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Distribution and timing of herring spawning in British Columbia

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ABSTRACT

This paper examines spatial and temporal variation in herring spawn in British Columbia, from 1928 to 1998. We present summaries of temporal variation in indexes of spawn abundance for 6 different regions: (1) Queen Charlotte Islands (QCI), (2) Prince Rupert District (PRD), (3) Central Coast (CC), (4) Johnstone Strait (JS), (5) Strait of Georgia (SOG), and (6) West Coast of Vancouver Island (WCVI). Within the regions we also distinguish between 'non-assessment' areas and 'assessment' areas. Assessment areas are the geographic units applicable to the annual stock assessments, and they make up approximately 55% of the total coast. In all regions the total amount of spawn has fluctuated during the last 71 years, but the trend varies with location. The trend in spawn deposition for the last 20 years has been to increase in 3 of the 5 assessment regions: PRD, CC and SOG. No trend is clear for WCVI but there is a long-term decline in QCI, although QCI spawn indexes have increased in the last few years. There appears to be a decline in spawn indexes for most non-assessment areas in the QCI, CC, and SOG. Spawn has decreased in the JS, a non-assessment region, but increased slightly in the non-assessment areas of WCVI.

In general, the geographical range of spawning areas is contracting. The BC coast consists of 108 different geographic units called herring sections, 101 of which have been used for spawning in one or more years since 1928. The numbers of herring sections receiving spawn is lower in 1998 than in all previous records since the 1930s, when the records were known to be incomplete. In part, however, this recent reduction could reflect declining survey effort in recent years. Similarly, the duration of the spawning period is becoming shorter, with later starts and early completions, in most areas. Some but not all of this trend also could be attributed to the reduction in survey effort. In the 3 major areas where spawn indexes are increasing, they are increasing substantially, so that the total coastal spawn deposition, if measured by the indexes presented here, is higher than in all previous assessment years. Therefore, as a generalization, we observe that spawning is contracting in space and time but increasing in abundance. The recent trend for an increase in spawn deposition is consistent with trends in spawning biomass reported in recent assessment documents, but the assessment documents do not consider the declining spatial and temporal ranges of herring, or make any comment about spawn in non-assessment areas. The reasons for the spatial and temporal changes in spawn deposition are not clear, but could be related to one or more factors including fisheries and climate change. Unfortunately some of the apparent changes could reflect declining survey efforts, particularly in the non-assessment areas.

RÉSUMÉ

Le document traite de la variation spatiale et temporelle de la ponte du hareng en Colombie-Britannique, de 1928 à 1998. Nous présentons des résumés de la variation temporelle fondés sur des indices de l'abondance des œufs dans six régions : 1) Îles de la Reine Charlotte (IRC), 2) district de Prince Rupert (DPR), 3) côte du Centre (CC), 4) détroit Johnstone (DJ)¸ 5) détroit de Georgia (DG) et 6) côte ouest de l'île de Vancouver (COIV). Nous établissons aussi une distinction au sein des régions entre les zones de « non évaluation » et les zones « d'évaluation ». Les zones d'évaluation sont les unités géographiques servant aux évaluations annuelles des stocks; elles représentent 55 % environ de la totalité de la côte. Dans toutes les régions, la quantité totale d'œufs a fluctué au cours des 71 dernières années, mais la tendance varie selon l'endroit. Au cours des 20 dernières années, la ponte a augmenté dans trois des cinq régions d'évaluation : DPR, CC et DG. Aucune tendance nette n'est décelable en COIV, mais l'on note un déclin à long terme pour la région IRC bien que l'indice y ait augmenté au cours des dernières années. Il semble y avoir déclin des indices dans la plupart des zones de non évaluation IRC, CC et DG. La ponte a diminué en DJ, une région de non évaluation, mais s'est accrue légèrement dans les zones de non évaluation de COIV.

De façon générale, la superficie des zones de frai diminue. La côte de la C.-B. est divisée en 108 unités géographiques, les sections du hareng, dont 101 ont été utilisées pour le frai au moins au cours d'une année depuis 1928. Le nombre de sections où il y a eu ponte en 1998 est inférieur à celui de toutes les années depuis les années 1930, où les registres étaient incomplets. Cette baisse récente pourrait cependant s'expliquer par un déclin de l'effort des relevés au cours des dernières années. De façon semblable, la durée de la période de frai se raccourcit, débutant plus tard et se terminant plus tôt, dans la plupart des zones. Une partie seulement de cette tendance peut être attribuable à une réduction des relevés. Dans les trois principales zones où les indices de ponte sont à la hausse, l'augmentation est appréciable de sorte que la ponte totale sur la côte, si elle était mesurée par les indices présentés ici, serait plus importante que celle de toutes les années d'évaluation antérieures. Nous notons donc, de façon générale, une contraction spatiale et temporelle de la ponte, mais une augmentation de son abondance. La tendance récente d'une augmentation de la ponte est cohérente avec les tendances de la biomasse signalée dans les récents documents d'évaluation, mais ces derniers ne prennent pas en compte la réduction spatiale et temporelle des aires de répartition du hareng ni ne font état de la ponte dans les zones non évaluées. Les raisons de cette variation spatiale et temporelle de la ponte sont mal comprises, mais elles pourraient être liées à un ou plusieurs facteurs, comme la pêche et le changement climatique. Malheureusement, une partie des changements notés pourrait s'expliquer par la baisse des efforts des relevés, particulièrement dans les zones non évaluées.

INTRODUCTION

The objectives of this paper are to (1) describe the spatial and temporal variation in herring spawn distribution in British Columbia and (2) compare and contrast this variation between within and between different geographical regions. The Department of Fisheries and Oceans, in conjunction with the (now defunct) Fisheries Research Board of Canada, has collected data and records of herring spawning, for more than 70 years. Earlier reports described the spawn data and surveys (Haegele et al. 1981, Hay and Kronlund 1987, Schweigert et al. 1990, Schweigert 1993). Hay et al. (1989) described BC herring spawning in a detailed 6-volume account of spatial changes in local areas. More recently, Hay and McCarter (1997) described changes in the Strait of Georgia, where spawn deposition appeared to be contracting to fewer areas in shorter spawning periods, although total spawn deposition was near historical highs. In this paper we extend the analyses to other regions of the BC coast.

For approximately 10 years, herring assessments and management have concentrated on 5 management or 'assessment' areas (Fig. 1). The objective of the annual stock assessments has been to estimate the spawning biomass in each of these areas. In general, the assessment areas are the largest spawning areas, receiving most of the spawn consistently over time. For the other areas, outside the 'assessment' areas and which we call 'non-assessment' areas, there usually is no estimate of total biomass. Exceptions are sometimes made for several small areas, including parts of the West Coast of the Queen Charlotte Islands and Winter Harbour on Vancouver Island. The total area of the 'non-assessment' areas is about 45% of the total coast (46 of 101 sections). The relationship between assessment and non-assessment areas and other geographical definitions is shown in Fig 2 and described in Table 1.

Spawn records exist for the entire coast including both assessment and non-assessment areas. For many reasons it is important to monitor spawning in the non-assessment areas. Many of these areas include geographically distinct marine waters, such as Knight Inlet or Bute Inlet. These areas usually have relatively small but consistent spawn deposition over time - and these areas may represent distinct stocks. Other locations within the non-assessment areas may sometimes receive substantial amounts of spawn, but not regularly. Knowledge of the spawning times, spawning areas, and relative spawn deposition is important for protection of spawning habitat and as indicators of the well-being of herring that are not fished. Also, further information on non-assessment area herring stocks will contribute to refinement of our understanding of herring stock structure and the role(s) of herring in marine ecosystems.

To review changes in spawn deposition in the non-assessment areas we required an index of herring spawn that would apply equally to assessment and non-assessment areas. Usually, data records consist of estimates of (1) spawn length in metres (or yards), (2) spawn width in metres and (3) the thickness of eggs, expressed in units of intensity or, more recently, egg 'layers'. Hay and Kronlund (1987) noted that estimates of width were increasing in time, and intensity was decreasing in time. They attributed these time trends to gradual changes in survey methodology. Without adjustment, these time trends confound attempts to compare spawn deposition in time and space. To address this problem, Hay and Kronlund (1987) calculated section-specific, ‘coefficients of spawn’ based on the *means* of the spawn width and intensity of each section. These were calculated for each of the approximately 100 sections of the coast, as they were defined in 1987. For any given year, this index (which we call the SECTION INDEX) was the product of the cumulative spawn length (*m*) and the spawn index. In the present paper we have re-calculated this index based on the more recently defined geographic sections (Haist and Rosenfield 1988). A weakness of the SECTION INDEX, however, is that it does not recognize differences in spawning areas within sections. We are aware that adjacent spawning sites (within sections) can vary markedly in spawn width. Therefore in the present paper, we present a refinement, called the LOCATION INDEX, which is defined for each of the approximately 1300 different locations. The location index is based on median spawn widths and spawn intensity (or layers) and should better incorporate information on geographical differences of spawning areas within sections. Both the SECTION and LOCATION indexes, which are defined precisely below, are intended to apply equally to all areas of the coast, including assessment and non-assessment areas. In contrast, the spawn index used for the assessment models, which we call the ASSESSMENT INDEX (Schweigert et al. 1998) applies only to assessment areas.

Each spawn index is based on an estimate of an area-specific coefficient of spawn width and spawn intensity (or layers). These coefficients are needed because of the strong time-trends in the data. Since their beginning in 1928, spawn surveys have gradually increased in complexity, from simple measurements of spawn length, made from shore-based or vessel based surveys, to comprehensive SCUBA diver estimates spawn width, and *in situ* estimates of the numbers of egg layers on different vegetation types (Schweigert et al. 1998). Presently we distinguish between ‘surface’ surveys, made from shore or from small vessels, and SCUBA surveys. The intention of SCUBA surveys is to derive an estimate of the number of eggs from which an estimate of spawning biomass can be determined. SCUBA surveys began in the 1980’s and by the 1990’s they were conducted routinely throughout all major stock assessment areas of the BC coast, but not in the non-assessment areas which are mainly examined by ‘surface’ surveys. As SCUBA surveys became routine, there may have been two other subtle changes in spawn surveys (1) a decrease in survey effort in non-assessment areas and (2) a decrease in the effort to assess very early and very late spawns in all areas. As a consequence, the intention of the present paper to describe spatial and temporal changes in spawn distribution may be partially confounded by the recent changes in spawn methods. The early spawn data, particularly before 1937, are incomplete in many areas. These earlier records are included, however, to illustrate the deficiencies of analyses based on incomplete spawn data. We cannot rule out the possibility that some of the recent trends we observe in the 1990’s are not also a function of incomplete spawn survey data.

For additional criteria of spawn deposition, we include the estimates of the total cumulative length of spawn and the annual number of spawn records. The variation in spatial distribution of spawn is examined by comparing the number of herring sections and herring locations that receive spawn each year. The temporal ranges of spawning times are estimated by comparing the mean and ranges of spawning, by year, for all areas.

METHODS

Geographical Definitions

For the purposes of herring management, the BC coast is divided into 6 different regions: (1) Queen Charlotte Islands (QCI), (2) the North Coast (NC), or Prince Rupert District (PRD), (3) the Central Coast (CC), (4) Johnstone Strait (JS), (5) the Strait of Georgia (SOG) and (6) the West Coast of Vancouver Island (WCVI) (Fig. 1). Within all regions except JS, there are areas that are designated as 'assessment areas' that comprise the areas over which annual spawn deposition is quantified to provide an estimate of spawning biomass. The spawn in areas outside of the 'assessment areas' is not usually included in the annual spawn assessments, although until recently, surveys of spawn in these areas were made.

Each of the regions can be divided further into the Fisheries and Ocean Statistical Areas of which subsets are called sections (Haist and Rosenfeld, 1988). In total, there are 101 different herring spawning sections of roughly equal size, as can be seen in Figure 2. Of these 56 are included in the 5 major assessment areas, which correspond approximately to each region, and 45 sections occur outside the assessment areas. The numbers, however, do not correspond exactly to 'fishing' areas because some areas, such as section 273 (Winter Harbour) are not in the assessment areas but have roe fisheries. Others, such as section 51 and 53 (Prince Rupert District) or Section 280, 290 (in the vicinity of the city of Vancouver area) are in assessment areas but have never had roe fisheries. Note that sections 132 and 135, from the southern JS region, are included in the SOG assessment area.

In this paper, we distinguish between *assessment* and *non-assessment* areas as indicated in Table 1. The format for these follows exactly from the sections defined as assessment area in the 1997 assessment document (Schweigert et al. 1998). Table 1 shows the relationship between regions, assessment areas and sections. Note, for example that all of the PRD is part of the assessment area, and nearly all of Johnstone Strait (except for Sections 132 and 135) is a non-assessment area. Sections 132 and 135 are included as part of the Strait of Georgia assessment areas. All other regions consist of a mixture of 'assessment' and 'non-assessment' sections.

Spawn indexes

Herring spawn is quantified using two indexes, the LOCATION and SECTION index. The LOCATION index is derived from estimates of the median spawn width and median spawn intensity, and is calculated for each of the 1303 different spawn locations. The index is the product of the length of spawn (m) by the estimate of median egg layers and median width, determined for each location. For continuity with the earlier literature, we also present a SECTION index from Hay and Kronlund (1987) that estimates a spawn coefficient for each section. This coefficient is the arithmetic mean of the products of spawn width and intensity, calculated for each section. Originally the coefficients were calculated for each herring sections, as they were defined before changed in 1988 (Haist and Rosenfeld 1988).

The Hay and Kronlund (1987) SECTION index is the product of the spawn length and a section-specific spawn coefficient (SC_{sec}) estimated for each herring section as follows:

$$\mathbf{SC_{sec} = 1/n \; ; \; (W_{rj}D_{rj})}$$

where $\mathbf{W_{rj}}$ is the spawn width of spawn record **r** in year **j** and $\mathbf{D_{rj}}$ is the spawn intensity (or spawn layers) for spawn record **r** in year **j**. The spawn section index ($\mathbf{SEC\ I_{sj}}$), estimated for a single section (**s**) in year (**j**), is the product of the cumulative spawn length ($\mathbf{;L_j}$) in metres by the section-specific spawn coefficient ($\mathbf{SC_{sec}}$) as follows:

$$\mathbf{SEC\ I_{sj} = \; ;L_j \; (SC_{sec}).}$$

The index for larger areas (i.e. Statistical areas or assessment areas) is the sum of composite areas. Since the development of this index, the geographical boundaries of sections have changed and the intensity of spawn is replaced by an estimate of layers (Schweigert et al. 1998). Therefore in this paper, we re-calculate the spawn coefficients for the re-defined herring sections as drawn in Haist and Rosenfeld (1988) and we substitute layers for intensity. These are relatively small changes to the original SECTION index.

A refinement of this index, called a LOCATION index, has two modifications. (1) Area-specific coefficients are estimated constants for all of the 1313 different 'locations' used to document spawn. There are between 153 and 306 different spawn locations within each of the herring regions and 1313 different locations for the entire coast. (2) We used **median** estimates for spawn width and layers to avoid potential errors associated with skewed width and intensity (layer) data. For each location we estimate a spawn coefficient ($\mathbf{SC_{loc}}$) as follows:

$$\mathbf{SC_{loc} = (median\ width) \times (median\ layers)}$$

The spawn location index (**LOC I_{kj}**) estimated for a single location (k) in any year (j) is the product of the cumulative spawn length (**L_{kj}**) in metres and the location-specific spawn coefficient (**SC_{loc}**):

$$\mathbf{LOC\ I_{kj} = ;L_{kj}\ (SC_{loc})}$$

For any year the spawn index for larger geographical groupings (section, statistical area or Region) is simply the sum of the component parts.

Data and Analyses

The herring spawn data (approximately 26,000 records) were imported into Systat© and Minitab© for further analyses. All analyses and plots, including the line-fitting 'LOWESS' functions, were made using Minitab© statistical software. For most plots we included a LOWESS line which fits a smoothed line between two variables (Minitab Reference Manual 1998). All of the data used in these analyses are summarised, by region, in Appendix Tables 1-6. The spawn index used for 1997 assessment was extracted from Appendix Tables 2 in Schweigert et al. (1998). The assessment index is a combination of historical survey data and detailed estimation of absolute egg numbers from SCUBA surveys (Schweigert et al. 1990, Schweigert 1993). Subsequently we refer to this index as the 'ASSESSMENT' index (upper case) which we distinguish from the others called the 'LOCATION' and 'SECTION' indexes (uppercase).

RESULTS AND DISCUSSION

Changes in estimates of mean width and egg layers

Estimates of mean spawning width have increased with time and are particularly high in recent years, especially 1998 (Fig. 3a). The trend for an increase with time occurs mainly in the assessment areas (Fig. 3b) and not in the non-assessment areas (Fig. 3c) except for 1998. The particularly wide widths for 1998 appear to be associated with the unusual spawning in WCVI. Estimates of mean layers have decreased with time (Fig. 4a) both in the assessment (Fig. 4b) and non-assessment (Fig. 4c) areas. Hay and Kronlund (1987) concluded that these trends (to increase width and decrease intensity of layers) were related to changes in survey methodology. It is surprising, however, to see that the trajectories of these trends remains the same through the 1990's. In recent years, most observations in assessment areas have been made by SCUBA divers, so it is unclear if the continuing changes have been affected by methodological changes.

The mean spawn coefficients for each index, shown for the whole coast and the assessment areas (Figs. 5a-b) do not show strong time trends. Except for the last 3-4 years, the estimates of the mean spawn coefficients, calculated from the mean width and layers (for the SECTION Index) or the median width and layers (for the LOCATION Index) do not appear to be either increasing or decreasing. There appears to be a long-term decline in the indexes for the non-assessment areas.

Record numbers

The numbers of spawn records have declined in almost all areas (Figs. 6a-c), but the reasons are not clear. In part this decrease seems to be associated more with the use of SCUBA surveys which make many detailed records that are synthesized into a single record (C. Fort, personal communication). Therefore the apparent decline in records is not necessarily meaningful, but we included them here as an illustration of the continuing changes in data collected from spawn surveys.

Spawn length

Since 1980, the cumulative spawn length has increased in 3 assessment areas (PRD, CC, SOG) and decreased in 2 (WCVI and QCI) (Fig. 7). The length decreased in 3 non-assessment areas (QCI, CC, and SOG) but increased in 2 (JS and WCVI). In some ways, the estimate of length is the most unbiased estimate of total spawn, but only if examined *within* areas. For instance, some regions have generally wider spawning areas than others do, so comparisons of spawn length *between* areas might be misleading. On the other hand, consistent changes within areas probably are meaningful. Therefore, we suggest that the general trends in spawn deposition, as seen in Fig. 7, may be roughly accurate, but that the cumulative lengths may not provide a basis for quantification of spawn. Therefore, estimates of 200 km of spawn in WVCI in the 1970's do not necessarily mean that there was twice as much spawn there compared to SOG during the same period, when cumulative lengths were about 100 km.

Spawn indexes: comparison of the SECTION, LOCATION and ASSESSMENT Indexes

Since 1980, all spawn indexes have increased within the assessment areas in PRD, CC and SOG (Fig. 8) which are now the major spawning sites on the coast. All indexes have declined in the QCI assessment areas. The temporal trend is inconsistent in WCVI, where the LOCATION index shows a decline since 1980, although the last 3 years show an increase. In contrast, the ASSESSMENT index appears to increase. The SECTION and LOCATION indexes have declined in non-assessment areas in QCI, CC, JS, and SOG but increased in WCVI, although the last 5 years show a decline.

Comparisons of Figs. 7 and 8 show that the major trends in the indexes are roughly similar to the changes in spawn length. Spawn indexes are decreasing in QCI (except for the last 2-3 years) and increasing in PRD, CC, and SOG. The major difference between Figs. 7 and 8 is the scale. For instance, the spawn indexes are much greater in SOG compared to WCVI, although this is not the same for a comparison of lengths. There also are some interesting similarities and differences between the indexes, particularly the LOCATION index, and the ASSESSMENT index. In general, in most regions, these indexes are very similar during the years prior to 1980, but they diverge in more recent years – although the smoothed LOWESS-line trends (increasing or decreasing) are approximately the same. As the ASSESSMENT index has no reported dimension, (i.e. It does not represent a discrete area or volume) comparisons of the absolute numbers with the SECTION or LOCATION index are not meaningful. On the other hand, the post-1980 divergences may reflect some distinct difference in the behaviour of the ASSESSMENT index with the LOCATION index presented here. Specifically, we suggest that the ASSESSMENT Index may be too conservative in recent years. (Alternately, it may be too liberal in earlier (i.e. 1950's) years, although this seems unlikely because for most years in the 1950's, estimates of spawning biomass are much lower than the estimated catch.)

The SECTION and LOCATION indexes are approximate estimates of area (in square km). They represent a length (m) multiplied be a width (m) adjusted according to constant density of eggs. For the purposes of illustration, the units are adjusted to represent square km. We can, however, compare the relative estimates among regions, as shown in Table 2. For instance, the mean LOCATION index and ASSESSMENT index are roughly the same for QCI, CC, and WCVI, but the LOCATION index is about 50% greater than the ASSESSMENT index for PRD and SOG. Ignoring the recent divergence in the ASSESSMENT and LOCATION indexes, the LOCATION index seems to provide a reasonable approximation of total spawn in non-assessment areas, at least within a factor of 2. Therefore comparisons of total spawn between assessment and non-assessment areas, within regions, provides an approximate estimate of the total spawn that is not included in the annual assessments. For the QCI, the spawn indexes in the non-assessment areas are approximately equal to those in the assessment areas (compare the QCI panels between Figs. 8 and 9). Similarly, although the recent estimates of total spawn in the non-assessment areas of CC is much less than the assessment areas, this was not the case in the 1960's and early 1970's when spawn deposition was highest in non-assessment areas.

