Fisheries and Oceans Canada
Science

Pêches et Océans Canada
Sciences

C S A S

Canadian Science Advisory Secretariat

S C C S

Secrétariat canadien de consultation scientifique

Research Document 2003/051

Document de recherche 2003/051

Not to be cited without
permission of the authors *

Ne pas citer sans
autorisation des auteurs *

Indicators and 'response' points for management of Fraser River eulachon: A comparison and discussion with recommendations.

Revue des indicateurs potentiels et des points de réponse pour la gestion de l'eulakane du fleuve Fraser.

D. E. Hay, K.C. West and A. D. Anderson

Fisheries and Oceans Canada
Biological Sciences Branch
Nanaimo, British Columbia V9R 5K6

* This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

This document is available on the Internet at:

* La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

Ce document est disponible sur l'Internet à:

http://www.dfo-mpo.gc.ca/csas/

ISSN 1499-3848 (Printed)

Canada

ABSTRACT

This report reviews potential indicators and response points for the management of eulachons (*Thaleichthys pacificus)* in the Fraser River. Concern for the conservation of eulachons in the Fraser River peaked in 1994, following poor returns in First Nations and commercial fisheries. This concern prompted field research to estimate spawning biomass and the introduction of fishing closures and other restrictions. Future management and fisheries require explicit management plans based on objective criteria - or 'indicators' and ‘response points’ about the status of spawning stock biomass and fisheries. The main indicator is the spawning stock biomass (SSB) estimated annually (since 1995) from egg and larval surveys. With such a short time series, we were not able to develop quantitatively explicit response points based on population dynamic models. Instead, for the SSB and other indicators defined in this paper, we propose and define several 'response' points that we suggest are both precautionary and biologically realistic. For instance, as a response point for the SSB indicator, we explain why a SSB of less than 150 tonnes, for 2 consecutive years, could be a response point for conservation. Another indicator is an offshore index of abundance of eulachons estimated during annual shrimp trawl surveys in May. Offshore biomass estimates include two cohorts from the Fraser and Columbia Rivers. An offshore biomass estimate of less than 1000 tonnes in offshore waters could be a response point for concern about Fraser River eulachon fisheries. Another indicator is catch data from Columbia River fisheries. Columbia River eulachon spawn mainly in January and February, about four months earlier than Fraser River eulachons. In most years, a cumulative annual catch of less than 500 tonnes in the Columbia could be cause for conservation concern, and therefore a response point, for the spawning run in the Fraser River. Test fishery data, collected for seven years since 1995 provides a potential response point that may be useful for 'in-season' management decisions. The utility of these test fishery data as an indictor, however, remains to be demonstrated. The comparison of test fishery catches with SSB estimates is promising but yet not convincing. Nevertheless, we discuss some potential response points related to test fishery data. We suggest that there are no firm biological criteria, or sufficient biological information to set a 'biological' quota, but the long term catch history of the Fraser has often seen catches in excess of several hundred tonnes. We do not recommend such catch levels be set at the present time but point out that annual catch levels in the commercial fishery since 1980 have been about 20 tonnes, for a total removal of about 30 tonnes. The combined removals from other sources (First Nations and recreational catches) may have been another 10 tonnes (although this last estimate is very rough). Therefore under normal conditions the Fraser River probably has a spawning biomass of about 500-1000 tonnes so removal of 30 tonnes would constitute an annual catch rate about three to six percent. We suggest that such a removal is sustainable. An unresolved issue, beyond the scope of the present paper, is the potential removal of Fraser River eulachons as bycatch in offshore trawl fisheries.

RÉSUMÉ

Ce rapport comporte une revue des indicateurs potentiels et des points de réponse pour la gestion de l'eulakane (*Thaleichthys pacificus)* du fleuve Fraser. Les préoccupations que suscitait la conservation de ce stock ont atteint un pic en 1994 à la lumière des faibles prises autochtones et commerciales. Cela a entraîné des recherches sur le terrain en vue d'estimer la biomasse des reproducteurs et l'introduction de restrictions incluant la fermeture de pêcheries. La gestion future des pêches requiert des plans explicites de gestion reposant sur des critères objectifs - ou des indicateurs et des points de réponse quant à l'état de la biomasse du stock reproducteur et des pêches. L'indicateur principal est la biomasse du stock reproducteur (BSS), estimée annuellement depuis 1995 par le biais de relevés des oeufs et des larves. Avec une série chronologique de données aussi courte, il nous a été impossible d'établir des points de réponse explicites au plan quantitatif reposant sur des modèles de la dynamique des populations. Au lieu de cela, nous proposons et définissons, pour la BSS et les autres indicateurs définis dans la présente étude, plusieurs points de réponse que nous considérons comme pratiques et prudents au plan biologique. Par exemple, comme point de réponse pour l'indicateur de la BSS, nous expliquons pourquoi une BSS de moins de 150 tonnes pendant deux années consécutives pourrait être un point de réponse pour la conservation. Un autre indicateur est un indice de l'abondance hauturière de l'eulakane, telle qu'estimée lors des relevés annuels de la crevette au chalut effectués en mai. Les estimations de la biomasse hauturière d'eulakane incluent deux cohortes des fleuves Fraser et Columbia. Une estimation de la biomasse hauturière de moins de 1 000 tonnes pourrait être un point de réponse soulevant des préoccupations à l'endroit des pêches de l'eulakane dans le Fraser. Les données sur les prises dans le fleuve Columbia sont un autre indicateur. L'eulakane du Columbia fraye principalement en janvier et en février, soit environ quatre mois avant l'eulakane du Fraser. Pour la plupart des années, des prises annuelles cumulatives de moins de 500 tonnes dans le Columbia pourraient être une source de préoccupations à l'endroit de la conservation et donc servir de point de réponse pour la montaison dans le Fraser. Les données des pêches expérimentales, collectées pendant sept années depuis 1995, constituent un point de réponse potentiel qui pourrait être utile pour prendre des décisions de gestion en saison. L'utilité de ces données comme indicateur reste toutefois à démontrer. La comparaison des prises issues des pêches expérimentales et des estimations de la BSS est prometteuse mais n'est pas encore probante. Néanmoins, nous discutons de quelques points de réponse potentiels liés aux données sur les pêches expérimentales. Nous suggérons qu'il n'y ait aucun critère biologique ferme ou suffisamment de données biologiques pour fixer un quota « biologique », mais l'historique des prises dans le Fraser révèle qu'elles ont souvent dépassé plusieurs centaines de tonnes. Nous ne recommandons pas que de tels niveaux de prises soient établis à ce moment-ci mais nous soulignons que les niveaux annuels des prises commerciales depuis 1980 ont atteint environ 20 tonnes, ce qui a donné des ponctions totales d'environ 30 tonnes. Les ponctions combinées d'autres sources (prises autochtones et récréatives) peuvent représenter un autre 10 tonnes (quoique cette dernière estimation soit très approximative). Par conséquent, dans des conditions normales, le Fraser abrite probablement une biomasse de reproducteurs d'environ 500 à 1 000 tonnes, de sorte que des ponctions de 30 tonnes représenteraient un taux annuel de capture d'environ 3 à 6 %. Nous sommes d'avis que ce niveau de prises est durable. Une question non résolue, hors de la portée de la présente étude, est la récolte potentielle d'eulakane du Fraser comme prises accessoires des pêches hauturières au chalut.

INTRODUCTION

In recent years the terms 'indicators' and 'reference points' have acquired specific meaning in the context of fisheries management, both within Canada and other nations. Within Fisheries and Oceans Canada, these terms refer to the implementation of 'Objective Based Fisheries Management Plans' (OBFM) and Integrated Fishery Management Plans (IFMP). The requirement for the development of such plans for eulachons (*Thaleichthys pacificus)* led to the preparation of this report. In this report we apply the term 'indicator' to data or observations related to the state of population abundance of eulachons, either in the river or the sea. Indicators may consist of a *range* of values, usually a time series. Within this range of indicators, we identify specific 'response points' (RP) as specific points or observations that provide a basis for a decision about fisheries management, such as the opening of a fishery. We point out, however, that the available data for commenting on Fraser River eulachon abundance is limited, so we cannot compute specific RP's based on population dynamics or statistical models. Instead, we attempt to provide response points based on simple biological criteria, that we call 'judgmental' response points (or response point's). While such response point's may lack the statistical rigor, they are not arbitrary and are based both on our best understanding of the biology and history of eulachon fisheries in the Fraser. Therefore, the response point's should be both precautionary and biologically realistic.

The objectives of this report are to describe each potential indicator and then define specific response points, some of which have already have been applied to Fraser River eulachon management but not yet formally described. We compare the independent indicators for as many years as possible. These indicators include; (1) sixty-two years of annual commercial catch data for the Fraser and Columbia River eulachon fisheries from 1941-2002, (2) estimates of spawning stock biomass (SSB) from egg and larval surveys, made annually since 1995; (3) indices of eulachon abundance in offshore waters based on incidental capture of eulachons in annual shrimp surveys conducted since 1973; (4) data from an experimental test fishery conducted since 1995 in the Fraser River. We briefly examine the relationship of some environmental data to the indicators. Also, we consider the preliminary results of genetic analyses of offshore eulachons stocks that indicates the river origin of offshore eulachons.

From these analyses we comment on the efficacy of the indicators and suggest recommendations for management of Fraser River eulachons. The report begins with a brief description of eulachon life history and eulachon fisheries in the Fraser River. Then we describe and compare the indicators and response point. We conclude the report with comments regarding an annual fishing quota, and make recommendations for future research and management.

Eulachon life history

The biology of eulachons was reviewed by Hay and McCarter (2000) in a report that included summaries of known and new information, so we present only a brief overview here. Eulachons are members of the smelt family (Osmeridae) and are distributed from the southern Bering Sea to northern California, although no spawning runs have been observed in California for more than 20 years (Hay and McCarter 2000). Eulachons spawn during the late winter and spring. The earliest spawning occurs in the Columbia River (the largest run in the world), in January and February, and the latest in the Fraser (perhaps the second largest) in April and May. Most populations in northern rivers in BC spawn in March and April. There is no clear geographic pattern of spawning times with latitude.

Water temperatures of spawning rivers vary widely, with spawning occurring in the Fraser River at temperatures exceeding 6 or 7 ^{o}C whereas temperatures in northern rivers, which sometimes are ice-covered during spawning, are much lower. Also, there is little in common among many of the rivers, with some being small and clear (i.e. the Kemano River in northern BC) and others being large and turbid (i.e. the Fraser). What most rivers do have in common, however, is that they mainly have spring freshettes, and drain snowpacks or glaciers. For instance, there are no regular eulachons runs in rivers that drain coastal islands or peninsulas, that mainly have fall freshettes following rains in November and December.

Fraser River eulachons are semelparous (die after spawning) with most living for three years before spawning and dying (Hay and McCarter 2000). Probably some spawn at age two and others at age four or five. At lower latitudes, like southern BC (49^{o}-54^{o}) post-spawning mortality seems to be the rule, although there may be some iteroparity (survive spawning) at higher latitudes, in Alaska. The evidence for semelparity in the Fraser, and other BC rivers, is strong. In the Fraser, and many other rivers, post-spawning mortality can be directly observed by floating and beached carcasses of spent fish. Also, we have confirmed that eulachons resorb teeth during spawning, and all Fraser fish we have examined (thousands) have evidence of substantial tooth loss. Further, we find only eulachon with well-developed teeth in the sea, and we also have examined thousands of these fish. Finally, the size (standard length) of eulachons in the river constitutes the largest group of eulachons we see, and they are distinctly larger than marine-captured eulachons. If any survived spawning, we would expect, but do not, see a few very large marine eulachons, consistent with size distributions in rivers.

Eulachon fisheries in the Fraser River

A small commercial fishery for eulachons has occurred in the Fraser River since the early part of the twentieth century. This is the only river to support a commercial fishery for eulachons in BC, though previously, in the late 1800's and early 1900's, the Nass River, in northern BC, supported a large commercial fishery. The only other regularly occurring commercial fishery, on the Pacific Coast, for eulachons is in the Columbia River. In other parts of BC, eulachons are fished by First Nations in most of the 14 rivers that support regular runs (Hay and McCarter 2000). Eulachons also are captured as bycatch in offshore trawl fisheries (Hay et al 1998, 1999). Eulachon stocks declined sharply in the Fraser River in 1994. Concerns about the apparently low spawning biomass led to research investigations to estimate spawning biomass and spawning locations and the introduction of regulations. Rumors of impending management change for eulachons in the Fraser River prompted a sharp increase in the number of fishers in 1996 to more than 70 from an average of 22. The commercial fishery was closed for eulachon in 1997 because of the inability to control effort, participation and, to ensure catches stayed within the recommended quota. In 1998, a limited entry license regime was initiated in the commercial eulachon fishery, but due to conservation concerns no fishery took place. There are presently 16 holders of a special commercial eulachon license (ZU) that allows commercial harvest by gillnet. Each license is held by an individual, who must designate a harvest vessel each year. The designated vessel must be eligible for a commercial vessel-based license. The gillnet may have a maximum length of 275 m and a mesh size of between 25 and 50 mm. The license holder is required to hail their catch and other fishing information within 24 hours of a fishery opening. In addition, the license holder is responsible by condition of license to provide fish slips reporting landings and value, and logbooks reporting location (within the Fraser River), effort and catch.

