009 or Cleary et al. 2010-present). Individual data records of herring spawns observed since 1928 can also be viewed by clicking a numbered, geographical "pool" on any cumulative spawn habitat map in each herring section of BC.

FIGURE 2. A blue and yellow section map showing the names of locations utilized by field surveyors to identify herring spawning sites. Infrequently used names were not labelled if they were eclipsed by more colloquial names. Geographical names were plotted on maps using the mean latitude and longitude coordinates of every shoreline kilometre segment located within the boundaries of each herring spawn location. Location names frequently cluster and overlap.

FIGURE 3. A line plot showing herring catches (t) during the approaching spawning season (Jan 1 to Apr 30 only) and estimated spawners (t) calculated using annual, egg deposition survey data and a catch-age model for each calendar year from 1950 to the present year. Spawners were estimated by apportioning spawner biomass (SB) as determined for each region and year (Stock Assessment and Management Advice for the British Columbia Herring Stocks: 2010 Assessment and 2011 Forecasts by J.S. Cleary and J.F. Schweigert) to each assessed herring section using an area-based spawn habitat index (SHI). Spawners in non-assessed herring sections were estimated using a SHI versus spawner biomass (SB) linear regression equation of post-1950 spawn records.

FIGURE 4. A bubble plot that indicates the magnitude of herring spawning in each each herring section. The size or extent of each egg deposition is based on the spawn habitat index and is determined at the kilometre centroid position of each spawning event throughout the previous 64 years.

FIGURE 5. A line plot showing the frequency of spawns along each kilometre segment in each herring section over all survey years since 1928. As herring can spawn in "waves" over the same kilometre of shoreline in the same year, several weeks apart, the frequency of spawning events can sometimes exceed the number of years in the time-series.

FIGURE 6. A scatter plot of spawning dates in each herring section throughout the previous 64 years. A Day-Of-Year (DOY) or Julian date x-axis and 64 year, y-axis is utilized.

TABLE 1. A collection of spawn tables summarize spawn records since 1940 by herring section, statistical area, region and the entire British Columbia coast. These tables can be viewed by selecting a BC region and choosing a section number (hotspot or hyperlink) on any of the six regional maps. The scroll bar can be used to scroll through values located beneath the table header. The header contains a Day-of-Year (DOY) to calendar date conversion table. Columns in the tables are described below.

Columns	**Description**
Year	Survey year.
Total records	Total number of spawn records (spawning events).
Spawn Habitat Index	Sum of the product of each spawn length (m) and the median spawn width (m) and egg layers adjusted by percent cover and pooled geographically (see complete description below).
Total length	Total length (along shoreline) of the spawning area (m).
Mean width	Mean width (perpendicular to the shoreline) of the spawning area (m).
Mean layers	Mean number of egg layers (spawn thickness).
Wgt SST	Mean sea-surface temperature (oC) weighted by the Spawn Habitat Index. Sea-surface temperatures in this calculation were measured at daytime, high tide on the dates of each spawning event. Source: nearest lighthouse oceanographic stations.
Mean date	Mean spawn date (Day-Of-Year, DOY).
Wgt date	Mean spawn date (Day-Of-Year, DOY) – the spawn date is adjusted (or weighted) by the Spawn Habitat Index to incorporate differences in the magnitude of spawns at different sites within regions, statistical areas or herring sections.
Min date	Earliest spawn date (Day-Of-Year, DOY).
Max date	Latest spawn date (Day-Of-Year, DOY).
Diver Survey (%)	Percentage of recorded spawn deposition assessed by divers.

DOY = Day of year (i.e. January 1 = 1, February 28 = 59, December 31 = 365)

TABLE 2. A collection of catch tables summarize catch records since 1888 by herring section, statistical area, region and the entire British Columbia coast. These tables can be viewed by selecting a BC region and choosing a section number (hyperlinked area) on any of the six regional maps. Herring catches (tonnes) are summed by season (Jan-Apr, May-Aug, Sep-Dec) and gear type (gillnet, seine, trawl and seine-caught spawn-on-kelp) for each year.