Total spawn in JS (a 'non-assessment' area) has never been high, but present levels may exceed those in the QCI (an 'assessment' area). Spawning in non-assessment areas of SOG is negligible at the present time, but for a short period in the 1960's and 1970's it was substantial (Fig. 9). The spawn in WCVI non-assessment areas in increasing, and if the present long-term trend continues (see LOWESS line in Fig. 9) it could equal that of the WCVI assessment areas.

When the spawn indexes are all standardized (to a percentage by year) the general trends (seen by comparisons of the LOWESS lines in Fig. 10) are similar but there are some notable differences, mainly in PRD and SOG. In those two areas the assessment index, compared to the LOCATION and SECTION index), is higher in earlier years (1950's) and lower in recent years (late 1980's and 1990's). The shift (from higher to lower) begins approximately when spawn surveys started to use SCUBA diver data. A potential implication is that the Assessment index may be slightly underestimating spawn in these areas (relative to the past) or that the Section and Location Indexes are slightly inflated. In this present paper we cannot distinguish between these (or other) explanations, but some further research may help to clarify the reasons for these divergences in the indexes.

Changes in the spatial diversity of spawn - numbers of sections and locations

The numbers of sections receiving spawn has declined in all regions, including those in which the spawn indexes have increased (Fig. 11). The numbers involved were too low to distinguish between assessment and non-assessment areas within regions). Remarkably, the numbers of locations has not necessarily declined with time in the CC, WCVI, or SOG and in JS the numbers of locations are increasing (note, however, that no 1998 data are reported for JS because no surveys were conducted in 1998 in that area). The numbers of locations have declined in QCI and PRD. In all areas except QCI, these declines in spatial range could reflect deteriorating survey effort, particularly at times that are relatively early or late relative to usual spawning times. (See the next section for more discussion on this point.) This apparent contradiction between a decline in the number of sections, but no change, or increases in the numbers of locations, is consistent with the idea that more herring are concentrating in fewer sections, and therefore forced to spread their activity spawning within the Section, hence, using more locations. This also is consistent with the apparent recent increases in spawn length and spawn indexes. If spawning herring are concentrating in fewer larger areas, they may be forced to 'spread-out' laterally, perhaps through some form of density-dependent control of spawning behaviour (Hay 1985) and therefore use greater spawning widths within locations.

Changes in spawn timing – mean, first and last dates

The range of spawning times has declined steadily in the QCI, and there seems to be a decline in the long-term mean (12). Almost certainly, these QCI data are incomplete for some areas and some years. Probably there is a small population spawning in Masset in late June or July, which rarely gets reported. In the late 1970's and early 1980's there was an unusually early (February) spawning of herring in Naden Harbour that accounts for some of the earliest spawns.

Since 1970, the PRD timing data show nearly identical trends to that of QCI, with a reduction in the range of spawning dates and a decline in the mean date. It is interesting that the PRD herring also had an episode of early spawners at approximately the same time as the QCI fish. This is indicated on Fig. 12 with an arrow pointing to the two approximately synchronous events. The long-term mean and range of spawning times in the CC are relatively steady, although since 1990 there appears to be a reduction in the number of early spawning events. Similarly, there are no particular changes in the mean dates or range of JS fish.

The SOG shows a striking contraction of the range of spawning times, mainly from the loss of early spawning fish, which mainly spawned in the vicinity of the Gulf Islands and Boundary Bay. There may also be a reduction in late spawners. The mean WCVI spawning seems consistent with time but, like SOG, the early spawnings no longer occur. Both in SOG and WCVI, this change might be attributed to declining survey effort, but it seems probable that if the early spawns occurred regularly, as they did in the 1950's and 60's, then at least a few would have been reported in recent years. This is especially true for SOG where most of the early spawns occurred in the vicinity of coastal habitat where they would be easily observed and reported.

Synthesis - Trends in spawn deposition from spawn indexes

The longer-term trends (20+ years) in British Columbia spawn deposition can be summarized as follows:

(1) - an increase spawn deposition in PRD, CC, SOG, and in the non-assessment areas of WCVI;
(2) - no clear trend for the assessment areas of WCVI where the SECTION and ASSESSMENT indexes have increased but the LOCATION index has decreased;
(3) - a general decrease in spawn indexes for the QCI assessment areas, at least until 1997 or 1998 when the indexes may have started to increase;
(4) - a decrease in most non-assessment areas including the QCI, CC, JS and SOG;
(5) - an increase in the non-assessment areas on the WCVI, mainly Area 27.
(6) - the spatial range of spawning is decreasing, with fewer parts of the coast receiving spawn;
(7) - the duration of the spawning period is becoming shorter.

Total spawn deposition, for the whole coast (assessment and non-assessment areas) is summarized in Fig. 13. The cumulative spawn length, and both the LOCATION and SECTION indexes are at historical highs in the 1990's. The recent increase in these spawn indexes however, has occurred in fewer sections (Fig. 14) and the spatial diversity in at historical lows. If the apparent decline in spatial diversity can be attributed to declining survey effort, then it is probable that recent estimates of the spawn indexes, although near maximal in the time series, may be under-estimated.

In a general way, the results indicate that spawn has increased in most areas that have had fisheries (assessment areas) and decreased – or 'appeared' to decrease - in areas with no fisheries (non-assessment areas). A problem with this tentative conclusion, however, is that many of the present ‘non-assessment areas’ were once included in herring fisheries and some critics have claimed that these fisheries have led to local depletions, particularly in areas such as the southern and eastern parts of SOG and JS. The trends in the data from the present paper do not necessarily contradict those assertions. They do show, however, that most areas with relatively long-term roe fisheries still have abundant spawn deposition, and indeed, most have had distinct increases in spawn. Therefore, over the time scales of the roe fishery (about 25 years) fishing activity has not necessarily led to depletions in the areas where fishing has occurred, as is sometimes suggested. Rather, if any trend has occurred, it has been for a concentration of spawn in the areas that have supported the largest fisheries.

The probable explanations for many of the changes in spawn deposition are (1) changes in ocean climate, particularly temperature, that affect pre-spawning herring distributions and (2) changes in the quality of the database. Addressing these issues is beyond the scope of the present paper, which set out only to document and describe the changes. Explaining the changes is the next step, but we can make one comment at the present time, particularly with respect to the second point: the quality of the database. We have suggested that some of the apparent decreases in spawning areas and spawning times may be associated with a reduction in survey effort, relative to that of previous years. There is firm evidence that this has occurred in JS in 1998: no 1998 data were collected in JS. This is the first time that the entire area has been missed in the last 60 years. There also are some concerns about the incorporation of collected data into the present database. On the other hand, managers present at the 1998 PSARC meetings felt that the spawn surveys in most other areas of the coast were well done and complete (D. Chalmers, V. Fradette, pers. comm). Even if there were some systematic deterioration of survey effort, we still see evidence of long-term increases in spawn deposition in 3 assessment areas: GS, CC and PRD. All are at, or near, historical highs. Therefore, any impact of declining survey effort in these areas, and other areas, will be to underestimate the spawn in recent years. If so, perhaps the spawning biomass was greater in these areas, and perhaps in all areas, than the data would indicate. Unless spawn surveys are re-established in all areas, however, we may never know and management decisions could appear to be wrong, even if they are not.

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Table 1. Relationship between the regions, sections, non-assessment (NON-ASSESS) and assessment (ASSESS) areas for the BC coast. The total number of spawn records is shown for each section. Sections 132 and 135 (underlined) in Johnstone Strait are included within the Strait of Georgia assessment area (See Fig. 2).

	REGION	SECTION	NON-ASSESS	ASSESS
QCI	1	1	63	0
	1	2	228	0
	1	3	204	0
	1	4	30	0
	1	5	180	0
	1	6	0	244
	1	11	30	0
	1	12	132	0
	1	21	581	0
	1	22	378	0
	1	23	0	228
	1	24	0	301
	1	25	0	538
PRD	2	32	0	39
	2	33	0	303
	2	41	0	6
	2	42	0	849
	2	43	0	442
	2	51	0	42
	2	52	0	817
	2	53	0	116
CC	3	61	14	0
	3	62	99	0
	3	63	140	0
	3	64	35	0
	3	65	15	0
	3	66	49	0
	3	67	0	1066
	3	72	0	870
	3	73	0	125
	3	74	0	1264
	3	75	0	179
	3	76	0	469
	3	77	0	138
	3	78	0	124
	3	82	45	0
	3	83	230	0
	3	84	213	0
	3	85	0	587
	3	86	0	87
	3	91	40	0
	3	92	116	0
	3	93	351	0
	3	102	373	0
	3	103	57	0
JS	4	111	8	0
	4	112	103	0
	4	121	11	0
	4	122	207	0
	4	123	186	0
	4	124	79	0
	4	125	323	0
	4	126	656	0
	4	127	778	0
	4	131	1	0
	5	132	0	186
	4	133	74	0
	4	134	302	0
	5	135	0	206
	4	136	40	0
SOG	5	141	0	15
	5	142	0	675
	5	143	0	369
	5	151	0	17
	5	152	0	374
	5	161	0	1
	5	162	0	54
	5	163	0	226
	5	164	0	62
	5	165	0	134
	5	172	0	549
	5	173	0	960
	5	181	0	950
	5	182	0	188
	5	191	0	80
	5	192	0	4
	5	193	0	75
WCVI	6	202	8	0
	6	220	1	0
	6	231	0	124
	6	232	0	1215
	6	233	0	84
	6	241	0	55
	6	242	0	221
	6	243	0	413
	6	244	0	325
	6	245	0	1131
	6	251	0	11
	6	252	0	255
	6	253	0	772
	6	261	58	0
	6	262	169	0
	6	263	139	0
	6	271	8	0
	6	272	163	0
	6	273	468	0
	6	274	29	0
SOG	5	280	0	39
	5	291	0	15
	5	292	0	4
	5	293	0	88

Table 2. Summary and comparison of spawn indexes. The variables describe the mean and variation of the annual mean index for each area, with the number of years indicated by 'N'. The ASSESSMENT index is presented in the 1997 herring stock assessment document, and has been scaled (divided by 10^5) to allow comparison with the other 2 indexes. The LOCATION index is presented in this paper and the SECTION index was presented by Hay and Kronlund (1987). After scaling, the mean ASSESSMENT index (bold underlined) is approximately the same as the mean LOCATION Index (bold underline italics) for the Queen Charlotte Islands, Central coast, and West Coast of Vancouver Island. The LOCATION index is about 50% greater both for the Prince Rupert District and the Strait of Georgia.

Place/Variable	N	Mean	StDev	SEMean	Minimum	Maximum
Queen Charlotte Islands						
Assessment Index	47	**<u>0.915</u>**	0.650	0.094	0.071	2.501
Location Index	58	***<u>1.094</u>***	0.757	0.099	0.020	3.003
Section Index	58	1.439	0.925	0.121	0.030	3.473
Prince Rupert District						
Assessment Index	47	**<u>1.746</u>**	0.962	0.140	0.084	3.661
Location Index	62	***<u>2.524</u>***	1.307	0.166	0.153	5.678
Section Index	62	4.366	2.352	0.299	0.271	10.180
Central Coast						
Assessment Index	47	**<u>1.473</u>**	0.988	0.144	0.177	4.621
Location Index	63	**<u>1.502</u>**	0.997	0.126	0.139	4.621
Section Index	63	3.151	2.026	0.255	0.546	10.442
Strait of Georgia						
Assessment Index	47	**<u>4.841</u>**	2.530	0.369	0.511	10.051
Location Index	71	***<u>7.102</u>***	5.136	0.610	0.152	19.970
Section Index	71	11.684	7.614	0.904	0.205	30.929
West Coast of Vancouver Island						
Assessment Index	47	**<u>2.980</u>**	1.595	0.233	0.458	6.366
Location Index loc	65	***<u>2.811</u>***	2.071	0.257	0.039	8.432
Section Index sec	65	4.917	2.482	0.308	0.133	9.940

Appendix Tables – Explanation of columns

Data for years prior to 1937 and year 1998 may be incomplete. Columns 1 the year. Column 2 is the Assessment index from Schweigert et al. (1998). Columns 3 and 4 are the LOCATION indexes for assessment and non-assessment areas as defined in the text. Columns 5 and 6 are the SECTION indexes for assessment and non-assessment areas as defined in the text. Columns 7 and 8 are the cumulative spawn lengths for assessment and non-assessment areas as defined in the text. Columns 9 and 10 are the number of spawn records in assessment and non-assessment areas. Column 11 is the number of sections with herring spawn in any year. Column 12 is the number of locations with herring spawn in any year. Columns 13-15 are minimum, mean and maximum spawning dates, shown as the DOY (day of the year).

Appendix Table 1. Summary of spawn survey data and spawn indexes for the Queen Charlotte Islands.

1 Year Index	2 Assess Index	3 Location Index AA	4 Location Index NonA	5 Section Index AA	6 Section km NonA	7 Length km AA	8 Length km NonA	9 Number Recs AA	10 Number Recs NonA	11 Number Secs.	12 Number Locs.	13 Min DOY	14 Mean DOY	15 Max. DOY
1928	*	*	*	*	*	*	*	0	0	*	*	*	*	*
1929	*	*	*	*	*	*	*	0	0	0	*	*	*	*
1930	*	*	*	*	*	*	*	0	0	0	*	*	*	*
1931	*	*	*	*	*	*	*	0	0	0	*	*	*	*
1932	*	*	*	*	*	*	*	0	0	0	*	*	*	*
1933	*	*	*	*	*	*	*	0	0	0	*	*	*	*
1934	*	*	*	*	*	*	*	2	0	1	*	*	*	*
1935	*	*	*	*	*	*	*	0	0	0	*	*	*	*
1936	*	*	*	*	*	*	*	2	0	1	*	194	194.00	194
1937	*	1.214	*	1.071	*	7.238	*	3	0	2	*	69	140.33	176
1938	*	1.214	*	1.071	*	7.238	*	3	0	2	*	74	138.67	171
1939	*	1.214	*	1.071	*	7.238	*	3	0	2	*	60	137.33	176
1940	*	2.346	2.978	2.731	1.299	32.173	19.304	4	3	6	7	89	119.43	177
1941	*	1.152	2.978	1.691	1.299	25.739	19.304	2	3	5	5	88	93.40	95
1942	*	0.494	3.003	0.966	1.637	20.108	23.810	7	11	6	12	91	94.00	95
1943	*	1.261	0.948	1.134	0.870	19.157	14.688	6	6	6	11	91	105.25	119
1944	*	0.220	1.517	0.286	1.089	7.367	19.651	5	5	3	9	80	115.30	137
1945	*	0.230	2.827	0.415	1.969	6.087	26.844	6	13	4	11	84	101.58	123
1946	*	0.115	1.922	0.210	1.049	3.337	15.556	4	17	4	8	83	107.10	115
1947	*	0.148	1.066	0.259	1.740	3.473	24.587	2	21	3	9	91	97.22	109
1948	*	0.737	1.653	1.017	1.626	16.387	21.869	10	7	4	10	93	114.65	157
1949	*	0.159	0.523	0.185	0.716	3.290	10.072	9	5	4	10	102	121.07	163
1950	*	0.067	0.648	0.131	0.819	2.330	11.169	6	11	4	12	93	112.71	166
1951	2510	0.063	0.886	0.124	0.731	2.560	9.050	6	11	3	13	91	111.35	171
1952	2398	0.390	0.271	0.530	0.105	7.587	1.417	6	2	4	7	100	122.25	154
1953	4759	0.171	0.631	0.280	1.105	7.422	14.609	15	6	6	18	91	119.71	163
1954	9853	0.482	0.860	0.942	1.375	13.721	22.218	13	6	4	17	90	123.68	176
1955	6143	0.561	0.041	1.283	0.081	17.183	1.005	8	2	2	6	91	95.40	105
1956	4014	0.027	1.065	0.063	1.628	0.868	20.162	4	9	3	10	87	110.62	171
1957	1578	0.154	*	0.359	*	4.964	*	5	0	3	4	91	121.60	166
1958	787	0.080	0.027	0.169	0.059	3.044	0.731	4	2	5	6	81	91.17	112
1959	6941	0.322	1.182	0.615	1.551	21.250	22.942	10	6	9	14	78	92.00	112
1960	6470	0.274	0.562	0.589	0.533	12.341	9.963	12	5	9	12	84	104.06	146
1961	6976	0.852	0.696	1.605	0.776	31.679	13.254	11	5	8	13	82	94.94	134
1962	4654	0.410	0.598	0.770	0.816	19.880	11.698	16	6	9	19	80	98.41	141
1963	6176	0.139	0.436	0.448	0.928	10.337	11.562	15	7	5	8	81	95.00	148
1964	4223	0.427	0.183	0.934	0.301	19.105	6.124	20	6	9	17	59	84.50	131
1965	1446	0.123	0.125	0.260	0.166	5.502	3.656	6	4	7	7	79	95.30	140
1966	2764	0.297	0.040	0.677	0.076	9.577	1.151	18	4	7	11	90	101.09	133
1967	710	0.178	0.021	0.335	0.035	7.268	0.641	18	5	8	11	81	97.22	155
1968	750	0.403	0.037	0.603	0.057	5.854	0.937	24	4	8	15	79	119.82	177
1969	1877	0.242	0.040	0.508	0.030	11.152	0.366	15	1	7	13	95	121.06	174
1970	4308	0.328	0.833	0.519	0.681	11.784	10.541	28	23	10	16	72	99.90	152
1971	13616	0.486	1.073	0.979	0.995	19.742	18.417	38	4	7	14	95	137.14	197
1972	9951	0.416	1.281	0.681	1.546	20.263	26.336	31	25	8	13	80	113.62	183
1973	7706	0.246	1.177	0.377	1.878	13.418	34.247	20	46	7	17	87	104.21	173
1974	9903	0.604	1.620	0.969	2.790	21.661	42.265	37	29	7	22	48	97.11	164
1975	8951	0.516	1.207	0.813	1.997	20.441	32.423	24	24	9	21	60	108.65	157
1976	15143	2.077	1.454	2.698	2.684	40.923	46.441	47	57	11	27	43	104.44	181
1977	12516	1.619	1.785	3.171	2.857	52.330	44.556	58	35	10	27	32	88.29	172
1978	11452	1.644	1.544	2.913	2.555	55.798	38.392	71	43	10	37	32	94.32	157
1979	8657	0.619	1.171	1.937	2.240	31.497	33.315	85	77	12	41	35	104.77	152
1980	21204	1.544	1.908	3.264	3.066	57.488	43.912	153	67	9	31	33	89.43	117
1981	19023	1.654	2.356	3.494	3.402	69.927	50.953	202	147	12	50	60	92.03	176
1982	19009	1.394	1.997	3.425	3.473	67.789	48.815	89	79	11	49	32	80.07	167
1983	19082	1.717	1.188	2.824	1.879	57.754	33.595	94	94	12	37	60	89.61	141
1984	20438	1.266	1.468	2.155	2.472	44.390	37.830	94	78	10	40	64	96.57	149
1985	14393	0.982	1.355	2.840	2.169	43.932	32.420	62	38	11	22	76	103.66	169
1986	5636	0.642	0.273	1.564	0.666	34.216	11.350	63	26	8	20	68	111.51	141
1987	13132	0.768	1.004	1.563	2.047	28.245	30.965	70	45	8	27	66	96.04	157
1988	14456	1.075	0.992	1.969	1.999	47.372	36.783	50	35	10	26	87	101.15	120
1989	23986	2.270	1.226	3.696	2.749	67.000	47.295	97	41	8	36	75	105.82	121
1990	25011	4.509	1.046	3.699	1.880	71.700	33.530	28	11	8	26	78	90.28	98
1991	14220	1.186	0.844	1.559	2.076	28.340	39.720	19	12	8	19	80	102.87	115
1992	9815	1.169	0.779	1.544	1.772	30.110	30.950	12	9	9	19	86	97.38	109
1993	5825	0.471	1.544	0.609	2.815	12.015	43.101	11	17	9	24	70	91.50	114
1994	5245	0.736	1.303	1.112	1.844	17.840	27.780	10	21	8	25	69	82.12	100
1995	4946	0.197	0.906	0.333	1.365	4.465	18.605	3	10	4	12	72	92.85	115
1996	5827	0.540	1.208	0.686	1.120	9.365	16.610	15	12	9	25	60	95.84	117
1997	11791	0.847	1.039	1.215	1.586	20.600	22.210	7	11	5	18	65	90.53	102
1998	*	0.385	0.125	0.804	0.389	15.400	7.700	8	2	5	9	77	85.30	94

Appendix Table 2. Summary of spawn survey data and spawn indexes for the Prince Rupert District. All of the region is within the assessment areas.