In most years, the fishery has occurred in the lower Fraser River- or in Pacific Fisheries Management Areas (PFMA) 29-7, 29-9 to 17 which includes all tidal waters below the Mission Bridge. Prior to 1995, the commercial eulachon fishery in the Fraser River was not restricted to holders of special licenses and fishing times (6 days per week). In 1995 the fishery was cut back to 3 days per week with voluntary weekly hails and a mandatory log book program was started. The commercial fishery in the Fraser River was closed in 1997 and remained closed for a five year period reopening in 2002. The commercial fishery in 2002 had a 6 hour opening on May 2.

Recreational fishery catches are not reported on either river. In the Columbia River the recreational catch may be substantial, rivaling the commercial fishery (G. Bargmann, pers. comm). On the Fraser River, the size of the recreational catch is uncertain, but it also may be substantial. Fishing is in tidal waters, by gillnet (less than 7.5 m in length with a mesh size greater than 25 mm and less than 50 mm) or dipnet. The daily limit has varied depending on conservation concerns. Recreational fishing was closed from 1998-2000. It re-opened in 2002, with a daily limit of 5 kg/day between April 2 and May 16, with fishing only during daylight hours. Then due to increased in-season estimates of abundance from the test fishery, the daily limit was increased to 20 kg per day effective May 17. The historic recreational catch limit is 20 kg per day with a possession limit of 40 kg.

There also is a distinct First Nations eulachon fishery in the Fraser River for food, social and ceremonial purposes. This fishery is managed through a communal Aboriginal fishing license which indicates the location, gear and species being harvested. Fishing is by drift gillnet (less than 275 m in length and mesh size between 25 and 50 mm mesh size), set net or dipnet and harvest opportunities are provided through consultation between the First Nations and the Department of Fisheries. The First Nations catch of fish for food, social and ceremonial purposed is monitored and catch data are available for recent years. Total catches in recent years are small. We suspect that the combined First Nations and recreational fishery remove about of 10 tonnes annually.

METHODS

Indicators and data

As sources of indicators, we collected, examined and analyzed data that were directly related or potentially related to eulachon abundance in the Fraser River. To determine the efficacy of data sets as indicators, and to develop response point's, we examined the temporal variation in each indicator and when possible, compared temporal trends among different indicators.

1. Indicator data from egg and larval survey estimates of SSB. The SSB is estimated as the product of mean egg and larval (e+l) density (n/m^3) and river discharge (m^3/s) . Details for the estimation of SSB are presented by Hay et al (1997b, 2002) and the data are summarized in Table 1 (adapted from Hay et al. 2002). For each of a number of sampling sites on the river, the SSB was estimated as the biomass required to produce the observed e+l density. SSB estimates are made in the two-three months following spawning. Therefore the value of the SSB estimates, as an 'after-the-fact' estimation of abundance, has no direct application as an 'indicator' to management of the fishery in the same year in which the SSB was made. The SSB estimates begin in 1995, and therefore there are relatively few data points for comparison with other indicator series. To investigate relative usage of different parts of the river for spawning, SSB estimates were made for several different locations on the Fraser River (Fig. 1). Exact spawning locations within the river appear to change among years but in general, SSB estimates are lowest in the most upstream locations, above most spawning locations, and greatest in the most downstream location.

For the purposes of the present paper we estimate the total SSB for the entire river, as the sum of the production for the North and South Arms (Table 2).

2. Indicator data from offshore surveys and biological data of eulachon. Offshore indices of eulachon abundance were estimated from analysis of bycatch in annual shrimp trawl research surveys conducted off the west coast of Vancouver Island since 1973 (Boutillier et al. 1997, Rutherford 2002). The shrimp trawl survey design is based on systematic sampling of the shrimp grounds with spatial analysis used to provide estimates of shrimp abundance (Hay et al. 1997a). Eulachon are caught as by-catch in this survey and the method used to estimate shrimp abundance has also been used to provide and index of eulachon abundance in the surveyed area. The detailed survey methodology for assessing shrimp stocks is documented in Boutillier et al. (1998) and Martell et al. (2000). Methods of estimating the eulachon biomass index from the survey are described in Hay et al. (1997a). The biomass indices are shown separately for several areas off the west coast of Vancouver Island: Statistical Areas 124, 125 and the combined areas of 121 and 123 (Fig. 2). The later areas are not used as part of the time series index, because they have only been surveyed for a few of the last 30 years. The index is not completely represented for both Areas 124 and 125 in all years, so these are treated as two separate indices (i.e. not summed or pooled).

Indices of eulachon biomass are available by DFO Statistical Areas (or Pacific Fishery Management Areas, PFMA) 121/123 for years 1996 to 2002; for Areas 124 for years 1973 to 2002, except for 1974, 1984, 1986; and for Area 125 for years 1973 to 2002 except for 1974, 1984, 1986, 1989, and 1991 (Table 3).

Prior to 1999 the total catch weight of eulachon taken during the research surveys was the only biological parameter recorded for eulachon. Commencing in 1999 eulachon were also sampled for length and a sub-sample of the catch was counted and weighed to estimate an average number per kilogram. Then age composition (Table 4) was estimated from length frequency analysis of data from all the tows within a management area Rutherford (2002).

Age determination from conventional scale or otolith analysis has been difficult because trawl-captured eulachons have no scales and otoliths have not been reliable (Hay and McCarter 2000). In recent years, size mode analysis of the eulachon catches (Fig. 3) has allowed a distinction between several putative age groups, and a separate biomass estimate of each age group (Tables 4). The size composition of eulachons from the sea consists of two main modes, which we believe top represent age 1+ and age 2+ respectively (Fig. 3). When observed during annual May-shrimp surveys, these eulachons would be about 14 and 26 months of age respectively. The largest size mode corresponds to the size modes observed in spawning rivers. Although there are always two distinct modes each year, the size distributions change rapidly within years (from growth) and they differ between years, indicating that there are substantial inter-annual differences in growth rate, perhaps in response to changing trophic conditions in the sea. From Table 5 we note that both the offshore biomass and the percentage of age 2+ fish, (from the 2000 cohort) in 2002 is unprecedented in the time series. It will be interesting to see if this (apparently) exceptionally strong cohort appears in the Columbia and Fraser Rivers, as an exceptionally strong spawning run, in 2003)

3. Catches from the Fraser and Columbia Rivers as an indicator data. Catch data from commercial fisheries in the Fraser River (Ricker at al. 1954) and Columbia River (Anon. 1993) have been collected since the 1930's (Table 3). In the Columbia River annual trends in catch data probably are roughly representative of trends in abundance, at least until the 1990's when catch restrictions were imposed (Hay and McCarter 2000). In the Fraser River, however, trends in catch data may vary widely from trends in abundance, probably for most of the last four decades. Instead catch data probably reflects many factors other than abundance, including limited markets, incomplete reporting of catch, changing spawning areas (Hay et al. 2002), and occasional suspensions of fishing imposed by the Department of Fisheries for conservation purposes (D. Stacey, pers.comm.). Further, changes in spawning habitat, related to nearshore industrial developments, dredging, and pollution (i.e. Rogers et al. 1990) also may have affected spawning distribution, and catches.

4. Fraser River test fishery data as a potential indicator. Systematic catches in the New Westminster test fishery have been conducted in the Fraser River since 1995, except 1999 (Table 6). The catches are made daily using identical gillnet gear (mesh size 3.18 cm or 1.25 inches, 50 fathoms or 92 m long and 380 meshes deep, fished at the same location (New Westminster), for the same duration (15 minutes), and at the same stage of tide (low slack at New Westminster). All of the catch was sorted by sex, counted, weighed and a biological sample is taken for further analysis. Catch numbers are provided to DFO daily with detailed datasheets submitted weekly.

5. Other data relevant to indicators and response points. (a) Following Hay et al 1997a, who considered variation in the offshore index, and trends in Fraser and Columbia River catches, we also have used temperature data collected annually from the DFO-operated lighthouse at Amphitrite Point, near Barkley Sound, on the west coast of Vancouver Island. (b) We present brief summaries of preliminary genetic analyses on the river origin (mainly Columbia and Fraser River eulachons) of samples taken in waters offshore of the west coast of Vancouver Island.

Data analyses

Simple time series plots, scatterplots and correlation analyses were used to compare temporal trends in different indicators, although there was only a short temporal duration for some of the series. We compare and contrast the temporal data between Fraser and Columbia River catches. We also compare these catch data from each river with offshore indices (~30-year time series from 1973-2002). We compare the between-year temporal trends in the test fishery data with the SSB estimates. We compare the Fraser River SSB (8-year time series from 1995-2002) with offshore indices, and consider the effects of monthly changes in mean sea-surface temperature.

Although the utility of the test fishery data is still uncertain, we examine the 'within-season' or within-year changes in catch rate to determine if daily catch rates, especially during the early part of the spawning period, could be useful as potential 'in-season' indicators. We estimated the annual 'cumulative' test fishery catches (Table 7) in an attempt to identify any specific response points applicable to in-season management (i.e. setting catch levels or rates according to the apparent abundance as judged 'within the spawning season)'.

We used information from recently acquired but unpublished genetic analyses (T. Beacham, pers. comm.), on the composition, by river of origin, of eulachons taken from waters offshore of the west coast of Vancouver Island

RESULTS

Temporal trends in the indicators

1. Spawning stock biomass (SSB) in the Fraser River - variation in time and space. The surveys indicate that the spawning sites vary annually in the river: some years more is in upstream areas (Table 1). It follows that SSB estimates were usually lower in upstream locations, so the most complete SSB estimates are from downstream survey locations. The Fraser River divides into the north and south arms at New Westminster. Hay et al. (2002) showed that spawning was greater on the north side of the river. This presents a minor problem because the SSB must then represent a sum of the estimates from both arms, but the estimates of sampling error vary in each location. Therefore SSB estimates used here are based on all samples combined for the south ('SARM') and north ('NARM') arms respectively (Table 2). A plot of the total Fraser River SSB shows substantial variation between 1995 and 2002 (Fig. 4), with lowest years between 1997, 1998 and 2000. The lowest year was 1997, with a SSB estimate of less than 80 tonnes.

As an indicator, a year with a low SSB (i.e., <150 tonnes) should not necessarily be cause for fisheries management action, such a closure or catch restriction, in the next year. We understand that in most years, there are at least three eulachon cohorts present in the population. We also know that osmerid species such a eulachons are subject to considerable interannual fluctuations. Therefore, we suggest that a SSB estimate < 150 tonnes would be cause for management caution, not alarm. Using the example of a traffic light, where a green light signals an advance, a yellow light signals an advance but slower and with caution and a red light signals a full stop, then a single year with a low SSB could be seen as a yellow indicator. Two sequential years with a low SSB, however, would represent a red light - a full stoppage of all removals.

2. Annual variation in Columbia and Fraser River catches. In 1994 the apparent abundance of eulachons in the Fraser River was lower than most previous years (an observation first made by commercial fishers who brought this to the attention of Fisheries and Oceans, in a series of meetings). The commercial eulachon fishery was closed in the Fraser River for a five year period 1997-2001 inclusive. Compared to the 1940's and 1950's Fraser River catches declined in the 1960's and 1970's and remained low throughout the 1980's and 1990's (Fig. 5A). In contrast to the Fraser, Columbia River catches remained high throughout the 1970's and 1980's (Fig 5B). There were some years, such as 1983, when Columbia River catches were low (Table 3) and also some periods of fluctuations throughout the time series. Explanations for the low 1983 catch have included negative impacts of ash in spawning areas following the 1983 Mount St. Helen volcanic eruption (Hay et al 1997a). There also was a strong el Nino event in the same year, however, so it is difficult to rule out explanations associated with the marine environment. Given the variation in Fraser River commercial catch data, it is unlikely that they are useful as an indicator of past trends in abundance. On the other hand, the relative magnitude of catches in the 1940's and 1950's may provide an approximate response point for determining present and future catch levels. Specifically, catch levels for much of the 1980's and 1990s was about 20 tonnes and this appeared to be sustained over several decades.

3. Annual and spatial variation in offshore biomass indices. From 1973 to 1993 the eulachon index in Statistical Areas 124 and 125 was variable and without trend. From 1994 to 1999 eulachon abundance was at a low level in all the areas surveyed. Eulachon abundance increased sharply in most areas in 2000 and all areas were at record high levels in 2002. The biomass index for Statistical Area 124 fluctuated between low levels (<100 tonnes) and nearly 2000 tonnes between 1973 and the early 1990's, when it declined sharply (Fig. 6A). It remained low though much of the 1990's but increased sharply in 2000, and the increase has continued into 2002, to unprecedented high levels. The sharp decline in 1983 stands out as a year when offshore abundance may have been affected by the strong El Nino conditions. The offshore index in Statistical Area 125 follows a roughly similar trend although the estimated biomass in most years between 1973 and 1993 is lower (< 1000 t). Like Area 124, Area 125 (Fig. 6B) has increased recently, but the sharp increase did not occur until 2002.

