Fisheries and Oceans Canada / Pêches et Océans Canada
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Research Document 2007/086

Document de recherche 2007/086

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Potential impacts of the British Columbia herring roe fishery on the spatial and temporal distribution of herring spawn: examination of the serial depletion hypothesis

Répercussions possibles de la pêche du hareng rogué en Colombie-Britannique sur la répartition spatiale et temporelle de la ponte de hareng : examen de l'hypothèse d'épuisement continu

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ISSN 1499-3848 (Printed / Imprimé)

Canada

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Abstract

The British Columbia herring roe fishery is conducted on or near inter- and sub-tidal spawning locations. It is a conservative fishery, taking a maximum of 20 percent of the spawning biomass in any of the five major assessment areas. The assessment areas are large and may contain a number of different spawning and fishing sites. As a rough approximation, each assessment area consists of about 5-10 smaller geographic units, called sections. Sections are geographic units used almost exclusively by the Fisheries and Oceans Canada Science Branch. In most years the fishery may be concentrated in a few sections, so the section-specific catch rates sometimes exceed twenty percent. Some observers suggest that these localized intense fisheries may lead to serial depletion of unique spawning components of the populations. This report addresses the hypothesis that, since its inception in the early 1970's, the herring roe fishery has led to systematic reduction in the number of distinct spawning locations. We examined the spatial-temporal patterns of spawning by comparing the frequency of section-specific spawning between two periods: a 31-year period between 1940 and 1970 (prior to the roe fishery, when catch rates were very high in most years) and a 36 year period corresponding to the roe fishery, from its initiation to the present. When examined among assessment areas, there was no evidence of a decrease in the frequency of spawning between the two periods. We also compared the temporal pattern of catch and spawn data for each of the approximately 100 geographic sections. Using the annual assessment estimates (from 2006) we scaled spawn data units to metric tonnes and then examined the temporal history of spawn and catch in each section. We found three instances where a cessation of spawning coincided approximately with a roe fishery. In each instance, however, more detailed analyses showed that none represented a clear example of depletion following a fishery. Instead these examples represented fisheries that occurred in locations where spawning activity was not consistent in time or space in years prior to the fishery, or where the geographic dimensions of the section were exceptionally small. The geographic range of each section is arbitrary, and not based on biology. We show that in one case, in the central coast of BC, the simplest explanation is a slight shift in spawning between adjacent spawning sites in sections that are much smaller than others on the BC coast. Herring spawn locations are dynamic and changes in spawning patterns are evident from the results of this report and many previous studies. However our results indicate that there is no evidence to support the hypothesis of serial depletion during the roe fishery as an explanation for those changes. The report concludes with a discussion of the tradeoffs and associated risks between the managerial and logistical benefits and of taking the (total allowable catch) TAC in a fewer number of larger openings in small areas (few sections) versus the preferable biological goal of spreading the TAC and fishing effort to a larger number of smaller openings over a broad geographic area (many sections).

This report contains two substantial appendices. One is an annotated list of each herring section, showing graphical analyses and key statistics on spawning and catch data from 1940-2006 (mean spawning date, cumulative spawn area and cumulative catches by season). The second appendix is a brief report, titled "Spatial and temporal distribution of the fishery" that describes the development of a spatial data base of the herring roe and discusses the technical limitations to geo-referencing herring roe catch data.

Résumé

La pêche du hareng rogué en Colombie-Britannique est pratiquée dans les eaux médiolittorales et infralittorales ou à proximité. Il s'agit d'une pêche prudente au cours de laquelle ne sont pris que 20 % au maximum de la biomasse génitrice dans l'une ou l'autre des cinq principales zones de l'évaluation. Ces dernières sont vastes et peuvent contenir un certain nombre de lieux de ponte et de pêche différents. De façon générale, chaque zone d'évaluation comprend environ de 5 à 10 petites unités géographiques, appelées sections. Celles-ci sont des unités géographiques utilisées presque exclusivement par la Direction des sciences de Pêches et Océans Canada. Au cours de la plupart des années, la pêche est concentrée dans quelques sections, de sorte que le taux de prise dans certaines sections en particulier peut dépasser 20 %. Selon certains observateurs, ces pêches intensives localisées pourraient mener à l'épuisement continu de composantes de ponte uniques de la population. Le présent rapport prend pour point de départ l'hypothèse selon laquelle, depuis son introduction, au début des années 1970, la pêche du hareng rogué a entraîné une réduction systématique du nombre de lieux de ponte distincts. Nous avons examiné les tendances spatiales et temporelles de la ponte en comparant les fréquences de ponte dans des sections particulières au cours de deux périodes : une période de 31 ans, entre 1940 et 1970 (avant la pêche du hareng rogué, quand les taux de prise étaient très élevés au cours de la plupart des années) et une période de 36 ans, correspondant à la pêche du hareng rogué, depuis ses débuts jusqu'à maintenant. Quand on compare les données des zones d'évaluation, il ne semble y avoir aucun signe de diminution de la fréquence de ponte entre les deux périodes. Nous avons aussi comparé la tendance temporelle dégagée des données sur les prises et la ponte pour chacune des 100 sections géographiques environ. En utilisant l'estimation obtenue à partir de l'évaluation annuelle (de 2006), nous avons réduit les unités des données sur la ponte en tonnes métriques, puis examiné les antécédents temporels de ponte et de prise de chaque section. Nous avons découvert trois cas où la cessation de la ponte a coïncidé approximativement avec la pêche du hareng rogué. Dans chaque cas, toutefois, des analyses plus détaillées ont révélé qu'aucune ne constituait un exemple clair d'épuisement consécutif à la pêche. Ces situations représentaient plutôt des pêches qui ont eu lieu à des endroits où l'activité de ponte n'était pas constante dans le temps ou l'espace au cours des années précédant la pêche, ou encore dans des sections dont les dimensions géographiques étaient exceptionnellement restreintes. L'étendue géographique de chaque section est arbitraire et n'est pas fondée sur des caractéristiques biologiques. Nous montrons que dans un des cas, sur la côte centrale de la C.-B., l'explication la plus simple est un léger déplacement de la ponte entre des lieux de ponte adjacents dans des sections qui sont beaucoup plus petites que d'autres sur les côtes de la province. Les lieux de ponte du hareng sont dynamiques et les tendances changent comme en témoignent les résultats de notre rapport et de nombreuses études précédentes. Toutefois, nos résultats révèlent que rien ne vient appuyer l'hypothèse d'un épuisement continu pendant la pêche du hareng rogué pour expliquer ces changements. Nous concluons par une discussion des compromis et des risques connexes des avantages administratifs et logistiques et de la réalisation du TAC (total autorisé de captures) dans un nombre moins important de grandes ouvertures dans de petites zones (quelques sections) comparativement à l'objectif biologique privilégié de la répartition du TAC et de l'effort de pêche entre un plus grand nombre de petites ouvertures dans une grande zone géographique (de nombreuses sections).

Le présent rapport contient deux annexes substantielles. L'une est une liste annotée de chaque section du hareng, montrant les analyses graphiques et les principales statistiques issues des données sur la ponte et les captures entre 1940 et 2006 (date de ponte moyenne, zone de ponte cumulative et prises cumulatives par saison). La seconde est un bref rapport sur la répartition spatiale et temporelle de la pêche, qui décrit la création d'une base de données spatiale sur la pêche du hareng rogué et expose les limites techniques du géo-référençage des données sur les prises de hareng rogué.

Introduction

The British Columba (BC) herring roe fishery has been subjected to considerable scrutiny since its initiation in the early 1970's. The conservative harvest policy documented by Stocker (1993) is well known and highly regarded. Wallace and Glavin (2003) also review other aspects of the fishery and conclude that the fishery operates with adequate precaution and reasonable understanding of the biology and population dynamics. Nevertheless, some observers remain concerned about local impacts of the fishery. These concerns focus on the perception that a fishery conducted near or on the spawning areas might cause the depletion of local spawning populations. Such concerns usually make implicit assumptions about herring stock structure – specifically an assumption that British Columbia herring subjected to roe fisheries consist of many, small genetically different populations. Such population structure would require a high rate of fidelity of each population to (natal) spawning sites. Recent analyses have shown that such assumptions are not correct in most instances. Tagging studies do not support the case for high degrees of local spawning fidelity (Hay et al. 2001) and results from genetic analyses (Beacham et al. 2001) indicate that most herring populations mix extensively. On the other hand, some important scientific literature on herring claims that small (< 100 tonnes), geographically isolated herring stocks do exist in some areas (Iles and Sinclair 1981). Recent genetic studies on Atlantic and Baltic herring reveal unexpected spatial and temporal variation in samples taken in relatively confined areas (Jørgensen et al. 2005a, 2005b, McPherson et al. 2003, 2004) although the geographic scale of this variation usually exceeds that of the assessment areas used in BC. Further, there are valid concerns about local or serial depletion that have occurred in other fisheries, especially some shrimp fisheries that have collapsed following intensive fisheries (Armstrong and Hilborn 1998).

The main objective of this paper is an examination of the *serial depletion* hypothesis that the herring roe fishery has altered the spatial distribution of herring spawn by systematically eliminating distinct spawning components of the population. Two main approaches are presented, each of which examines a different aspect of the hypothesis. The first examines the spatial-temporal patterns of spawning and compares the frequency of section-specific spawning between a 31-year period from 1940-1970 (prior to the roe fishery) and a 35 year period (1971-2006) corresponding to the beginning of the roe fishery to the present. If herring roe fisheries caused a decrease in spawning, leading to local depletions, then we would expect to see more frequent and larger decreases in annual spawning during the recent years of the roe fishery compared to the earlier period of the reduction fishery, when catches were much greater. We acknowledge, however, that this is a comparison between two different fishing regimes, both of which could have altered distribution and abundance compared to a virgin, or pre-fishery state. Nevertheless, when examined over decadal periods, the relative abundance of BC herring, estimated in terms of density or g/m^2 (or tonnes/km^2) is among the highest in the Pacific and even in the world (Hay and McCarter 1997). Therefore while we cannot rule out any impact of the reduction fishery on spawn distribution, we can suggest that the subsequent recovery has returned the population to levels that compare favorably, in terms of density, with any in the world.

The second analysis is a review of catch and spawning data relevant to potential serial depletion. For approximately 100 geographic subsections of the BC coast, we examined historical spawn records to examine the frequency and temporal continuity of spawning cessations following fisheries. Catch and spawn data were compared to determine if there were instances where the continuity of spawning stopped. We also examined areas without fisheries to estimate the changes in spawn that occur without fishery impacts.

In the Discussion we comment on the limitations of the available data and discuss the implications for our results and conclusions. Each of the two approaches makes assumptions about the completeness and accuracy of data – and we note that the data have inherent limitations. In the first analyses we recognize that analysis of only the *frequency* of spawns does not recognize inter-annual differences in spawn quantity. The second analysis relies on assumptions about scaling – or adjusting spawn data to the same biomass units as the catch data. In spite of these limitations, the main conclusion is clear: there is no evidence to support the serial depletion hypothesis. Spawning deposition patterns do change but our analyses indicate that none has disappeared as a direct consequence of the roe fishery.

Materials and Methods

Geographic divisions - management and science categories

For routine management the British Columbia (BC) coast is divided into six Regions (Fig.1a-b). Stock assessments are conducted for substantial components in five of these six Regions. These components are known as assessment areas and these represent the geographic areas over which spawn assessments are conducted. Herring within the assessment area are assumed to be part of the same biological stock.

The operations and management sectors of the Department of Fisheries and Oceans (DFO) also divide the coastal areas of British Columbia into Fisheries Management Areas' (FMA's). These geographic divisions (Fig. 2a) are further divided into 'sub-Management Areas' (Fig. 2b). Herring research and assessment in DFO use the same geographic divisions as the 'Management Areas' (but are known as 'Statistical Areas') and use a different geographic sub-division known as 'sections' (Haist and Rosenfeld 1988, Hay and Kronlund 1987, Hay and McCarter 2006). The relationship between regions, statistical areas and sections is shown in Fig. 3. In the analysis presented in this paper, we use 29 different statistical areas (Fig 3b) that are divided into 101 different sections (Fig. 3c). The geographic ranges of some sections have been modified since they were defined by Hourston and Hamer (1979). The geographic definitions and divisions used in this paper correspond with those defined by Haist and Rosenfeld in 1988. The changes in estimates of spawn deposition and catch also were adjusted to match the changes in the geographic ranges of the sections.

At the present time (2007) there are five main assessment areas on the BC coast: (1) South-east Queen Charlotte Island which is mainly Statistical Area 2; (2) the Prince Rupert District including Statistical Areas 3-5; the (3) the Central Coast including Statistical Areas 7, 8 and parts of Statistical Areas 6; (4) the Strait of Georgia including Statistical Areas 14-19, 28, 29 and parts of Statistical Area 13; (5) the west coast of Vancouver Island including Statistical Areas 23-25.

Calculating the surface-area of sections, assessment areas and non-assessment areas

The geographic areas of all geographic groupings of the BC coast were estimated using GIS software (©Arcview) and Canadian Hydrographic Service (CHS) marine charts that have digitized bathymetry. (DFO unpublished data provided by Bryan Rusch.) Total surface area of each herring section, from the inter-tidal to a maximum depth of 200m was estimated. The cumulative areas for any combination of sections was simply the cumulative sum of the areas.

Depletion hypothesis - approach 1: spawn frequency analysis: (1951-1967 versus 1971-2005)

Egg deposition varies in intensity and frequency among sections subject to fisheries. To estimate spawn frequency and distinguish between areas subject to varying sizes of fisheries we classified sections according to the cumulative *catch* during the approximate spawning period (January to April). Then we compared the inter-annual frequency of spawning among sections relative to the scale of fishery removals. The null hypothesis was that there was no decrease in the frequency of spawning within sections between the two periods: the reduction fishery period preceding the roe fishery (1940 to 1970) and the roe fishery period (1971-2006).

This hypothesis is only applicable to sections where roe fisheries occurred. It is difficult, however, to make a sharp distinction for all sections as either a 'roe fishing section' or a 'non-roe-fishery section' because in the early days of the herring row fishery (~1970-1977) broad areas of the BC coast were open to fishing. Although this practice was soon revised to restrict fishing to the main assessment areas, a consequence of these early, geographically widespread openings is that small catches of roe herring were made in many different parts of the BC coast, from many sections that were subsequently excluded from roe fisheries for nearly 30 years. In contrast, during more recent years (~1980-2006), the roe fishery has been geographically confined to relatively small areas of the coast. To refine the test we classified each section according to the cumulative tonnage of roe fishery catch (Table 1) or cumulative sum of the catches in tonnes, taken between January 1 and April 30, from 1970 to 2006. Note that 15 of the 101 sections that had records of spawning activity had no records of catches from those sections.

To estimate and compare spawn frequency, catch and spawn data were divided into two periods. One represented the roe fishery (R) period (1971-2005). The other represented the fish-meal fishery (M) from 1940-1967. For each section, the years with, and without spawn were designated as 'sp' and 'no', respectively. For each period, the number of years (n) with spawning records were n_{Rsp} and n_{Msp} and those without spawning records were n_{noR} and n_{noM} For each section the frequency of spawning for the pre-roe fishery period (f_{Msp}) was:

$$\mathbf{f_{Msp} = n_{Msp} / (n_{Msp} + n_{Mno})}$$

The frequency of spawning during the roe period (f_{Rsp}) was:

$$\mathbf{f_{Rsp} = n_{Rsp} / (n_{Rsp} + n_{Rno})}$$

The change in frequency, between the two periods, was the difference (f_{Rsp}) - (f_{Msp}). Negative numbers indicate a decrease in the incidence of spawning in a section during the roe fishery period. The spawn frequencies (f_{Msp} and f_{Rsp}) in each section were compared with a Chi-square test (with Yates correction for continuity).

For each year and each section the herring spawn data were used to determine whether or not spawning occurred. For each section a Chi-square test (with Yates correction for continuity) examined whether any changes in frequency between the two periods were significant.

Depletion hypothesis - approach 2: section-specific spawn and catch analyses

We reviewed the temporal patterns of spawn and catch data for each section and searched for instances where the continuity of spawning stopped after one or more fisheries. The requirement for this approach is that both herring spawn and catch be examined in approximately the same units – preferably as biomass units (i.e., tonnes) as in the catch data. To do this we first calculated a herring spawn habitat index (SHI) based on an earlier version described by Hay and Kronlund (1987) and which differs from the SI used in the annual assessment reports (i.e., Schweigert and Haist 2006). There are two key features of the SHI. (1) One is that it is calculated in the same units for the entire BC coast, whereas the SI is calculated only for assessment areas. In its most simple form the SHI is dimensionless - although it technically represents the three dimensions of each spawn data record: (i) length; (ii) width); (iii) egg layers or density. (2) The other characteristic of the SHI is that it is based on area-specific spawn coefficients (q_{sp}) that are presumed to remain constant over time. In other words, this method assumes that the coastal topography of spawning areas (depth, inclination of beach, substrates, macrophyte density and composition) provides a reasonable basis for estimation of a spawn coefficient. The best coefficients are those that capture the greatest amount of topographical and physical variation, so it is preferable to estimate the coefficients on the smallest possible area. An earlier approach by Hay and Kronlund (1987) estimated coefficients for each of approximately 70 sections that had adequate records of spawn. For the present analysis these coefficients are calculated for each of 282 smaller units called 'sec-pools', shown as 'x' in the following equation. Sec-pools represent topographically similar areas for which spawn data were combined to provide a most realistic representation of herring spawning areas as follows:.

$$\mathbf{q_{sp(x)} = \text{median (spawn width* spawn layers)}}$$

In instances where long spawns intersected two or more sec-pools, each was adjusted according to the pre-determined geographic limits of each sec-pool. We also used a bootstrapping approach to estimate the error for each sec-pool (see Hay and McCarter, 2006) but these are not included in the analysis here. The estimation of the SHI is made by calculating the product of the spawn length (L), in meters, from a single spawn record, by the spawn coefficient (q) for the area. The SHI for a length of a 100 m spawn in sec-pool 'x' would be:

$$\mathbf{SHI = L\, q_{sp(x)} = 100 q_{sp(x)}}$$

In contrast to the spawn index (SI) that is used in the annual assessment report (i.e., Schweigert and Haist 2007) that is used exclusively for assessment areas only, sec-pool analysis can estimate spawn deposition consistently in both assessment and non-assessment areas. As we show in Part 1 of this report (Hay et al 2007) the total spatial area of non-assessment areas comprises over 50 percent of the BC coast. Therefore it is useful to have a procedure that permits comparison of spawn deposition both within, and outside of assessment areas. Another benefit of the SHI is that it nearly eliminates time trends that have developed from methodological changes in the acquisition of spawning data. Specifically, the estimates of the widths of herring spawning areas, estimated from surveys conducted in recent years, far exceed the estimates from earlier years when most spawn surveys were carried out from the surface (sometimes called Fishery Officer surveys). Such time trends are eliminated in most sections and substantially reduced but not completely eliminated in a few sections. The main cause of such trends arises when herring spawn in new locations, and when assessed by SCUBA divers, provides a width that is relatively wide. In contrast, sec-pool median values that are based on both SCUBA diver and Fishery Officer data, tend to be less extreme or more moderate. In general, we have attempted to use SCUBA diver data as much as possible for the estimation of median spawn widths and layers used in the SHI (Hay and McCarter 2006). (As explained by Hay and McCarter (2006) and elsewhere, egg densities have been measured directly in "egg layer" units starting in 1977. Densities were previously measured and recorded in the database by an "intensity" scale (1-5 from 1928-1950 and 1-9 from 1951-1981) and were subsequently converted to an "egg layer" measurement consistent with the current "egg layer" measurement.)

Expressing spawn data in tonnes: estimation methodology

The spawning stock biomass (SSB), estimated for each of the five assessment Regions in 2006 (Schweigert and Haist 2006), was compared with the total SHI estimated in 2006 for each of the same Regions for which SSB was estimated. The annual SHI is an estimate of the total spawning area (m^2) adjusted for difference in egg layers. The SHI can be estimated for individual spawn records and can be aggregated to correspond to the different geographic units such as sections, statistical areas or assessment areas (or regions). We estimated the spawning biomass for each section, including those outside the assessment areas, by assuming that the SSB is spatially distributed like the spawn or SHI. This assumption is also based on the observation that for Pacific herring, relative fecundity (or the number of eggs/g of spawning female) is almost constant at about 200 eggs/g of female body weight (Hay 1985). Therefore with an equal sex ratio, the estimate is about 100 eggs/g of SSB (both sexes). Therefore, the spawning biomass varies directly with the number of eggs, and the SHI is assumed to be proportional to the number of eggs.

We used the estimate of spawning biomass (SSB in tonnes) for each assessment area as was presented in the annual assessment report (Schweigert and Haist 2006). We used the cumulative SHI for each assessment area to estimate the biomass of spawning herring per unit of SHI. We call this *interpolated* biomass as the IB. The IB was estimated for each section by calculating the product of the annual SSB (converted to Kg) for each Region and the SHI proportion as follows:

$$\mathbf{IB_S = SSB_R * SHI_S/SHI_R}$$

where R is the Region. This equation provides a section-specific estimate of the spawning biomass per square m (kg /m^2) of spawning herring. (*In effect, this is simply a method of using the current biomass estimate, from the stock assessment report, and pro-rating it into different geographic units, with the simple and reasonable assumption that the recorded spawn distribution is representative of the distribution of spawning herring.*) This was estimated for each year and each of the assessment Regions from 1951 to 2006. For the purposes of the analysis in this report, we present the interpolated SHI in tonnes. Spawning biomass in non-assessed herring sections was estimated using a linear regression equation comparing the SHI (as the independent variable versus the SB (as the dependent variable) for post-1950 spawn records (r^2 = 72.2 %). This estimate will vary slightly every year as the database expands but this procedure is a practical way of scaling peripheral spawning areas to be consistent with the major core spawning areas.

Adjusting catch data to match the geographic groupings of sections

Catch data are not recorded or reported by section but instead are recorded according to the Fisheries Management area (Fig. 2) and the geographic location name also is often included. Sometimes during some fishery openings catches may have been taken from section boundaries or in one or more sections. Therefore estimating the annual section-specific catch is not simple and involved some error. Clearly the greatest error is associated with catches taken in sections that are small and geographically contiguous. We estimated section-specific catch by noting the geographic location noted on the catch records, and matching that with the section in which that location occurs. Nearly all coastal location names in BC and corresponding coordinates have been digitized, and can be associated with a specific section. We used this association to allocate these data to individual sections.

In some years small roe fisheries are conducted on two smaller areas: Statistical Area 27 (Winter Harbour) on the north end of Vancouver Island and Statistical Area 2W off the west coast of the Queen Charlotte Islands. These two small areas are known as minor assessment areas and are not subjected to the same sampling intensity. Also they are not subjected to age-structured assessment of spawning biomass. Area 27 is extremely small and supports a highly localized fishery in some years. In Area 2W catch vary among years and are subject to effects of bad weather. For these reasons we have not included these sections in the section-specific analyses of serial depletion.

Results

Surface areas of BC coastal waters related to sections, assessment and non-assessment areas

The total assessed area of the BC coast is 385,725 km^2 but over 90 percent of this area is open, deep water (>200m). The total nearshore area (<200m) included in the main Statistical Areas is about 37 000 km^2 (Table 1). The cumulative area of the six main Regions of BC that are included in the analyses of herring spawn data is less, about 33 000 km^2. Of a total of 108 herring sections listed in BC, a total of 101 have some records of spawning. Slightly more than half of the BC coastal area (~18 000 km^2) are in non-assessment areas.

Spawn frequency analyses

Of the 101 herring sections that have some record of spawning, 86 had some record of roe fishery catches, but in many the roe catches were from only a short period at the early stages of the fishery, prior to the implementation of the present geographically-based management system. The classification of section according to catches is shown in Table 2. Fifteen sections had no records of catches (class 0) and thirty had only small catches (class 1, with cumulative catches between 1-500 tonnes). Fifty-six other sections had roe fisheries, for some or all of the years from 1970-2006. Eleven had cumulative catches between 500-1999 tonnes (class 2), 21 had cumulative catches between 2000-9999 tonnes (class 3), 16 had cumulative catches between 10,000-49,999 tonnes (class 4), and 8 had cumulative catches greater than 50,000 tonnes (class 5).

The frequency of spawning was highest in sections that had the highest SHI (Figs 4a-b). About 10-20 sections had spawning frequencies that were very high (>95%) so spawning was continuous in these. All of the remainder had some temporal gaps in spawning. There was no apparent relationship between section size (in km^2) and the frequency of spawning (Fig 4c).

When examined among different classes of fisheries (see Table 1) there were only 11 frequency changes that were significant among class-4 and class-5 fisheries. One class-5 section had a significant increase in frequency – so that the frequency of herring spawning increased in locations that had the most intense fisheries. Ten class-4 sections had significant frequency changes: six were positive and four were negative (Table 3). Figure 5 seems to show that there is no reduction of spawn frequency in sections that support herring roe fisheries. Of course, it could be argued that these results might be confounded because they do not consider inter-annual temporal changes in spawn frequency. Specifically, if spawning distributions change with time, and if the geographic location of fisheries tends to follow fisheries, then the results presented in Fig. 5 could obscure temporal trends to reduce total spawn frequency *after* fishing starts. This issue is examined in the next section that considered the temporal trends of spawning and catches within each section.

Serial depletion analyses – review by region

Each section with a history of catch and spawn was included in these analyses. Detailed plot of catch (in tonnes) and spawn (in tonnes) by year are presented for each section in Figs. 6-12. Corresponding statistics for each section are shown in Table 3. Trends in spawn and catch for each Region are described below. (More detailed statistical information on spawn and catch are shown in Appendix 1, Tables 1-3. Also, higher-resolution graphs of the plots of catch and spawn for each section are shown in Appendix 1 figures.)

Queen Charlotte Islands (Fig. 6)

All sections have declined in the last 10-15 years. Although roe fisheries have been small or closed, spawning remains *continuous but reduced* in all sections. Section 6 (Louscoone), which is included in the QCI assessment area, declined sharply after a fishery. Based on the co-occurrence of the fishery and sharp decline in spawning this could be an instance of fishery-induced spawn depletion (see symbol on Fig. 6). However the timing of the decline was synchronous with the decline of spawn in other sections (see grey vertical line) where no fisheries occurred. Also, there has been some small spawning activity in Louscoone after the last major herring catch. (Note: this is difficult to see in Fig. 6, but it is clear from the figures describing Louscoone in Appendix 1.) The mean spawning time in Louscoone (Mean DOY = 85) is nearly identical with that of the adjacent section 25 (Skincuttle with a mean DOY of 83) so spawning herring from these two adjacent sections could mix in some years. Therefore the most parsimonious explanation for these trends is that Louscoone is part of a larger spawning group, mainly centered in the Juan Perez Inlet area represented by section 25 (Fig. 6), and that the decline of spawning was a regional phenomenon, not a local one in Louscoone.

Prince Rupert District (Fig. 7)

There are few obvious trends in spawn or catches in this area except that there are no instances where roe fisheries precede sharp reductions, or possible depletions of spawn.

Spawning in the tiny section 33 is usually contiguous with spawns in section 42 (see the thick dotted line on the map and the double pointed arrow joining the charts). Sections 42, (+33), 43 and 52 are the main spawning areas. Section 42 is separated from sections 43 and 52 by the Skeena River outflow. Section 43 has continuous record of spawning but it is slightly diminished in recent years. In some (but not all) years spawning is nearly contiguous with section 52 (Kitkatla) spawns. Spawning times in the three main spawning areas are slightly different: the mean DOY is 95 for section 42, 108 for section 43 and 100 for section 52.

Central Coast –assessment areas (Fig. 8)

There are no sections with spawn depletions following a fishery. However there is a trend toward a general increase in spawn in northern area sections and a decrease in the southern sections. These trends are shown by the block arrows in Fig. 8. Many of the important spawning sections in the central coast area are very small, and collectively are smaller than some of the important herring spawning sections in other areas, such as section 172 or 142 in the Strait of Georgia.

Probably the best explanation for the changes in these central coast sections (within the assessment area) is that spawn is shifting slightly to the north, probably in response to environmental change such as sea temperature. Such changes in spawn distribution have been described for the Strait of Georgia (Hay and McCarter 1999).

Central Coast –non-assessment areas (Fig. 9)

Some non-assessment sections of the central coast of BC may have biological connections to the herring within the assessment areas (dark lines) but several probably are distinct groups. Sections 83 and 84 have exceptionally late spawning times, and when data from both sections are pooled, spawning is continuous. Sections 92 and 93 (Rivers Inlet) and sections 102 and 103 (Smith Inlet) also may be one or two separate populations, but all sections are very close to one another, including close proximity to Fish Egg Inlet (section 091). The catch and spawn data from Fish Egg Inlet, if examined without a geographic context, may appear to be a clear example of depletion after a fishery (in the pre-roe-fishery reduction fishery period), but the close proximity spawns in Rivers Inlet, and other areas, which were relatively high during the time when spawns in Fish Egg Inlet diminished, makes that unlikely. Also, this is a remote area and it is not always clear if herring spawns occur, and even if they do they may go unreported and un-surveyed.

Johnstone Strait (Fig. 10)

There are no examples of serial depletion in this area, and probably this would not be expected because the roe fishery only occurred in this area for a few years in the 1970's. In general, spawning in many areas seems to be more frequent in the 1960's and 1970's, except for Kingcome and Knight Inlet. In part, the post-1980 decreases in this area may reflect a much lower level of spawn surveys, because this area has not been included for fishery assessments or commercial roe fisheries. This area also has developed a spotty record for spawn surveys – and in at least one year, spawn records from the entire area were not collected.

Strait of Georgia (Fig. 11)

Two sections (152 and 182) are noted as being possible examples of local depletion. During the late 1980's and 1990's section 152 was an area of considerable local concern that roe fisheries led to local spawning depletion. The evidence from spawn surveys does not support the contention of local depletion in section 152. Most importantly, spawning has occurred there for a number of years subsequent to the last roe fishery. In more recent years there have been substantial, but episodic instances of large spawns in this section.

It is difficult to rule out the possible depletion of spawn in section 182 because spawning stopped at the same time as a relatively large fishery. However, there is no record of continuous spawn in this section *prior* to the decline. Also, the decline in spawn occurred in many adjacent sections, with and without roe fisheries.

West Coast of Vancouver Island (Fig. 12)

Prior to 2004, no sections show evidence of serial depletion. In recent years however, the spawn index has decreased in some sections, especially sections in Section 253 (Nuchatlitz) where roe fisheries were conducted. It is too early, however, to conclude that the decline of spawn in this area is associated with recent roe fisheries. Also, we note that spawn has declined in other sections on the West Coast of Vancouver Island where no roe fisheries have occurred. In general spawning seems to be decreasing in the south and increasing in the north. For examples spawning increased in sections 242 and 245 while decreasing in sections 243 and 244. These changes may be indicative of environmentally-induced shifts in spawning locations.

Discussion

Depletion and spatial scales

This report attempts to compare geographic distributions of fisheries relative to the geographic distribution of herring spawning. To make such comparisons, we first had to develop methods to array herring catch data (collected with a different set of geographic criteria known as Pacific Fishery Management Areas, shown in Fig. 2) against the historical herring spawn data, which are analyzed in related but different geographic units known as sections. An additional requirement was the scaling of the herring catches and spawn data in the same units (i.e., metric tonnes). As we point out below, however, there are limits to these analyses related to the accuracy and precision of spawn and catch data. A fundamental objective related to the comparison of catch and spawn data was to determine if there were geographic mis-matches between fishing effort and spawning had resulted in spawn depletions.

The question of geographic depletion of spawning components is integral to assumptions about the biological definition and criteria of a stock. This issue has been a long-standing concern for understanding the biology, assessment and management of Pacific herring in BC, and it continues to be a major focus of modern fisheries research (Cadrin et al. 2005). Even the understanding and definition of stocks continues to evolve (Waldman 2005) and understanding the biological basis of Pacific herring populations also is an evolving process. It seems clear, however, that there is very little genetic variation among the populations considered to be part of the major herring stock assessment areas of the BC coast (Beacham et al. 2001). Clearly there are some locations in northern BC waters where there is evidence of genetic differentiation (e.g., Skidigate Inlet, or section 022 (Fig. 6). Another is the Cherry Point herring population in northern Puget Sound, off Washington State, USA (Gustafson et al. 2006). Such areas, however, are not part of the BC commercial roe herring fishery, as it has developed in the last 30 years. Therefore while the scientific debate about the structure of fish (and herring) stocks will continue into the future, it is vital to appreciate that the present roe fishery operates in areas that do not jeopardize genetic variation among the smaller, peripheral stocks.

Matching fishing effort with spawning distribution

In general, within each assessment area, the current roe fishery is designed to take a maximum of twenty percent of the estimated spawning biomass, provided that the biomass is above the pre-determined ‘cutoff’ level (Stocker 1993). Within each assessment area, however, there are no formal management protocols to ensure that the exact sites of fishing effort are proportional to the spawning that occurs there. Such a system would be difficult to design because spawning locations vary among years. Also, it would be logistically unrealistic to control fishing effort so exactly. It follows, therefore, that in the BC herring roe fishery there probably will be some imbalance between the geographic focus of fisheries and the geographic distribution of spawn. Such an imbalance is not a biological concern unless there is some degree of population structure *within* assessment areas.

There are many examples of different spawning areas within assessment areas and some observers have considered these to be separate populations. The fundamental biological questions, however, concern the degree of connectivity among such putative populations or spawning concentrations (Warner and Cowen 2002). Clearly in BC herring such putative local populations are not genetically distinct (Beacham et al. 2001). Each potential sub-component within an assessment area might not make a proportional contribution to recruitment. Ideally the geographic structure of a roe fishery should match the geographic structure of a herring spawning stock. However even a fishery where the geographic distribution of fishing effort was perfectly matched with the distribution of spawning fish, could have different impacts on subsequent recruitment *if* some areas were more successful at producing recruits than others. Further, some spawning areas, by virtue of their oceanographic characteristics, may produce recruits with greater tendencies to migrate to other areas. Geographic differences in the relative contribution to future recruitment (which might result from geographic differences in survival of early life history stages) now appear to be commonly seen in studies of coral reef fishes (e.g. Armsworth 2002) and other marine fishes with a larval dispersal phase. It seems probable that similar variation exists in BC herring populations, both between and within the present assessment areas.

The size of assessment areas relative to the geographic range of fisheries

Present assessment area boundaries are much larger than the geographic ranges of actual fisheries (See Appendix 2 for a description of the areas of the roe fishery.) There may be valid logistical reasons for maintaining very large assessment areas relative to the much smaller areas used for fisheries but this also creates some concerns. Clearly herring spawning distributions can change from year-to-year so it may be comforting to managers to maximize the probability that all spawning, and therefore herring fisheries, can be contained *within* the assessment areas. However maintaining the large assessment areas also represents a potential management liability because the boundaries of the present assessment areas can be misleading. Changes in spawn deposition that are not related to fishery activity can occur in the peripheral areas of the assessment areas. This has led some observers to erroneously conclude that such changes are fishery-induced, even when there is absolutely no interaction with fishing activity.

Implications for management

Based on the evidence of widespread mixing from genetic analysis, a geographically focused fishery may not represent a risk for loss of genetic diversity (Beacham et al. 2001). However there may be a risk of a reduction in recruitment of spawning components that contribute disproportionately high rates of recruits to surrounding areas. If so it is plausible that this could eventually lead to lower SSB from different spawning components *within* assessment areas. The alternative to this risk is a revised assessment process that examined smaller geographic units of herring to be used for assessment areas. At the extreme, this could involve the identification of dozens of small stocks. Each additional amount of complexity added to the management stock structure adds substantially to the corresponding management tasks that would require more specialized and costly planning, additional monitoring and enforcement to have a larger number of smaller fisheries. Therefore there is a necessary and valid management tradeoff between (i) maintaining the present definitions of herring stock configuration and (ii) a stock definition revision that recognized more spatial variation that may be more biologically appealing but much more expensive and awkward to manage. A compromise is to continue to urge managers to spread catches spatially and whenever possible, resist taking the entire target catch from the same location. Indeed, such a practice has been incorporated into Fisheries and Oceans management for years and we recommend that it continue. Such an approach is especially important in assessment areas where potential fisheries occur geographically in two or three disjunct locations, such as the West Coast of Vancouver Island and the Prince Rupert District.

Natural changes in spawning distribution

Given the present precautionary management of Pacific herring in British Columbia, the concerns about loss of genetic diversity and serial depletion from the herring roe do not appear to be warranted. Also there is no evidence that the present fishery has led to enduring local depletions of spawn, although it is clear that spawn abundance fluctuates widely in some areas. So, because spawning abundances and distributions change naturally it is probable that some observers of the herring fishery will, in the absence of other simple explanations, continue to hold the fishery responsible for such changes in spawn distribution. There are, however, other explanations for such change. These other explanations are related to variation in inter-annual changes in oceanographic events and biotic variation. The significance of these naturally-occurring factors becomes especially clear when spatial and temporal changes occur in areas without any history of a roe fishery.