1 Year Index	2 Assess Index	3 Location Index AA	4 Location Index NonA	5 Section Index AA	6 Section km NonA	7 Length km AA	8 Length km NonA	9 Number Recs AA	10 Number Recs NonA	11 Number Secs.	12 Number Locs.	13 Min DOY	14 Mean DOY	15 Max. DOY
1928	*		*		*		*		0	*	0	*	*	*
1929	*		*		*		*		0	*	0	*	*	*
1930	*		*		*		*		0	*	0	*	*	*
1931	*		*		*		*		4	*	3	72	82.25	87
1932	*		*		*		*		1	*	1	80	80.00	80
1933	*		*		*		*		10	*	4	81	92.60	115
1934	*		*		*		*		4	*	5	79	79.50	81
1935	*		*		*		*		0	*	0	*	*	*
1936	*		*		*		*		2	*	1	82	90.00	98
1937	*		1.418		3.097		23.911		10	*	4	79	83.50	91
1938	*		1.479		3.140		24.989		13	*	7	71	77.83	83
1939	*		1.278		2.399		17.658		9	*	7	74	83.62	111
1940	*		1.536		3.897		25.116		9	9	6	75	81.25	94
1941	*		1.591		3.153		19.998		11	11	6	74	84.10	109
1942	*		2.160		3.132		18.463		11	10	6	82	88.18	108
1943	*		0.395		0.708		4.357		6	6	6	81	90.00	104
1944	*		0.771		1.172		7.567		9	7	5	85	88.00	97
1945	*		0.880		1.124		9.415		12	8	6	89	92.75	104
1946	*		2.621		3.763		26.664		12	10	7	76	85.58	94
1947	*		2.428		4.033		24.494		12	10	6	74	83.67	104
1948	*		2.853		4.834		33.673		16	14	7	68	80.69	105
1949	*		2.734		5.572		34.601		22	14	8	79	87.18	100
1950	*		2.396		5.223		42.222		21	14	7	86	93.29	113
1951	30098		2.069		3.968		33.170		20	13	8	86	92.35	104
1952	18726		1.741		2.501		19.311		20	9	6	91	95.80	109
1953	26180		2.581		3.734		27.755		32	17	5	78	95.19	109
1954	13290		1.543		2.944		25.298		29	15	8	79	91.07	126
1955	25629		1.552		3.136		36.243		27	9	7	88	98.70	116
1956	15498		1.658		3.455		28.871		31	15	9	89	99.55	114
1957	28280		2.584		4.869		46.631		30	17	7	91	103.97	143
1958	12044		1.605		1.435		22.697		13	5	8	80	87.23	100
1959	36608		2.739		5.116		32.064		10	8	8	87	99.10	113
1960	19072		2.041		3.881		32.649		20	13	7	79	97.60	117
1961	12882		2.288		3.644		29.878		28	16	9	83	98.75	120
1962	24760		3.190		5.620		48.574		33	19	5	77	95.94	118
1963	15652		2.811		3.006		20.200		21	10	5	89	94.29	102
1964	29266		2.358		4.627		33.028		35	15	5	90	100.03	116
1965	6709		1.372		1.772		14.180		21	11	4	92	99.71	110
1966	7487		0.812		1.379		7.769		6	6	5	99	101.00	105
1967	2719		0.576		0.836		6.168		13	6	5	92	102.77	111
1968	4788		1.032		1.591		13.594		33	10	7	92	112.24	140
1969	844		0.153		0.270		2.194		9	7	8	83	108.00	141
1970	8436		1.906		3.021		34.541		27	14	9	83	100.33	121
1971	9751		1.782		2.499		26.590		32	15	10	79	108.41	131
1972	9852		1.923		3.873		31.300		31	14	7	94	112.90	170
1973	11260		1.866		2.681		24.111		42	20	7	92	106.83	133
1974	8893		1.642		2.421		21.489		48	19	9	89	103.87	141
1975	11109		2.239		3.004		22.813		41	12	8	98	111.98	152
1976	14213		2.353		4.260		36.760		106	31	7	92	106.25	151
1977	9736		2.578		5.302		44.188		121	29	9	87	117.62	163
1978	4738		1.419		2.571		25.395		80	24	6	85	111.22	153
1979	7554		2.092		2.792		30.940		58	20	7	85	101.36	135
1980	10236		2.747		5.368		50.260		104	27	7	85	97.57	129
1981	10532		3.268		4.007		42.227		61	29	7	68	91.43	127
1982	12631		2.155		4.608		39.135		79	22	6	75	87.76	108
1983	19653		3.338		6.624		58.621		115	26	9	66	95.81	142
1984	22927		4.115		7.700		63.420		192	25	6	66	96.37	138
1985	35858		5.033		8.420		55.176		177	26	9	77	90.37	111
1986	32526		4.914		8.177		57.880		213	27	7	87	106.77	141
1987	31422		4.751		9.629		83.559		173	39	9	73	89.95	124
1988	33680		3.997		8.114		65.119		68	18	6	87	102.53	115
1989	12783		3.117		5.595		40.333		16	14	5	82	94.31	110
1990	19398		4.398		6.824		47.487		14	14	7	84	88.71	101
1991	21544		5.678		9.729		77.265		37	27	7	81	97.73	110
1992	36307		5.335		7.239		56.026		17	17	8	75	89.24	103
1993	21755		4.239		6.578		44.386		26	17	9	75	95.19	118
1994	13719		3.646		6.632		54.270		22	19	5	82	91.23	96
1995	16138		3.044		5.677		42.250		20	17	5	82	89.89	100
1996	22524		4.004		7.504		52.715		25	24	6	84	95.30	113
1997	21129		5.396		10.180		68.930		26	25	5	86	94.42	97
1998	*		4.267		6.609		47.100		18	15	5	79	81.00	83

Appendix Table 3. Summary of spawn survey data and spawn indexes for the Central Coast

1 Year Index	2 Assess Index	3 Location Index AA	4 Location Index NonA	5 Section Index AA	6 Section km NonA	7 Length km AA	8 Length km NonA	9 Number Recs AA	10 Number Recs NonA	11 Number Secs.	12 Number Locs.	13 Min DOY	14 Mean DOY	15 Max. DOY
1928	*	*	*	*	*	*	*	0	0	*	0	*	*	*
1929	*	*	*	*	*	*	*	0	0	*	0	*	*	*
1930	*	*	*	*	*	*	*	0	0	*	0	*	*	*
1931	*	*	*	*	*	*	*	6	1	*	6	69	105.00	141
1932	*	*	*	*	*	*	*	0	0	*	0	*	*	*
1933	*	*	*	*	*	*	*	4	4	*	6	71	83.20	93
1934	*	0.047	0.628	0.206	1.887	4.826	34.878	10	6	*	8	69	80.75	91
1935	*	*	*	*	*	*	*	0	0	*	0	*	*	*
1936	*	0.046	*	0.111	*	32.172	*	8	4	*	8	75	78.00	80
1937	*	0.175	0.547	0.362	1.354	35.974	34.558	10	11	*	9	66	80.26	108
1938	*	0.332	1.301	0.720	2.760	47.654	56.431	11	10	*	8	64	76.24	105
1939	*	0.325	1.542	0.675	3.330	48.038	68.567	14	12	*	12	66	82.46	105
1940	*	0.099	1.210	0.196	2.539	20.510	54.693	9	11	19	10	64	79.72	102
1941	*	0.143	1.862	0.547	3.187	35.390	68.368	9	6	15	8	60	73.13	90
1942	*	0.470	2.480	0.514	3.619	29.028	78.079	10	26	29	11	56	85.94	96
1943	*	0.356	1.470	1.142	2.659	54.265	55.078	19	17	30	12	66	83.67	96
1944	*	0.613	1.519	0.879	2.448	39.303	49.738	13	15	25	10	56	84.00	95
1945	*	0.395	0.902	0.896	1.443	36.432	33.836	13	10	19	11	70	79.57	95
1946	*	0.798	2.169	1.492	3.399	40.298	71.657	16	14	27	11	74	87.31	97
1947	*	0.466	2.526	1.353	2.884	39.509	64.894	17	10	24	9	77	86.07	101
1948	*	0.452	1.877	0.924	3.379	22.302	70.287	13	26	32	10	76	91.38	109
1949	*	0.444	0.922	0.696	1.774	24.564	42.573	14	26	31	10	70	85.83	98
1950	*	0.142	1.959	0.176	2.767	7.518	68.962	13	28	18	11	73	88.33	110
1951	23134	0.202	1.392	0.620	2.314	13.778	57.994	13	32	38	10	74	91.93	105
1952	10709	0.060	0.511	0.205	1.196	7.723	29.865	10	25	21	9	79	91.54	116
1953	20001	0.232	0.877	0.607	2.190	19.377	56.164	10	42	28	8	76	83.35	93
1954	18635	0.091	0.651	0.281	1.629	18.463	41.679	11	25	26	9	66	79.78	95
1955	14983	0.202	0.658	0.358	1.899	25.748	47.225	16	37	33	12	67	93.15	183
1956	8244	0.130	0.434	0.357	1.291	15.584	29.796	11	17	19	8	82	94.86	153
1957	6224	0.074	0.239	0.159	0.715	8.226	18.371	10	11	15	8	74	82.43	104
1958	4226	0.152	0.400	0.628	1.221	16.905	29.374	17	21	24	10	74	85.00	105
1959	4105	0.193	0.424	0.592	1.233	23.853	27.969	24	35	35	11	74	85.27	110
1960	14684	0.114	0.954	0.373	2.268	14.899	54.164	16	31	33	9	73	91.98	160
1961	4567	0.105	0.440	0.276	1.066	12.110	25.224	19	15	21	8	71	82.44	97
1962	14181	0.213	1.538	1.288	2.865	25.730	65.740	16	53	34	11	63	90.13	103
1963	8467	0.097	0.503	0.211	1.299	8.297	32.082	14	27	23	11	67	87.41	104
1964	7058	0.148	0.529	0.823	1.351	21.633	33.571	13	27	23	8	50	81.85	96
1965	2365	0.247	0.199	0.556	0.561	27.371	12.542	15	18	20	10	74	94.30	164
1966	1774	0.111	0.274	0.473	0.546	13.549	11.791	16	21	23	8	74	96.16	114
1967	5905	0.260	0.626	0.766	1.117	30.600	22.506	15	22	27	11	57	94.59	154
1968	6366	0.142	0.431	0.640	1.239	16.763	27.756	16	33	28	9	69	94.59	150
1969	2331	0.112	0.139	0.420	0.564	16.543	13.408	16	19	25	10	73	89.54	114
1970	10133	0.465	1.175	1.637	2.141	91.455	46.059	32	39	38	12	63	83.82	161
1971	6056	0.609	0.443	2.415	1.195	117.365	25.667	41	33	41	11	75	98.65	174
1972	3928	0.837	0.426	3.218	1.390	116.656	32.162	31	91	28	11	69	99.52	161
1973	14471	0.844	1.799	2.818	3.257	138.130	69.199	50	141	59	13	71	94.93	175
1974	10624	0.634	1.321	1.493	2.872	114.799	67.327	46	78	47	13	63	103.10	169
1975	9165	0.777	1.371	2.389	2.638	130.029	60.856	53	123	45	14	66	95.37	172
1976	16134	0.842	2.009	1.944	4.593	138.869	104.849	92	192	64	13	70	106.10	182
1977	18481	0.797	1.781	2.448	4.037	117.925	91.670	68	216	56	13	63	92.06	166
1978	10097	0.332	1.142	1.251	2.377	59.657	54.620	113	181	49	12	59	88.84	150
1979	6550	0.388	0.984	0.803	2.293	57.547	51.053	54	138	43	12	65	98.96	155
1980	15978	0.238	2.018	1.069	3.764	52.776	84.523	30	165	48	10	69	87.31	129
1981	16949	0.301	2.109	1.245	4.423	44.810	95.104	50	294	48	13	63	83.47	161
1982	18412	0.355	2.577	0.574	4.176	23.498	92.713	27	164	49	10	67	81.99	96
1983	16618	0.237	2.328	0.410	5.318	31.046	117.166	53	202	43	10	57	91.83	152
1984	14197	0.312	1.510	0.784	3.715	44.120	85.090	26	203	37	11	63	86.44	144
1985	8480	0.381	1.412	0.682	3.953	34.254	90.496	32	212	38	8	44	92.84	158
1986	15534	0.380	1.456	0.723	4.256	54.010	98.339	37	221	43	10	68	95.98	170
1987	12992	0.482	1.528	1.188	4.032	77.263	87.484	53	177	49	9	69	88.42	156
1988	27018	0.471	2.346	1.790	6.328	116.311	145.339	44	144	50	12	64	89.62	160
1989	32335	0.398	1.879	0.802	5.202	56.507	130.142	28	102	42	13	71	87.32	152
1990	31048	0.348	2.573	1.073	6.386	51.262	147.478	31	193	48	11	62	90.75	169
1991	20155	0.343	2.560	1.071	5.891	51.246	140.006	49	134	54	11	36	84.51	147
1992	46211	0.496	4.407	1.380	10.442	79.836	245.864	96	209	67	13	49	84.36	141
1993	39888	0.269	2.843	1.350	7.352	63.428	179.405	71	124	51	13	63	84.66	159
1994	29956	0.319	4.621	1.196	8.417	43.385	196.385	53	160	54	11	67	104.66	185
1995	19164	0.094	3.020	0.342	5.757	12.024	136.225	11	75	49	7	82	91.10	114
1996	18291	0.197	2.768	0.910	4.817	29.983	114.115	13	52	46	9	85	94.03	156
1997	25663	0.023	3.481	0.054	5.888	2.500	143.455	4	53	51	10	83	93.95	171
1998	*	0.065	2.614	0.203	5.588	7.150	136.175	2	45	38	9	72	80.48	102

Appendix Table 4. Summary of spawn survey data and spawn indexes for Johnstone Strait (Section 135 is NOT included as a Johnstone Strait area). No spawn data were recorded for 1998.

1 Year Index	2 Assess Index	3 Location Index AA	4 Location Index NonA	5 Section Index AA	6 Section km NonA	7 Length km AA	8 Length km NonA	9 Number Recs AA	10 Number Recs NonA	11 Number Secs.	12 Number Locs.	13 Min DOY	14 Mean DOY	15 Max. DOY
1928	*		*		*		*		*	*	*	*	*	*
1929	*		*		*		*		8	*	*	51	61.00	91
1930	*		*		*		*		2	*	*	79	83.00	87
1931	*		*		*		*		11	*	*	29	74.40	116
1932	*		*		*		*		10	*	*	55	73.00	94
1933	*		*		*		*		1	*	*	80	80.00	80
1934	*		*		*		*		5	*	*	80	91.60	103
1935	*		*		*		*		11	*	*	58	76.10	102
1936	*		*		*		*		5	*	*	81	89.40	99
1937	*		0.957		1.005		22.575		13	*	*	7	68.08	95
1938	*		0.970		0.991		25.738		12	*	*	56	70.50	104
1939	*		1.061		1.224		35.171		15	*	*	48	78.73	117
1940	*		1.158		1.519		63.341		24	8	18	48	83.13	103
1941	*		1.358		1.574		69.629		27	9	22	60	88.26	118
1942	*		0.095		0.215		4.979		17	7	13	61	80.18	109
1943	*		0.258		0.714		17.621		15	6	12	70	85.60	104
1944	*		0.196		0.471		12.914		14	6	11	68	78.86	100
1945	*		0.135		0.328		8.122		15	6	14	59	84.60	106
1946	*		0.147		0.325		8.136		20	6	14	68	82.90	104
1947	*		0.193		0.431		21.667		23	8	14	59	87.00	111
1948	*		0.221		0.496		20.281		19	8	14	68	98.11	119
1949	*		0.363		0.721		30.470		23	7	15	60	92.78	113
1950	*		0.619		1.460		54.678		29	10	22	74	95.00	118
1951	*		0.355		0.664		31.218		33	11	18	78	92.91	115
1952	*		0.272		0.538		26.181		29	10	16	61	89.86	114
1953	*		0.534		1.247		45.051		26	9	18	62	91.96	123
1954	*		0.272		0.743		29.805		27	11	16	35	89.59	106
1955	*		0.277		0.657		29.729		17	10	13	62	90.35	110
1956	*		0.337		0.878		37.152		24	10	13	63	99.58	116
1957	*		0.169		0.435		20.683		15	8	9	85	99.47	116
1958	*		0.492		0.881		33.767		31	13	19	66	96.13	137
1959	*		0.457		1.028		56.239		22	9	13	65	92.36	124
1960	*		0.536		0.808		58.640		37	11	16	59	95.84	117
1961	*		0.376		0.828		41.634		28	9	15	78	100.11	118
1962	*		0.261		0.538		27.722		22	9	12	69	93.82	117
1963	*		0.413		0.837		40.627		24	6	9	57	92.29	117
1964	*		0.569		1.414		62.106		36	11	20	65	92.42	113
1965	*		0.253		0.542		18.645		10	5	8	69	82.00	119
1966	*		0.352		0.772		33.691		22	8	12	70	91.00	114
1967	*		0.289		0.741		29.082		28	10	20	67	93.07	124
1968	*		0.491		0.833		31.103		32	9	15	77	87.47	111
1969	*		0.585		1.258		62.505		44	10	19	66	87.32	118
1970	*		1.133		2.761		112.812		56	10	21	58	85.09	117
1971	*		0.850		1.869		115.262		49	10	21	60	98.57	121
1972	*		0.923		2.111		122.202		79	10	20	53	87.80	131
1973	*		0.785		1.749		82.695		55	9	15	57	83.91	123
1974	*		0.803		1.482		79.601		51	10	15	61	86.84	127
1975	*		0.957		1.490		82.811		57	10	18	75	88.26	130
1976	*		0.636		1.294		75.142		61	11	20	54	90.34	137
1977	*		0.730		1.227		69.844		36	10	15	72	90.58	108
1978	*		0.285		0.558		39.510		29	7	11	69	84.97	116
1979	*		0.355		0.758		60.908		51	9	13	69	84.61	119
1980	*		0.773		1.621		88.296		69	11	31	73	92.54	121
1981	*		0.522		1.017		73.425		73	9	14	70	83.64	109
1982	*		0.379		0.792		60.924		61	5	14	74	84.13	98
1983	*		0.241		0.695		56.525		45	7	18	72	83.69	109
1984	*		0.294		0.746		44.017		39	6	8	69	89.54	107
1985	*		0.277		0.783		58.819		27	7	14	67	84.56	99
1986	*		0.183		0.553		39.325		41	6	10	76	85.93	114
1987	*		0.399		0.936		70.186		54	6	9	73	79.70	108
1988	*		0.342		0.849		62.672		59	4	12	70	81.78	104
1989	*		0.438		1.066		64.797		116	6	18	72	79.48	108
1990	*		0.481		1.140		96.828		133	6	16	70	80.41	98
1991	*		0.424		0.902		71.721		107	6	15	73	81.42	100
1992	*		1.466		2.677		151.465		179	8	22	68	79.75	106
1993	*		0.494		1.287		112.769		119	5	16	67	84.29	132
1994	*		0.445		1.335		80.392		159	4	14	79	82.09	91
1995	*		0.296		0.746		65.295		77	5	16	60	79.56	106
1996	*		0.431		1.120		86.507		97	9	17	61	77.09	116
1997	*		0.303		0.692		44.068		149	6	23	65	82.18	116

Appendix Table 5. Summary of spawn survey data and spawn indexes for the Strait of Georgia and Sections 132 and 135 from Johnstone Strait.