4. Variation in age composition and origin of offshore eulachons. Approximate age determination of offshore eulachons started in 1999, based on the distinct size modes seen in length frequency data (Hay and McCarter. 2000). From this method, the size (or age) modes of offshore samples have been identified since 1999. From this approach, the estimated numbers and proportions of eulachons in the two main age categories were estimates for all areas (Tables 4, 5). In most years, most of the eulachons are in the size mode corresponding to eulachons ages at 2+ years. Because these fish were captured in May, and because most probably hatched between March (in Columbia River) and April or May (in Fraser River), most are between 24 and 27 months of age. Most eulachons appear to spawn at age 3, so the larger size mode would correspond to the spawning fish in the next spring, following the survey. It follows that if reliable estimates of the relative abundance of age 2+ eulachons can be estimated in year n, in offshore waters, this would be a useful indicator of future spawning abundance in year n+1. The difficulty with such an estimate however, is that we are uncertain of the origin, or destination of eulachons caught in offshore waters. This uncertainty may be resolved with genetic analysis that indicates the river origin of eulachon in offshore waters,

Preliminary analysis of offshore mixed-stock samples, based on comparisons of genetic samples from most of the larger rivers in BC, indicates that eulachons on the west coast of Vancouver Island consist of approximately 60 percent Columbia River fish and 40 percent Fraser River fish. These estimates, however, are preliminary and could change in other years or with further samples and analysis. The dissection of the offshore index to account for variation of age structure and river origin shows that the offshore index has the potential to be both useful, and misleading. If the years with a high index consisted mainly are age 1+ fish, then we may not expect to see any correspondence between the index and SSB (or catches) in the next year in rivers. On the other hand, the systematic collection of data on size (or age) and genetic composition could provide a precise and accurate indicator for spawning abundance in the Fraser River, and perhaps other rivers.

5. Temporal trends in the test fishery data. The start and finish dates of the test fishing vary slightly among years, the duration of the test-fishing activity has included the main spawning runs. In general, the earliest fishing days begin approximately in Julian Day 80 (March 21) and extend about 9 weeks until Julian Day 143 (about May 23). Direct comparison of the catches among years indicates that (1) in some years catches occur earlier than others; (2) sometimes there appears to be several periods (or waves) of high catches punctuated by periods with lower catches; (3) total (or cumulative) catches in some years are much greater than other years. The cumulative catch is compared among all years in Fig. 7. No test fishery was conducted in 1999.

Comparison and contrast among the indicator data

1. Comparison of the Fraser and Columbia River catches. Although there is no significant correlation between Fraser River and Columbia River catches, we see that when the Columbia River catches are high Fraser River catches often are low, (see square symbols in Fig. 8). Therefore, high catches in the Columbia (i.e. high SSB) do not provide assurance that there would be high catches (i.e. SSB) in the Fraser River. More importantly, however, in all years when Columbia River catches were low (<500 tonnes), indicated by the points to the left of the vertical dotted line in Fig 8., the Fraser River catches also were low . Therefore, low catches in the Columbia River, where spawning and fishing occurs in January and February, may provide a rough but useful indicator of years with low SSB in the Fraser. For this reason, we suggest that catches less than 500 tonnes in the Columbia River could serve as a useful response point for pre-season Fraser River management. Of course, this would be subject to annual confirmation from U.S. sources that low catches are not a product of specific management restrictions.

2. Comparison of offshore surveys and Fraser and Columbia River catches. Hay et al. (1997) noted that the offshore biomass index was positively and significantly correlated with Columbia River catches (Fig 9A, B). The offshore biomass estimation techniques used in the 1997 report have been modified slightly in recent years (as per Table 3) but the positive covariance between the Columbia River and offshore indices remains, although only for the offshore biomass index from Statistical Area 124. There is, however, no apparent relationship between the offshore biomass indices and Fraser River catches (Fig. 10A, B). This precludes the use of the offshore biomass index as a direct predictor of Fraser River biomass. We caution, that this lack or correspondence (Fig.10) is based on a comparison of estimated offshore 'biomass' (which includes two separate age groups) and which is made at a time which is one or two years prior to the time when these same fish would be able to spawn in the Fraser, if that were their ultimate spawning destination. We also reiterate that that the Fraser River catch data are not necessarily accurate. For these reasons we cannot conclude that here is no meaningful relationship between the observed offshore biomass and Fraser River SSB, but we can conclude the data are insufficient to allow us to use the offshore biomass as a direct pre-season indicator of Fraser River SSB. On the other hand, a correlation matrix between Columbia and Fraser River catches and the offshore biomass index, indicates a significant positive relationship between offshore biomass and the Columbia River (Table 8.)

3. Sea surface temperature and Fraser catches. Hay et al. (1997a) noted a significant negative relationship between SST and Fraser River catches and this relationship is confirmed here (Table 9). Specifically, Fraser River catches were higher when SST was lower. Probably this is spurious because in recent years there have been trends for SST to increase and for eulachon biomass to decrease. Such trends may occur independently so the significant correlation between these factors is not evidence of any functional relationship between these variables. There is no significant correlation between monthly SST and offshore biomass, or between SST and Columbia River catches (Table 9).

4. SSB and Offshore biomass. The offshore biomass also can be compared with the much shorter data series of SSB, from egg and larval surveys (Fig. 11). There is no apparent covariance in the comparison of eight years of data, but the year 1996 is of special interest. This year (1996) had an exceptionally large SSB estimate of about ~1900 tonnes (Table 2) but the offshore biomass index was not exceptional. This indicates that the offshore biomass estimates may not always apply to Fraser River fish. There are some years when the offshore biomass is low, and the Fraser appears to be relatively high, and vice versa. Nevertheless, the lack of a meaningful relationship may be more attributable to the inadequacies of the data, and when faced with insufficient information for management of the Fraser River, it is reassuring to know that eulachons are present in offshore waters. We also note that in the years when the offshore biomass index was very low (approximately between 1995 and 1999) the Fraser River catches also were low - with the exception of 1996. Therefore very low estimates of offshore eulachon abundance (as observed between 1995 and 1999 (excluding 1996) would be sufficient cause for restricting catches on the Fraser. We suggest that an index of less than 500 tonnes (which occurs in 6 of the 27 years) would be sufficient to implement fishing restrictions - and we suggest that this *could be a response point.* Such a point would be subject to revision, if the quantification methods for the offshore index were revised.

5. Comparison of the test fishery data with catch, offshore and SSB data
The test fishery data (Table 2) is highly correlated with the total Fraser River SSB (r = 0.962, p = 0.001) and with the SSB estimated for the South Arm (SARM) (Fig. 12). These relationship are based only on seven points, and the high significance is dependent only on the 1996 data point. We also compared the test fishery data and SSB estimates at other locations in the river. There are no significant relationships between the test fishery data (cumulative annual totals) and other SSB estimates (from Table 2). The correlation coefficients (r) and probability levels (p) are, for each area shown in Table 2 are as follows:

(i) Barnston Island	r = -0.020	p = 0.920
(ii) New Westminster	r = 0.015	p = 0.992
(iii) SARM	r = 0.962	p = 0.001
(iv) NARM	r = 0.993	p = 0.007
(v) Total	r = 0.964	p = 0.001

Significant correlations occur only when the South Arm SSB data are included in the analyses. If the 1996 test fishery data point is removed then none of the correlations between the test fishery and the SSB are significant.

The test fishery occurs approximately at the New Westminster site (Fig. 1) but the year in the which the high test fishery catches were made, most of the spawning occurred below New Westminster (Hay et al 2002). Therefore, while we do not necessarily challenge the apparent close relationship between the test fishery and the SSB, there are some uncertainties associated with data - but such concern about the apparent fine-scale difference between the location of the test fishery and the apparent location of spawn deposition, may be unwarranted. Recent work in Alaska, that has examined eulachon movements in spawning rivers using radio tags, has found that eulachons are very active prior to spawning, and move extensively up- and down stream (Kitto 2002). Therefore if the same eulachons pre-spawning behaviour applies in the Fraser River, the specific locations of the test fishery, relative to spawning sites, may be inconsequential.

The main value of the test -fishery data would be as an 'in-season' estimator whereby the results of the survey would be immediately evaluated and incorporated into predetermined management schedules. Aside from the uncertain validity of such an approach, the successful application depends on the temporal pattern of the data, as they are being collected. Specifically, to be used successfully, the test fishery data must be distributed in time so the earlier part of the data, is somehow indicative of the latter part. A simple examination of the data in Tables 6 and 7 reveals that the test catches occur early in some years, and later in others (Fig. 13). In some years the catches tend to peak early and then slowly decline, and in other years, they begin slow and stop suddenly. In an attempt to further understand annual variation in the test fishery data, we examined daily variation in (i) tidal variation, and (ii) temporal patterns in Fraser River discharge (in m^3/s), from Hope, (Hay et al. 2002).and (iii) variation in daily temperature as measured at the NW site for a few of the years. We do not report these analyses here, however because there were no clear relationships between one or more variables, and patterns of test fishery catches. We suggest that the utilization of test fishery data should proceed cautiously because we cannot confirm that the test fishery data varies with eulachon SSB. We acknowledge the significant correlation relationship between the test fishery data and the SSB estimates (Fig. 12) but reiterate that the relationship consists only of seven points and the significance is dependent on a single data point.

From examination of the temporal relationship between test fishery relationship (Fig. 13), it seems clear that the SSB in the two lowest years (1997 and 1998) was too low to support fisheries. In both years the cumulative test fishery catches were below 5000 pieces (Table 7). Therefore, if test fishery data were to be used for in-season response point's, there are two which can be identified. One is that there should be a minimum catch level before fisheries are considered, and this could be a cumulative catch of 5000 fish. From Table 7, such a catch failed to occur only in two years, 1997 and 1998. This could be regarded as an in-season response point that for a 'start' to a fishery, perhaps at a reduced scale. A second point, say 10000 fish, could be used to establish a point where fishing would occur up to some pre-determined point.

We caution against using the test fishery data as anything but a guide to (a) whether fisheries open and (b) the dates on which they open and (c) perhaps some step-function, that related pre-determined catch ceilings to the amount of fish in the test fishery (i.e. 5000 pieces is a start, and 10000 is fully open, with a total allowable catch (TAC) in place. A suggested format is presented (Fig. 13) as the cumulative test fishery catch, for 6 years, relative to the day of the year (DOY). In two of the years, the cumulative catch did not reach 5000 pieces, so in such years, the fishery would not open and remain closed for the season. While we suggest that the test-fishery data may be useful as a precautionary indicator, the evidence that the test fishery results are related to SSB is not yet convincing.

DISCUSSION

Implementation of the OBFM and IFMP for eulachon

Since 1997 the commercial fishery for eulachon on the Fraser River has been changed to a limited entry fishery that currently has 16 licenses. With the application of a precautionary approach, through the formulation and implementation of Objective Based Fishery Management (OBFM) and an Integrated Fisheries Management Plan (IFMP), the commercial fishery could be closed if some combination of pre-season, or in-season indicators cannot rule out conservation concern. Using this approach the in-season New Westminster test fishery could be a vital component for management of Fraser River eulachon fisheries. A problem with this approach, however, is that the test fishery data have not yet been shown to be either reliable or sensitive to the wide range in SSB seen through egg and larval surveys. It is possible that the test fishery data is reasonably sensitive to low SSB conditions. Therefore setting a predetermined minimum level of test fishery catch (say 5000 pieces) before a partial opening and 10000 before a full opening, established such levels as 'reference' points. A logistical and ethical concern, however, is that the fishing season is very short, only a few weeks in most years, so extensive delays in achieving such a test-fishery-based response point is the time required to meet it. If fishing operations are to proceed, it usually takes time and costs for fishers to prepare, so it would be unfair to announce openings without some form of earlier identification about the likelihood of a fishery. For this reason we suggest that the different forms of response point's be developed sequentially.

Integrated response points: suggestion for sequential implementation.

The first sequential (pre-season) response point: SSB in year n-1. The earliest 'pre-season' response point could actually be the SSB estimate from the previous year. In this sense, and given the three-year life cycle of eulachons (Hay et al 2002) we suggest that fishery openings in any year would not be expected if the SSB in the previous two years was below a fixed 'response point. For the Fraser River, we suggest that this level be set at 150 tonnes. This is slightly greater that the approximate biomass estimates observed during the lowest years of the 1990's (1997, 1998 and 2000- Table 2). Therefore if the SSB in two consecutive years was less than 150 tonnes, we suggest that no fishery would occur in the next year, regardless of other indicators. This estimate could be available by about October of each year.