The explanations for non-fishery induced changes in spawn distribution are beyond the scope of this paper. We point out, however that systematic changes in spawn distribution have been noted previously in BC (Hay and McCarter 1997, 1998). Changes in spawn distribution also have been described elsewhere in the eastern Pacific including Washington State (Gustafson 2006), Alaska (Brown and Norcross 2001) and California (Spratt 1981). In other herring populations changes in spawning locations have been related to changes in trophic conditions and feeding in the Baltic (Rajasilta et al. 1992) and Norwegian Sea (Slotte 1999). In the Sea of Okhotsk spawning locations may change with ice conditions (Tyurnin 1973).

In most cases of changes in spawning distribution in other populations, such as those in Atlantic herring, the geographic range of spawn changes is considerably greater than many of the relatively fine-scale changes that occur in BC where shifts of spawning, sometimes by only a few km, can be interpreted by some as examples of depletion. In contrast, changes of spawning sites in the North

Atlantic have been documented as occurring over hundreds and even thousands of km (Hay et al. 2001). Nevertheless, we do not have fully satisfactory explanations for changes in spawn distribution observed in BC, although probably there are several factors that affect spawning distribution. A credible explanation is sea surface temperature. Hay and McCarter (unpublished analysis) have shown that the center of distribution (centroid) of spawning in the Strait of Georgia changes as a function of mean sea-surface temperature. Alderdice and Velsen (1971) showed that herring egg survival to hatching was optimal at about 8.0 C^o. Using lighthouse data it can be shown that the mean annual temperature at the time of spawning changes, with a shift to the north (within the Strait of Georgia) within recent years. Such a geographic shift is also seen in the distribution of herring spawning. A shift in spawn distribution related to oceanographic conditions also may explain the apparent shift of spawning to the north during recent years in the Central Coast area of BC. There are other explanations however, including instances of intense predation in specific locations by predators such as seabirds (Haegele 1993a, Bishop and Green 2001) or epibenthic predators, especially crabs (Haegele 1993b).

Limitations of the data used in the analyses

Regional variation

The estimate of spawning biomass per unit area varies among regions. Theoretically such differences should not exist. One potential explanation for these differences could be small differences in relative fecundity, so the biomass required to produce eggs would vary among Regions. However, that is not the explanation for the variation observed here because there is no evidence for such geographic variation in relative fecundity within BC. Instead there may be several other reasons for such variation, related to the assumptions in the assessment methodology about area-specific differences in the catchability, or geographic differences in the relative importance of age-structure data versus spawn data. Although noteworthy, these regional differences are relatively small and, in any event, cannot be resolved in this paper except to note that there are some process-oriented assumptions in the assessment model related to regional differences in catchability or recruitment.

Coast-wide annual variation in estimates of SSB/km^2

The computation of the estimate of kg/m^2 for spawning areas will change year by year as the retrospective estimates of past biomass estimates change. In general, unless there are substantial changes made in the assessment models (as there were between 2005 and 2006) these annual variations should be small.

Area-pro-rating

Clearly, the assumptions made in the calculation of the SHI will result in some location-specific deviation between the estimates of spawn made from diver surveys. For instance, it is probable that in instances where especially heavy spawn deposition occurs over small areas, the actual spawn deposition may deviate significantly from a location-specific estimate of spawn based on the SHI. Nevertheless, such deviations would be short-term (i.e., ~ one year) and would not be sufficient to alter the temporal patterns of relative amounts of spawn and catch seen over many years in the sections (as in Figs. 6-12).

Acknowledgments

Funding for this project was provided by the Herring Conservation and Research Society. Lorena Hamer provided helpful useful comments on an earlier draft. Rick Gustafson (NOAA, Seattle) and Bryan Rusch (Fisheries and Oceans Canada) and other participants of the PSARC pelagic sub-committee made many useful and helpful comments.

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Table 1. Total area in square km (km^2) of the five main fishing regions in the British Columbia coast, and the number of sections in each region. The 'NON' region refers to areas of the coast that are not part of the main stock assessment areas and therefore not considered for openings in the herring roe fishery. Note that there are seven more sections listed here than are shown in Table 1. These sections are 31, 71, 81, 101, 171, 201 and 211 and the locations of most can be seen in Figures 6-12 or more clearly in the Appendix 1 figures. These sections have no records of spawn.

Region	km^2	Number of sections
CC	2883.2	10
NON	18353.4	51
PRD	4533.6	8
QCI	1619.1	5
SOG	8483.3	23
WCVI	1478.9	11
Total	**37351.5**	**108**

Table 2. Classification of sections according to the cumulative tonnes of catch in the roe fishery. All of the sections have some records of spawning activity but 15 of those have no records of roe catches.

Scale	Number of sections	Range of cumulative tonnage
0	15	0
1	30	0-499
2	11	500-1999
3	21	2000-9999
4	16	10000-49999
5	8	>50000
All	**101**	

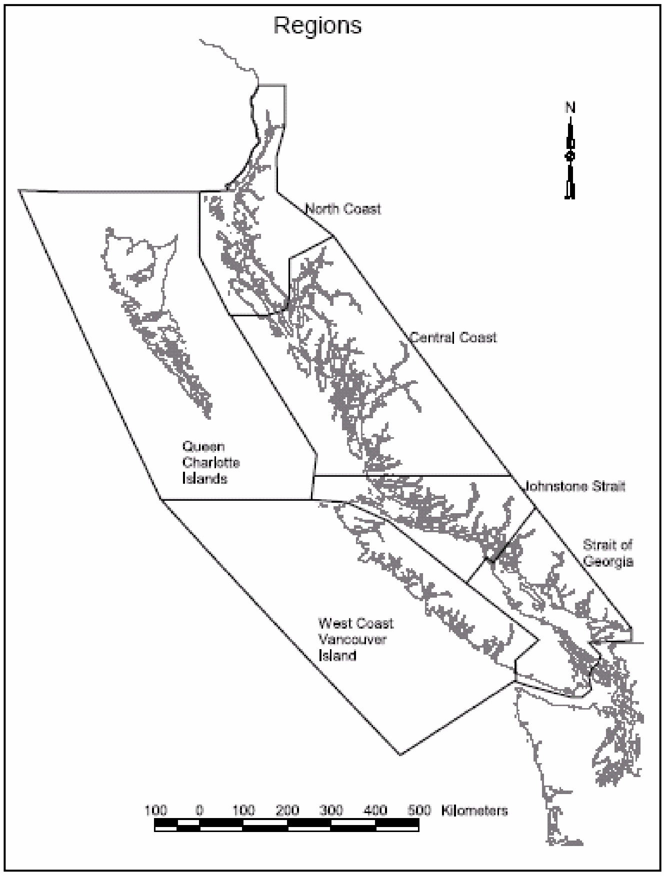
Table 3. The annual frequency of spawns by Section. The cumulative tonnes of catch are shown as the 'Tonnes catch' column. The size class of the fishery (see text and Table 1 for explanation) is shown as from 'Class RF' (where RF represents the 'Roe Fishery'). The frequency of annual spawning for the RF, the periods prior to the RF (Pre-RF) and for the entire time series (1941-2006) are shown as f(RF), f(pre-RF) and f(all), respectively. An increase or decrease is shown as '+/-'. The last column shows the Chi-square estimate. Significant values are shown on the left, if negative (significant decrease in spawn frequency) and on the right, if positive (increase in spawn frequency). The Chi-square value is shown in bold font, in a 'box' if it represents a Section with Class-4 or Class-5 fisheries. Significant changes occurring in Class-5 Sections are highlighted in a bold box.

Section	Tonnes catch	Class RF	f(RF)	f(pre-RF)	f(all)	+/-	Chi square		
							negative		positive
1	339	1	0.250	0.226	0.239	0.024		0.003	
2	2292	3	0.806	0.355	0.597	0.451			12.253
3	7182	3	0.917	0.419	0.687	0.497			16.902
4	*	0	0.278	0.161	0.224	0.117		0.717	
5	5481	3	0.750	0.387	0.582	0.363			7.588
6	19993	4	0.833	0.387	0.627	0.446			**12.337**
11	48	1	0.056	0.065	0.060	-0.009		0.132	
12	346	1	0.306	0.032	0.179	0.273			6.705
21	27309	4	0.889	0.968	0.925	-0.079		0.575	
22	2703	3	0.500	0.936	0.702	-0.436	13.077		
23	15201	4	0.639	0.097	0.388	0.542			**18.394**
24	4495	3	0.861	0.710	0.791	0.151		1.486	
25	72141	5	0.972	0.903	0.940	0.069		0.451	
32	1311	2	0.222	0.097	0.164	0.125		1.105	
33	18566	4	0.944	0.613	0.791	0.332			**9.162**
41	392	1	0.056	0.032	0.045	0.023		0.018	
42	76977	5	1.000	1.000	1.000	0.000		*	
43	3894	3	0.944	0.710	0.836	0.235			5.089
51	164	1	0.139	0.161	0.149	-0.022		0.008	
52	64452	5	1.000	0.936	0.970	0.065		0.685	
53	176	1	0.333	0.226	0.284	0.108		0.493	
61	*	0	0.111	0.000	0.060	0.111		1.951	
62	*	0	0.333	0.097	0.224	0.237			4.089
63	*	0	0.306	0.710	0.493	-0.404	9.327		
64	*	0	0.028	0.452	0.224	-0.424	14.867		
65	*	0	0.111	0.097	0.105	0.014		0.044	
66	*	0	0.139	0.484	0.299	-0.345	7.891		
67	38653	4	1.000	0.968	0.985	0.032		0.006	
72	81261	5	1.000	0.774	0.896	0.226			**6.824**
73	2412	3	0.194	0.968	0.552	-0.773	37.215		
74	72071	5	0.972	1.000	0.985	-0.028		0.006	
75	2642	3	0.667	0.419	0.552	0.247		3.181	
76	16160	4	0.972	1.000	0.985	-0.028		0.006	
77	15145	4	0.639	0.000	0.343	0.639			**27.391**
78	10444	4	0.583	0.226	0.418	0.358			**7.345**
82	*	0	0.250	0.323	0.284	-0.073		0.149	
83	*	0	0.667	0.581	0.627	0.086		0.223	
84	171	1	0.667	0.226	0.463	0.441			11.309
85	4369	3	0.972	0.581	0.791	0.392			13.173
86	1755	2	0.528	0.226	0.388	0.302			5.188
91	19	1	0.056	0.484	0.254	-0.428	13.955		
92	996	2	0.528	0.774	0.642	-0.246		3.393	
93	2757	3	0.889	0.968	0.925	-0.079		0.575	
102	5677	3	0.972	0.968	0.970	0.005		0.375	
103	1466	2	0.389	0.226	0.313	0.163		1.371	
111	0	1	0.056	0.097	0.075	-0.041		0.03	
112	11	1	0.472	0.484	0.478	-0.012		0.023	
121	928	2	0.139	0.065	0.105	0.074		0.35	
122	11673	4	0.750	0.968	0.851	-0.218	**4.623**		
123	1740	2	0.444	0.936	0.672	-0.491	16.053		
124	37	1	0.333	0.807	0.552	-0.473	13.226		

Table 3
Continued

Section	Tonnes catch	Class RF	f(RF)	f(pre-RF)	f(All)	+/-	Chi square
125	857	2	0.667	0.936	0.791	-0.269	5.746
126	4380	3	0.944	0.936	0.940	0.009	0.132
127	2039	3	0.917	0.710	0.821	0.207	3.548
131	226	1	0.028	0.000	0.015	0.028	0.006
132	5663	3	0.639	0.903	0.761	-0.264	5.031
133	178	1	0.694	0.516	0.612	0.178	1.543
134	167	1	0.833	0.742	0.791	0.091	0.38
135	698	2	0.472	0.742	0.597	-0.270	3.978
136	11	1	0.000	0.581	0.269	-0.581	25.703
141	445	1	0.306	0.161	0.239	0.144	1.196
142	247314	5	0.972	0.903	0.940	0.069	0.451
143	41531	4	0.972	0.710	0.851	0.263	**7.093**
151	85	1	0.111	0.258	0.179	-0.147	1.549
152	12582	4	0.639	0.936	0.776	-0.297	**6.812**
161	135	1	0.028	0.032	0.030	-0.005	0.375
162	519	2	0.111	0.710	0.388	-0.599	22.673
163	315	1	0.389	1.000	0.672	-0.611	25.503
164	394	1	0.167	0.677	0.403	-0.511	16
165	526	2	0.250	1.000	0.597	-0.750	35.889
172	39528	4	0.806	0.936	0.866	-0.130	1.43
173	16953	4	1.000	1.000	1.000	0.000	*
181	7513	3	0.667	1.000	0.821	-0.333	10.423
182	5110	3	0.333	0.581	0.448	-0.247	3.181
191	142	1	0.167	0.710	0.418	-0.543	18.019
192	398	1	0.056	0.032	0.045	0.023	0.018
193	*	0	0.167	0.452	0.299	-0.285	5.169
202	*	0	0.028	0.161	0.090	-0.134	2.188
220	*	0	0.028	0.000	0.015	0.028	0.006
231	2667	3	0.250	0.871	0.537	-0.621	23.398
232	162333	5	1.000	1.000	1.000	0.000	*
233	396	1	0.167	0.677	0.403	-0.511	16
241	3535	3	0.028	0.742	0.358	-0.714	33.912
242	3202	3	0.806	0.548	0.687	0.257	3.994
243	33281	4	0.750	1.000	0.866	-0.250	**6.932**
244	7915	3	0.639	0.968	0.791	-0.329	8.999
245	29720	4	0.778	0.903	0.836	-0.125	1.105
251	*	0	0.028	0.129	0.075	-0.101	1.224
252	13892	4	0.639	1.000	0.806	-0.361	**11.676**
253	67877	5	1.000	0.968	0.985	0.032	0.006
261	*	0	0.000	0.645	0.299	-0.645	30.1
262	235	1	0.306	1.000	0.627	-0.694	31.437
263	102	1	0.083	0.903	0.463	-0.820	41.801
271	*	0	0.028	0.097	0.060	-0.069	0.451
272	1817	2	0.528	0.613	0.567	-0.085	0.206
273	7078	3	0.972	0.968	0.970	0.005	0.375
274	11	1	0.167	0.226	0.194	-0.059	0.09
280	14	1	0.139	0.355	0.239	-0.216	3.168
291	0	1	0.083	0.032	0.060	0.051	0.132
292	1	1	0.028	0.290	0.149	-0.263	7.093
293	18	1	0.472	0.484	0.478	-0.012	0.023

(a)



(b)

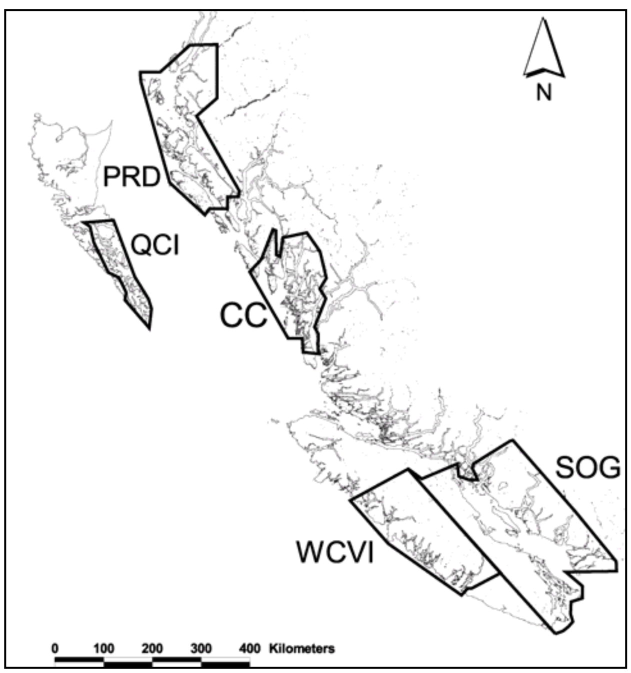


Fig. 1. (a) Fisheries and Oceans Regions and (b) assessment areas on the British Columbia coast. The assessment areas are smaller components of each Region. Annual stock assessments are made for each assessment areas.

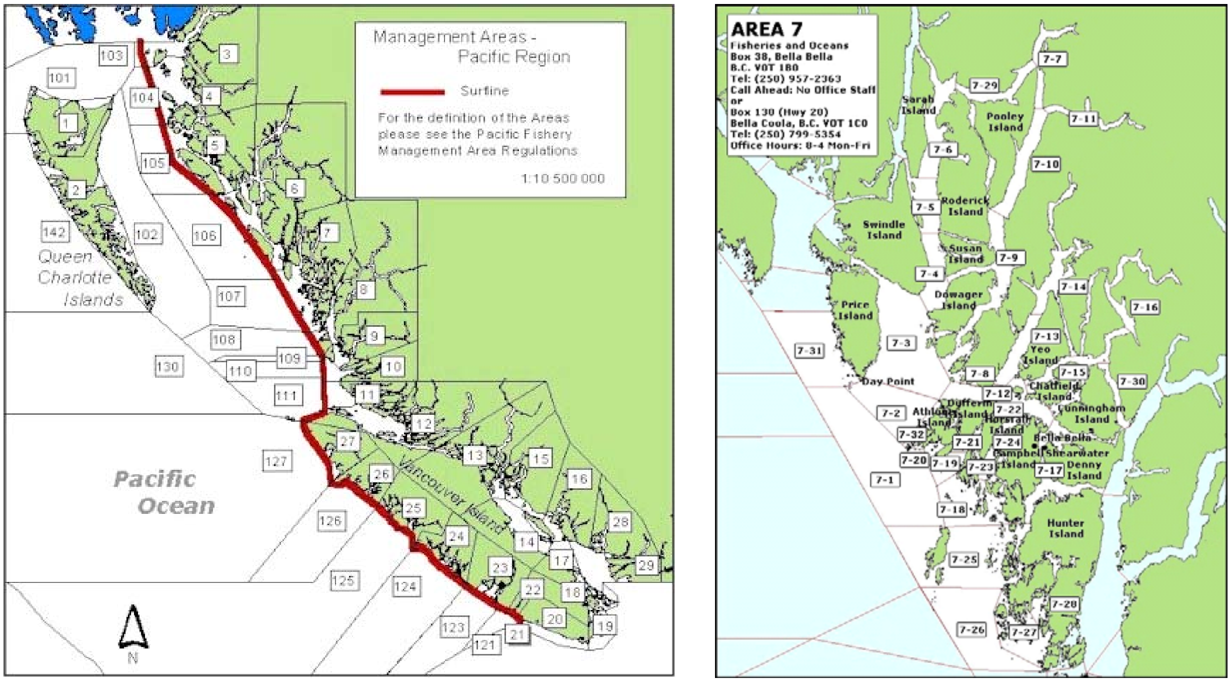


Fig. 2. (a) Fisheries and Oceans Management Areas and (b) and an example of a sub-management area. The Management Areas are identical to statistical areas (shown in Fig. 3) but the terminology and definitions of subdivisions of Management Areas (called sub-areas) differ between the Management and Science Sectors of DFO. Science based stock assessments and spawn surveys use sub-divisions of Statistical Areas called sections (See Fig. 3).

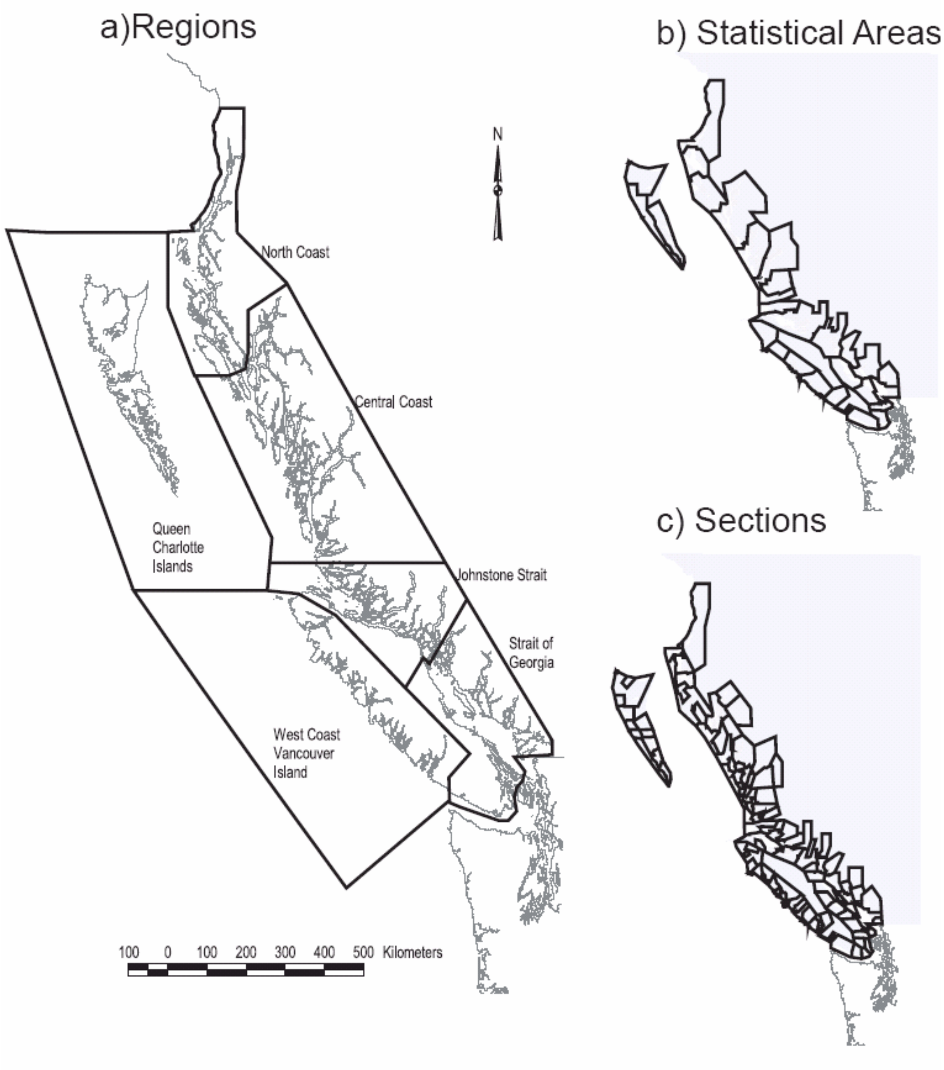
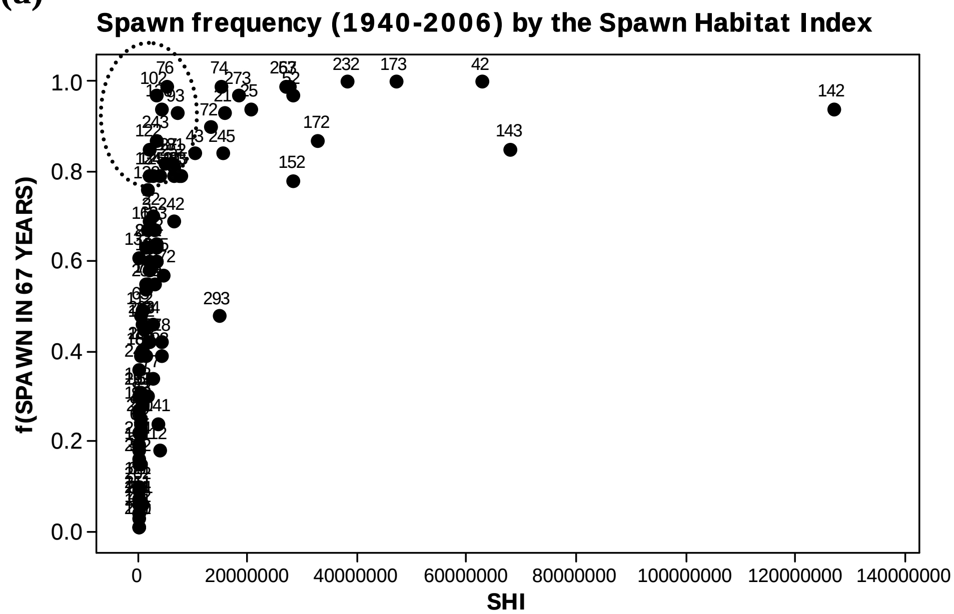


Fig. 3. The relationship between regions (a), statistical areas (b) and sections (c). Stock assessments and spawn surveys are based on geographic units or aggregations of units called sections.

(a)



(b)

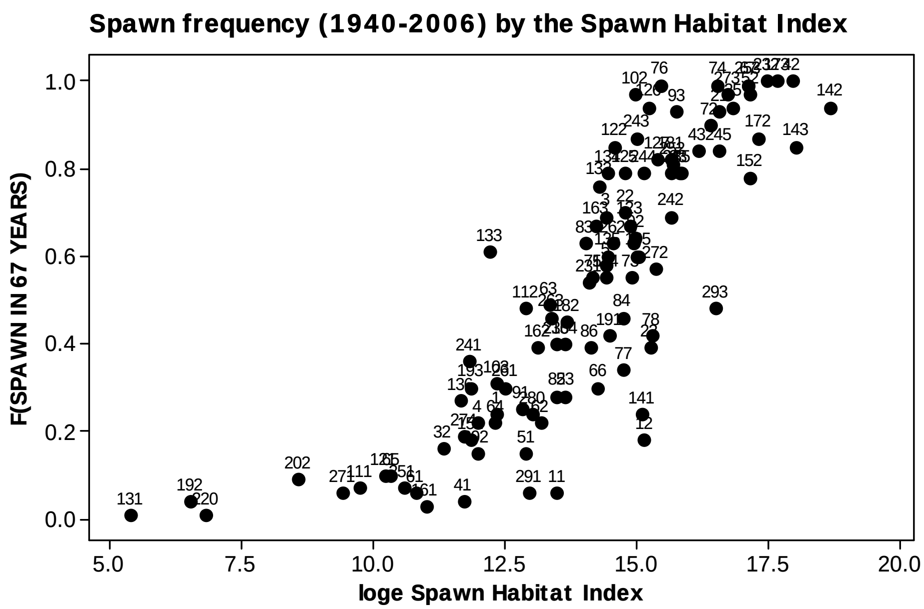


Fig. 4. (a) Variation in spawn frequency among sections (identified as the numbers beside the symbols) according to (a) the cumulative SHI (spawn habitat index). (b) Logarithm of the SHI. Some sections (like those within the dotted circle) have a relatively low cumulative SHI but still have a high frequency. (c) Spawn frequency and section area (km^2). There is little or no relationship between section area and spawn frequency.

(c)

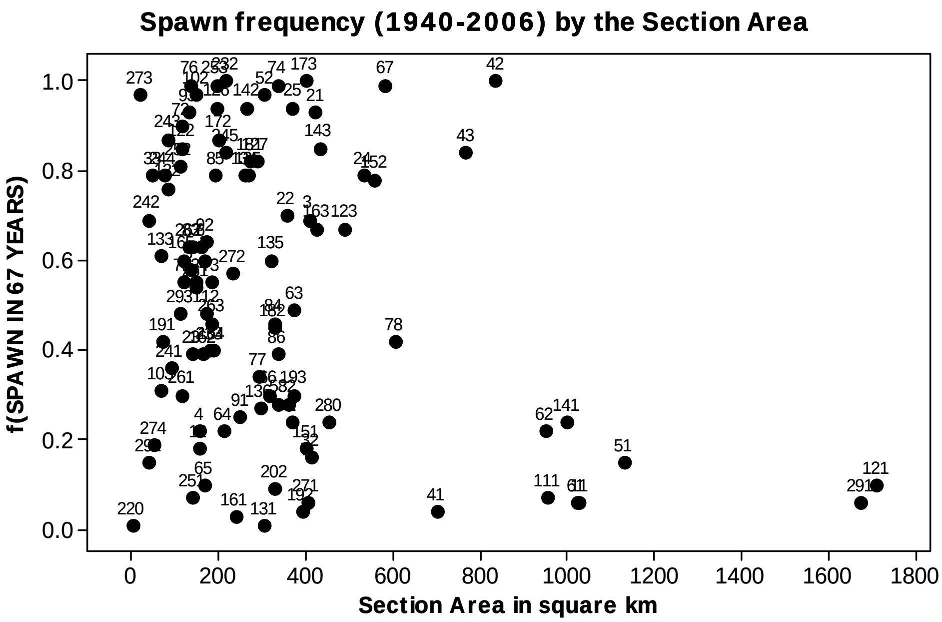


Fig. 4. Continued

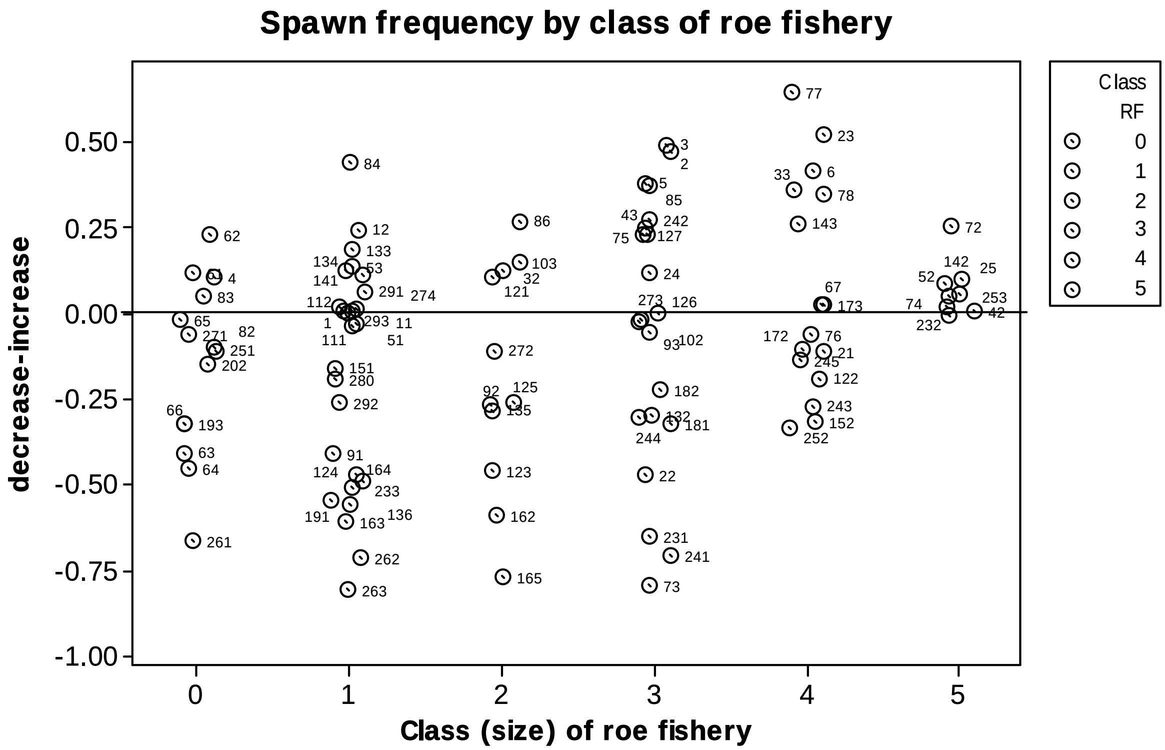


Fig. 5. Spawn frequency as a function of fishery class. Sections with Class 4 and 5 fisheries (defined in Table 1) are the main areas supporting herring roe fisheries. The frequency of spawning, between the period of the reduction fishery (from 1940-1970) has increased during the roe fishery period (1971-2006).

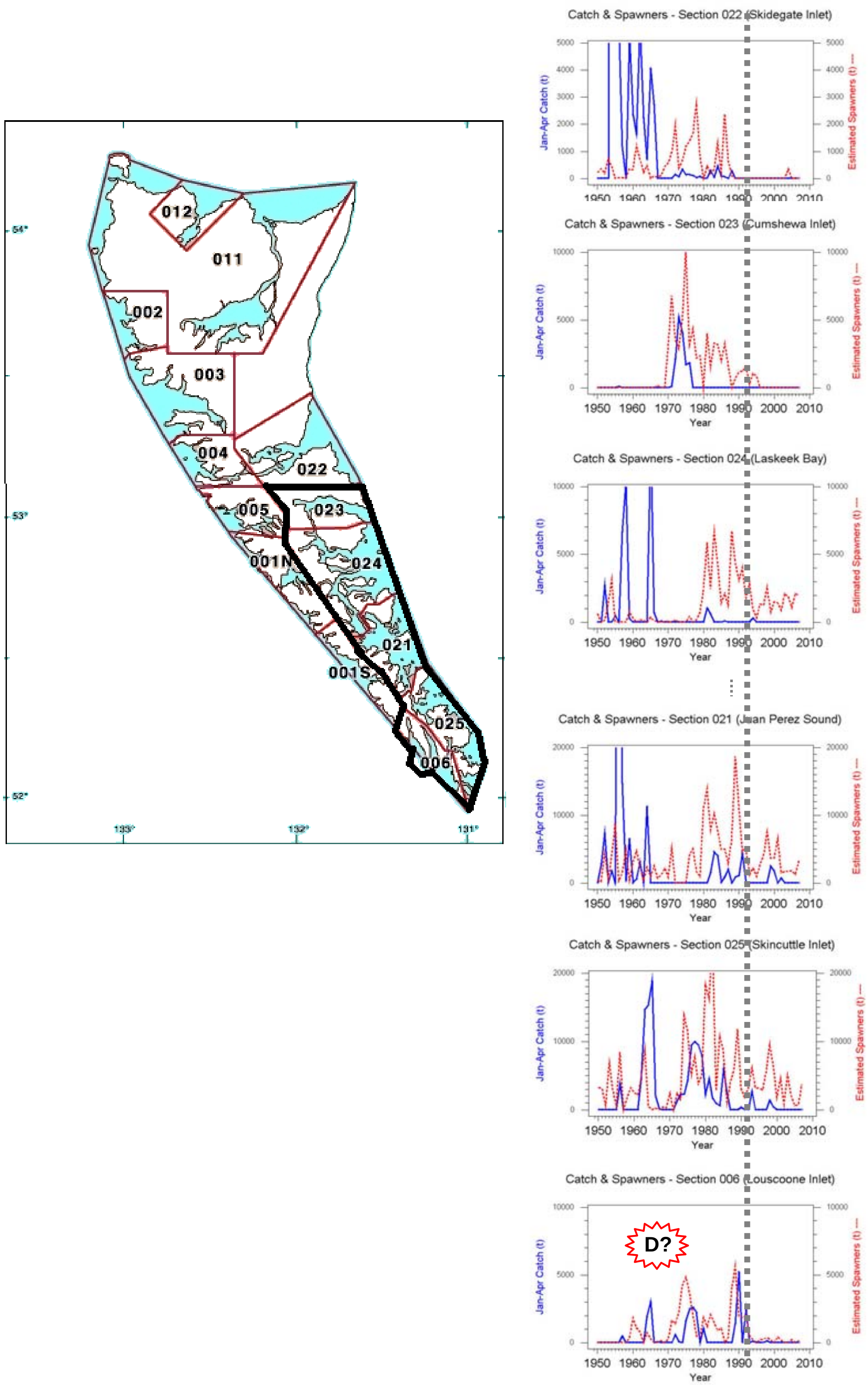


Fig. 6. The assessment Sections and 'minor' stocks of the Queen Charlotte Islands. Spawn in Section 6 (Louscoone), which is included in the QCI assessment area, declined sharply after a fishery and this may be an example of depletion (see symbol "D") although the timing of the decline was synchronous with the decline of spawn in other Sections (see grey vertical line). All of the Sections in this Assessment Area and Region have declined in the last 10-15 years. Roe fisheries have been small or closed but spawning remains *continuous but reduced* in all Sections. This may be difficult to see in the condensed size of the graph below, but it is clear from the corresponding Figure in Appendix 1 that describes Section 6 (Louscoone).