1 Year Index	2 Assess Index	3 Location Index AA	4 Location Index NonA	5 Section Index AA	6 Section km NonA	7 Length km AA	8 Length km NonA	9 Number Recs AA	10 Number Recs NonA	11 Number Secs.	12 Number Locs.	13 Min. DOY	14 Mean DOY	15 Max. DOY
1928	*	*	0.152	*	0.205	*	0.804	0	6	*	*	61	68.167	80
1929	*	*	1.076	*	1.419	*	8.043	0	23	*	*	41	71.652	120
1930	*	*	1.069	*	1.636	*	6.434	0	29	*	*	58	85.080	123
1931	*	*	0.879	*	1.819	*	11.260	0	44	*	*	40	80.341	114
1932	*	*	0.238	*	0.400	*	3.217	0	26	*	*	45	80.115	109
1933	*	*	2.057	*	3.682	*	14.477	0	34	*	*	62	80.412	108
1934	*	*	3.391	*	5.464	*	35.427	3	38	*	*	32	66.024	94
1935	*	*	2.968	*	6.076	*	38.279	0	31	*	*	41	75.000	104
1936	*	*	7.686	*	10.674	*	49.814	0	46	*	*	41	72.867	118
1937	*	*	5.394	*	8.487	*	69.243	0	41	*	*	60	83.171	142
1938	*	*	4.002	*	7.103	*	51.828	0	57	*	*	38	81.456	112
1939	*	*	7.992	*	12.747	*	90.400	0	59	*	*	30	75.847	127
1940	*	*	6.091	*	8.633	*	78.274	0	53	13	37	35	72.660	99
1941	*	*	10.117	*	13.437	*	85.028	0	56	13	41	29	72.833	107
1942	*	*	7.776	*	9.214	*	61.924	0	59	12	39	41	72.441	99
1943	*	*	8.624	*	15.564	*	88.018	0	45	11	33	43	69.267	102
1944	*	*	1.938	*	3.628	*	26.146	0	39	11	28	37	68.263	117
1945	*	*	3.683	*	3.947	*	36.890	0	50	11	32	45	75.040	104
1946	*	*	4.134	*	7.511	*	52.371	0	40	11	33	47	76.800	110
1947	*	*	3.961	*	7.636	*	44.857	0	58	12	35	28	66.517	105
1948	*	*	3.031	*	6.519	*	45.421	0	59	12	38	21	71.441	111
1949	*	*	6.942	*	9.136	*	59.936	0	58	12	36	38	67.397	115
1950	*	*	4.862	*	8.392	*	52.593	0	70	12	45	38	81.371	116
1951	66063	*	7.316	*	11.141	*	67.741	0	56	12	36	52	82.232	116
1952	66048	*	8.086	*	13.157	*	88.655	0	93	11	48	18	69.882	136
1953	100513	*	10.234	*	17.928	*	141.026	0	113	8	51	28	70.956	115
1954	90437	0.099	7.365	0.094	12.786	1.142	116.610	2	107	10	52	26	74.670	117
1955	74227	0.895	8.291	1.250	14.291	7.403	130.013	7	113	16	51	43	76.483	122
1956	29494	*	3.746	*	7.590	*	67.588	0	122	10	43	26	77.730	110
1957	28997	0.304	3.026	0.512	6.542	3.016	48.076	1	46	11	29	39	77.085	115
1958	20358	0.313	2.484	0.667	5.838	8.303	70.522	2	96	12	40	32	72.459	104
1959	44278	0.276	5.461	0.465	11.319	2.742	91.448	1	83	17	56	45	79.333	110
1960	37222	0.499	4.274	0.941	9.412	9.140	83.356	3	94	15	51	39	71.701	96
1961	25519	0.743	3.397	1.292	7.865	10.420	75.388	3	84	15	44	42	75.115	104
1962	23281	0.986	2.848	1.992	6.317	14.876	49.169	10	73	15	47	49	77.663	106
1963	27751	2.176	3.298	3.844	6.068	24.915	60.124	13	69	16	42	17	70.171	103
1964	20366	1.756	3.167	2.853	6.505	21.340	58.028	16	76	16	45	36	66.935	96
1965	18628	0.588	2.334	1.138	5.818	7.843	49.931	10	50	14	32	41	70.050	108
1966	05108	0.556	0.682	0.971	1.659	5.713	25.845	3	47	14	26	47	74.100	97
1967	06345	3.247	0.934	5.478	2.212	32.648	29.800	9	50	15	30	37	71.220	101
1968	12022	0.717	1.158	1.525	2.881	9.091	33.891	7	65	15	39	3	69.903	102
1969	18208	1.043	1.826	2.016	4.255	11.882	57.645	2	81	15	46	15	78.434	123
1970	44194	0.275	4.072	0.503	10.529	3.472	103.834	5	117	16	52	20	66.246	112
1971	47312	0.653	4.291	1.088	10.096	6.960	95.370	8	137	15	56	28	70.897	105
1972	25875	0.828	3.104	1.396	7.389	8.226	80.683	1	129	15	47	31	73.238	114
1973	18257	0.281	4.245	0.473	6.481	2.788	67.391	2	115	10	36	31	67.846	105
1974	64619	0.858	8.178	1.422	13.009	8.957	109.463	5	115	14	49	41	78.258	132
1975	76692	0.276	6.711	0.465	16.458	2.742	126.549	3	134	12	56	48	78.285	132
1976	57135	1.213	8.901	2.044	15.809	12.028	106.332	4	129	13	50	46	79.030	131
1977	58003	0.552	11.880	0.930	21.898	5.484	119.318	2	155	13	59	49	75.146	134
1978	97082	0.138	13.968	0.233	19.349	1.371	122.585	1	176	10	67	47	73.401	148
1979	59042	*	14.080	*	21.552	*	146.096	0	145	8	49	58	74.014	102
1980	74848	0.004	12.067	0.155	18.820	0.914	116.526	1	132	11	56	52	77.308	108
1981	48230	*	8.977	*	12.802	*	77.858	0	97	9	39	49	69.546	111
1982	90239	*	12.010	*	18.930	*	100.857	0	90	9	41	57	71.200	93
1983	47423	*	8.914	*	12.240	*	72.609	0	65	8	30	56	67.400	88
1984	27588	0.004	4.594	0.155	9.600	0.915	53.677	1	32	6	19	59	78.606	116
1985	26629	0.025	5.136	0.884	8.646	5.213	51.250	4	65	6	26	58	76.884	93
1986	61097	0.013	13.100	0.481	16.631	2.835	84.580	4	57	7	28	53	76.754	101
1987	39037	0.013	10.474	0.372	16.980	2.195	93.955	2	40	9	29	59	74.762	100
1988	25351	0.006	9.526	0.171	13.558	1.007	67.001	2	32	5	30	58	75.059	94
1989	54078	0.007	14.710	0.202	22.265	1.188	113.110	2	64	8	40	58	71.242	88
1990	58912	*	14.564	*	21.315	*	118.620	0	34	5	34	60	72.088	84
1991	43421	0.012	10.885	0.046	18.827	0.274	90.080	1	26	5	17	61	77.000	94
1992	80122	0.162	18.136	0.610	23.295	3.760	114.503	5	43	10	36	58	76.771	89
1993	84961	*	17.495	*	29.031	*	142.885	0	47	8	38	55	68.089	84
1994	60862	*	14.856	*	24.460	*	117.030	0	32	5	32	80	82.750	86
1995	59708	*	15.148	*	26.753	*	135.100	0	42	6	39	62	76.098	149
1996	76291	*	19.617	*	30.830	*	131.850	0	43	5	41	70	75.659	97
1997	53442	*	16.632	*	24.153	*	123.175	1	58	8	54	52	81.281	114
1998	*	*	19.970	*	30.929	*	140.775	0	49	4	47	65	71.889	91

Appendix Table 6. Summary of spawn survey data and spawn indexes for the West coast of Vancouver Island.

1 Year Index	2 Assess Index	3 Location Index AA	4 Location Index NonA	5 Section Index AA	6 Section km NonA	7 Length km AA	8 Length km NonA	9 Number Recs AA	10 Number Recs NonA	11 Number Secs.	12 Number Locs.	13 Min DOY	14 Mean DOY	15 Max. DOY
1928	*	*	*	*	*	*	*	5	0	3	*	45	66.09	112
1929	*	*	*	*	*	*	*	9	3	6	*	41	70.00	120
1930	*	*	0.436	*	0.881	*	4.825	8	30	14	*	32	78.41	123
1931	*	*	*	*	*	*	*	9	30	15	*	29	78.56	141
1932	*	*	0.039	*	0.132	*	1.206	7	22	12	*	38	74.31	109
1933	*	*	*	*	*	*	*	5	18	12	*	52	81.51	115
1934	*	0.061	0.151	0.103	0.862	1.609	5.228	9	25	15	*	32	70.83	103
1935	*	0.070	*	0.069	*	1.609	*	7	14	11	*	37	74.96	113
1936	*	*	*	*	*	*	*	13	41	16	*	16	76.33	194
1937	*	0.430	1.796	0.810	3.235	12.165	31.170	11	25	11	*	7	77.07	176
1938	*	0.204	0.727	0.625	1.706	5.938	14.386	17	12	13	*	34	77.13	171
1939	*	0.411	0.850	0.767	3.005	7.599	24.578	19	21	11	*	30	76.23	176
1940	*	0.381	1.544	0.699	4.231	6.916	35.315	21	26	14	31	33	76.56	177
1941	*	0.316	1.265	0.693	2.632	6.568	26.436	17	33	15	36	29	75.37	118
1942	*	0.773	0.222	1.362	0.653	13.624	6.382	24	20	14	27	27	75.10	109
1943	*	0.310	0.682	0.527	1.376	5.944	15.608	18	30	12	28	29	74.48	119
1944	*	0.129	0.780	0.297	1.556	3.409	13.733	15	21	14	27	16	74.72	137
1945	*	0.453	2.665	0.559	6.352	6.966	58.338	19	38	14	37	19	77.59	123
1946	*	0.484	1.188	0.754	3.016	6.517	27.046	12	27	13	26	26	81.30	115
1947	*	0.232	0.984	0.409	2.560	4.844	24.424	15	26	14	30	28	75.95	111
1948	*	0.746	1.876	1.333	4.466	12.569	32.008	16	26	11	26	16	81.21	157
1949	*	0.619	0.877	1.041	3.002	10.241	24.826	29	25	14	32	28	79.28	163
1950	*	0.326	1.441	0.714	4.950	7.364	41.901	33	34	13	41	21	84.63	166
1951	17007	0.420	1.544	1.001	4.183	9.782	37.247	21	33	15	38	21	85.92	171
1952	14383	0.151	1.099	0.321	2.578	3.322	23.455	15	25	12	26	18	80.19	154
1953	30675	1.011	2.161	2.094	5.218	22.571	41.723	23	60	15	39	28	79.60	163
1954	16556	0.627	1.561	1.458	3.821	16.097	29.505	25	54	15	35	26	80.30	176
1955	17555	0.507	1.348	1.395	3.853	18.147	31.094	17	61	15	33	32	79.39	183
1956	45168	0.080	3.185	0.107	7.026	1.727	49.275	13	70	14	30	26	82.26	171
1957	52651	0.283	2.513	0.696	8.601	7.527	56.406	14	57	12	38	27	81.95	166
1958	24399	0.170	2.158	0.288	6.011	3.958	54.006	14	83	13	38	32	77.31	137
1959	18396	0.095	1.279	0.139	3.740	1.918	28.847	7	64	14	28	40	81.26	124
1960	7039	0.254	0.848	0.582	2.301	8.523	22.380	10	48	15	27	38	82.56	160
1961	7912	0.218	0.927	0.450	2.463	6.846	29.498	9	49	14	25	42	84.07	134
1962	34579	0.106	1.550	0.241	5.762	3.404	52.237	9	46	15	25	34	84.40	141
1963	14618	0.579	0.737	1.379	1.993	13.756	25.907	9	39	11	25	17	80.28	166
1964	27863	0.107	1.966	0.243	6.505	4.433	65.214	10	34	11	27	36	78.81	131
1965	10863	0.537	1.533	1.150	5.050	10.176	42.132	19	31	15	32	41	80.58	164
1966	4584	0.056	0.755	0.168	2.051	1.994	20.154	4	26	12	25	36	85.56	133
1967	5118	0.141	0.820	0.251	1.838	3.908	17.546	8	21	12	19	37	84.81	155
1968	11278	0.059	1.053	0.127	2.590	1.965	20.850	4	31	12	21	3	88.55	177
1969	11206	0.379	1.324	0.913	2.937	11.220	21.822	19	30	13	27	15	85.47	174
1970	34923	0.355	2.440	0.819	6.607	9.198	56.136	23	50	14	37	20	78.74	161
1971	32476	0.192	4.245	0.236	7.278	4.571	59.101	11	78	14	41	28	91.57	197
1972	36069	0.255	4.276	0.344	7.901	6.122	58.059	10	80	12	34	31	90.30	183
1973	16219	1.083	2.113	1.104	3.944	12.584	29.395	24	69	13	45	31	87.60	175
1974	24774	0.160	2.331	0.194	3.967	3.154	28.200	3	90	6	22	41	90.00	169
1975	44594	0.429	4.204	0.931	7.270	8.937	54.982	19	262	11	58	48	88.55	172
1976	63335	0.135	6.113	0.223	7.437	3.045	61.864	9	165	10	43	43	94.57	182
1977	57398	0.356	5.773	0.592	8.580	6.197	63.685	18	165	13	44	32	88.04	172
1978	39931	1.989	4.281	2.212	7.968	18.748	57.411	34	165	10	48	32	84.07	157
1979	63663	1.699	7.462	2.289	8.950	19.195	64.296	31	214	11	40	35	86.71	155
1980	62619	2.918	5.119	3.894	8.084	33.800	55.608	22	189	7	48	33	84.64	129
1981	58518	0.677	4.398	0.946	7.889	7.680	59.045	16	219	9	48	49	83.18	176
1982	29424	0.825	2.682	1.523	5.762	13.434	39.607	28	114	6	35	32	78.57	167
1983	15329	0.612	2.695	1.145	3.976	9.294	28.584	19	117	6	32	56	85.71	152
1984	22142	0.501	3.278	0.826	4.467	6.700	31.410	11	67	6	25	59	89.70	149
1985	29132	0.153	4.209	0.443	4.467	4.100	33.965	11	118	9	28	44	87.56	169
1986	38347	0.406	4.379	1.094	6.862	8.880	46.234	14	109	5	25	53	95.61	170
1987	29915	0.943	4.889	1.921	7.764	17.020	54.282	11	119	9	43	59	87.13	157
1988	39289	0.619	5.780	1.247	9.939	10.115	72.243	14	204	8	47	58	89.78	160
1989	43331	1.084	6.344	1.935	7.640	17.250	58.209	12	101	7	30	58	86.79	152
1990	38337	1.503	6.907	2.096	7.264	18.035	53.093	17	128	8	46	60	84.17	169
1991	25907	1.177	5.031	1.565	5.505	13.215	41.085	14	56	8	33	36	84.46	147
1992	36916	1.294	6.073	2.138	5.318	18.505	38.780	11	54	7	37	49	82.22	141
1993	29307	1.438	8.432	2.879	8.229	24.115	69.560	25	88	10	49	55	80.80	159
1994	19869	1.232	4.292	2.195	6.279	18.155	48.649	12	59	9	35	64	89.45	185
1995	25284	1.133	4.401	2.010	7.243	16.700	48.830	11	29	8	33	55	83.45	149
1996	32209	0.707	4.298	1.331	5.332	10.800	39.205	8	24	7	31	58	83.41	156
1997	39394	0.752	6.050	1.742	9.182	14.250	78.255	9	39	10	46	52	84.21	171
1998	*	0.673	4.286	1.271	5.320	10.500	42.900	8	25	6	32	61	76.94	102

Fig. 1. The British Columbia coast showing the 6 major regions: Queen Charlotte Islands (QCI), Prince Rupert District (PRD), Central coast (CC), Johnstone Strait (JS), Strait of Georgia (SOG) and West Coast of Vancouver Island (WCVI). The dark lines indicate the assessment areas, about half of the total coast, which are geographical subsets of each region.

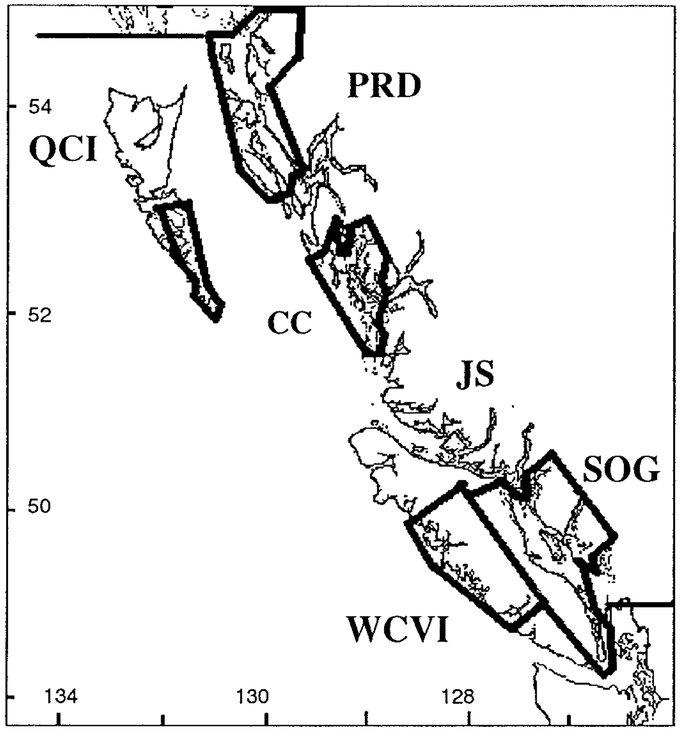


Fig. 2. Regions of the BC coast showing the herring sections (numbered) and assessment areas (outlined with a dark line) within each region. Two sections (132 and 135) from southern Johnstone Strait (Fig. 2d) are included in the Strait of Georgia assessment region (Fig. 2e).

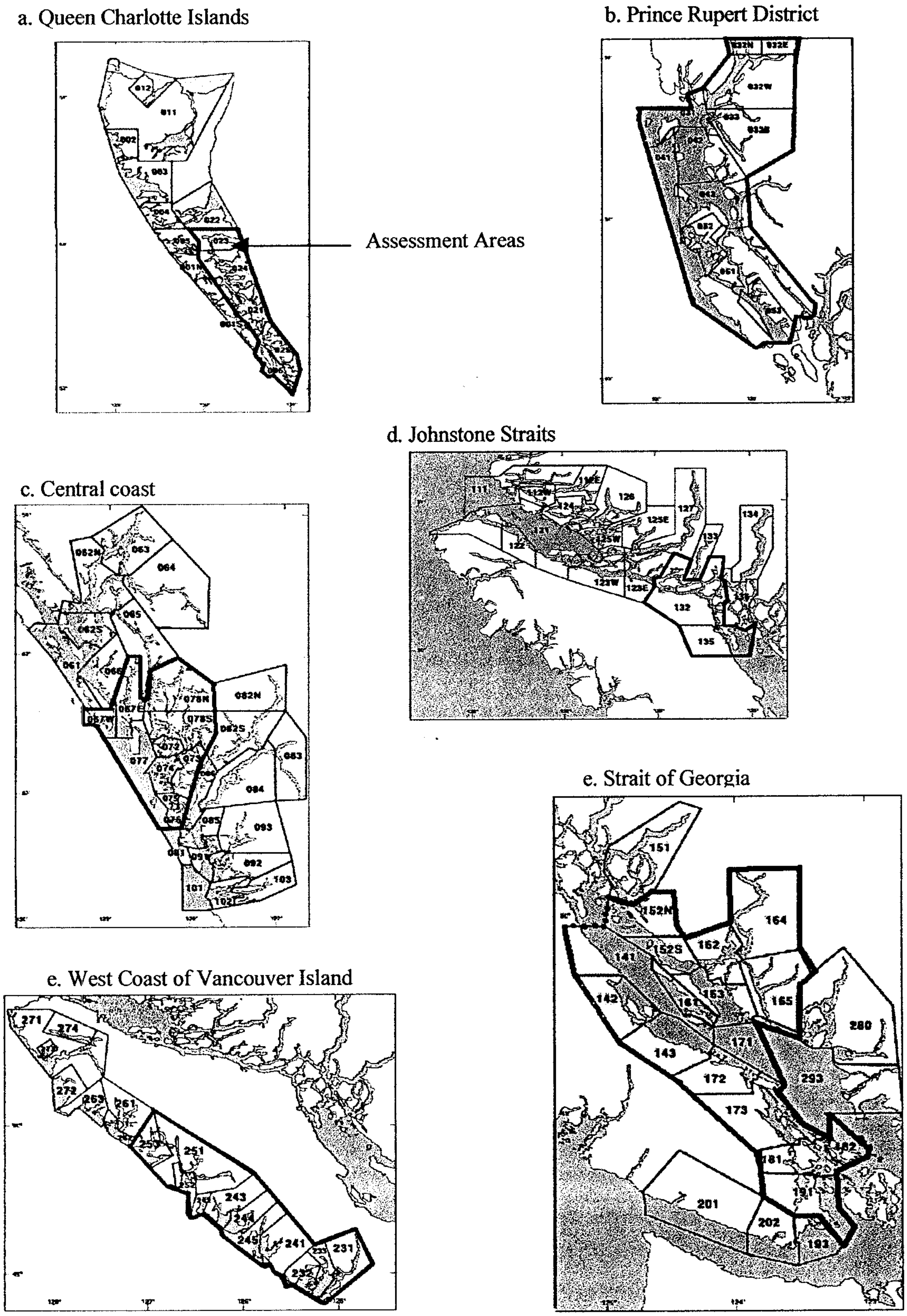


Fig. 3. Mean widths of spawning areas shown for (a) the total BC coast, (b) all assessment areas and (c) all non-assessment areas.

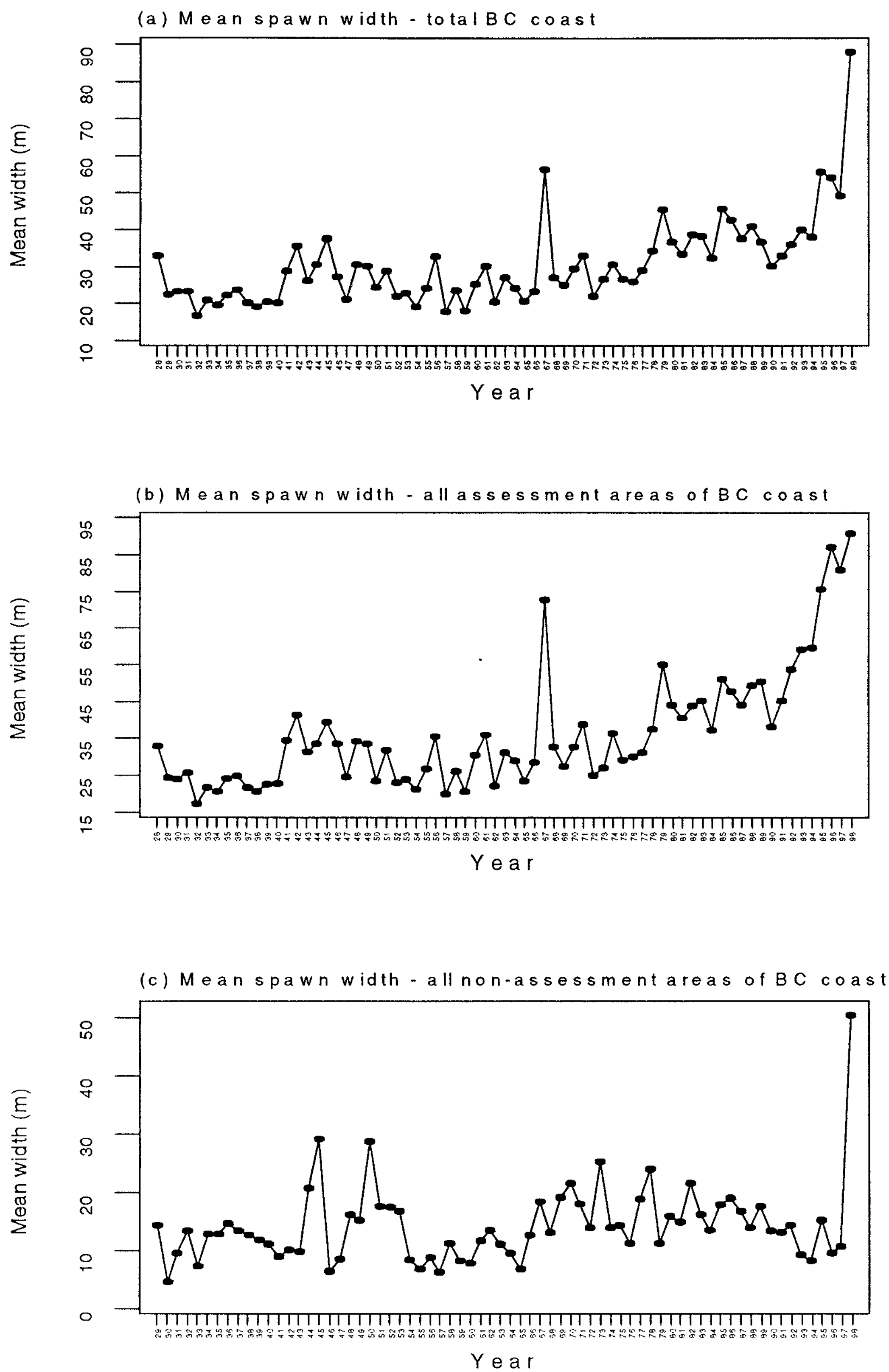


Fig. 4. Mean estimated 'layers' of spawn shown for (a) the total BC coast, (b) all assessment areas and (c) all non-assessment areas.