The second sequential (pre-season) response point: offshore biomass. There is no direct relationship between offshore biomass and Fraser River commercial catches (based on the historical time series of catch data) but it would be unwarranted to dismiss the probable connection between the abundance of eulachons in offshore marine waters and the size of the Fraser River SSB. Indeed, the reason such an apparent relationship may not appear to exist is that the offshore surveys if they encounter a mixture of Columbia River and Fraser River eulachons. Preliminary analyses of the genetics of mixed stock, from the lower east coast of Vancouver Island (Fig. 1) indicates they consist of about 60% Columbia River fish and 40% Fraser River fish (T. Beacham, pers. comm). Therefore, it follows that if there is a change between these two populations, such that one is lower, the percent composition of offshore eulachons may change. For instance, we observed a very high SSB in the Fraser in 1996 (~1800 tonnes), but there was no corresponding abundance observed in offshore waters. Was this an error in the SSB estimates, or in the offshore survey estimates? Clearly we cannot rule out error in either estimate but an alternate explanation is that the in 1996 eulachons from the Columbia River were relatively less abundant than in previous years, so the total biomass index would have been lower, because it consisted mainly of Fraser River fish. This is speculation but we point out the apparent negative correlation between SST and Fraser River eulachon commercial catch suggests that the populations of each river may respond differently to environmental change. Even with these uncertainties, precautionary management should require some minimal level of eulachons in the offshore biomass index and we suggest that this level be set at 1000 tonnes. Based on the offshore time series, such a limit (i.e. reference point) would have warranted a fishery closure for all years between 1994 and 1999. With future work, this limit could become more refined and explicit. Specifically, we advise that the estimation of age-specific numbers (and biomass), as per Table 3) will allow for partitioning of the offshore biomass into two groups, age 1+ and 2+, of which the age 2+ are the expected spawners in the next year. We also suggest that better estimates of mixed stock composition through genetic analyses, could allow some partitioning of the biomass that is expected to spawn in the Columbia and the Fraser. As a functional reference point, this estimate is available in about June of each year.

The third sequential (pre-season) response point: the Columbia River catches. As suggested above, based on the available data, the Columbia River catch is not correlated to Fraser River catches, although in most years when Columbia catches were low, the Fraser River catches also were low. A useful limit is 500 tonnes, so that if the Columbia River catches were less than 500 tonnes, this would be a response point for consideration of a closure of the Fraser River. This estimate is available in about February or March of each year, several months prior to the Fraser spawning time. A potential concern for utilization of this estimate, however, is that it is subject to sources of variation (such as local markets or adverse weather) and quantification techniques that are not necessarily available for review. Therefore we suggest that the implementation of such a response point would be at the discretion of the Fraser River managers.

The fourth sequential (in-season) response point: the test fishery. As explained above, the test fishery has only been operational for 7 years, and the accuracy of the data, as a guide to the state of the SSB is uncertain. We reiterate that data gathered to date do not appear to sensitive to the wide changes in spawning abundance that we observed through egg and larval surveys, especially at low levels of abundance. Therefore, the appearance of a highly significant correlation between the test fishery and the larval-based SSB is dependent only on the data from one extreme year (1996) when both the SSB and cumulative test fishery catch was very high. Therefore we advise that a predetermined minimum level of test fishery cumulative catch of 5000 pieces could be a response point requirement for a partial opening and test fishery cumulative catch of 10000 before a full opening, could be established such levels as 'reference' points.

Resolution of conflicting indicators. Probably, one or more of the indicators in any specific year may contradict the others. In such an instance there must be a mechanism for resolution of which indicators are most important, and the risks associated with either recognizing or ignoring an indicator. For instance, offshore abundance of eulachons would appear to be an especially useful indicator, but we note that a very large run occurred in the Fraser River in 1996, a year when the offshore abundance we apparently low. The Columbia River catch, as an indicator, is only useful if the catch reflects abundance in that river, and not a reflection of management changes practices in that river. We have already described limitations in the test fishery data, and we consider it only as a potential indicator. The SSB estimates can only be estimated well after the fishery, so SSB estimates from the previous year have little information about future years.

If all of the indicators - or response points - point in the same direction (i.e. all indicating downward or upwards trends) then management decisions would be relatively simple. Management decisions would be more complex and difficult if the signals are mixed. Resolution of 'mixed' signals, however, can be assisted by consideration of decision rules that anticipate some of the combinations of possibilities that could arise. For instance, we suggest that there are actually four distinct 'pre-season' response points described in the preceding sections.

1. SSB < 150 tonnes for one year;
2. SSB < 150 tonnes for two consecutive years;
3. Offshore biomass < 1000 tonnes;
4. Columbia River catch < 500 tonnes

There are at least two potential 'in-season' indicators that might be used.

5. Test fishery returns < 5000 pieces
6. Test fishery results < 10000 pieces

In addition to the indicators, there are many different potential management responses or options. Two obvious options are (1) a full fishery, and (2) no fishery. A third option is some form of partial fishery, and such an option may be appropriate during those times when the indicators are mixed. We have attempted to illustrate these options, relative to nine different combinations pre-season indicators (Table 11). In this table we suggest that the test fishery results may be most useful when there are one or more conflicting signals. In general, when there are two or more indicators that indicate caution, we advise that the fishery be stopped, or perhaps reduced in scale (i.e. a partial fishery). The decision scenarios indicated in Table 10 are only provided as an example of the process that might be considered at the present time. Probably all the response points would require modification with future information. Also, there could be reason to consider new indicators, or reconsideration of some of the indicators identified here.

Precautionary catch levels for the Fraser River

Readers may have noticed that we presented our analyses, descriptions and analyses of indicators and response points without any mention of the recommended catch levels. This omission was deliberate, because we have no biological basis for recommending biologically sustainable catches except by referring to past catch levels. In theory, catch rates or quotas for management of Pacific herring, or other species, establish catch levels that consider the size of the spawning stock biomass, age structure and biological capability of the population to replenish itself. Increasingly, new considerations are considered, such as the role of the species as prey for other species, and such requirements will compete for fish with other users. For eulachons, we do not have enough information to suggest catches based on biological criteria, but we suggest that the past levels of catches from the Fraser, especially in the 1980's and 1990's may be a useful guide. Specifically a commercial catch of about 20 tonnes occurred for several decades in the 1970's and 1980's, and that this level probably was accompanied by a First Nations and recreational catches of uncertain magnitude but perhaps the combined catches from all 'in-river' removals was as high as 40 tonnes.

The preceding discussion does not account for the removals by the offshore shrimp trawl fleet, as bycatch. The specific impact of the offshore shrimp bycatch on Fraser River SSB is difficult to quantify with precision, because (i) based on recent (preliminary genetic analysis) some of the fish offshore fish are of Columbia River origin and (ii) the offshore biomass consists of two cohorts - age 1+ and age 2+. It is only the age 2+ cohort that would contribute to the Fraser River SSB in the spring (April and May) of year following the year of removal as bycatch. In recent years DFO shrimp fisheries managers have allowed a maximal bycatch of 40 tonnes, although such a level has only been met in one year. The approximate mean weight of individual eulachon in the age 1+ cohort, during the period of the annual offshore surveys is May, about 3-6 g. The mean wt of age 2+ eulachons is about 25-35 g - almost ten times greater. Consequently, in most years, most (~80-90%) of the offshore biomass is made up of the age 2+ cohort, even when the numbers and proportion of age 1+ eulachons is high. Therefore, if 40 percent of the maximal offshore bycatch were Fraser River fish, and if 90% of the biomass were from the age 2+ cohort, the maximal reduction in SSB from offshore bycatch would be about 37% or 14.4 tonnes. In most years, when the maximal bycatch were less than 40 tonnes, the reduction of Fraser River SSB would be much less. On the other hand, if the maximal allowable bycatch were increased, there would be a direct reduction of Fraser River SSB in the next year.

Clearly there is a resource conflict between demands for eulachons as a catch of a target species in the river and as an avoidable bycatch species in offshore trawl fisheries. Such fisheries have the potential to catch more eulachons than any other Fraser River eulachon fisheries. In future years we anticipate that there will be pressure to allow some level of eulachons bycatch in the shrimp fishery as well as allow for in-river removals, especially in support of First Nation fisheries. Resolution of such a conflict between competing user groups is beyond the scope of this report. We suggest, however, that future resolution would be assisted with better information about the genetic structure of offshore stocks: specifically we suggest obtaining more genetic information on stock mixtures, and especially if the proportion of Fraser River fish varies spatially or temporally in offshore areas.

Summary

Efficacy of assessment indicators, response points and application to fishery management.

The four available assessment indicators and the analysis undertaken have been described in the preceding sections. The suggestion for the sequential implementation of these assessment indicators combined with response points has also been described. This section will comment on the efficacy of those indicators and the utility of response points in the application to fishery management regime. (Table 10)

Indicators
The biomass indicators are measures of the state of the annual population abundance that will return to the spawning and fishing areas, in this case the Fraser River. The indicators are classified as to those providing information prior, during and after the fishing season (pre, in or post-season).

Response Points
The response points identify varying levels of stock abundance at which different fishery management actions would occur to achieve conservation and varying degrees of catch removals. The response points identify the prioritized usage of the fish resource, ranging from conservation as the first priority, food social and ceremonial catches for First Nations and then varying levels of recreational and commercial catches.

Fishery Management Regime
This is the method of governance, through fishery management actions, that provides for the annual requirements of conservation and utilization. The characteristic of a regime is that of prescribed responses for fishery management to identified levels of stock abundance. The capabilities of the assessment and fishery processes need to be compatible. That is, a simplistic assessment capability would yield a simplistic fishery management regime. A complex fishery management regime would need a rigorous assessment system. A rigorous assessment would provide increased efficacy in the application of indicators and response points in the fishery management regime. This information is arrayed in summary in Table 10.

Conclusions

1. The correlation of Fraser River Test Fishery to that of spawning biomass is dependent on one year in a data set of seven years.

2. Each of the four Indicators is limited by their short time series.

3. Estimates from the four indicators may be improved by the collection of data for additional years. As well, some indicators such as the offshore biomass may be further improved with additional data such as age and stock composition.

4. The indicators, used separately, have limited capability to forecast/estimate the returning biomass and as such have limited utility in their application in potential fishery management responses.

5. The indicators, when used sequentially, may yield an increased capability to forecast/estimate the returning abundance.

Recommendations for management

1. A series of indicators with sequential response points may provide a basis for eulachon management in the Fraser River. Fraser River eulachon fisheries should be managed with reference to only occur when the following conditions (response points) are achieved:

(i) A SSB of less than 150 tonnes, for the previous year (but not for two consecutive years) would be a precautionary indicator, and the impact on fisheries would depend on trends in other indicators. Even though this SSB estimate is an 'after-the-fact estimate', or a 'post-season' indicator, when the SSB is as low as 150 tonnes, this should be regarded as a 'pre-season' indicator for the next year. This response point can be determined by about October of each year.

(ii) A related response point is the SSB from two previous years. A point where the SSB is less than 150 tonnes *for two consecutive years* should be considered as a critical response point and a conservation concern. No fisheries should occur in the subsequent year. This would represent a 'worst case scenario' and probably not occur frequently. This response point can be determined by about October of each year.

(iii) An offshore biomass index of less than 1000 tonnes (summed from Statistical Areas 124 and 125) is a pre-season indicator. The impact of this measure, when considered with other indicators, could sometimes result in the suspension of fishing activity, when eulachon stocks actually are plentiful, although based on the review of the offshore indices, this would not happen often. Rather the effect, had it been implemented, would have been to impact fishing for 9 of the last 26 years (excluding 2002), and all years between 1994 and 2000 when biomass indices were low.

(iv) Consider restrictions on fishing if the Columbia River catch indicator is less than 500 tonnes. The degree of restriction would depend on trends with other indicators. This is a not an especially conservative response point, because before 1994, there were very few years where such a response point would apply. Such a response point would be dependent on estimation procedures made in other jurisdictions, so we advise that managers should consider such a point as having more flexibility than others.

(v) If the previous indicators were positive, as would happen in many years, then a fishery could occur without dependence on in-season results of test fishery. On the other hand, if one or more of the previous indicators is not positive, then the test fishery results could be used to make 'in-season' decisions about the scale of catches - or 'partial' fisheries. Here we suggest implementation of two response points based on the rate of cumulative catches. First, suspension of all fishing activity might occur until the test fishery has accumulated a minimum of 5000 pieces, but once this is achieved, a partial fishery could open. 'Partial' could be a catch of no more than 50 % of an annual fixed quota (see below). Once the test fishery had captured 10000 pieces, then the full quota might be taken. In this regard, we advise that the time required to catch either 5000 or 10000 pieces varies among years, perhaps varying with environmental conditions. At the present time, we do not understand what determines the timing and duration of a spawning run, so it would be impractical to attempt to imbed dates (relative to cumulative catches in the test fishery) into the OBFM or IFMP.

2. In the absence of specific biological criteria about the size of the spawning stock *prior to a fishery* , and when all indicators are positive, an annual catch of 40 tonnes for all users (and which in the 1970's and 1980's about 20 tonnes was taken by a commercial fishery) could be sustained, and would not impose a risk to the stock.

3. Test fishery data and larval surveys in support of SSB estimates should continue. The validity and utility of the test fishery procedures require more attention. This might be done in the form of experimental fishing methods that would examine sources of variability associated with test fishery data.

4. There is a pressing requirement to reconcile the amount of eulachons taken by different users. A specific issue for management of Fraser River eulachons is the accounting for removals in the sea, before they reach the river. Such a task may be assisted by the continued development of genetic techniques, and perhaps other approaches, for the elucidation of stock differences and stock origins.

5. The annual offshore shrimp surveys from determination of shrimp biomass should be recognized as having substantial inherent value as a source of meaningful pre-season reference points for eulachon fisheries, in addition to shrimp fisheries.