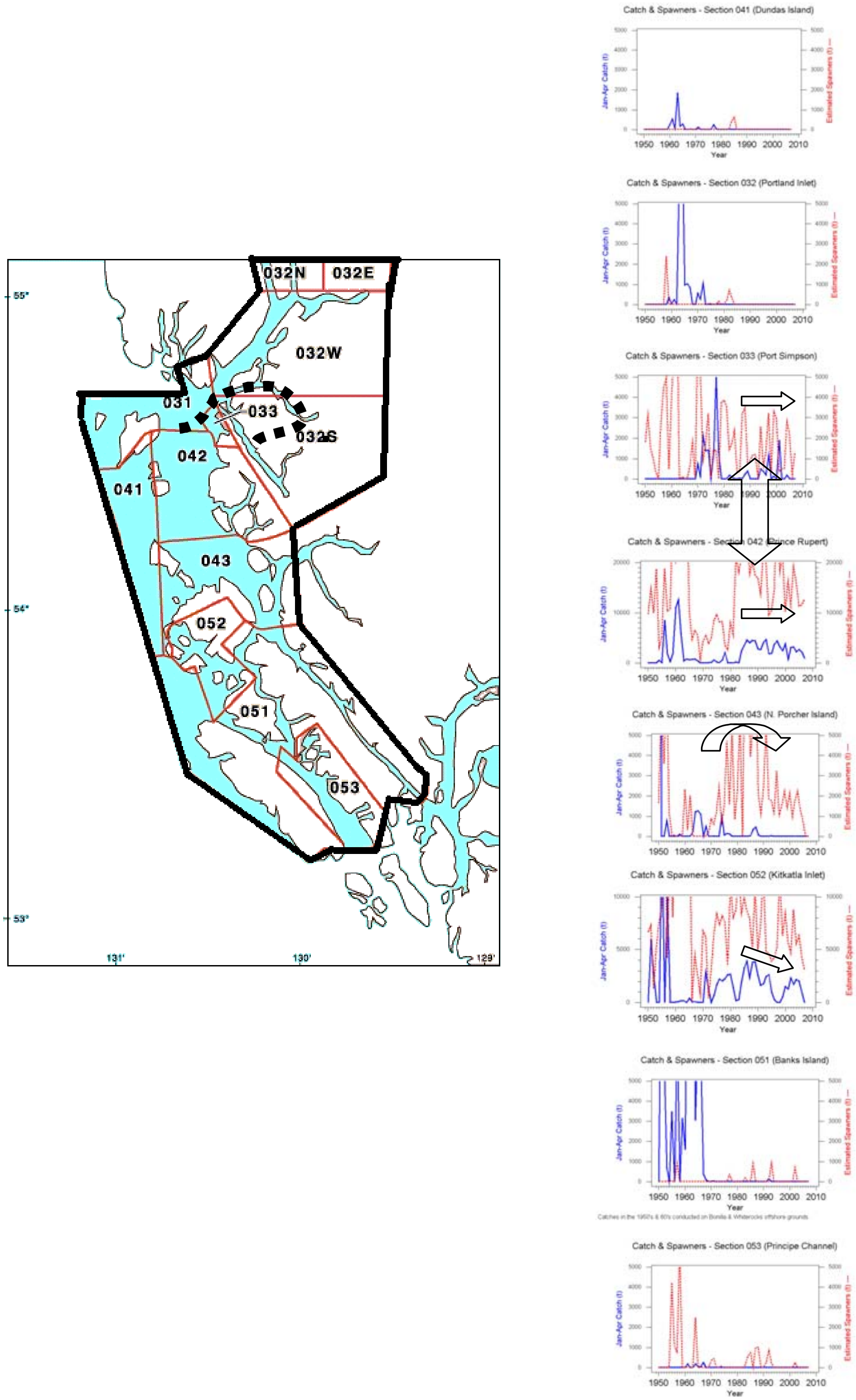


Fig. 7. The North coast of British Columbia herring Sections with adjacent charts showing Section-specific trends in spawning (and catches) with time. The dark lines indication the Sections that are part of the 'assessment areas'. There are few obvious trends in spawn or catches in this area. Spawning in the tiny Section 33 is usually contiguous with spawns in Section 42 (See thick dotted line on map and the double pointed arrow joining the charts.) Sections 42-43 (+33) in Chatham Sound and Section 52 near Porcher Island, are the two main spawning areas. Section 42 is separated from Sections 43 and 52 by the Skeena River outflow. Section 43 has a continuous record of spawning but it is slightly diminished in recent years. In some years spawning is spatially continuous with Section 52 (Kitkatla) spawns. Spawning times in three main spawning areas are slightly different: the mean DOY is 95 for Section 42, 108 for Section 43 and 100 for Section 52.

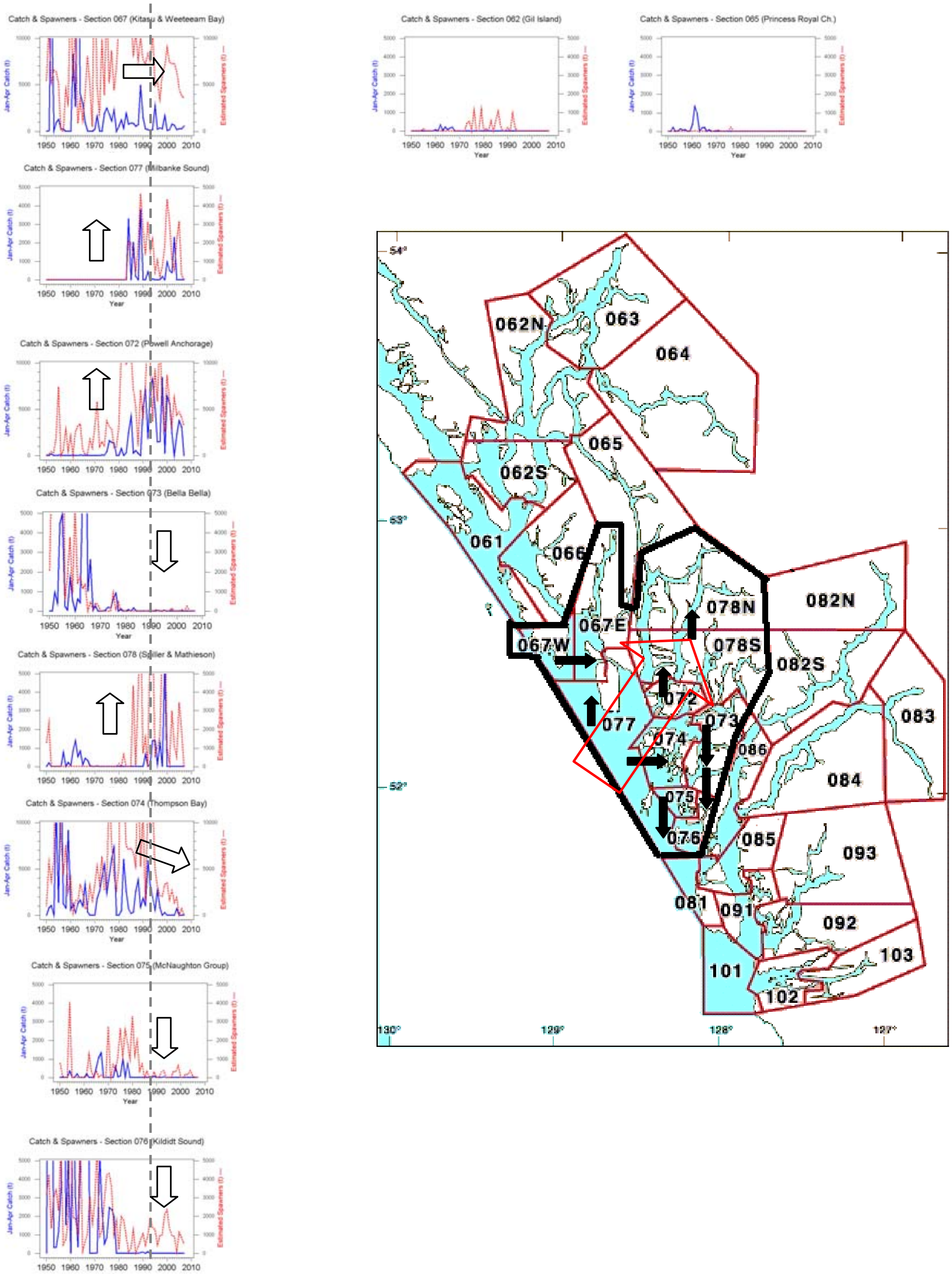


Fig. 8. The Central Coast of British Columbia herring Sections with adjacent charts showing Section-specific trends in spawning (and catches) with time. The dark lines on the map indicate Sections that are within ‘assessment areas’. The arrows on the charts and the maps show the trends toward increase (up arrow), decrease (down arrow) or no change (lateral arrows). No Sections appear to have suffered from spawn depletion following a fishery, but there is a trend toward a general increase in spawn in northern areas (Sections) and a decrease in the southern Sections. These trends are shown by the block arrows. The vertical dashed line joining the charts shows an approximate time when some Sections decreased as others increased.

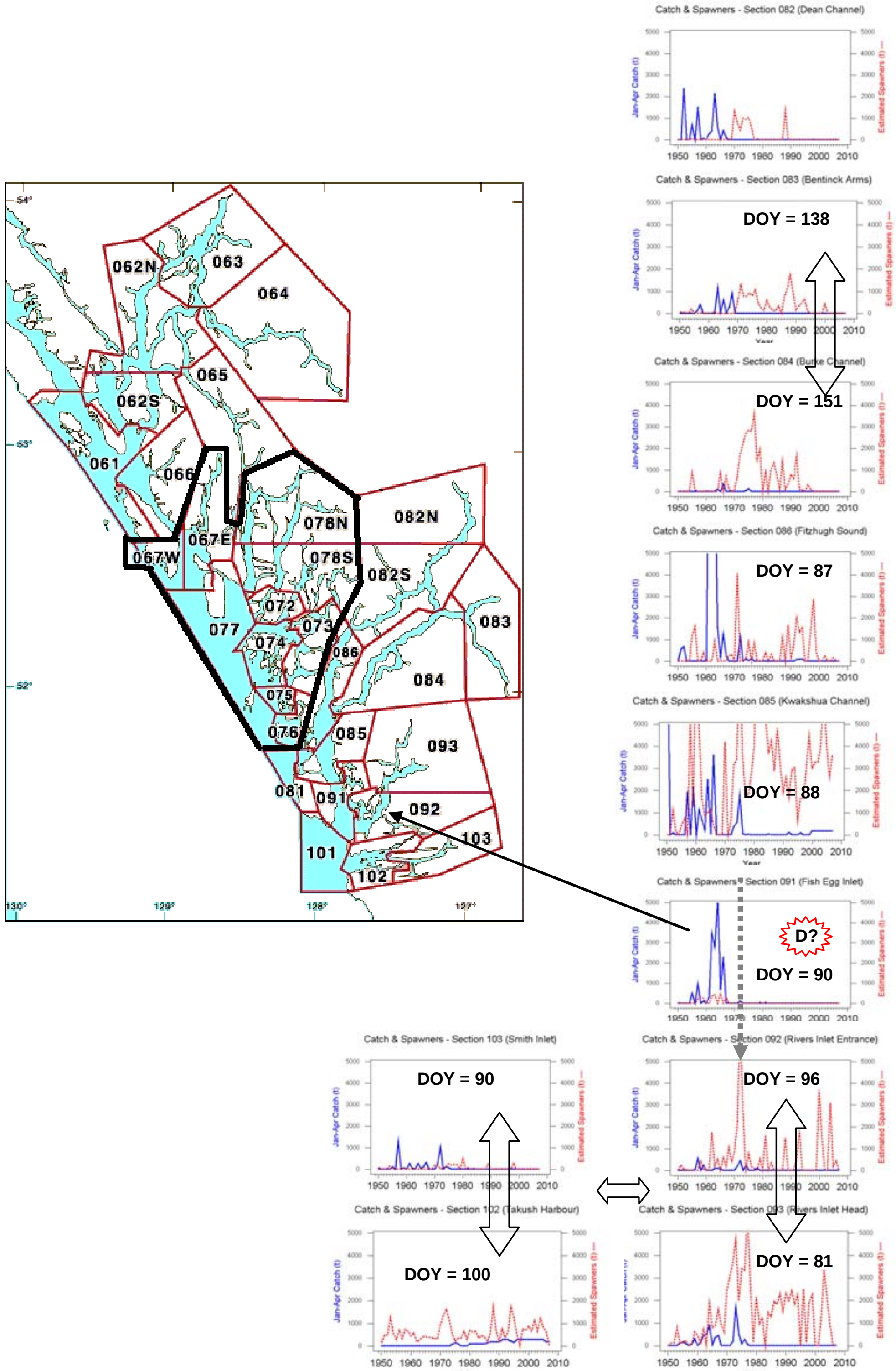


Fig. 9. The *non-assessment* Sections of the central coast of BC. Some Sections may have biological connections to the herring within the assessment areas (within the dark lines on the map) but probably several are distinct spawning groups. Sections 83 and 84 have exceptionally late spawning times, and when data from both Sections are pooled, spawning is temporally continuous. Sections 92 and 93 (Rivers Inlet) and Sections 102 and 103 (Smith Inlet) also may be one or two separate populations, but all are in close proximity to Fish Egg Inlet (Section 091). The catch and spawn data from Fish Egg Inlet, if examined without a geographic context, may appear to be a clear example of depletion after a fishery (in the reduction fishery period), but the close proximity to Rivers Inlet, and other areas, which had substantial spawning when Fish Egg spawns stopped, makes that unlikely (see vertical dashed arrow). Also, some recent spawning in Fish Egg Inlet probably has not been unreported.

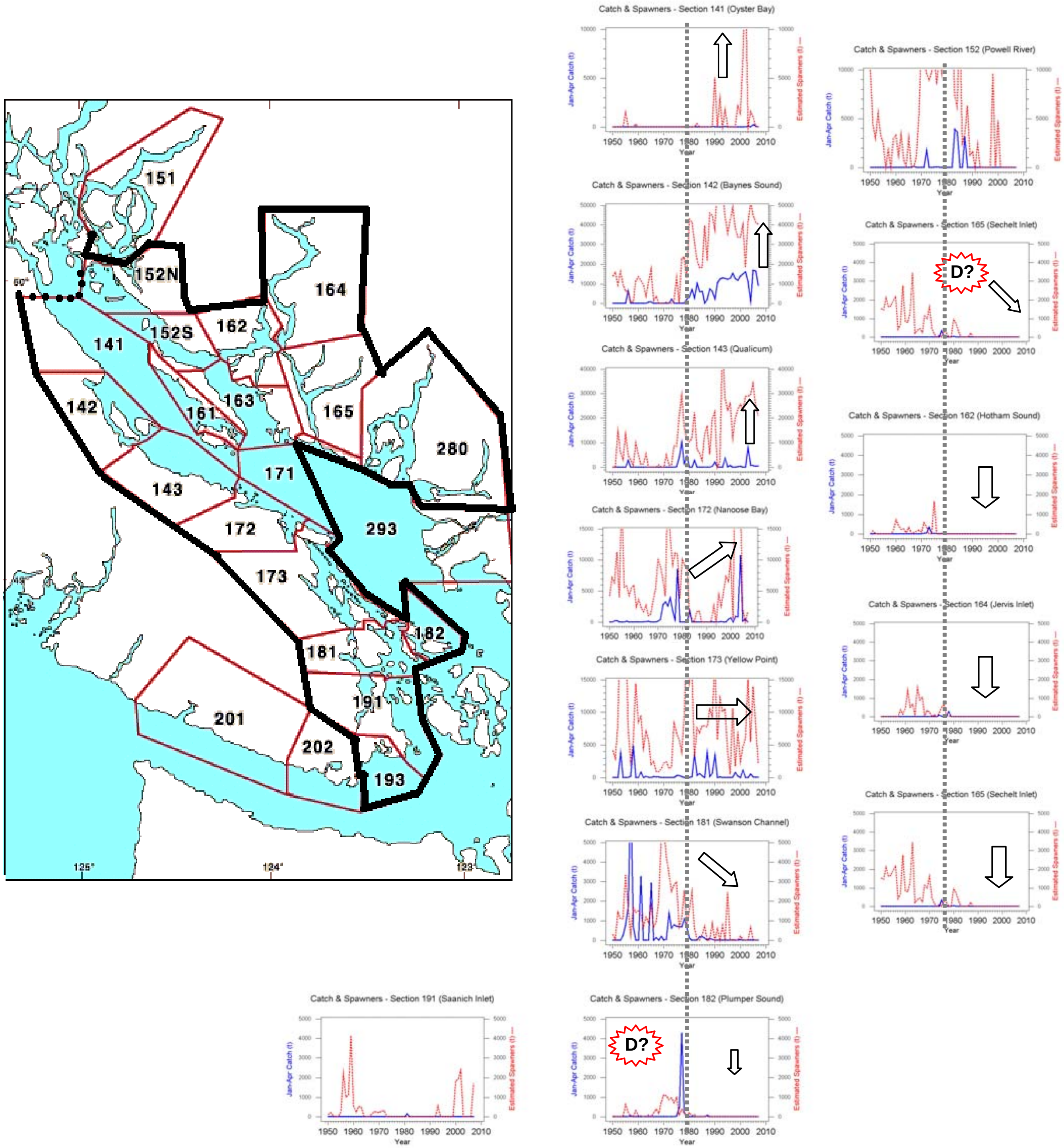


Fig. 10. The main assessment Sections of the Strait of Georgia, with charts of catch and spawn shown according to their approximate east-west and north-south positions. The two vertical dotted lines show a time when spawning seemed to decline in the eastern and southern Sections but increased in the northern and western Sections (see block arrows). Two Sections (152 and 182) are marked with a "D" (inside a callout) to indicate past concerns about local spawn depletion. The evidence from spawn surveys does not support the contention of local depletion in Section 152. Spawning has occurred there for a number of years since the last roe fishery. It is difficult to rule out the possible depletion of spawn in Section 182 because spawning stopped at the same time as a relatively large fishery. However, there was no record on continuous spawn in this Section and the decline in spawn occurred in many Sections, with and without roe fisheries.

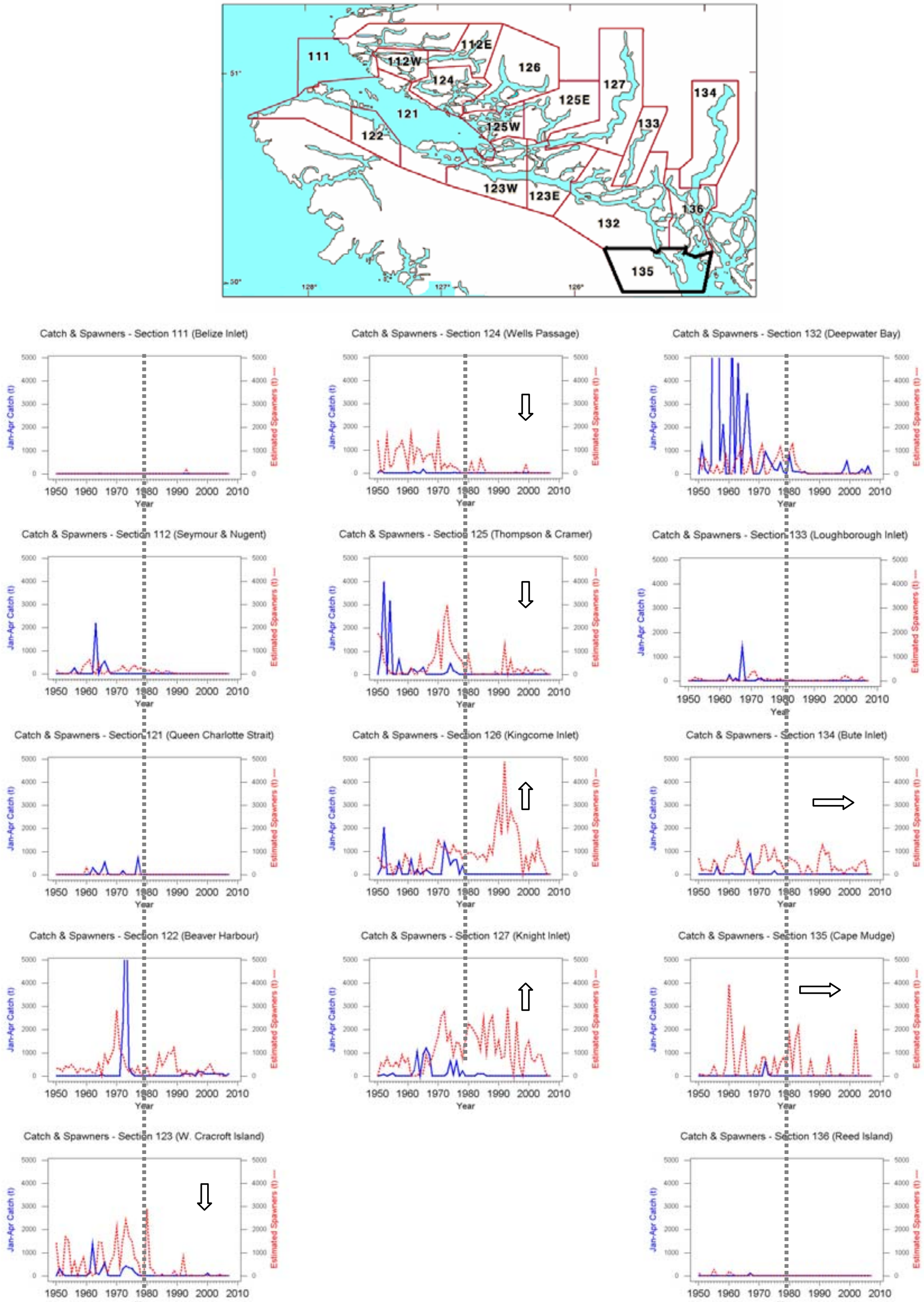


Fig. 11. Johnstone Strait herring Sections with adjacent charts showing Section-specific trends in spawning (and catches) with time. The dark lines indicate Sections that are part of the 'assessment areas'. Section 135 is included with the Strait of Georgia assessment area (See text for explanation). The arrows on the charts and the maps show the trends toward increase, decrease or no change (up, down and lateral arrows). The vertical dashed line joining the charts shows an approximate time when some Sections decreased as others increased. In general spawning in many areas seems to be more frequent in the 1960's and 1970's, except for Kingcome and Knight Inlet. In part, the post-1980 decreases in this area may reflect a much lower level of spawn surveys, because this area has not been included for fishery assessments or commercial roe fisheries.

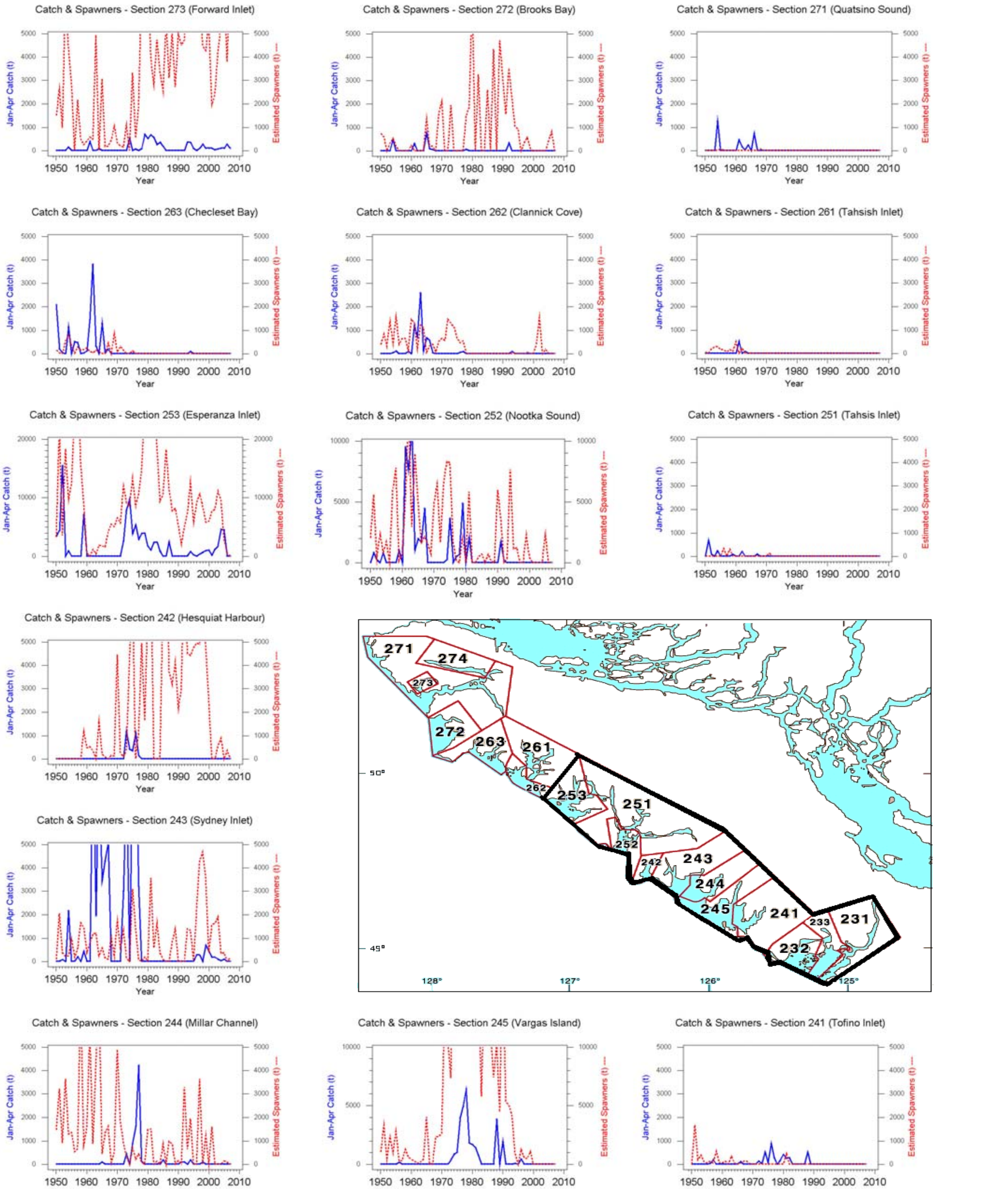


Fig. 12. The west coast of Vancouver Island herring Sections with adjacent charts showing Section-specific trends in spawning (and catches) with time. (Section 274 has little spawn and is excluded.) The dark lines on the map indicate Sections within 'assessment areas' (See text for explanation). There has been a widespread recent decline in spawning in all areas except for Section 273 (top left panel). Otherwise there are few obvious trends in the temporal pattern of spawning.

Appendix 1 - Tables

Appendix one presents three tables (numbered as Appendix Table 1 to 3) and a series of graphical summaries of spawning data for each herring section (identified as Appendix 1 Figures). All figures are larger-scale versions of the Figs. 6-12 that are, of necessity, small. Also, the appendix figures present section-specific statistical summaries of spawning data.

Appendix 1 - Table 1. The estimated cumulative total tonnes of spawning biomass (SB t) and catch (from January 1 and April 30) for all sections between 1980-2005. Also shown is the cumulative sum of the catch and spawn as the total cumulative pre-spawning biomass (PreF-SSB) estimated as the catch plus spawn. The total percentage of SSB removed as catch is shown as '% catch' and the cumulative area of the spawn habitat index (SHI) is shown in km^2. Each section is identified according to its position in either an assessment area (Assess), or in a minor area (Minor) or in a non-assessment area (Non). These are coded in the adjacent column as 3, 2 and 1, respectively. The column (AS-F-NoF) identifies assessment areas sections that have roe fisheries and distinguishes between sections with large roe fisheries (LRF), defined as those with cumulative catches exceeding 5000 tonnes, intermediate-sized fisheries (IRF) with total cumulative catches between 1000-5000 tonnes, and minor roe fisheries (MRF) with catches between 100 and 1000 tonnes. All others are classified as (NRF) and have either no fisheries or total cumulative catches less than 100 tonnes. The column (Sp-cont) identifies the temporal pattern of spawning as 'continuous' or' virtually continuous' (*cont*), nearly continuous (*nc*) with gaps generally not exceeding 3 consecutive years, or discontinuous but with one more large pulses of spawn (d-pul) or as discontinuous (d) usually with few, small spawns.

Section	SB t	Catch t	PreF-SSB	%catch	SHI - km^2	AS-Non-Mi	AS-F-NoF	Code	Sp-cont
1	986	271	1257	21.56	0.11	Non	Srf	1	d
2	23479	2292	25771	8.89	2.63	Minor	RF	3	nc
3	10879	6222	17101	36.38	1.22	Minor	Lrf	3	nc
4	476		476	0.00	0.05	Non	n	1	d
5	9797	3617	13414	26.96	1.10	Minor	Irf	3	d-pul
6	27725	10397	38122	27.27	1.43	Assess	Lrf	2	d-pul
11	2830	32	2862	1.12	0.32	Non	n	1	d
12	10020	91	10111	0.90	1.12	Non	n	1	d-pul
21	164039	27173	191212	14.21	9.02	Assess	Lrf	2	cont
22	4406	1495	5901	25.33	0.49	Non	Irf	1	nc
23	29401	182	29583	0.62	1.48	Assess	Srf	2	d-pul
24	72735	4495	77230	5.82	4.00	Assess	Lrf	2	ncont
25	176659	25308	201967	12.53	10.07	Assess	Lrf	2	cont
32	882	*	882	*	0.05	Assess	n	2	d
33	39688	5409	45097	11.99	4.01	Assess	Lrf	2	cont
41	910	8	918	0.87	0.05	Assess	n	2	d
42	416473	73088	489561	14.93	39.40	Assess	Lrf	2	cont
43	73586	2552	76138	3.35	6.50	Assess	Irf	2	cont
51	2355	546	2901	18.82	0.22	Assess	Srf	2	d
52	172721	48575	221296	21.95	16.15	Assess	Lrf	2	cont
53	4382	169	4551	3.71	0.35	Assess	n	2	d
61	441	*	441	*	0.05	Non	n	1	d
62	2529	*	2529	*	0.28	Non	n	1	d
63	2061	*	2061	*	0.23	Non	n	1	d
66	453	*	453	*	0.05	Non	n	1	d
67	251256	27132	278388	9.75	13.50	Assess	Lrf	2	cont
72	184272	76354	260626	29.30	10.91	Assess	Lrf	2	cont
73	529	327	856	38.20	0.04	Assess	Srf	2	d-pul
74	168168	37784	205952	18.35	9.07	Assess	Lrf	2	cont
75	9007	116	9123	1.27	0.52	Assess	Srf	2	nc
76	26026	198	26224	0.76	1.53	Assess	Srf	2	cont
77	41158	15145	56303	26.90	2.52	Assess	Lrf	2	nc
78	61388	10398	71786	14.48	3.89	Assess	Lrf	2	nc

Appendix Table 1 Continued

Section	SB t	Catch t	PreF-SSB	%catch	SHI - km2	AS-Non-Mi	AS-F-NoF		Sp-cont
82	887	*	887	*	0.10	Non	n	1	d
83	4823	*	4823	*	0.54	Non	n	1	nc
84	6567	*	6567	*	0.73	Non	n	1	nc
85	93563	1526	95089	1.60	5.25	Assess	Irf	2	cont
86	14262	345	14607	2.36	0.99	Assess	Srf	2	nc
91	44	*	44	*	0.01	Non	n	1	d
92	10804	*	10804	*	1.21	Non	n	1	nc
93	28250	*	28250	*	3.16	Non	n	1	cont
125	3059	*	3059	*	0.34	Non	n	1	d
126	22852	*	22852	*	2.56	Non	n	1	cont
127	22851	364	23215	1.57	2.56	Non	Srf	1	cont
131	2	226	228	99.12	0.00	Non	Srf	1	d
132	2968	2375	5343	44.45	0.21	Assess	Irf	2	d
133	576	4	580	0.69	0.06	Non	n	1	d
134	6478	15	6493	0.23	0.72	Non	n	1	nc
135	8242	15	8257	0.18	0.66	Assess	n	2	d
136	*	*	*	*	*	Non	n		d
141	36518	445	36963	1.20	3.26	Assess	Srf	2	d
142	968729	242855	1211584	20.04	91.35	Assess	Lrf	2	nc
143	470318	20557	490875	4.19	45.62	Assess	Lrf	2	nc
151	173	12	185	6.49	0.02	Assess	n	2	d
152	102854	10706	113560	9.43	9.76	Assess	Lrf	2	d-pul
161	435	123	558	22.04	0.06	Assess	Srf	2	d
162	*	17	17	100.00	0.00	Assess	n	2	d
163	1697	110	1807	6.09	0.20	Assess	Srf	2	d
164							n		d
165	2022	61	2083	2.93	0.14		n	2	d
171	*	*	*	*	*	Assess	n		d
172	130114	15821	145935	10.84	12.28	Assess	Lrf	2	nc
173	204649	16170	220819	7.32	18.59	Assess	Lrf	2	cont
181	10247	806	11053	7.29	0.86	Assess	Srf	2	nc
182	333	76	409	18.58	0.02	Assess	n	2	d
191	6538	142	6680	2.13	0.65	Assess	Srf	2	d
192									d
193	1035	*	1035	*	0.09	Assess		2	d
201									d
202	3	*	3	*	0.00	Non		1	d
220									d

Appendix Table 1 Continued

Section	**SB t**	**Catch t**	**PreF-SSB**	**%catch**	**SHI - km2**	**AS-Non-Mi**	**AS-F-NoF**		**Sp-cont**
231	3589	2106	5695	36.98	0.14	*	Irf	*	d
232	471114	99391	570505	17.42	19.93	Assess	Lrf	2	cont
233	3317	2	3319	0.06	0.23	Assess	n	2	d
241	403	1464	1867	78.41	0.01	Assess	Irf	2	d
242	98658	*	98658	*	4.82	Assess	n	2	nc
243	31460	2267	33727	6.72	1.74	Assess	Irf	2	nc
244	18395	632	19027	3.32	0.93	Assess	Srf	2	nc
245	214353	10243	224596	4.56	7.39	Assess	Lrf	2	d-pul
252	32099	3968	36067	11.00	1.65	Assess	Irf	2	nc
253	301173	27662	328835	8.41	13.58	Assess	Lrf	2	cont
261							n		d
262	1612	91	1703	5.34	0.18	Non	n	1	d
263							n		d
271	*	*	0	*	0.00	Non	n	1	d
272	26654	1737	28391	6.12	2.98	Minor	Irf	3	nc
273	101088	5711	106799	5.35	11.31	Minor	Lrf	3	cont
274							n		d
280	361	*	361	*	0.03	Assess	n	2	d
291	2483	0	2483	0.00	0.23	Assess	n	2	d
293	7881	*	7881	*	0.84	Assess	n	2	d-pul

Appendix 1 – Table 2. Summary of total cumulative spawn, mean spawning day of year (DOY) and cumulative catch (by Season) for the years from 1940 to 2006.

Region	Section	Tonnes spawners	km2	Mean DOY	Jan-April	May-Aug	Sept-Dec	Total catch	Spawn Class
NQCI	1	986	368	95.65	339	*	*	339	1
WQCI	2	24191	168	85.1	2292	*	*	2292	3
WQCI	3	11475	406	94.56	7182	*	*	7182	3
NQCI	4	686	154	100.91	*	*	*	*	0
WQCI	5	10078	133	98.4	5481	*	*	5481	3
PRD	6	27725	160	85.81	19993	*	*	19993	4
NPRD	11	2830	1027	170.41	48	117	931	1096	1
NPRD	12	10020	155	62.42	346	19	*	365	1
QCI	21	165777	421	92.87	27309	13	*	27322	4
QCI	22	4406	355	133.73	2703	1402	*	4105	3
QCI	23	29401	137	112.3	15201	381	*	15582	4
QCI	24	75748	532	101.51	4495	119	50	4665	3
QCI	25	177747	369	83.29	72141	192	*	72332	5
PRD	32	882	412	86.14	1311	*	34	1345	2
PRD	33	39825	47	94.46	18566	*	*	18566	4
PRD	41	910	700	99	392	97	457	946	1
PRD	42	426682	836	93.66	76977	234	102	77313	5
PRD	43	73586	767	107.59	3894	158	555	4607	3
PRD	51	2355	1131	110.66	164	*	4279	4442	1
PRD	52	176492	305	99.59	64452	118	2323	66893	5
PRD	53	4382	336	110.17	176	*	52	228	1
NCC	61	441	1022	69.4	*	63	609	672	0
NCC	62	2529	949	135.08	*	*	*	*	0
NCC	63	2061	373	80.19	*	*	*	*	0
NCC	66	453	314	112.29	*	*	*	*	0
CC	67	255300	582	87.35	38653	*	*	38653	4
CC	72	188475	113	87.01	81261	*	*	81261	5
CC	73	529	183	88.01	2412	6	*	2418	3
CC	74	168920	335	89.56	72071	41	*	72112	5
CC	75	9007	118	93.26	2642	*	*	2642	3
CC	76	26897	133	90.38	16160	26	2	16188	4
CC	77	41435	291	90.55	15145	*	*	15145	4
CC	78	63410	603	86.48	10444	*	*	10444	4
NCC	82	887	359	72.55	*	*	*	*	0
NCC	83	4823	138						
NCC	84	6567	326	151.82	171	2072	*	2243	1
NCC	85	96298	192	88.18	4369	*	30	4399	3
NCC	86	14262	334	87.31	1755	22	*	1777	2
NCC	91	44	249	89.7	19	*	*	19	1
NCC	92	11138	172	96.4	996	*	*	996	2
NCC	93	28279	130	81.22	2757	*	*	2757	3
NCC	102	13443	147	90.1	5677	*	*	5677	3
NCC	103	749	66	99.88	1466	*	*	1466	2
NJS	111	125	953	115	0	*	*	0	1
NJS	112	522	170	95.06	11	*	*	11	1

Appendix 1 – Table 2 Continued

Region	Section	Tonnes spawners	km2	Mean DOY	Jan-April	May-Aug	Sept-Dec	Total catch	Spawn Class
NJS	121	29	1709	122.42	928	313	*	1241	2
NJS	122	6092	115	91	11673	4	*	11677	4
NJS	123	3579	489	85.07	1740	329	367	2436	2
NJS	124	1271	146	105.36	37	*	*	37	1
NJS	125	3059	267	85.33	857	*	0	857	2
NJS	126	22852	196	79.65	4380	*	*	4380	3
NJS	127	22851	286	79.29	2039	*	*	2039	3
NJS	131	2	305	81	226	0	91	317	1
NJS	132	2968	82	101.32	5663	67	8367	14097	3
NJS	133	576	66	77.99	178	54	62	293	1
NJS	134	6478	259	72.55	167	0	*	167	1
SOG	135	8242	320	86.75	698	222	124	1043	2
SOG	141	36518	999	72.29	445	*	*	445	1
SOG	142	999268	265	71.32	247314	13	812	248138	5
SOG	143	488429	430	73.34	41531	4	354	41889	4
SOG	151	173	400	76.15	85	0	*	85	1
SOG	152	102854	558	77.83	12582	90	44	12716	4
SOG	161	435	237	83	135	*	*	135	1
SOG	162	*	164	79.77	519	115	41	675	2
SOG	163	1697	423	77.37	315	524	136	975	1
SOG	164		185	92.05	394	52	10	456	1
SOG	165	2022	117	91.69	526	95	37	657	2
SOG	172	130114	198	76.12	39528	*	1413	40941	4
SOG	173	210488	398	78.62	16953	11	19851	36815	4
SOG	181	10247	272	62.87	7513	69	14409	21991	3
SOG	182	333	326	68.12	5110	*	2207	7317	3
SOG	191	6538	71	84.68	142	*	539	681	1
SOG	193	1035	372	86.31	*	*	882	882	0
NWCVI	202	3	328	92	*	0	1	1	0
WCVI	231	3589	148	74.03	2667	9	80	2756	3
WCVI	232	472907	214	73.07	162333	33	238	162604	5
WCVI	233	3317	179	71.88	396	*	*	396	1
WCVI	241	403	89	60.78	3535	*	*	3535	3
WCVI	242	99016	36	68.8	3202	*	*	3202	3
WCVI	243	31460	83	78.48	33281	*	*	33281	4
WCVI	244	18485	72	79.97	7915	*	*	7915	3
WCVI	245	214353	215	76.42	29720	*	*	29720	4
WCVI	252	32099	109	84.75	13892	*	*	13892	4
WCVI	253	301710	193	69.15	67877	*	116	67993	5
NWCVI	262	1612	131	69.65	235	*	*	235	1
NWCVI	271	*	402	73.2	*	*	*	*	0
NWCVI	272	27278	233	69.12	1817	*	*	1817	2
MWCVI	273	104067	18	72.76	7078	*	0	7078	3
SOG	280	361	452	81.05	14	1	0	15	1
SOG	291	2483	1672	68	0	*	*	0	1
SOG	293	7881	112	60.23	18	25	1	45	1

Appendix 1 - Table 3. Descriptions of each section, showing whether it is in an assessment region, the cumulative spawn (since 1970), the geographic area (km^2), mean DOY (day of the year) of spawning, the cumulative catch (tonnes) by monthly periods, the total catch and the class of the fishery.