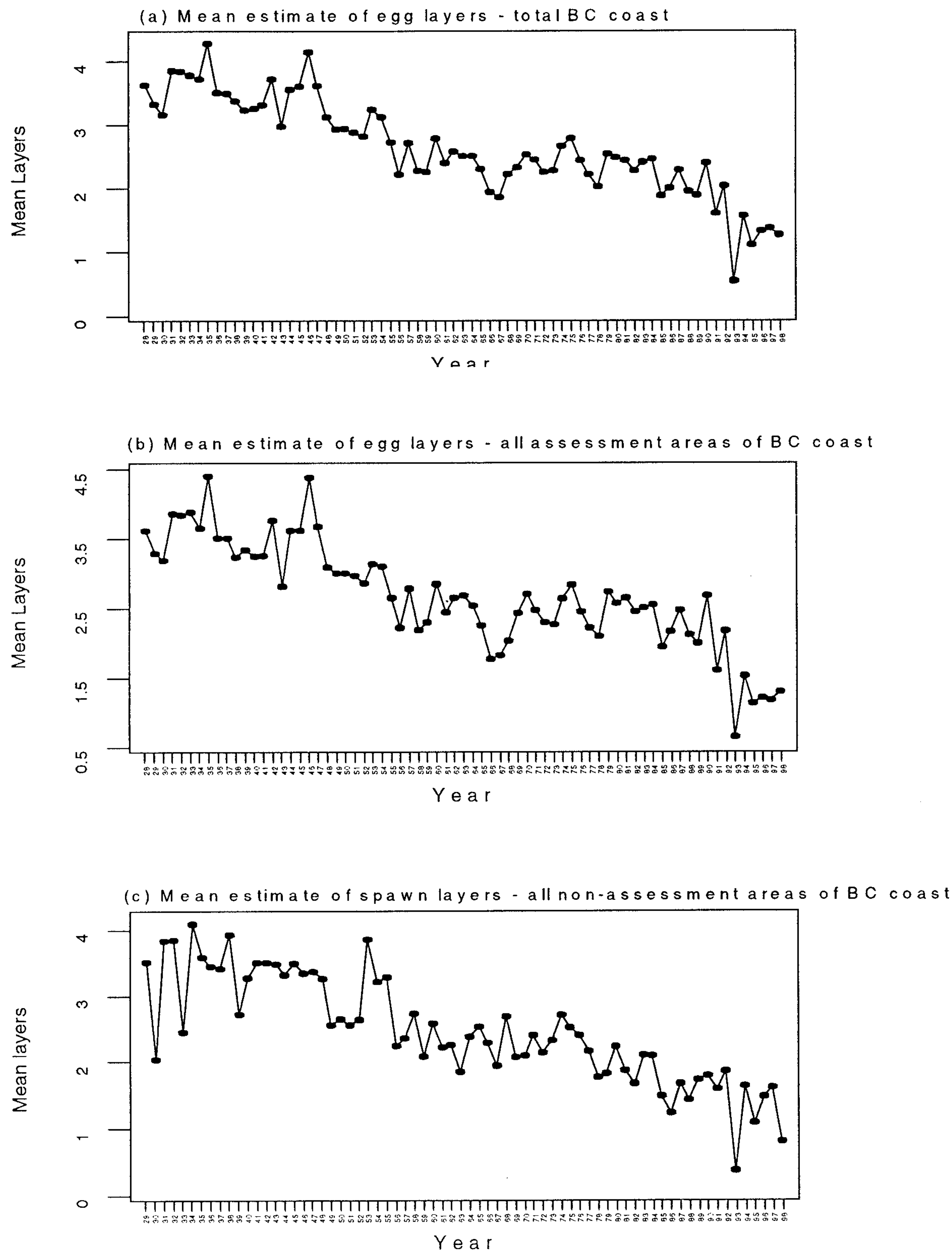


Fig. 5. Spawn coefficients, calculated for the SECTION and LOCATION indexes for (a) the total BC coast, (b) all assessment areas and (c) all non-assessment areas.

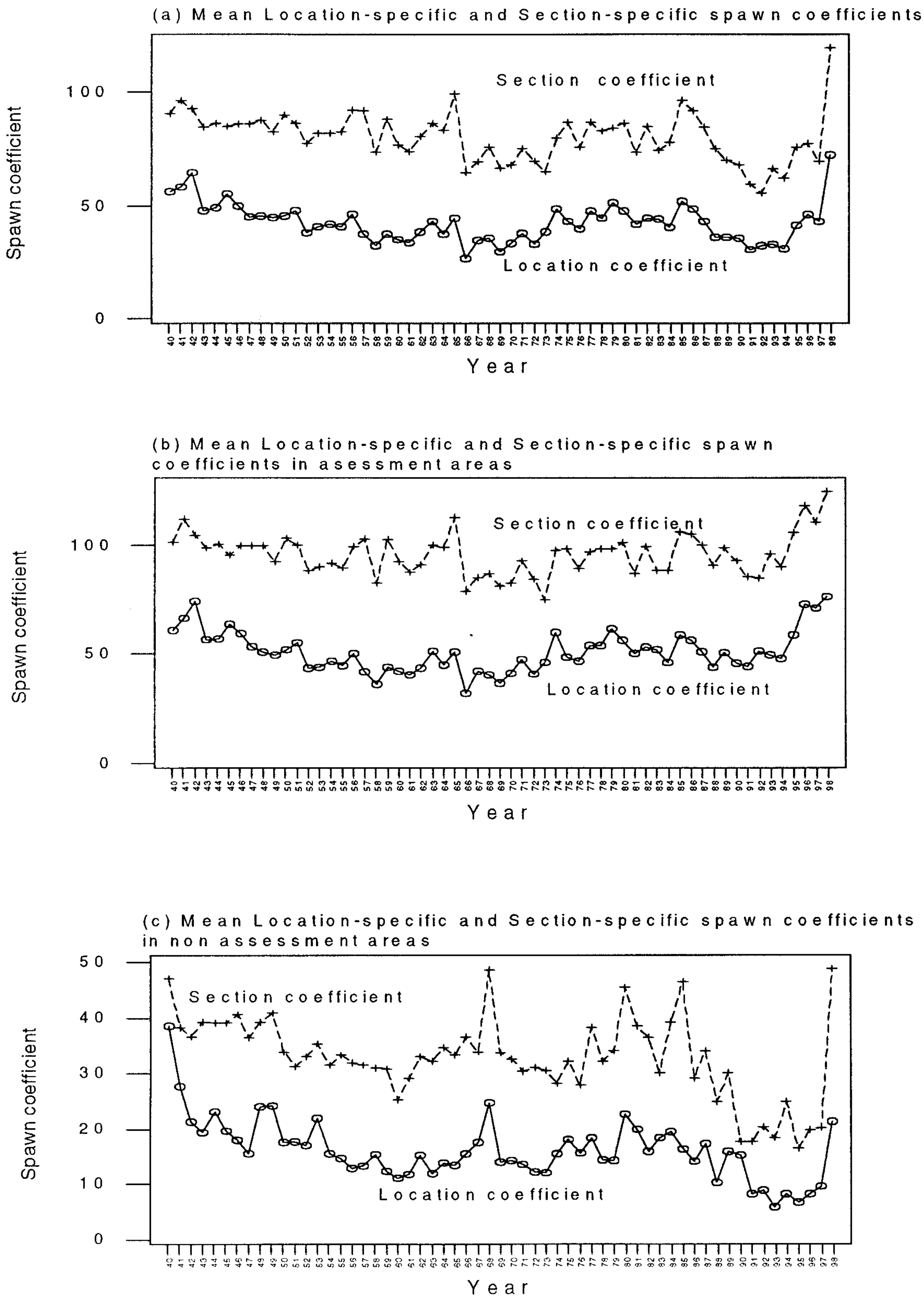
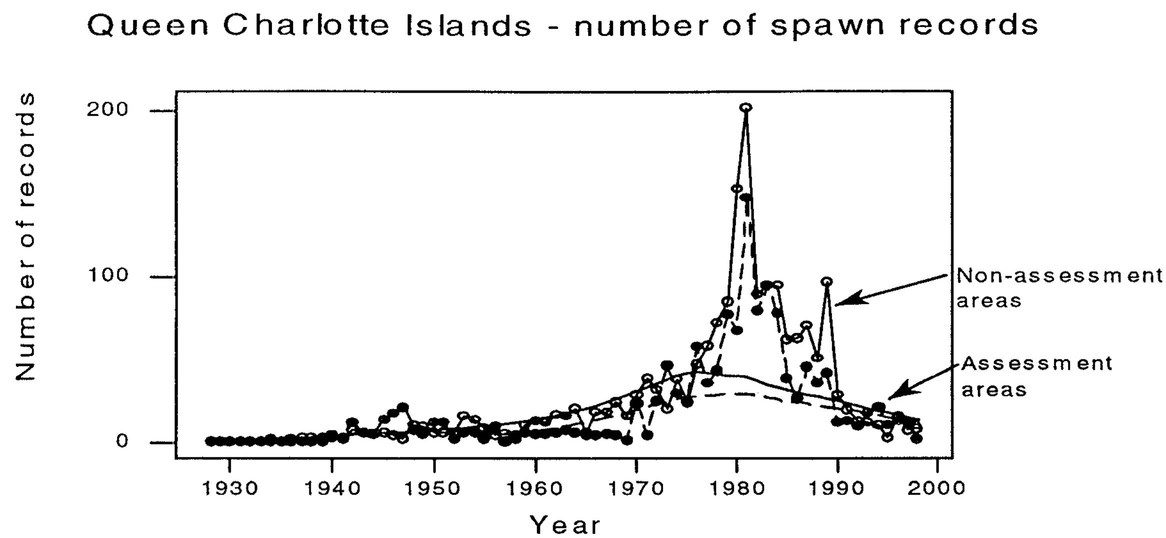
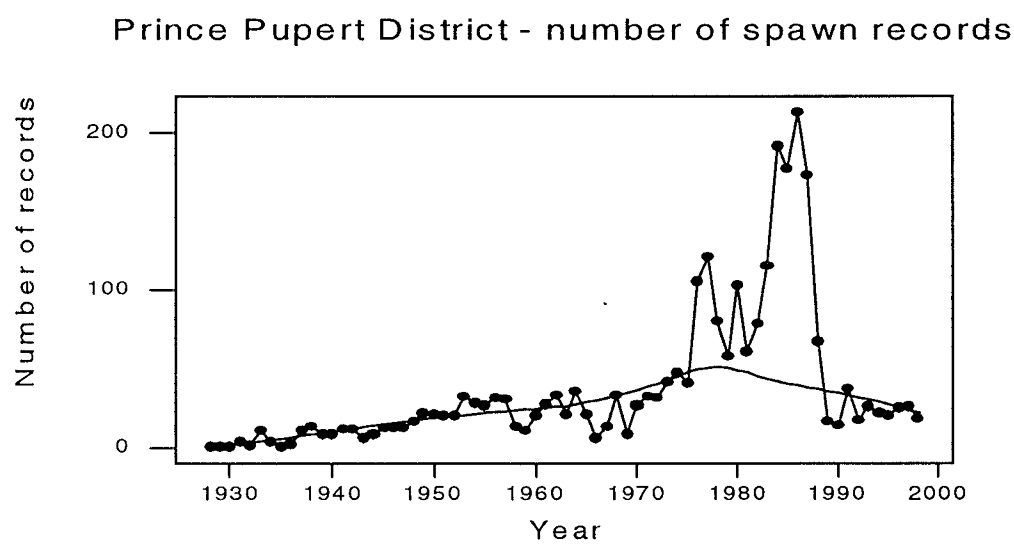


Fig. 6. Number of spawn records for assessment and non-assessment areas, by year, for each of the 6 regions.





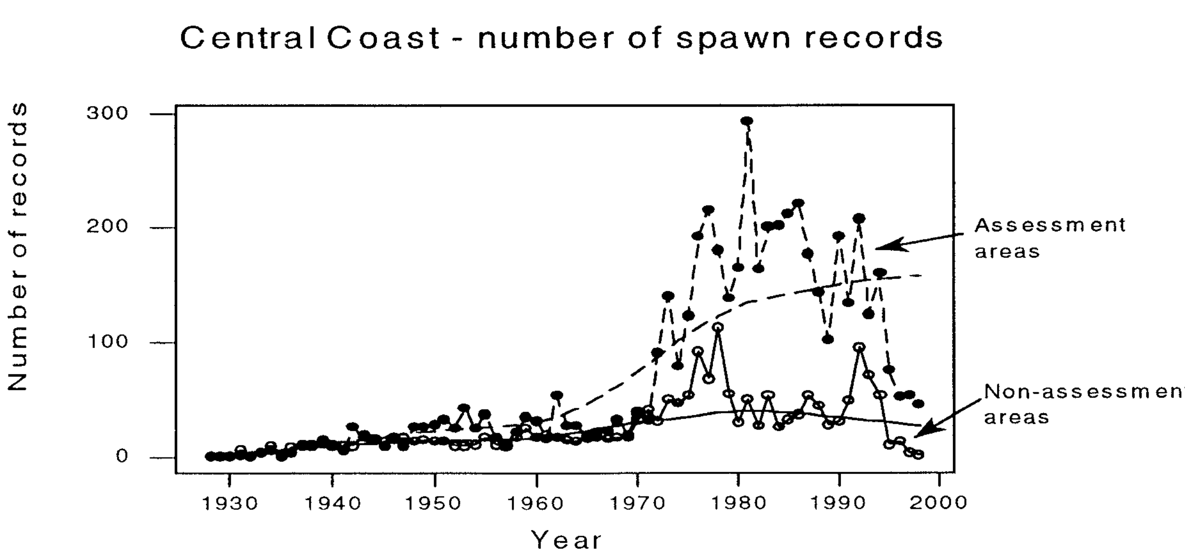
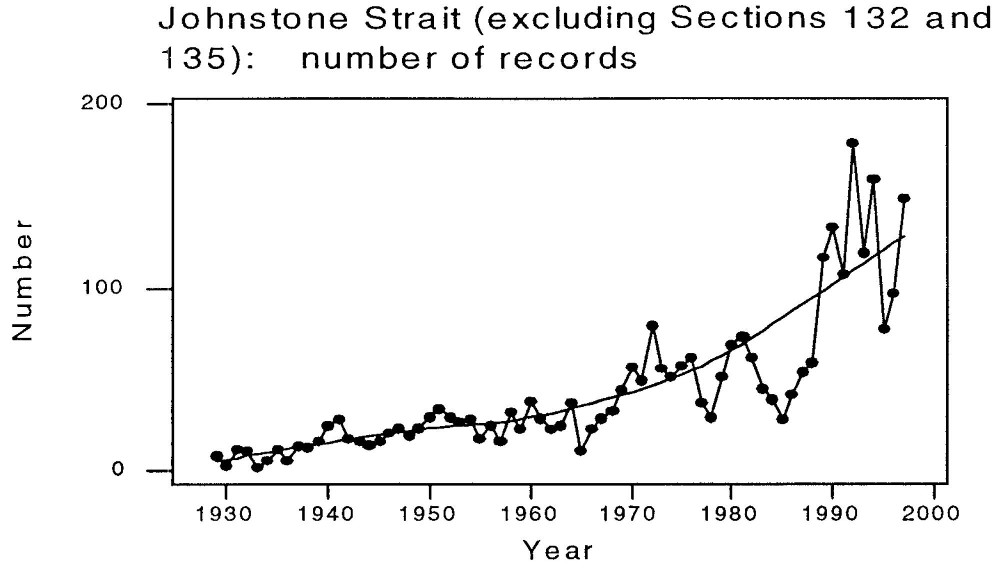
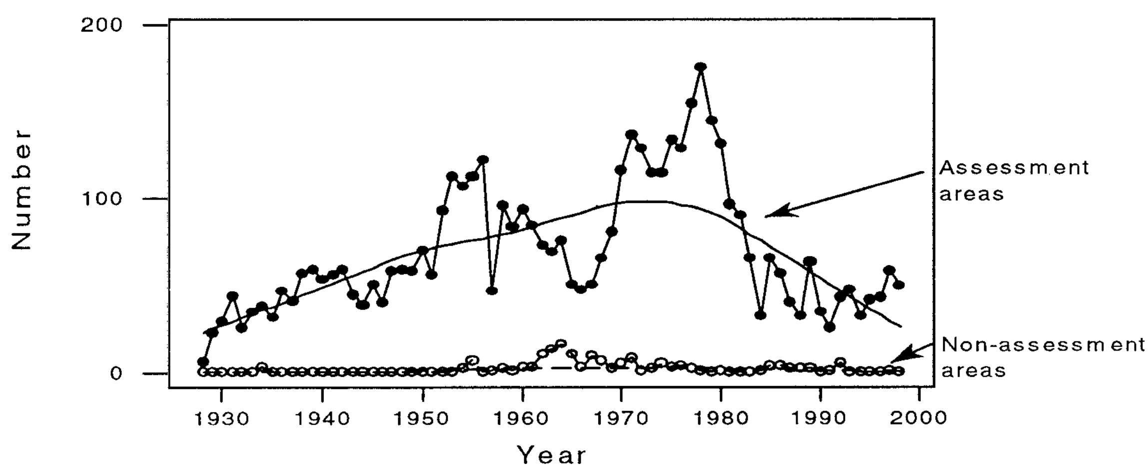


Fig. 6 continued. Number of spawn records for assessment and non-assessment areas, by year, for each of the 6 regions.





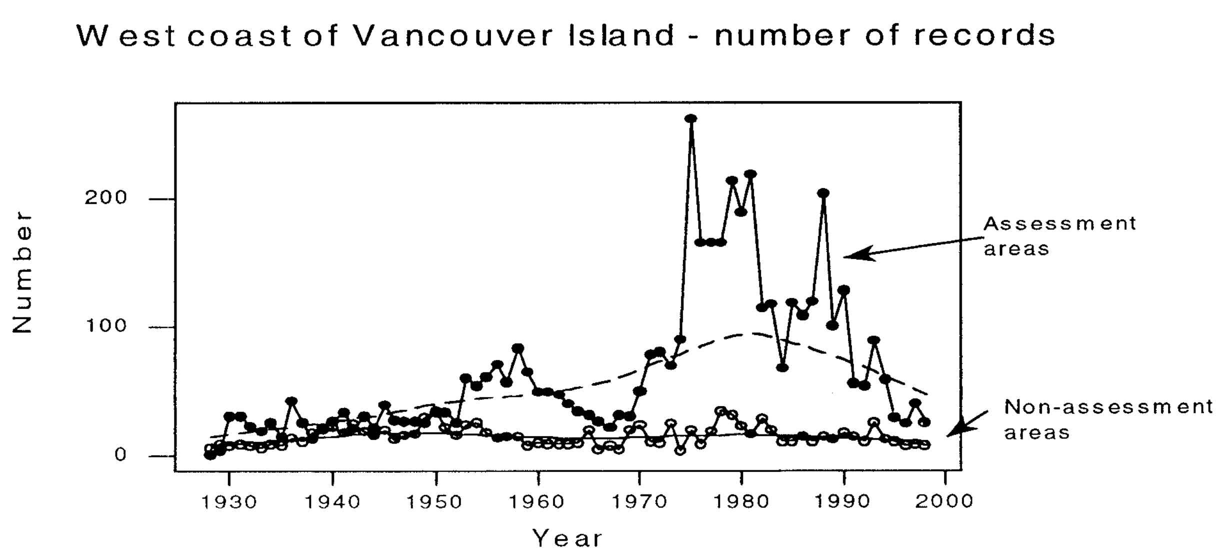
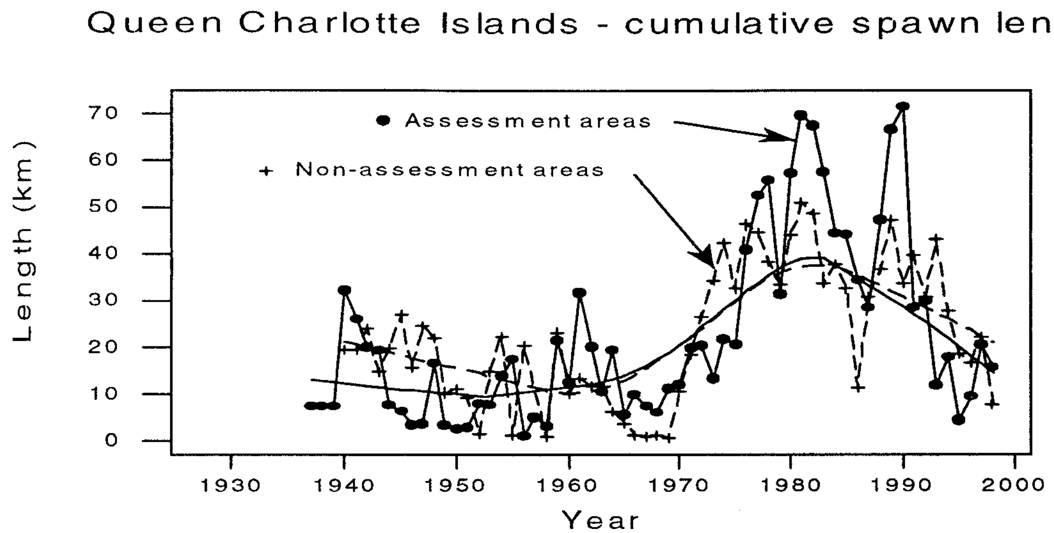
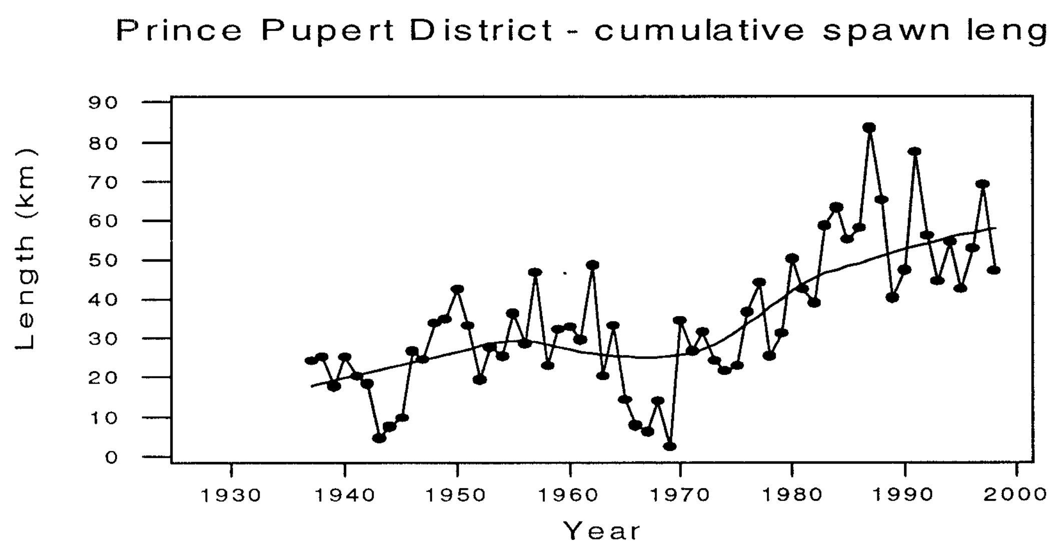


Fig. 7. Cumulative spawn length (km) for assessment and non-assessment areas, by year, for each of the 6 regions.