Limitations of Herring Spawn Records

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The precise geographical limits of herring spawning probably are accurate to within a kilometre, more in some specific sites and less in others. The original records were made with varying degrees of precision and the degree of precision often depended on the area and time of the survey. Spawning areas characterized by many geographical landmarks such as the Gulf Islands in the southern Strait of Georgia, were probably more precisely plotted than other areas with fewer geographical details, such as the relatively straight shorelines between Parksville and Deep Bay. It is also generally accepted that post-1987 diver surveys provide more accurate measures of spawning bed widths and egg densities (where measurements from several, diver transects were averaged) than standard surface surveys of the past. For example, surface survey, egg density measurements on extensive eelgrass beds (i.e. Boundary Bay sand flats) were frequently over-estimated because of difficulties in assessing patchiness (or percent cover). Similarly, spawning bed width measurements determined by grappling rakes on steeper shorelines were frequently under-estimated. In general, however, the summaries presented here should be reasonable indicators of the relative magnitude and locations of spawning activity to the nearest kilometre.

During the several years of preparatory work that has gone into this project, we often have heard the criticism that the herring spawning database has limited value because of alleged errors and omissions in the records. The most frequently cited error attributed to the records is that the data collected on the spawn dimensions were made in a sloppy way and "often by the cook on a patrol vessel". Alternately, we have heard that some fishery officers could not be bothered to go out and look for herring spawn rather, they simply noted the presence or absence of seabirds and assumed that herring spawn occurred whenever birds were reported. These stories undoubtedly could be correct, but probably for not more than a few of the nearly 30,000 records used in this analysis.

Based on detailed examination of the original records, it is clear that the overwhelming majority of the fishery officers and divers who report on herring spawns, have done it in a dedicated, professional and competent manner, often with detailed comments and charts accompanying the records. There are undoubtedly some errors in individual records, but usually the impact of such errors is diminished because of the relatively large number of records available for most locations. Furthermore, these records were gathered by hundreds of different individuals over a 75 year period. Within any single location, there were at least several different data recorders, and often many more over the years. So it is unlikely to expect a continuous run of poor data records.

There are, nevertheless, two kinds of systematic errors in these records which should be mentioned. The first appears to be a time-dependent trend for fishery officers to under-estimate the width of egg depositions. This occurred mainly in the earlier years, when it was generally believed that most of the spawn was confined to the intertidal zone. It has not been until relatively recent times that the significance of the subtidal fraction has been fully appreciated (Haegele et al. 1983). Also, there has been systematic changes (see Hay and Kronlund 1987) in the measurement of spawn density over the years, starting with a 1 to 5 "intensity" or categorical scale from 1928 to 1950, to a 1 to 9 "intensity" scale from 1951 to 1982 and then eventually to an egg layer measurement from 1977 to the present date. Each of these intensity measurements have been converted to average egg layers in the database. Previously, a spawn coefficient (Hay and Kronlund 1987) was applied to correct for these time-dependent errors. An area-specific coefficient was calculated by the mean of the product of spawn width and intensity, pooled at the herring section geographic scale. Today, a similar correction is applied whereby the median of the product of spawn width and egg layer measurements are pooled by a range of discrete kilometre segments along the coastline. This coefficient is incorporated into a cumulative spawn index described below.