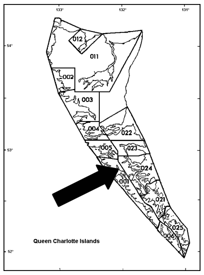
						Tonnes catch by period				
SECTION 1940-2006	Asses-nonasses	Region	Cumulative spawn (tonnes) since 1980	km2	Mean DOY	Jan-April	May-Aug	Sept-Dec	Total catch	Class RF
1	N	NQCI	*	368.29	95.65	339	*	*	339	1
2	MINOR	WQCI	*	167.67	85.1	2292	*	*	2292	3
3	MINOR	WQCI	*	405.86	94.56	7182	*	*	7182	3
4	N	NQCI	*	154.4	100.91	*	*	*	*	0
5	MINOR	WQCI	*	132.65	98.4	5481	*	*	5481	3
6	ASS	PRD	27725	160.07	85.81	19993	*	*	19993	4
11	N	NPRD	*	1027.15	170.41	48	116.5	931.3	1096	1
12	N	NPRD	*	154.51	62.42	346	19.4	*	365	1
21	ASS	QCI	165777	421.11	92.87	27309	12.7	*	27322	4
22	ASS	QCI	*	355.28	133.73	2703	1402	*	4105	3
23	ASS	QCI	29401	136.71	112.3	15201	380.9	*	15582	4
24	ASS	QCI	75748	532.42	101.51	4495	119.3	50.3	4665	3
25	ASS	QCI	177747	368.82	83.29	72141	191.5	*	72332	5
31	ASS	PRD		748.86						
32	ASS	PRD	882	411.66	86.14	1311	*	34	1345	2
33	ASS	PRD	39825	47.39	94.46	18566	*	*	18566	4
41	ASS	PRD	910	700.09	99	392	97	456.9	946	1
42	ASS	PRD	426682	835.71	93.66	76977	233.6	101.9	77313	5
43	ASS	PRD	73586	767.27	107.59	3894	158.2	555	4607	3
51	ASS	PRD	2355	1130.57	110.66	164	*	4278.5	4442	1
52	ASS	PRD	176492	304.57	99.59	64452	117.5	2323.2	66893	5
53	ASS	PRD	4382	336.33	110.17	176	*	51.7	228	1
61	N	NCC	*	1021.83	69.4	*	62.6	609.2	672	0
62	N	NCC	*	948.79	135.08	*	*	*	*	0
63	N	NCC	*	373.15	80.19	*	*	*	*	0
64	N	NCC		211.72	87.91	*	*	*	*	0
65	N	NCC		165.13	102	*	*	*	*	0
66	N	NCC	*	313.54	112.29	*	*	*	*	0
67	ASS	CC	255300	582	87.35	38653	*	*	38653	4
71		CC		1151.81						
72	ASS	CC	188475	112.61	87.01	81261	*	*	81261	5
73	ASS	CC	529	182.99	88.01	2412	6.2	*	2418	3
74	ASS	CC	168920	334.54	89.56	72071	41.2	*	72112	5
75	ASS	CC	9007	118.09	93.26	2642	*	*	2642	3
76	ASS	CC	26897	132.68	90.38	16160	26	1.6	16188	4
77	ASS	CC	41435	290.51	90.55	15145	*	*	15145	4
78	ASS	CC	63410	603.27	86.48	10444	*	*	10444	4
81	N	NCC		191.6	80.66	*	*	*	*	0
82	N	NCC	*	358.54	72.55	*	*	*	*	0
83	N	NCC	*	138.17						
84	N	NCC	*	326.08	151.82	171	2072	*	2243	1
85	N	NCC	96298	192.37	88.18	4369	*	30.3	4399	3
86	N	NCC	14262	334.11	87.31	1755	22.2	*	1777	2
91	N	NCC	*	248.79	89.7	19	*	*	19	1
92	N	NCC	*	171.65	96.4	996	*	*	996	2
93	N	NCC	*	129.76	81.22	2757	*	*	2757	3
101	N	NCC		629.68						
102	N	NCC	*	146.83	90.1	5677	*	*	5677	3
103	N	NCC	*	66.12	99.88	1466	*	*	1466	2
111	N	NJS	*	952.83	115	0	*	*	0	1

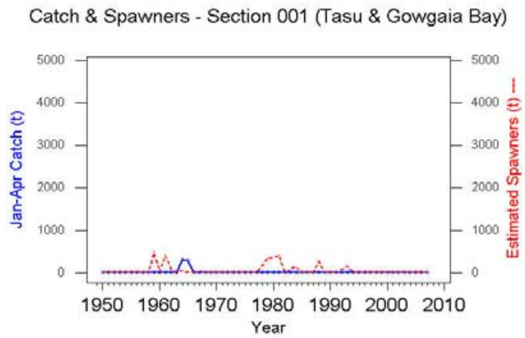
Appendix Table 3 Continued

SECTION 1940-2006	Asses-nonasses	Region	Cumulative spawn (tonnes) since 1980	km2	Mean DOY	Tonnes catch by period: Jan-April	May-Aug	Sept-Dec	Total catch	Class RF
112	N	NJS	*	170.28	95.06	11	*	*	11	1
121	N	NJS	*	1709.11	122.42	928	312.9	*	1241	2
122	N	NJS	*	114.55	91	11673	4.1	*	11677	4
123	N	NJS	*	488.85	85.07	1740	329.1	367.3	2436	2
124	N	NJS	*	146.09	105.36	37	*	*	37	1
125	N	NJS	*	266.8	85.33	857	*	0.1	857	2
126	N	NJS	*	196.4	79.65	4380	*	*	4380	3
127	N	NJS	*	286.01	79.29	2039	*	*	2039	3
131	N	NJS	*	304.74	81	226	0.1	90.7	317	1
132	N	NJS	2968	82.11	101.32	5663	67.4	8366.6	14097	3
133	N	NJS	*	65.94	77.99	178	53.8	61.7	293	1
134	N	NJS	*	258.9	72.55	167	0.4	*	167	1
135	ASS	SOG	8242	320.11	86.75	698	221.8	123.6	1043	2
136	N	NJS		293.69	86.07	11	22.9	0.9	35	1
141	ASS	SOG	36518	999.35	72.29	445	*	*	445	1
142	ASS	SOG	999268	264.76	71.32	247314	12.9	811.5	248138	5
143	ASS	SOG	488429	430.47	73.34	41531	4.4	353.8	41889	4
151	ASS	SOG	173	399.71	76.15	85	0	*	85	1
152	ASS	SOG	102854	558.26	77.83	12582	89.9	44.4	12716	4
161	ASS	SOG	435	237.47	83	135	*	*	135	1
162	ASS	SOG	0	163.69	79.77	519	115.4	40.7	675	2
163	ASS	SOG	1697	423.02	77.37	315	523.8	135.6	975	1
164	ASS	SOG		185.27	92.05	394	52.2	10.2	456	1
165	ASS	SOG	2022	116.96	91.69	526	94.6	36.5	657	2
171	ASS	SOG		589.87						
172	ASS	SOG	130114	198.26	76.12	39528	*	1412.9	40941	4
173	ASS	SOG	210488	398.29	78.62	16953	10.5	19851	36815	4
181	ASS	SOG	10247	272.26	62.87	7513	69.3	14409	21991	3
182	ASS	SOG	333	325.65	68.12	5110	*	2207.1	7317	3
191	ASS	SOG	6538	71.02	84.68	142	*	539	681	1
192	ASS	SOG		390.02	81.67	398	*	*	398	1
193	ASS	SOG	1035	372	86.31	*	*	881.8	882	0
201	N	NWCVI		865.54						
202	N	NWCVI	*	328.13	92	*	0	0.5	1	0
211	N	NWCVI		75.52						
220	N	NWCVI		0.1	104	*	*	*	*	0
231	ASS	WCVI	3589	148.36	74.03	2667	8.5	79.9	2756	3
232	ASS	WCVI	472907	214.14	73.07	162333	32.7	237.9	162604	5
233	ASS	WCVI	3317	179.21	71.88	396	*	*	396	1
241	ASS	WCVI	403	89.12	60.78	3535	*	*	3535	3
242	ASS	WCVI	99016	36.27	68.8	3202	*	*	3202	3
243	ASS	WCVI	31460	83.25	78.48	33281	*	*	33281	4
244	ASS	WCVI	18485	72.4	79.97	7915	*	*	7915	3
245	ASS	WCVI	214353	215.29	76.42	29720	*	*	29720	4
251	ASS	WCVI		138.67	91.4	*	*	*	*	0
252	ASS	WCVI	32099	109.24	84.75	13892	*	*	13892	4
253	ASS	WCVI	301710	192.97	69.15	67877	*	115.9	67993	5
261	N	NWCVI		114.24	76.19	*	*	*	*	0
262	N	NWCVI	*	130.6	69.65	235	*	*	235	1
263	N	NWCVI		184.85	70.4	102	*	*	102	1
271	N	NWCVI	*	402.04	73.2	*	*	*	*	0
272	N	NWCVI	*	232.59	69.12	1817	*	*	1817	2
273	MINOR	MWCVI	*	18.42	72.76	7078	*	0.1	7078	3
274	N	WCVI		49.45	103.24	11	*	*	11	1
280	ASS	SOG	361	452.34	81.05	14	1.3	0	15	1
291	ASS	SOG	2483	1672.14	68	0	*	*	0	1
292	ASS	SOG		37.66	82.92	1	3.9	367.3	372	1
293	ASS	SOG	7881	112.45	60.23	18	25.3	0.8	45	1

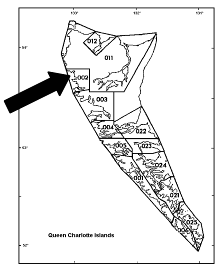
Appendix 1 - Figures – Review of catches and spawning by section

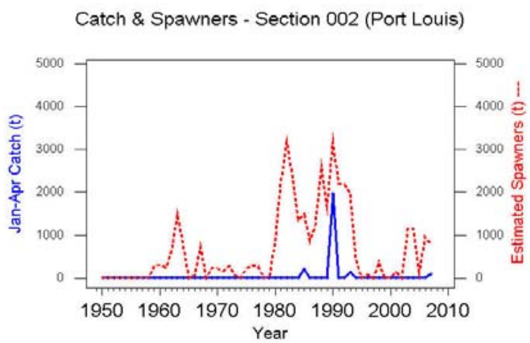
Graphical summaries are shown for each section with data. Each graphical summate is shown with an accompanying map showing the geographic position and boundaries of the section, relative to the assessment areas (see text for definitions and explanations). A brief statistical summary is shown for each section, that includes the mean date of spawning (as DOY or 'day of the year'), the total geographic area of the section, the cumulative catches (tonnes) by season (Jan-April, May-August, September-December). The fishery in each section is ranked by scale or class (See Table 2 in the text). The frequency (F) of spawning by year is shown for the entire time series and also separately for each of the reduction fishery and roe fishery periods. The change in spawn frequency (gain or reduction) is shown between the periods of the two fisheries, with gains representing increases in frequency during the roe fishery period. The statistical summery is estimated for all years from 1940-2006. The graphical summaries are shown for the period of 1940-2007.



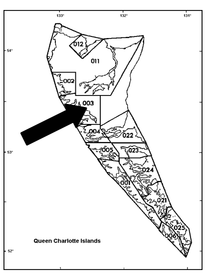


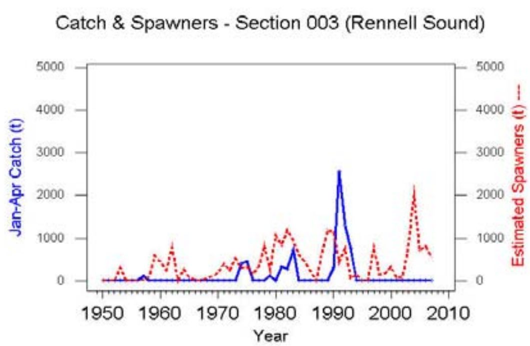
SECTION	1
km2 (1940-2006)	368.29
Mean DOY	95.65
Jan-April	339
May-Aug	*
Sept-Dec	*
Total catch	339
Class RF	1
F(sp roe fish)	0.250
F(sp pre RF)	0.226
F(sp- all)	0.239
F(gain or reduction)	0.024



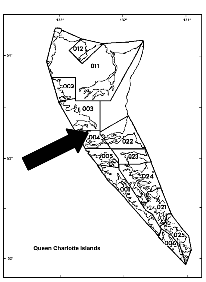


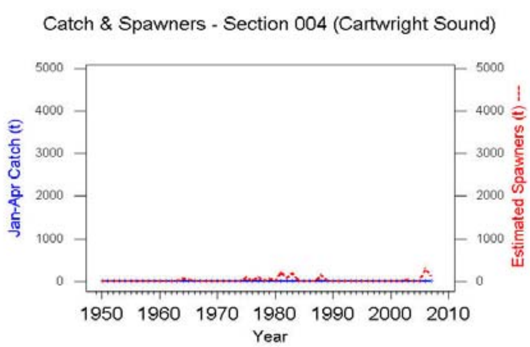
SECTION	2
km2 (1940-2006)	167.67
Mean DOY	85.1
Jan-April	2292
May-Aug	*
Sept-Dec	*
Total catch	2292
Class RF	3
F(sp roe fish)	0.806
F(sp pre RF)	0.355
F(sp- all)	0.597
F(gain or reduction)	0.451



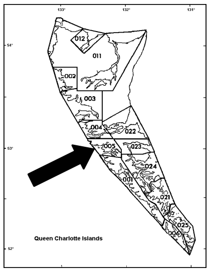


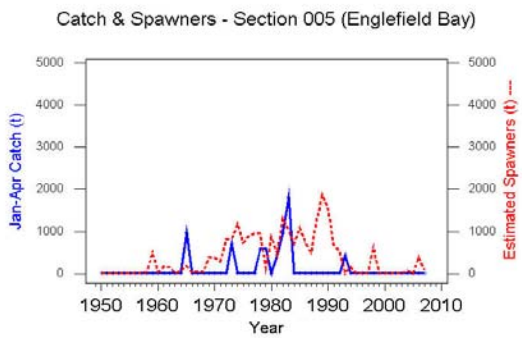
SECTION	3
km2 (1940-2006)	405.86
Mean DOY	94.56
Jan-April	7182
May-Aug	*
Sept-Dec	*
Total catch	7182
Class RF	3
F(sp roe fish)	0.917
F(sp pre RF)	0.419
F(sp- all)	0.687
F(gain or reduction)	0.497



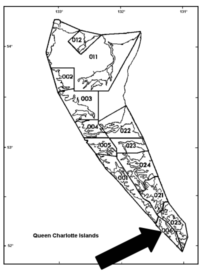


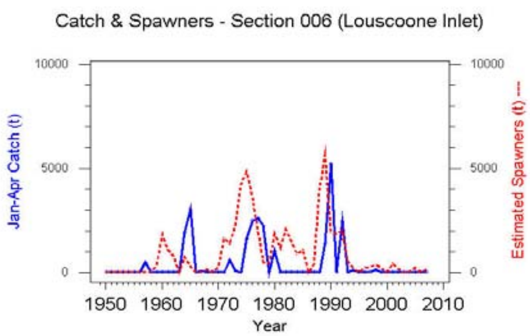
SECTION	4
km2 (1940-2006)	154.4
Mean DOY	100.91
Jan-April	*
May-Aug	*
Sept-Dec	*
Total catch	*
Class RF	0
F(sp roe fish)	0.278
F(sp pre RF)	0.161
F(sp- all)	0.224
F(gain or reduction)	0.116



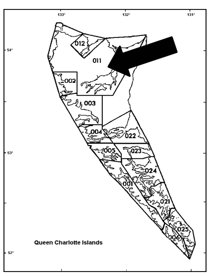


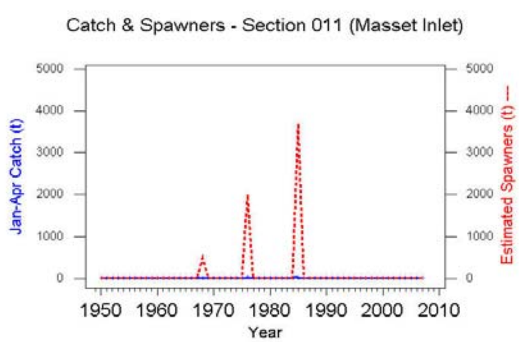
SECTION	5
km2 (1940-2006)	132.65
Mean DOY	98.4
Jan-April	5481
May-Aug	*
Sept-Dec	*
Total catch	5481
Class RF	3
F(sp roe fish)	0.750
F(sp pre RF)	0.387
F(sp- all)	0.582
F(gain or reduction)	0.363



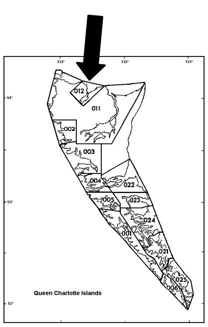


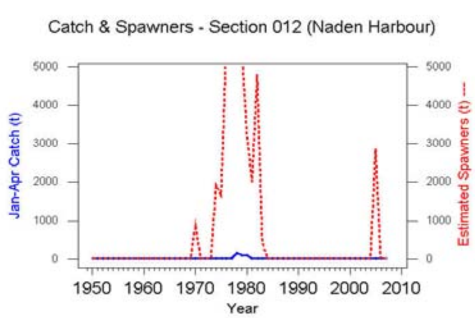
SECTION	6
km2 (1940-2006)	160.07
Mean DOY	85.81
Jan-April	19993
May-Aug	*
Sept-Dec	*
Total catch	19993
Class RF	4
F(sp roe fish)	0.833
F(sp pre RF)	0.387
F(sp- all)	0.627
F(gain or reduction)	0.446



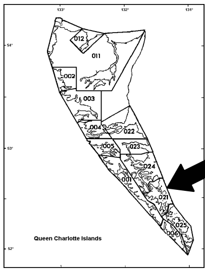


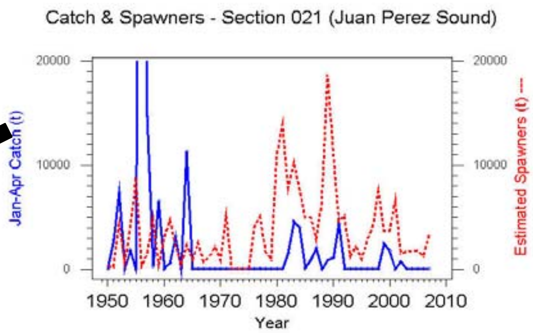
SECTION	11
km2 (1940-2006)	1027.15
Mean DOY	170.41
Jan-April	48
May-Aug	116.5
Sept-Dec	931.3
Total catch	1096
Class RF	1
F(sp roe fish)	0.056
F(sp pre RF)	0.065
F(sp- all)	0.060
F(gain or reduction)	-0.009



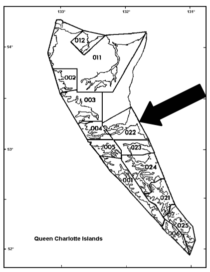


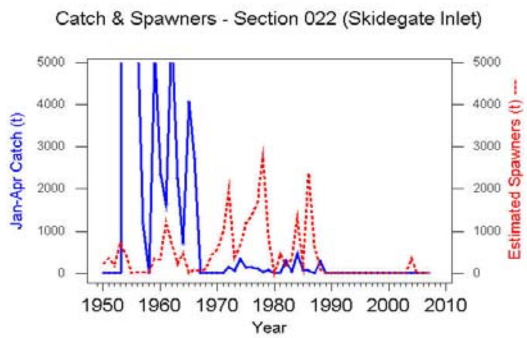
SECTION	12
km2 (1940-2006)	154.51
Mean DOY	62.42
Jan-April	346
May-Aug	19.4
Sept-Dec	*
Total catch	365
Class RF	1
F(sp roe fish)	0.306
F(sp pre RF)	0.032
F(sp- all)	0.179
F(gain or reduction)	0.273



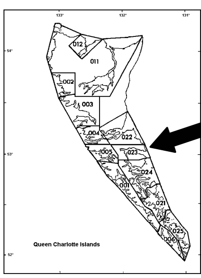


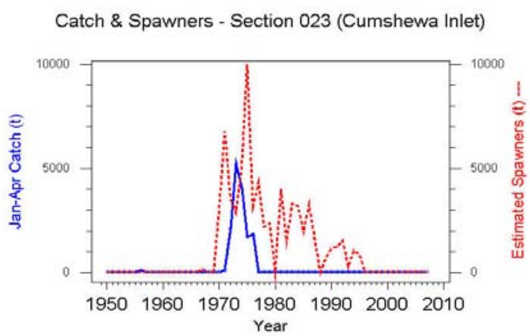
SECTION	21
km2 (1940-2006)	421.11
Mean DOY	92.87
Jan-April	27309
May-Aug	12.7
Sept-Dec	*
Total catch	27322
Class RF	4
F(sp roe fish)	0.889
F(sp pre RF)	0.968
F(sp- all)	0.925
F(gain or reduction)	-0.079



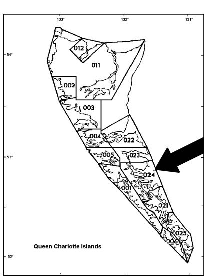


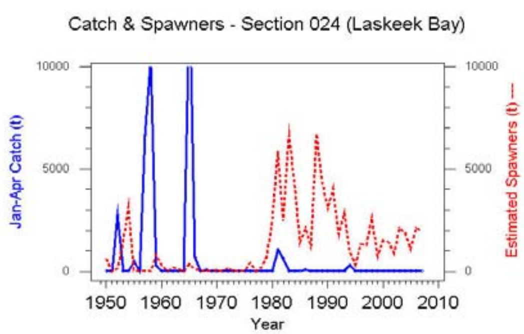
SECTION	22
km2 (1940-2006)	355.28
Mean DOY	133.73
Jan-April	2703
May-Aug	1401.6
Sept-Dec	*
Total catch	4105
Class RF	3
F(sp roe fish)	0.500
F(sp pre RF)	0.935
F(sp- all)	0.701
F(gain or reduction)	-0.435



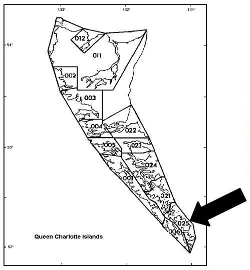


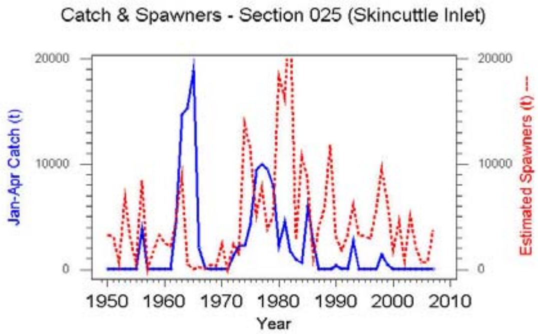
SECTION	23
km2 (1940-2006)	136.71
Mean DOY	112.3
Jan-April	15201
May-Aug	380.9
Sept-Dec	*
Total catch	15582
Class RF	4
F(sp roe fish)	0.639
F(sp pre RF)	0.097
F(sp- all)	0.388
F(gain or reduction)	0.542



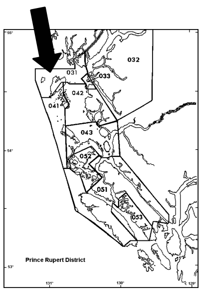


SECTION	24
km2 (1940-2006)	532.42
Mean DOY	101.51
Jan-April	4495
May-Aug	119.3
Sept-Dec	50.3
Total catch	4665
Class RF	3
F(sp roe fish)	0.861
F(sp pre RF)	0.710
F(sp- all)	0.791
F(gain or reduction)	0.151





SECTION	25
km2 (1940-2006)	368.82
Mean DOY	83.29
Jan-April	72141
May-Aug	191.5
Sept-Dec	*
Total catch	72332
Class RF	5
F(sp roe fish)	0.972
F(sp pre RF)	0.903
F(sp- all)	0.940
F(gain or reduction)	0.069



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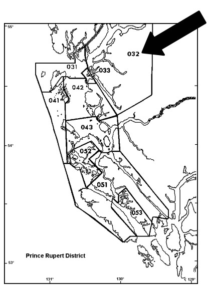
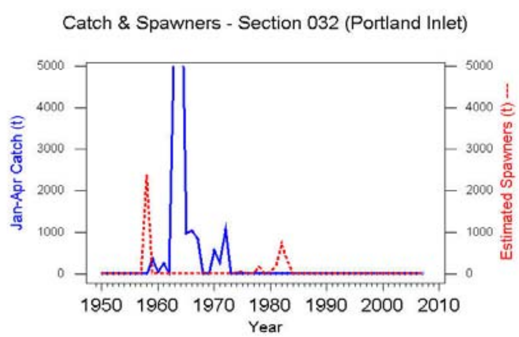
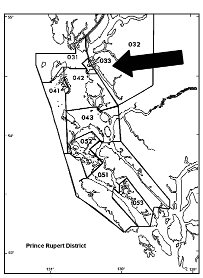
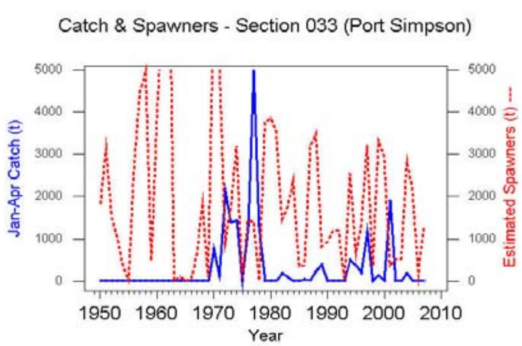
SECTION	31
km2 (1940-2006)	748.86



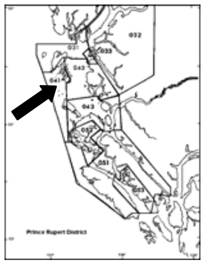


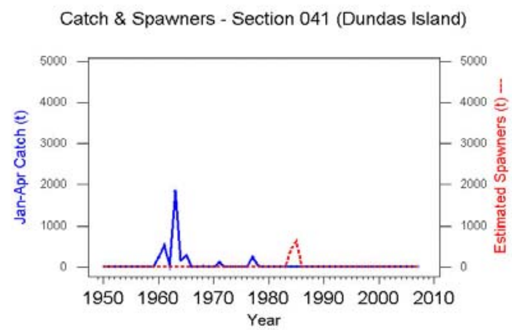
SECTION	32
km2 (1940-2006)	411.66
Mean DOY	86.14
Jan-April	1311
May-Aug	*
Sept-Dec	34
Total catch	1345
Class RF	2
F(sp roe fish)	0.222
F(sp pre RF)	0.097
F(sp- all)	0.164
F(gain or reduction)	0.125



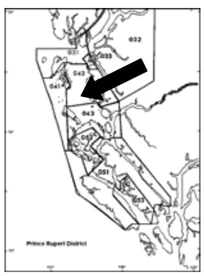


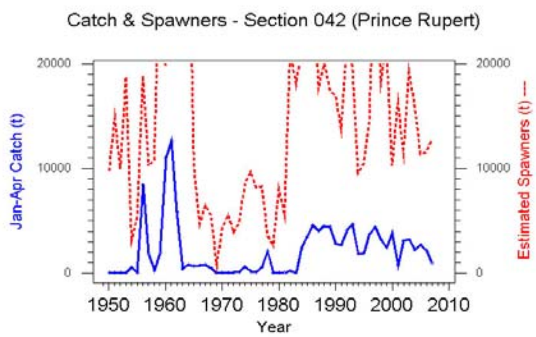
SECTION	33
km2 (1940-2006)	47.39
Mean DOY	94.46
Jan-April	18566
May-Aug	*
Sept-Dec	*
Total catch	18566
Class RF	4
F(sp roe fish)	0.944
F(sp pre RF)	0.613
F(sp- all)	0.791
F(gain or reduction)	0.332



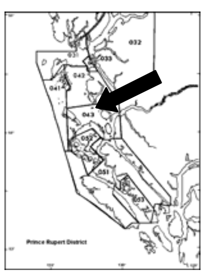


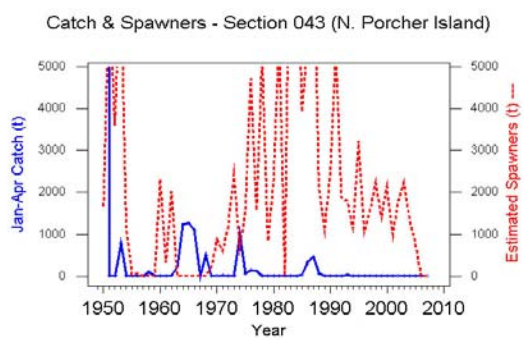
SECTION	41
km2 (1940-2006)	700.09
Mean DOY	99
Jan-April	392
May-Aug	97
Sept-Dec	456.9
Total catch	946
Class RF	1
F(sp roe fish)	0.056
F(sp pre RF)	0.032
F(sp- all)	0.045
F(gain or reduction)	0.023



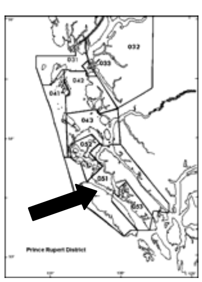


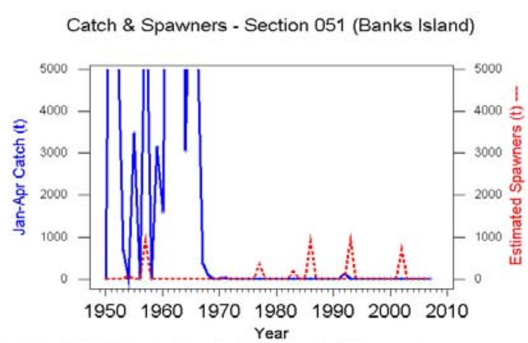
SECTION	42
km2 (1940-2006)	835.71
Mean DOY	93.66
Jan-April	76977
May-Aug	233.6
Sept-Dec	101.9
Total catch	77313
Class RF	5
F(sp roe fish)	1.000
F(sp pre RF)	1.000
F(sp- all)	1.000
F(gain or reduction)	0.000





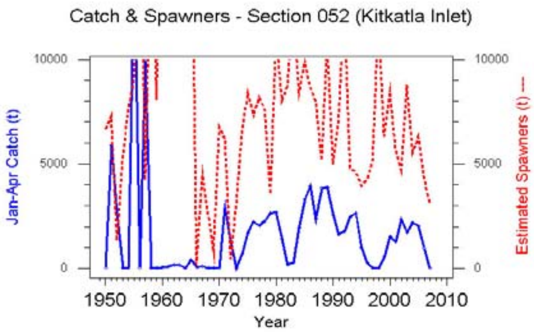
SECTION	43
km2 (1940-2006)	767.27
Mean DOY	107.59
Jan-April	3894
May-Aug	158.2
Sept-Dec	555
Total catch	4607
Class RF	3
F(sp roe fish)	0.944
F(sp pre RF)	0.710
F(sp- all)	0.836
F(gain or reduction)	0.235



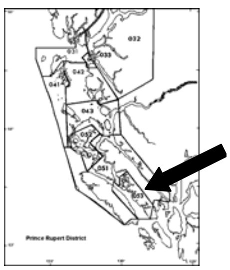


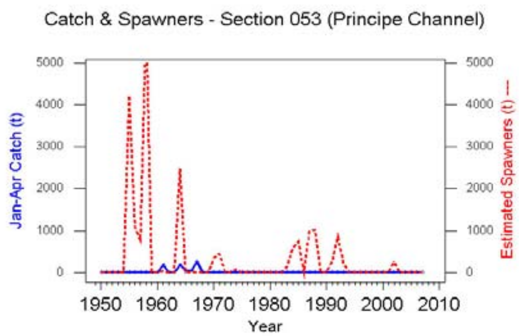
Catches in the 1950's & 60's conducted on Bonilla & Whiterocks offshore grounds.