Recommendations for research

1. Investigate the possibility of earlier but smaller and undetected spawning runs of eulachons in the Fraser River. Such runs have been suggested by some fishers.

2. Investigate factors affecting the timing and location of spawning as a factor affecting test fisheries. One factor is water temperature. The relationship between temperature and estimated incubation time is known, so future research could attempt to use the timing of peaks in egg and larval production data to estimate peaks in spawning period. This would provide a potential check for the test fishery data.

3. Use estimated dates of historic catch data from data presented by Ricker et al (1954) and compare these with tidal state (that can be computed for all previous years). This would allow a comparison of the approximate time of the spawning run for an additional 10-12 years. These data also could be examined according the annual variation in Sea

Surface Temperature (SST) and Fraser River discharge rates. The dates of the older catch data, however, may lack sufficient precision to make this approach useful.

4. The compilation of historic Fraser River catch data should be re-examined and recompiled if necessary. There are several published sources that appear to present different estimates, especially during the years when catches were maximal.

5. More genetic analyses of eulachons from offshore locations is required to better differentiate between Fraser and Columbia River fish. In the longer term, a time series of mixed stock analyses would be very useful for determining the effect of marine environmental conditions (SST, etc.) on the distribution and mixtures of eulachons from the Fraser and Columbia Rivers, and perhaps from other sources.

ACKNOWLEDGEMENTS

Dennis Rutherford provided the data for offshore biomass estimates of eulachons. Bruce McCarter assisted with parts of the data compilation. Many others assisted with the collection of field and laboratory data that were used in this report.

REFERENCES

Anon. 1993. Status Report - Columbia River fish runs and fisheries, 1938-1992. Joint Publication of the Oregon Dept. of Fish and Wildlife and the Washington State Dept. of Fisheries. 257p.

Boutillier J. A., R. I. Perry, B. Waddell, and J. Bond. 1997. Assessment of the Offshore *Pandalus jordani* Trawl Fishery off the West Coast of Vancouver Island. PSARC Working Paper I-97-11.

Boutillier, J.A., J.A. Bond, H. Nguyen, and R.M Harbo. 1998. Shrimp survey off the West Coast of Vancouver Island and Resulting Management Actions – May 1998. Can. Manuscr. Rep. Fish. Aquat. Sci. 2461: 110 p.

Hay, D.E., R. Harbo, C. E. Southey, J. R. Clarke, G. Parker, P. B. and PB.McCarter 1998. Catch composition of British Columbia shrimp trawls and preliminary estimation of bycatch - with emphasis on eulachons. PSARC Working Paper I98:8. 40 pp. (Also presented as Canadian Stock Assessment Secretariat Research Document 99/26. 45p.)

Hay, D.E., R. Harbo, J. Boutillier, E. Wylie, L. Convey, and P.B. McCarter. 1999. Assessment of bycatch in the 1997 and 1998 shrimp trawl fisheries in British Columbia, with emphasis on eulachons. Can. Stock Assessment Secretariat Research Document 99/179. 44 p.

Hay, D.E., J. Boutillier, M. Joyce and G. Langford. 1997a. The eulachon (*Thaleichthys pacificus*) as an indicator species in the North Pacific. Proceedings. Forage Fishes in Marine Ecosystems. Wakefield Fisheries Symposium. Alaska Sea Grant College Program AK-SG-97-01, p 509-530.

Hay, D.E. and P.B. McCarter. 2000. Status of the eulachon *Thaleichthys pacificus* in Canada. Can. Stock Assessment Research Document 2000/145. 92 p.

Hay, D.E., P. B. McCarter, M. Joyce, and R. Pedersen. 1997b. Fraser river eulachon biomass assessments and spawning distribution based on egg and larval surveys. PSARC Working Paper. November 1997. 60 pp.

Hay, D. E., P. B. McCarter, R. Joy, M. Thompson and K. West. 2002. Fraser River eulachon biomass assessments and spawning distribution: 1995-2002 .PSARC Working Paper P2002-08. 60p.

Kitto, E.A. 2002. The ecology of the eulachon (*Thaleichthys pacificus*) in Turnagain Arm, Alaska. M.Sc. thesis. University of Alaska, Fairbanks.

Martell, S., Boutiller, J. Nguyen, H. and C. Walters. 2000. Reconstructing the offshore *Pandalus jordani* trawl fishery off the west coast of Vancouver Island and simulating alternate management policies. Can. Stock Assessment Secretariat Research Document. 2000/149. 38 p.

Ricker, W.E., D.F. Manzer and E.A. Neave. 1954. The Fraser River eulachon fishery, 1941-1953. Fish. Res. Bd. Canada. MS Rept. Biol. Sta., No. 583, 35 p.

Rogers, I.H., Birtwell, I.K. and G.M. Kruzynski. 1990. The Pacific eulachon (*Thaleichthys pacificus*) as a pollution indicator organism in the Fraser River estuary, Vancouver British Columbia. Science of the Total Environment. 97/98. 713-727.

Rutherford, D.T. 2002. Shrimp Survey Bulletin 02-01: Description and Results of the West Coast of Vancouver Island Shrimp survey, April 23 – May 7, 2002. http://www.pac.dfo-mpo.gc.ca/ops/fm/shellfish/shrimp/Default.htm

Table 1. Site-specific Spawning Stock Biomass (SSB) from 1995-2002 with 95 percent confidence limits.(From Hay et al. 2002)

Year/Area	Mean	95% CI (low)	95% CI (high)
Barnston Island			
1995	200.01	91.88	331.61
1996	24.17	11.02	41.28
1997	18.38	14.11	23.95
1998	51.16	15.57	104.88
1999	43.09	10.97	110.09
2000	16.50	6.28	32.77
2001	1123.28	732.50	1507.39
2002	265.44	151.20	424.79
New Westminster			
1995	135.74	83.75	200.36
1996	92.08	70.07	117.69
1997	44.18	32.87	56.41
1998	106.32	67.97	155.00
1999	123.30	77.36	172.60
2000	93.62	49.51	149.27
2001	803.60	400.34	954.32
2002	785.47	408.56	1114.98
Tilbury Island			
1997	86.235	58.20	116.228
1998	99.279	61.79	157.039
1999	506.30	210.48	1128.50
2000	117.654	63.53	180.890
2001	450.21	332.99	571.84
2002	253.70	145.68	396.12
Deas Island			
1997	45.40	35.04	56.75
1998	103.31	72.93	137.62
1999	391.20	286.92	513.45
2000	49.35	34.52	65.77
2001	402.97	341.51	467.72
2002	414.18	352.59	481.22
SARM: all 'South Arm' samples			
1995	257.46	184.04	335.01
1996	1587.80	1406.72	1775.45
1997	56.93	45.22	69.38
1998	105.90	83.18	131.03
1999	395.12	289.59	525.86
2000	71.64	54.48	91.17
2001	421.81	366.48	478.86
2002	351.68	302.29	401.07
NARM: all 'North Arm' samples			
1995	44.500	7.621	74.532
1996	327.69	38.43	441.66
1997	17.050	2.6277	26.322
1998	27.509	2.753	35.491
1999	25.252	3.456	37.059
2000	54.820	6.729	79.136
2001	186.61	12.02	218.66
2002	139.73	111.07	168.39

Table 2. The cumulative catch from the test fishery and the SSB estimates for different locations in the Fraser River. The column on the right (Total) provides an estimate of the total eulachon SSB for the entire river as the sum of the North and South Arms.

Year	Test fishery (pieces)	Barnston Island SSB-tonnes	NW SSB-tonnes	SARM SSB-tonnes	Narm SSB-tonnes	Total SSB-tonnes
1995	11651	200.01	135.74	257.46	44.50	302
1996	42071	24.17	92.08	1587.80	327.69	1915
1997	3116	18.38	44.18	56.93	17.05	74
1998	2052	51.16	106.32	105.90	27.510	133
1999	-	43.09	123.30	395.12	25.25	420
2000	12991	16.50	93.62	71.64	54.82	126
2001	14578	1123.28	803.60	421.81	186.61	608
2002	14754	264.44	785.47	351.68	139.73	492

Table 3. Annual offshore eulachon index (biomass) from 1973-2002 for Statistical areas 124 and 125 and annual catch data (tonnes) from the Fraser and Columbia Rivers.

Year	Offshore 124	Offshore 125	Fraser Catch	Columbia Catch
1941	-	-	50.14	1265.90
1942	-	-	152.74	1343.00
1943	-	-	154.79	1988.65
1944	-	-	65.70	1134.25
1945	-	-	73.87	2859.65
1946	-	-	115.71	1638.00
1947	-	-	231.10	772.45
1948	-	-	112.80	1987.05
1949	-	-	102.70	1666.80
1950	-	-	36.20	741.25
1951	-	-	189.30	758.45
1952	-	-	421.00	637.45
1953	-	-	158.60	855.50
1954	-	-	151.60	942.15
1955	-	-	238.80	1118.55
1956	-	-	235.50	841.95
1957	-	-	33.20	789.50
1958	-	-	92.10	1308.20
1959	-	-	132.00	878.05
1960	-	-	84.00	586.10
1961	-	-	216.90	526.15
1962	-	-	178.20	736.80
1963	-	-	159.30	538.55
1964	-	-	105.50	420.90
1965	-	-	87.80	455.35
1966	-	-	101.90	514.15
1967	-	-	86.80	500.40
1968	-	-	46.00	473.75
1969	-	-	29.80	541.85
1970	-	-	71.70	591.95
1971	-	-	34.50	888.35
1972	-	-	53.20	821.75
1973	222	107	53.10	1217.20
1974	-	-	75.30	1180.90
1975	566	421	27.70	1038.80
1976	741	335	36.70	1537.55
1977	1581	659	32.20	876.50
1978	1244	25	38.60	1340.15
1979	701	456	22.30	578.35
1980	1013	291	24.40	1605.75
1981	431	561	21.20	836.15
1982	1599	541	13.70	1105.00
1983	116	176	10.80	1365.20
1984	-	-	11.80	249.00
1985	1197	222	29.20	1019.00
1986	-	-	49.60	1919.40
1987	1304	518	19.30	947.85
1988	1295	643	39.50	1433.85
1989	932	-	18.70	1533.40
1990	1132	370	19.90	1392.10
1991	1252	-	12.30	1475.20
1992	1989	1027	19.60	1836.90
1993	278	1024	8.70	256.95
1994	112	69	6.10	21.70
1995	166	115	15.50	220.00
1996	89	52	63.20	4.55
1997	168	110	closed	29.30
1998	19	125	closed	6.00
1999	124	28	closed	10.45
2000	836	310	closed	closed -
2001	1340	187	closed	-
2002	3993	5343	~5.76	-

Table 4. Eulachon biomass indices and estimates of numbers of eulachon per age class (1,000s) for the West Coast of Vancouver Island 1999 to 2002. The biomass is the highest observed since the surveys started in 1973.

Year	Area	Biomass (t)	Number (1,000s)	
			Age 1+	Age 2+
1999	121OFF, 23IN, 23OFF	335	5862	16512
	124OFF	124	5630	3736
	125OFF	28	351	959
2000	121OFF, 23IN, 23OFF	1971	128199	20002
	124OFF	846	61884	5880
	125OFF	***346***	18789	1948
2001	121OFF, 23IN, 23OFF	4896	111359	181922
	124OFF	1340	85533	32980
	125OFF	187	5684	4272
2002	121OFF, 23IN, 23OFF	5862	264348	136735
	124OFF	3993	35459	131949
	125OFF	5343	11894	190130

Table 5. Age composition of eulachon sampled from the WCVI shrimp survey, 1999 - 2002. Note the very high frequency of age 2+ fish in 2002.

Year	Area	Proportion Age 1+	Proportion Age 2+
1999	121/123	0.26	0.74
	124	0.60	0.40
	125	0.27	0.73
2000	121/123	0.87	0.13
	124	0.91	0.09
	125	0.91	0.09
2001	121/123	0.38	0.62
	124	0.72	0.28
	125	0.57	0.43
2002	121/123	0.66	0.34
	124	0.21	**0.79**
	125	0.06	**0.94**

Table 6. Results of test fishery catches, 1995-2002. The numbers represent the number of eulachons captured per day in a standard length of gillnet fished for the same duration each day.