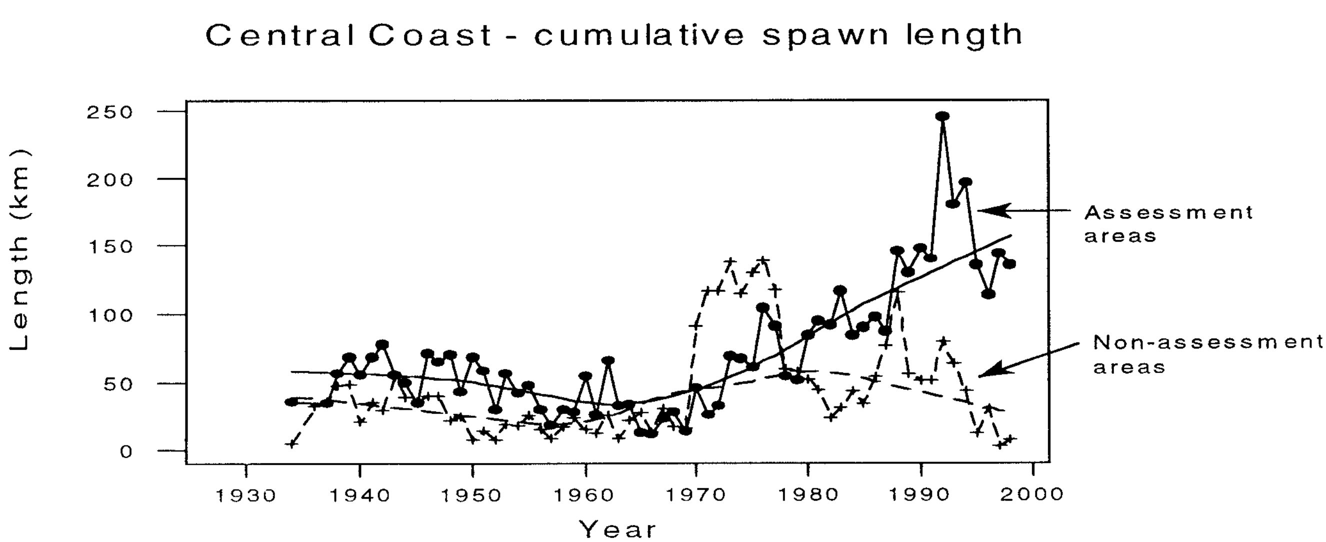
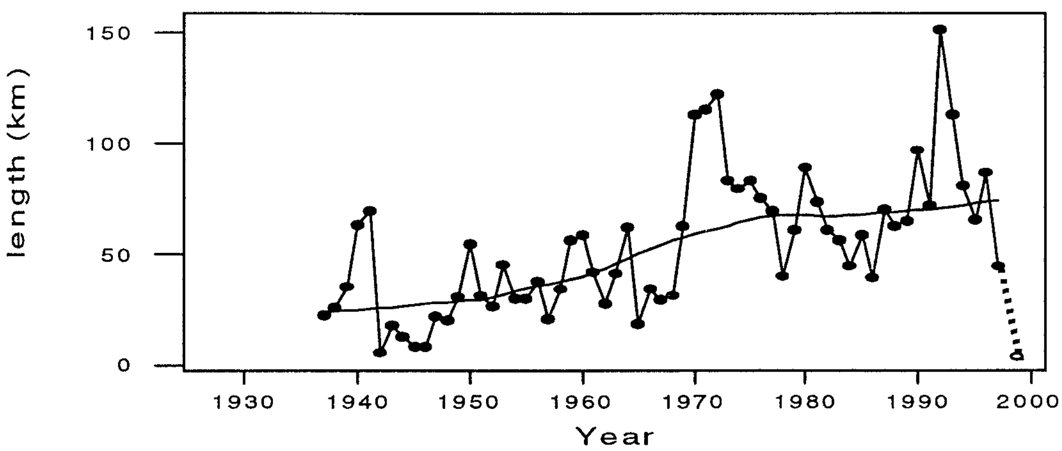
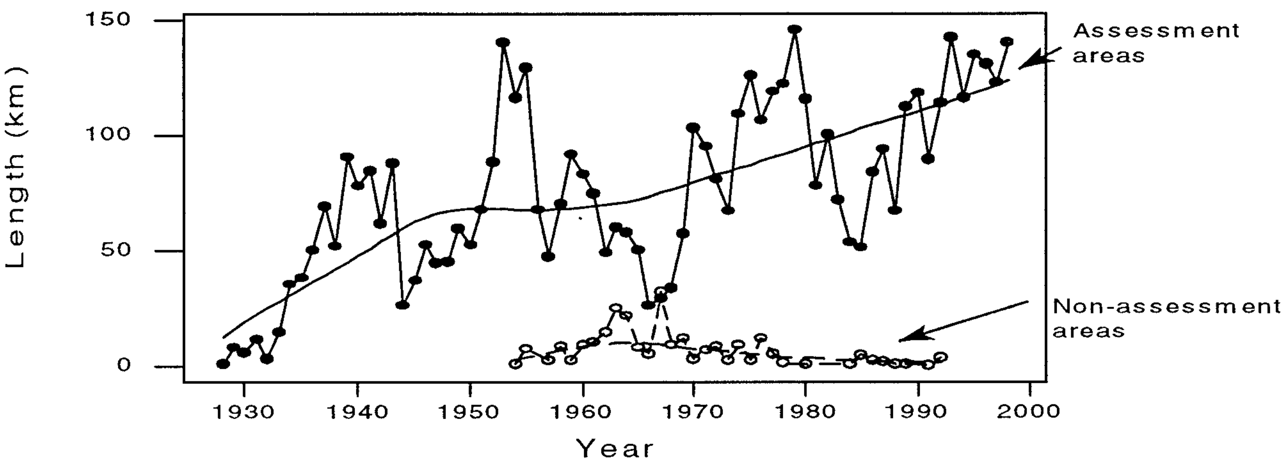


Fig. 7 continued. Cumulative spawn length (km) for assessment and non-assessment areas, by year, for each of the 6 regions.

Johnstone Strait (excluding Section 135): cumulative spawn length



Strait of Georgia - cumulative spawn length



West coast of Vancouver Island
cumulative spawn length

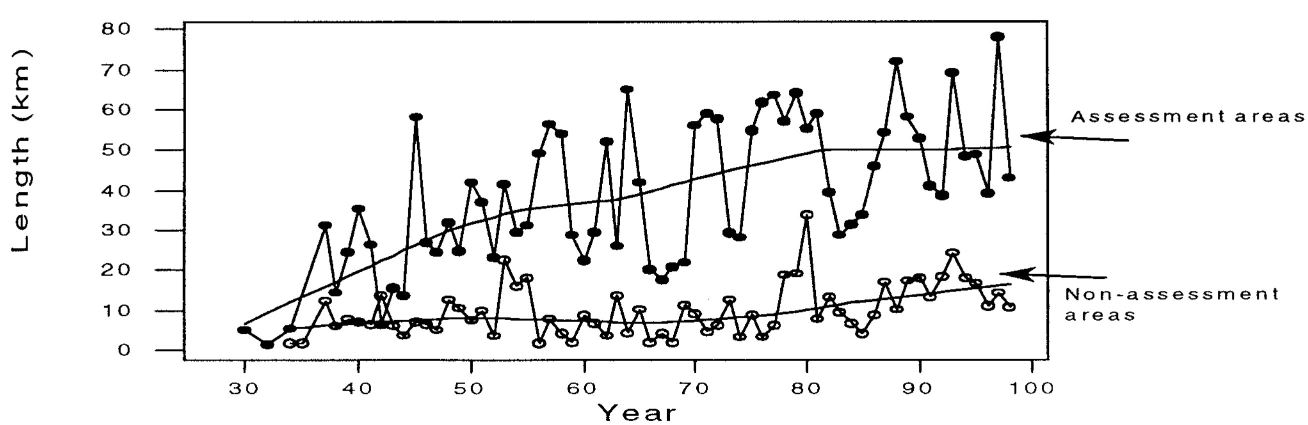
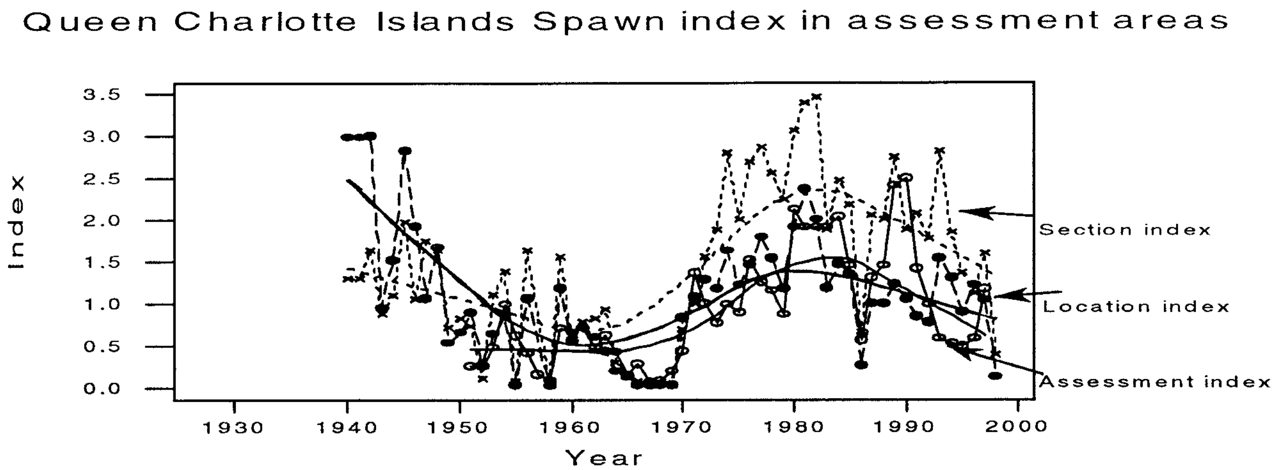
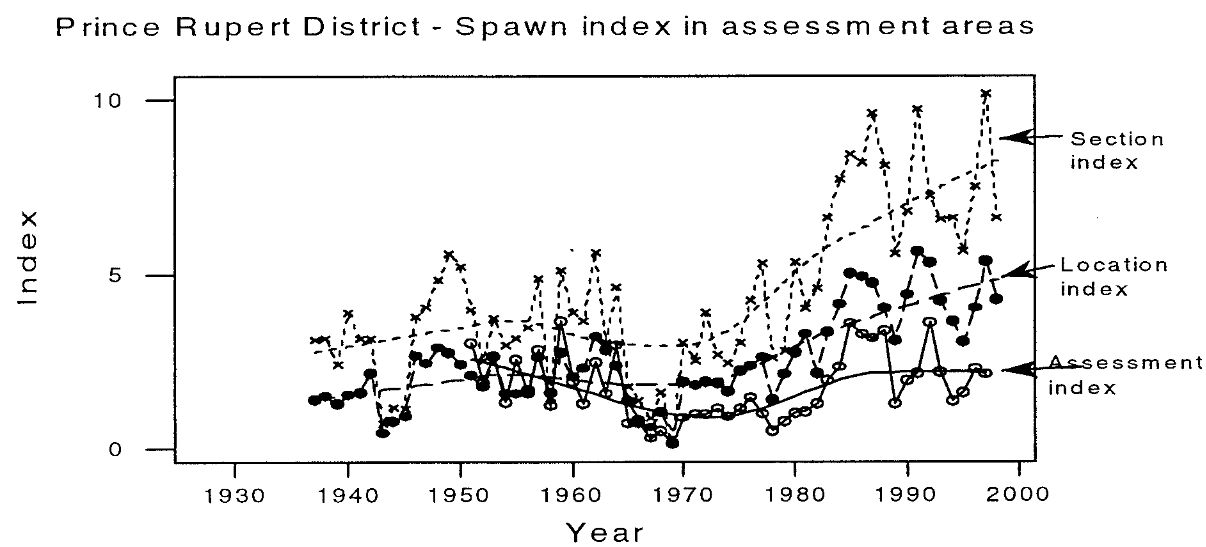


Fig. 8. Three spawn indices, by year, for assessment areas in all 5 regions except Johnstone Strait. The Section and Location indices are calculated in this paper. The assessment index is from the 1997 stock assessment document (Schweigert et al. 1998)





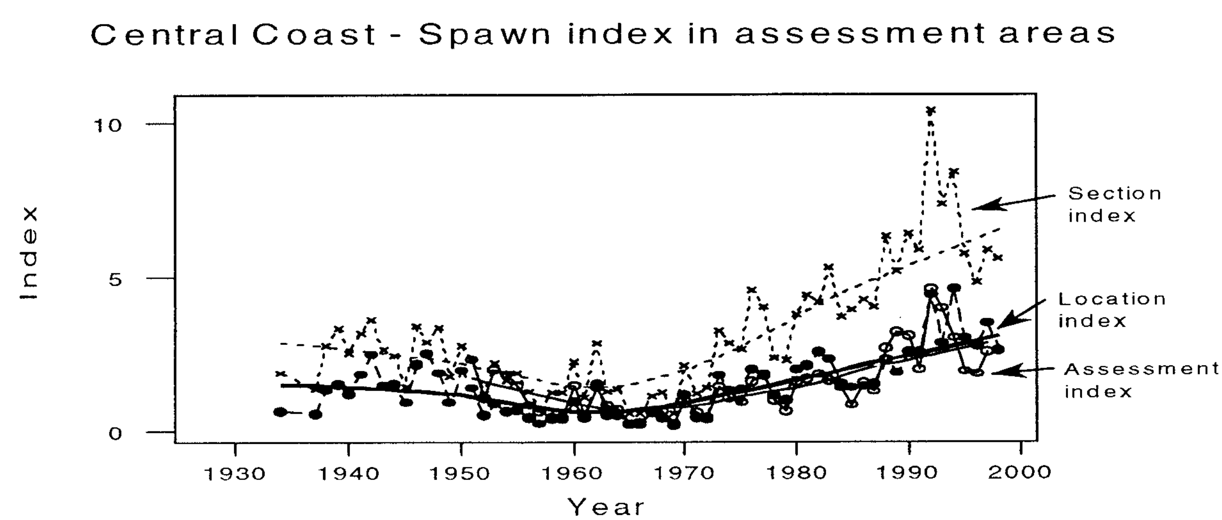
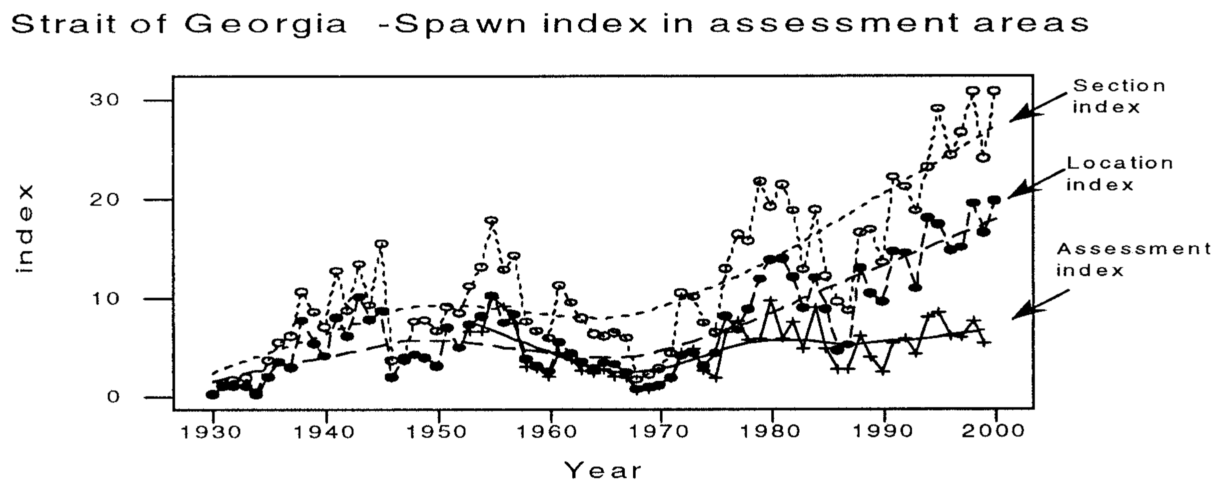


Fig. 8 continued. Three spawn indices, by year, for assessment areas in all 5 regions except Johnstone Strait. The Section and Location indices are calculated in this paper. The assessment index is from the 1997 stock assessment document (Schweigert et al. 1998)