SECTION	51
km2 (1940-2006)	1130.57
Mean DOY	110.66
Jan-April	164
May-Aug	*
Sept-Dec	4278.5
Total catch	4442
Class RF	1
F(sp roe fish)	0.139
F(sp pre RF)	0.161
F(sp- all)	0.149
F(gain or reduction)	-0.022

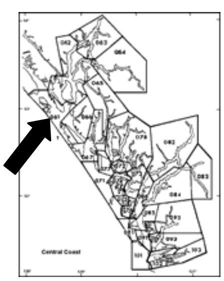


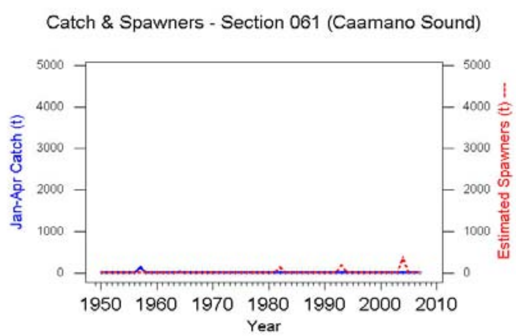
SECTION	52
km2 (1940-2006)	304.57
Mean DOY	99.59
Jan-April	64452
May-Aug	117.5
Sept-Dec	2323.2
Total catch	66893
Class RF	5
F(sp roe fish)	1.000
F(sp pre RF)	0.935
F(sp- all)	0.970
F(gain or reduction)	0.065



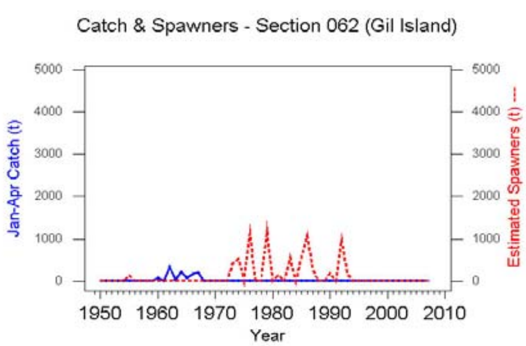


SECTION	53
km2 (1940-2006)	336.33
Mean DOY	110.17
Jan-April	176
May-Aug	*
Sept-Dec	51.7
Total catch	228
Class RF	1
F(sp roe fish)	0.333
F(sp pre RF)	0.226
F(sp- all)	0.284
F(gain or reduction)	0.108

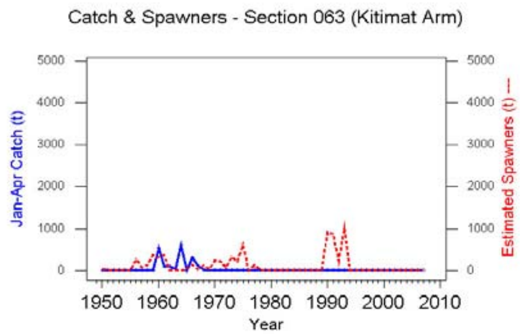




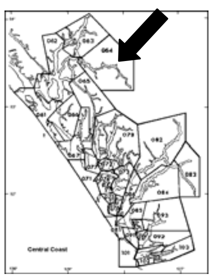
SECTION	61
km2 (1940-2006)	1021.83
Mean DOY	69.4
Jan-April	*
May-Aug	62.6
Sept-Dec	609.2
Total catch	672
Class RF	0
F(sp roe fish)	0.111
F(sp pre RF)	0.000
F(sp- all)	0.060
F(gain or reduction)	0.111

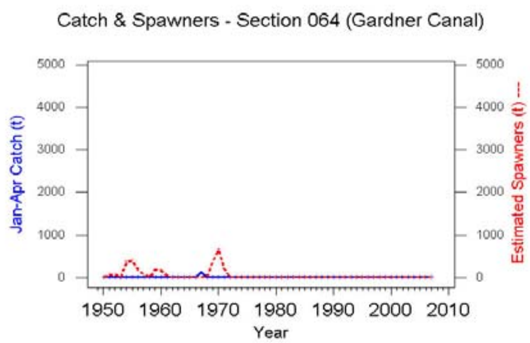


SECTION	62
km2 (1940-2006)	948.79
Mean DOY	135.08
Jan-April	*
May-Aug	*
Sept-Dec	*
Total catch	*
Class RF	0
F(sp roe fish)	0.333
F(sp pre RF)	0.097
F(sp- all)	0.224
F(gain or reduction)	0.237

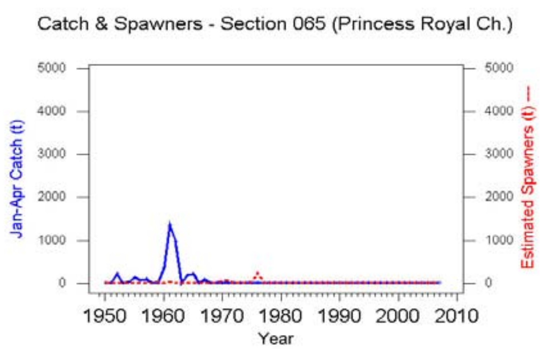


SECTION	63
km2 (1940-2006)	373.15
Mean DOY	80.19
Jan-April	*
May-Aug	*
Sept-Dec	*
Total catch	*
Class RF	0
F(sp roe fish)	0.306
F(sp pre RF)	0.710
F(sp- all)	0.493
F(gain or reduction)	-0.404

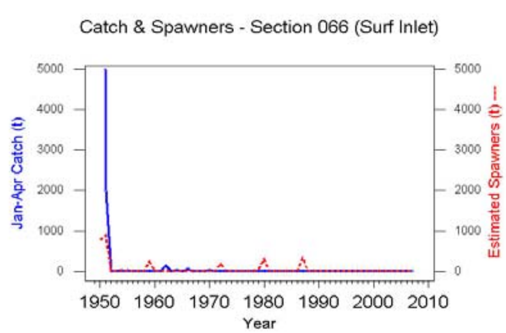




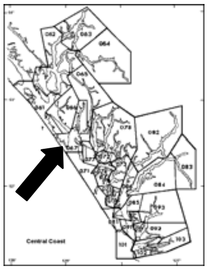
SECTION	64
km2 (1940-2006)	211.72
Mean DOY	87.91
Jan-April	*
May-Aug	*
Sept-Dec	*
Total catch	*
Class RF	0
F(sp roe fish)	0.028
F(sp pre RF)	0.452
F(sp- all)	0.224
F(gain or reduction)	-0.424

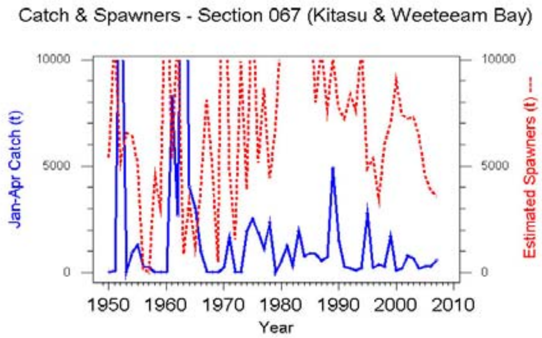


SECTION	65
km2 (1940-2006)	165.13
Mean DOY	102
Jan-April	*
May-Aug	*
Sept-Dec	*
Total catch	*
Class RF	0
F(sp roe fish)	0.111
F(sp pre RF)	0.097
F(sp- all)	0.104
F(gain or reduction)	0.014

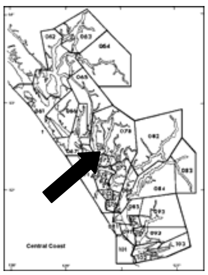


SECTION	66
km2 (1940-2006)	313.54
Mean DOY	112.29
Jan-April	*
May-Aug	*
Sept-Dec	*
Total catch	*
Class RF	0
F(sp roe fish)	0.139
F(sp pre RF)	0.484
F(sp- all)	0.299
F(gain or reduction)	-0.345





SECTION	67
km2 (1940-2006)	582
Mean DOY	87.35
Jan-April	38653
May-Aug	*
Sept-Dec	*
Total catch	38653
Class RF	4
F(sp roe fish)	1.000
F(sp pre RF)	0.968
F(sp- all)	0.985
F(gain or reduction)	0.032



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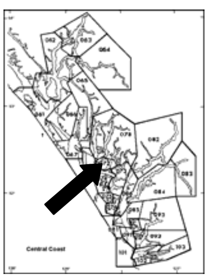
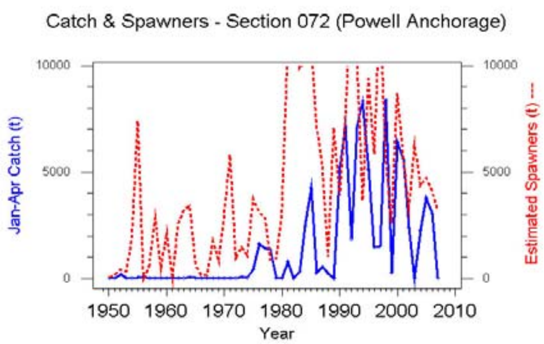
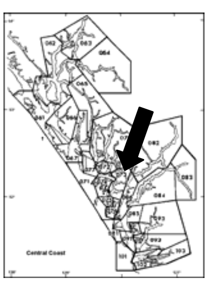
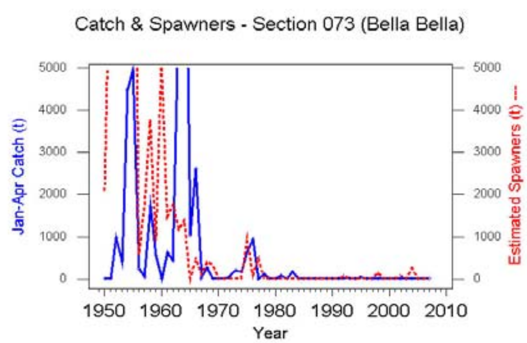
SECTION	71
km2 (1940-2006)	1151.81



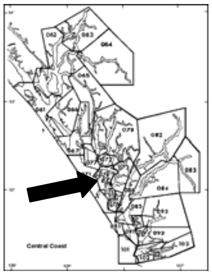


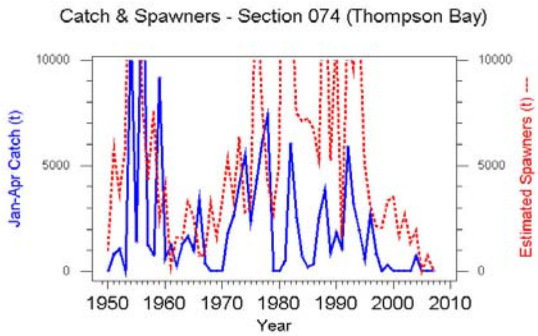
SECTION	72
km2 (1940-2006)	112.61
Mean DOY	87.01
Jan-April	81261
May-Aug	*
Sept-Dec	*
Total catch	81261
Class RF	5
F(sp roe fish)	1.000
F(sp pre RF)	0.774
F(sp- all)	0.896
F(gain or reduction)	0.226



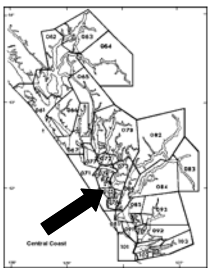


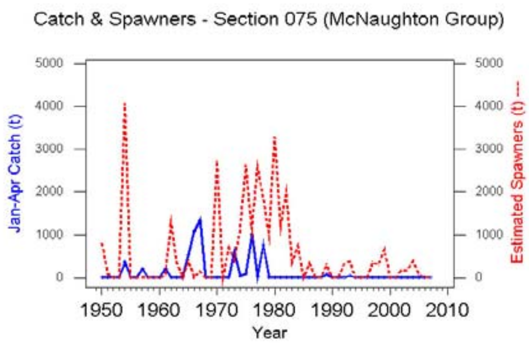
SECTION	73
km2 (1940-2006)	182.99
Mean DOY	88.01
Jan-April	2412
May-Aug	6.2
Sept-Dec	*
Total catch	2418
Class RF	3
F(sp roe fish)	0.194
F(sp pre RF)	0.968
F(sp- all)	0.552
F(gain or reduction)	-0.773



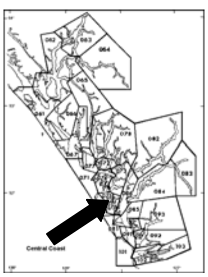


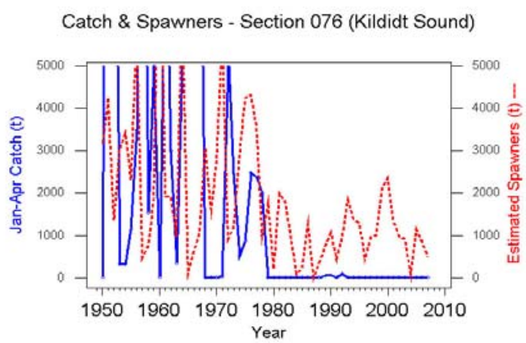
SECTION	74
km2 (1940-2006)	334.54
Mean DOY	89.56
Jan-April	72071
May-Aug	41.2
Sept-Dec	*
Total catch	72112
Class RF	5
F(sp roe fish)	0.972
F(sp pre RF)	1.000
F(sp- all)	0.985
F(gain or reduction)	-0.028



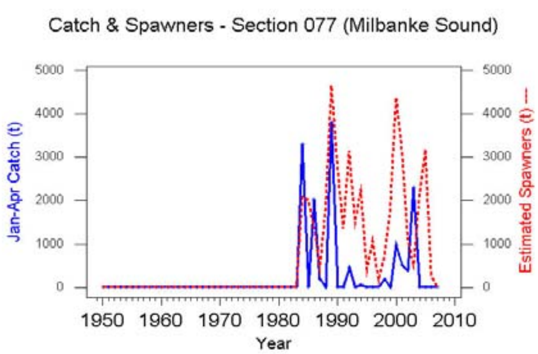


SECTION	75
km2 (1940-2006)	118.09
Mean DOY	93.26
Jan-April	2642
May-Aug	*
Sept-Dec	*
Total catch	2642
Class RF	3
F(sp roe fish)	0.667
F(sp pre RF)	0.419
F(sp- all)	0.552
F(gain or reduction)	0.247

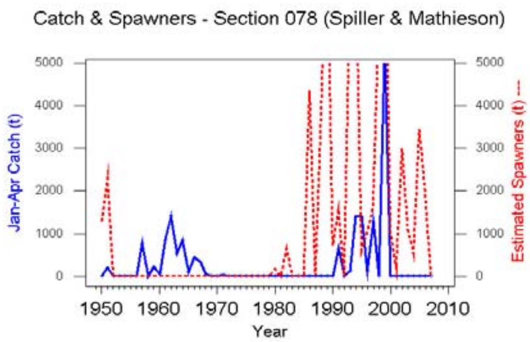




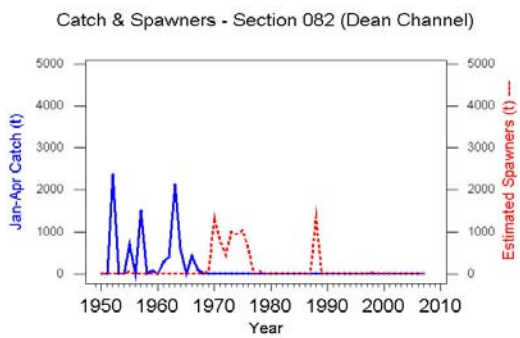
SECTION	76
km2 (1940-2006)	132.68
Mean DOY	90.38
Jan-April	16160
May-Aug	26
Sept-Dec	1.6
Total catch	16188
Class RF	4
F(sp roe fish)	0.972
F(sp pre RF)	1.000
F(sp- all)	0.985
F(gain or reduction)	-0.028



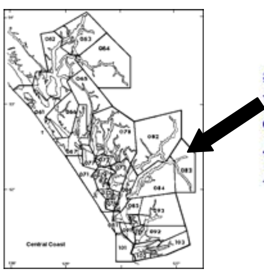
SECTION	77
km2 (1940-2006)	290.51
Mean DOY	90.55
Jan-April	15145
May-Aug	*
Sept-Dec	*
Total catch	15145
Class RF	4
F(sp roe fish)	0.639
F(sp pre RF)	0.000
F(sp- all)	0.343
F(gain or reduction)	0.639

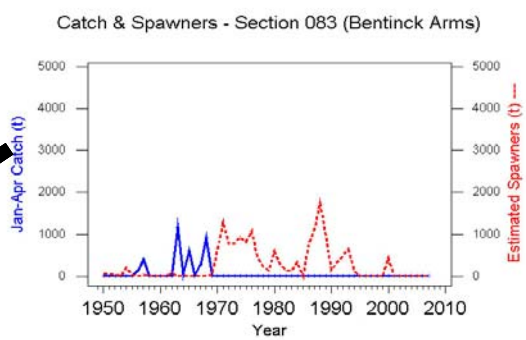


SECTION	78
km2 (1940-2006)	603.27
Mean DOY	86.48
Jan-April	10444
May-Aug	*
Sept-Dec	*
Total catch	10444
Class RF	4
F(sp roe fish)	0.583
F(sp pre RF)	0.226
F(sp- all)	0.418
F(gain or reduction)	0.358

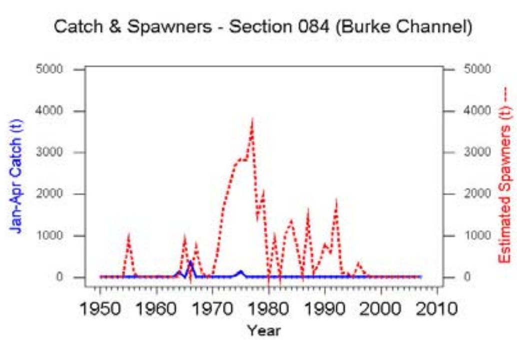


SECTION	82
km2 (1940-2006)	358.54
Mean DOY	72.55
Jan-April	*
May-Aug	*
Sept-Dec	*
Total catch	*
Class RF	0
F(sp roe fish)	0.250
F(sp pre RF)	0.323
F(sp- all)	0.284
F(gain or reduction)	-0.073

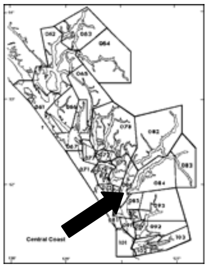


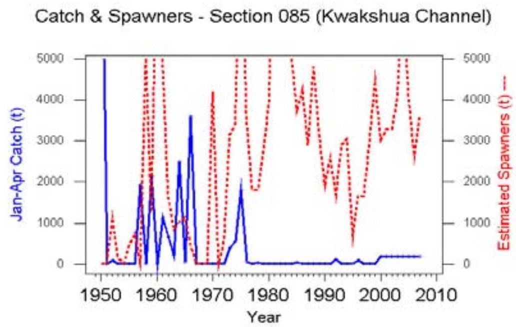


SECTION	83
km2 (1940-2006)	138.17
Mean DOY	
Jan-April	
May-Aug	
Sept-Dec	
Total catch	
Class RF	
F(sp roe fish)	0.667
F(sp pre RF)	0.581
F(sp- all)	0.627
F(gain or reduction)	0.086

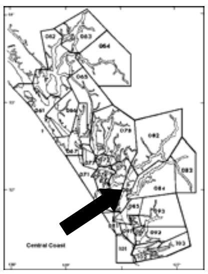


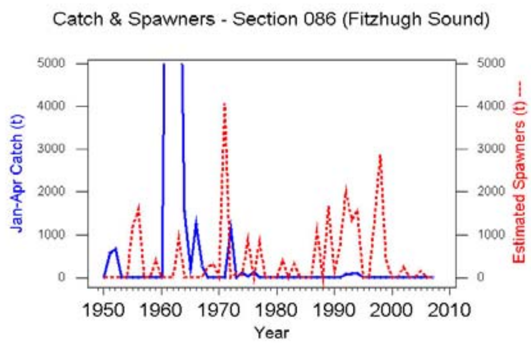
SECTION	84
km2 (1940-2006)	326.08
Mean DOY	151.82
Jan-April	171
May-Aug	2072.4
Sept-Dec	*
Total catch	2243
Class RF	1
F(sp roe fish)	0.667
F(sp pre RF)	0.226
F(sp- all)	0.463
F(gain or reduction)	0.441



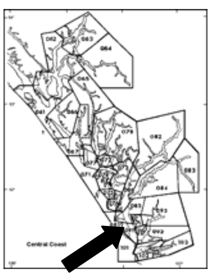


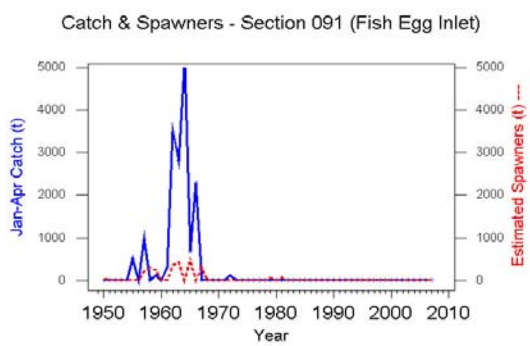
SECTION	85
km2 (1940-2006)	192.37
Mean DOY	88.18
Jan-April	4369
May-Aug	*
Sept-Dec	30.3
Total catch	4399
Class RF	3
F(sp roe fish)	0.972
F(sp pre RF)	0.581
F(sp- all)	0.791
F(gain or reduction)	0.392



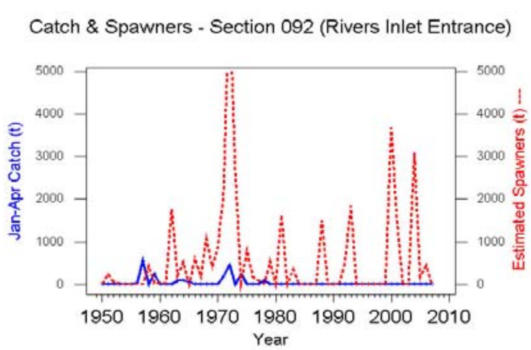


SECTION	86
km2 (1940-2006)	334.11
Mean DOY	87.31
Jan-April	1755
May-Aug	22.2
Sept-Dec	*
Total catch	1777
Class RF	2
F(sp roe fish)	0.528
F(sp pre RF)	0.226
F(sp- all)	0.388
F(gain or reduction)	0.302

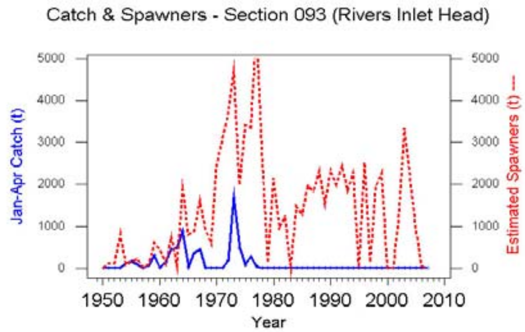




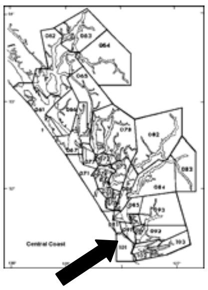
SECTION	91
km2 (1940-2006)	248.79
Mean DOY	89.7
Jan-April	19
May-Aug	*
Sept-Dec	*
Total catch	19
Class RF	1
F(sp roe fish)	0.056
F(sp pre RF)	0.484
F(sp- all)	0.254
F(gain or reduction)	-0.428



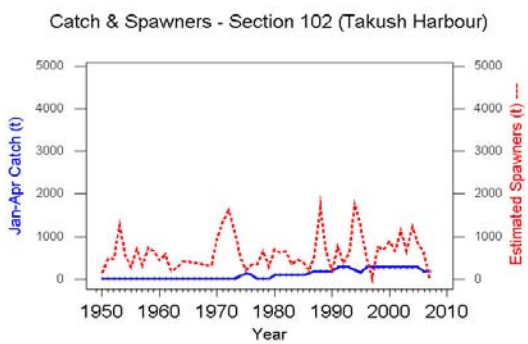
SECTION	92
km2 (1940-2006)	171.65
Mean DOY	96.4
Jan-April	996
May-Aug	*
Sept-Dec	*
Total catch	996
Class RF	2
F(sp roe fish)	0.528
F(sp pre RF)	0.774
F(sp- all)	0.642
F(gain or reduction)	-0.246



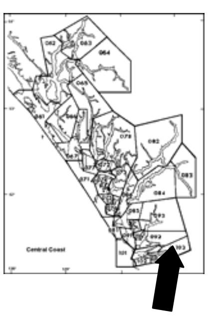
SECTION	93
km2 (1940-2006)	129.76
Mean DOY	81.22
Jan-April	2757
May-Aug	*
Sept-Dec	*
Total catch	2757
Class RF	3
F(sp roe fish)	0.889
F(sp pre RF)	0.968
F(sp- all)	0.925
F(gain or reduction)	-0.079

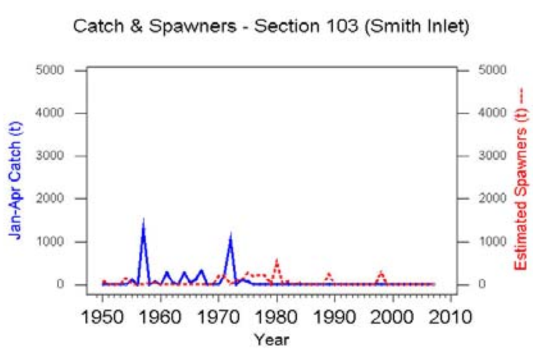


SECTION	101
km2 (1940-2006)	629.68
Mean DOY	
Jan-April	
May-Aug	
Sept-Dec	
Total catch	
Class RF	
F(sp roe fish)	
F(sp pre RF)	
F(sp- all)	
F(gain or reduction)	

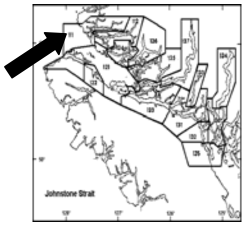


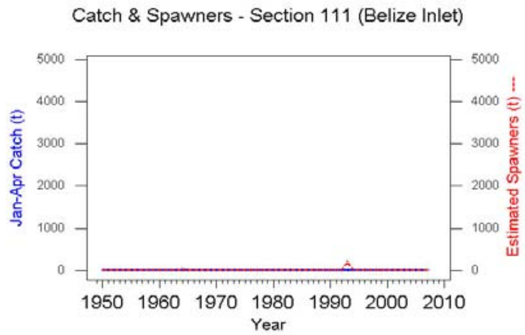
SECTION	102
km2 (1940-2006)	146.83
Mean DOY	90.1
Jan-April	5677
May-Aug	*
Sept-Dec	*
Total catch	5677
Class RF	3
F(sp roe fish)	0.972
F(sp pre RF)	0.968
F(sp- all)	0.970
F(gain or reduction)	0.004



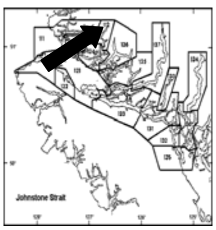


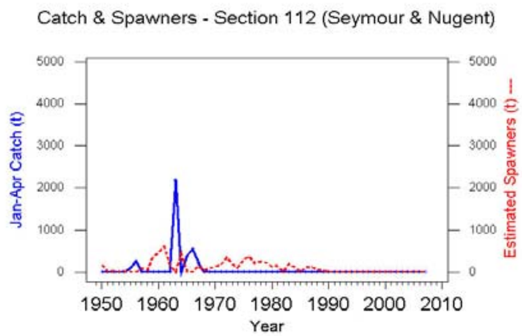
SECTION	103
km2 (1940-2006)	66.12
Mean DOY	99.88
Jan-April	1466
May-Aug	*
Sept-Dec	*
Total catch	1466
Class RF	2
F(sp roe fish)	0.389
F(sp pre RF)	0.226
F(sp- all)	0.313
F(gain or reduction)	0.163



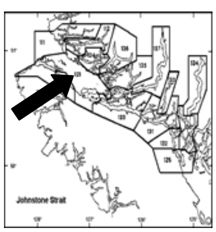


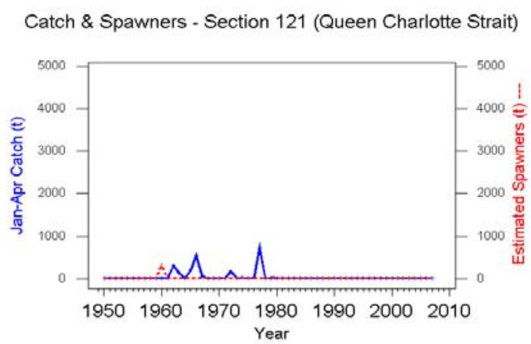
SECTION	111
km2 (1940-2006)	952.83
Mean DOY	115
Jan-April	0
May-Aug	*
Sept-Dec	*
Total catch	0
Class RF	1
F(sp roe fish)	0.056
F(sp pre RF)	0.097
F(sp- all)	0.075
F(gain or reduction)	-0.041



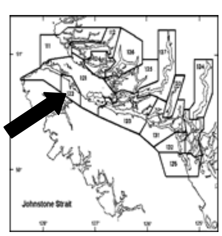


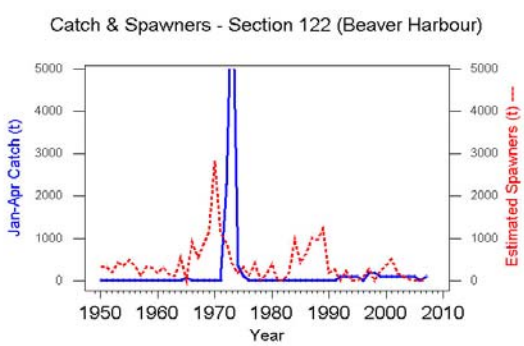
SECTION	112
km2 (1940-2006)	170.28
Mean DOY	95.06
Jan-April	11
May-Aug	*
Sept-Dec	*
Total catch	11
Class RF	1
F(sp roe fish)	0.472
F(sp pre RF)	0.484
F(sp- all)	0.478
F(gain or reduction)	-0.012



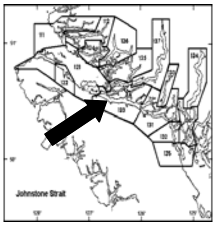


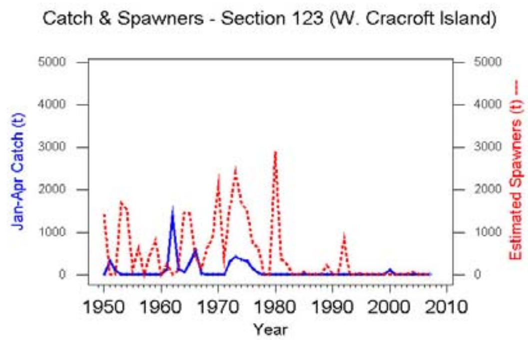
SECTION	121
km2 (1940-2006)	1709.11
Mean DOY	122.42
Jan-April	928
May-Aug	312.9
Sept-Dec	*
Total catch	1241
Class RF	2
F(sp roe fish)	0.139
F(sp pre RF)	0.065
F(sp- all)	0.104
F(gain or reduction)	0.074



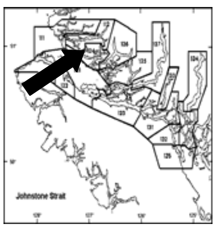


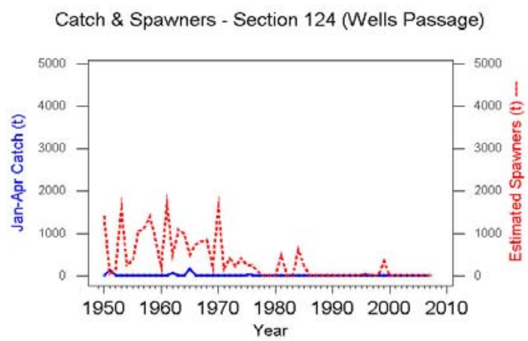
SECTION	122
km2 (1940-2006)	114.55
Mean DOY	91
Jan-April	11673
May-Aug	4.1
Sept-Dec	*
Total catch	11677
Class RF	4
F(sp roe fish)	0.750
F(sp pre RF)	0.968
F(sp- all)	0.851
F(gain or reduction)	-0.218



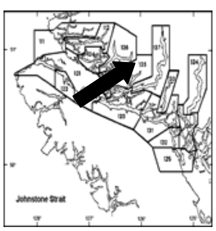


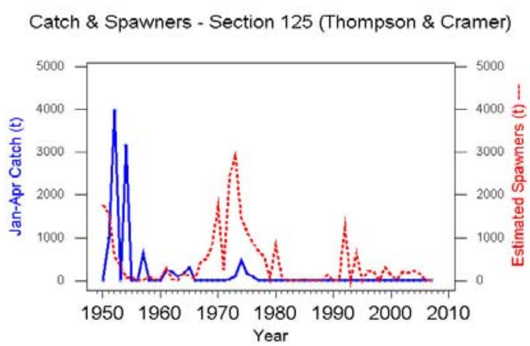
SECTION	123
km2 (1940-2006)	488.85
Mean DOY	85.07
Jan-April	1740
May-Aug	329.1
Sept-Dec	367.3
Total catch	2436
Class RF	2
F(sp roe fish)	0.444
F(sp pre RF)	0.935
F(sp- all)	0.672
F(gain or reduction)	-0.491



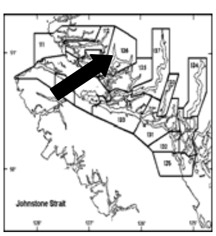


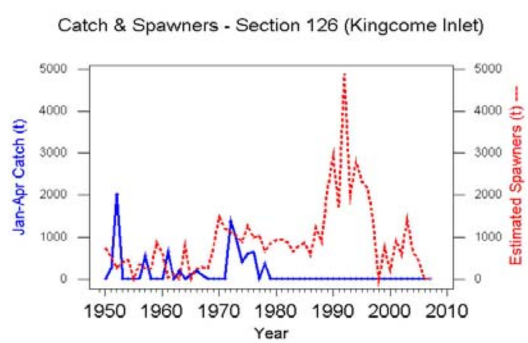
SECTION	124
km2 (1940-2006)	146.09
Mean DOY	105.36
Jan-April	37
May-Aug	*
Sept-Dec	*
Total catch	37
Class RF	1
F(sp roe fish)	0.333
F(sp pre RF)	0.806
F(sp- all)	0.552
F(gain or reduction)	-0.473



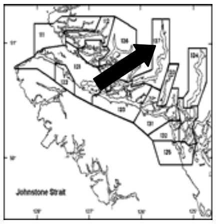


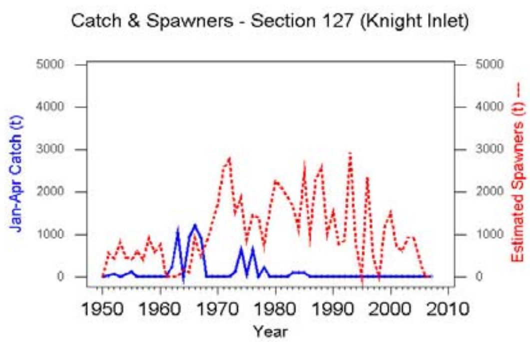
SECTION	125
km2 (1940-2006)	266.8
Mean DOY	85.33
Jan-April	857
May-Aug	*
Sept-Dec	0.1
Total catch	857
Class RF	2
F(sp roe fish)	0.667
F(sp pre RF)	0.935
F(sp- all)	0.791
F(gain or reduction)	-0.269



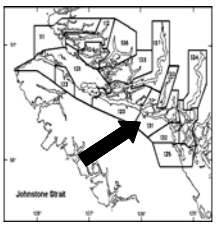


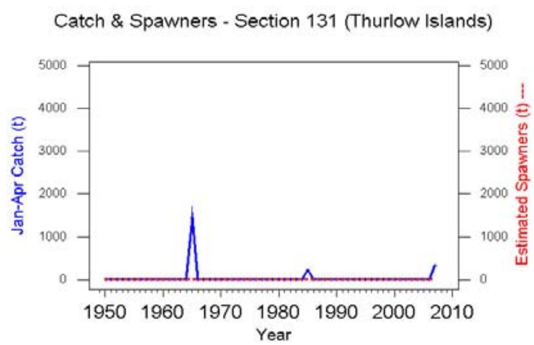
SECTION	126
km2 (1940-2006)	196.4
Mean DOY	79.65
Jan-April	4380
May-Aug	*
Sept-Dec	*
Total catch	4380
Class RF	3
F(sp roe fish)	0.944
F(sp pre RF)	0.935
F(sp- all)	0.940
F(gain or reduction)	0.009



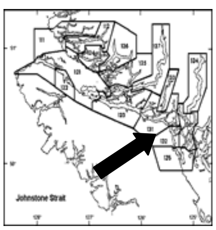


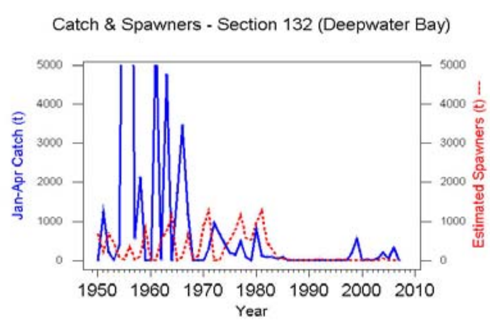
SECTION	127
km2 (1940-2006)	286.01
Mean DOY	79.29
Jan-April	2039
May-Aug	*
Sept-Dec	*
Total catch	2039
Class RF	3
F(sp roe fish)	0.917
F(sp pre RF)	0.710
F(sp- all)	0.821
F(gain or reduction)	0.207



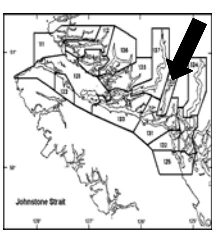


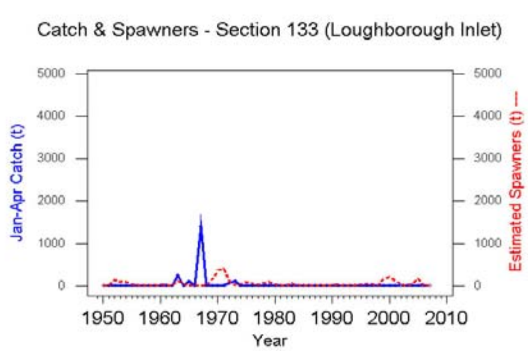
SECTION	131
km2 (1940-2006)	304.74
Mean DOY	81
Jan-April	226
May-Aug	0.1
Sept-Dec	90.7
Total catch	317
Class RF	1
F(sp roe fish)	0.028
F(sp pre RF)	0.000
F(sp- all)	0.015
F(gain or reduction)	0.028



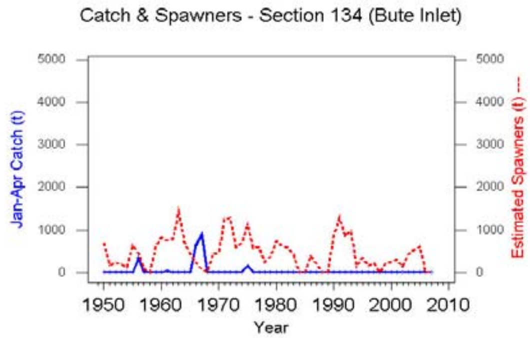


SECTION	132
km2 (1940-2006)	82.11
Mean DOY	101.32
Jan-April	5663
May-Aug	67.4
Sept-Dec	8366.6
Total catch	14097
Class RF	3
F(sp roe fish)	0.639
F(sp pre RF)	0.903
F(sp- all)	0.761
F(gain or reduction)	-0.264

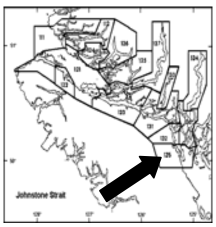


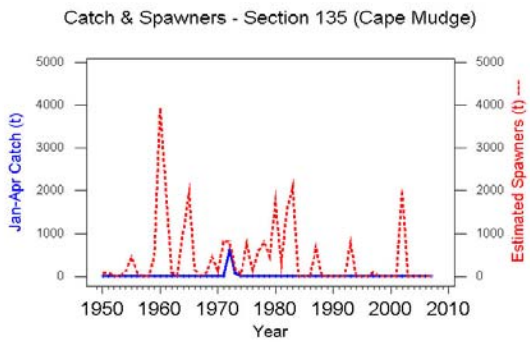


SECTION	133
km2 (1940-2006)	65.94
Mean DOY	77.99
Jan-April	178
May-Aug	53.8
Sept-Dec	61.7
Total catch	293
Class RF	1
F(sp roe fish)	0.694
F(sp pre RF)	0.516
F(sp- all)	0.612
F(gain or reduction)	0.178