	1995	1996	1997	1998	2000	2001	2002
23-Mar	-	11	11	-	-	-	-
24-Mar	-	43	33	-	-	-	-
25-Mar	-	74	55	-	-	-	-
26-Mar	-	53	34	3	-	2	-
27-Mar	-	31	12	34	-	10	-
28-Mar	-	22	12	15	0	5	-
29-Mar	36	12	12	29	0	5	-
30-Mar	76	11	13	59	6	7	-
31-Mar	47	9	14	67	10	5	-
01-Apr	5	22	29	50	13	13	-
02-Apr	12	34	29	59	14	14	-
03-Apr	15	32	44	41	21	17	1
04-Apr	41	30	66	30	20	13	0
05-Apr	3	9	88	29	28	7	4
06-Apr	14	14	81	71	34	16	1
07-Apr	14	27	74	1	39	16	1
08-Apr	5	40	141	33	56	12	4
09-Apr	35	26	52	2	71	11	6
10-Apr	142	231	36	8	54	11	6
11-Apr	176	579	48	2	42	34	1
12-Apr	210	616	40	6	89	15	1
13-Apr	302	743	30	19	84	14	0
14-Apr	822	195	50	7	79	23	0
15-Apr	623	2,709	112	6	95	45	26
16-Apr	922	1,964	58	3	16	16	30
17-Apr	434	2,640	108	8	75	42	13
18-Apr	557	368	92	16	75	90	21
19-Apr	2,185	5,980	173	18	57	170	40
20-Apr	958	3,855	83	12	144	404	105
21-Apr	2,857	1,730	169	6	85	488	233
22-Apr	242	3,218	20	252	250	864	553
23-Apr	37	1,929	54	109	177	1,239	659
24-Apr	32	866	88	8	256	1,217	1981
25-Apr	85	824	270	14	180	400	1316
26-Apr	97	68	155	73	685	352	651
27-Apr	130	421	20	59	708	280	893
28-Apr	54	580	211	33	820	305	751
29-Apr	54	831	401	243	1,860	313	856
30-Apr	24	369	48	257	1,000	573	960
01-May	20	236	29	308	1,300	1,207	928
02-May	17	2,343	9	52	1,600	894	845
03-May	13	2,059	8	4	570	1,159	761
04-May	22	1,729	6	2	239	888	548
05-May	30	1,729		0	314	760	669
06-May	56	1,399		2	316	619	424
07-May	56	360		3	370	464	424
08-May	81	492			70	367	158
09-May	56	238			161	270	170
10-May	30	75			87	89	138
11-May	16	58			180	54	153
12-May	2	58			195	54	148
13-May	3	41			205	45	142
14-May	3	21			44	43	49
15-May	3	21			75	53	38
16-May					32	92	31
17-May					27	142	15
18-May					34	103	
19-May					29	113	
20-May						36	
21-May						64	
22-May						15	

Table 7. Cumulative catches, by day for the Fraser River, derived from Table 3. The days of cumulative catches of 5000 and10000 fish are marked in bold. See text for explanation.

	1995	1996	1997	1998	2000	2001	2002
23-Mar	0	11	11	0	0	0	0
24-Mar	0	54	44	0	0	0	0
25-Mar	0	128	99	0	0	0	0
26-Mar	0	180	133	3	0	2	0
27-Mar	0	211	145	37	0	12	0
28-Mar	0	233	157	52	0	17	0
29-Mar	36	245	169	81	0	22	0
30-Mar	112	255	182	140	6	29	0
31-Mar	159	264	196	207	16	34	0
01-Apr	164	286	225	257	29	47	0
02-Apr	176	320	254	316	43	61	0
03-Apr	191	352	298	357	64	78	1
04-Apr	232	382	364	387	84	91	1
05-Apr	235	391	452	416	112	98	5
06-Apr	249	405	533	487	146	114	6
07-Apr	263	432	607	488	185	130	7
08-Apr	268	472	748	521	241	142	11
09-Apr	303	498	800	523	312	153	17
10-Apr	445	729	836	531	366	164	23
11-Apr	621	1308	884	533	408	198	24
12-Apr	831	1924	924	539	497	213	25
13-Apr	1133	2667	954	558	581	227	25
14-Apr	1955	2862	1004	565	660	250	25
15-Apr	2578	**5571**	1116	571	755	295	51
16-Apr	3500	7535	1174	574	771	311	81
17-Apr	3934	***10175***	1282	582	846	353	94
18-Apr	4491	10543	1374	598	921	443	115
19-Apr	**6676**	16523	1547	616	978	613	155
20-Apr	7634	20378	1630	628	1122	1017	260
21-Apr	***10491***	22108	1799	634	1207	1505	493
22-Apr	10733	25326	1819	886	1457	2369	1046
23-Apr	10770	27255	1873	995	1634	3608	1705
24-Apr	10802	28121	1961	1003	1890	4824	3686
25-Apr	10887	28944	2231	1017	2070	**5224**	**5002**
26-Apr	10984	29012	2386	1090	2755	5576	5653
27-Apr	11114	29434	2406	1149	3463	5856	6546
28-Apr	11168	30013	2616	1182	4283	6161	7297
29-Apr	11222	30844	3017	1425	**6143**	6474	8153
30-Apr	11246	31213	3065	1682	7143	7047	9113
01-May	11266	31449	3094	1990	8443	8254	***10041***
02-May	11283	33792	3103	2042	***10043***	9148	10886
03-May	11296	35851	3110	2046	10613	***10307***	11647
04-May	11317	37580	*3116*	2048	10852	11195	12195
05-May	11347	39309	*3116*	2048	11166	11955	12864
06-May	11403	40708	*3116*	2049	11482	12574	13288
07-May	11458	41068	*3116*	*2052*	11852	13038	13712
08-May	11539	41560	*3116*	*2052*	11922	13405	13870
09-May	11595	41798	*3116*	*2052*	12083	13675	14040
10-May	11625	41873	*3116*	*2052*	12170	13764	14178
11-May	11641	41931	*3116*	*2052*	12350	13818	14331
12-May	11643	41989	*3116*	*2052*	12545	13872	14479
13-May	11645	42030	*3116*	*2052*	12750	13917	14621
14-May	11648	42051	*3116*	*2052*	12794	13960	14670
15-May	*11651*	*42071*	*3116*	*2052*	12869	14013	14708
16-May	*11651*	*42071*	*3116*	*2052*	12901	14105	14739
17-May	*11651*	*42071*	*3116*	*2052*	12928	14247	*14754*
18-May	*11651*	*42071*	*3116*	*2052*	12962	14350	*14754*
19-May	*11651*	*42071*	*3116*	*2052*	*12991*	14463	*14754*
20-May	*11651*	*42071*	*3116*	*2052*	*12991*	14499	*14754*
21-May	*11651*	*42071*	*3116*	*2052*	*12991*	14563	*14754*
22-May	*11651*	*42071*	*3116*	*2052*	*12991*	14578	*14754*

Table. 8. A correlation matrix between Columbia and Fraser River catches and the offshore biomass index River indicates a significant positive relationship between offshore biomass and the Columbia River catches, but the Fraser River catches to not correspond to either the Columbia River or offshore areas.

	Offshore	Fraser
Fraser	-0.081 0.727	
Columbia	0.551 0.005	-0.066 0.631

(The top number of each pair represents the Pearson correlation coefficient, and the lower number is the probability value)

Table 9. Lists of correlation coefficients (top number in pair) and associated probability levels (low number in pair) in comparisons of catch data (1934-2002) from the Fraser and Columbia Rivers, and the offshore biomass index, with monthly mean Sea surface temperature, from Amphitrite Point. The five months showing significant correlation (for the Fraser River) are shown in bold.

Month	Fraser River	Columbia River	Offshore biomass
January	-0.057	0.033	-0.017
	0.675	0.799	0.935
February	-0.056	-0.071	-0.112
	0.680	0.586	0.577
March	**-0.281**	-0.006	-0.228
	0.036	0.964	0.252
April	**-0.384**	0.001	-0.219
	0.003	0.994	0.273
May	**-0.335**	0.032	-0.319
	0.012	0.807	0.104
June	**-0.304**	0.011	-0.125
	0.023	0.936	0.535
July	-0.175	0.044	-0.143
	0.197	0.736	0.477
August	-0.248	-0.071	-0.075
	0.065	0.586	0.708
September	**-0.345**	-0.173	-0.330
	0.009	0.183	0.093
October	-0.149	-0.213	-0.308
	0.273	0.099	0.125
November	-0.165	-0.149	-0.171
	0.224	0.252	0.404
December	-0.128	-0.116	-0.157
	0.349	0.373	0.443

Table 10. Efficacy of assessment Indicators, response points and application to fishery management.

A) Indicators of Biomass	**Response Points**		**Purpose of Indicator**	**Limitations**
	Conservation concern	**Fishable to various levels**		
1) Spawning Stock Biomass (SSB) (pre and post-season**)**	Less than 150 tonnes	Greater than 150 tonnes	Precautionary for SSB<150 t for previous year. Conservation concern for SSB<150 t two consecutive years.	Limited time series, 8 years only (Table 7)
2) Off-Shore Biomass (pre-season**)**	Less than 1000 tonnes	Greater than 100 tonnes	Indication of marine survival for multi brood and multi stock.	No apparent relationship to Fraser but positive to Columbia (Fig. 11) Index for Fraser may be improved by stock and age.
3) Columbia River Catch **(**pre-season**)**	Less than 500 tonnes	Greater than 500 tonnes	Indication of overall survival for single return year and single stock (Columbia).	No convincing relationship to Fraser. However, when Columbia was low, Fraser was low (Fig. 8)
4) Fraser Test Fishery (in-season)	Less than 5000 piece cumulative catch	Greater than 5000 piece cumulative catch	Indicator of in-season returning abundance and overall survival of post season for Fraser.	Limited time series, 7 years only. Correlation to SSB dependant on one year (Fig. 12) Temporal variations, cause of flow, tide etc unknown.
B) Efficacy of indicator to Response Point	Yes for 1), 3) and 4) No for 2)	Yes for 4) No for 2 and 3)		

Table 11. Array of sequential indicators points showing similar and conflicting results for specific reference points - presented in the context of a traffic light regulation for nine different scenarios. Two indicators for the SSB (spawning stock biomass) are G (for green) and Y (for a yellow) that indicate a SSB of more, and less than, 150 tonnes respectively. Similarly, the offshore biomass indicator is G or Y for a biomass greater, or less than, 1000 tonnes, respectively. The Columbia River indicator is G or Y for a catch greater, or less than 500 tonnes, respectively. The bold 'R' indicates a red signal. Each combination of the nine different scenarios, is indicated with bold, underlined letters (G or Y or R), with alternates shown in lighter font. The suggested management response to each scenario is indicated on the left. In all instances of conflicting indicators, the suggested response is to either (1) to proceed with caution consulting the results of the test fishery, or (2) proceed with extreme caution, and consider only partial fisheries. Three independent Y signals is sufficient rational for a full closure, and a Red (R) signal would require a full closure.

Scenario	SSB	Offshore Biomass	Columbia Catch	Management response
1.	**G** Y R	**G** Y	**G** Y	Proceed with full fishery
2.	**G** Y R	**G** Y	G **Y**	Proceed with moderate caution, consult test fishery results
3.	**G** Y R	G **Y**	**G** Y	Proceed with moderate caution, consult test fishery results
4.	**G** Y R	G **Y**	G **Y**	Consider only partial fishery
5.	G **Y** R	**G** Y	**G** Y	Proceed with caution, consult test fishery results
6.	G **Y** R	**G** Y	Y **G**	Proceed with caution, consult test fishery results
7.	G **Y** R	**G** Y	G **Y**	Consider only partial fishery
8.	G **Y** R	G **Y**	G **Y**	Full closure justifiable
9.	G Y **R**	G Y	G Y	Full closure necessary- conservation concern

Fig. 1. The key sampling locations examined throughout all years (1995-2002) for estimates of spawning stock biomass (SSB) from egg and larval surveys. The abbreviations refer to sampling stations as follows: Deas Island (DI), Barnston Island (BI) New Westminster (BW), Tilbury Island (TI). The test fishery was conducted in the vicinity of New Westminster.

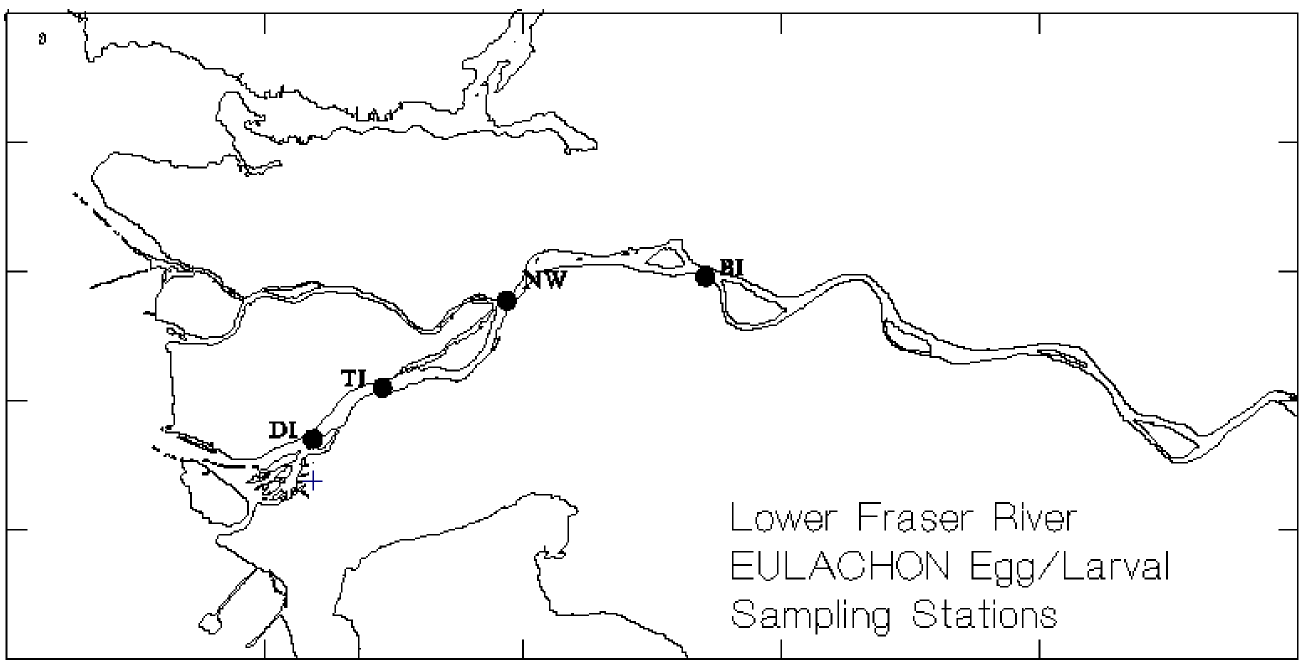


Fig. 2. Offshore sample locations (gray polygons) examined during the annual shrimp trawl survey conducted in May of most years. The numbers within the polygons correspond to the Statistical Areas refereed to in the text.