Spawn Habitat Index

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We have computed a cumulative spawn habitat index (SHI) to represent the combined, long-term frequency and magnitude of spawns along each kilometre of coastline over time. The index is simply a measure of shoreline utilization by spawning herring. This index should not be confused with the "spawn index" as applied to escapement, age-structure or more recently, catch-age assessment models (Cleary et al. 2010-2012, Schweigert et al. 1993-2009 or Haist et al. 1984-1992). The cumulative Spawn Habitat Index is calculated by the sum of the product of each measured spawn length (m) and the median of the product of spawn width (m) and egg layers adjusted by percent cover and pooled geographically. Spawn width and egg layer measurements were pooled by a range of discrete, coastal shoreline kilometre segments, over all years (1928 to the current year) and reflect the bathymetric (depth and slope) and vegetative features (seaweed species compositions) of the spawning sites (area-specific spawn coefficient). The measured length (m) of shoreline that is utilized by spawners is considered the most reliable of the three, primary spawn measurements in terms of database completeness and consistency and has the most influence on the Spawn Habitat Index (SHI = Length x Spawn Coefficient) at a spawning area. Previously, the spawn coefficient was pooled at either a broader herring section level or at a narrower herring location geographical scale (Hay and McCarter 1999). This latter practice, however, can sometimes exacerbate time-dependent errors because the geographical positions of herring location names frequently cluster and overlap, and were inconsistently assigned during database evolution and development. The former practice (pooling by geographical sections) on the other hand, does not always provide accurate representation, as a great diversity of spawning habitats can exist within a single, aggregate herring section. Intermediate pooling by discrete ranges of shoreline kilometre segments (or pools) has facilitated a more accurate representation, reduced systematic errors and has been implemented since the year 2000. A bootstrap procedure, adopted in 2003, is used to determine spawn coefficients at the geographical "pool" aggregation level. If there are fewer than 10 years of spawn survey measurements in a "pool", a broader "section" spawn coefficient is applied.

The only other kind of error in the records which can severely affect conclusions presented in these analyses, is that of incompleteness. It is clear that for some locations, records were not collected systematically each year. Sometimes, problems with field communications, equipment and weather resulted in data deficiencies. It is also known that many small, but observable spawns, do not reach the doorstep of the database while others do. These spawns may be important from a habitat perspective but are not high on the list from a stock assessment viewpoint, where survey priorities are set.

Utility of Herring Spawn Records

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This geographical compilation and historical synopsis of herring spawns represents the culmination of several earlier but briefer versions. One of the earlier analyses, presented at the 1986 Herring Stock Assessment Meetings as PSARC Working Paper 86-5, had widespread distribution and was used for the examination and evaluation of ecologically sensitive areas relative to potential impacts from oil exploration activities and mariculture developments. A subsequent, detailed version (Hay et al. 1989) consisted of six volumes and was published in the Canadian Manuscript Series of Fisheries and Aquatic Sciences (No. 2019). Until recently, the herring spawn database has been utilized primarily for stock assessment purposes. Applications in habitat assessment have had to wait for the development and evolution of geographical information systems (GIS) and long-term, distributional analysis software.

The data and analysis that are presented here have been available for many years, on request (or on the internet) to anyone with an interest in the historical distribution of herring spawning areas. These analyses have already been used many times for the examination of impacts of various nearshore developments and environmental perturbations such as oil spill and climate change scenarios. It appears that one of the most useful aspects of this work is that some geographical areas are clearly identified as important spawning locations while others, with a negligible history of herring spawning, are shown to be less important. There are many locations, however, which are intermediate in importance. These locations have a record of spawning which varies in time. These intermediate spawning locations are the most difficult to evaluate in terms of their role in maintaining the well-being of the herring resource. The habitat classification system proposed in this report should address some of these distributional issues and prove useful in assessing the relative importance of each kilometre of British Columbia shoreline. A few core spawning locations stand out from the rest and are easily distinguished from the many peripheral locations that were frequently recorded during the early 1970s (a period of stock rebuilding). These peripheral spawning areas were utilized for about 10-15 years but many have not been actively utilized since the early to mid-1980s. This spawning distribution and behavioural pattern supports the adopted-migrant hypothesis suggested in Huse et al. (2002) and is consistent with the observed distributional contraction (as oppose to area contraction) of herring spawning areas since 1985. As spawn surveying efforts shifted from surface-type or shore-based to diver-based assessments in 1988, it may be argued that this apparent distributional contraction may simply be a result of changes in survey methodology and priorities. Most of these peripheral spawning areas, however, were not recorded *before* the 1970 to 1985 expansion years (only, during this period) and all throughout a period when surface-type or shore-based surveys were actively employed before, during and after distributional changes. Furthermore, the duration of these changes were gradual (10-15 years) as opposed to the more sudden change from "surface" to "diver" survey methodology that occurred between 1986 and 1988. Since seasonal herring spawning events often contribute immensely to local productivity and bolster carrying capacity (Hay and Fulton 1983) this analysis may also have important implications to the abundance and distribution of other shoreline inhabitants including invertebrates, seabirds, other fish and marine mammals that depend on herring and herring spawn for food.