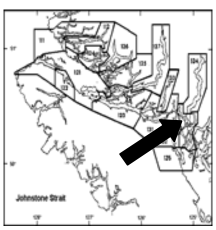


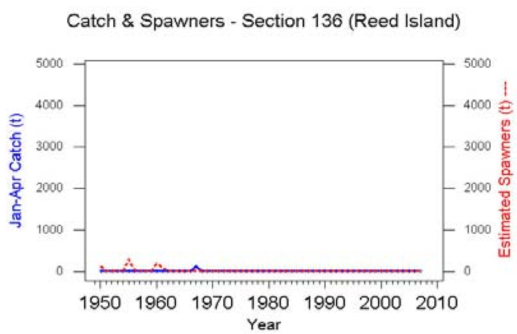
SECTION	134
km2 (1940-2006)	258.9
Mean DOY	72.55
Jan-April	167
May-Aug	0.4
Sept-Dec	*
Total catch	167
Class RF	1
F(sp roe fish)	0.833
F(sp pre RF)	0.742
F(sp- all)	0.791
F(gain or reduction)	0.091



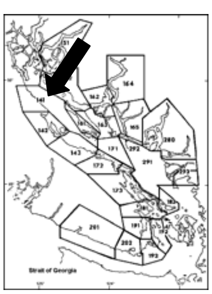


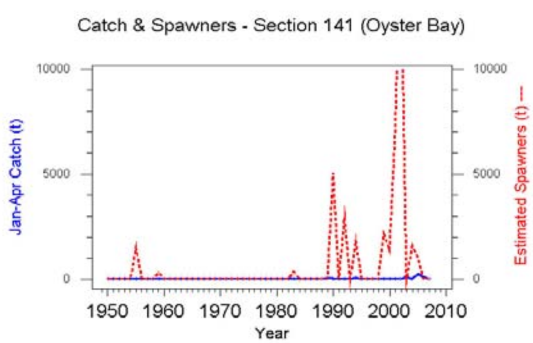
SECTION	135
km2 (1940-2006)	320.11
Mean DOY	86.75
Jan-April	698
May-Aug	221.8
Sept-Dec	123.6
Total catch	1043
Class RF	2
F(sp roe fish)	0.472
F(sp pre RF)	0.742
F(sp- all)	0.597
F(gain or reduction)	-0.270



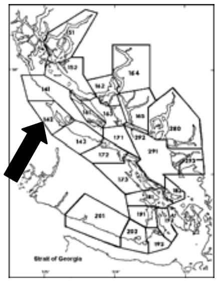


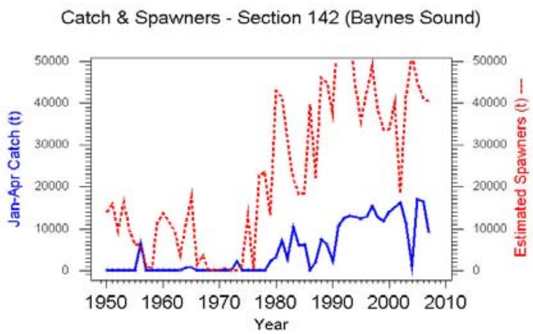
SECTION	136
km2 (1940-2006)	293.69
Mean DOY	86.07
Jan-April	11
May-Aug	22.9
Sept-Dec	0.9
Total catch	35
Class RF	1
F(sp roe fish)	0.000
F(sp pre RF)	0.581
F(sp- all)	0.269
F(gain or reduction)	-0.581



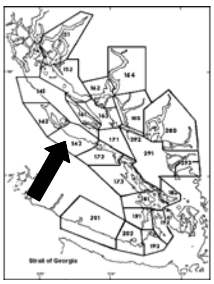


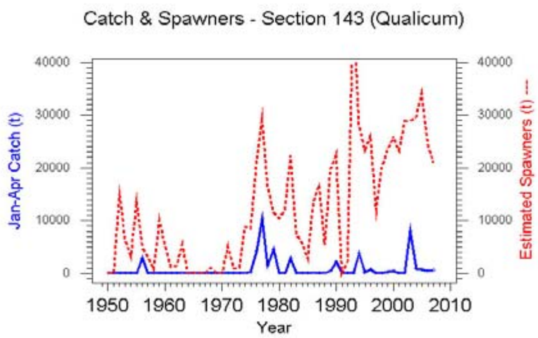
SECTION	141
km2 (1940-2006)	999.35
Mean DOY	72.29
Jan-April	445
May-Aug	*
Sept-Dec	*
Total catch	445
Class RF	1
F(sp roe fish)	0.306
F(sp pre RF)	0.161
F(sp- all)	0.239
F(gain or reduction)	0.144



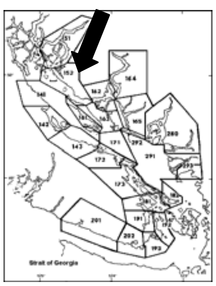


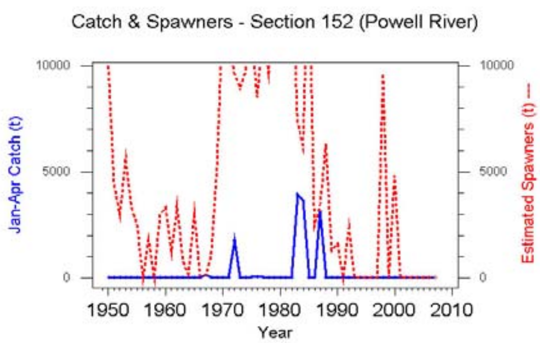
SECTION	142
km2 (1940-2006)	264.76
Mean DOY	71.32
Jan-April	247314
May-Aug	12.9
Sept-Dec	811.5
Total catch	248138
Class RF	5
F(sp roe fish)	0.972
F(sp pre RF)	0.903
F(sp- all)	0.940
F(gain or reduction)	0.069



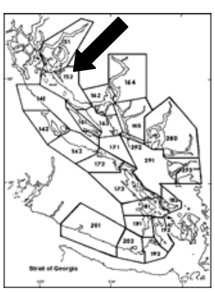


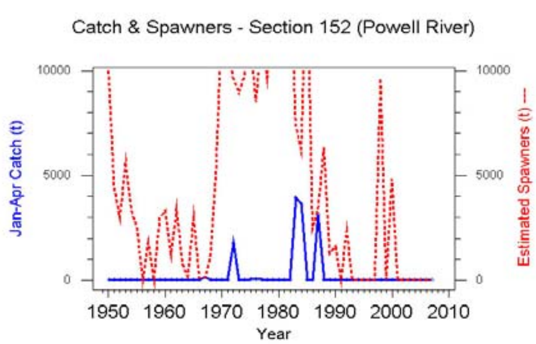
SECTION	143
km2 (1940-2006)	430.47
Mean DOY	73.34
Jan-April	41531
May-Aug	4.4
Sept-Dec	353.8
Total catch	41889
Class RF	4
F(sp roe fish)	0.972
F(sp pre RF)	0.710
F(sp- all)	0.851
F(gain or reduction)	0.263



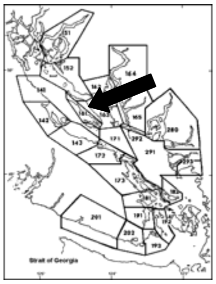


SECTION	151
km2 (1940-2006)	399.71
Mean DOY	76.15
Jan-April	85
May-Aug	0
Sept-Dec	*
Total catch	85
Class RF	1
F(sp roe fish)	0.111
F(sp pre RF)	0.258
F(sp- all)	0.179
F(gain or reduction)	-0.147

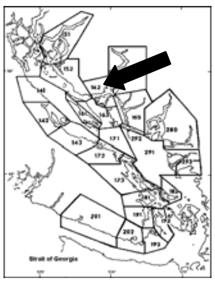


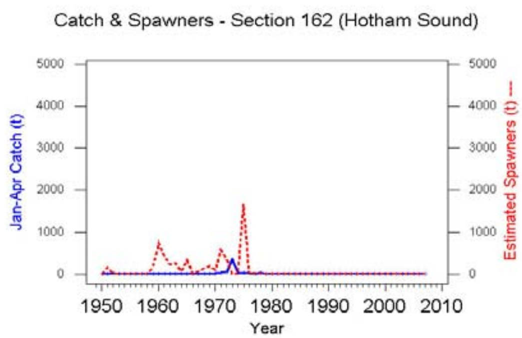


SECTION	152
km2 (1940-2006)	558.26
Mean DOY	77.83
Jan-April	12582
May-Aug	89.9
Sept-Dec	44.4
Total catch	12716
Class RF	4
F(sp roe fish)	0.639
F(sp pre RF)	0.935
F(sp- all)	0.776
F(gain or reduction)	-0.297

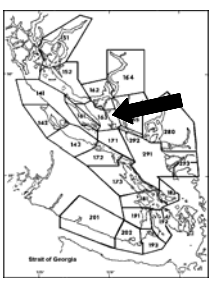


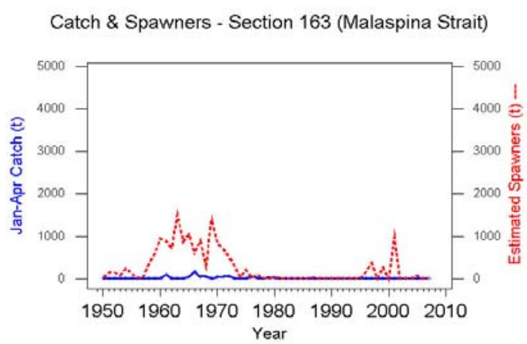
SECTION	161
km2 (1940-2006)	237.47
Mean DOY	83
Jan-April	135
May-Aug	*
Sept-Dec	*
Total catch	135
Class RF	1
F(sp roe fish)	0.028
F(sp pre RF)	0.032
F(sp- all)	0.030
F(gain or reduction)	-0.004



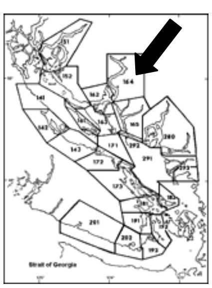


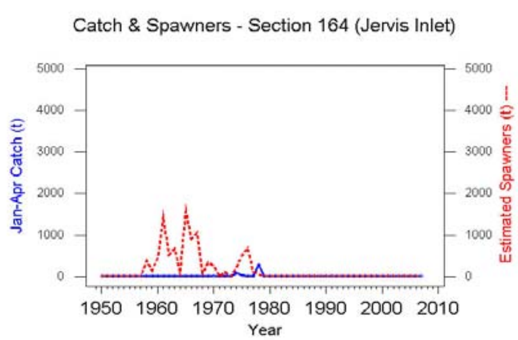
SECTION	162
km2 (1940-2006)	163.69
Mean DOY	79.77
Jan-April	519
May-Aug	115.4
Sept-Dec	40.7
Total catch	675
Class RF	2
F(sp roe fish)	0.111
F(sp pre RF)	0.710
F(sp- all)	0.388
F(gain or reduction)	-0.599



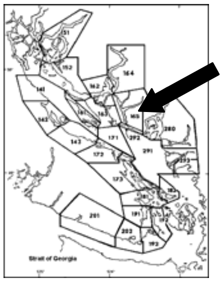


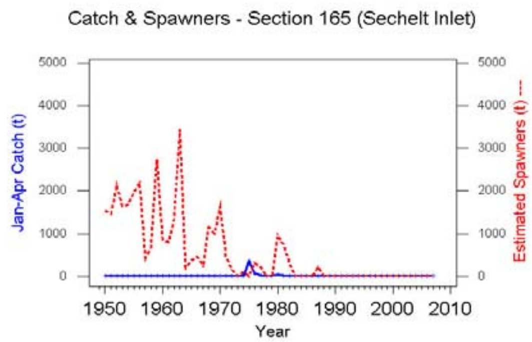
SECTION	163
km2 (1940-2006)	423.02
Mean DOY	77.37
Jan-April	315
May-Aug	523.8
Sept-Dec	135.6
Total catch	975
Class RF	1
F(sp roe fish)	0.389
F(sp pre RF)	1.000
F(sp- all)	0.672
F(gain or reduction)	-0.611



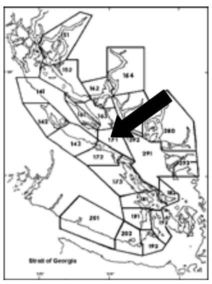


SECTION	164
km2 (1940-2006)	185.27
Mean DOY	92.05
Jan-April	394
May-Aug	52.2
Sept-Dec	10.2
Total catch	456
Class RF	1
F(sp roe fish)	0.167
F(sp pre RF)	0.677
F(sp- all)	0.403
F(gain or reduction)	-0.511

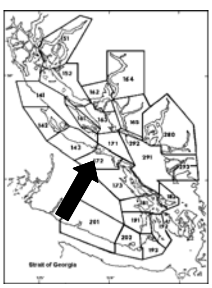


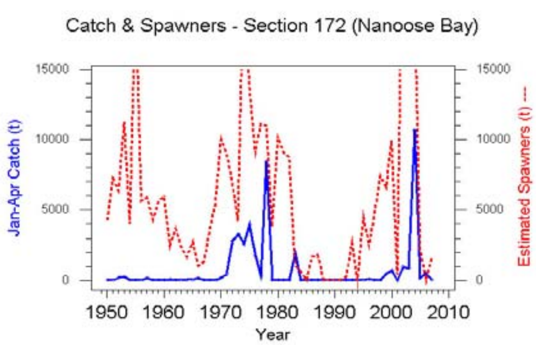


SECTION	165
km2 (1940-2006)	116.96
Mean DOY	91.69
Jan-April	526
May-Aug	94.6
Sept-Dec	36.5
Total catch	657
Class RF	2
F(sp roe fish)	0.250
F(sp pre RF)	1.000
F(sp- all)	0.597
F(gain or reduction)	-0.750

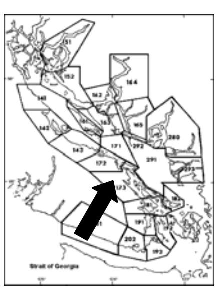


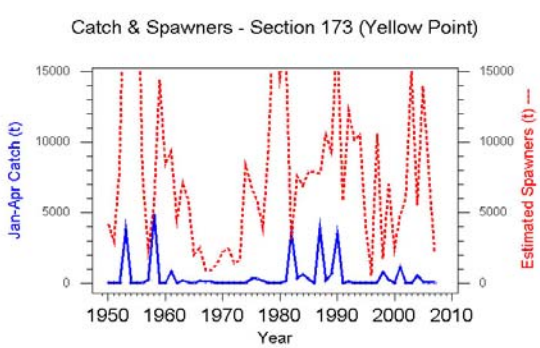
SECTION	171
km2 (1940-2006)	589.87
Mean DOY	
Jan-April	
May-Aug	
Sept-Dec	
Total catch	
Class RF	
F(sp roe fish)	
F(sp pre RF)	
F(sp- all)	
F(gain or reduction)	



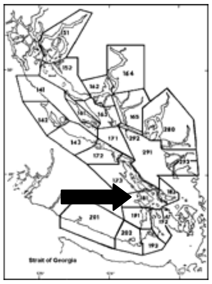


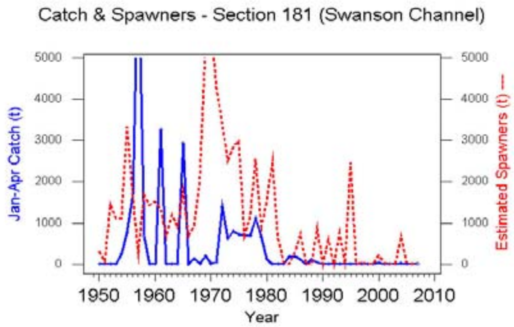
SECTION	172
km2 (1940-2006)	198.26
Mean DOY	76.12
Jan-April	39528
May-Aug	*
Sept-Dec	1412.9
Total catch	40941
Class RF	4
F(sp roe fish)	0.806
F(sp pre RF)	0.935
F(sp- all)	0.866
F(gain or reduction)	-0.130



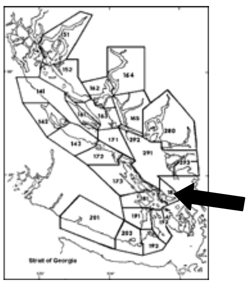


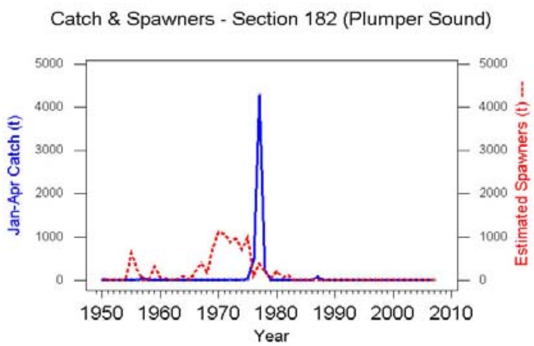
SECTION	173
km2 (1940-2006)	398.29
Mean DOY	78.62
Jan-April	16953
May-Aug	10.5
Sept-Dec	19851.4
Total catch	36815
Class RF	4
F(sp roe fish)	1.000
F(sp pre RF)	1.000
F(sp- all)	1.000
F(gain or reduction)	0.000



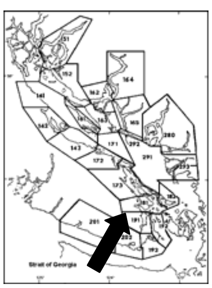


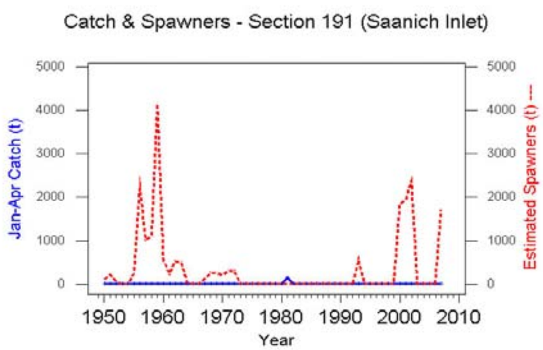
SECTION	181
km2 (1940-2006)	272.26
Mean DOY	62.87
Jan-April	7513
May-Aug	69.3
Sept-Dec	14408.9
Total catch	21991
Class RF	3
F(sp roe fish)	0.667
F(sp pre RF)	1.000
F(sp- all)	0.821
F(gain or reduction)	-0.333



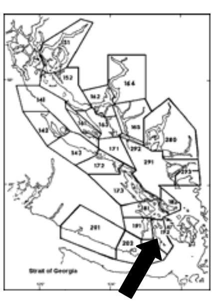


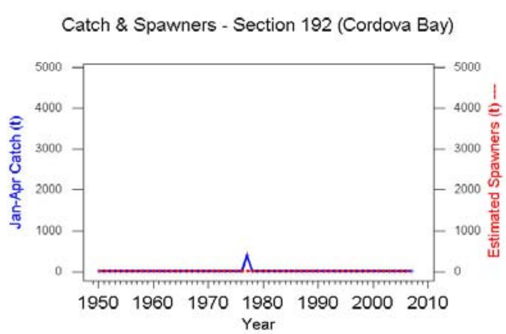
SECTION	182
km2 (1940-2006)	325.65
Mean DOY	68.12
Jan-April	5110
May-Aug	*
Sept-Dec	2207.1
Total catch	7317
Class RF	3
F(sp roe fish)	0.333
F(sp pre RF)	0.581
F(sp- all)	0.448
F(gain or reduction)	-0.247



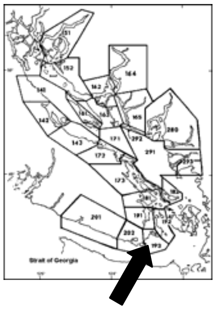


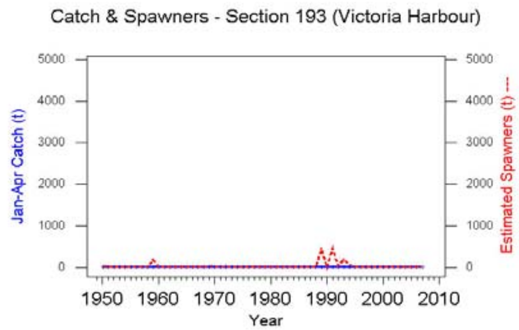
SECTION	191
km2 (1940-2006)	71.02
Mean DOY	84.68
Jan-April	142
May-Aug	*
Sept-Dec	539
Total catch	681
Class RF	1
F(sp roe fish)	0.167
F(sp pre RF)	0.710
F(sp- all)	0.418
F(gain or reduction)	-0.543



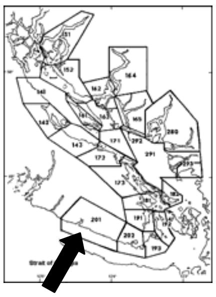


SECTION	192
km2 (1940-2006)	390.02
Mean DOY	81.67
Jan-April	398
May-Aug	*
Sept-Dec	*
Total catch	398
Class RF	1
F(sp roe fish)	0.056
F(sp pre RF)	0.032
F(sp- all)	0.045
F(gain or reduction)	0.023



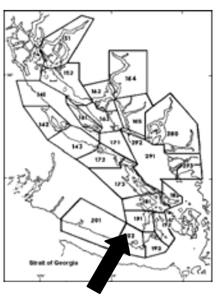


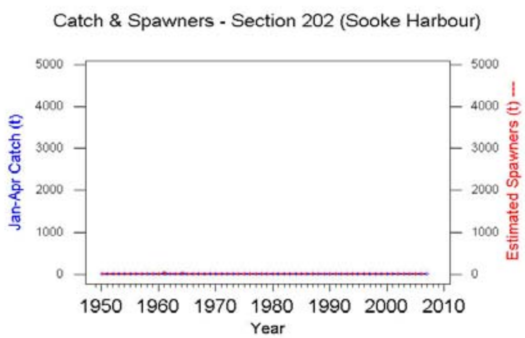
SECTION	193
km2 (1940-2006)	372
Mean DOY	86.31
Jan-April	*
May-Aug	*
Sept-Dec	881.8
Total catch	882
Class RF	0
F(sp roe fish)	0.167
F(sp pre RF)	0.452
F(sp- all)	0.299
F(gain or reduction)	-0.285



No data

SECTION	201
km2 (1940-2006)	865.54
Mean DOY	
Jan-April	
May-Aug	
Sept-Dec	
Total catch	
Class RF	
F(sp roe fish)	
F(sp pre RF)	
F(sp- all)	
F(gain or reduction)	





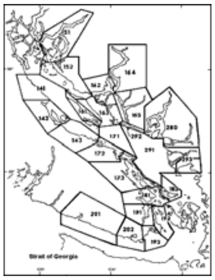
SECTION	202
km2 (1940-2006)	328.13
Mean DOY	92
Jan-April	*
May-Aug	0
Sept-Dec	0.5
Total catch	1
Class RF	0
F(sp roe fish)	0.028
F(sp pre RF)	0.161
F(sp- all)	0.090
F(gain or reduction)	-0.134

No Map

No data

SECTION	211
km2 (1940-2006)	75.52
Mean DOY	
Jan-April	
May-Aug	
Sept-Dec	
Total catch	
Class RF	
F(sp roe fish)	0.028
F(sp pre RF)	0.000
F(sp- all)	0.015
F(gain or reduction)	0.028

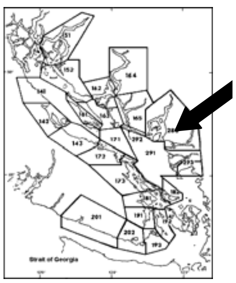
i

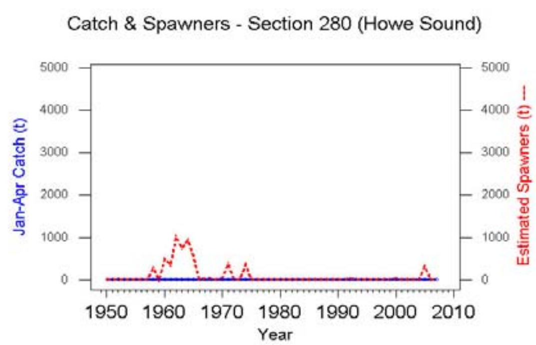


No data

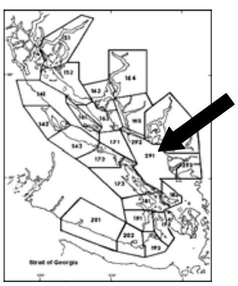
i

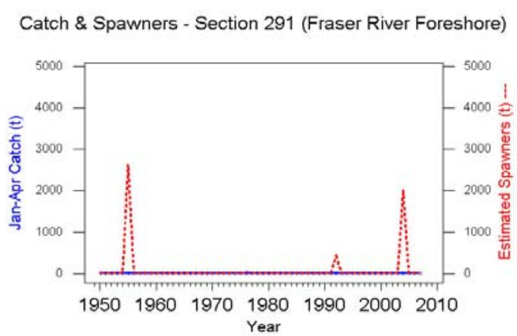
SECTION	220
km2 (1940-2006)	0.1
Mean DOY	104
Jan-April	*
May-Aug	*
Sept-Dec	*
Total catch	*
Class RF	0
F(sp roe fish)	
F(sp pre RF)	
F(sp- all)	
F(gain or reduction)	



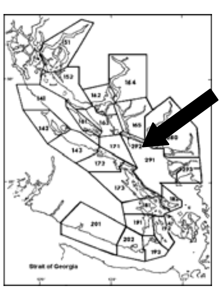


SECTION	280
km2 (1940-2006)	452.34
Mean DOY	81.05
Jan-April	14
May-Aug	1.3
Sept-Dec	0
Total catch	15
Class RF	1
F(sp roe fish)	0.139
F(sp pre RF)	0.355
F(sp- all)	0.239
F(gain or reduction)	-0.216

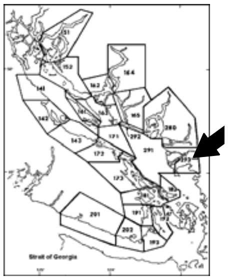


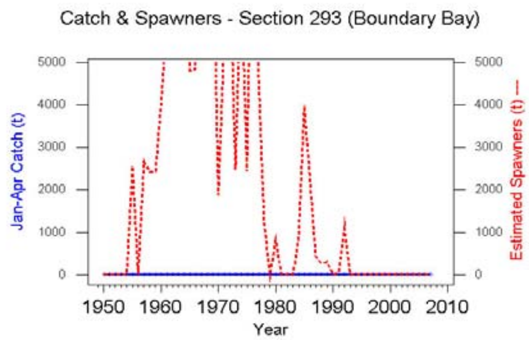


SECTION	291
km2 (1940-2006)	1672.14
Mean DOY	68
Jan-April	0
May-Aug	*
Sept-Dec	*
Total catch	0
Class RF	1
F(sp roe fish)	0.083
F(sp pre RF)	0.032
F(sp- all)	0.060
F(gain or reduction)	0.051

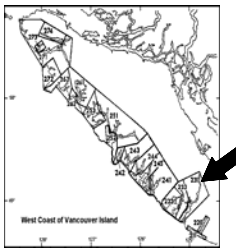


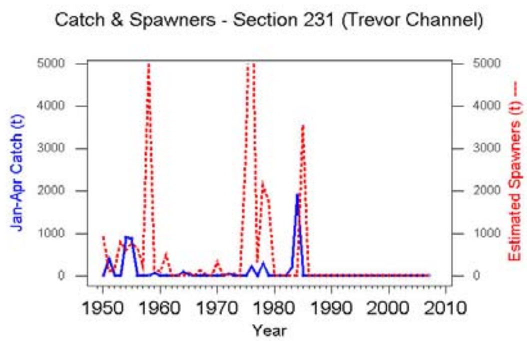
SECTION	292
km2 (1940-2006)	37.66
Mean DOY	82.92
Jan-April	1
May-Aug	3.9
Sept-Dec	367.3
Total catch	372
Class RF	1
F(sp roe fish)	0.028
F(sp pre RF)	0.290
F(sp- all)	0.149
F(gain or reduction)	-0.263



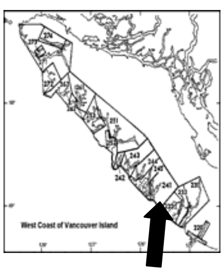


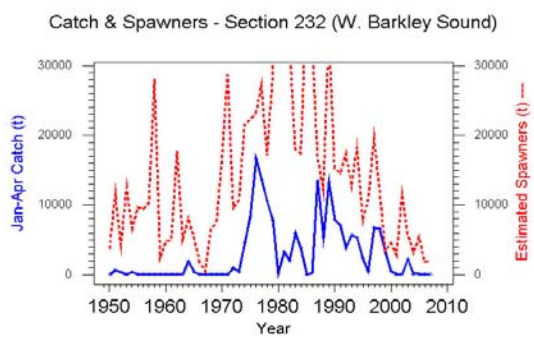
SECTION	293
km2 (1940-2006)	112.45
Mean DOY	60.23
Jan-April	18
May-Aug	25.3
Sept-Dec	0.8
Total catch	45
Class RF	1
F(sp roe fish)	0.472
F(sp pre RF)	0.484
F(sp- all)	0.478
F(gain or reduction)	-0.012



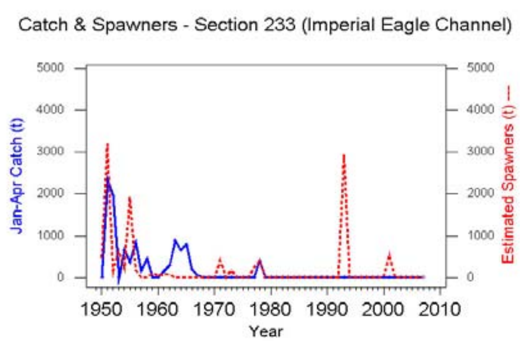


SECTION	231
km2 (1940-2006)	148.36
Mean DOY	74.03
Jan-April	2667
May-Aug	8.5
Sept-Dec	79.9
Total catch	2756
Class RF	3
F(sp roe fish)	0.250
F(sp pre RF)	0.871
F(sp- all)	0.537
F(gain or reduction)	-0.621

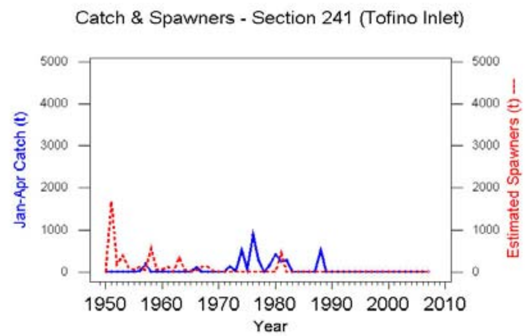




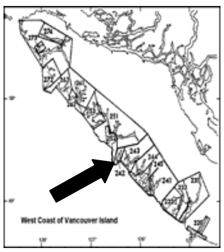
SECTION	232
km2 (1940-2006)	214.14
Mean DOY	73.07
Jan-April	162333
May-Aug	32.7
Sept-Dec	237.9
Total catch	162604
Class RF	5
F(sp roe fish)	1.000
F(sp pre RF)	1.000
F(sp- all)	1.000
F(gain or reduction)	0.000

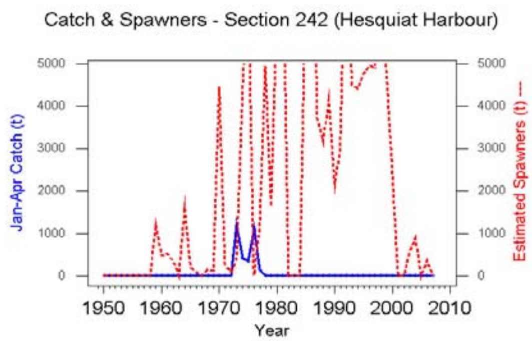


SECTION	233
km2 (1940-2006)	179.21
Mean DOY	71.88
Jan-April	396
May-Aug	*
Sept-Dec	*
Total catch	396
Class RF	1
F(sp roe fish)	0.167
F(sp pre RF)	0.677
F(sp- all)	0.403
F(gain or reduction)	-0.511

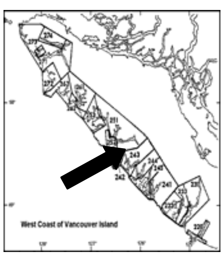


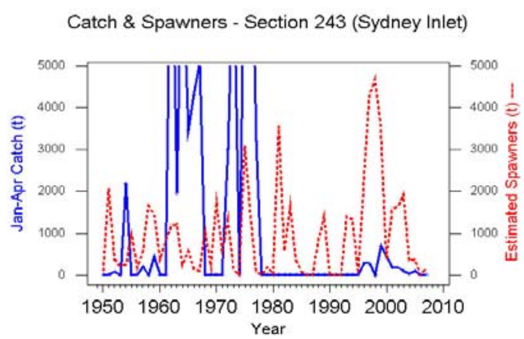
SECTION	241
km2 (1940-2006)	89.12
Mean DOY	60.78
Jan-April	3535
May-Aug	*
Sept-Dec	*
Total catch	3535
Class RF	3
F(sp roe fish)	0.028
F(sp pre RF)	0.742
F(sp- all)	0.358
F(gain or reduction)	-0.714



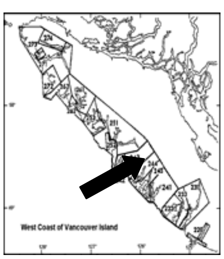


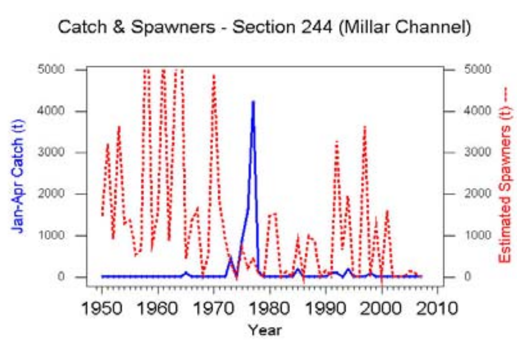
SECTION	242
km2 (1940-2006)	36.27
Mean DOY	68.8
Jan-April	3202
May-Aug	*
Sept-Dec	*
Total catch	3202
Class RF	3
F(sp roe fish)	0.806
F(sp pre RF)	0.548
F(sp- all)	0.687
F(gain or reduction)	0.257



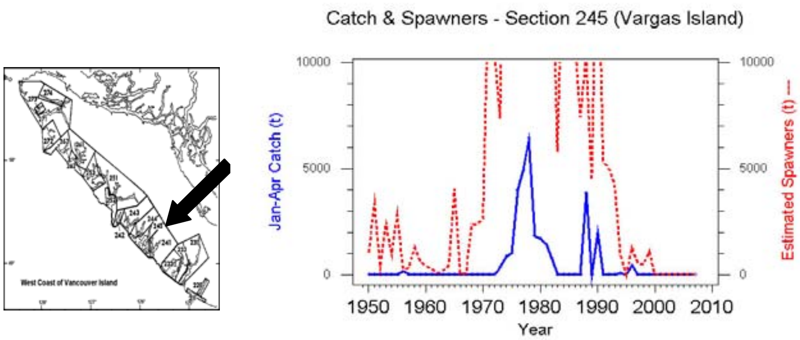


SECTION	243
km2 (1940-2006)	83.25
Mean DOY	78.48
Jan-April	33281
May-Aug	*
Sept-Dec	*
Total catch	33281
Class RF	4
F(sp roe fish)	0.750
F(sp pre RF)	1.000
F(sp- all)	0.866
F(gain or reduction)	-0.250

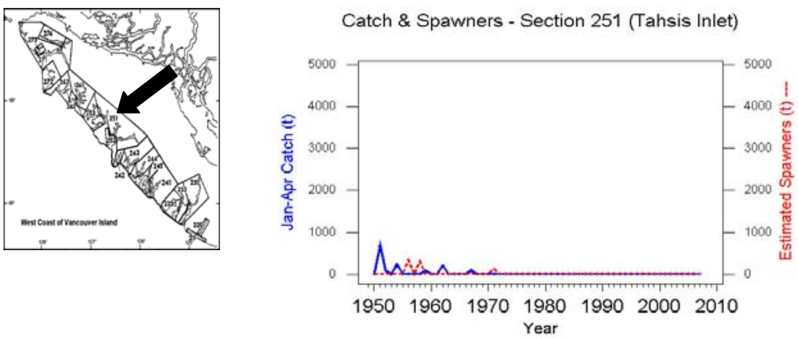




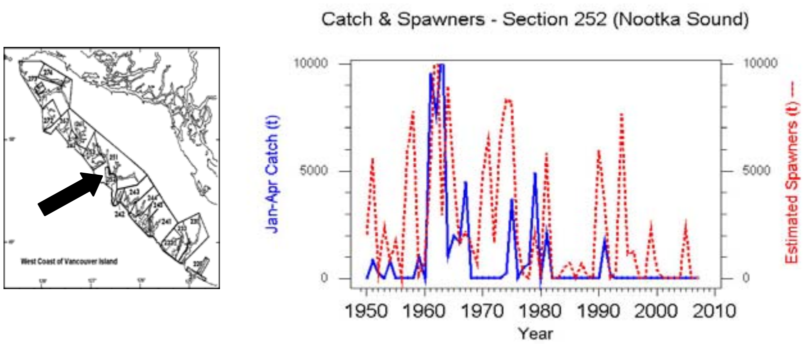
SECTION	244
km2 (1940-2006)	72.4
Mean DOY	79.97
Jan-April	7915
May-Aug	*
Sept-Dec	*
Total catch	7915
Class RF	3
F(sp roe fish)	0.639
F(sp pre RF)	0.968
F(sp- all)	0.791
F(gain or reduction)	-0.329