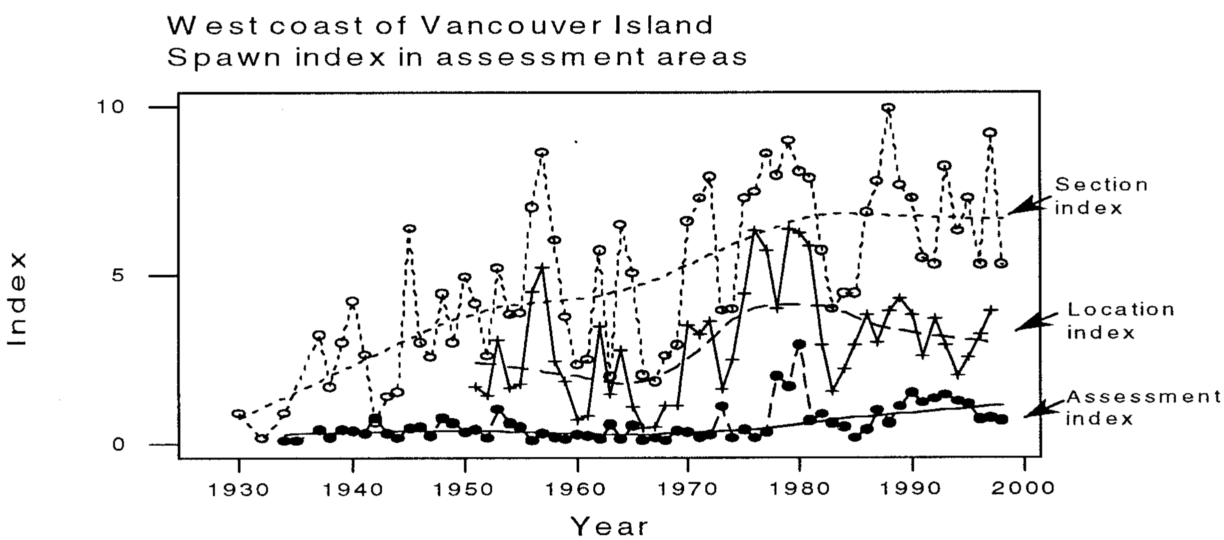
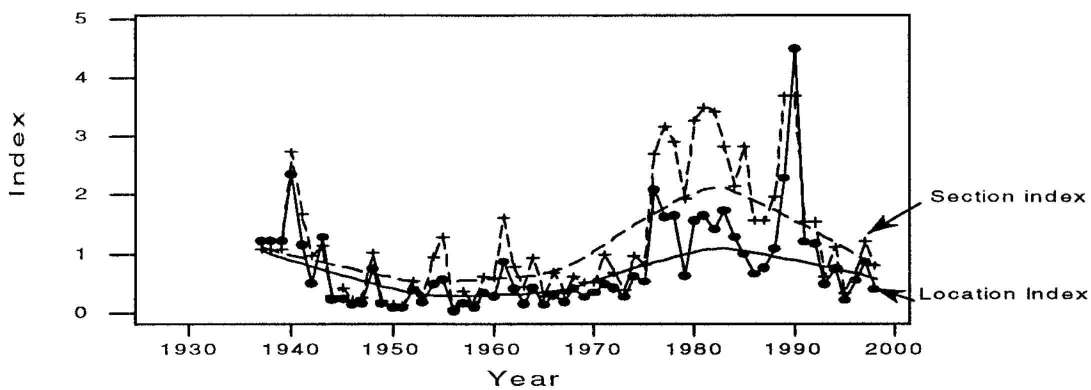
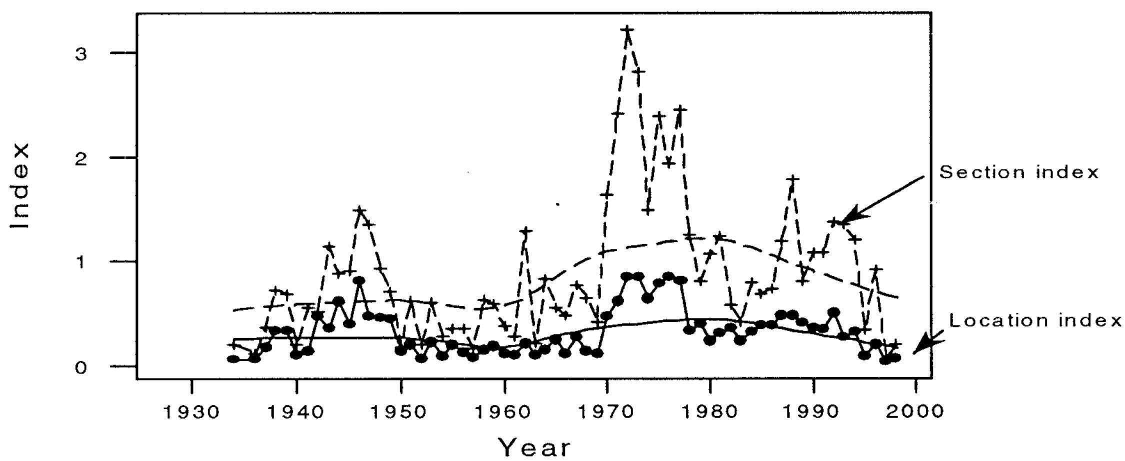


Fig. 9. Two spawn indices shown by year for non-assessment areas in each region. These areas are not included in recent assessment documents (Schweigert et al. 1998)

Queen Charlotte Islands - Spawn index in non-assessment areas



Central Coast - Spawn index in non-assessment areas



Johnstone Strait (excluding Section 135): Spawn Index

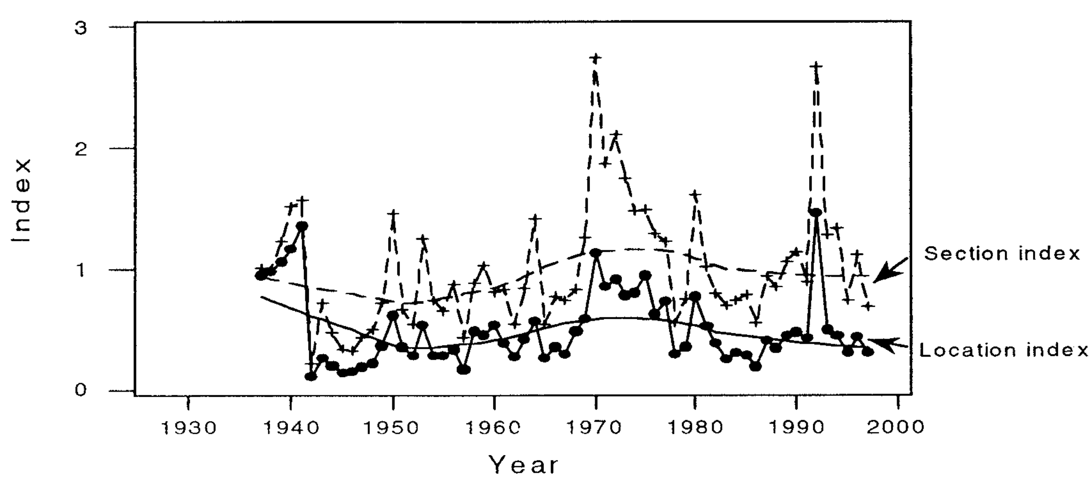
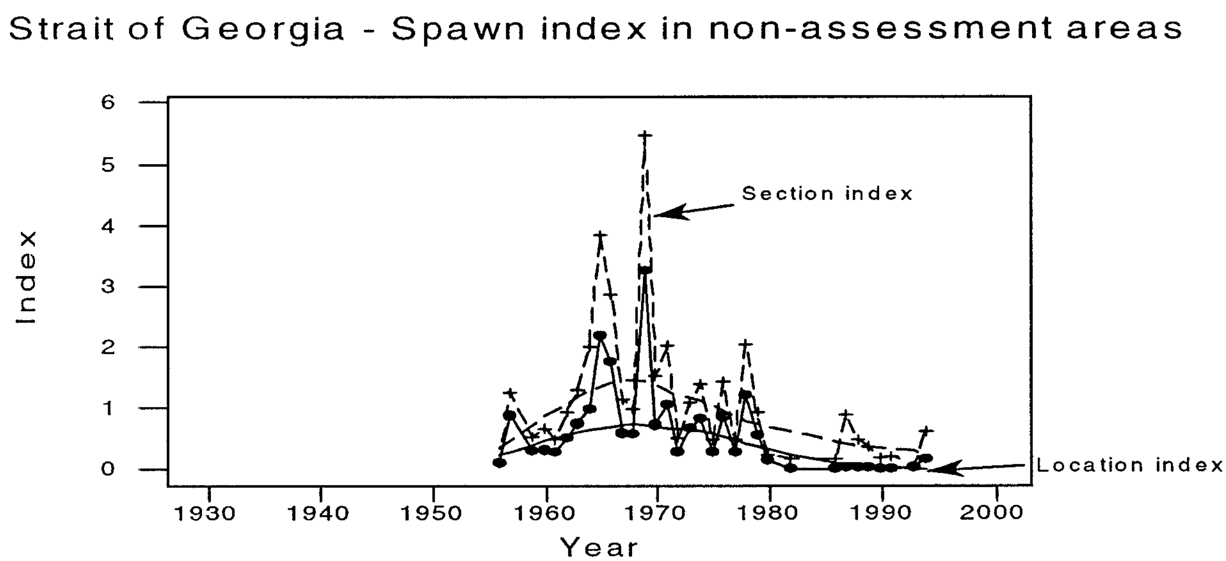


Fig. 9 continued. Two spawn indices shown by year for non-assessment areas in each applicable region. These areas are not included in recent assessment documents (Schweigert et al. 1998)



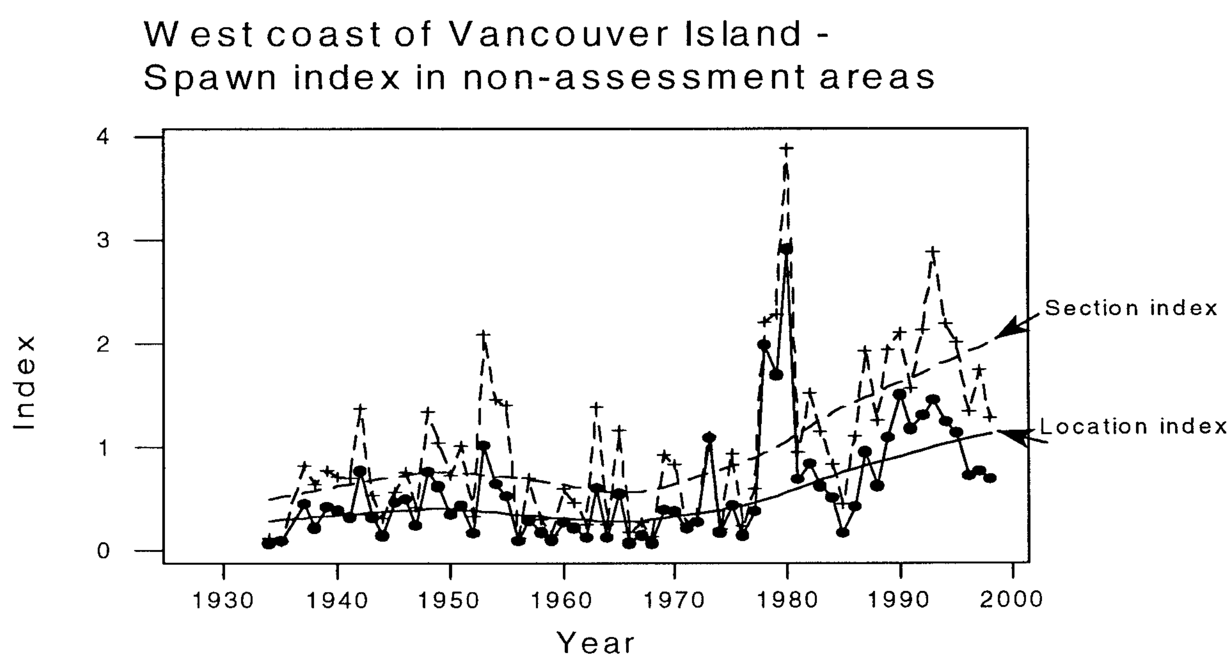


Fig. 10. Comparison of the 4 spawn indexes after each is standardized to a percentage per year. The 4 indexes are the Location index, Section index Assessment index(dashed line) and sum of length. The solid lines are smoothed to emphasize the temporal differences.

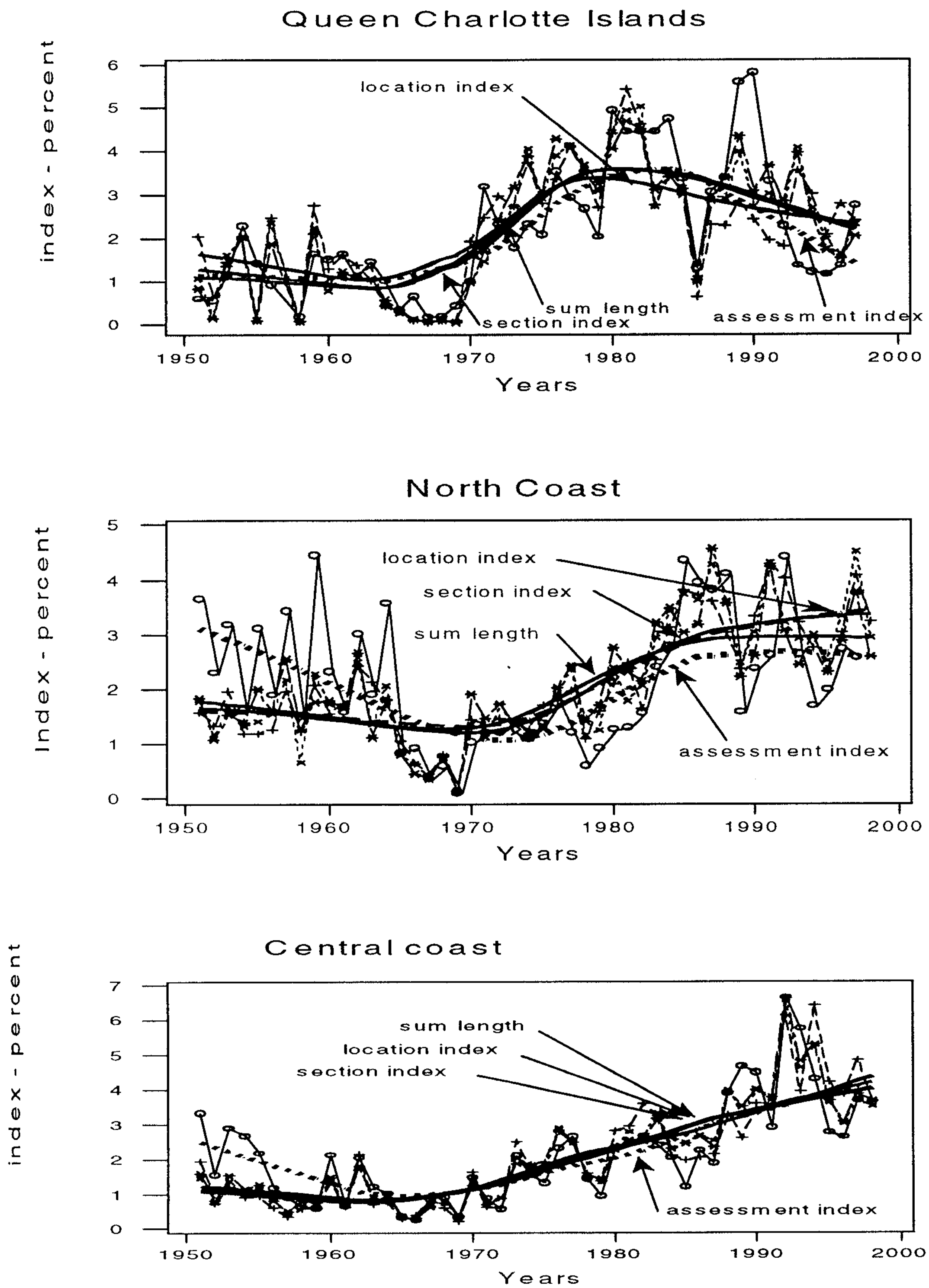
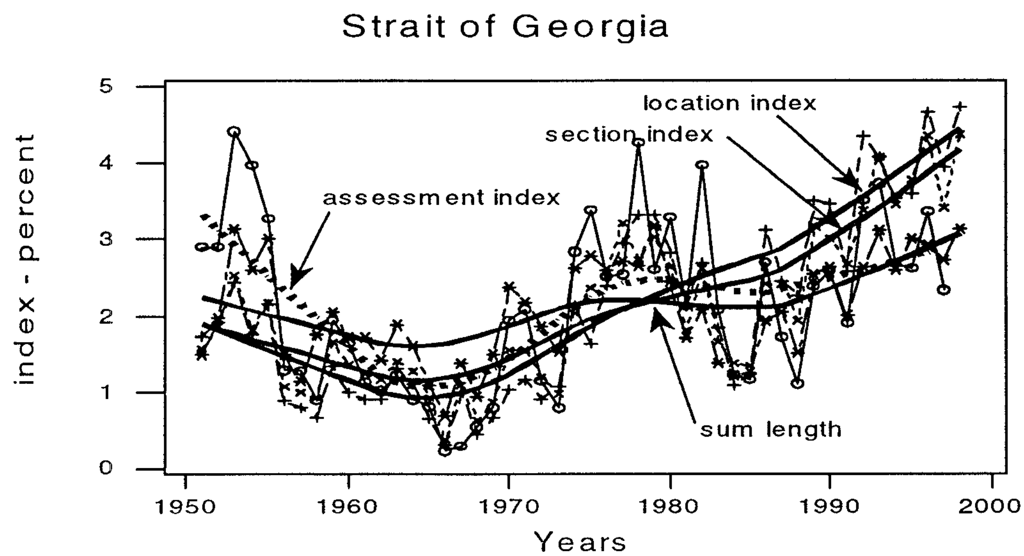


Fig. 10 continued. Comparison of the 4 spawn indexes after each is standardized to a percentage per year. The 4 indexes are the Location index, Section index Assessment index (dashed line) and sum of length. The solid lines are smoothed to emphasize the temporal differences.



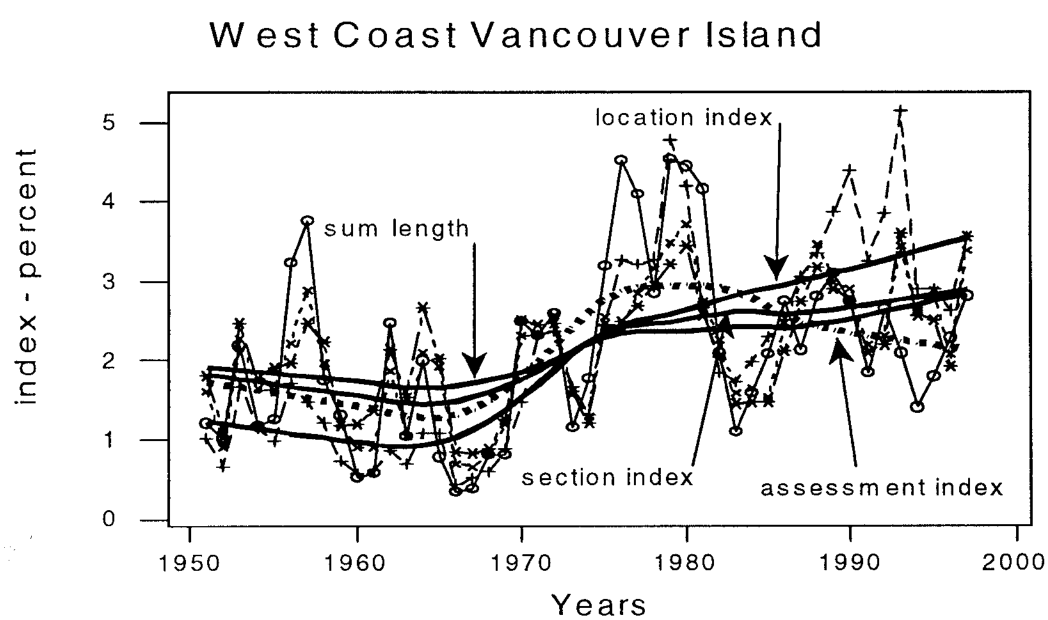
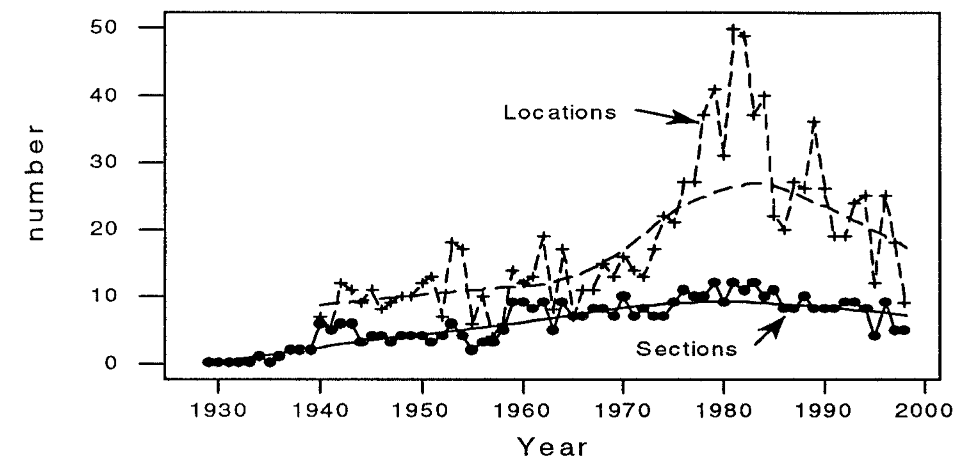
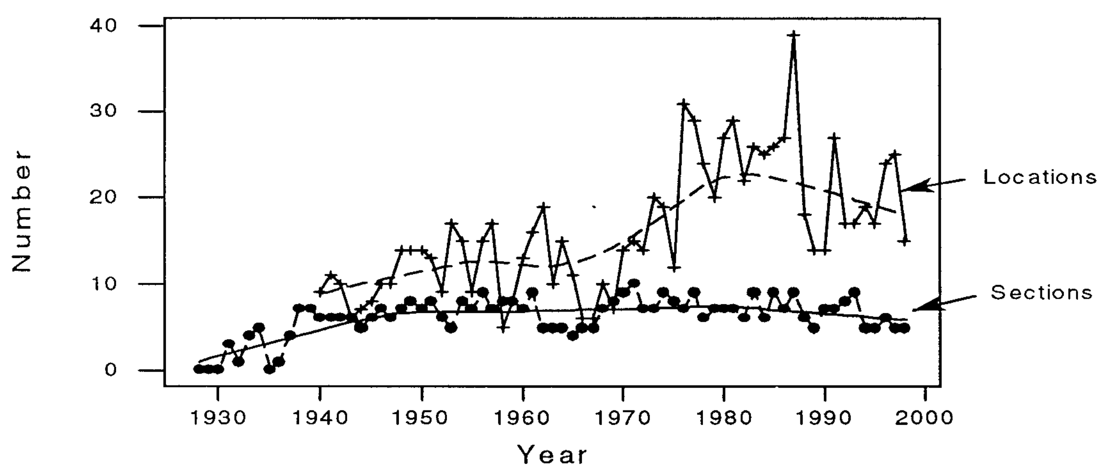


Fig. 11. The number of different sections and location with records of spawn, by year, for each region. Assessment and non-assessment areas are not distinguished.