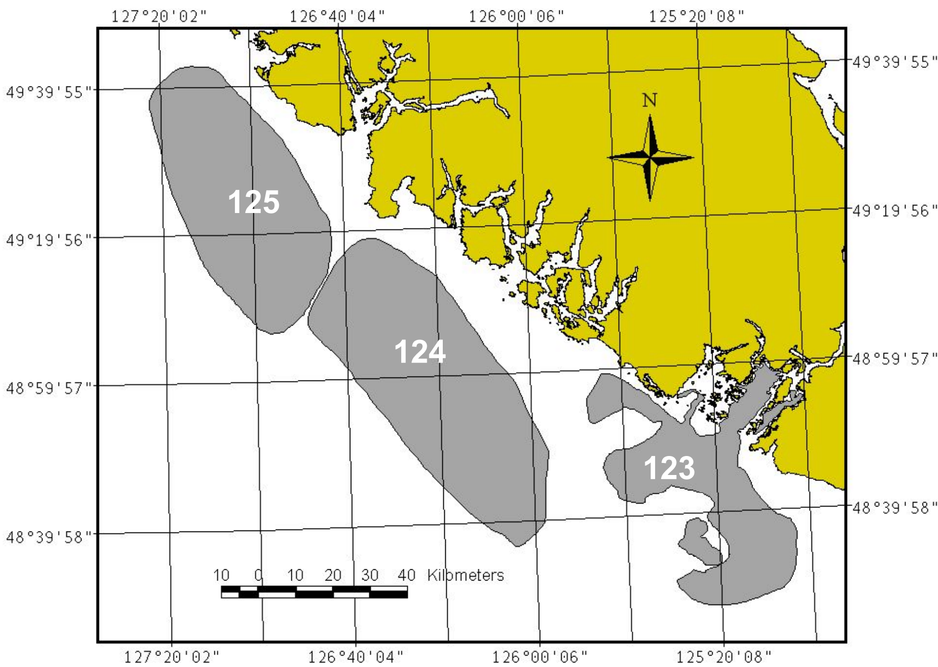
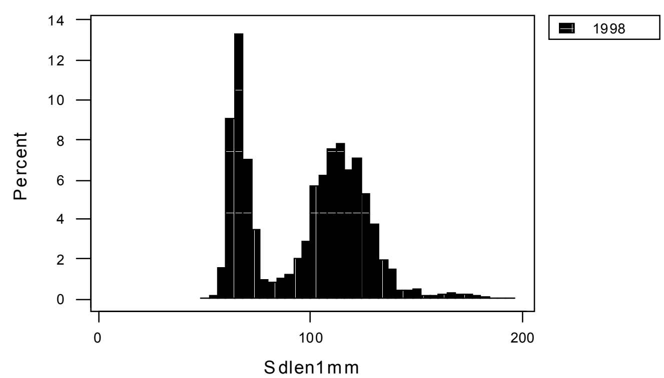


Fig. 3. Size modes of offshore eulachons, corresponding to age groups 1+ (about 15 months of age) and 2+ (about 27 months of age) from size composition data collected from eulachons in 1997 and 1998 during annual shrimp surveys in May, off the lower west coast of Vancouver Island. (Adapted from Hay and McCarter 2000).



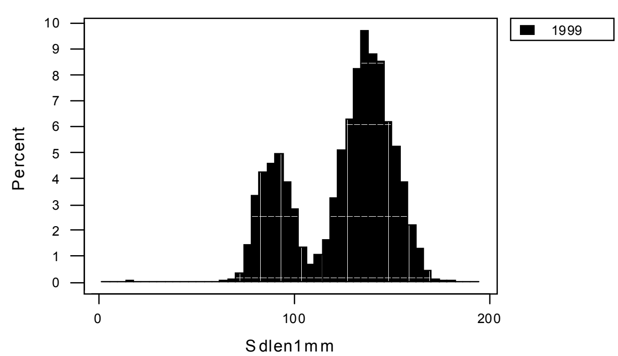


Fig. 4. Temporal variation in spawning stock biomass (SSB) for the Fraser River, 1995-2002 (Data from Table 2, and adapted from Hay et al. 2002).

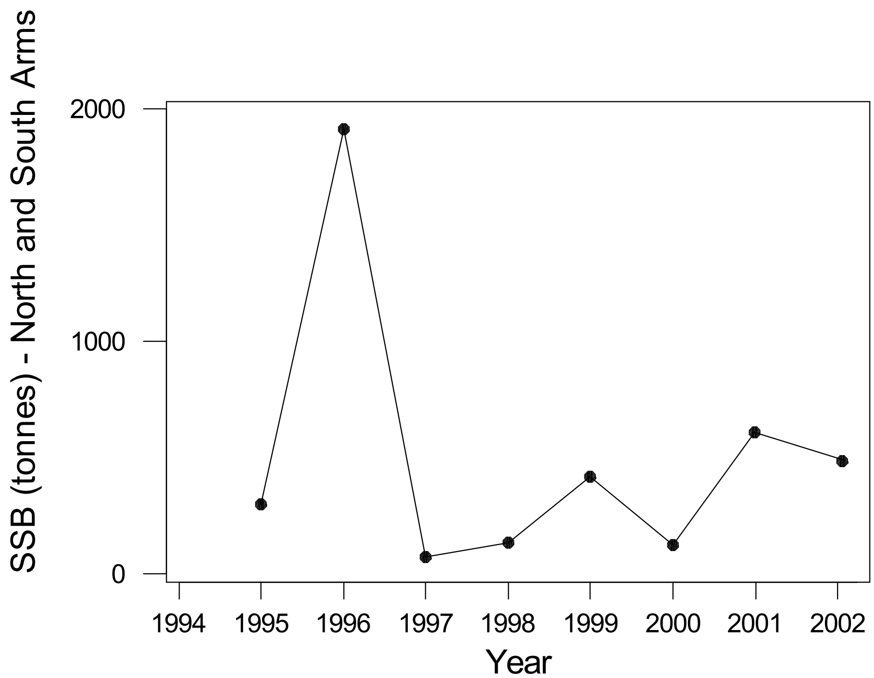
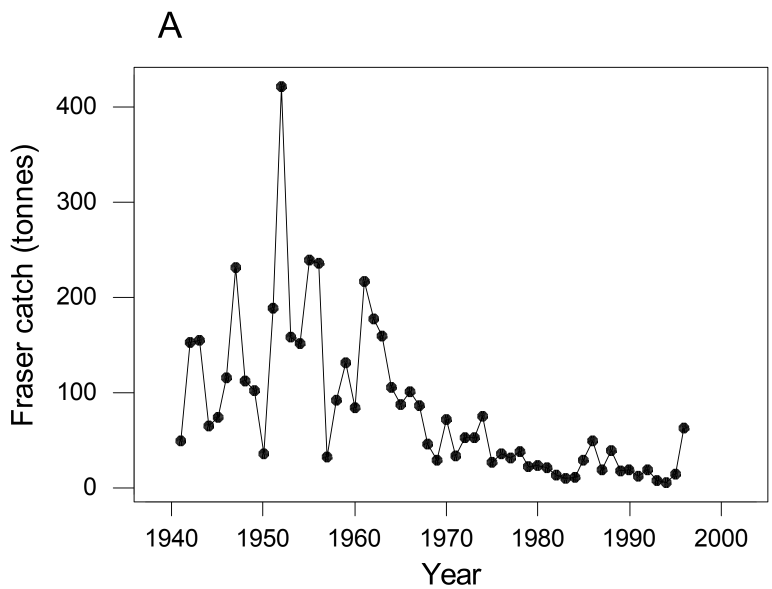


Fig. 5. The commercial catches of the Fraser River (A) and Columbia River by year. Catch data for recent years in the Columbia river are incomplete.



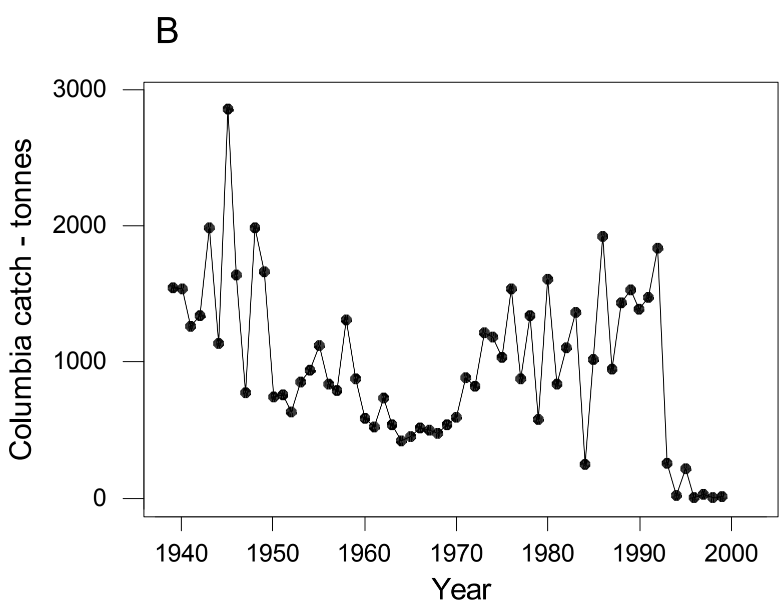
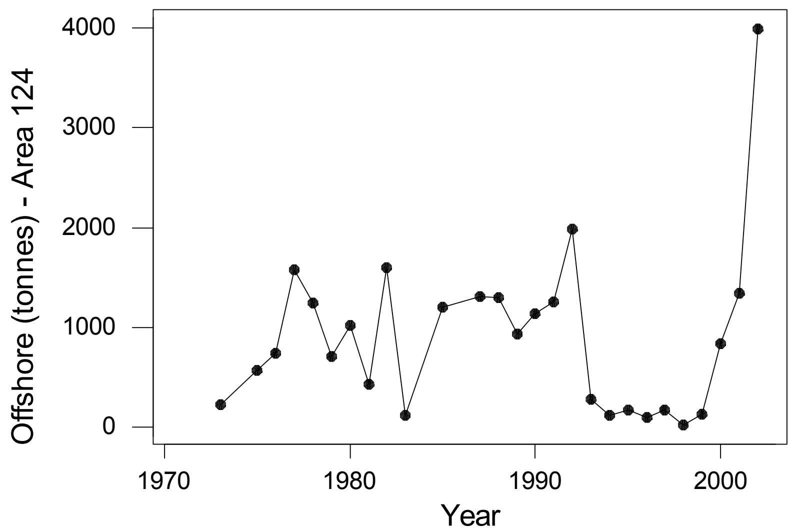


Fig. 6. The offshore biomass index from 1973 to 2002 for Statistical Areas 124 (A) and 125 (B).

A



B

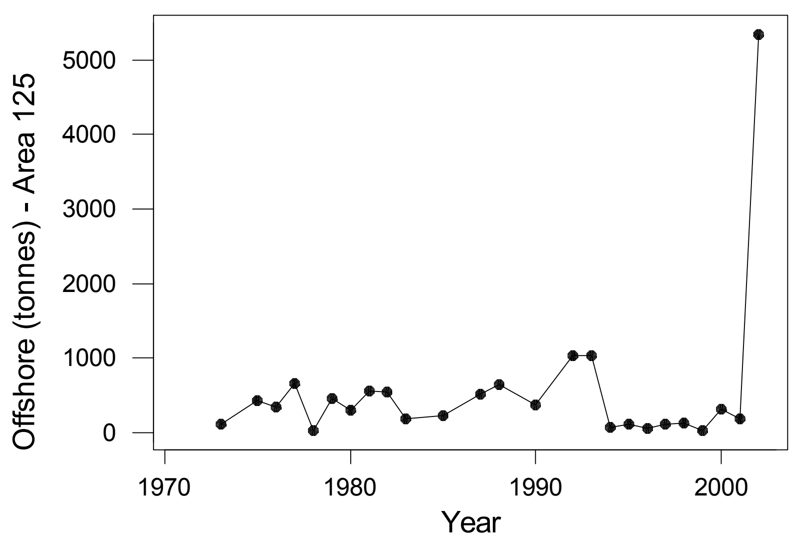


Fig. 7. The cumulative catches of the test fishery (in pieces) by year. The test fishery was not conducted in 1999.