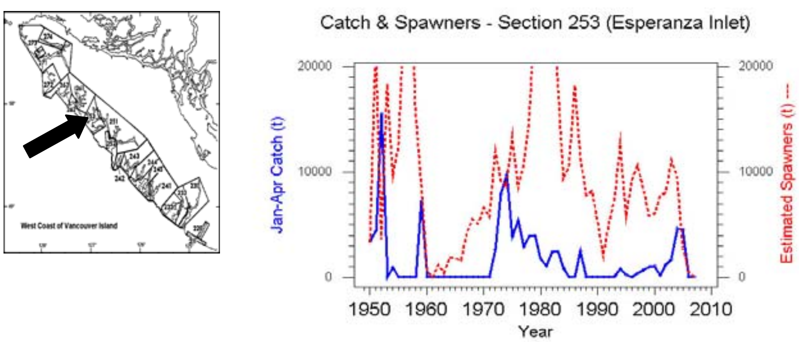
SECTION	245
km2 (1940-2006)	215.29
Mean DOY	76.42
Jan-April	29720
May-Aug	*
Sept-Dec	*
Total catch	29720
Class RF	4
F(sp roe fish)	0.778
F(sp pre RF)	0.903
F(sp- all)	0.836
F(gain or reduction)	-0.125



SECTION	251
km2 (1940-2006)	138.67
Mean DOY	91.4
Jan-April	*
May-Aug	*
Sept-Dec	*
Total catch	*
Class RF	0
F(sp roe fish)	0.028
F(sp pre RF)	0.129
F(sp- all)	0.075
F(gain or reduction)	-0.101

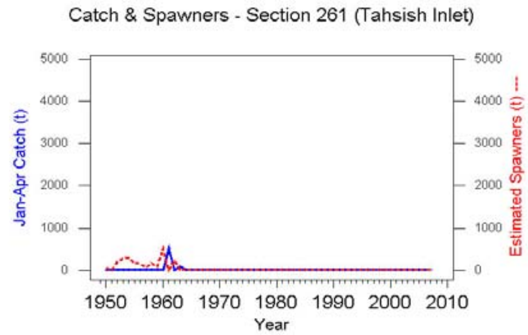


SECTION	252
km2 (1940-2006)	109.24
Mean DOY	84.75
Jan-April	13892
May-Aug	*
Sept-Dec	*
Total catch	13892
Class RF	4
F(sp roe fish)	0.639
F(sp pre RF)	1.000
F(sp- all)	0.806
F(gain or reduction)	-0.361

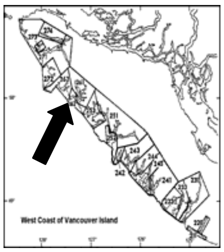


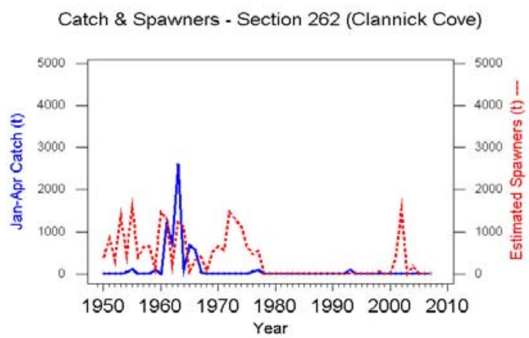
SECTION	253
km2 (1940-2006)	192.97
Mean DOY	69.15
Jan-April	67877
May-Aug	*
Sept-Dec	115.9
Total catch	67993
Class RF	5
F(sp roe fish)	1.000
F(sp pre RF)	0.968
F(sp- all)	0.985
F(gain or reduction)	0.032

Appendix 1 figures

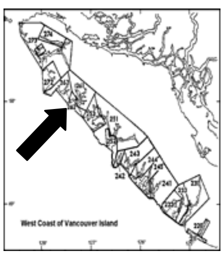


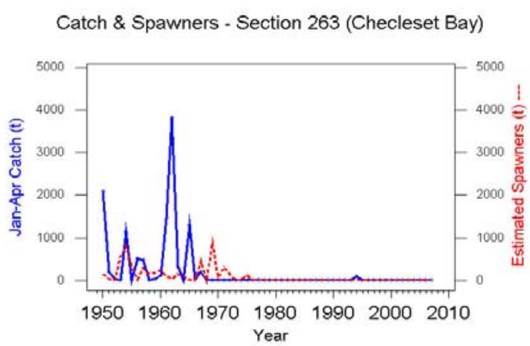
SECTION	261
km2 (1940-2006)	114.24
Mean DOY	76.19
Jan-April	*
May-Aug	*
Sept-Dec	*
Total catch	*
Class RF	0
F(sp roe fish)	0.000
F(sp pre RF)	0.645
F(sp- all)	0.299
F(gain or reduction)	-0.645



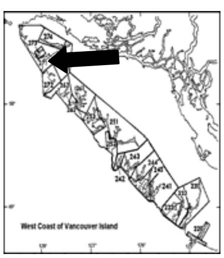


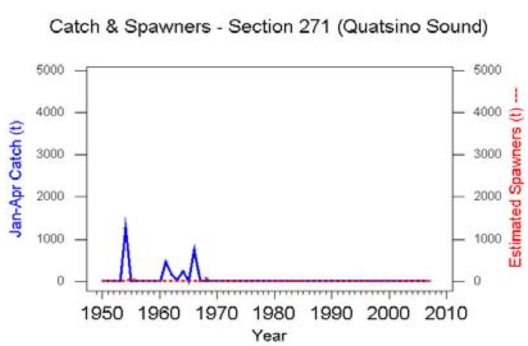
SECTION	262
km2 (1940-2006)	130.6
Mean DOY	69.65
Jan-April	235
May-Aug	*
Sept-Dec	*
Total catch	235
Class RF	1
F(sp roe fish)	0.306
F(sp pre RF)	1.000
F(sp- all)	0.627
F(gain or reduction)	-0.694



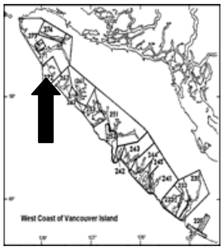


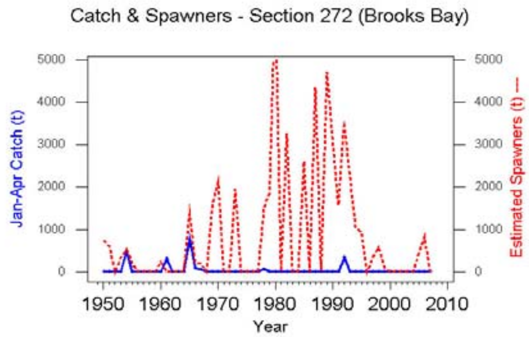
SECTION	263
km2 (1940-2006)	184.85
Mean DOY	70.4
Jan-April	102
May-Aug	*
Sept-Dec	*
Total catch	102
Class RF	1
F(sp roe fish)	0.083
F(sp pre RF)	0.903
F(sp- all)	0.463
F(gain or reduction)	-0.820



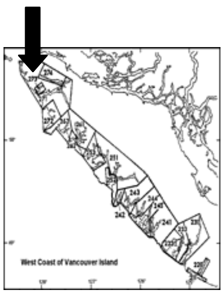


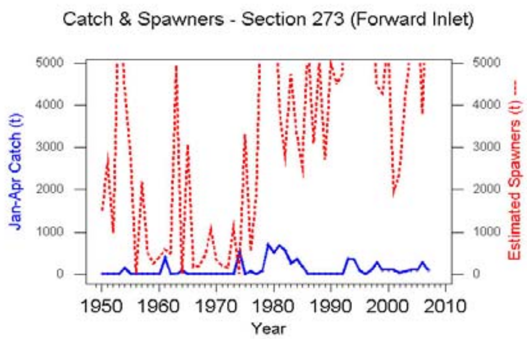
SECTION	271
km2 (1940-2006)	402.04
Mean DOY	73.2
Jan-April	*
May-Aug	*
Sept-Dec	*
Total catch	*
Class RF	0
F(sp roe fish)	0.028
F(sp pre RF)	0.097
F(sp- all)	0.060
F(gain or reduction)	-0.069



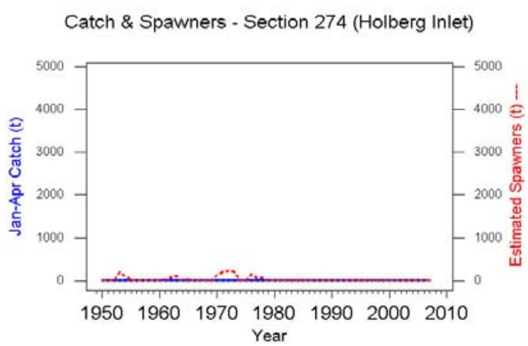


SECTION	272
km2 (1940-2006)	232.59
Mean DOY	69.12
Jan-April	1817
May-Aug	*
Sept-Dec	*
Total catch	1817
Class RF	2
F(sp roe fish)	0.528
F(sp pre RF)	0.613
F(sp- all)	0.567
F(gain or reduction)	-0.085





SECTION	273
km2 (1940-2006)	18.42
Mean DOY	72.76
Jan-April	7078
May-Aug	*
Sept-Dec	0.1
Total catch	7078
Class RF	3
F(sp roe fish)	0.972
F(sp pre RF)	0.968
F(sp- all)	0.970
F(gain or reduction)	0.004



SECTION	274
km2 (1940-2006)	49.45
Mean DOY	103.24
Jan-April	11
May-Aug	*
Sept-Dec	*
Total catch	11
Class RF	1
F(sp roe fish)	0.167
F(sp pre RF)	0.226
F(sp- all)	0.194
F(gain or reduction)	-0.059

Appendix 2 - Spatial and temporal distribution of the fishery

Appendix 2 is a stand alone report that describes the development of a geo-referenced database for the catches of the British Columbia herring roe fishery. Although this is an independent report it is complementary to the main body of the report concerned with examining the serial depletion hypothesis that examines changes in the inter-annual distribution of spawning as a function of the e herring roe fishery. The report in Appendix 2 explains and comments on the geographic distribution of the roe fishery. Although related, many aspects of Appendix 2 are not directly related to the issue of serial depletion. Therefore it is presented separately as an appendix.

Appendix 2 - Spatial and temporal distribution of the fishery - a geo-referenced roe herring catch database

D.E. Hay, K.S. Daniel and P.B. McCarter

Abstract

The British Columbia herring roe fishery is conducted near inter-and sub-tidal spawning locations. The areas open to fishing may change slightly each year but, since the late 1970's, always occur *within* the much larger assessment areas used for determination of spawning stock biomass. We used a GIS approach to construct a database on the geographic location and total area (km^2) of annual fishery openings for both gears used in the fishery: gill nets and purse seines. We include data on the dates, time-of-day and durations of fishery openings (hours). The BC roe fishery is conservative, taking a maximum of 20 percent of the spawning biomass in any of the five major assessment areas. However the assessment areas are large and may contain a number of different spawning and fishing sites. The assessment areas are divisible into Statistical Areas that are further divisible into Sub-Management Areas or SMA's. As a rough approximation, each assessment area consists of about 10-20 SMA's. We examine temporal (dates and duration) and geographic variation in fishing. In general, most changes in timing and duration reflect policy changes in fishery management, not changes in herring biology or population dynamics. Our analyses distinguished between sites of fishing opportunities (called openings) and catch locations, although these are related. In most years the fishery is conducted in less than twenty percent of the available area of the British Columbia coast, a much smaller area than the sum of the assessment areas. The identification of the fishing locations is useful for coastal zone planning, consideration of potential Marine Protected Areas and also to provide a basis for avoiding conflicts with other fisheries, mariculture, and other shore-based activity.

This report is presented as an appendix to a PSARC Pelagic Sub-committee working paper (Potential impacts of the British Columbia herring roe fishery on the spatial and temporal distribution of herring spawn: examination of the serial depletion hypothesis, by D.E. Hay, P.B. McCarter and K.S. Daniel) that examines the hypothesis that the herring roe fishery has resulted in serial depletion of coastal herring populations.

Introduction

The British Columba (BC) herring roe fishery began in the early 1970's. Management of the fishery developed during its first decade and by the 1980's there was a coherent management plan in place. Since its inception, managers have been cognizant of the preceding meal fishery conducted from the 1940's to the 1960's, and ending with the collapse of most populations and a coast-wide moratorium on herring fishing (Stocker 1993). Consequently, this fishery has been conducted in a conservative way, taking much smaller catches than the preceding reduction fishery. Recent reviews have tended to be supportive of fishery policies (Wallace and Glavin 2003).

The main objective of this paper is to examine the spatial and temporal distribution of the modern roe fishery. Specifically, what was the extent and duration of fishing activity in BC? To address this and other issues, we investigated the dates, durations, locations and spatial dimensions of each fishery. The roe fishery is conducted within five different assessment areas of the BC coast. Each year, an annual TAC (Total allowable Catch) is estimated from an annual stock assessment review (i.e., Schweigert and Haist 2006). A recommended maximum biological catch is determined for each assessment area and is usually no more than twenty percent of the total anticipated spawning biomass. This biological quota is then reviewed and sometimes adjusted downwards by a Department of Fisheries and Oceans (DFO) management committee ('Herring Working Group'). Then, in consultation with the DFO Science Branch and the industry, the biological quota may be revised (lowered) to allow for logistical considerations for the scheduling of the fishery. Specifically, managers have to plan for using two different fishing gears: approximately 250 purse seine vessels with an allocation of 55 percent of the TAC, and about 1300 gill nets, with an allocation of 45 percent of the TAC. Each year before the fishery, managers (in consultation with the industry) must determine the maximum number of vessels of each gear type that can be permitted to fish in each assessment area. They make their decision based on consideration of the available catch size and safety concerns.

Once the annual fishing plan is in place, operational decisions are made, as required, in the field. This includes the exact date (day and hour) and place that each fishery (seine and gillnet can open). The decision is based on prior pre-fishery acoustic monitoring of herring distribution, abundance and maturation stage. In most years a single opening may actually consist of a number of distinct openings, closures and re-openings, perhaps with different geographic limits or boundaries, until the target catch is taken. Our analysis defines and distinguishes between each of these within-season openings as 'sub-openings'. We developed a new database that compiled information on the times and dates of fishery openings. To do this we created a new term, 'sub-opening', as a distinct spatial and temporal opening that resulted in only a partial contribution to the TAC or target catch in the assessment area. We used GIS techniques to estimate the geographic areas (km^2) of annual fishery openings or sub-openings for both gill-nets and purse seine fisheries.

In general we show that the execution of the herring roe fishery is confined to relatively small areas of the BC coast, usually between ten and twenty percent of the total available areas. We show that this area is much smaller than the assessment areas used for estimation of spawning biomass. The duration of the fishery is relatively constant among years but is changing in recent years in response to industry-sponsored policy changes that have reduced fishing capacity.

Overview of the Roe Fishery

A TAC is determined each year for each assessment area during the annual assessment process. The annual assessment estimates both the returning spawning stock from the previous year plus an estimate of recruited spawning stock. The estimated TAC is based on a maximal removal of 20 percent of the estimated spawning biomass for each assessment area. This TAC is recommended only if the predicted estimate of spawning biomass (returning fish plus recruits) is above an estimated minimal spawning level (defined as the 'cutoff') (Stocker 1993).

The term 'target catch' might be used to differentiate the anticipated catch from the TAC (which is a derivative of the scientific assessment process). The target catch recommended by the DFO Management for each assessment area considers other factors. These include safety and enforcement issues as well as logistical aspects of the fishery that require allocation to the two gear types (purse seines or gillnets). Usually the target catch is the same or slightly lower than the TAC. Therefore the target catch represents the maximum allowable catch, by each gear type, within an assessment area.

There is a theoretical maximum of 14 target catches each year (two gear types operating in seven assessments areas – five major and two minor) but in all years the number of target catches is lower. This occurs because of the historical allocation of catch by gear type: purse seines take 55 percent and gillnets take 45 percent. In recent years the herring industry, in consultation with DFO managers, decide how to spread the seine and gillnet fisheries between the areas. DFO provides advice to industry, but it is the industry who ultimately decides what gear type they will fish in which area. It is also industry who decides the size of the target catch (or quota), subject to the TAC for the area.

In most years, for logistical reasons, catches may be restricted in one or more assessment areas to one gear type. The basis for these decisions varies and depends on a variety of factors including the absolute and relative size of the TAC's among assessment areas. Also, some areas with sheltered water are more suitable for fisheries by the smaller gillnet vessels, so safety concerns during fishing operations, also are considered.

Materials and Methods

Geographic estimation of catches

There are two types of catch estimates in the fishery. A 'hailed' catch is the catch (biomass in tonnes) that is made during a fishery based on estimates provided by fishers to the managers. When the cumulated hailed catches reach the target catch a fishery will be closed. This estimate of catch is useful because the geographic location of the hailed catch is specific, but sometimes, especially in the developing years of the fishery, the tonnages may have underestimated the actual catch. In contrast, a different estimate of 'landed catch', estimated after the fishery from sales slip data in fish processing plants, provides a better estimate of the actual tonnage, but a less reliable guide to the exact location of catches. This can happen because catch vessels of both gear types may offload to packing vessels. Sometimes packing vessels load catches from different areas. More common, however, is that packing vessels may take catches from multiple openings (see definitions below).

Fisheries are often closed on the basis of hailed catch (i.e. on the grounds estimates) combined with validated weights so it is vital that this estimate be as accurate as possible. Catches from both gear types are not loaded onto the same packing vessels. Gillnet fish is kept separate from seine fish. At the plants catches from each gear type are offloaded and validated separately. In recent years, the local fishery manager usually receives within-season information from processing plants about validated or 'landed' weights. This rapid feedback on validated catch weights can then be used to adjust estimated weights from the hailed catches. This process provides an accurate way to determine how much of the target catch (quota) remains to be captured.

Geographic and divisions - management and science categories

The operations and management sectors of the Department of Fisheries and Oceans (DFO) divide the coastal areas of British Columbia into Fisheries Management Areas or 'FMA's (Fig. 1) that are further divided into the smaller sub-management areas (SMA's). For the purposes of herring management and assessment these geographic divisions often are divided into six major Regions (Appendix 2 - Fig. 2a). These are aggregates of smaller units called Statistical Areas (Appendix 2 - Fig. 2b).

Herring research and assessment in DFO use the same Statistical Areas (SA) (Appendix 2 - Fig. 2) but use a special geographic sub-division known as a herring sections (Haist and Rosenfeld 1988, Hay and Kronlund 1987, Hay and McCarter 2006). An assessment area (Appendix 2 - Fig. 2c) is the geographic area over which an estimate of spawning biomass is made. It is based on the assumption that the herring within the assessment area are all part of the same biological stock. The Assessment areas are all sub-sections of the Regions (Appendix 2 - Fig. 2a) except for the Strait of Georgia, which includes a small part of the southern Johnstone Strait area within its boundaries.

At the present time there are five main assessment areas on the BC coast: (1) South-east Queen Charlotte Island which is mainly Statistical Area 2; (2) the Prince Rupert District including Statistical Areas 3-5; (3) the Central Coast including Statistical Areas 7, 8 and parts of Statistical Areas 6; (4) the Strait of Georgia including Statistical Areas 14-19, 28, 29 and parts of Statistical Area 13; (5) the west coast of Vancouver Island including Statistical Areas 23-25. In some years smaller additional fisheries are conducted on two smaller areas: Statistical Area 27 (Winter Harbour) on the north end of Vancouver Island and the north-west coast of the Queen Charlotte Islands (often called Statistical Area 2W).

Roe fishery openings and sub-openings: geographic definitions

In its simplest form, a fishery opening is the time (beginning time, date and duration) available to fish for each gear type in each of the five coastal management Regions (QCI, PRD, CC, WCVI, SOG), as well as possible fisheries in two other minor areas (Winter Harbour, - Statistical Area 27) and the west coast of the Queen Charlotte Islands (WCQCI). Fishery openings in these areas almost never include the entire geographic area of the Region. Instead they usually are scheduled for some subset of areas, usually considerably smaller than the whole region. The geographic boundaries open to fishing changes among years, and even within a year. Further, for any specific Region and gear type, the fishery may be subject to multiple sub-openings, which may, or may not involve exactly the same area each time. There are several reasons for this. Sometimes bad weather can interfere with fishing, so in the interest of safety, managers suspend fishing until the weather improves. When it does, the fishery may reopen, sometimes with minor changes in fishery boundaries.   Another reason for temporary within-season closures is to monitor the cumulative hailed catch. From careful monitoring of the fishery, managers can estimate the approximate catch rate (i.e., cumulative tonnes per hour for gillnets). Sometimes catch rates may be variable or very high so managers may announce a closure to 'take stock' and ensure that the quota is not exceeded. If the cumulative catch is below the quota, they may announce a re-opening.   Sometimes such a process may occur several times within a Region, and each sub-opening time may be scheduled for a different area. Multiple sub-openings also occur in Regions and years when catch rates are low, so managers may open new areas in an attempt to improve the fleets access to fish.

For the purposes of the analyses in this paper, an opening is defined generally as a specific spatial area in Fisheries and Oceans Management Area (MA) or sub-Management Area (SMA) or a part of a SMA (Appendix 2 - Fig 1), or some combination of these areas.   Also an opening has a specific date, time and duration (hours) defined as the time, from the moment when a fishery is announced until it is closed. However, defined in this way, we could often identify two or more sequential openings for single target catches. This can happen for several reasons. Often a fishery will open but the catch rates (determined from hailed catches) are slow, so managers may decide to expand the geographic area open to a fishery. If, for example, a gillnet fishery with a target catch of 2000 tonnes was opened only for one Statistical area (i.e. 14) at 0800 on March 1 (day 1 of the fishery) and later expanded to include Statistical area 17 beginning at 0800 of March 2 (Day 2 of the fishery) then we would call this <u>two</u> sub-openings. The first sub-opening would be for 24 hours and limited to Area 14. The second sub-opening would be for 24 hours and include both Statistical areas 14 and 17.   Alternately, managers may open an area for a short time (say 2 hours) and then temporarily close because of unanticipated problems such as bad weather, etc.   We would call this a single sub-opening. If the same area re-opened again later, we would call this a different sub-opening. Clearly, there is room for different interpretation about what constitutes a single opening (or sub-opening), but our approach has been to define each opening according to the smallest divisions of time and space.

In our analysis a quantitative characteristic of each sub-opening included the date or 'day of year' (DOY) of the opening, where DOY 1 is January 1, DOY 2 is January 2, etc.   Each sub-opening was usually announced at a time of day, followed by a similar time of day for a closure. Therefore the duration of each sub-opening was estimated in hours, with one and two decimal points equal to 0.1 and 0.01 hours respectively. Usually for gillnets managers set the duration of a sub-opening to the nearest hour, but because the catching power of seines was much higher, the durations of seine sub-openings frequently was set to the nearest minute.

Fishing capacity and effort

We used the number of licenses available to fish each sub-opening (and this would not vary significantly among the sub-openings) to estimate the approximate fishing capacity for each sub-opening. Theoretically, the product of the number of fishing licenses by the duration of a sub-opening would provide an estimate of 'vessel hours of fishing' as a measure of effort.   We point out however, that such an estimate of capacity and effort is not always reliable, for several reasons. First, some vessels hold multiple licenses, so the estimate of licenses is not necessarily an estimate of the exact fishing power of each gear type. Also, some fishers may not have been able to be present at all fisheries, so again the number of licenses may over-estimate fishing power.   Still, this is the only available estimate of fishing power available, and we noted this estimate to provide a perspective about the relative duration of fishing openings among assessment areas and inter-annual variation of effort within assessment areas. For instance, increase in the duration of fisheries would be expected if the capacity was low.

Fishery duration, area estimation and catch

The estimation of the total duration of fishing time for each target catch is the cumulative opening duration of all sub-openings. A similar estimate for total area is more complex because different sub-openings covered different areas. Also, the catch associated with different sub-openings varied: sometimes geographically large sub-openings had small catches that were followed by small geographic sub-openings with large catches. Theoretically, it would be possible to adjust, or pro-rate each sub-opening according to some estimate of catch-per-unit-area but this would require knowing the catch (tonnes) for each sub-opening and this is not known for many sub-openings. Therefore to estimate the total area for each opening we used the maximum geographic *range* for each sub-opening. For example, if for a single opening, one sub-opening consisted of SMA 14-9 and 14-7 and a later sub-opening included SMA 14-9 and 14-5 plus 14-4, then the area of the opening would be the combined areas (or sum of the areas) of all four SMA's (14-9, 14-7, 14-5, 14-4) without counting the overlapped area twice.

Most often we cannot link a catch to a single sub-opening, especially in the most recent years. The Canadian Fisheries and Oceans Regional Management System provides only total catches for each opening by season and gear (gillnet and seine). In some years there are instances where a catch estimate is provided for 2 or more sub-openings. Such 'within-sub-opening' catch sub-totals are known as the hailed catch and these hailed catch data reflect in-season total cumulative catch. (As mentioned above, however, in recent years there may be opportunity for calibration of the hailed catch data based on information received back from processing plants). Managers use these data to estimate the cumulative catch-to-date relative to the TAC. The alternate and more reliable catch estimate is from the validated catch, based on tallied weights landed in plants. Sometimes there is a considerable disparity between the hailed and validated catch estimates; usually the hailed catch is lower than the validated catch.

Calculating the geographic area of fishery operations and spawning areas

The geographic areas of all SMA's have been estimated by DFO management using GIS software (©Arcview) and Canadian Hydrographic Service (CHS) marine charts (DFO unpublished data provided by Bryan Rusch). Sometimes geographically complex fishery openings included one or more partial SMA's but in these instances we used the area estimate for the whole SMA. Therefore, in some instances our estimates of the total fishing areas were slightly inflated but the inclusion of this extra area was small relative to the area of the total opening or sub-opening.

Results and Discussion

Surface areas of BC coastal waters

The total assessed area of the BC coast, including all FMA's (Appendix 2 - Fig. 1a) is 385,725 km^2 but over 90 percent of this area is open deep water. The total nearshore area, defined as the area between the inter-tidal zone and a depth of 200m in the main Statistical Areas, is about 37 000 km^2.

Not all sections contain spawn. The cumulative area of the six main Regions of BC that are included in the analyses of herring spawn data, is about 33 000 km^2 (Appendix 2 - Table 1).

Sub-openings

The numbers of sub-openings, by Region, year and gear are shown in Appendix 2 - Tables 2a-b. There were a total of 455 sub-openings in all regions for both gear types, between 1977 and 2004. This included 220 gillnet sub-openings (Appendix 2 - Table 2a) and 235 seine sub-openings (Appendix 2 - Table 2b). The numbers of sub-openings has declined in recent years, especially for gill-net gear.

Total area and proportion of BC coast open to fishing

In all years between 1977 and 1980, the total coastal area open to fishing was much greater for gillnets (Appendix 2 - Fig. 3). The total area open to fishing, since 1978, was greatest for gillnet gear in 1984 and 1988 at about 6000 km^2 (Appendix 2 - Table 3a). In most years, in all Regions, the open areas were much less, usually 2000-3000 km^2 for purse seines (Appendix 2 - Table 3b). The spatial area used by each gear varied among Regions and by year: surface areas of fisheries increased in some areas but decreased in others (Appendix 2 - Fig. 4a-b) although in every year, the spatial area open to purse seines was lower than that of gillnets.

As a percentage of the total BC coastline, the cumulative area open to fishing in a single year has been relatively consistent for each gear type since 1980 (Appendix 2 - Fig 5a-b) and was a (post-1980) maximum of 17 percent (for gillnets) in 1989 (Appendix 2 - Table 3a) and 9.7 percent for purse seines in 2002 (Appendix 2 - Table 3b).

Duration of fisheries

The cumulative hours of the fishery durations decreased both for gillnets and purse seines from the inception of the fishery until the early 1990's and then began to increase (Appendix 2 - Fig. 6a-b). The cumulative duration of opening for gillnets plummeted from more than 1000 hours in the late 1970's to about 100 hours in the 1990's. Subsequently it has increased to about 300-400 hours per year, except for 2005 which was exceptionally high again. The duration of openings for purse seines decreased until the mid-1980's and then increased to about 100 hours in between 2000-2005. These trends, however, are less clear when examined at the finer geographic level of the assessment areas (Appendix 2 - Fig. 7a-b). The cumulative duration of openings (hours) is most variable in the late 1990's and early 2000's.

There are several reasons why the durations of openings have increased since the early 1990's. Although, *a priori*, one might expect the durations of fisheries to be mainly a function of biomass and the size of the TAC, there are other explanations. Mainly the establishment of fishing 'pools' and 'multiple licenses' (one vessel with multiple licenses) meant that the fishing capacity, in terms of the numbers of fishing vessels (but not licenses), was reduced. Relative to earlier years, it takes longer for the reduced fishing capacity to take the target catch. Therefore the increased duration and variability in the cumulative durations of openings reflect the development of cooperative pools and deliberately reduced fishing capacity. Another reason is that the fleets now have more time to focus on catching higher quality fish, rather than focusing on the quantity of fish. Fishers now can take better care of catches while at sea. Purse seine fishing is slower because fishers check each set before pumping fish from the pursed seine to the holding vessel. Pumping is now done more carefully. Gillnet fishing is slower because most fishers use larger size mesh nets to catch the optimal size fish, particularly at the beginning of the fishery. In some cases in the Strait of Georgia both gillnets and seines will suspend fishing to deliver their catch into Vancouver processing plants and then return to the fishing grounds to start fishing again.

It is interesting that in most Regions the response of the fishery (management in cooperation with the industry) to the reduced capacity has been to increase the duration of the fishery and not the total area (km^2) open to fishing. The only clear exception to this is the gillnet fishery in the Strait of Georgia where, in recent years, gillnet catch rates appear to be lower so fishers are forced to fish for longer periods. A consequence is a longer-duration fishery occurring over a broader area.

Dates (DOY) of fishery openings

Although there is substantial inter-annual variation in opening dates among assessment areas, the mean coast-wide dates of fishery openings is very consistent with means ranging from DOY 70-80 (Appendix 2 - Fig. 8). Since the early 1980s, the mean date of gillnet openings has been about 5 days later than that for seines. The trends are more complex when examined at the level of each assessment area for both gear types (Appendix 2 - Figs. 9a-b). The mean date for gillnets has been declining slightly in the PRD, but gradually increasing in the SOG and WCVI. There appears to be less inter-annual variation among purse seine openings than among gillnets but there are no obvious trends to either earlier or later spawning among the purse seines.

Implications of the results for management

The analyses in this report provide technical descriptions for changes in the herring roe fishery, as it has been managed since the early 1970's. There are no specific recommendations for changes to management except to point out that relatively recent policy changes, mainly those that result in a reduction of fishing capacity, will result in some continuing structural changes in the spatial and temporal aspects of the fishery. In general, the durations of openings will be longer and the geographic range will be broader. Potentially useful components of the report include an explanation of the geographic and temporal aspects of fishery openings and sub-openings. In general there may be a series of sub-openings, each varying in time and space, but all directed at a single target catch (or quota). These attributes of the fishery have not been described previously.

A potential longer-term utility of information on the geographic patterns of fishing activity could be related to coastal zone management. This report shows that the herring roe fishery occurs in relatively confined and predictable areas of the BC coast. Present and future decision-makers may be faced with future decisions regarding trade-offs between maintaining a viable herring fishery versus some other activity that could occur in the same coastal waters. Therefore understanding the spatial and temporal characteristics of the fishery will be essential for guiding such future decisions.

Acknowledgments

Funding for this project was provided by the Herring Conservation and Research Society. Lorena Hamer provided helpful useful comments on an earlier draft.

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Appendix 2 - Table 1. The total area (km^2) of the five main fishing regions in the British Columbia coast, and the number of sections in each region. The 'NON' region refers to areas of the coast that are not part of the main stock assessment areas and therefore not considered for openings in the herring roe fishery (i.e., the cumulative area of all coastal areas except the assessment areas as shown in Appendix 2 - Fig. 2c).

Region	**Square km**
CC (Central Coast)	2883.179
NON	18353.424
PRD (Prince Rupert District)	4533.603
QCI (Queen Charlotte Islands)	1619.123
SOG (Strait of Georgia)	8483.269
WCVI (West Coast Vancouver Island	1478.9229
Total	**33098.649**

Appendix 2 - Table 2a. Sub-openings by year and Region for gillnets.

	Regions						
	QCI	**PRD**	**CC**	**JS**	**SOG**	**WCVI**	**All Regions**
Year							
1977	3	2	2	1	3	5	**16**
1978	3	2	7	2	4	5	**23**
1979	3	2	0	0	2	3	**10**
1980	4	1	3	0	1	4	**13**
1981	2	1	4	0	2	4	**13**
1982	1	0	3	0	1	3	**8**
1983	1	0	2	0	1	2	**6**
1984	1	1	1	0	2	2	**7**
1985	1	1	2	0	2	0	**6**
1986	1	2	1	0	0	0	**4**
1987	0	4	0	0	5	1	**10**
1988	0	4	3	0	1	1	**9**
1989	0	3	5	0	3	1	**12**
1990	1	1	2	0	2	1	**7**
1991	1	2	2	0	3	1	**9**
1992	0	1	1	0	2	1	**5**
1993	0	1	2	0	2	1	**6**
1994	0	2	1	0	2	2	**7**
1995	0	1	2	0	1	0	**4**
1996	0	1	1	0	1	0	**3**
1997	0	2	1	0	1	0	**4**
1998	0	1	3	0	3	4	**11**
1999	0	1	1	0	1	1	**4**
2000	0	1	2	0	1	1	**5**
2001	0	1	1	0	1	0	**3**
2002	0	1	2	0	1	1	**5**
2003	0	1	1	0	1	1	**4**
2004	0	1	0	0	4	1	**6**
All Years	**22**	**41**	**55**	**3**	**53**	**46**	**220**

Appendix 2 - Table 2b. Sub-openings by year and Region for purse seines.

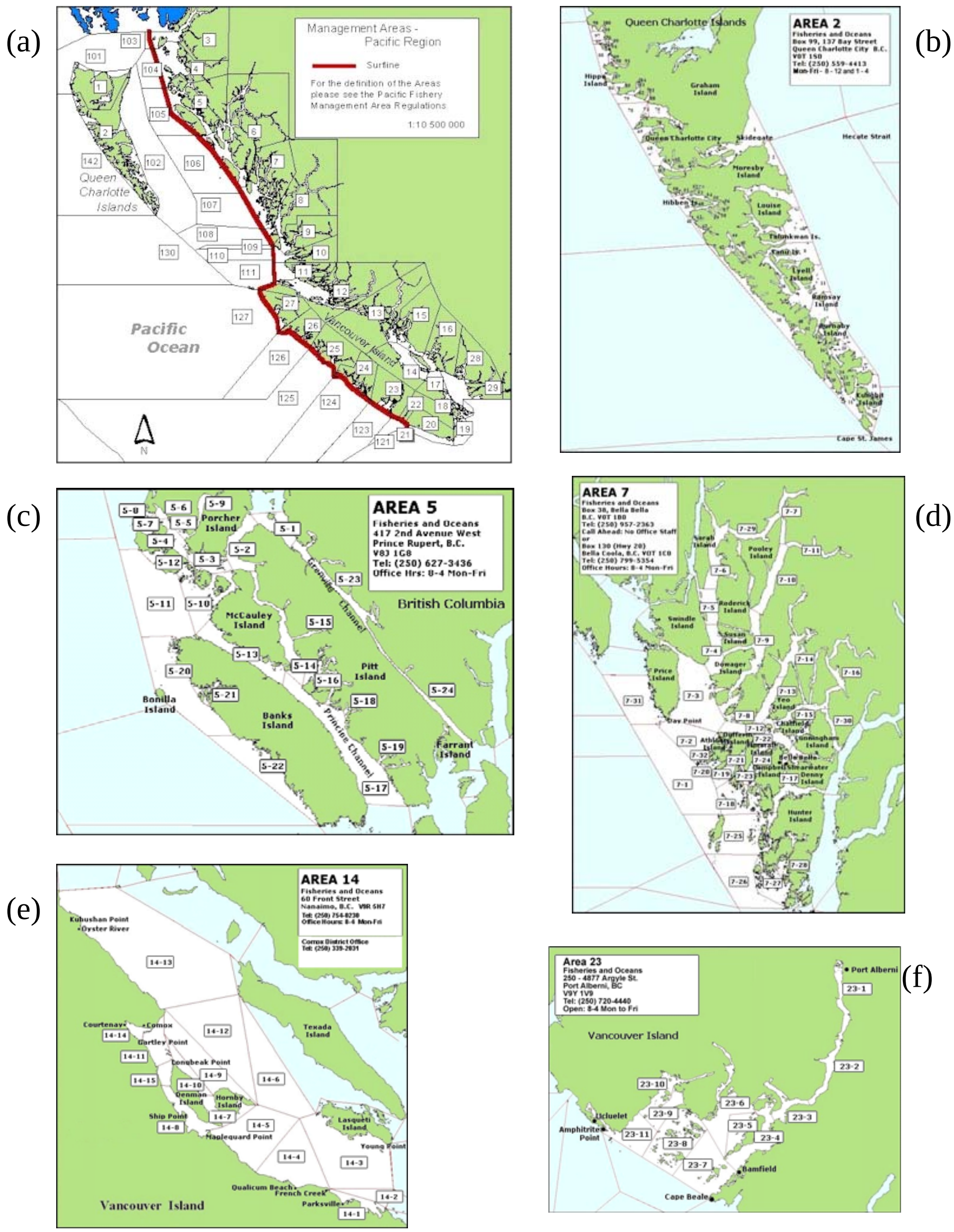
	Regions						
	QCI	**PRD**	**CC**	**JS**	**SOG**	**WCVI**	**All Regions**
Year							
1977	2	2	3	0	2	5	**14**
1978	4	3	3	1	3	4	**18**
1979	4	1	0	0	0	4	**9**
1980	2	4	0	0	2	1	**9**
1981	4	1	0	0	1	3	**9**
1982	4	0	1	0	1	4	**10**
1983	2	0	1	0	4	1	**8**
1984	1	1	2	0	2	1	**7**
1985	1	1	1	0	1	0	**4**
1986	2	2	1	0	0	0	**5**
1987	1	3	1	0	0	1	**6**
1988	0	1	1	0	1	2	**5**
1989	1	2	2	0	4	3	**12**
1990	2	2	2	0	0	2	**8**
1991	2	1	1	0	1	2	**7**
1992	2	1	1	0	1	3	**8**
1993	5	2	2	0	1	2	**12**
1994	0	2	2	0	1	1	**6**
1995	0	2	4	0	2	1	**9**
1996	0	0	1	0	2	4	**7**
1997	0	0	1	0	1	1	**3**
1998	4	0	3	0	2	1	**10**
1999	0	0	2	0	3	2	**7**
2000	2	2	3	0	2	1	**10**
2001	0	1	4	0	1	0	**6**
2002	1	4	3	0	2	0	**10**
2003	0	1	2	0	1	4	**8**
2004	0	2	1	0	4	1	**8**
All Years	**46**	**41**	**48**	**1**	**45**	**54**	**235**

Appendix 2 - Table 3a. Areas (km^2) of gillnet fishing by assessment area, and estimated percentage of the total British Columbia coast open to gillnet fishing from 1977-2004.