Queen Charlotte Islands - numbers of locations and sections



Prince Pupert District - numbers of locations and sections



Central Coast - number of locations and sections

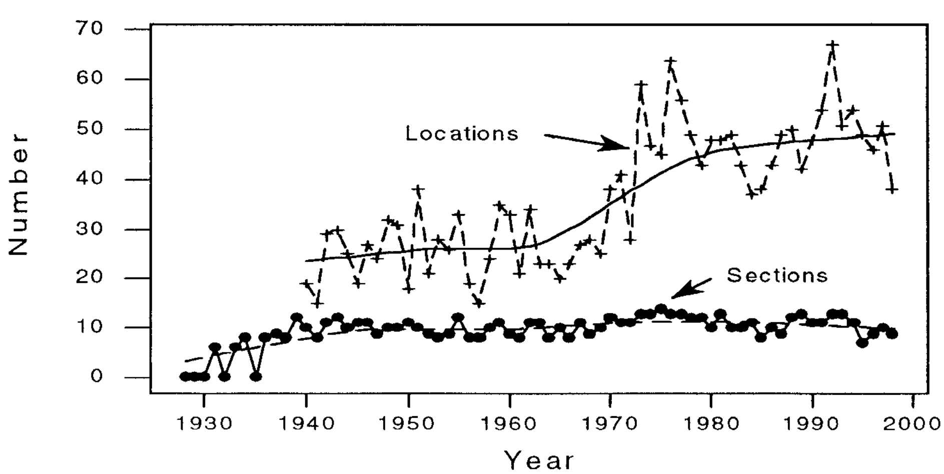
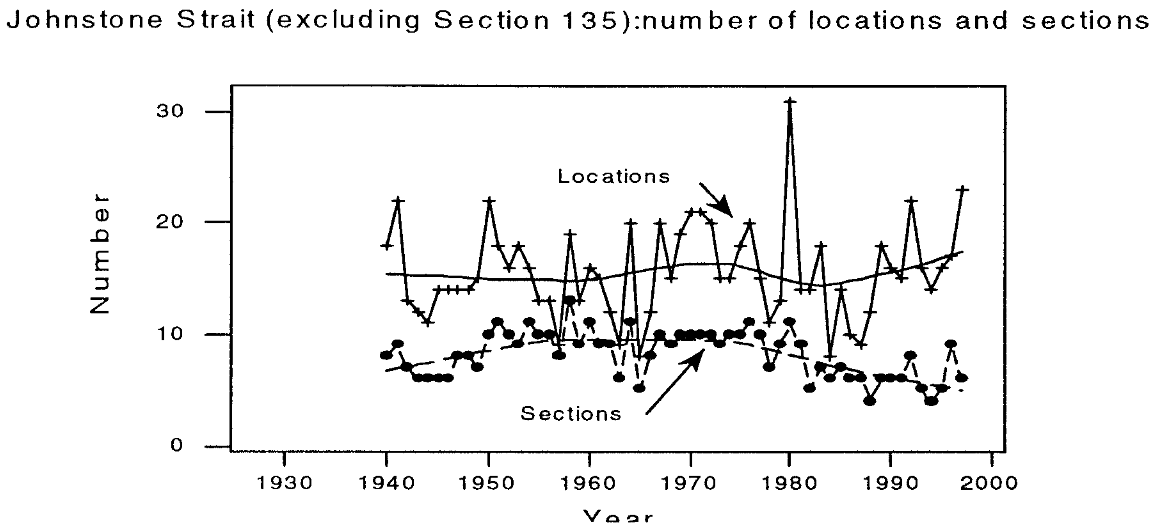
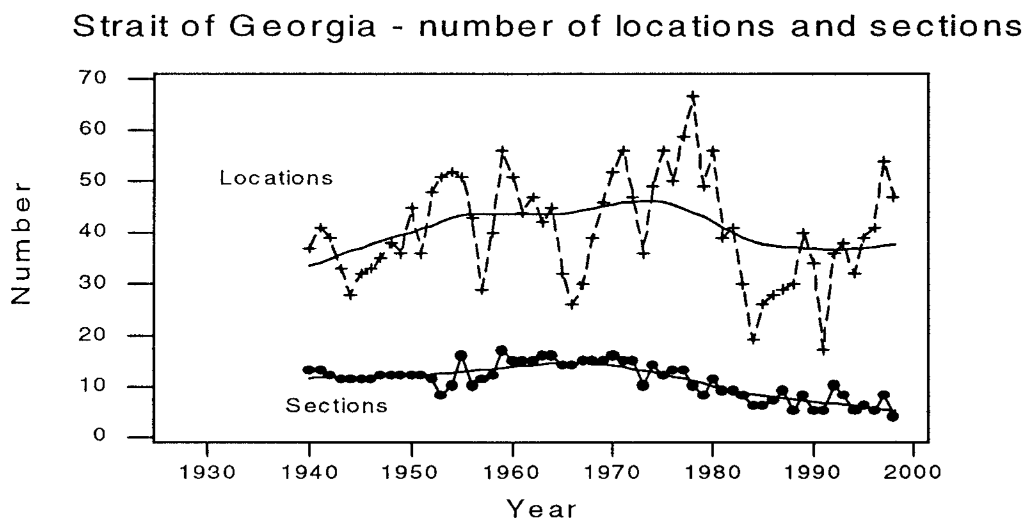


Fig. 11 continued. The number of different sections and location with records of spawn, by year, for each region. Assessment and non-assessment areas are not distinguished.





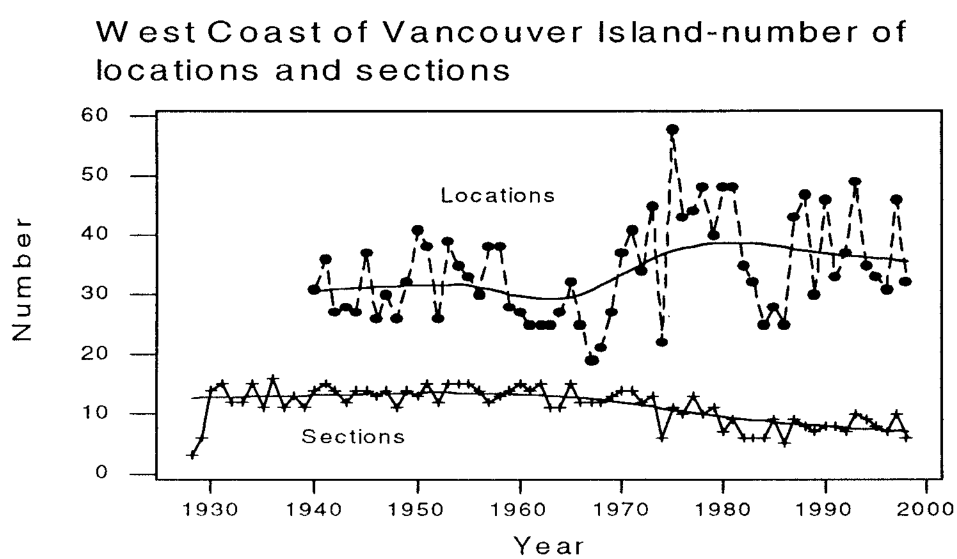
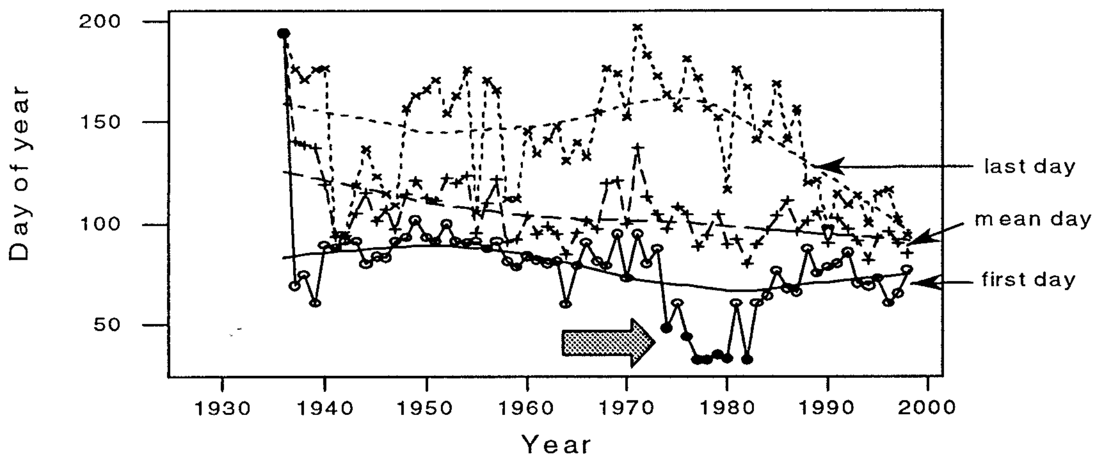
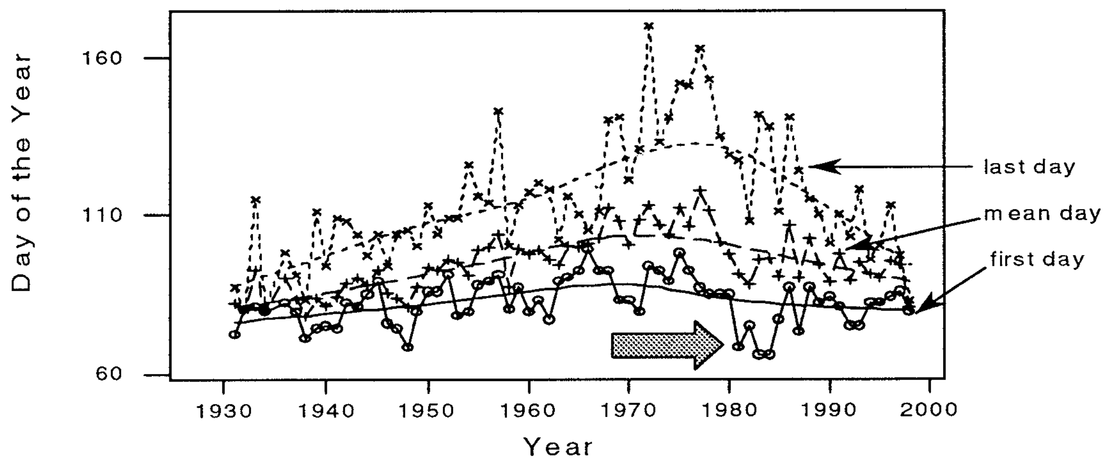


Fig. 12. The minimum, mean and maximum day of spawning, by year, for each region. Assessment and non-assessment areas are not distinguished. Note the similarity of trends in late and early spawning dates between QCI and PRD in the 1980's (example indicated by arrows).

Queen Charlotte Islands - date of spawning



Prince Pupert District - date of spawning



Central Coast - date of spawning

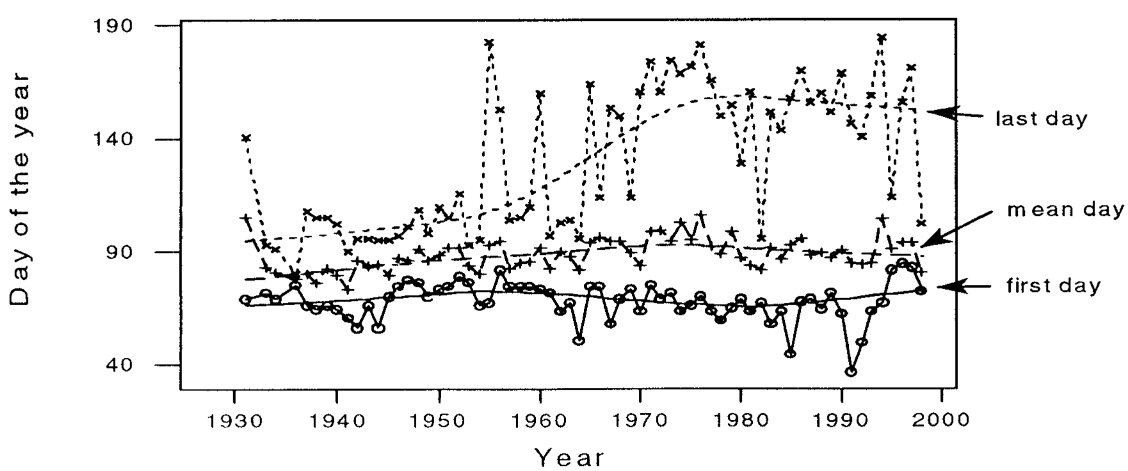
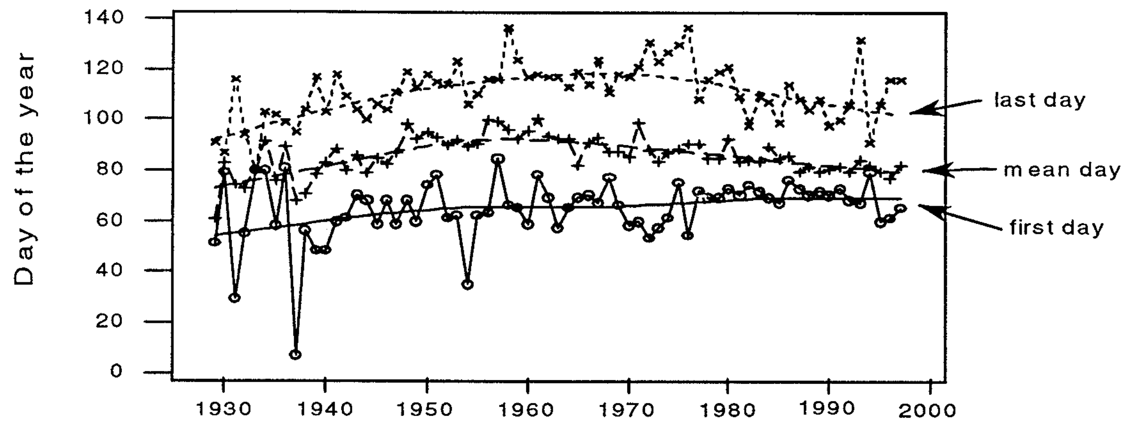
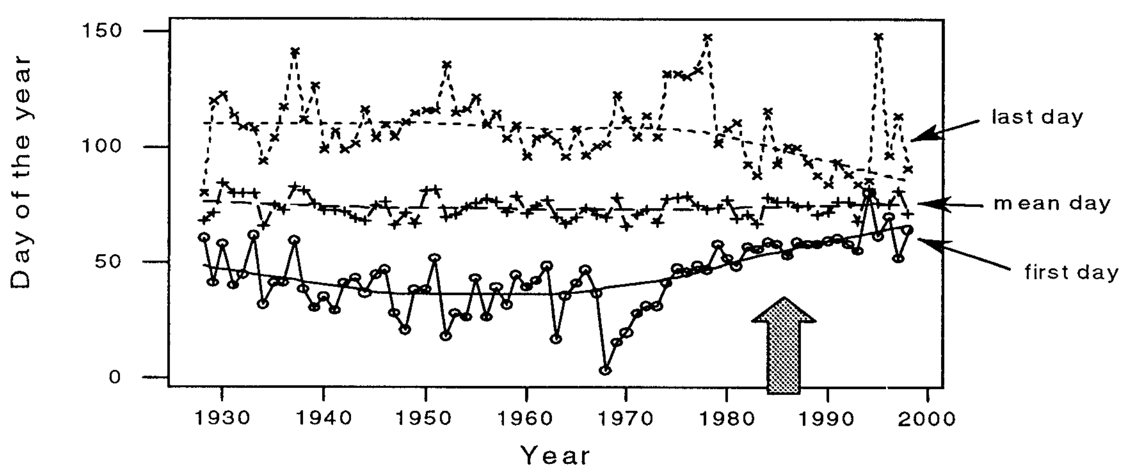


Fig. 12 continued. The minimum, mean and maximum day of spawning, by year, for each region. Assessment and non-assessment areas are not distinguished. Note the similarity of trends for the decline in early spawning in SOG and WCVI (indicated by arrows).

Johnstone Strait (excluding Section 135) - date of spawning



Strait of Georgia - date of spawning



West coast of Vancouver Island - date of spawning

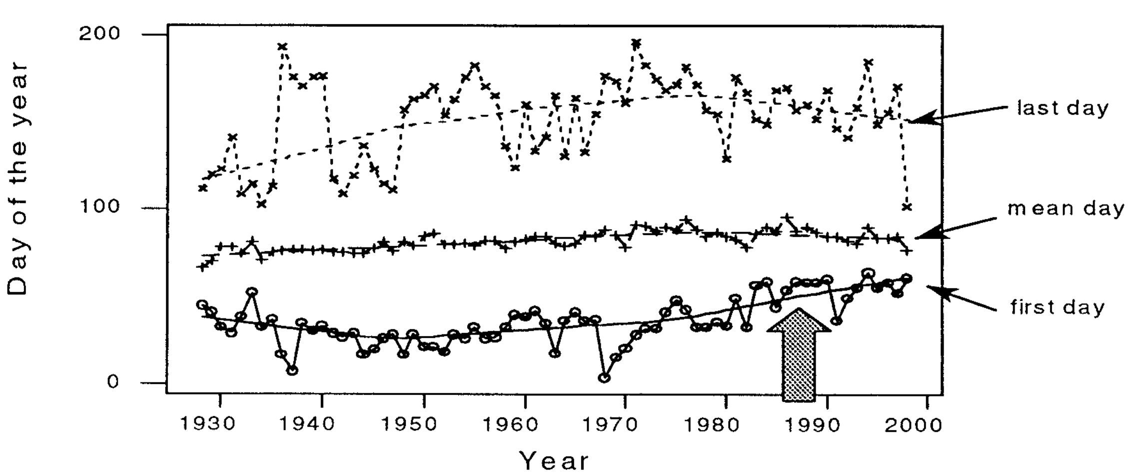


Fig. 13. Summary of spawning for the total BC coast. Total estimates are shown for assessment areas, non-assessment areas and the total coast for (a) cumulative km of spawn, (b) the LOCATION index and the SECTION index. The 1998 data may be incomplete for the total and non-assessment areas.

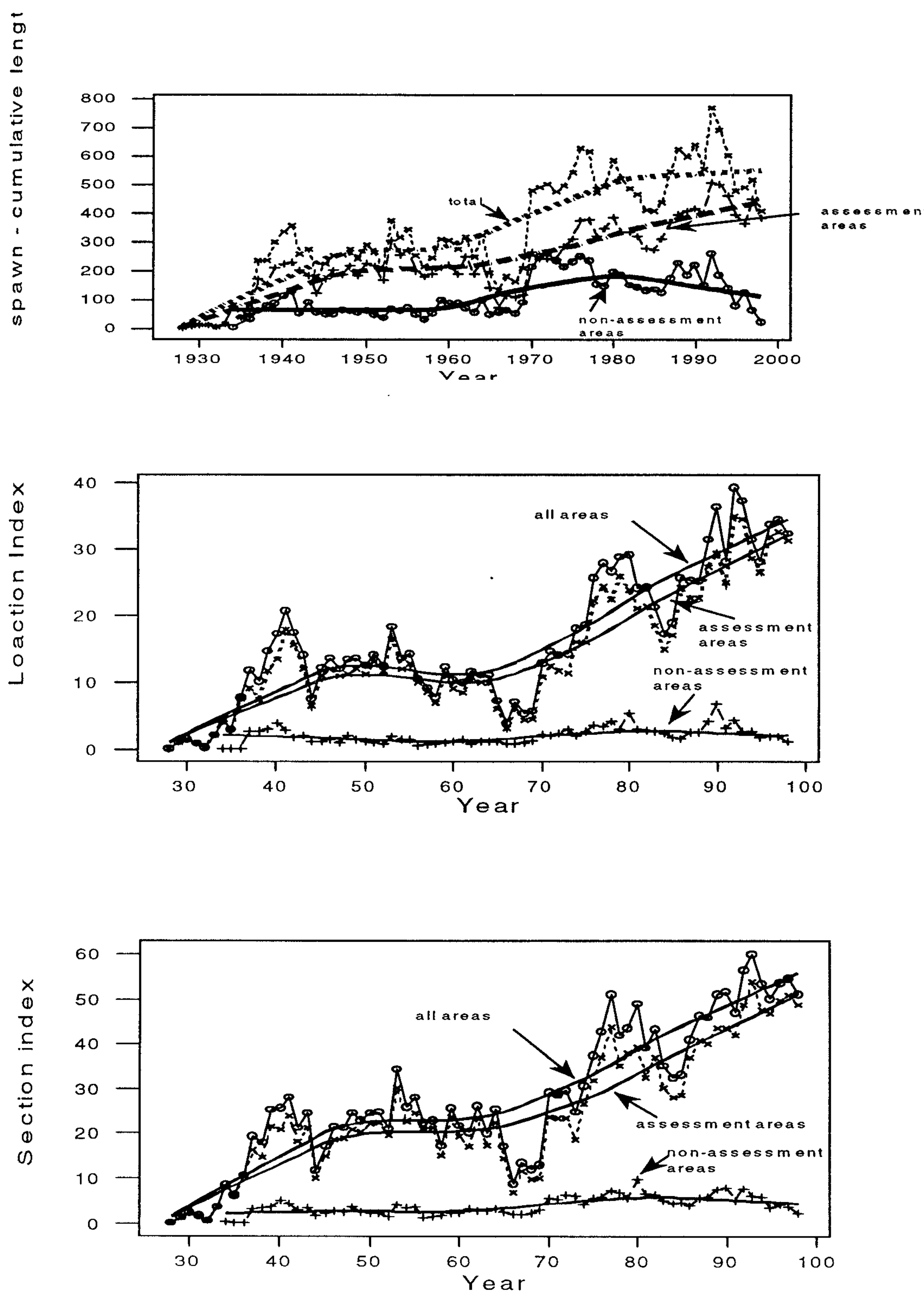


Fig. 14. Total numbers of sections with reported spawn for the total BC coast. Data for the years prior to 1940 may be incomplete. Similarly data for recent years (1990's) also may be incomplete, particularly 1998 that has no data for Johnstone Straits.