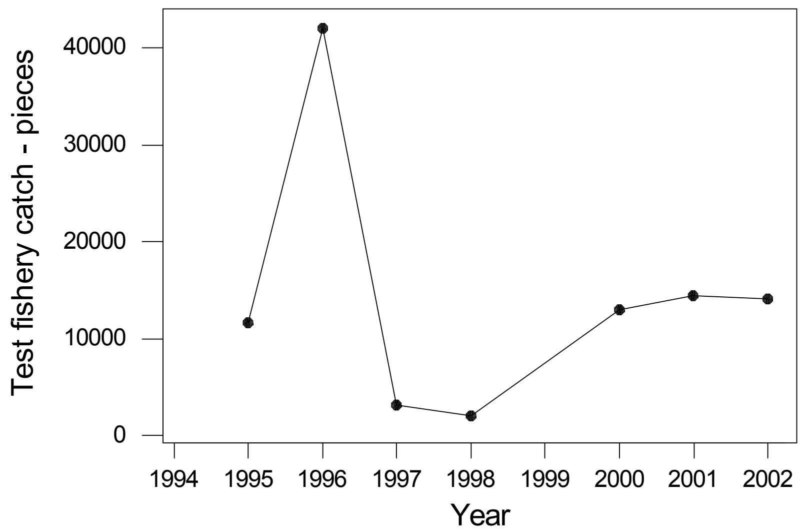


Fig. 8. Fraser River versus Columbia River catches. Offshore biomass index and Columbia river catches. There are some years when the Columbia River catches are high but Fraser River catches are low, less than 100 tonnes (square symbols). On the other hand, in all years when Columbia River catches are low (<500 tonnes), indicated by the points to the left of the vertical dotted line, the Fraser River also had low catches (dark triangles).

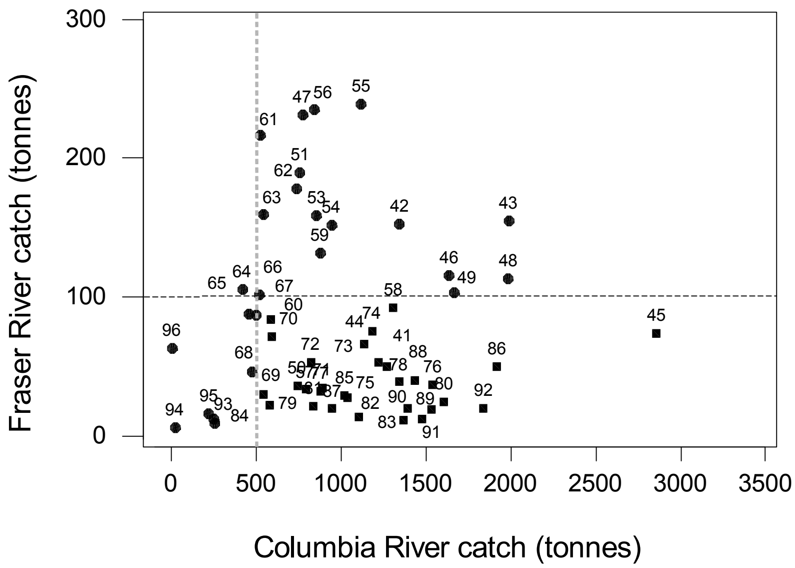


Fig. 9. The Columbia river eulachon catch (tonnes) versus the offshore biomass index estimates for Fisheries and Oceans Statistical areas 124 and 125. The correlation coefficient (r = 0.702) for data shown in panel A is significant (p <<0.01). The correlation in panel B (r = 0.363) is not significant.

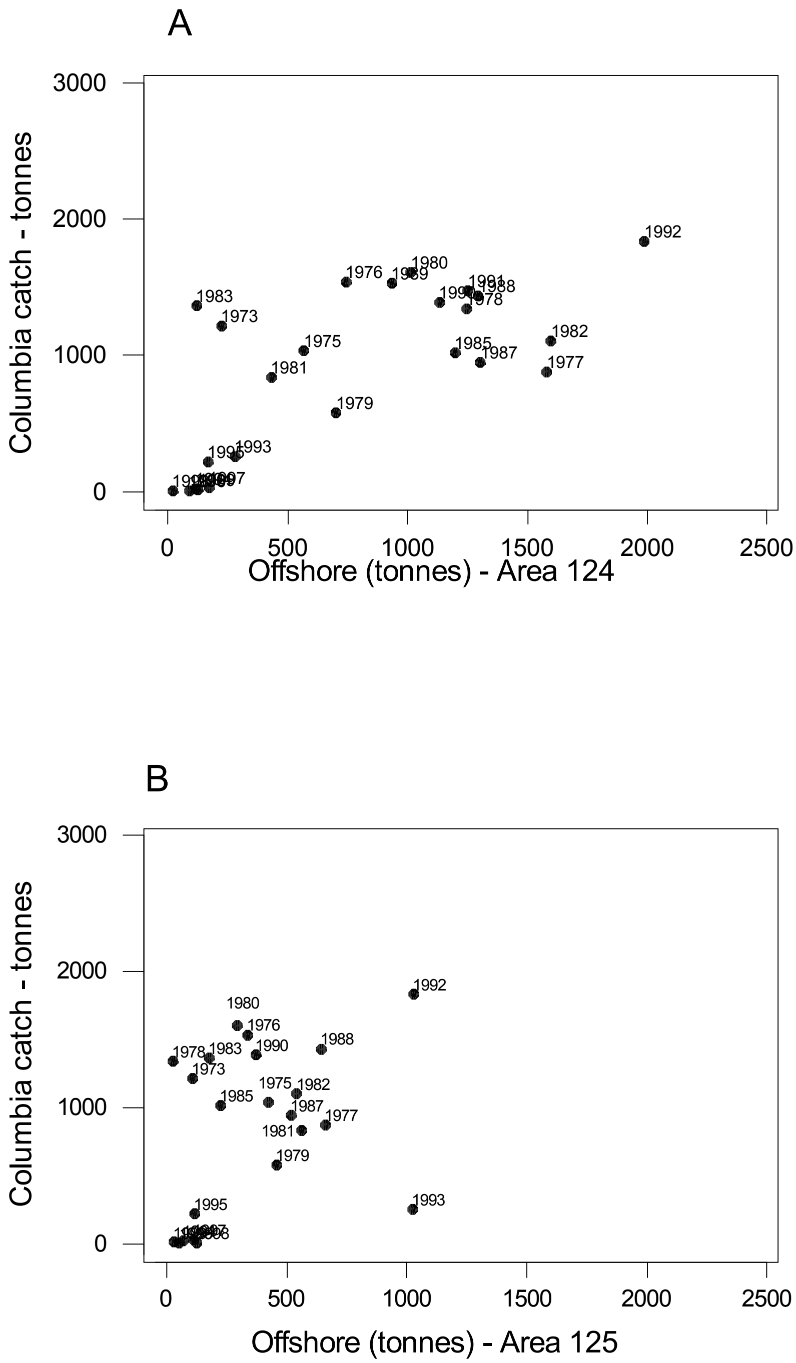
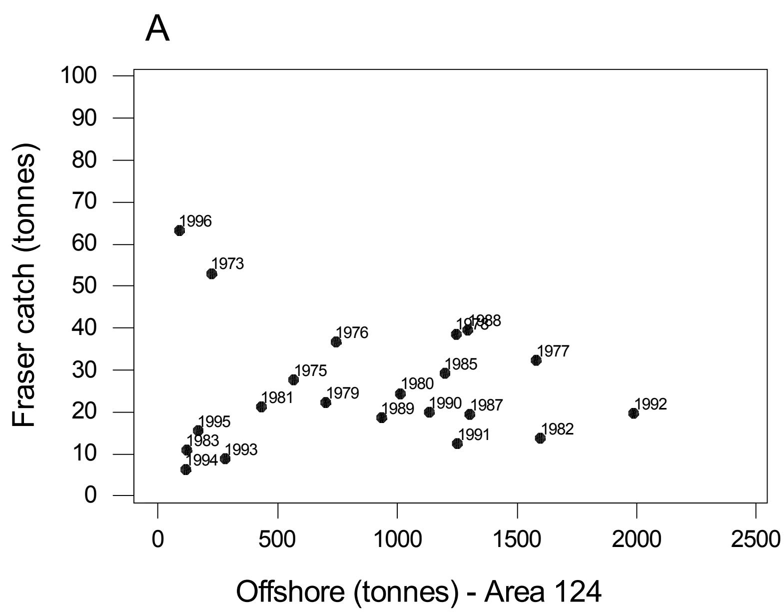


Fig. 10. The Fraser river eulachon catch (tonnes) versus the offshore biomass index estimates for Fisheries and Oceans Statistical areas 124 and 125. The correlation coefficient for the data shown in panels A and B are -0.075 and -0.337 respectively. Neither is significant.



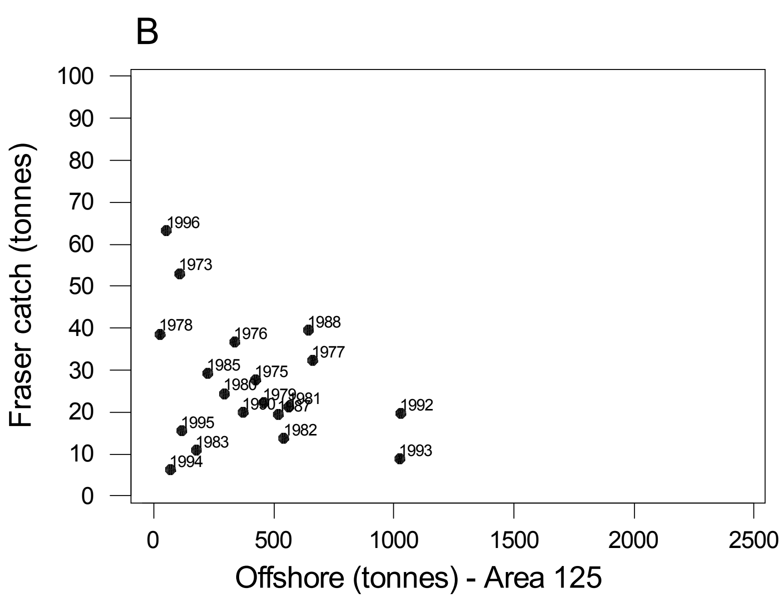


Fig. 11. Fraser River SSB estimates versus the offshore biomass index. There is no apparent relationship. There 1996 data point appears to be an outlier, but there is good evidence that this year had an exceptionally strong spawning run in the Fraser River.

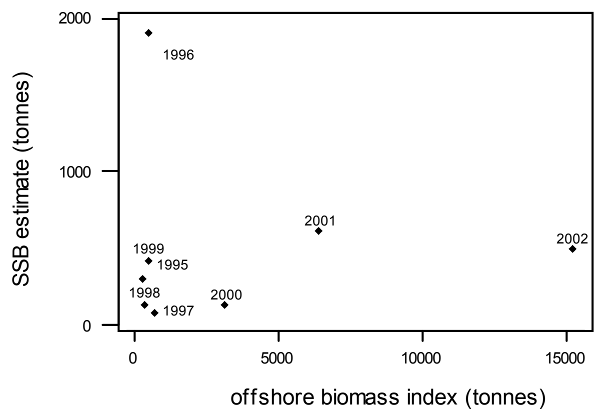


Fig. 12. The Fraser River SSB (from Table 2) versus the cumulative Fraser River Test fishery catch (in pieces). A highly significant correlation (P<0.01) is dependent on the 1996 data point (see text for explanation).

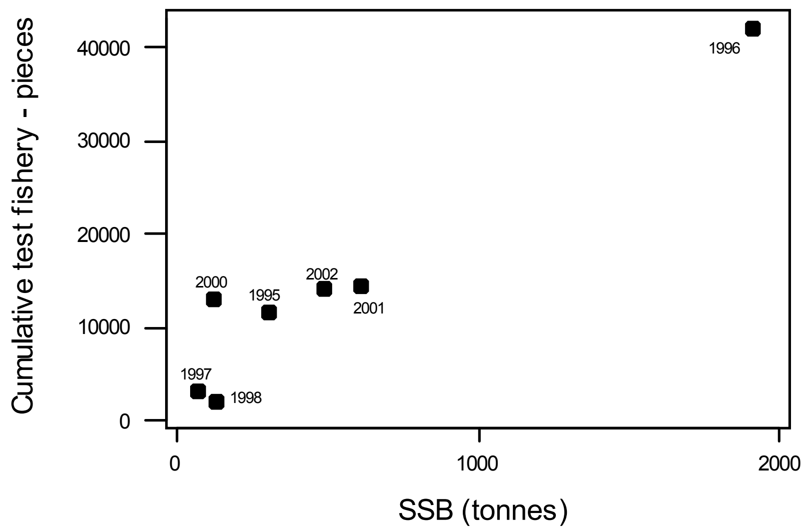


Fig. 13. Patterns of cumulative catch from test fisheries for eulachons in the Fraser River, 1995-2002. In two of the years, the cumulative catch did not reach 5000 pieces (lowest horizontal dotted line). In all other years, the cumulative catch exceeded 10000 pieces (higher horizontal dashed line). See text for further explanation