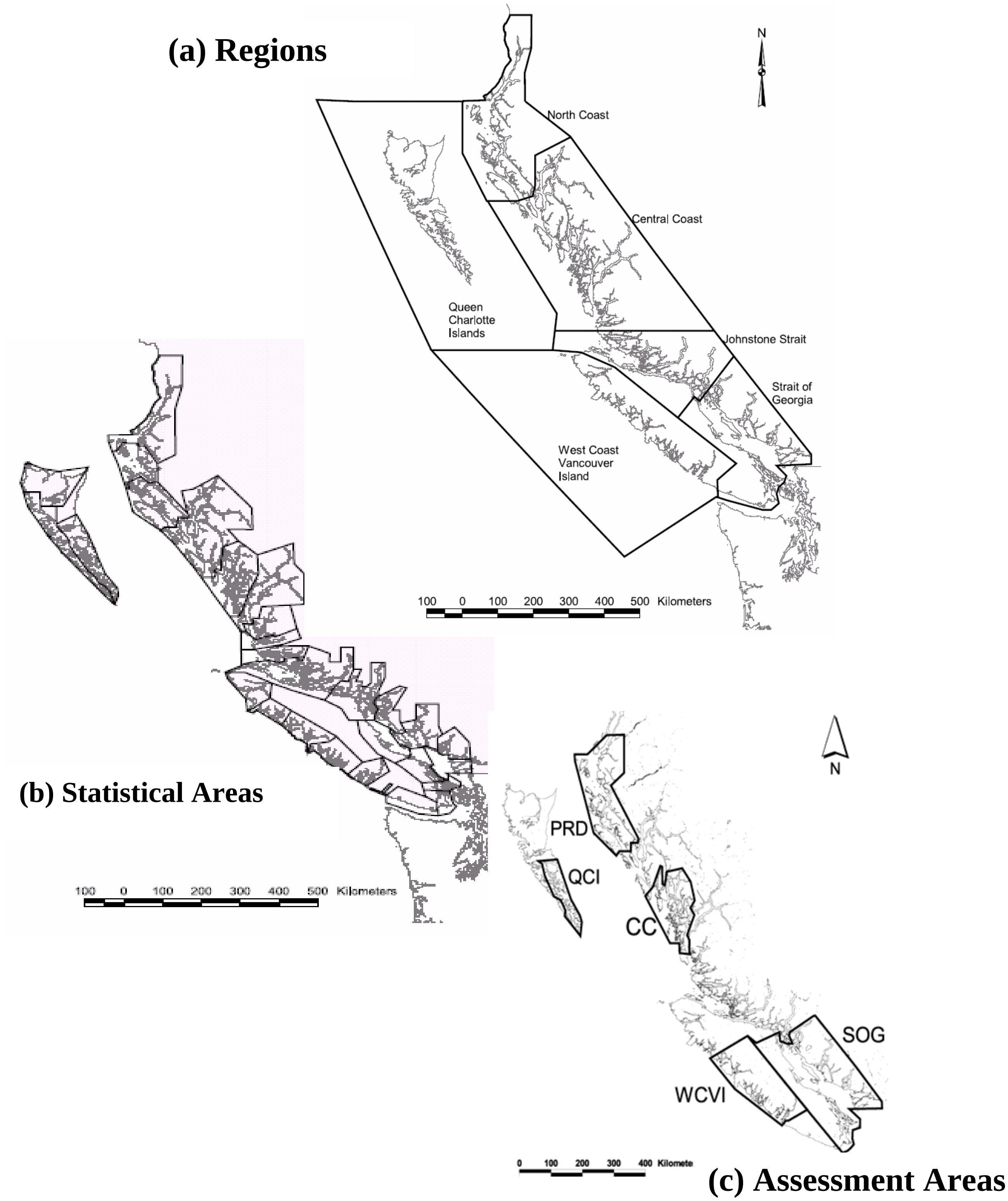
Year	**QCI**	**PRD**	**CC**	**JS**	**SOG**	**WCVI**	**All**	**Percent open**
1977	396.3	131.7	11920.9	3100.4	1746.7	3517.7	20813.6	55.72
1978	109	703.9	12601.8	316.8	582.1	1834.7	16148.2	43.23
1979	1878.8	101.4	-	-	179	548.8	2708	7.25
1980	150.1	72.7	494.4	-	156.7	360.6	1234.5	3.31
1981	88.5	30.2	1130.2	-	801.7	489.6	2540.3	6.80
1982	10.5	-	1408.6	-	230.5	399.9	2049.5	5.49
1983	94.5	-	1703.8	-	54.9	175.2	2028.4	5.43
1984	94.5	425.5	203.1	-	593	175.2	1491.3	3.99
1985	10.5	429.6	1128.1	-	109.7	-	1677.9	4.49
1986	194.7	2037.4	300.1	-	-	-	2532.3	6.78
1987	-	1915.7	282.1	-	1133.2	134.7	3465.7	9.28
1988	-	1892.2	750.5	-	738.2	224.7	3605.7	9.65
1989	-	1308.4	3803.3	-	1322.1	129.2	6563	17.57
1990	299.7	1014.6	700.9	-	1729.6	156.4	3901.2	10.44
1991	194.7	2011.1	1139.8	-	2330.1	119.8	5795.5	15.52
1992	-	429.6	289.9	-	1476.4	92	2287.9	6.13
1993	-	1018.7	935.3	-	933.3	18.1	2905.5	7.78
1994	-	1720	891	-	3353.6	152.8	6117.4	16.38
1995	-	555.6	793.4	-	1691.9	-	3041	8.14
1996	-	1130.2	515.8	-	1148.9	-	2794.9	7.48
1997	-	2289.6	502.3	-	1691.9	-	4483.8	12.00
1998	-	1144.8	732.7	-	3718.1	459.7	6055.4	16.21
1999	-	1284.8	652	-	1676.8	70.5	3684.1	9.86
2000	-	1144.8	394.6	-	1691.9	134.7	3366	9.01
2001	-	1111.4	593.5	-	1691.9	-	3396.8	9.09
2002	-	1067.1	738.7	-	1833.3	134.7	3773.8	10.10
2003	-	1068.9	593.5	-	2830.2	134.7	4627.2	12.39
2004	-	1018.7	-	-	3841.9	134.7	4995.3	13.37

Appendix 2 - Table 3b. Areas (km^2) of purse seine fishing by assessment area, and estimated percentage of the total British Columbia coast open to purse seine fishing from 1977-2004.

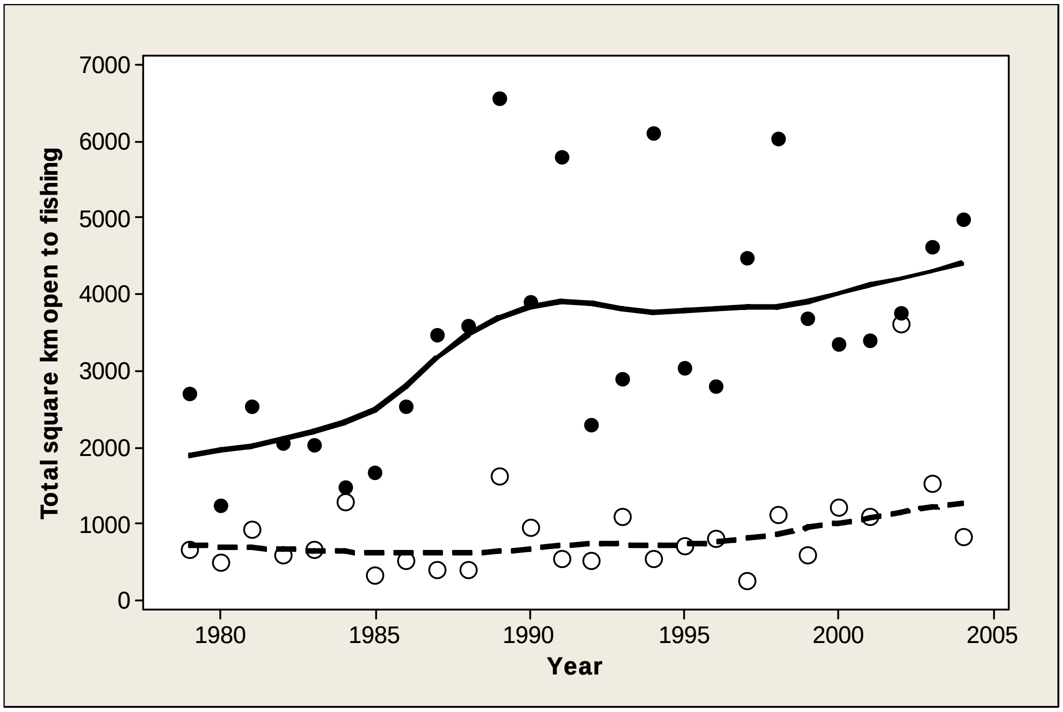
Year	**QCI**	**PRD**	**CC**	**JS**	**SOG**	**WCVI**	**All**	**Percent open)**
1977	224	74.5	5762.4	-	2029.9	1705.5	9796.3	26.23
1978	251.8	1399.5	299.6	30.2	37.3	1075.4	3093.9	8.28
1979	336.6	50.7	-	-	-	269.3	656.7	1.76
1980	65.9	202.9	-	-	51.1	189.8	509.7	1.36
1981	282.2	30.2	-	-	400.9	221.3	934.5	2.50
1982	168.9	-	108.1	-	11.6	316.4	605	1.62
1983	50.5	-	29.2	-	556.6	32.2	668.5	1.79
1984	29.6	7.3	535	-	505.7	221.2	1298.8	3.48
1985	58.6	58	97	-	127.9	-	341.5	0.91
1986	117.3	134.8	267.5	-	-	-	519.6	1.39
1987	29.6	167.4	137.2	-	-	60	394.3	1.06
1988	-	110.3	150.8	-	38.5	112.5	412	1.10
1989	106.9	166.6	622.7	-	275.7	465.6	1637.4	4.38
1990	156.6	166.6	243.6	-	-	382.6	949.4	2.54
1991	201.8	42.5	146.7	-	38.5	127.9	557.4	1.49
1992	140.2	7.3	137.2	-	53.5	180	518.2	1.39
1993	75.3	160.7	666.1	-	53.6	147.6	1103.3	2.95
1994	-	166.6	293.3	-	38.5	59.8	558.2	1.49
1995	-	101.4	468.8	-	92	60	722.3	1.93
1996	-	-	234.9	-	145.6	429.4	809.9	2.17
1997	-	-	97	-	49	119.8	265.7	0.71
1998	465.1	-	390.3	-	205.2	60	1120.6	3.00
1999	-	-	193.9	-	160.8	239.6	594.3	1.59
2000	128.4	150.2	612.2	-	220	119.8	1230.5	3.29
2001	-	58.1	945.6	-	102.6	-	1106.3	2.96
2002	194.7	1855.1	1446.1	-	128.1	-	3624	9.70
2003	-	7.3	932.8	-	102.6	479.2	1521.9	4.07
2004	-	116.3	139.4	-	440.4	134.7	830.9	2.22



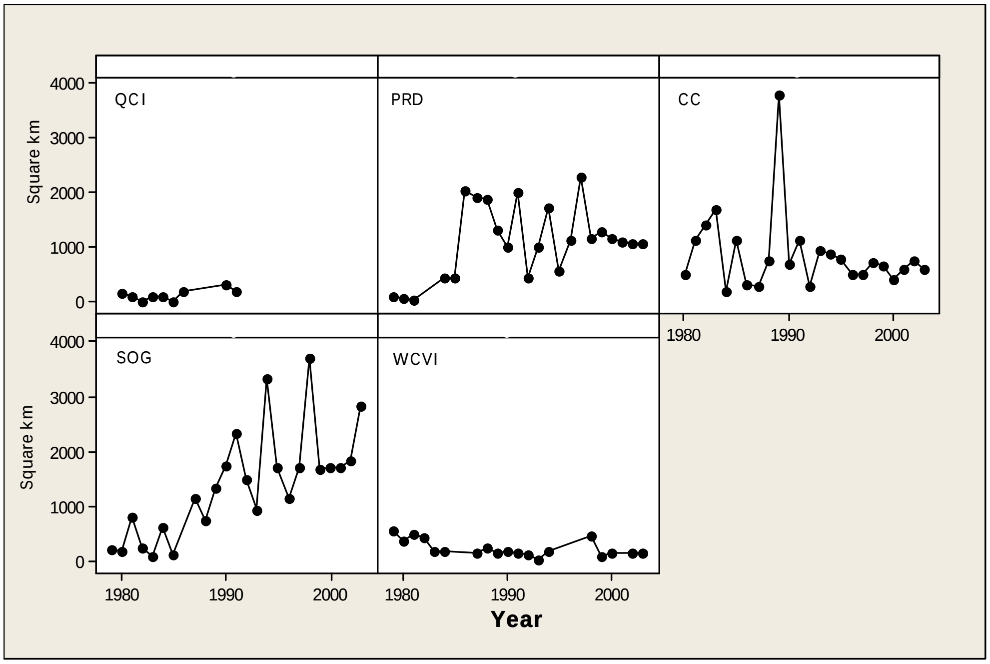
Appendix 2 - Fig. 1. Management areas and Sub-areas. (a) The coastal area of British Columbia. (b) Detailed map of the Queen Charlotte Islands showing management areas, corresponding to Statistical Area 2. Detailed maps showing Fishery Management Areas and sub-Management areas (SMA's) in (c) part of the Prince Rupert District Management Area, (d) the Central Coast Management Area, (e) the Strait of Georgia Management Area, (f) Barkley Sound (Statistical Area 23) on the West Coast of Vancouver Island.



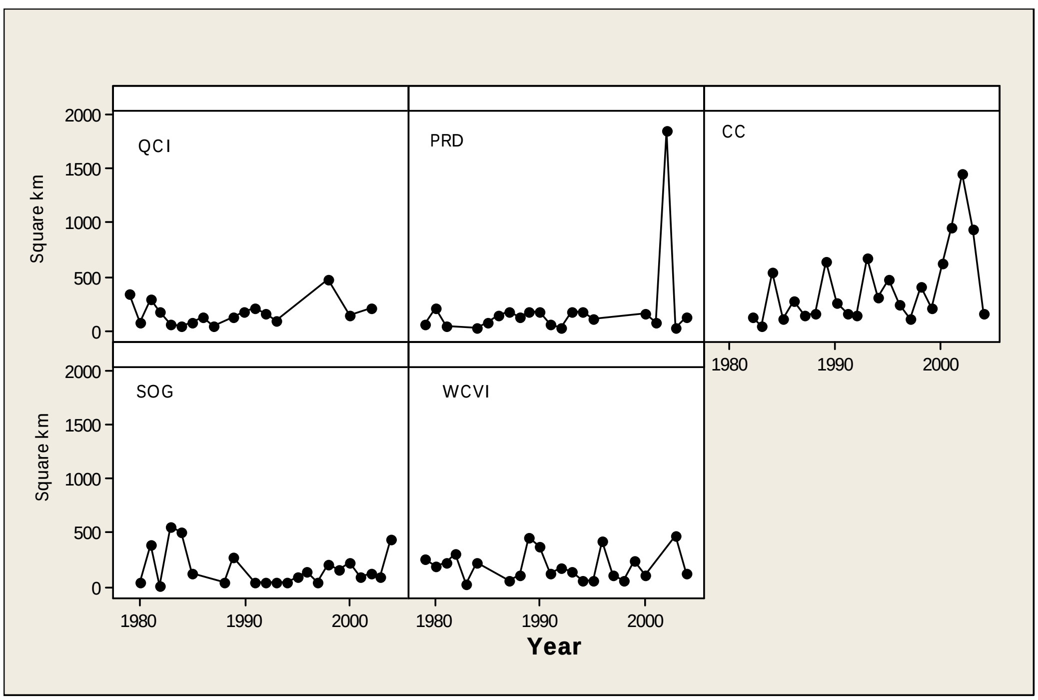
Appendix 2 – Fig. 2. (a) Six coastal Regions of the BC coast; (b) statistical areas of the BC coast. (c) assessment areas. Assessment areas are occur within regions but may contain one or more statistical areas. Biomass assessments are based on estimates of spawning biomass within



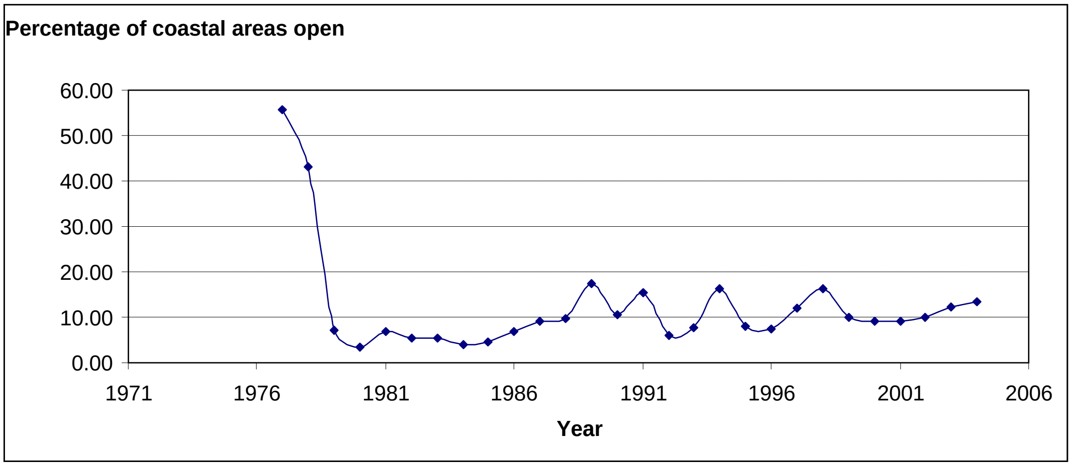
Appendix 2 - Fig. 3. Relationship between total area fished, by year and gear. For the entire BC coast, there has been an increase in the total area open to fishing with both gear types since 1980. The coastal area open to gillnets is larger than that for seines. The range of areas is more variable for gillnets but there appears to be little or no change in the areas open to gillnets since about 1990. The lines are trend lines calculated as the Minitab© 'lowess' (locally weighted) smoothing function.



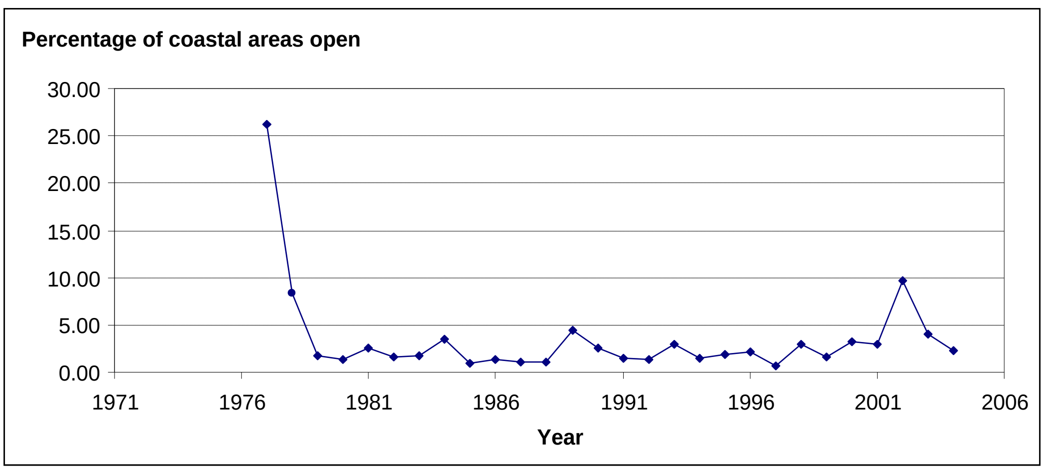
Appendix 2 - Fig. 4a. Maximal area (km^2) open to gillnet fishing by Region.



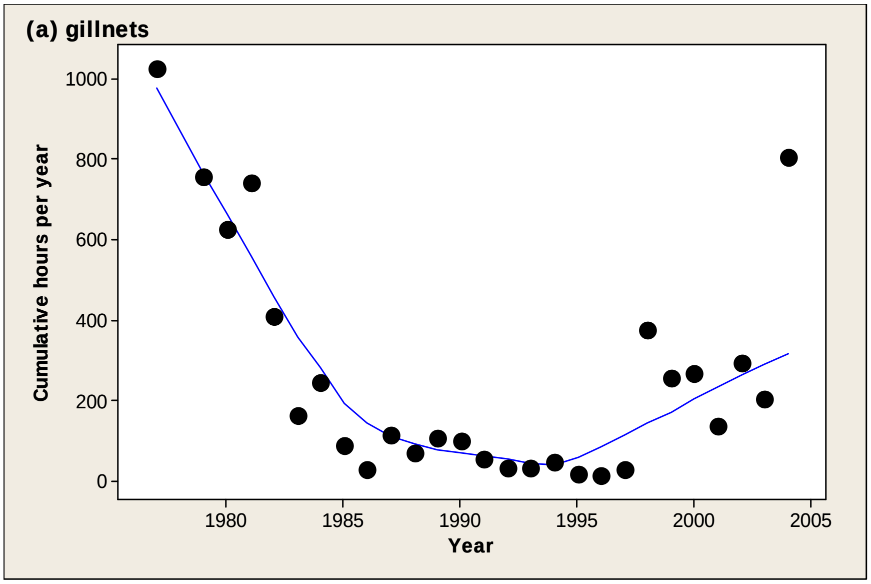
Appendix 2 - Fig. 4b. Maximal area (km^2) open to purse seine fishing by Region.



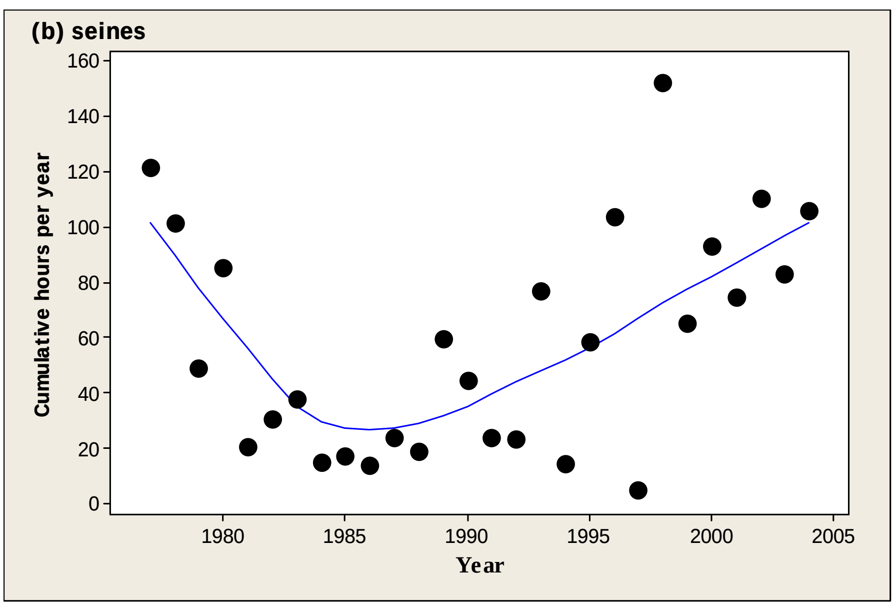
Appendix 2 - Fig. 5a. Percentage of the total BC coastal area open to fishing by gillnets, by year.



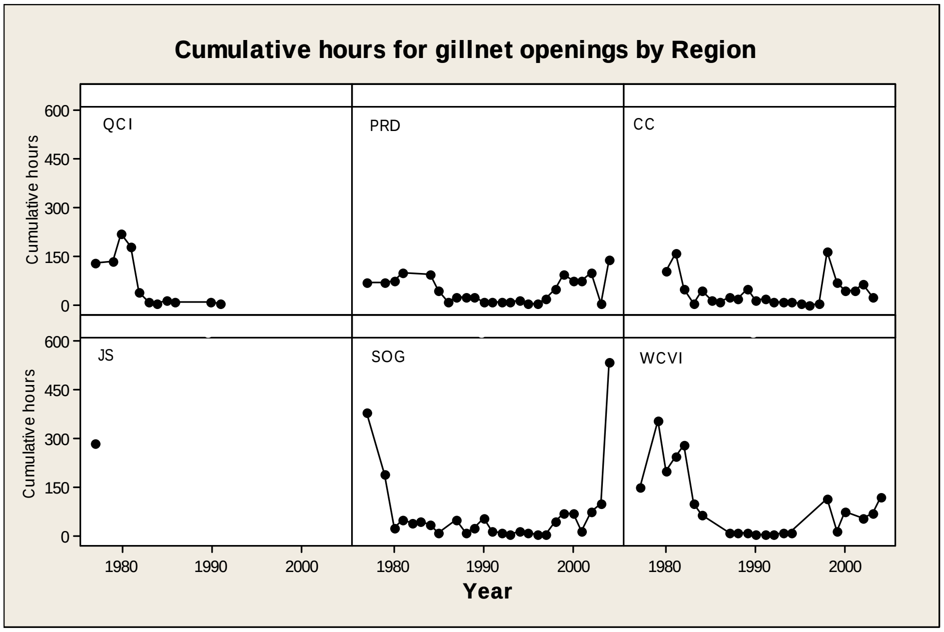
Appendix 2 - Fig. 5b. Percentage of the total BC coast open to fishing by purse seines, by year.



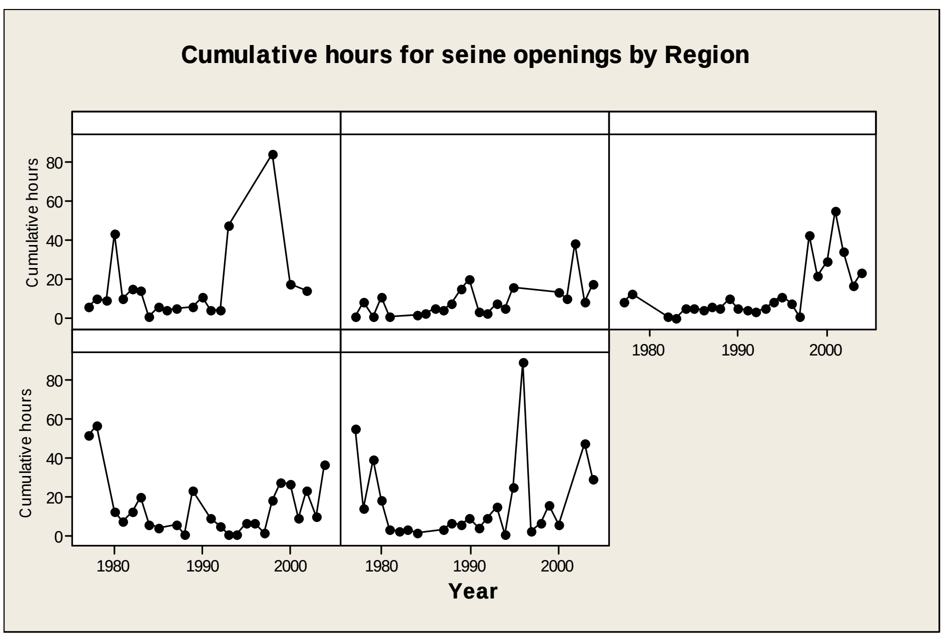
Appendix 2 - Fig. 6a. The cumulative number of hours that the roe fishery was open for gillnets for all fishing regions in BC. The line is the trend line calculated as the Minitab© 'lowess' (locally weighted) smoothing function.



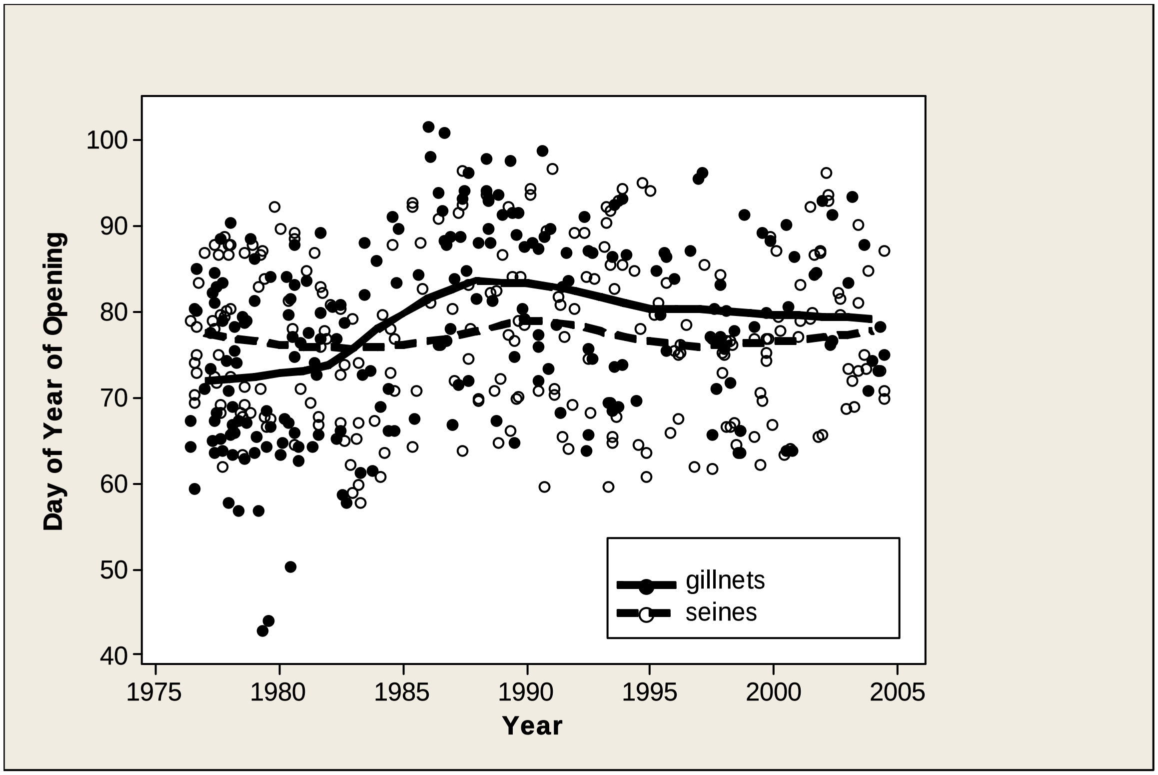
Appendix 2 - Fig. 6b. The cumulative number of hours that the roe fishery was open for purse seines for all fishing regions in BC. The line is the trend line calculated as the Minitab© 'lowess' (locally weighted) smoothing function.



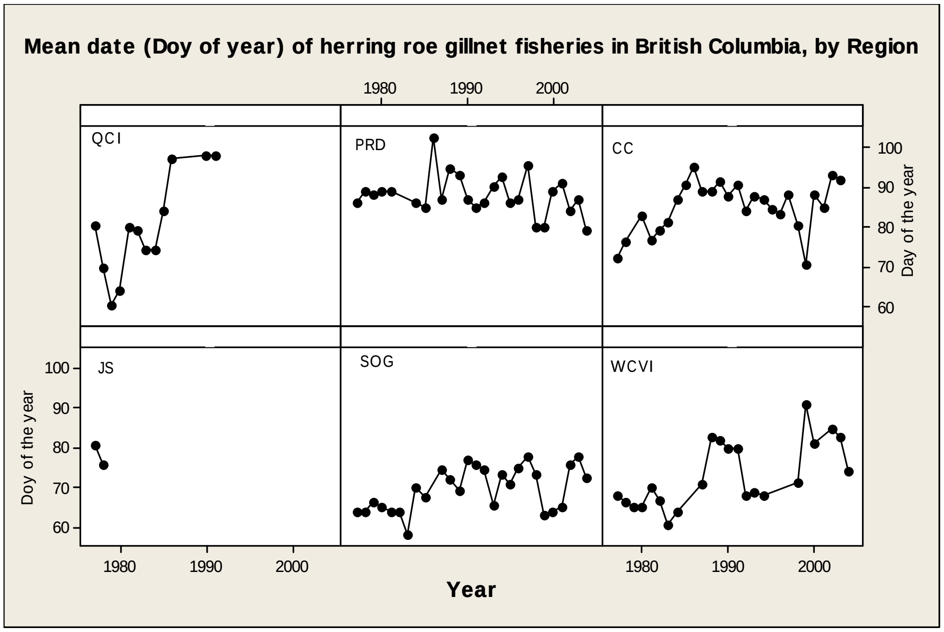
Appendix 2 - Fig.7a. The cumulative number of hours that the roe fishery was open for gillnets shown for each Region.



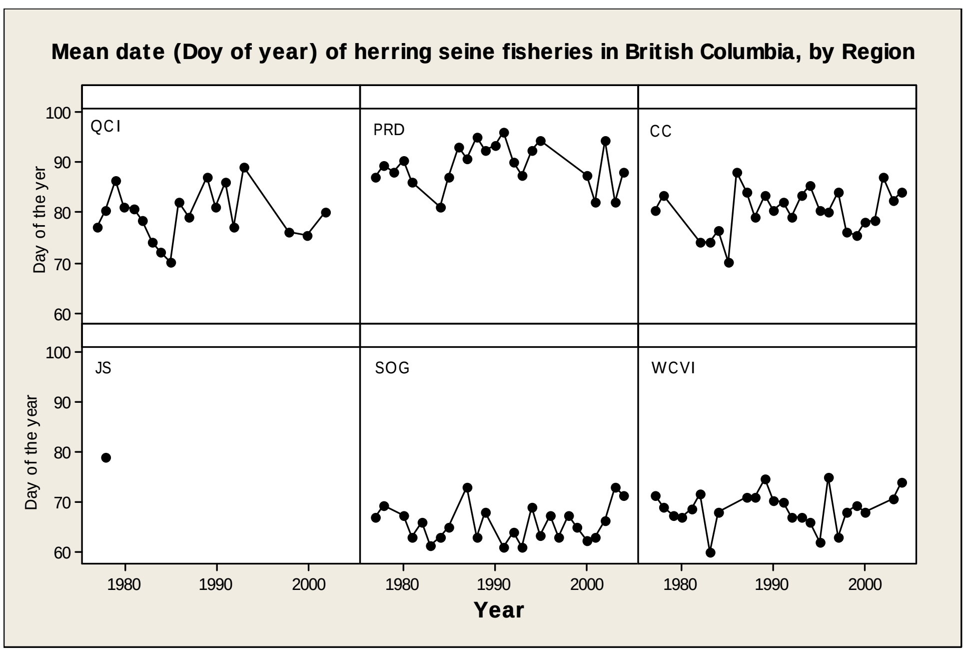
Appendix 2 - Fig. 7b. The cumulative number of hours that the roe fishery was open for purse seines shown for each Region.



Appendix 2 - Fig. 8. The dates of fishing, shown by gear types (open and closed circles) for all areas of BC. The lines are trend lines calculated as the Minitab© 'lowess' (locally weighted) smoothing function.



Appendix 2 - Fig. 9a. The dates of fishing openings shown as the DOY (day of the year) for gillnets by Region.



Appendix 2 - Fig. 9b. The dates of fishing opening shown as the DOY (day of the year) for purse seines by Region.