In general, we suggest that it is essential to conserve the spawning areas that have a history of repetitive spawning over time. Also, areas immediately adjacent to spawning habitat must be protected to some degree. Ultimately however, each instance of a nearshore development that might impact herring spawning areas must be decided on its own merits and it should be kept in mind that we still do not understand why some sites are utilized as spawning areas while others are not. There is, as yet, no single, definitive explanation for the observed episodic utilizations of "inner" and "outer" spawning areas and apparent "spawn shifts". Heavily utilized spawning sites are often recorded on the leeward sides of islands or along mainland shores, sheltered by islands or headlands as opposed to the windward or more exposed shorelines. Overly sheltered and sometimes stagnant areas (e.g. the heads of long, narrow inlets or fjords) with only minimum estuarine circulation are also utilized but to a much lesser degree. Spawning sites with low or intermediate ocean exposures that additionally, have the capacity to maintain significant water body circulation seem to be favoured. Protection from swells or long fetch waves, large vessel traffic effects, transient lighting, prevailing winds, local seawater temperature, salinity, dissolved oxygen and turbidity tolerances, siltation avoidance, dynamically variable distributions of predators (marine mammals, other fish, fishers and seabirds) and decadal-scale trends in sea-surface temperatures have all been suggested as possible influences. One must also consider that there are many potential spawning locations which have never been documented as spawning areas but still appear to have all the appropriate vegetative substrates and local oceanographic conditions that are found in heavily utilized areas (Hay et al. 1984). Moreover, it should be realized that herring "enhancement" or "re-establishment" does not appear to be possible or practical at the present time (Hay and Marliave 1988). Therefore, if herring spawning habitat is lost, we cannot necessarily expect the impacted stocks to spawn in other locations nor can we realistically expect that new spawning habitat can be created.

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The authors would like to thank the fishery officers, field personnel and diver teams for their efforts in contributing to this Web site (or CD-ROM). The original 1989 edition of this publication has been a precursor to the web version of the "Herring Geographical Bulletin" first launched in 1999. Throughout developmental stages, we also acknowledge the efforts of Charles Fort, Lorena Hamer and former data custodians for helping to build and maintain the integrity of the herring spawn database. Students, Chris Oikawa, Alice Ortmann, Michael Luckach and Naomi Akune participated in kilometre positioning and geo-referencing tasks. Glen Langford, Geo-Spatial Systems Ltd., provided the original digitized CHS British Columbia map from which all SYSTAT maps were derived (time-series and cumulative spawn maps). Cliff Robinson, Parks Canadian Heritage, was instrumental in the development of an earlier VISUAL BASIC presentation of this data which has subsequently been developed further into the present, browser-based version. Andrew Thomson assisted in the initial conversion of multiple SYSTAT maps to animation format and supervised and coordinated the initial digitization of herring spawns using SPANS and ARCVIEW GIS software. Kristen Daniel, GIS technician has done much of the more recent digitization and GIS work. Tricia Boxwell assisted with the first HTML web pages in 1997 which have subsequently been standardized to Fisheries and Ocean's "Common Look and Feel" format in 2000 with the assistance of Megan Adam.

Over the years funding was provided from various sources, but we especially thank the Herring Conservation and Research Society, Norm Sloan, Parks Canadian Heritage, Jim Bunch, DFO, Ottawa, Colin Levings, DFO, West Vancouver and Brad Mason, DFO, Vancouver. We would also like to thank Vancouver Island University for supporting the internship program.

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